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DYNAMIC TESTING OF CHILD OCCUPANT PROTECTION CONCEPTS

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16. Abstract

Alternatives to officially accepted restraint systems for children were tested to show the dangers of or potential value of these concepts. Results are given in terms relating to FMVSS 213. The discussion and conclusions highlight important points that will benefit public understanding and use of restraint systems.

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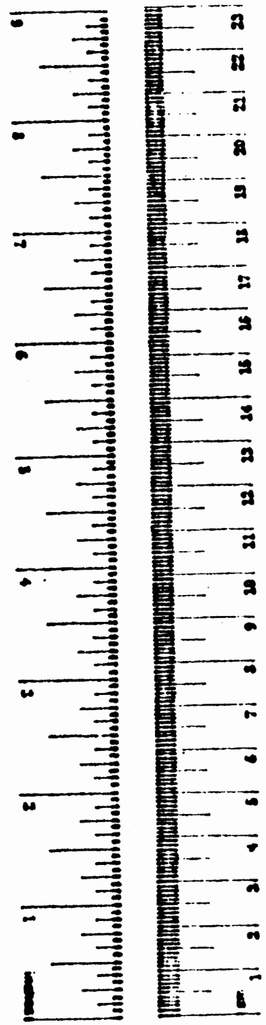
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

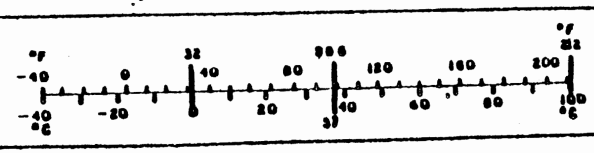


TABLE OF CONTENTS

1.0 Introduction

There are many real-world problems associated with restraining motor vehicle occupants, particularly children, for crash protection. Effective restraint systems for both adults and children are now either provided in the vehicle or available as after-market equipment. There are still, however, many everyday situations in which these systems are either unavailable or impractical. As a result, clever ways have often been devised by the public to deal with some of these temporary or long-term problems. These "solutions," however, have rarely been tested to determine what might actually happen in a crash. Although some may have promise, some are obviously questionable in concept and/or design.

The objective of this program was to subject various child occupant protection concepts, that have been suggested or are currently in use, to dynamic testing on an impact sled. The results of these tests would then be disseminated to the public to show the effectiveness or ineffectiveness of these concepts. In this context, negative results are just as valuable as positive results, because they provide a definitive answer to the question, "Would this work?" As the results are channeled through the child occupant protection networks, proper restraint techniques will be encouraged and dangerous practices discouraged.

2.0 Methodology

Based on our own observations and on suggestions from other safety professionals, typical alternatives to proper child restraint practices were identified, and tests were set up to simulate these alternatives. All configurations were then subjected to 30-mph (21g) impacts as called for in Federal Motor Vehicle Safety Standard (FMVSS) 213, Child Restraint Systems.

The tests were performed on an impact sled that operates on a rebound principle, achieving a desired velocity change by reversing its direction of motion during the impact event. Sled velocity is monitored immediately before and after impact.

Unless otherwise noted, the system tested was mounted on the Standard Bench Seat of FMVSS 213, and all belts used to attach the restraint system or the dummies to the test buck were pretensioned to 13.5 lb.±1.5 lb. The test data were recorded on a magnetic tape recorder and then digitized, digitally filtered, and analyzed on a digital computer. All test signals were filtered to the requirements of SAE J-211b. Photographic instrumentation consisted of high speed (800 frame/second) 16-mm motion picture cameras for side and overhead views and an automatic time-sequenced Polaroid camera. The transducer data and the motion picture data were marked simultaneously by a timing pulse generator at 10 millisecond intervals and by a strobe flash at the onset of impact.

To generate a frame of reference with which the test results could be compared, we first tested a Part 572 3-year-old dummy restrained by a lap belt. We then tested the alternative of two 3-year-old dummies in a single lap belt, both with the belt pretensioned and with the belt only "snug." The final lap belt alternative was three dummies (two 3-year-olds and one 6-year-old) restrained by two crossed belts. Details are in Section 3.0, Test Configurations and Results. In multiple-dummy tests, only one 3-year-old was instrumented.

Another series of tests addressed tethered child restraints. Two commonly used models, Child Love Seat and Strolee 599, were tested at 30 mph without tethers attached. Two alternative tether anchor locations were also tested using Strolees. These were a tether tied to the head restraint on a Chevrolet bench seat and a tether anchored to the floor just behind the Standard Bench Seat.

The last two tests addressed concepts often suggested but not tried as far as we know. The first placed the 6-month-old dummy in a Gerry Cuddlepack, which is specifically labeled as "not meant for holding infants in motor vehicles." The babypack was then hung over the chest of an adult dummy restrained by lap and shoulder belts. The second concept was the use of Velcro strips as a child restraint harness adjustment and/or closure mechanism on the shoulder straps. Details of these configurations are in the next section.

3.0 Test Configurations and Results

Details of the set-up and results of each test are given in this section. The tests are presented in a logical order, as outlined above, rather than in the order they were actually run. The Polaroid sequence of eight shots taken automatically during each test are included here. In addition, high-speed color films of this test series have been provided to the sponsor.

All but one test used an instrumented Part 572 3-year-old dummy. For these tests, data indicating injury potential are outlined in each test summary, and further details are provided on computer plots.[1] The results of these tests can best be evaluated using the criteria from FMVSS 213:

Head excursion ≤ 32 in.

Knee excursion ≤ 36 in.

Head Injury Criterion (HIC) ≤ 1000

Chest peak resultant acceleration ≤60g
except for cumulative duration ≤3 ms

There is currently no criterion for abdominal injury, but peak lap belt loads for each side are given when appropriate for comparison purposes.

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[1]Abbreviations used on computer plots for acceleration components:

A-P = Anterior (front) - Posterior (back)
L-R = Left - Right
S-I = Superior (top) - Inferior (bottom)

The dotted lines on the plots indicate the zero acceleration level. The numbers on the y-axis, such as S-I 400, indicate the number of units between the major divisions on the scale.

Test No.: 82D031

Dummy: 3-Year-Old (Part 572)

Set-Up: The dummy was restrained by a pretensioned lap belt.

Results: The belt performed as intended, containing the dummy within the excursion limits. The chest accelerations were also acceptable, but the HIC exceeded 1000. This occurred, as it usually does in this configuration, because the dummy head hits the unrealistically rigid knees, creating an artificial resonance in all three accelerometers. The belt loads were typical for this configuration.

Head excursion	31.1 in.
Knee excursion	21.0 in. approx. (obscured by seat cushion)
HIC	1949
Chest peak accel.	51g
Belt loads	Right 581 lb. Left 639 lb.

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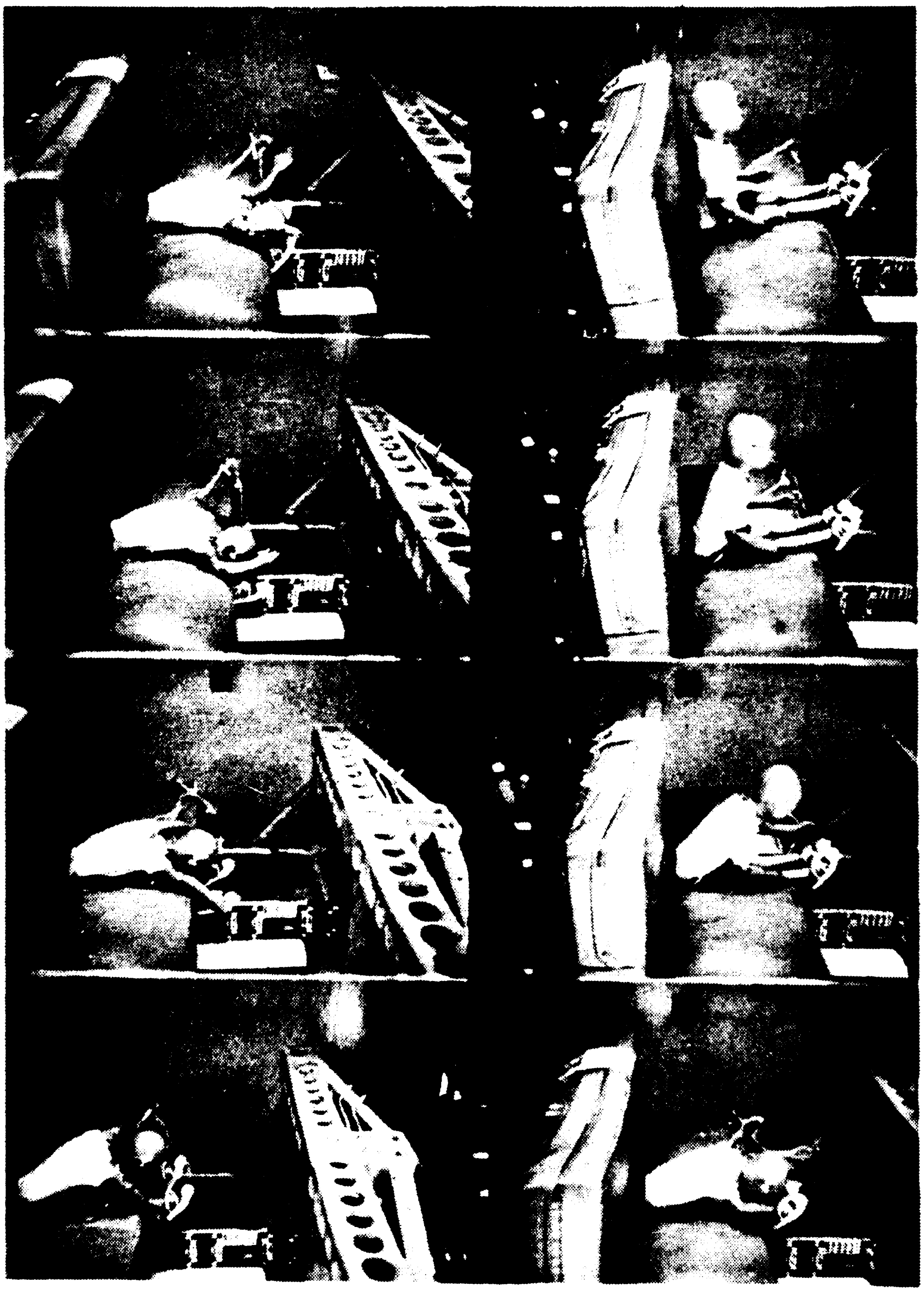

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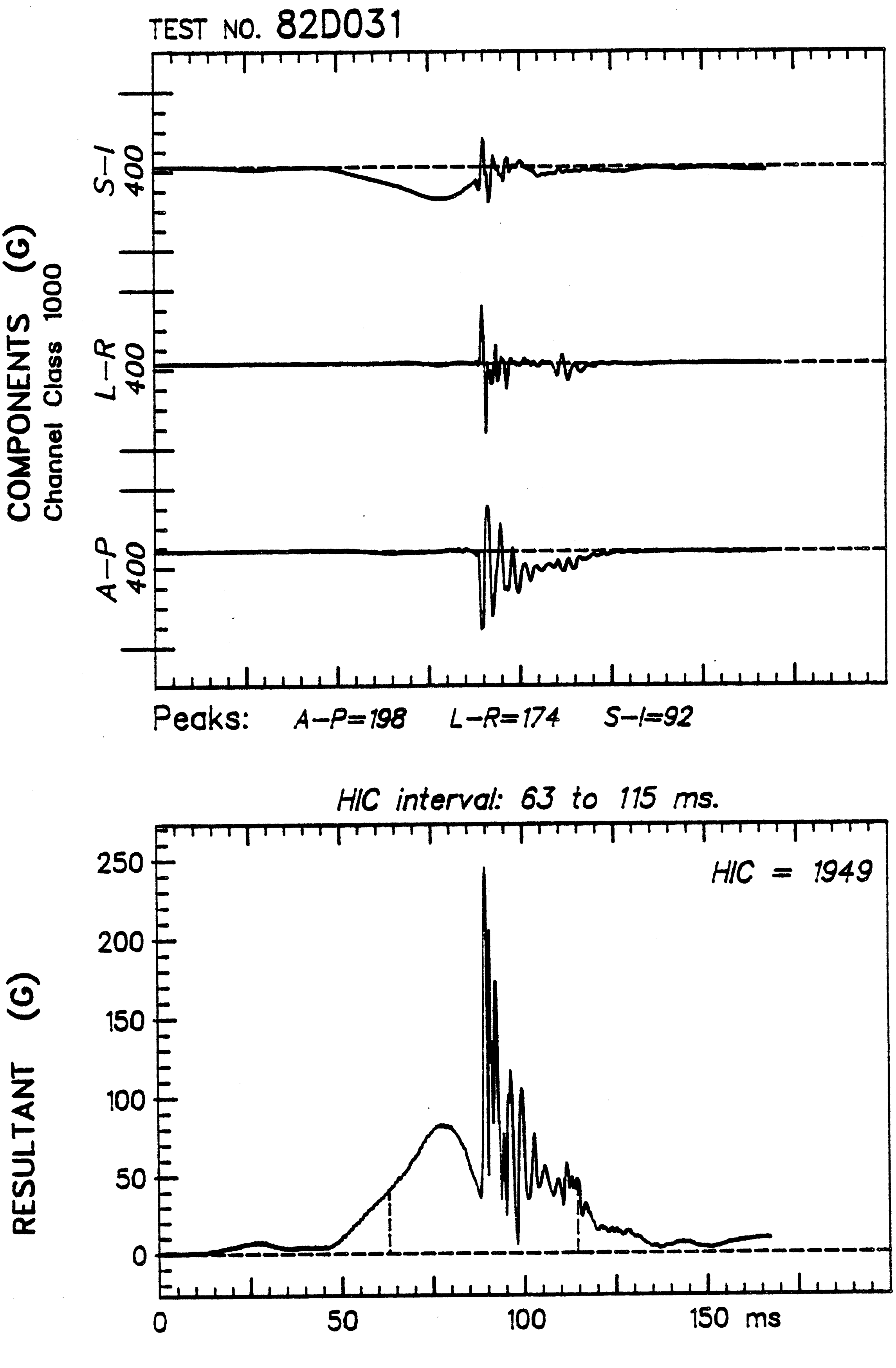
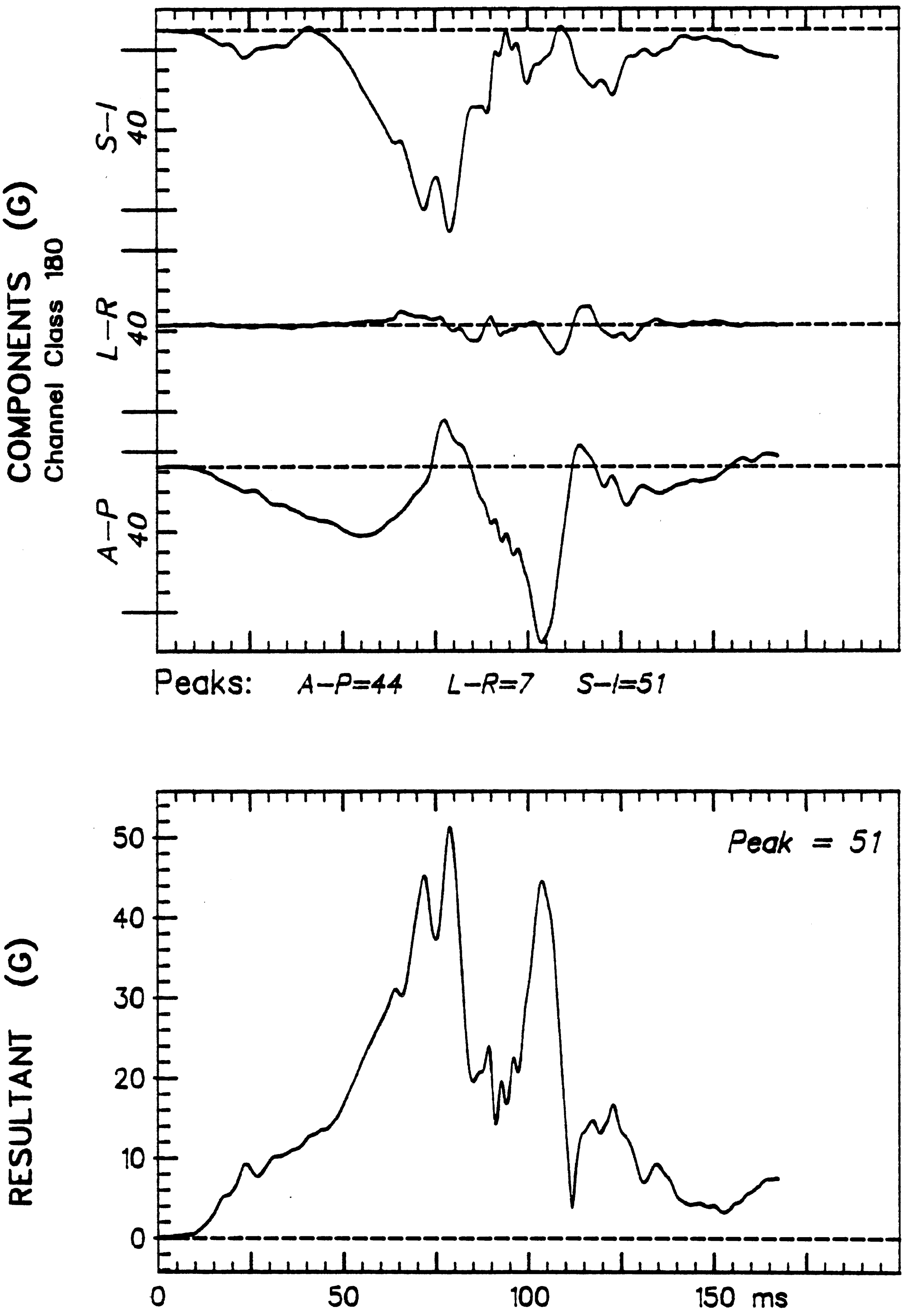


Head Accelerations

TEST NO. 82D031



Chest Accelerations

Test No.: *82D032*

Dummies: 3-Year-Old (Part 572)
3-Year-Old (Sierra)

Set-Up: Two dummies were restrained by a single pretensioned lap belt.

Results: The dummies' heads and upper torsos flung toward each other during the impact, resulting in higher L-R chest accelerations than in the baseline test and some additional real head accelerations in the A-P and L-R directions that occurred prior to the head/knee impact. The greater belt length and less compact dummy configuration also resulted in a higher head excursion. The heads did not actually hit each other, because the dummy necks are stiffer than human necks and the elbows were in the way. After maximum excursion, the dummies rebounded away from each other. The belt loads reflect the doubling of dummy weight, but each dummy experiences only half the total load.

Head excursion	34.4 in.
Knee excursion	Obscured
HIC	1630
Chest peak accel.	41g
Belt loads	Right 1037 Left 1039

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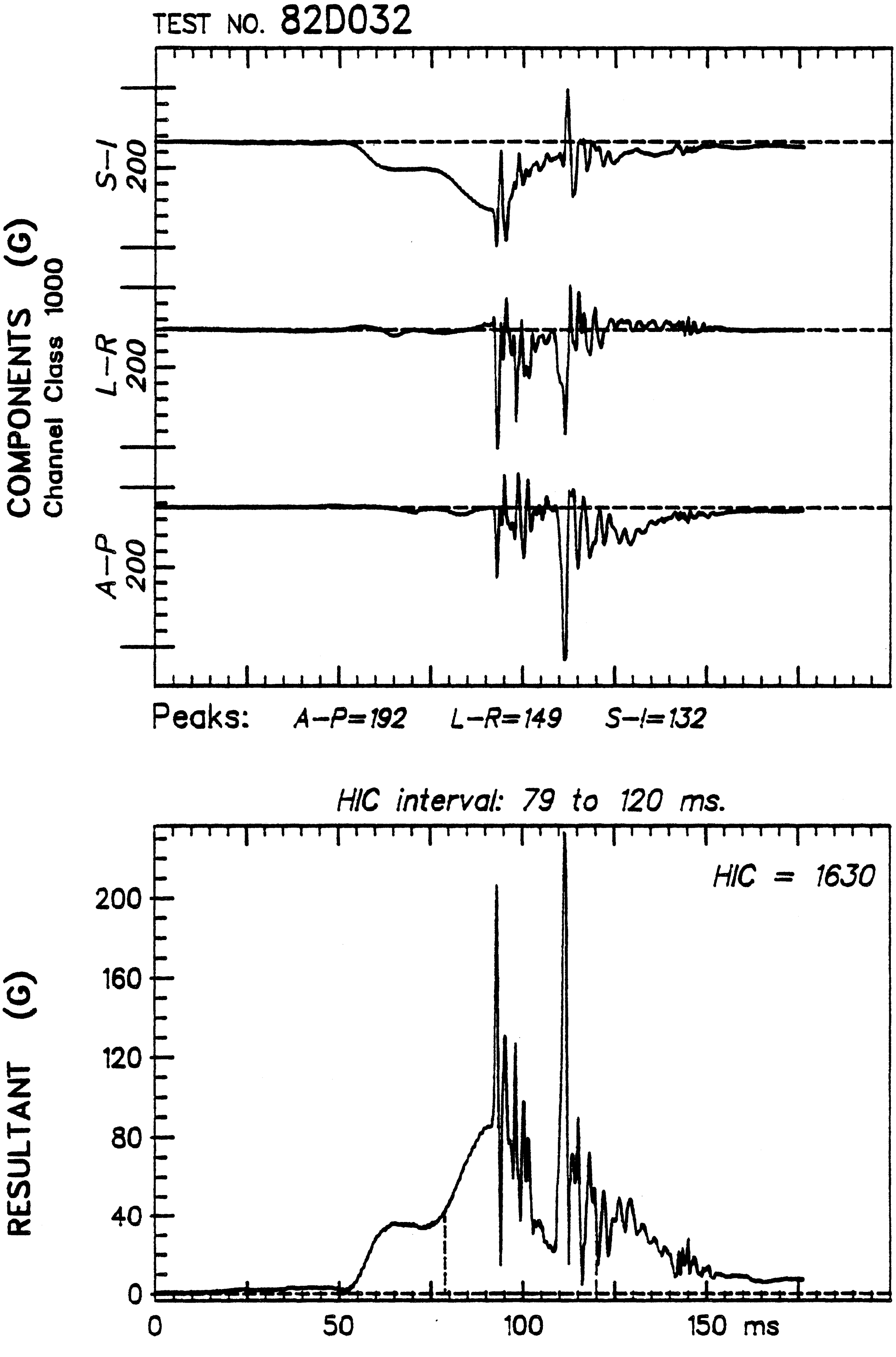
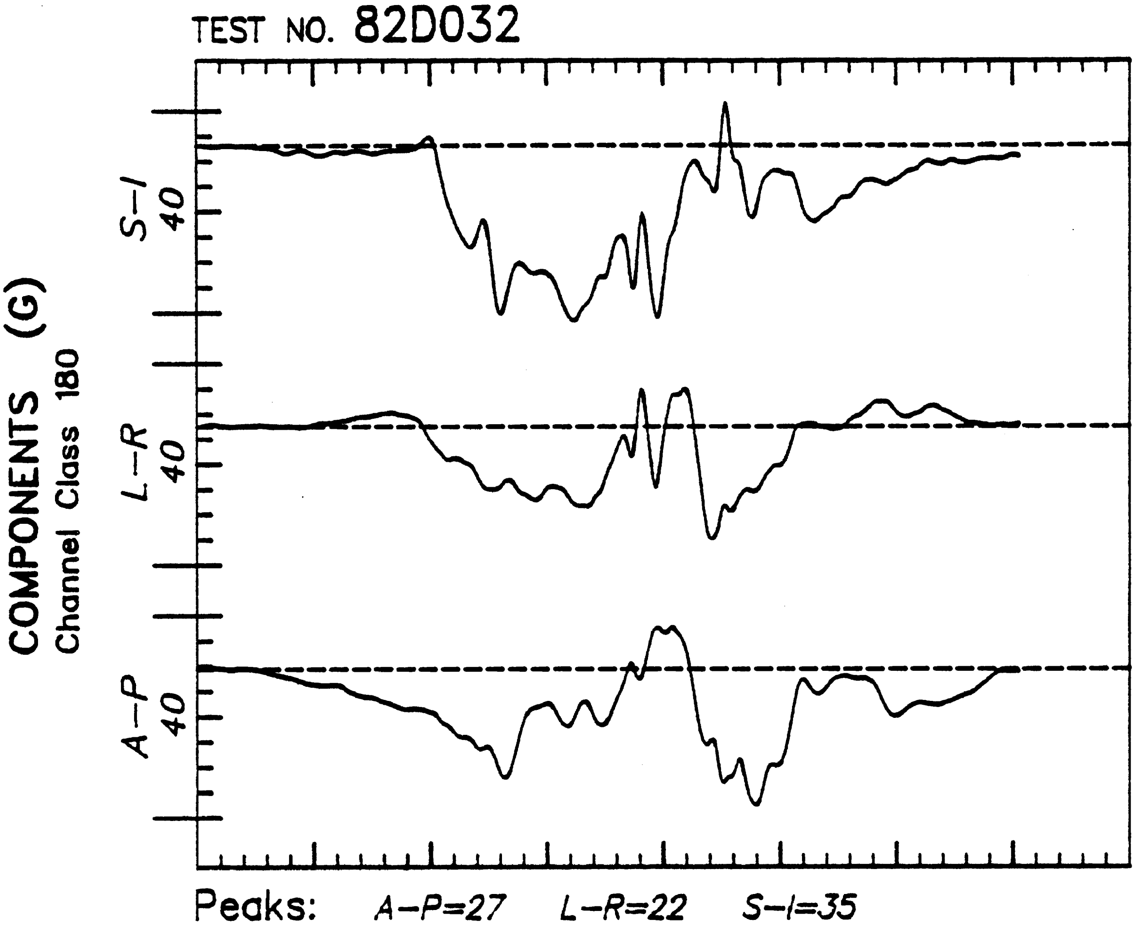
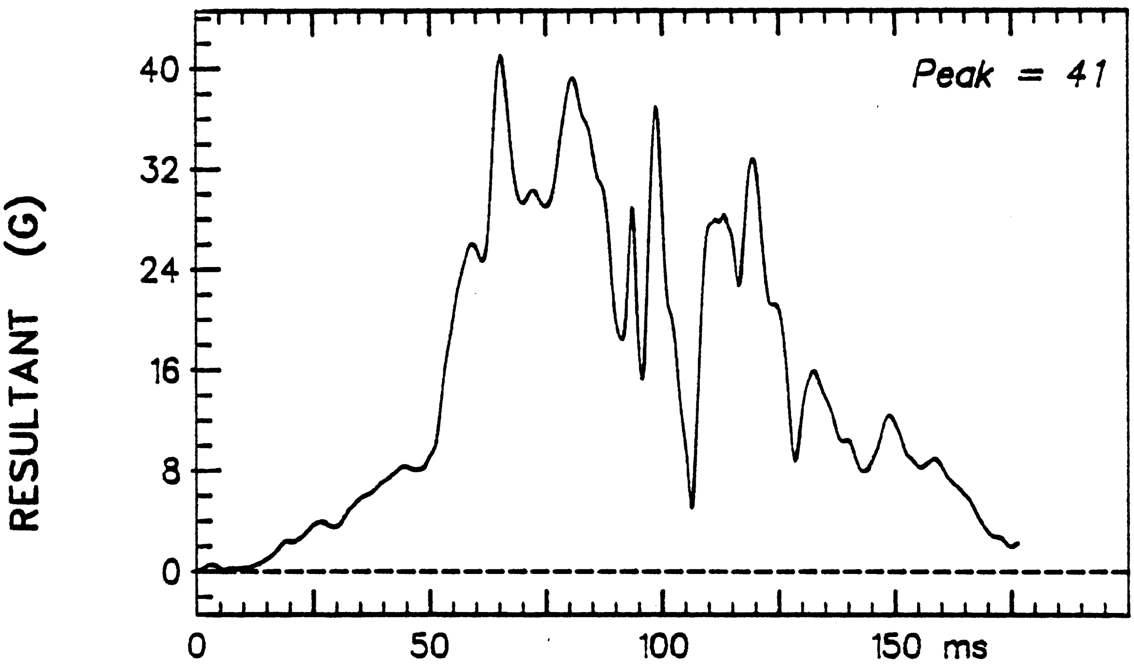
82D032



Head Accelerations





Chest Accelerations

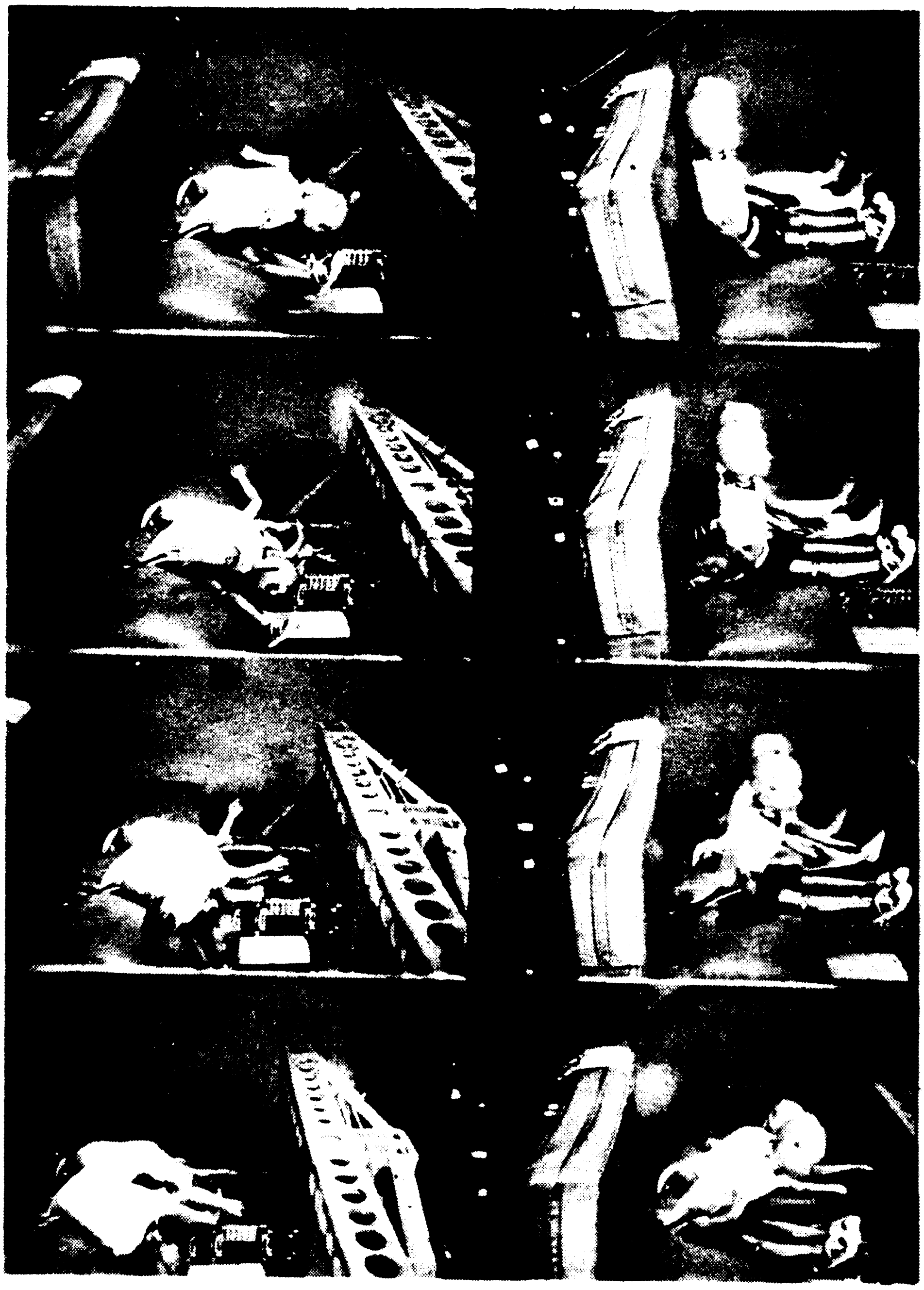
Test No.: *82D033*

Dummies: 3-Year-Old (Part 572)
3-Year-Old (Sierra)

Set-Up: Two dummies were restrained by a single "snug" lap belt, simulating a more realistic condition than the pretensioned belt.

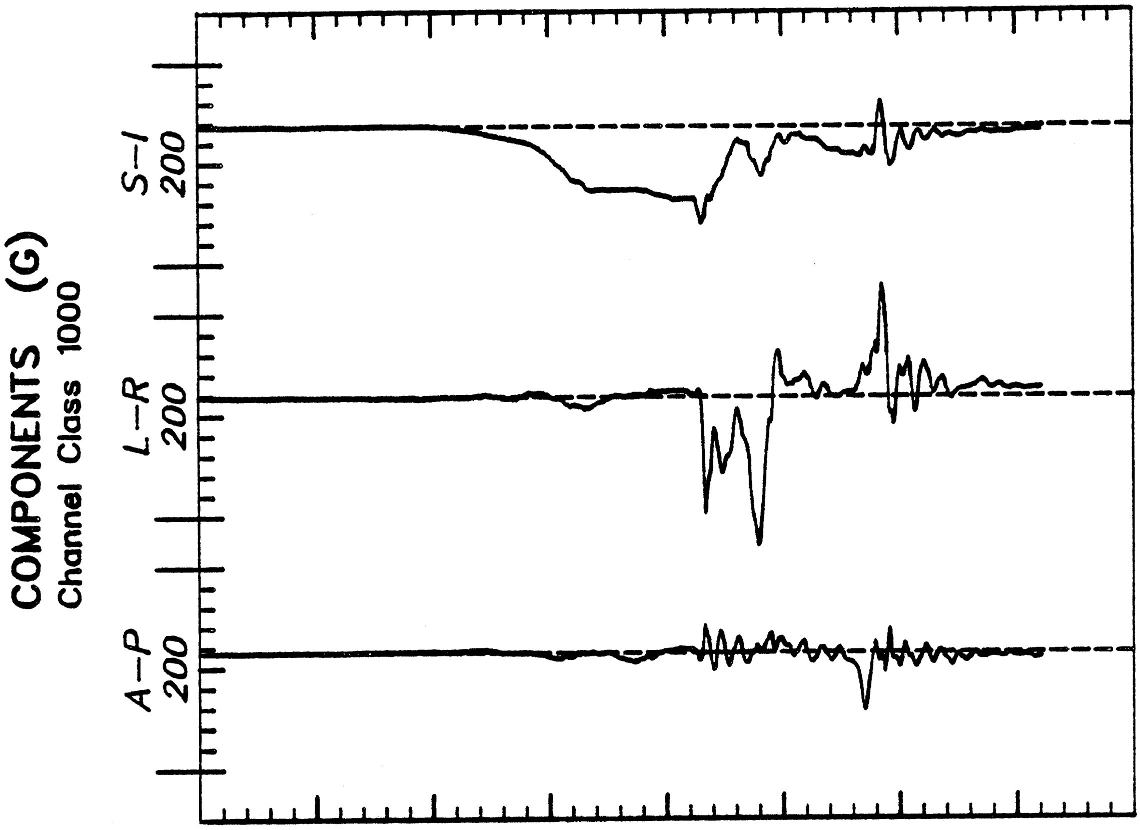
Results: The dummies' heads and upper torsos again flung together, and, because of the looser restraint, generated an even higher L-R chest acceleration, a much higher head excursion, and greater belt loads than the previous tests. After maximum excursion, the dummies again rebounded away from each other.

Head excursion	37.3 in.
Knee excursion	Obscured
HIC	1884
Chest peak accel.	49g
Belt loads	Right 1259 Left 1277



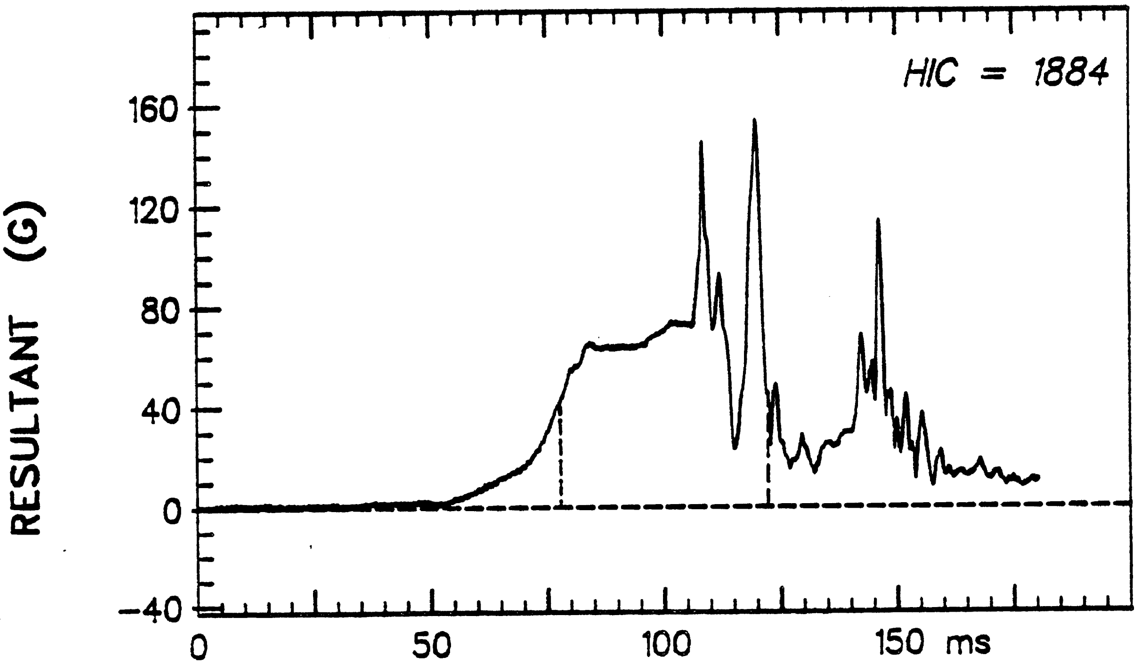
82D033

TEST NO. 82D033

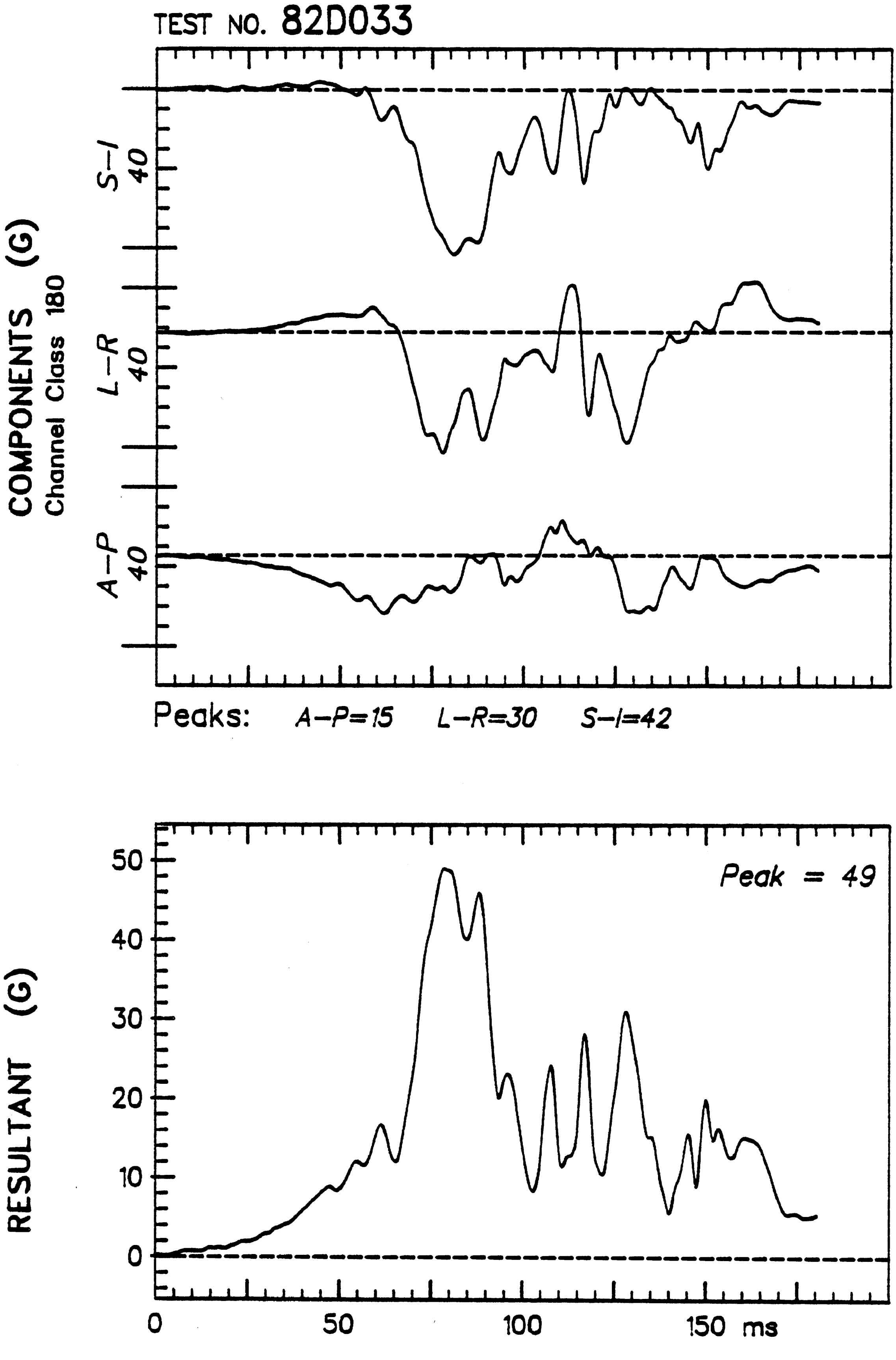


Peaks: *A–P=58* *L–R=148* *S–I=98*

HIC interval: 78 to 122 ms.



Head Accelerations

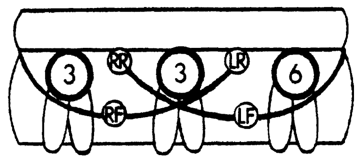


Chest Accelerations

Test No.: 82D034

Dummies: 3-Year-Old (Sierra)
3-Year-Old (Part 572, instrumented, center position)
6-Year-Old

Set-Up: Three dummies were restrained by two "snug" lap belts, crossed over the center (Part 572) dummy as illustrated. Belt load cells were placed as indicated by the small circles on the diagram.



Results: The dummies all moved straight ahead as though restrained by separate belts. The center dummy's head excursion was slightly less than that of the baseline test, and the HIC and chest accelerations were comparable. The belt loads of interest are those that most directly load the center dummy, identified as RR (right rear) and LR (left rear). Although the direction of loading may have been somewhat different, due to the cinching action, than that of a single lap belt, the magnitude was not substantially greater. The high load at the RR anchor reflects the extra weight of the 6-year-old dummy.

Head excursion	Right 3-year-old	32.6 in.
	Center 3-year-old	30.8 in.
	Left 6-year-old	36.0 in.
Knee excursion	Obscured	
HIC	1989	
Chest peak accel.	40g	
Belt loads	Right rear	920
	Left rear	677
	Right front	884
	Left front	1065

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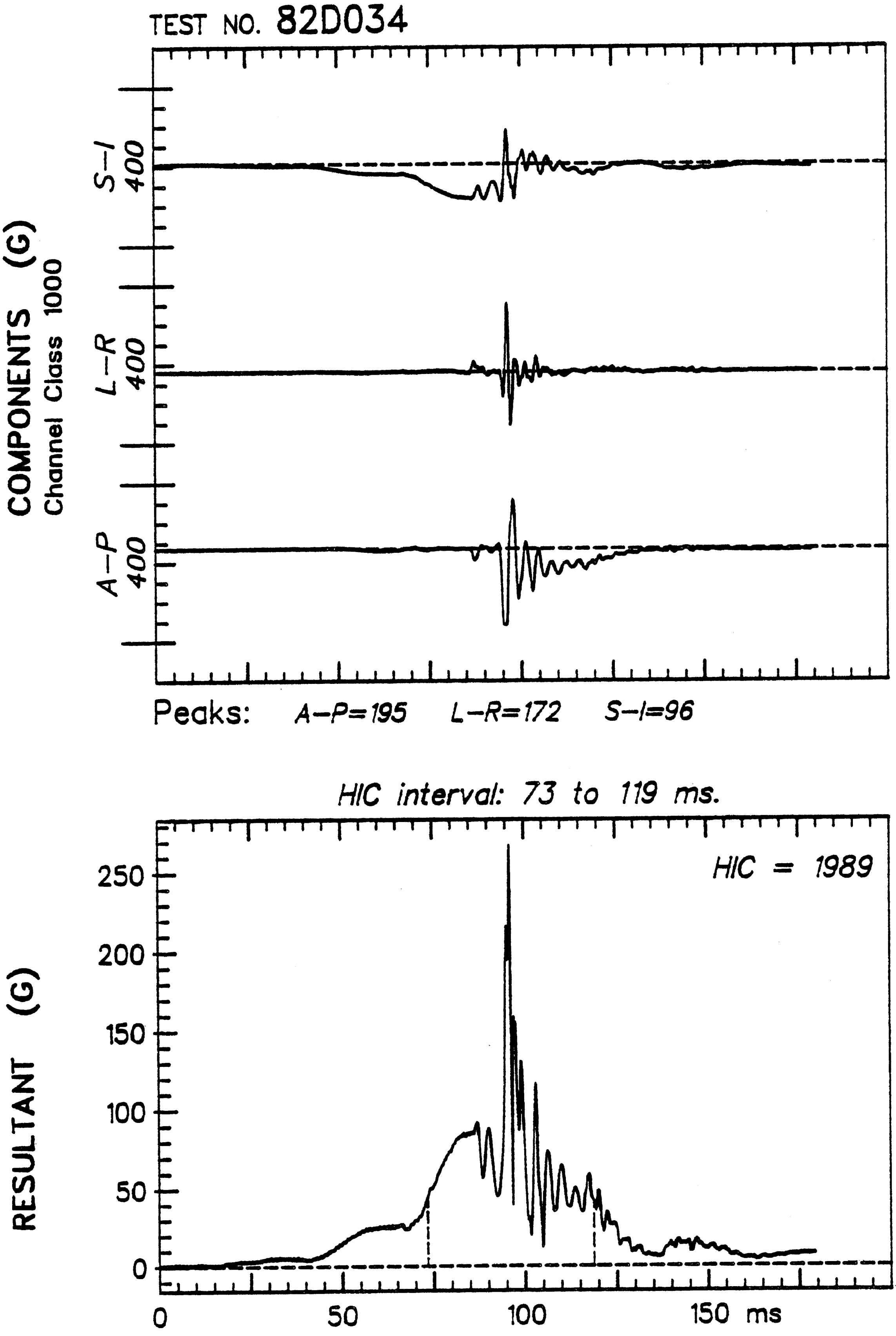
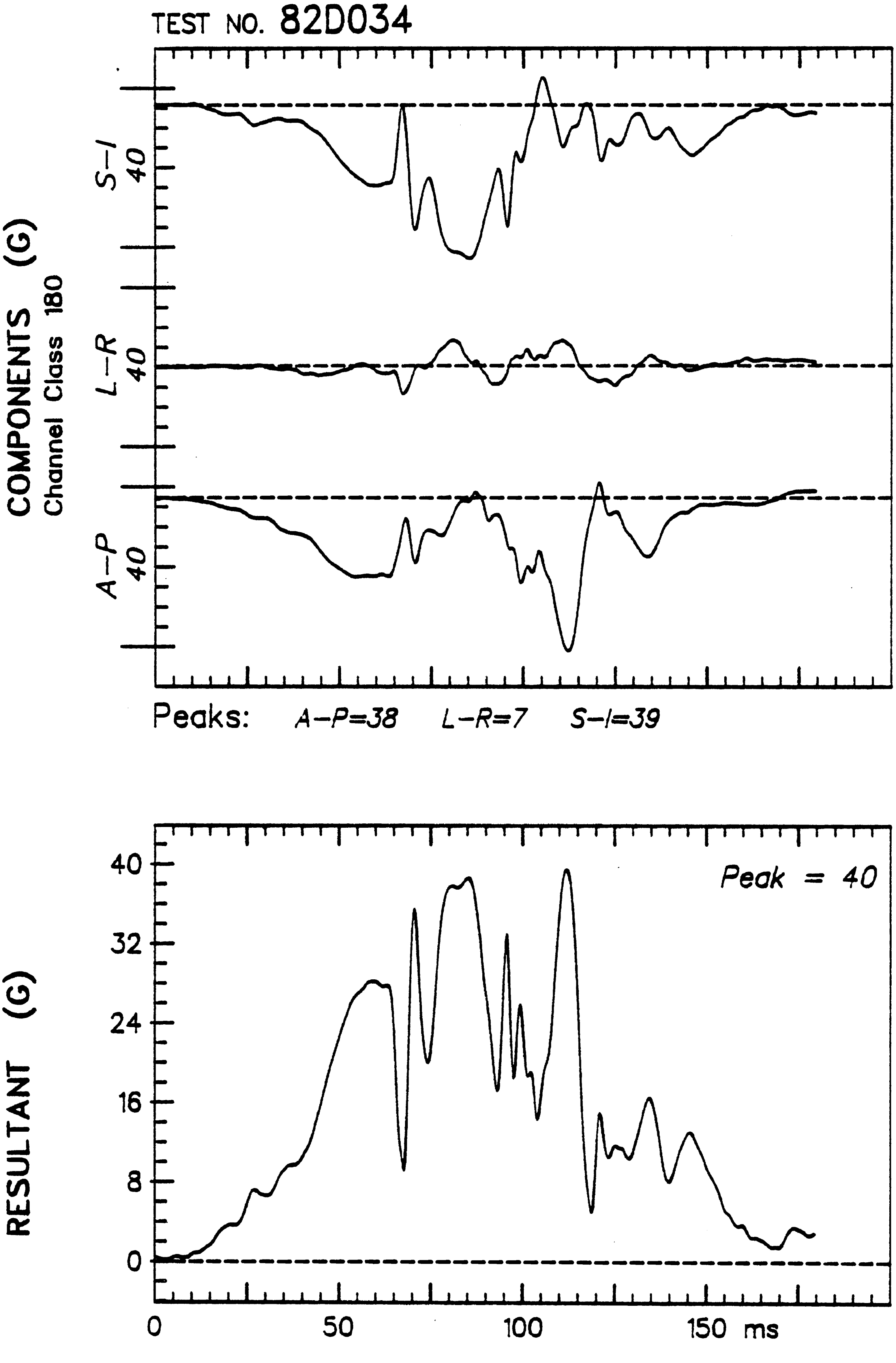
82D034



Head Accelerations



Chest Accelerations

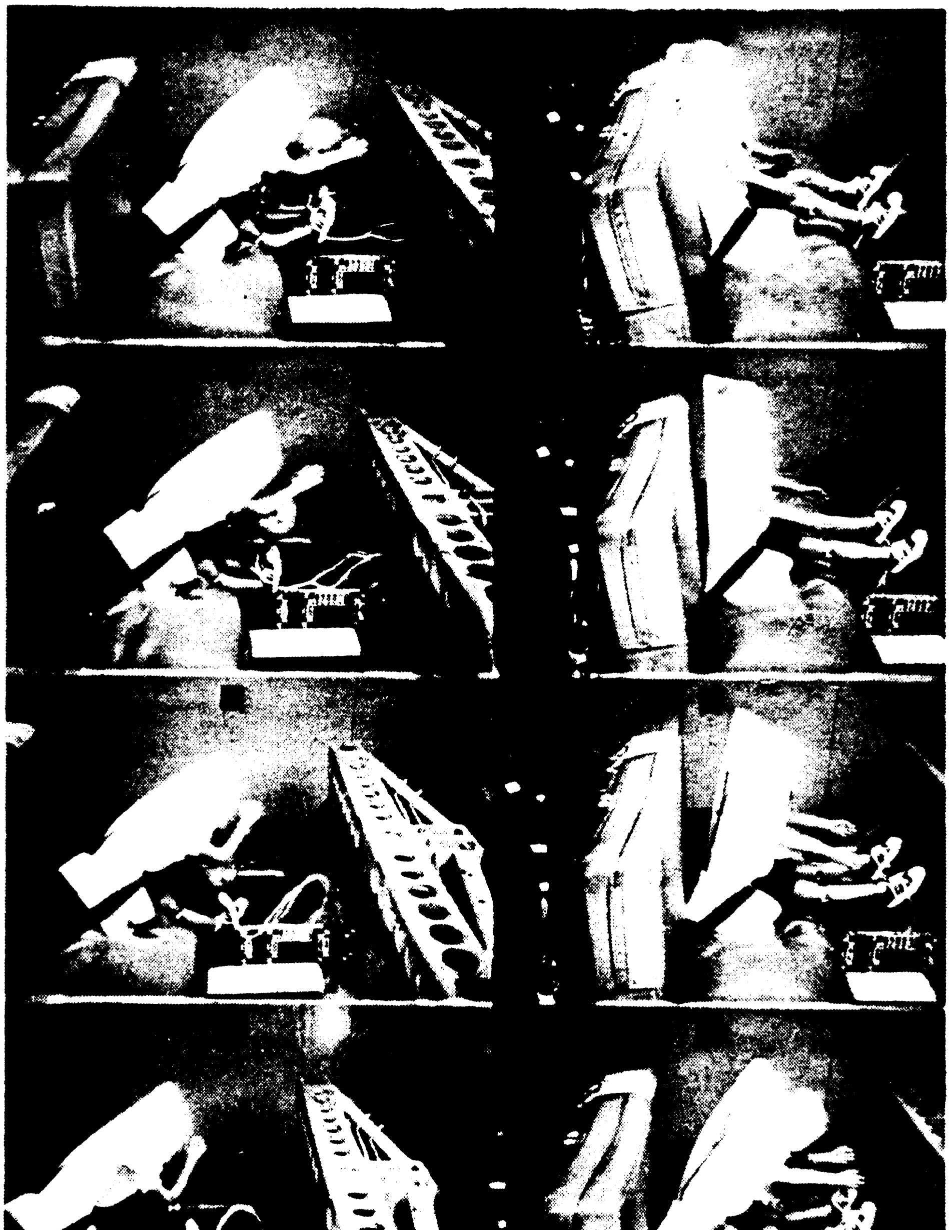
Test No.: 82D036

Dummy: 3-Year-Old (Part 572)
Child Restraint: Child Love Seat

Set-Up: The top tether was removed, but otherwise the CR was properly installed and the dummy properly harnessed.

Results: The CR rotated forward, allowing an excessive head excursion. It might have rotated farther had the lap belt not temporarily caught the left rear corner of the base. Other injury indicators were well below accepted limits. The CR remained in a tipped position after the impact.

Head excursion	35.4 in.
Knee excursion	26.6 in.
HIC	405
Chest peak accel.	30g



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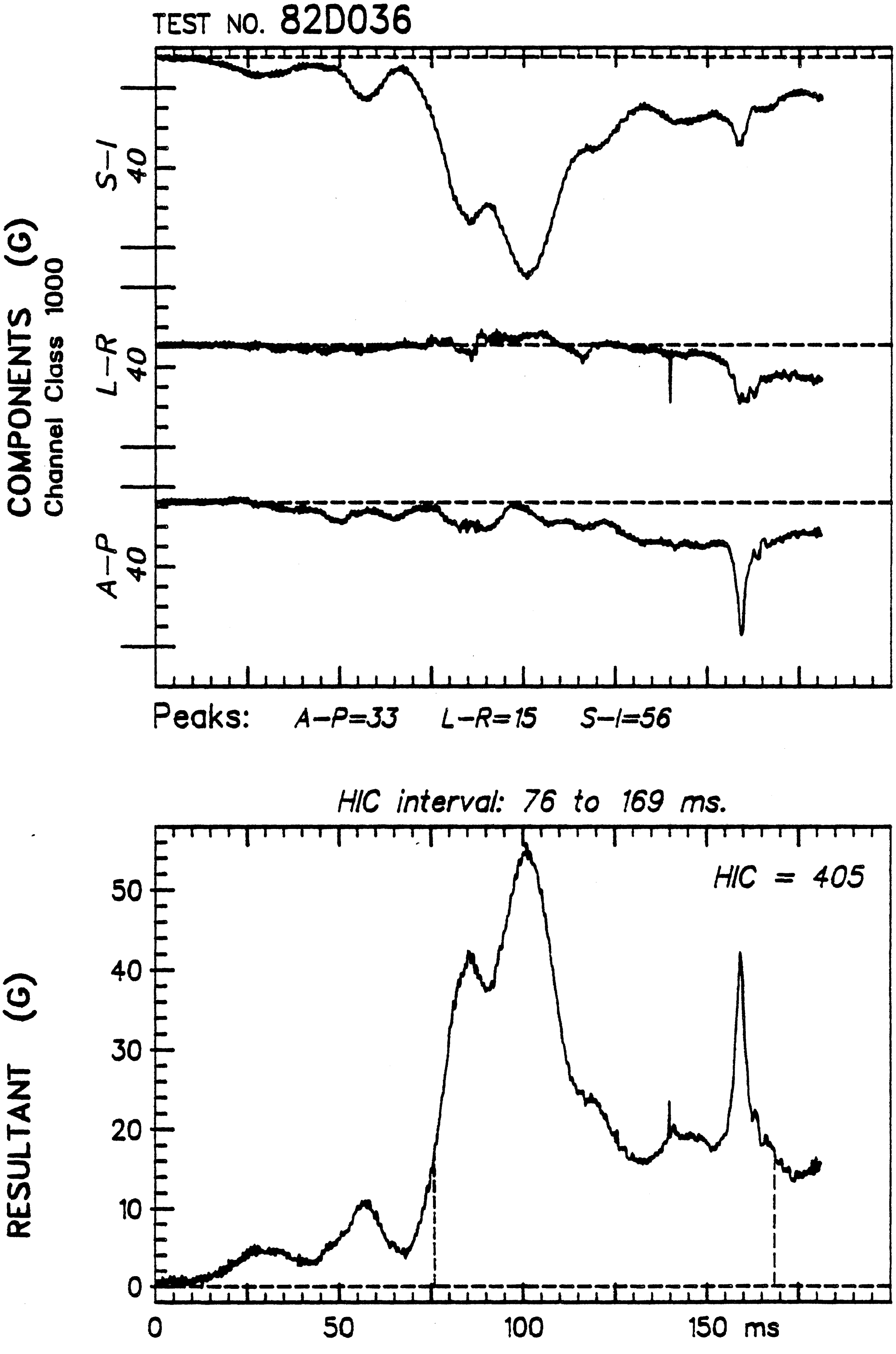
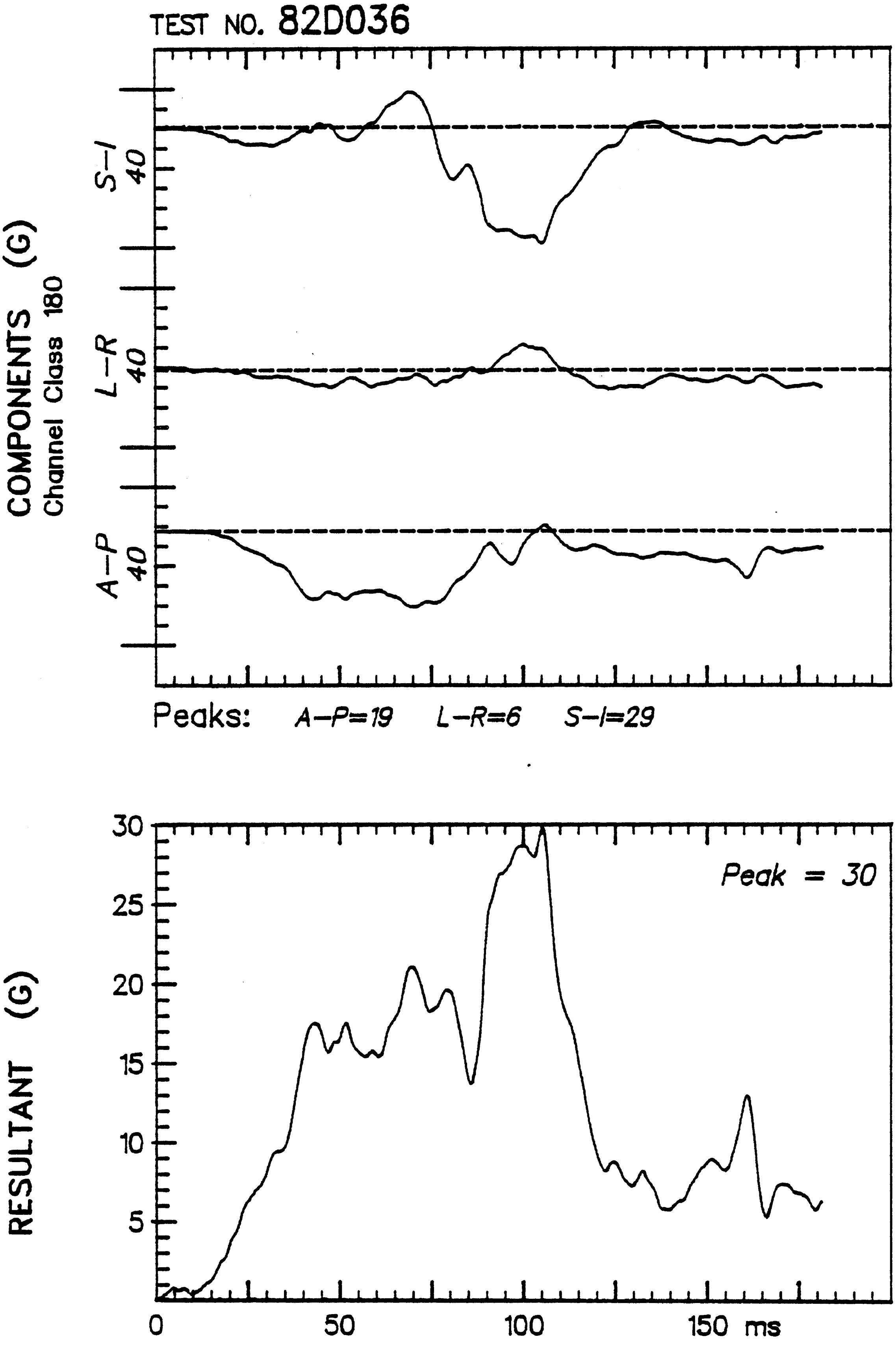


Head Accelerations



Chest Accelerations

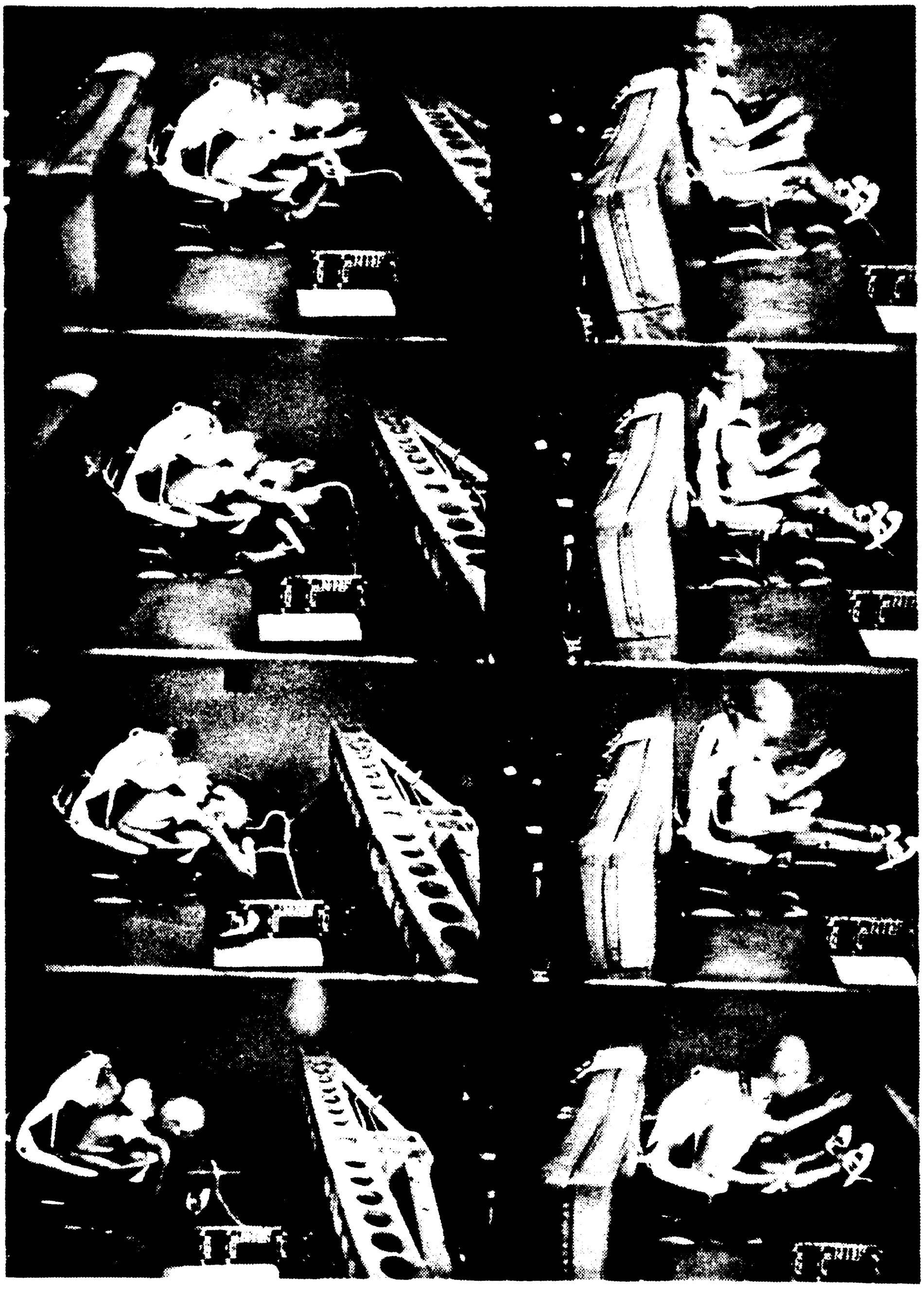
Test No.: ***82D035***

Dummy: 3-Year-Old (Part 572)
Child Restraint: Strolee 599

Set-Up: The top tether was removed, but otherwise the CR was properly installed and the dummy properly harnessed. This CR model is equipped with an arm rest that is not part of the restraining system but is held down by the buckled harness.

Results: The CR plastic shell deformed forward, allowing an excessive head excursion. The dummy's chin hit the far edge of the arm rest, generating a higher HIC than that seen with the Child Love Seat, although still not an excessive level.

Head excursion	34.9 in.
Knee excursion	29.1 in.
HIC	716
Chest peak accel.	41g



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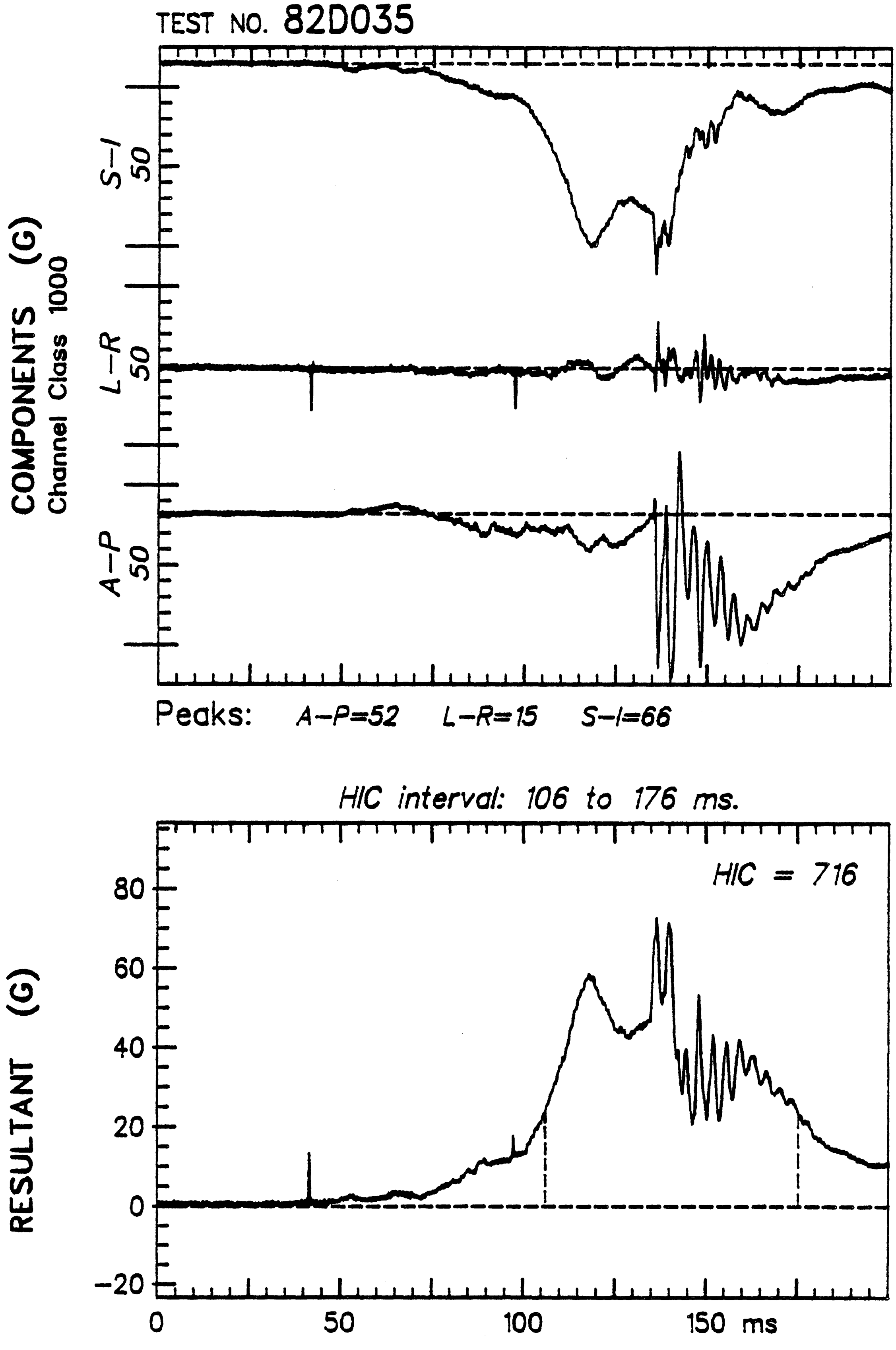
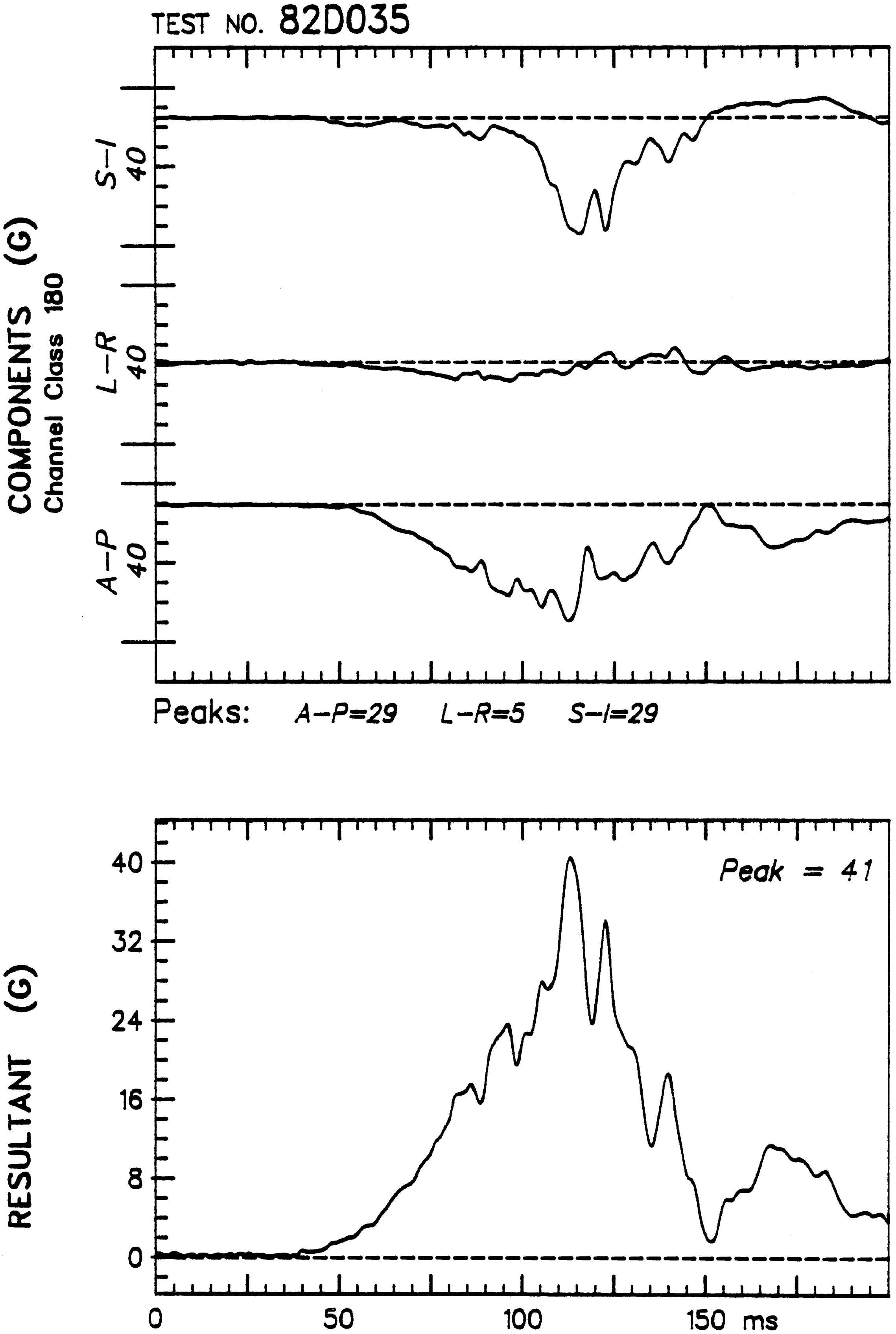
82D035



Head Accelerations



Chest Accelerations

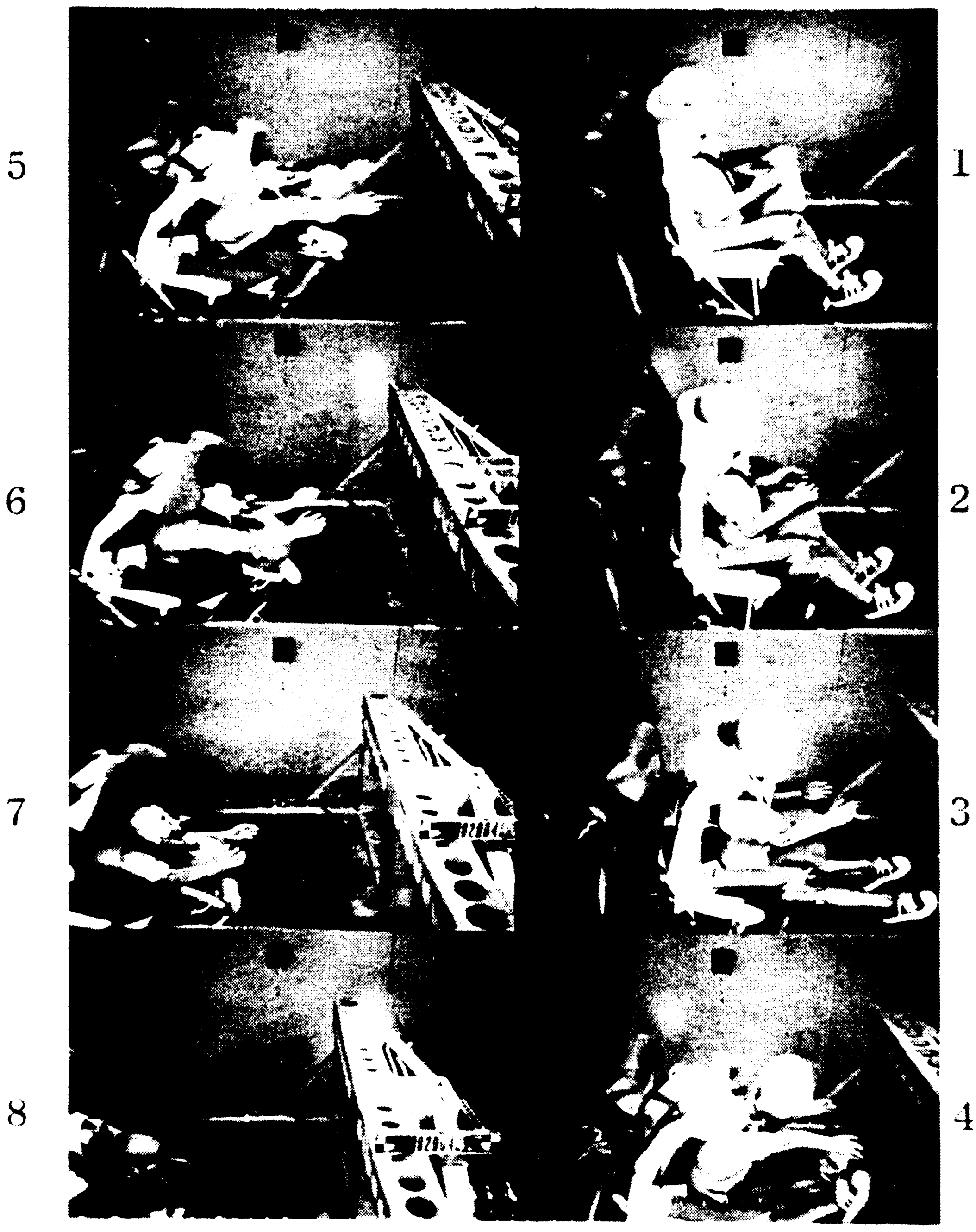
Test No.: 82D040

Dummy: 3-Year-Old (Part 572)
Child Restraint: Strolee 599
Test Buck: Chevrolet Front Bench Seat

Set-Up: The top tether was tied firmly around the metal post supporting the head restraint on the Chevrolet seat. The head restraint was then placed in its lowest position. The CR was otherwise properly installed and the dummy properly harnessed.

Results: The Chevrolet seatback deformed forward, and the tether pulled the head restraint up, allowing an excessive head excursion. Although the measured excursions for this and the untethered test are not directly comparable, because of the different test bucks, the vehicle seat itself was clearly not strong enough to provide a good tether anchorage.

Head excursion	35.9 in.
Knee excursion	29.7 in.
HIC	621
Chest peak accel.	39g



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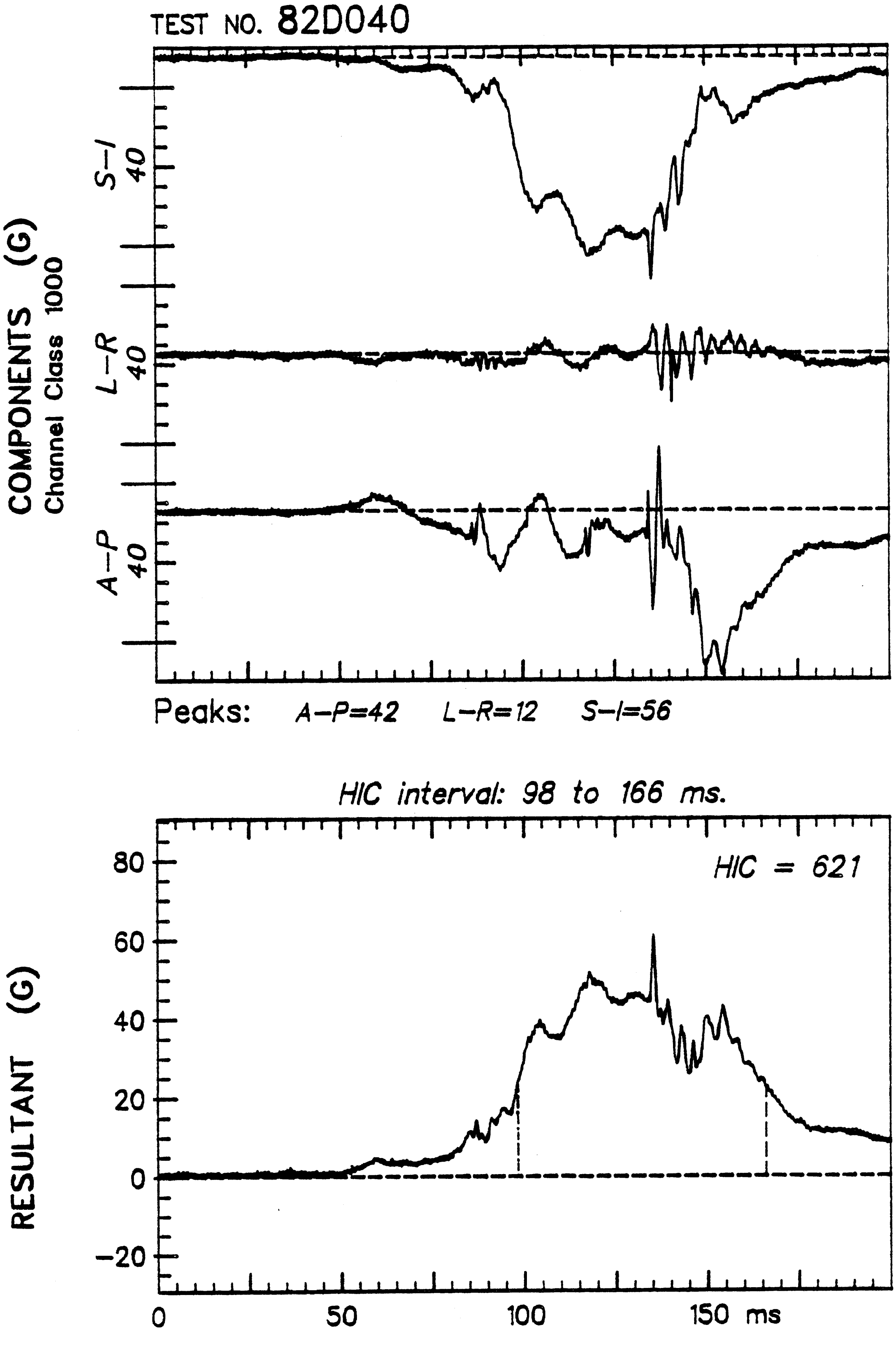
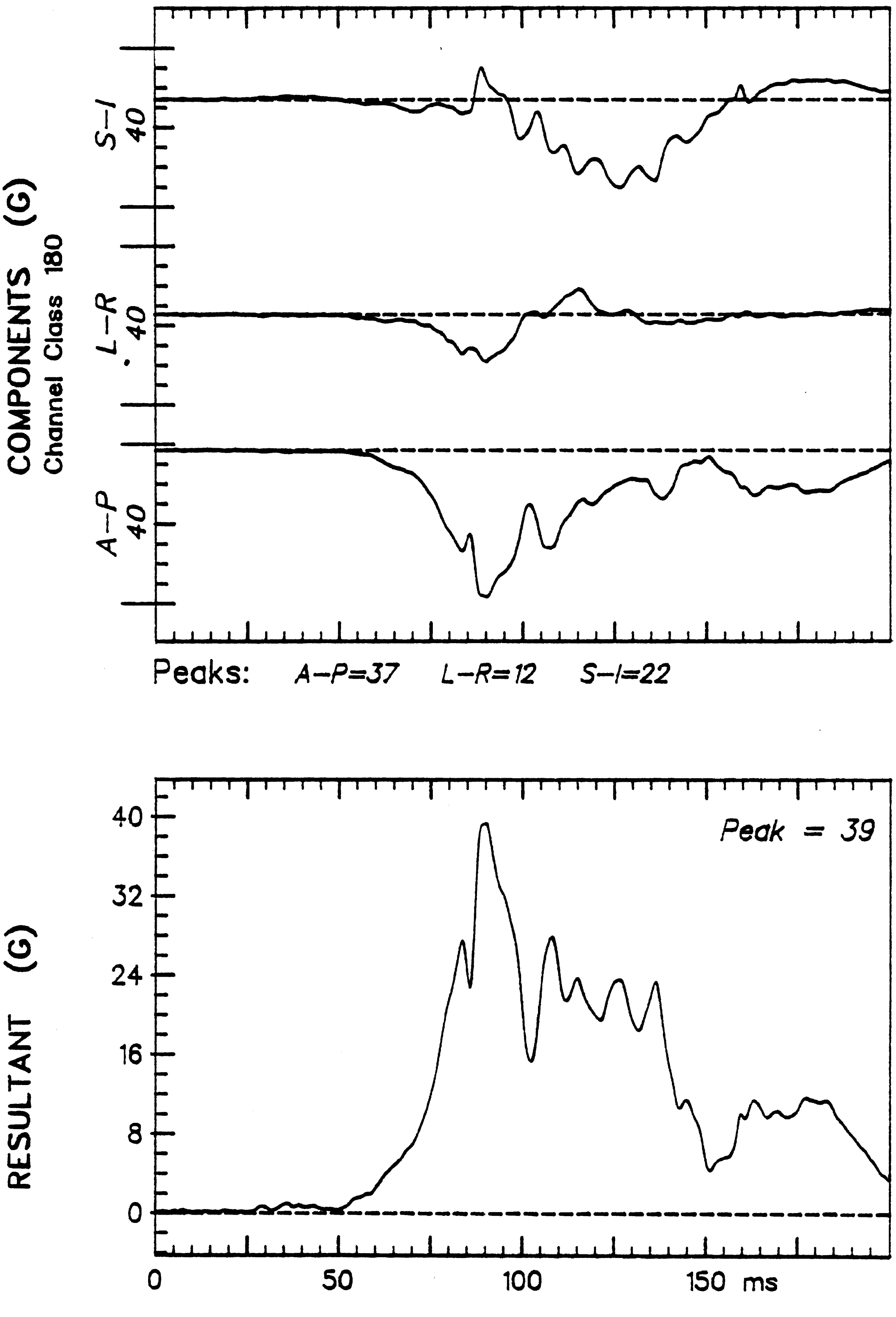


Head Accelerations

TEST NO. 82D040



Chest Accelerations

Test No.: 82D038

Dummy: 3-Year-Old (Part 572)
Child Restraint: Strolee 599
Test Buck: Standard Bench Seat (SBS)

Set-Up: The top tether was routed over the back of the SBS and straight down. It was then anchored to the buck floor, simulating tether configurations observed in the rear seat of station wagons.

Results: The CR traveled forward along with the back of the SBS, but, because this seatback is quite rigid, the head excursion was not excessive. The dummy's face contacted the arm rest, but with less force than in the untethered test.

Head excursion	30.6 in.
Knee excursion	27.9 in.
HIC	573
Chest peak accel.	31g

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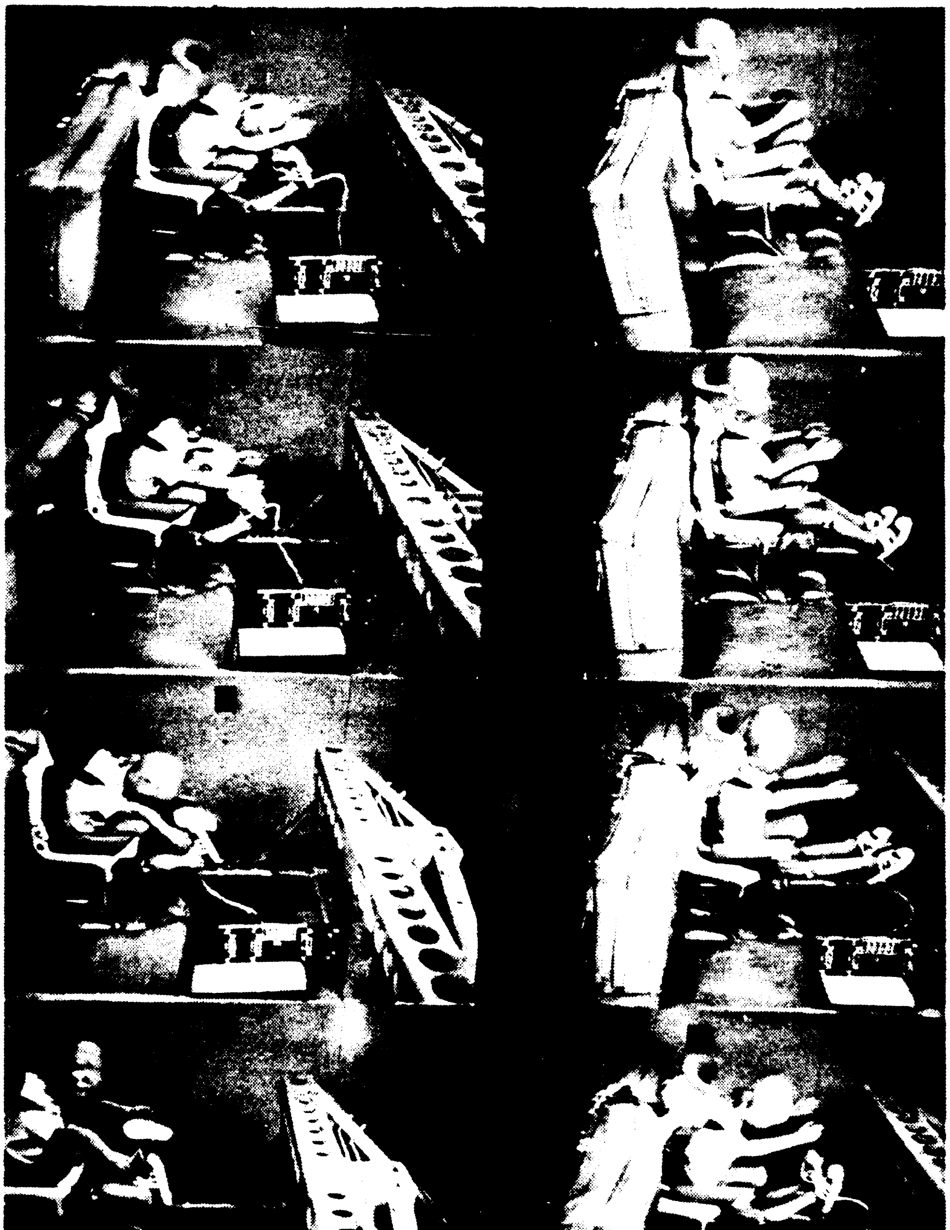

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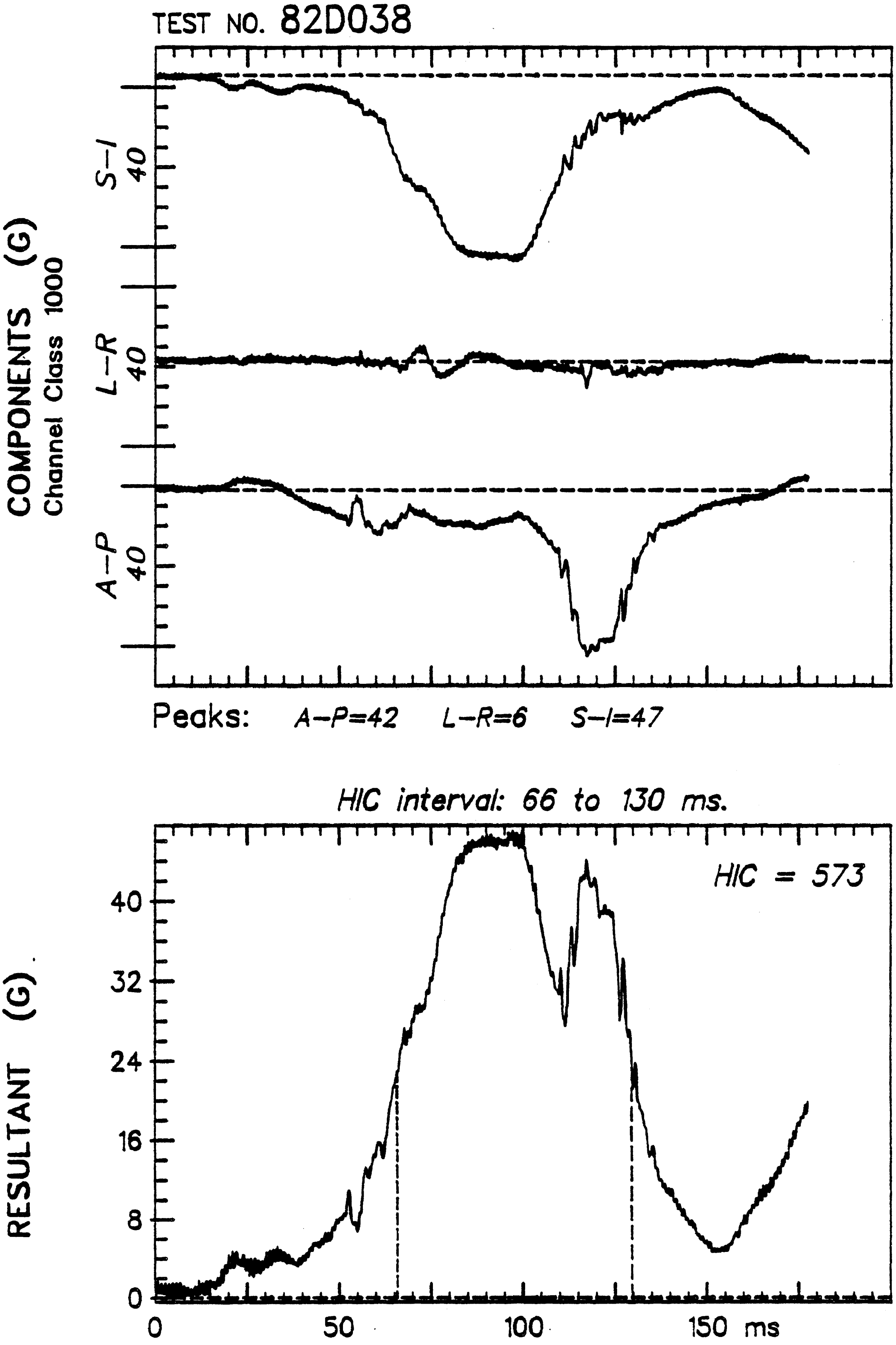
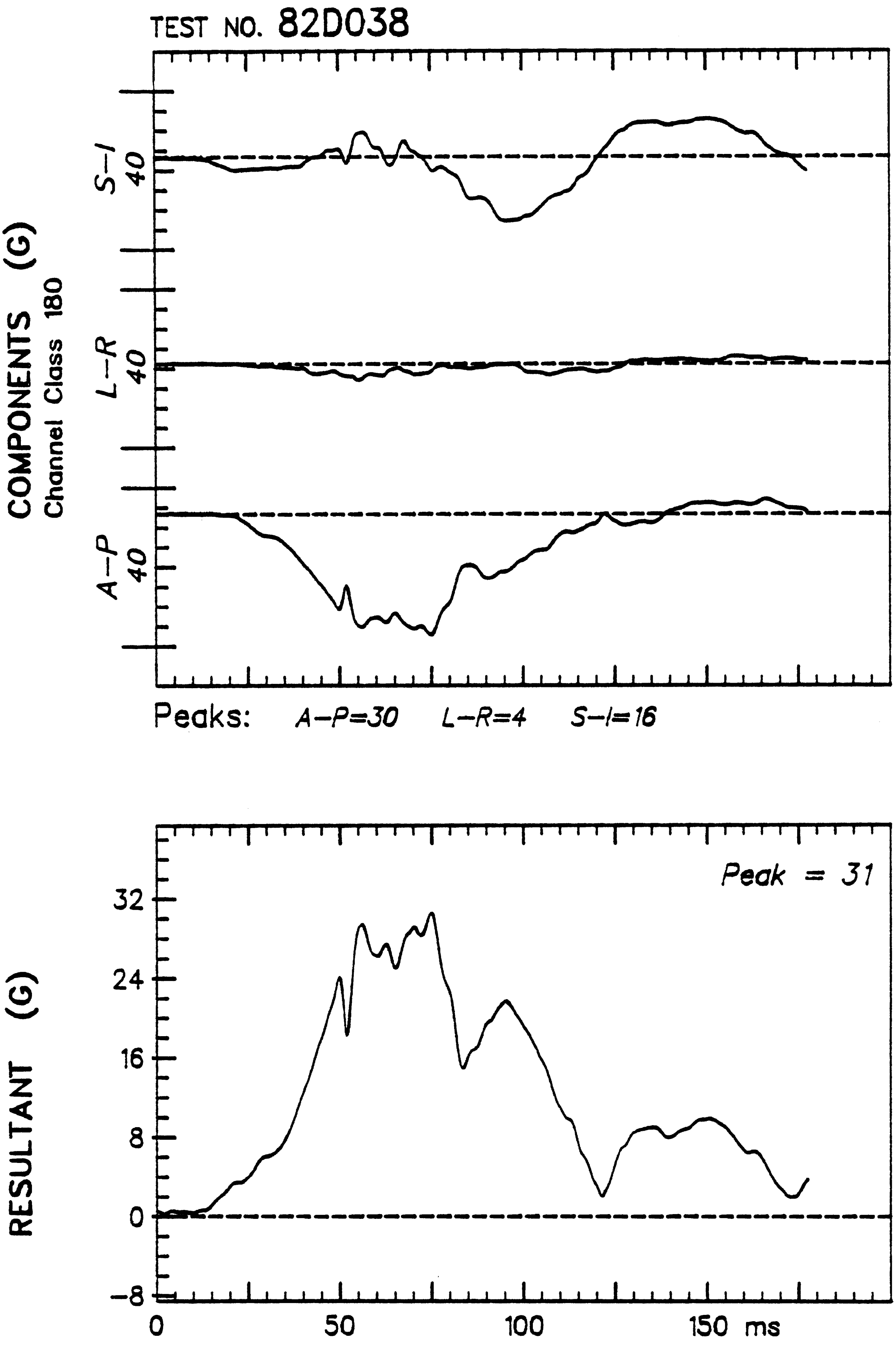


Head Accelerations



Chest Accelerations

Test No.: *82D037*

Dummies: 6-Month-Old (Part 572)
HSRI 50th Percentile Male

Set-Up: The adult dummy was restrained by lap and shoulder belts. The infant dummy was placed in a cloth babypack (Gerry Cuddlepack) that was properly hung on the shoulders and over the chest of the adult dummy, and straps provided were tied around the adult dummy's waist.

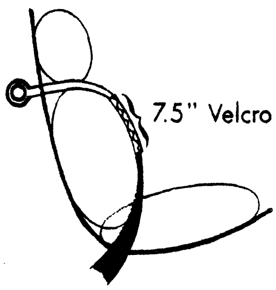
Results: The cloth of the babypack was not strong enough to restrain the infant dummy. It ripped apart, and the dummy flew forward. The belted adult dummy was effectively restrained, but, had the infant remained in place, the adult's head would have impacted the infant's head. In this test, the adult's neck flexed such that its facial surface traveled 5.5 inches below the initial position of the infant's head.

82D037

Test No.: *82D039*

Dummy: 3-Year-Old (Part 572)
Child Restraint: Astroseat 9100

Set-Up: The production harness of the CR was replaced with a new one that had 7.5-inch strips of Velcro sewn on the shoulder straps. These straps were actually doubled as illustrated in cross-section, the webbing having been threaded through the shoulder slots, around the horizontal upper frame tubing, back through the slots, and back over the dummy's chest. The Velcro thus functioned as a webbing closure and potentially as a harness adjustment mechanism. A loose rope was attached to the dummy in case the Velcro did not hold. The CR was properly installed; no tether is required with this model.



Results: The Velcro held and did not even slip. The harness functioned as intended, and in fact the doubled shoulder straps generated an especially low head excursion for a non-tethered CR.

Head excursion	27.6 in.
Knee excursion	30.0 in.
HIC	300
Chest peak accel.	42g

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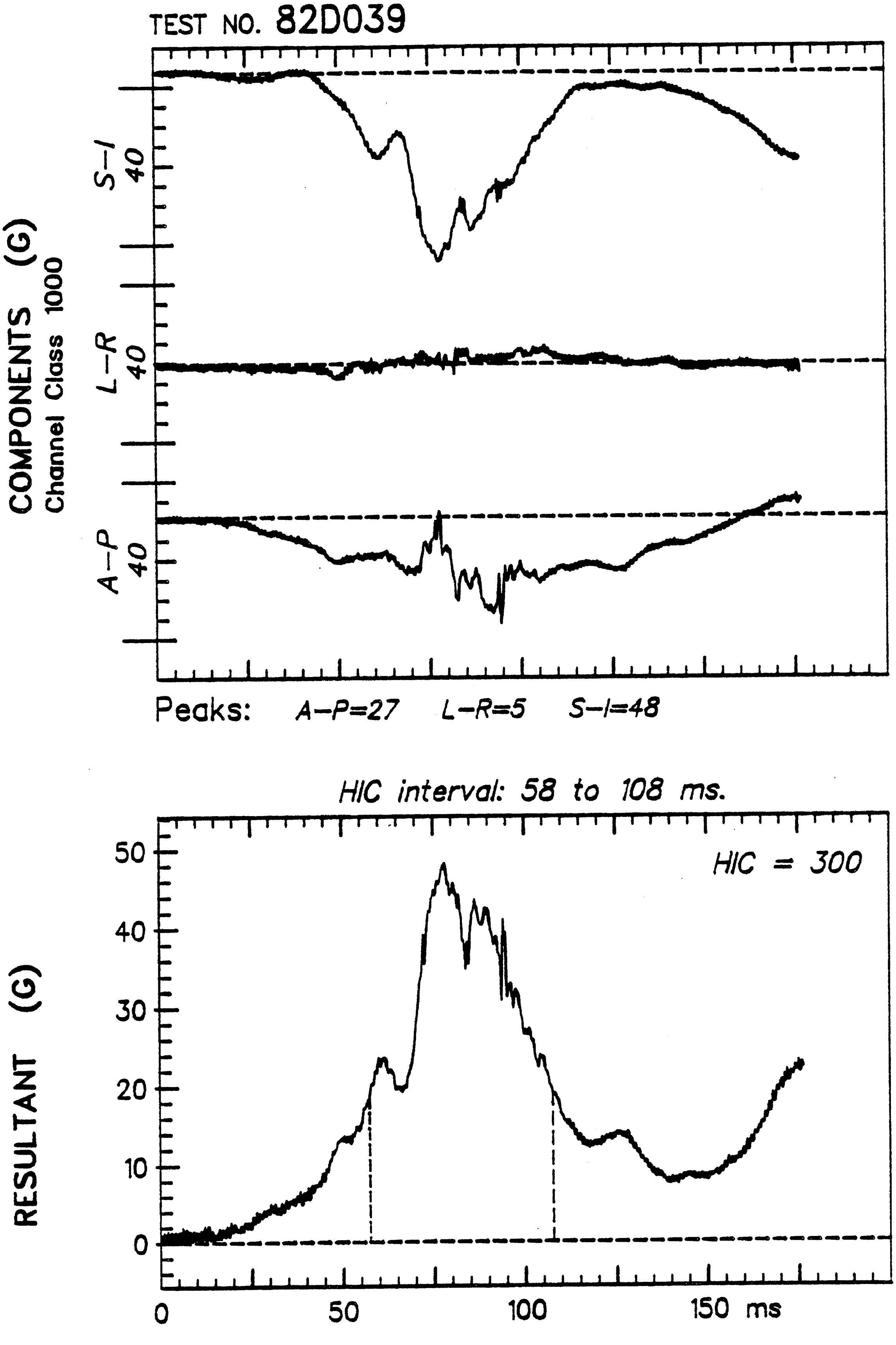
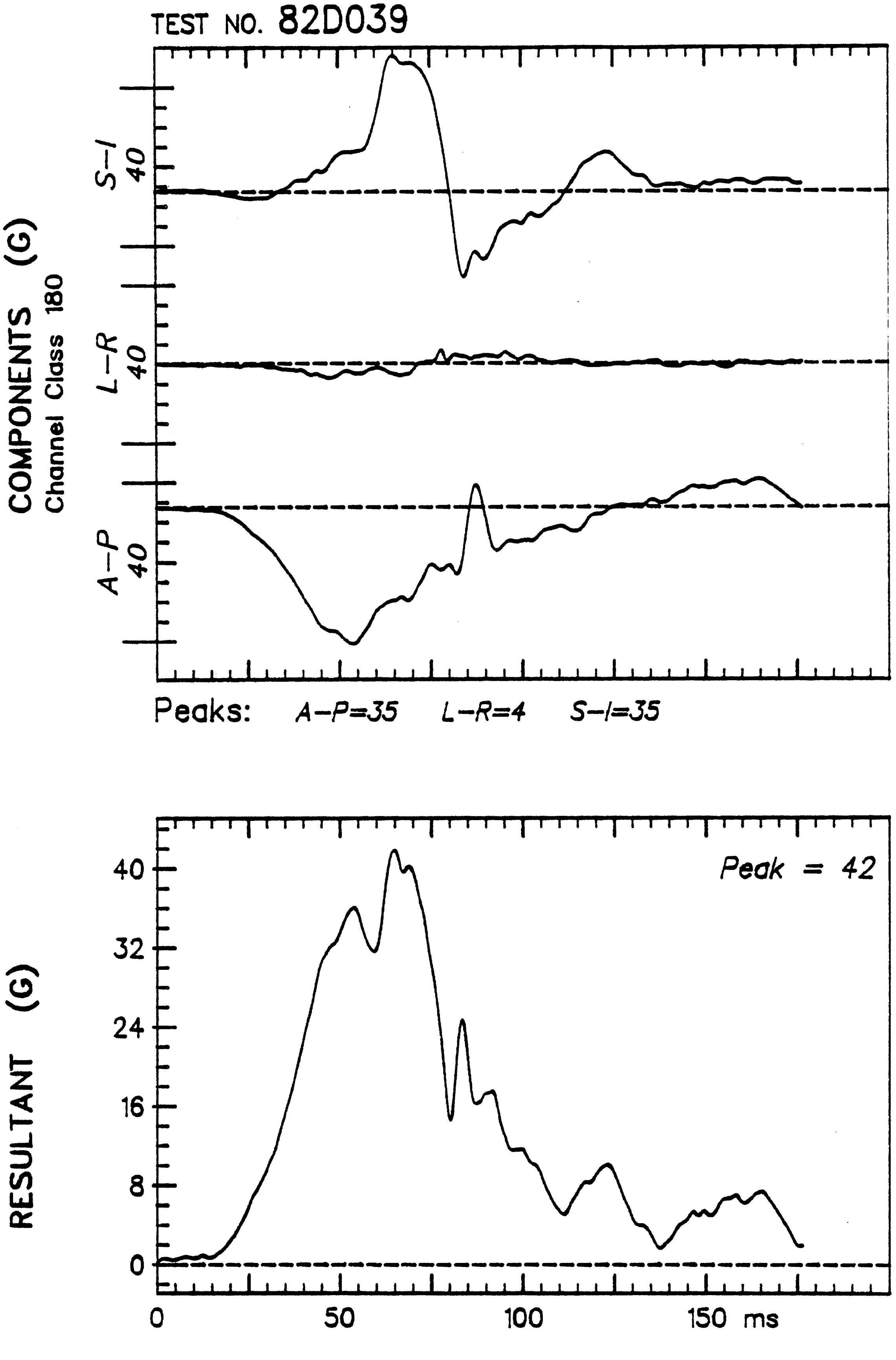
82D039



Head Accelerations



Chest Accelerations

4.0 Discussion

The tests in this program were successful in that they demonstrated that certain child occupant protection concepts had promise while graphically showing the dangers intrinsic in others. The discussion that follows emphasizes the important points that should benefit the public through a better understanding of restraint system dynamics.

4.1 Lap Belts

Although a lap belt is designed to restrain a single occupant, there are real-world situations in which there are more occupants than belts, particularly when children are involved. At the same time, there is often adequate seating space for an additional small person. Typically, three children are placed in a rear seat equipped with only two belts. In the past, safety advisors have suggested that two children should share a belt rather than one child being allowed to ride completely unrestrained. As demonstrated in these tests, head-to-head impact would occur in a frontal crash that could result in the type of severe injuries restraint systems are supposed to prevent.

A better alternative appears to be the 3-in-2 configuration, in which three children are restrained by two belts crossed over the center child. The advantage of this system over a 2-in-1 configuration is that all three children will bend directly forward during the impact avoiding any head-to-head contact. The dummies in our test did, however, splay apart somewhat upon rebound, making contact with the vehicle side interior a possibility.

Head excursion for the center dummy was actually better in the 3-in-2 configuration than for the normally lap-belted dummy, because the forces exerted by the outboard dummies cinched the center belt tighter and tighter during the impact. These outboard dummies, however, were somewhat more loosely restrained than they would be under normal 1-in-1 conditions, but they were still more effectively restrained than in the "snug" 2-in-1 configuration of test 82D033.

Our major initial concern about the 3-in-2 configuration was the possibly injurious effects of the belt forces on the center child. Although the loads at the center belt anchorages were not particularly high, the scissoring action of the crossed belts deserved some attention. We determined, however, that, as long as the anchor points were as far apart as the child's hips were wide, the direction of belt forces was essentially the same as for a single lap belt. As the space between the anchor points narrows, different forces are generated around the pelvis. Although a normal lap belt will perform as though slack when the anchor points are too close together for the occupant, crossed belts will probably remain tight. Further study of the effects of belt geometry are needed. Until then, we advise against using the 3-in-2 configuration if the center belt anchors are closer together than the width of the child's hips.

A curious result of this test was the surprisingly low belt loads, considering that the weight of one and one-half dummies was acting on each belt. This result indicates that such a crossed system couples the dummies more closely to the impact sled and thus, taken as a whole, is a more efficient pelvic restraint system than three individual belts. Unfortunately, the gains in head excursion of the center dummy are partially offset by losses experienced by the outboard dummies.

Finally, we speculate that the 3-in-2 configuration would be most effective with three children of about the same size, because belt fit would be optimum and all three children would load the belts at about the same time. With children of different sizes, however, we advise placing the largest in the center for three reasons. First, reduced head excursion will be of greatest benefit to the tallest child. Second, heavier bodies produce higher belt loads, and the largest child would best be able to withstand the loads generated by the other children. Third, thicker bodies load belts sooner than thinner ones, and, if the smallest child were in the center, he would be squeezed laterally by the crossed belt before receiving the frontal restraining load. The effects of this lateral loading are unknown.

Although the 3-in-2 configuration is a better alternative than the 2-in-1 configuration, it is still not an optimum restraint system for all occupants. Until further study suggests otherwise, it should still be used only as a temporary solution in an emergency situation. We do not advise using this configuration as a regular means of restraining children in motor vehicles.

4.2 Tethers

Although the public has been repeatedly advised in safety publications that child restraints requiring tethers to pass the 30-mph impact test are seriously degraded without their tethers, the low rate of tether installation, observable in any parking lot, clearly shows the public either does not believe the warnings or does not care. Perhaps pictures will be able to convince where words have gone unheeded.

The two brands that were tested untethered at 30-mph were selected because they have been the most frequently purchased tethered CRs and they represent two different design types. The Child Love Seat (CLS), which is virtually identical to the model formerly known as the GM Child Love Seat, is a hollow plastic shell, over which the vehicle seatbelt is passed. The Strolee 599, which is constructed similarly to the 597-A but has been structurally improved over the 597-S, is a plastic shell bolted to a metal frame, through which the seatbelt is passed.

In the case of the CLS, the entire shell rotated around the seatbelt until both the belt and the back edge of the CLS were about 55° from vertical. It is possible that, on a more contoured vehicle seat than the SBS, the back of the base might not have slipped up so high. It is also possible that, with a less tight seatbelt, the CLS would have rotated completely out of the belt. If this CR were in the rear seat of a real car, a 3-year-old child's head might only impact the padded back of the front seat. But in the front, this level of head excursion (35.4 in.), along with the elevated seating position, might put the child's head into the windshield, the metal frame around the windshield, or the instrument panel, particularly if the vehicle crushed into the passenger area.

The Strolee behaves differently when subjected to impact untethered. The shell is held firmly by the frame only at the base of the shell. During impact the single wall of plastic then bends at a point partway up the back of the shell. Again, the level of head excursion allowed, along with the head elevation, would be quite dangerous, particularly in the front seat.

Tying the tether to the front seat head restraint does not appear to improve the situation, at least not for the Strolee design. Inertial forces not only bend the shell but also pull the vehicle seatback forward. This seatback appears to provide no restraint whatsoever. If we apply these results to a situation in which a tether may be anchored to the floor close to the base of a station wagon or hatchback rear seat, the tether thus pulling on the top of the seatback in a crash, we can assume that this tether will also be worthless. Further testing with an actual rear seat configuration may be necessary, however, to provide convincing evidence.

The question now arises as to the crash protection trade-offs between using an untethered CR that needs this extra anchorage and using a lap belt alone with the child sitting directly on the vehicle seat. We have shown that head excursion is much lower for the lap-belted dummy than for the dummy in either untethered CR, but the CR harnesses do spread the impact forces over a larger body area than does a lap belt.

Because brain damage is irreversible, the most critical part of the body to protect is the head. There is thus no question that, in the front seat, a lap belt would be better than one of these tested CR models used untethered. Better still would be a lap belt in the rear seat. Because the potential for head injury in the rear seat is less than in the front, an untethered CR that <u>needs</u> a tether provides protection somewhere between rear seat and front seat lap belts. If the child refuses to stay in the rear seatbelt, because he cannot see out, for instance, then the untethered CR in the rear seat is the better alternative.

4.3 Babypacks

Cloth packs used by parents to carry small infants on their chest look tempting as a convenient way for a passenger to transport a baby in the car as well. Our test revealed two reasons that this system is not and could not be developed into a good restraint system.

First, the product as constructed was not made of materials that could withstand 30-mph impact-level forces. Second, even if a babypack were reinforced with seatbelt webbing, there would be injurious interactions between the adult and the infant. Specifically, the adult's head would probably crush the vulnerable top of the infant's head. If further convincing of the dangers of this system is needed, a strong enough babypack could be constructed for another test.

4.4 Velcro

The suggestion is often made that Velcro should be tried on child restraint harnesses to facilitate adjustment and/or closure. To test this concept in the most optimum configuration that was also a fairly simple one to construct, we attached long strips of Velcro to the shoulder straps as described in the previous section. As noted in the test results, the Velcro held firm and even contributed to reducing head excursion.

The questions now are, how much Velcro is needed, and how would it hold up over time under real use conditions? The first question could be addressed using the same harness configuration with less and less Velcro overlap area. For the second, the manufacturer of this product may be able to advise on its degradation with use.

Additional practical problems remain, however, of designing a harness or other restraining system using Velcro that would be adjustable through a wide range of sizes and could not be opened by a child trying to get out of the CR. It would not be possible, for instance, to attach Velcro to the entire length of the shoulder straps to overlap as needed, because the two adhering surfaces are of different texture. What might overlap well for a large toddler might not match up for a newborn. Because of the wide variation of harness length needed for different size children, it may be necessary to make only small adjustments with a Velcro system, such as for clothing changes, and leave major and less frequent size adjustments to other means. Also, because Velcro is relatively easy to open (release force required tested at less than 2 pounds), the closure or adjustment system on a CR used with a toddler would have to be located out of a child's reach while being accessible to adults. Velcro might thus be most appropriate in infant-only restraints.

Finally, as a side-issue, the excellent performance of this non-tethered CR should be compared with the performance of other systems tested in this series.

5.0 Conclusions and Recommendations

The approach of testing and filming popular alternatives to officially accepted child restraint systems, as well as testing unconventional but promising ideas, is important for determining the trade-offs that exist when the ideal is not possible. The films themselves are also an effective teaching tool to convince the public of the dangers of some systems that are in common use. The films that accompany this report have been shown thus far only to fairly knowledgeable audiences, but the visual results still generate expressions of surprise among the viewers.

The recommendations we are able to make to the public from this limited series of tests are as follows:

1. If children are to be restrained by lap belts, if there are more children than belts, and if there is no additional vehicle available, restrain three children in two belts crossed over the center child, with the largest child in the center position. (See Test No. 820034 for belt routing details.)

2. If a CR requires a tether, it should not be used in the front seat unless it is anchored to a rear-seat lap belt. If all lap belts in the rear are in use, the child should be placed directly on the vehicle seat and should use the adult seatbelts. (The shoulder belt should be placed behind the child only if it crosses the child's face or rubs uncomfortably on his neck.)

3. If a CR requires a tether and no properly-installed anchor is available behind the rear seat (i.e., anchored in solid metal and routing the tether at an angle no greater than 45° from horizontal), the child should be allowed to use this degraded restraint only if he cannot be made to stay in a lap belt sitting directly on the vehicle seat.

4. The concept of a chest babypack for restraining infants is totally unacceptable. Existing ones are not structurally adequate, but there is an additional danger of severe injury to the infant from the adult. The test films show that the adult's head would swing down and crush the infant's head if the infant were tied to the adult's chest.

5. The use of Velcro as a means of adjusting and/or closing child restraining systems has promise, but several practical problems relating to degradation, geometry, and child containment need further study.

We also recommend that further testing be undertaken of other commonly used as well as innovative restraining systems, so that the public can be better advised of the most reasonable alternatives available when the best is beyond reach.