CHILD RESTRAINT SYSTEMS
Frontal Impact Performance
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REPORT No. 36 A

Stockholm 1974
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FRONTAL IMPACT PERFORMANCE

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CHILD RESTRAINT SYSTEMS

A Series of Investigations to Promote Safer Transportation of Children.

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Road User and Vehicle Research Division

Stockholm 1974
This report covers the first part of a series of investigations of child restraint systems. The project was initiated by the Institute in 1972 and has been sponsored by the Transport Research Delegation. The following parts of the project are completed and will be reported in 1974:

- Frontal impact performance. Report no 36a
- Handling performance of buckles and harnesses on child seats. Report no 37a /1/.
- Psychological problems related to the use of rearward facing child seats. Report no 38a /2/.

The following parts of the project are planned:

- Head angular accelerations in child restraint systems.
- Side and rear-end impact performance.
- Performance of restraint systems for infants.
- Accident investigations of child restraint systems.

ACKNOWLEDGMENTS

This project was carried out by staff members of the Road User and Vehicle Dept. of the National Swedish Road and Traffic Research Institute, Stockholm, Sweden. The project was under the direction of Thomas Turbell. Impact sled testing was carried out by Helge Lofroth, Arne Pettersson and Christer Lenn.

Professor Bertil Aldman, Chalmers University of Technology, Göteborg, Sweden has served as medical consultant.

The contents of this report refer strictly to the products as investigated. This report is not a certification and the Institute provides no assurance, either expressed or implied, concerning the products.

// Refers to References at end of paper.
SUMMARY

Since the international recommendations for testing child restraints for several reasons not have been found applicable to the present situation in Sweden, where rearward facing child seats are quite common and well accepted, this project was started in order to:

1. Define the state of the art of design concepts, medical knowledge, regulations and impact performance of different systems.

2. Recommend compliance test procedures and performance criteria.

The first parts of the report describe earlier research in this field and the present hardware situation in Sweden. Medical aspects and current test methods are also presented.

In order to define the impact performance of different systems 34 frontal impact tests were made with 25 systems. Impact speed was 30 mph and the deceleration level 15-20 g. The relatively low deceleration level and the use of soft standard car seats are considered important to simulate the dynamic interactions. Fully instrumented Alderson 3 and 6 years old anthropometric dummies were used and the measurements included: dummy and sled accelerations, forces and displacements. 15 data channels and 2 high-speed cameras were used.

Based upon the design and the results from the tests, the systems were separated into five types:

Type I: Rearward facing systems, front seat
Type II: Rearward facing systems, back seat
Type III: Forward facing systems and belts with upper torso straps
Type IV: Lap belts, shields, cushions and harnesses
Type V: Hookover seats
It is shown that the rearward facing systems of type I and II have a considerably better protection performance than the other types, especially what concerns head acceleration and displacement.

Even though the tolerance limits for accelerations are unknown today it is proposed that the head accelerations are used as the main performance criteria.

It is considered that it is important to keep these accelerations as low as possible and the proposed limits (max resultant: 50 g, max vertical: 20 g) are well above the accelerations measured on the rearward facing systems. Most of the forward facing systems are far above these limits.

General recommendations for improvements of the protection performance and handling of rearward facing seats are also included in the report.
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Approximately 1 out of 13 people killed as car passengers in Sweden is a child younger than twelve years of age. By proper use of the restraint systems available for the older people in this group, several of them could have been saved. These restraint systems e.g. seat-belts and air-bags are constantly being developed and improved by researchers all over the world. Regulations on performance and installation of these systems are also frequently being issued.

Compared to this, very little has been done about restraint systems for children. Most existing child restraint systems today are either too weak to secure the child in a collision or, if strong enough, not reflecting the present knowledge of how to apply great loads on a child’s body.

The compliance test procedures issued in some countries have had the effect of removing some systems with a very low protection ability from the markets. Many of these systems even have a negative protection effect as they introduce new hazards in case of an accident. There are today no regulations or test procedures for child restraints in Sweden.

The international recommendations issued some years ago were not accepted by Sweden due to the fact that these recommendations mainly deal with forward facing systems. Earlier research in Sweden has resulted in rearward facing child seats whose protection performance has been regarded as superior to that of the forward facing systems. Although convinced about the very good protection abilities of the rearward facing seats, most foreign researchers regard the rearward facing seats as an unrealistic solution to the problem. The main objections have been that the child will not accept or get ill, riding backwards or that the seat will obstruct the driver’s vision.
Several years of experience with the approx. 100,000 rearward facing seats sold in Sweden have been very positive which was one of the reasons to start this project. The main objectives of the project have been:

1. To define the state of the art of design concepts, medical knowledge, regulations and impact performance of different systems.
2. To recommend compliance test procedures and performance criteria.
2 STATE OF THE ART

2.1 BACKGROUND

Research on child restraint systems started in Sweden about ten years ago when Aldman in 1963 /4/ presented a paper about the demands on restraint systems based upon the differences between child and adult body characteristics. Three types of harnesses were tested dynamically. The lack of head support and the large excursions obtained with these systems were pointed out and the need for full-body support was stressed.

In 1964 Aldman /5/ presented the development of a rearward facing child seat. Sled and car crash tests indicated a very good protection performance for these seats mounted in the front seat of the car. Production of this type of seats started at this time in Sweden.

Appoldt /6/ reported in 1966 on tests with seven forward facing systems in frontal and side sled impacts. The systems tested showed a poor protection performance and dynamic test procedures were recommended for future research.

The development of the Ford Tot-Guard system was presented by Heap and Grenier in 1968 /7/. This is a forward facing system consisting of a force-distributing shield and a low seat intended to be used with an adult lap belt. The rearward facing concept is discussed and regarded as too cumbersome for American cars.

Rogers and Silver /8/ discussed in a report from 1968 child restraint systems in terms of impact performance, child contentment, convenience and market appeal. The excellent protection performance of rearward facing seats was mentioned. These seats were however considered to be too inconvenient to use and it was also assumed that the child's need to look outside the car is not met. The assumed risk for motion sickness when riding backwards was also pointed out.
In 1969, Aldman and Asberg /9/ reported on sled tests with new types of rearward facing seats available on the Swedish market. Regulations permitting only rearward facing seats and dynamic strength tests for these seats were recommended.

The design and development of the General Motors Infant Safety Carrier was presented by Feles in 1970 /10/. This carrier is a rearward facing seat fixed to the car with the adult lap belt.

A large research program carried out at the Highway Safety Research Institute, (HSRI), University of Michigan was reported by Robbins et al in 1970 /11/ and Roberts and McElhaney in 1972. /12/. Compliance test procedures were developed and different performance criteria were discussed. Like most foreign investigations on child restraint systems, very little was done on rearward facing seats.

Hontschik and Schmid /13/ presented in 1972 a paper on sled tests with 23 forward facing systems from the European market. These tests showed that many systems didn’t work satisfactory.

Similar, not yet reported, tests with mainly forward facing systems have been made during 1973 in the Netherlands, Germany and England.
Since Aldman introduced the rearward facing child seat in 1964 there has been a growing interest for this type of child restraint system in Sweden. The National Swedish Road Safety Office and other organizations have recommended rearward facing systems for several years. These recommendations were based on simple dynamic tests carried out by the former National Council on Road Safety Research. There has been publicity in the press, radio and TV and it is our opinion that a relatively large number of Swedish parents are aware of the advantages of rearward facing child seats. About 100,000 child seats of this type have been sold in Sweden. Since there is a second-hand market for these seats, most of them are probably still in use.

Forward facing seats are very common. There is no sales statistics available on these seats but there are probably 5-10 times as many sold as rearward facing seats. Most common are cheap hookover seats manufactured in Sweden. Very exclusive looking, and expensive, hookunder seats have been imported from Germany recently.

Strong forward facing seats, many of them approved in other countries, have lately been introduced also on the Swedish market.

Despite the sales figures mentioned above, the general impression when studying the actual use of child seats, is that there is a fifty-fifty distribution between forward and rearward facing systems in the cars today. /2/.

There are at present almost no child belts and harnesses for sale in Sweden.

Most of the systems included in this project were available in Sweden 1973. There are however some prototypes and some systems imported especially for these tests.
2.3 MEDICAL ASPECTS.

The pediatric and anatomical considerations for design of child restraints have been reviewed in an excellent paper/14/ by A.R. Burdi, et al 1969. The following conclusions are quoted from this paper:

"Infants and children are not miniature adults. Their anatomy differs from the adult in a number of ways which cannot be overlooked in the proper design of occupant restraint systems specific to their age. Safe vehicular packaging for the infant and child requires protective devices based on child anatomy rather than on the anatomy of the adult. Within the framework of automobile safety design we have emphasized that:

(1) The frequency of head injuries in children involved in automobile accidents may be due to the child's proportionately large head and higher center of gravity. As a consequence, infants and children restrained by a lap belt have a greater chance of being projected over the restraining belt because the CG and body fulcrum is located above the belt location.

(2) Observations that the child's head is relatively massive and supported poorly from below have been implicated in head snapping with rapid body deceleration. Such sudden snapping or rotation of the relatively unrestrained child's head can traumatize related nerves, blood vessels, and spinal cord segments.

(3) Contributing to brain injuries of the young child is the relative lack of skull protection since, early in life, the skull is not an intact bony case for the brain but is a series of broadly spaced elastic bones."
(4) Growth rates of different parts of the body vary with age. For example, the midpoint of the body is above the navel at birth, slightly below it at 2 yr, and nearer the pubic bones at 16 yr.

(5) Since growth of the child is dependent upon the normal activity of growth centers, protection of these centers is vital. Abnormalities of body stature and limb mobility might result from injury to growth centers of the extremities. Similarly, in the head, the arrangement of teeth as well as the facial profile can be affected by traumatic injuries to the facial growth centers.

(6) Difference in size, structure, shape, and biomechanical properties of the infant, child, and adult pelvic skeleton are clearcut and must be considered in terms of proper lap belt design, position, and vehicle anchorage. Key differences include the absence of the anterior superior iliac spines and sufficient space in the pelvic-thigh angle for adequate positioning of the adult lap belt on the child.

(7) Unlike the adult, the organs of the chest are housed in an elastic and highly compressible thoracic cage. Organs as the lungs and heart are extremely vulnerable to nonpenetrating impacts to the chest. The smaller rib cage also means less protection is offered to larger abdominal organs which would normally receive some protection from the larger stronger rib cage of the adult. The highly elastic structure of the thoracic cage is not amenable to direct trauma or loading of webbed restraints in children.

(8) The most effective restraint systems for children are those which distribute impact forces over a large portion of the body" (end of quotation).
2.4 CURRENT TEST METHODS

Most national standards on child restraint systems are based on the ISO Recommendation R 1713, 1970. The draft recommendation was circulated to all the ISO Member Bodies in 1968 and was approved by 22 Member Bodies. The approval of the draft was opposed by the Netherlands, Norway and Sweden.

This recommendation includes requirements for the components of the system. There are for instance requirements for the width and strength of the webbing and for the buckle strength and design.

The system test is performed as follows:
A stiff dummy is placed in the restraint system which is mounted on a rigid seat. The test load (4500 N) is slowly applied to the dummy in a horizontal direction. The performance criteria is described in terms of dummy displacement which must not exceed 300 mm.

No dynamic test is included in the ISO Recommendation. The British Standard BS AU 157 includes a dynamic test. In this test a rather simple dummy is placed in the restraint system which is mounted in a rigid seat. The performance criteria are specified as maximum displacements of the hip and upper torso datum points of the dummy.

The test procedures mentioned above are mainly intended for strength tests of forward facing systems.

The protection performance of the systems is covered mainly by securing that the systems will be strong enough to avoid that the occupant's head contacts the interior of the car.
3 DYNAMIC TEST CONDITIONS

The test conditions in this study were set up in order to get realistic performance tests. All measuring equipment available at the test laboratory was used to get a complete coverage of the events. The test conditions and equipment are described in this chapter.

3.1 TYPE OF IMPACT

Only frontal impact performance has been studied in this project. Since this is the most common impact direction the primary goal for a child restraint system has to be protection at frontal impacts. Other impact directions will be discussed later on in this report.

Impact speed was chosen to be 50 km/h (30 mph) which is a typical speed for testing adult restraint systems.

The deceleration profile was a 15-20 g pulse with a stopping distance of approx. 65 cm. This is a lower level than typically used in frontal impact simulation but we consider it a more relevant pulse for real impacts than the 25-35 g pulses commonly used. These higher levels can be justified when making e.g. dynamic strength tests on seat belts.

Then the dummy is simplified to merely a load simulator and the softness of the car seat is not simulated. When studying the performance of child restraint systems we consider it important to use this lower level in order to get a good simulation of the dynamic interaction between the child restraint system and the soft car seat.
3.2 IMPACT SLED.

A new impact sled (Figure 1) was developed for this project. The sled was made with a modular structure to get maximum flexibility of the installations. For the simulation of the instrument panel a rigid plate 20x40 cm with (r=1 cm) rounded edges was chosen. A padded panel was considered but not used because of definition problems.

A commercially available seat (Be-Ge Motor, Sweden) was used for the simulation of the car seat. After some reinforcements, this seat was found suitable to be used in repeated tests. Standard car seats were not used because of their poor strength and wide variety of softness. The seat used in the tests is slightly harder than most standard seats. The seatback is 50 cm high and the seat is 60 cm deep and 70 cm wide.

When simulating a front seat, in the cases where the systems were anchored to the seatbacks, the back was allowed to pivot around its joints. This can be justified by the fact that most standard seats can hardly withstand more than their own inertial forces during impact.

In the simulation of rear seat installations, the seatback was firmly attached to the sled. Anchor points on the floor and hatrack were made strong enough to withstand all forces on these points.

In order to protect the dummies, special padding were installed in the tests where excessive dummy motion could be expected.
3.3 DUMMIES

At the present time, no formal specifications or standards exist for anthropometric child dummies. Purchase specifications have been issued by the National Highway Traffic Safety Administration, (NHTSA) USA. The 50th percentile 3 and 6 year old dummies, manufactured by Alderson Research Laboratories, Inc., used in this project conform with the NHTSA requirements. (Figure 2).

Similar dummies are also manufactured by Sierra Engineering Company. The Alderson dummies were chosen because of their more favourable price and delivery conditions. Even if similar in dimensions, the Alderson and Sierra dummies can not be expected to give exactly the same results in the same test conditions. No investigations on the difference in dynamic response of these dummies are known to us. It must therefore be remembered that the results in this report obtained with the Alderson dummies are not necessarily comparable to tests with Sierra or other dummies.

The main anthropometric data are:

<table>
<thead>
<tr>
<th>Dummy name</th>
<th>VIP-3C</th>
<th>VIP-6C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>3 years</td>
<td>6 years</td>
</tr>
<tr>
<td>Standing height</td>
<td>99 cm</td>
<td>121 cm</td>
</tr>
<tr>
<td>Sitting height</td>
<td>56 cm</td>
<td>66 cm</td>
</tr>
<tr>
<td>Weight</td>
<td>15 kg</td>
<td>21 kg</td>
</tr>
</tbody>
</table>

In order not to destroy these dummies in tests where a complete failure of the system was expected a special "Stunt-3" dummy was made. This dummy has the same main anthropometric data, weight distribution and ranges of motion as the VIP-3C. There are however no provisions for instrumentation and this dummy is more rugged in order to withstand severe impacts into the sled structure or the barrier.
3.4 ELECTRICAL MEASUREMENTS

Some important details of the electrical measurements are described below. A block diagram can be found in figure 4 and a photo of the instrumentation racks in figure 3.

3.4.1 SAE Recommended Practice J 211 A

The instrumentation was designed to follow SAE J 211 A, instrumentation for impact tests, where applicable.

3.4.2 Dummy Accelerations

The dummy accelerations were measured by Kyowa AS 200 TA triaxial transducers placed in the head centre of gravity and chest cavity. An extra oneaxial Kyowa AS 200 A was placed parallel to the head x-axis just below the skin on the top of the head. The intention of this accelerometer was to determine the angular acceleration of the head. These measurements of the angular accelerations are part of another project and will not be presented in this report.

3.4.3 Anchor point forces

Bofors KRG-4 force transducers were used to measure the forces on the anchor points in all cases where it was possible to install the transducers without affecting the performance of the system.
The instrument panel force was measured by strain-gauges on the panel attachment to the sled. The dynamic mass of the instrument panel was compensated for by an extra accelerometer placed on the back of the panel.

3.4.4 Sled data

Sled acceleration was measured by a CEC 4-202 accelerometer placed on the sled frame. Sled velocity immediately before impact was registered by timing a 1 m distance with a photocell barrier. The sled propulsion system was cut off 10 m before impact in order to allow the sled to roll at a constant speed and to let the test objects regain an undistorted position.

3.4.5 Data recording

All electrical data from the sled were transmitted by cables to the amplifier systems, (Bofors BKF and FFA 1046). Recordings were made on Philips ANA-LOG 7 and ANA-LOG 14 FM tape recorders. A maximum number of 21 channels could be recorded. Calibration signals were recorded before and after each test. The calibration and tape recorder controls were connected to the sequence control system.

3.4.6 Data conditioning

Output data from the tape recorders were fed into an analog computer capable of compensating the dynamic forces on the instrument panel and calculating the resultant accelerations of the head and chest. All signals were then filtered in a Krohn-Hite 3750 filter according to the following channel classes (SAE J 211 A).

<table>
<thead>
<tr>
<th>Channel class</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head acceleration</td>
<td>1000</td>
</tr>
<tr>
<td>Chest acceleration</td>
<td>180</td>
</tr>
<tr>
<td>Forces</td>
<td>60</td>
</tr>
<tr>
<td>Sled acceleration</td>
<td>60</td>
</tr>
</tbody>
</table>
3.4.7 Data output

The conditioned and scaled signals were stored one by one in a digital Event Recorder with a 4 K memory. Printed data sheets were put into a Servogor XY-recorder for the plots. One sheet was used for the Sled acceleration and Force outputs. SI-units (m/s², kN) were used on this sheet. Head and Chest accelerations were plotted on two separate sheets.

The AGARD system was used for the definition of directions and units on these sheets (Figure 5).

Film synchronization pulses were also included on the sheets mentioned above.

To provide a visual presentation of the components of the resultant head acceleration a twodimensional graph called Brain Inertial Forces on the summary data sheets was made. This graph is made by the Gx and Gz components of the resultant head acceleration. In terms of vectors it represents the direction and relative value of the resultant inertial force vector on the brain. This output had to be made directly on the XY-recorder from a slowed down tape recording. The frequency response is therefore, in this case, limited.
Figure 4 Instrumentation
### BODY ACCELERATION — COMPARATIVE TABLE OF EQUIVALENTS

#### SYSTEM 1

<table>
<thead>
<tr>
<th>LINEAR MOTION</th>
<th>TABLE A</th>
<th>TABLE B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Aircraft Computer Standard (Sys. 1)</td>
<td>Acceleration Descriptive (Sys. 3)</td>
</tr>
<tr>
<td>Forward</td>
<td>+ $a_x$</td>
<td>Forward accel.</td>
</tr>
<tr>
<td>Backward</td>
<td>- $a_x$</td>
<td>Backward accel.</td>
</tr>
<tr>
<td>Upward</td>
<td>- $a_z$</td>
<td>Headward accel.</td>
</tr>
<tr>
<td>Downward</td>
<td>+ $a_z$</td>
<td>Footward accel.</td>
</tr>
<tr>
<td>To Right</td>
<td>+ $a_y$</td>
<td>R. Lateral accel.</td>
</tr>
<tr>
<td>To Left</td>
<td>- $a_y$</td>
<td>L. Lateral accel.</td>
</tr>
</tbody>
</table>

#### ANGULAR MOTION

| Roll Right    | + $\dot{p}$ | Roll | - $\dot{R}_x$ |
| Roll Left     | - $\dot{p}$  | Pitch | + $\dot{R}_y$ |
| Pitch Up      | + $\dot{q}$  | Yaw | + $\dot{R}_z$ |
| Pitch Down    | - $\dot{q}$  | | - $\dot{R}_z$ |
| Yaw Right     | + $\dot{r}$  | | |
| Yaw Left      | - $\dot{r}$  | | |

#### FOOTNOTES:

1. Large letter, G, used as unit to express inertial resultant to whole body acceleration in multiples of the magnitude of the acceleration of gravity. Acceleration of gravity, $g_0 = 980.665 \text{ cm/sec}^2$ or 32.1739 ft/sec$^2$.

Figure 5 AGARD-system
3.5 PHOTOGRAPHICAL MEASUREMENTS

3.5.1 Introduction

Special care was taken to produce motion pictures and still photos that could be used not only for evaluating test results but also to satisfy the great public demand for information.

Due to limited space at the test track all photographic activities had to take place from only one side. In order to get "clean" pictures the background was painted black and light colors were used to paint seats and other important details on the sled. The dummies and the sled were marked with targets made by Scotchlite material.

Spotlights placed close to the centerlines of all cameras made the targets very clear on the films.

A total effect of 35 KW halogen light was available and gave sufficient illumination to run the high-speed motion picture cameras stopped down to about f:4.

All light and camera equipment were remote controlled by the sequence system.

A 20 ms/revolution clock was placed in the field of all cameras and used for camera speed control, camera synchronization and electronics synchronization via a clock contact recorded on the tape.

3.5.2 High-speed motion pictures

Two high-speed 16 mm cameras were used.

A Locam operating at 500 fps was placed perpendicular to the test track and covered the expected area of dummy motion. The exposure time was 1/2000 sec. All measurements were made from films exposed in this camera.
As a back-up for the Locam and in order to get a general coverage a Fastax operating at 1000 fps was used. This camera was placed 45° to the track and covered the whole impact area.

The evaluations from the high-speed films were made by plotting the dummy motion on a screen.

3.5.3 Motion pictures

A 24 fps Paillard was used to take motion pictures of the test rig before, during and after each test. Ektachrome EF film, exposed at 125 ASA, was used for all motion pictures.

3.5.4 Sequence photos

Color slides on Ektachrome High-Speed film were exposed at a rate of 4 fps by a Nikon F with Motordrive. These slides have no great value for evaluation of test results, but give excellent pictures for information purposes. A Graphcheck sequence camera provided 8 pictures from the crash on Polaroid film for a quick-look directly after the test.

3.5.5 Still photos

6x6 cm black and white and 35 mm color pictures were taken before and after each test of all details of interest.
Before each test, the restraint systems were carefully assembled in accordance with the enclosed instructions. If there were no instructions, the systems were assembled in the way which was expected to give the best performance. As "the typical car interior" doesn't exist the following principles were regarded when installing the systems:

Rearward facing systems in the front seat were mounted with a backrest inclination of approx. 20°. The upper edge of the child seat was in contact with the upper edge of the instrument panel. Approx. 75% of the seat bottom rested on the car seat.

Rearward facing systems in the back seat were mounted with a backrest inclination of approx. 20°. The seats were in this case placed 80 cm apart. The systems not primarily intended for this application were anchored to the front seat by straps over and around the seatback and down to the floor. The back of the front seat was, in these tests, free to move and secured only by the straps.

Forward facing systems intended to be used in the back seat were tested without the front seat installed on the sled in order not to get any interaction at excessive dummy motions.

A total number of 34 tests were carried out at a rate of two tests per day. The test time included instrumentation checkup, installation, documentation and playback of all electrical measurements.

The performance of the test equipment was very good. One data channel was lost once due to a malfunction of a tape recorder amplifier. The Locam high-speed camera failed in one test, probably due to improper loading. All tests were regarded as relevant and are included in this report.
5 RESULTS

The results presented in this chapter are only those regarded as being relevant for the performance requirements proposed later, i.e. dummy accelerations, dummy displacement, load distribution and dynamic strength. All data from the individual tests are presented in appendix 1.

5.1 SYSTEM TYPES.

As will be shown in this chapter, it is convenient to divide the restraint systems into five types. This division is based upon impact performance and the type of system.

Type I. Rearward facing systems, front seat.

The child seats of this type are placed on the front seat of the car and are attached to the floor by straps or directly to the underframe of the front seat. These seats have a high back, leaning on or attached to the instrument panel.

Type II. Rearward facing systems, back seat.

The seats of this type are the same as in Type I but the installation is different. Due to the poor strength of the front seat back special straps have to be attached around the front seat back in order to obtain a good anchorage.

Type III. Forward facing systems and belts with upper torso straps.

These seats are mainly to be placed in the back seat of the car and anchored by straps to the car body. They have different types of fullbody restraints and the seat frame has no force distributing mission in the initial stage of a frontal impact. The belts in this group are well anchored to the car and have a restraining effect similar to that of the seats.
Type IV. Lap belts, shields, cushions and harnesses.

The systems of this type are the adult lap belt itself or in combination with special devices to distribute the force. Harnesses which are not tightly fastened to the car also belong to this type.

Type V. Hookover seats.

The seats of this type are hooked over the seatback or squeezed between the seat and seatback.
5.2 DUMMY ACCELERATIONS

On the following pages the accelerations measured in the head and chest of the dummies are presented. The conventional way to present this data is to tabulate the peak values for the individual tests. In order to achieve a better understanding of the differences between the types of systems we have preferred to make outputs where all measurements on a specific variable are plotted on the same data sheet for each type of system. Extreme values from non-typical events are not included in these outputs.

Gy (Left-Right) accelerations are small in frontal impacts and therefore not included in the following discussion. The Gy components are part of the presented resultant accelerations however.

Before going into the details of these recordings we want to stress that the accelerometers indicate the acceleration in the coordinate system fixed to the dummy head and chest. Due to the motions of the dummy this coordinate system is translated and rotated and the direction of the axis is not constant relative to the axis of e.g. the sled coordinate system. This means that e.g. a Gx (Anterior-Posterior) acceleration not necessarily is a horizontal one when studying the system performance from the film. Another important thing to remember is that resultant acceleration value is calculated \( \sqrt{G_x^2 + G_y^2 + G_z^2} \) from the components measured in the dummy. The resultant accelerations can therefore be the same for two different restraint systems although the kinematic is completely different.
This is illustrated in the simplified figure below where the resultant accelerations are the same in both cases. The left part of the figure represents an impact where the head is decelerated in its initial position. The right part of the figure represents an impact where the head is subjected to rapid changes of attitude during the deceleration.

Figure 6 Comparison of resultant accelerations
5.2.1 HEAD ACCELERATIONS

TYPE I REARWARD FACING SYSTEMS, FRONT SEAT

![Graph of head accelerations](image)

**Figure 7** $G_x$ (Anterior - Posterior) Head Accelerations

**Figure 8** $G_z$ (Superior - Inferior) Head Accelerations

**Figure 9** Resultant Head Accelerations
HEAD ACCELERATIONS

TYPE II REARWARD FACING SYSTEMS, BACK SEAT

FIGURE 10 Gx (ANTERIOR - POSTERIOR) HEAD ACCELERATIONS

FIGURE 11 Gz (SUPERIOR - INFERIOR) HEAD ACCELERATIONS

FIGURE 12 RESULTANT HEAD ACCELERATIONS
HEAD ACCELERATIONS

TYPE III FORWARD FACING SYSTEMS AND BELTS WITH UPPER TORSO STRAPS

**Figure 13** Gx (ANTERIOR - POSTERIOR) HEAD ACCELERATIONS

**Figure 14** Gz (SUPERIOR - INFERIOR) HEAD ACCELERATIONS

**Figure 15** RESULTANT HEAD ACCELERATIONS
HEAD ACCELERATIONS

TYPE IV LAP BELTS, SHIELDS, CUSHIONS AND HARNESSES

Figure 16 Gx (Anterior - Posterior) Head Accelerations

Figure 17 Gz (Superior - Inferior) Head Accelerations

Figure 18 Resultant Head Accelerations
Type I Rearward facing systems, front seat.

These systems have very favourable acceleration values for the head. The resultant accelerations contain almost only Gx components and the pulses start early and follow the sled deceleration. With a better padding it seems to be possible to reduce the two-peak effect and to get a curve more like a square wave. In these systems the dummy is restrained in its initial position and there are comparatively low forces acting on the neck. Some Type I systems had too low a seatback for the 3-year dummy or a padding that was not energy absorbing enough. This resulted in rather high Gx peaks when the head hit the instrument panel or totally compressed the padding. This is illustrated in the figure below:

![Figure 19 Gx (A-P) Head accelerations](image)

Type II Rearward facing systems, back seat.

These systems have about the same characteristics as those of type I. Due to the problem of getting a good anchorage to the front seat back there is greater slack in these systems. This implies that the head accelerations will start later and reach slightly higher levels due to dynamic amplification. The Gz components are about twice as large as those of Type I systems. This depends on the larger movements occurring with these seats.
Type III. Forward-facing systems and belts with upper torso straps.

These systems show a completely different behavior of the head accelerations. The first peaks of the resultant accelerations are a bit late in time depending on system slack but the peak values are just a bit higher than those of type I and II. The most important difference is that the Gz components are the main parts of the resultant accelerations. This means that the head is decelerated by tension forces in the neck. The tension is at least three times as large as in type I systems. Since the normal travelling attitude is with the head x-axis in an almost horizontal direction and the sled deceleration also is horizontal the curves show that there must be a rapid change of the head direction at the beginning of the impact. This rapid change of direction has to be the result of angular accelerations on the head. These angular accelerations are probably in themselves a very important injury factor as has been mentioned earlier in this report. The high peaks in the later stages of the collisions depend on rebound effects. Spring phenomenas in the harnesses and the seat throw the dummy back into the seatback or the hatrack.

Type IV. Lap belts, shields, cushions and harnesses.

These systems show a more complex acceleration pattern. After quite a long time delay due to system slack the head rotates forward and starts to decelerate in the z-direction by neck tension. During this deceleration the face hits the system or the car interior resulting in high Gx accelerations. These systems also have severe rebound effects resulting in impacts on the back of the head. As these impacts often take place after more than 250 ms they are not always visible on the curves presented here.

Type V. Hookover seats.

These systems have not been measured due to the risk of destroying the equipment when the systems collapse.
5.2.2 Chest Accelerations

Figure 20 Type I Rearward Facing Systems, Front Seat
Resultant Chest Accelerations

Figure 21 Type II Rearward Facing Seats, Back Seat
Resultant Chest Accelerations
Chest accelerations

Figure 22 Type III Forward facing systems and belts with upper torso straps
Resultant chest accelerations

Figure 23 Type IV Lap belts, shields, cushions and harnesses
Resultant chest accelerations
The chest accelerations show a similar pattern as the head accelerations. Only resultant accelerations are presented in this chapter. The complete measurements can be found on the summary data sheets. Changes of body direction can be discussed in a similar way as has been previously done for the head. These effects are however much better reflected by the head accelerometer readings and we consider it is therefore sufficient to study only the resultant chest accelerations. Type I, II and III systems, where upper torso restraints are available, give almost the same resultant chest accelerations.

Type IV systems, where upper torso restraints are not available in the initial phase of the impact show, due to system slack, higher levels of the resultant chest accelerations than the other types.
5.3 DUMMY DISPLACEMENT

The excursion of the head's centre of gravity relative to its initial position in the sled coordinate system was plotted and the maximum excursion was measured. These plots can be found on the summary data sheets. The maximum values of the displacement vectors are presented in the figure below:

![Figure 24. Maximum head displacement.](image)

(C 101 - C 134 indicate test number and the figures in the table displacement in cm).
Type I systems give, as expected, the lowest figures in this table. The values for type V are not relevant because there was in one case (C121) an impact into a protection structure on the sled and in another case (C126) a large movement sidewards which could not be measured from the film.

The significance of displacement measurements like these can, from a protection performance point of view, be discussed from two aspects:

1. It is important to keep the excursions within certain limits in order to avoid contact with the car interior. A maximum value of the excursions measured conventionally as above can not be considered good enough as a performance criterion. The reason for this is that the available distance from the initial position of the head to a car structure varies with different types of systems.

2. A large excursion is not a bad thing by itself. The distance can be used to give the occupant a longer total stopping distance which implies lower acceleration levels. This can be the case with e.g. air bag systems. Considering these two aspects it is felt that the following test procedure would have been more relevant.

The minimum car interior space is simulated by impact areas on the sled or as geometrical limits when evaluating the films. It seems to be a practical solution to simulate the car interior with a simplified straight-line model which can be made with plywood panels on the sled. The performance criterion could then be that no contact with these areas is permitted. Contact can be decided by covering the panels with a suitable material or even by head accelerometer readings.
5.4 LOAD DISTRIBUTION

Load distribution is a very important factor in reducing the risk of injury. The ideal concept, for one-directional impacts, is a system that is formfitted to the body and applies a constant contact pressure over the whole projection of the body area. There are no experimental means to measure these pressures. Contact pressures can, theoretically, be calculated via the forces and contact areas but this method has not been found applicable for these tests. The reason for this is that the actually active forces and areas can not be sufficiently well described. It is, however, obvious that the Type I and II systems give the best load distribution of the systems tested. These systems are also the only ones capable of decelerating the head and torso simultaneously with an unchanged position of the head relative to the torso. These facts are reflected by the accelerometer data presented earlier.

5.5 DYNAMIC STRENGTH

The dynamic strength of the systems has been evaluated by measuring the anchor point forces and by making film and after-test observations. With the exception of Type V, hookover systems, there were no major problems with the dynamic strength of the systems. In a few cases, anchor points on the child seats failed. This is, of course, unacceptable but there seems to be no great problem for the manufacturers of Type I - IV systems to make the necessary improvements.
As has been shown in the previous chapter there is a great difference in protection performance between different types of systems. It is our opinion that the performance tests used in this project reflect the differences in a significant way. The great problem with this type of work is to specify performance criteria which can discriminate the good, not so good and bad systems. Even if this discrimination can be done one must decide if the acceptance limit shall be between the good and not so good systems or between the not so good and bad systems.

The regulations for the adult restraint systems, seat belts, aim at approving only the best systems and it is obvious that the same philosophy must be valid for child restraints. With this philosophy combined with the results of our tests only rearward facing systems should, at the present time, be approved.

Apart from the impact protection aspects discussed above there are also other important factors that must be considered. It is desirable that the performance criteria can be met by existing designs. This is the case with some of the rearward facing systems tested in this project. The systems to be approved must be convenient to use and accepted by parents and children. The psychological parts of this project show that this is the case with rearward facing systems. /1/ /2/.

It is desirable that the regulations conform with international regulations. This is not possible at present but we know that the international work in this field tends toward test procedures similar to those in this report.
The introduction of dynamic performance tests for child restraints in Sweden will also affect the international standardization work in this field.

The performance requirements and test procedures proposed in the next chapters do not necessarily imply rearward facing systems. A forward facing system capable of decelerating the head at fairly low levels can be approved. This is one of the reasons why we have not proposed a "design-standard" specifying a typical construction of the restraint system.
7 PROPOSED PERFORMANCE CRITERIA

7.1 ACCELERATION TOLERANCE LIMITS

For the definition of the acceleration performance criteria we want to make the following statements:
1. Acceleration tolerance limits for children are not known today.
2. Acceleration tolerance limits for adults are known only to a very limited extent.
3. When testing adult restraint systems one has since a long time accepted that accelerations measured in a test dummy are correlated to injury to an adult in the same crash situation.
4. Acceleration tolerance limits can only be described in probability terms. (% killed, degrees of injury etc.)
5. The intention of a restraint system must always be to minimize the accelerations measured in a test dummy.

Considering these statements the following definition of the acceleration performance criteria can be made:

Accelerations measured in a test dummy in a specified test procedure must not considerably exceed the accelerations obtained at tests with restraint systems representing the best existing designs from a protection performance point of view.

Since the results in this report show great differences in the accelerations measured with different types of systems and since the acceleration, as stated above, is the best available "trauma-indicator" today, the main performance criteria must be based on acceleration measurements.
7.2 ACCELERATION PERFORMANCE CRITERIA

Based upon the results presented earlier, it is our opinion that the following criteria represent the lowest acceptable protection performance in the test procedures used in this report.
Resultant head acceleration max 50 g.
Gz (Superior-Inferior) head acceleration max 20 g.
Resultant chest acceleration max 40 g.

7.3 DISPLACEMENT CRITERIA

It is recommended that the displacement criteria is formulated in terms of the dummy's head not contacting the minimum car interior limits as discussed in 5.3 above.

7.4 LOAD DISTRIBUTION CRITERIA

At present we can not propose any criteria for the load distribution. These aspects will partly be covered by the acceleration criteria and only general recommendations such as a minimum webbing width of 25 mm can be made.

7.5 STRENGTH CRITERIA

As it can be expected that the acceleration and displacement criteria will expose strength failures, no specific tests are at this time recommended for the static and dynamic strength of the systems. The strength criteria can therefore be formulated in general terms such as:
Failures of the system must not introduce any new hazards to the child. The protection must not be lost in the first impact and the system must be ready to provide a reasonable protection at rollovers and secondary impacts following the first impact.
8 PROPOSED TEST PROCEDURES

8.1 TYPE OF IMPACT

The 50 km/h frontal impact with 65 cm stopping distance used in this project is recommended for the compliance tests. A shorter stopping distance implies higher deceleration levels and will change the dynamic interactions in the systems. It is our opinion that protection at side and rear impact directions can be covered by recommendations in the standard and must not be impact tested. The competition between different manufacturers will probably lead to good solutions of these problems. If it however, depending on the outcome of the new regulations, shows to be necessary to make tests at these impact directions, procedures and requirements can be added later based upon achievable designs as has been the case in this work. It is recommended that at least three samples of the systems shall be tested at the compliance tests and provisions shall be made for production-control tests.

8.2 IMPACT SLED AND MOUNTING PROCEDURES

The same type of impact sled and mounting procedures as used in this project are recommended.

8.3 DUMMIES

The three and six years old 50th percentile Alderson dummies used in this project are recommended for the compliance tests. Other types of dummies can be used if the dynamic performance can be regarded as similar. Since especially the three years old dummy's weight and size represents the upper end of suggested usage for some systems it might be necessary to design a smaller dummy. A practical approach can be to modify an Alderson VIP-3C by making the spine and limbs a bit shorter. This problem will however probably not occur since the manufacturers can be expected to make the seats large enough for the three years old dummy.
8.4 ELECTRICAL MEASUREMENTS

The same measuring procedures as used in this project are recommended. The head rotational acceleration and force measurements are not necessary for the performance criteria and can therefore be excluded in the regulations. It is however recommended that these measurements are made in order to collect data for future research and development.

8.5 PHOTOGRAPHICAL MEASUREMENTS

Enough photographic coverage can be obtained by a 500 fps. high-speed camera placed perpendicularly to the test track. Still photos shall be made of all objects of interest before and after each test.
9  PROPOSED GENERAL RECOMMENDATIONS

9.1  BUCKLES

In order to prevent the child from disturbing the driver, the buckles shall be designed so that they can not easily be unlatched by the child. On the other hand they must not be difficult to use for an adult, especially in emergency situations. These problems have been subjected to a special investigation that will be reported separately. /1/.

9.2  HARNESSES

It is recommended that 3-point belts with a moveable upper anchorage point are used in rearward facing seats. This geometry makes it very convenient to get the child in and out of the seat and will stabilize a sleeping child adequately. Other, more complex, harnesses may give a slightly better performance in rear-end impacts but we believe that this comfort aspect is very important. Getting the child out quickly enough in an emergency situation is also much easier with a 3-point belt. These aspects are covered in a special report. /1/. It must also be remembered that rear-end impacts usually occur at low speeds and give lower acceleration levels than frontal barrier impacts.

9.3  TWIN-SEATS

It seems to be possible to make a rearward facing seat accommodating two children. We recommend that the regulations cover also such seats.
9.4 ACCIDENT INVESTIGATIONS

It is recommended that the results of the regulations are followed up by accident investigations. An important part of these investigations will be to find out if there is a need for additional regulations on e.g. the dynamic strength of the systems. All approved seats can be labeled with instructions to contact the proper authority in case of an accident.
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/18/ A Table of Equivalents of Acceleration Terminologies.
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Appendix 1

SUMMARY DATA SHEETS

In this appendix all data from the separate tests are presented on two pages for each test.

### Type I  Rearward facing seats, front seat.

<table>
<thead>
<tr>
<th>System</th>
<th>Dummy: VIP-3C</th>
<th>Test: C101</th>
<th>Page: 1:02</th>
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<tr>
<td>Hylte</td>
<td>VIP-3C</td>
<td>C102</td>
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<td>Klippan</td>
<td>VIP-3C</td>
<td>C103</td>
<td>1:06</td>
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<td>Klippan</td>
<td>VIP-3C</td>
<td>C104</td>
<td>1:08</td>
</tr>
<tr>
<td>Jolly</td>
<td>VIP-3C</td>
<td>C105</td>
<td>1:10</td>
</tr>
<tr>
<td>Prototype</td>
<td>VIP-3C</td>
<td>C106</td>
<td>1:12</td>
</tr>
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<td>Niki Astronaut</td>
<td>VIP-3C</td>
<td>C107</td>
<td>1:14</td>
</tr>
<tr>
<td>Volvo</td>
<td>VIP-3C</td>
<td>C128</td>
<td>1:16</td>
</tr>
<tr>
<td>Volvo</td>
<td>VIP-6C</td>
<td>C129</td>
<td>1:18</td>
</tr>
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### Type II  Rearward facing systems, back seat.

<table>
<thead>
<tr>
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<th>Test: C122</th>
<th>Page: 1:20</th>
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<tr>
<td>Contra</td>
<td>VIP-3C</td>
<td>C123</td>
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<td>Klippan</td>
<td>VIP-3C</td>
<td>C124</td>
<td>1:24</td>
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<tr>
<td>Jolly</td>
<td>VIP-3C</td>
<td>C125</td>
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### Type III  Forward facing systems and belts with upper torso straps.

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<th>Test: C111</th>
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<td>Niki Astronaut</td>
<td>VIP-3C</td>
<td>C112</td>
<td>1:30</td>
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<tr>
<td>Niki Commodore</td>
<td>VIP-3C</td>
<td>C113</td>
<td>1:32</td>
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<td>Mothercare</td>
<td>VIP-3C</td>
<td>C114</td>
<td>1:34</td>
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<td>K L Jeenay Safety Seat</td>
<td>VIP-3C</td>
<td>C115</td>
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<td>3-Point Belt</td>
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### Type IV  Lap belts, shields, cushions and harnesses.

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<td>STUNT-3</td>
<td>C119</td>
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<td>Sears Safety Harness</td>
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### Type V  Hookover seats.

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<td>C126</td>
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</tr>
<tr>
<td>A-stolen</td>
<td>STUNT-3</td>
<td>C127</td>
<td>1:68</td>
</tr>
</tbody>
</table>
SUMMARY DATA SHEET
TYPE: I
TEST: C 101
SYSTEM: HYLTE
DUMMY: VIP-3C
MANUFACTURED BY: HALLGRENS INDUSTRI AB
SLED VELOCITY: 49.4 km/h
SWEDEN
STOPPING DISTANCE: .60 m
MAX HEAD DISPLACEMENT: .10 m

BEFORE TEST
AFTER TEST

0 MS
50 MS
100 MS
150 MS
TIME AFTER IMPACT
200 MS
250 MS
TYPE: I
TEST: C 101
DUMMY: VIP-3C
SLED VELOCITY: 49.4 km/h
STOPPING DISTANCE: .60 m
MAX HEAD DISPLACEMENT: .10 m
SUMMARY DATA SHEET

SYSTEM: KLIPPAN
MANUFACTURED BY: AB BRODERNA OTTOSSON & CO

TYPE: I
TEST: C 102
DUMMY: VIP-3C
SLED VELOCITY: 50.0 KM/H
STOPPING DISTANCE: .58 M
MAX HEAD DISPLACEMENT: .13 M

BEFORE TEST

AFTER TEST

0 MS
50 MS
100 MS
150 MS
200 MS
250 MS
TYPE: I
TEST: C 102
DUMMY: VIP-3C
SLED VELOCITY: 50.0 KM/H
STOPPING DISTANCE: .58 M
MAX HEAD DISPLACEMENT: .13 M

HEAD DISPLACEMENT

BRAIN INERTIAL FORCES
SUMMARY DATA SHEET
TYPE: I
SYSTEM: KLIPPAN
TEST: C 103
DUMMY: VIP-3C
MANUFACTURED BY: AB BRODERNA OTTOSSON & CO
SLED VELOCITY: 49.4 KM/H
SWEDEN
STOPPING DISTANCE: .55 M
MAX HEAD DISPLACEMENT: .05 M

BEFORE TEST
AFTER TEST

CAMERA FAILURE

0 MS
50 MS
150 MS
TIME AFTER IMPACT
200 MS
100 MS
250 MS

CAMERA FAILURE
SUMMARY DATA SHEET

SYSTEM: KLIPPAH

TYPE: I

TEST: C 103

DUMMY: VIP-3C

SLED VELOCITY: 49.4 KM/H

STOPPING DISTANCE: .55 M

MAX HEAD DISPLACEMENT: .05 M

HEAD DISPLACEMENT

1 meter

BRAIN INERTIAL FORCES

INSTRUMENT PANEL

LEFT ANCHOR POINT

RIGHT ANCHOR POINT

LEFT EYES

RIGHT EYES

LEFT ARM

RIGHT ARM

LEFT LEG

RIGHT LEG

INST. SWEDISH ROAD AND TRAFFIC RESEARCH INSTITUTE

Resultant Acceleration

INST. SWEDISH ROAD AND TRAFFIC RESEARCH INSTITUTE

INST. SWEDISH ROAD AND TRAFFIC RESEARCH INSTITUTE
SUMMARY DATA SHEET
SYSTEM: JOLLY
MANUFACTURED BY: DOUGLAS S.R.L.
ITALY

TYPE: I
TEST: C 104
DUMMY: VIP-3C
SLED VELOCITY: 50.7 km/h
STOPPING DISTANCE: 0.65 m
MAX HEAD DISPLACEMENT: 0.20 m
SYSTEM: JOLLY

TYPE: I
TEST: C 104
DUMMY: VIP-3C
SLED VELOCITY: 50.7 km/h
STopping DISTANCE: .65 m
MAX HEAD DISPLACEMENT: .20 m

HEAD DISPLACEMENT
1 meter

BRAIN INERTIAL FORCES
SUMMARY DATA SHEET

SYSTEM: JOLLY
MANUFACTURED BY: DOUGLAS s.r.l.
ITALY

TYPE: I
TEST: C 105
DUMMY: VIP-3C
SLED VELOCITY: 49.7 KM/H
STOPPING DISTANCE: .65 M
MAX HEAD DISPLACEMENT: .23 M

TIME AFTER IMPACT:
0 MS
50 MS
100 MS
150 MS
200 MS
250 MS
SLED DATA

FORCES

LEFT ANCHOR POINT

RIGHT ANCHOR POINT

INSTRUMENT PANEL

CHEST DATA

HEAD DATA

MAX HEAD DISPLACEMENT: .23 M

HEAD DISPLACEMENT

1 meter

INSTRUMENT PANEL:

HEAD DATA

MAX HEAD DISPLACEMENT: .23 M

INSTRUMENT PANEL:

HEAD DATA

MAX HEAD DISPLACEMENT: .23 M

INSTRUMENT PANEL:

HEAD DATA

MAX HEAD DISPLACEMENT: .23 M

INSTRUMENT PANEL:

HEAD DATA

MAX HEAD DISPLACEMENT: .23 M

INSTRUMENT PANEL:
SUMMARY DATA SHEET
SYSTEM: PROTOTYPE
MANUFACTURED BY:

TYPE: I
TEST: C 106
DUMMY: VIP-3C
SLED VELOCITY: 49.5 km/h
STOPPING DISTANCE: .68 m
MAX HEAD DISPLACEMENT: .28 m
TYPE: I  TEST: C 106
DUMMY: VIP-3C
SLED VELOCITY: 49.5 KM/H
STOPPING DISTANCE: .68 M
MAX HEAD DISPLACEMENT: .28 M

HEAD DATA

BRAIN INERTIAL FORCES

CHEST DATA
TYPE: I
TEST: C 107
DUMMY: VIP-3C
SLED VELOCITY: 51.2 km/h
STOPPING DISTANCE: .67 m
MAX HEAD DISPLACEMENT: .10 m

HEAD DISPLACEMENT
1 meter

BRAIN INERTIAL FORCES

CHEST DATA

HEAD DATA

TOTAL ACCELERATION

INSTRUMENT PANEL
SUMMARY DATA SHEET
SYSTEM: VOLVO
MANUFACTURED BY: VOLVO SWEDEN

TYPE: I
TEST: C 128
DUMMY: VIP-3C
SLED VELOCITY: 50.0 km/h
STOPPING DISTANCE: .67 m
MAX HEAD DISPLACEMENT: .04 m

BEFORE TEST

AFTER TEST

TIME AFTER IMPACT
0 MS
50 MS
100 MS
150 MS
200 MS
250 MS
SUMMARY DATA SHEET
SYSTEM: VOLVO

NATIONAL SWEDISH ROAD AND TRAFFIC RESEARCH INSTITUTE

TYPE: I  TEST: C 128
DUMMY: VIP-3C
SLED VELOCITY: 50.0 KM/H
STopping DISTANCE: .67 M
MAX HEAD DISPLACEMENT: .04 M

HEAD DISPLACEMENT

BRaIN INERTIAL FORCES

CHEST DATA

HEAD DATA

EYE BALLS

LEFT
SUMMARY DATA SHEET

SYSTEM: VOLVO
MANUFACTURED BY: VOLVO

SWEDEN

TYPE: I
TEST: C 129
DUMMY: VIP-6C
SLED VELOCITY: 50.3 km/h
STOPPING DISTANCE: .70 m
MAX HEAD DISPLACEMENT: .10 m

BEFORE TEST

AFTER TEST

0 MS
50 MS
100 MS
150 MS
200 MS
250 MS

TIME AFTER IMPACT
SUMMARY DATA SHEET
SYSTEM: VOLVO

NATIONAL SWEDISH ROAD AND TRAFFIC RESEARCH INSTITUTE

TYPE: I
TEST: C129
DUMMY: VIP-6C
SLED VELOCITY: 50.3 KM/H
STOPPING DISTANCE: .70 M
MAX HEAD DISPLACEMENT: .10 M

SLED DATA

FORCES

HEAD DISPLACEMENT

BRAIN INERTIAL FORCES

CHEST DATA

HEAD DATA

ACCELERATION
SUMMARY DATA SHEET
SYSTEM: CONTRA
MANUFACTURED BY: A/S HAMAS PLASTINDUSTRI
NORWAY

TYPE: II
TEST: C 122
DUMMY: VIP-3C
SLED VELOCITY: 51.1 km/h
STOPPING DISTANCE: .66 m
MAX HEAD DISPLACEMENT: .46 m

BEFORE TEST

AFTER TEST

0 MS
50 MS
100 MS
TIME AFTER IMPACT

150 MS
200 MS
250 MS
TYPE: II  
TEST: C122
DUMMY: VIP-3C
SLED VELOCITY: 51.1 km/h
STOPPING DISTANCE: .66 m
MAX HEAD DISPLACEMENT: .46 m

HEAD DISPLACEMENT
1 meter

BRAIN INERTIAL FORCES

SLED DATA

FORCES

CHEST DATA

HEAD DATA
SUMMARY DATA SHEET
SYSTEM: CONTRA
MANUFACTURED BY: A/S HAMAS PLASTINDUSTRI NORWAY

TYPE: II
TEST: C 123
DUMMY: VIP-3C
SLED VELOCITY: 51.2 km/h
STOPPING DISTANCE: .69 m
MAX HEAD DISPLACEMENT: .35 m

BEFORE TEST

AFTER TEST

0 MS
50 MS
100 MS
TIME AFTER IMPACT

150 MS
200 MS
250 MS
TYPE: II
TEST: C 123
DUMMY: VIP-3C
SLED VELOCITY: 51.2 km/h
STOPPING DISTANCE: .69 m
MAX HEAD DISPLACEMENT: .35 m

HEAD DISPLACEMENT
8 meters

BRAIN INERTIAL FORCES

NATIONAL SWEDISH ROAD AND TRAFFIC RESEARCH INSTITUTE
TEST: C 123
SUMMARY DATA SHEET
SYSTEM: KLIPPAN
MANUFACTURED BY: AB BRUDERNA OTTOSSON & CO
SWEDEN

TYPE: II
TEST: C 124
DUMMY: VIP-3C
SLED VELOCITY: 50.3 km/h
STOPPING DISTANCE: .68 m
MAX HEAD DISPLACEMENT: .28 m
SUMMARY DATA SHEET
SYSTEM: JOLLY
MANUFACTURED BY: DOUGLAS S.R.L.
ITALY

TYPE: II
TEST: C 125
DUMMY: VIP-3C
SLED VELOCITY: 50.0 km/h
STopping DISTANCE: .67 m
MAX HEAD DISPLACEMENT: .23 m
**SUMMARY DATA SHEET**

**SYSTEM: JOLLY**

**SYSTEM: JOLLY**

**EXTERNAL SWEDISH ROAD AND TRAFFIC RESEARCH INSTITUTE**

**SLED VELOCITY: 50.0 km/h**

**STOPPING DISTANCE: .67 m**

**MAX HEAD DISPLACEMENT: .23 m**

---

**HEAD DISPLACEMENT**

1 meter

---

**BRAIN INERTIAL FORCES**

---

**CHEST DATA**

---

**HEAD DATA**

---

**RESULT-OF ACCELERATION**

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---
SUMMARY DATA SHEET
TYPE: III
TEST: C III
SYSTEM: JOLLY
DUMMY: VIP-3C
MANUFACTURED BY: DOUGLAS S.R.L.
ITALY
SLED VELOCITY: 49.4 KM/H
STOPPING DISTANCE: .68 M
MAX HEAD DISPLACEMENT: .57 M

BEFORE TEST
AFTER TEST

0 MS
50 MS
TIME AFTER IMPACT
100 MS
150 MS
200 MS
250 MS
TYPE: III
TEST: C 111
DUMMY: VIP-3C
SLED VELOCITY: 49.4 km/h
STOPPING DISTANCE: .68 m
MAX HEAD DISPLACEMENT: .57 m
TYPE: III
TEST: C 112
DUMMY: VIP-3C
SLED VELOCITY: 50.3 km/h
STOPPING DISTANCE: .66 m
MAX HEAD DISPLACEMENT: .39 m
SUMMARY DATA SHEET

SYSTEM: NIKI COMMODORE 6070
MANUFACTURED BY: DIE STORCHENMUHLE
GERMANY

TYPE: III
TEST: C 113
DUMMY: VIP-3C
SLED VELOCITY: 50.5 KN/H
STOPPING DISTANCE: .68 M
MAX HEAD DISPLACEMENT: .51 M
SUMMARY DATA SHEET
SYSTEM: HIKI COMMODORE 6070

TYPE: III TEST: C 113
DUMMY: VIP-3C
SLED VELOCITY: 50.5 KM/H
STOPPING DISTANCE: .68 M
MAX HEAD DISPLACEMENT: .51 M

HEAD DISPLACEMENT
1 meter

BRAIN INERTIAL FORCES

CHEST DATA

HEAD DATA

REGRESSIVE ACCELERATION
SUMMARY DATA SHEET
SYSTEM: MOTHERCARE
MANUFACTURED BY: ? ENGLAND

TYPE: III
TEST: C 114
DUMMY: VIP-3C
SLED VELOCITY: 49.5 km/h
STOPPING DISTANCE: .64 m
MAX HEAD DISPLACEMENT: .27 m
**SYSTEM: Moothercare**

**TYPE:** III  
**TEST:** C 114  
**DUMMY:** VIP-3C  
**SLED VELOCITY:** 49.5 km/h  
**STOPPING DISTANCE:** .64 m  
**MAX HEAD DISPLACEMENT:** .27 m  

**HEAD DISPLACEMENT**

1 meter

---

**FORCES**

- **LOWER LEFT ANCHOR POINT**
- **LOWER RIGHT ANCHOR POINT**
- **UPPER LEFT ANCHOR POINT**
- **UPPER RIGHT ANCHOR POINT**

---

**BRAIN INERTIAL FORCES**

---

**CHEAT DATA**

---

**HEAD DATA**

---

**RELENTIVE ACCELERATION**

---
TYPE: III
TEST: C 115
DUMMY: VIP-3C
SLED VELOCITY: 49.6 km/h
STOPPING DISTANCE: .65 m
MAX HEAD DISPLACEMENT: .43 m

SLED DATA

HEAD DISPLACEMENT

1 meter

BRAIN INERTIAL FORCES
SUMMARY DATA SHEET
SYSTEM: STAR RIDER
MANUFACTURED BY: BRITAX ENGLAND

TYPE: III
TEST: C 116
DUMMY: VIP-3C
SLED VELOCITY: 50.0 KM/H
STOPPING DISTANCE: .66 M
MAX HEAD DISPLACEMENT: .30 M
TYPE: III
TEST: C 116
DUMMY: VIP-3C
SLED VELOCITY: 50.0 km/h
STOPPING DISTANCE: .66 m
MAX HEAD DISPLACEMENT: .30 m

HEAD DISPLACEMENT
1 meter

BRAIN INERTIAL FORCES

HEAD DATA

CHEST DATA
SUMMARY DATA SHEET
SYSTEM: KLIPPAK
MANUFACTURED BY: AB BRUDERNA OTTOSSON & CO
SWEDEN

TYPE: III
TEST: C 117
DUMMY: VIP-3C
SLED VELOCITY: 49.9 KM/H
STOPPING DISTANCE: .64 M
MAX HEAD DISPLACEMENT: .44 M
TYPE: III    TEST: C 117
DUMMY: VIP-3C
SLED VELOCITY: 49.9 km/h
STOPPING DISTANCE: .64 m
MAX HEAD DISPLACEMENT: .44 m
SUMMARY DATA SHEET
SYSTEM: 3-POINT BELT
MANUFACTURED BY:

TYPE: III
TEST: C 131
DUMMY: VIP-6C
SLED VELOCITY: 49.1 km/h
STOPPING DISTANCE: .70 m
MAX HEAD DISPLACEMENT: .22 m

BEFORE TEST

AFTER TEST

TIME AFTER IMPACT

0 MS

150 MS

100 MS

50 MS

100 MS

200 MS

250 MS
SUMMARY DATA SHEET
SYSTEM: 3-POINT BELT

TYPE: III
DUMMY: VIP-6C
SLED VELOCITY: 49.1 KM/H
STOPPING DISTANCE: .70 M
MAX HEAD DISPLACEMENT: .22 M

HEAD DISPLACEMENT

NATIONAL SWEDISH ROAD AND TRAFFIC RESEARCH INSTITUTE

CHEST DATA

HEAD DATA
SUMMARY DATA SHEET
SYSTEM: MOTHERCARE
MANUFACTURED BY: ? ENGLAND

TYPE: III
TEST: C 133
DUMMY: VIP-6C
SLED VELOCITY: 49.1 km/h
STOPPING DISTANCE: .69 m
MAX HEAD DISPLACEMENT: .28 m
TYPE: III  
TEST: C 133  
DUMMY: VIP-6G  
SLED VELOCITY: 49.1 km/H  
STOPPING DISTANCE: 6.9 m  
MAX HEAD DISPLACEMENT: 2.8 m

HEAD DISPLACEMENT

1 meter

BRAIN INERTIAL FORCES

Chest Data

Head Data

Summary Data Sheet

System: Mothercare

National Swedish Road and Traffic Research Institute

1:45
SUMMARY DATA SHEET
TYPE: IV
TEST: C 108

SYSTEM: GUARDWELL CS-100
DUMMY: VIP-3C
MANUFACTURED BY: DONLEE PLASTICS CANADA

SLED VELOCITY: 48.7 km/h
STopping DISTANCE: .62 m
MAX HEAD DISPLACEMENT: .57 m

TIME AFTER IMPACT

0 ms
50 ms
300 ms
100 ms
350 ms
400 ms
TYPE: IV
TEST: C 108
DUMMY: VIP-3C
SLED VELOCITY: 48.7 KM/H
STOPPING DISTANCE: .62 M
MAX HEAD DISPLACEMENT: .57 M

HEAD DISPLACEMENT
1 meter

BRAIN INERTIAL FORCES

HEAD DATA
SUMMARY DATA SHEET

SYSTEM: IRVIN 1-165
MANUFACTURED BY: IRVIN INDUSTRIES INC
USA

TYPE: IV
TEST: C 109
DUMMY: VIP-3C
SLED VELOCITY: 50.4 km/h
STOPPING DISTANCE: .69 m
MAX HEAD DISPLACEMENT: .71 m

BEFORE TEST

AFTER TEST

0 MS
50 MS
100 MS
200 MS
TIME AFTER IMPACT
250 MS
300 MS
TYPE: IV  TEST: C 109
DUMMY: VIP-3C
SLED VELOCITY: 50.4 KM/H
STOPPING DISTANCE: .69 M
MAX HEAD DISPLACEMENT: .71 M
SUMMARY DATA SHEET
SYSTEM: TOT - GUARD
MANUFACTURED BY: FORD?
USA

TYPE: IV
TEST: C118
DUMMY: VIP-3C
SLED VELOCITY: 50.1 km/h
STOPPING DISTANCE: .67 m
MAX HEAD DISPLACEMENT: .54 m

BEFORE TEST
AFTER TEST

0 ms
50 ms
100 ms
200 ms
300 ms
500 ms
TIME AFTER IMPACT
TYPE: IV
TEST: C 118
DUMMY: VIP-3C
SLED VELOCITY: 50.1 km/h
STOPPING DISTANCE: 0.67 m
MAX HEAD DISPLACEMENT: 0.54 m
SUMMARY DATA SHEET
SYSTEM: TOT-GUARD
MANUFACTURED BY: FORD USA

TYPE: IV
TEST: C 130
DUMMY: VIP-6C
SLED VELOCITY: 49.0 km/h
STOPPING DISTANCE: .68 m
MAX HEAD DISPLACEMENT: .55 m

BEFORE TEST
AFTER TEST

TIME AFTER IMPACT
0 MS 50 MS 100 MS 200 MS 300 MS 400 MS
SUMMARY DATA SHEET  
SYSTEM: TOT-GUARD

NATIONAL SWEDISH ROAD AND TRAFFIC RESEARCH INSTITUTE  

TYPE: IV  
TEST: C 130  
DUMMY: VIP-6C  
SLED VELOCITY: 49.0 KM/H  
STOPPING DISTANCE: .68 M  
MAX HEAD DISPLACEMENT: .55 M

HEAD DATA

HEAD DATA

BRAIN INERTIAL FORCES

NATIONAL SWEDISH ROAD AND TRAFFIC RESEARCH INSTITUTE

CHEST DATA

CHEST DATA

NATIONAL SWEDISH ROAD AND TRAFFIC RESEARCH INSTITUTE

Chest Data

Head Data
SUMMARY DATA SHEET
TYPE: IV  TEST: C 110
SYSTEM: LAP BELT  DUMMY: VIP-3C
MANUFACTURED BY: --
SLED VELOCITY: 49.7 km/h
STOPPING DISTANCE: 0.67 m
MAX HEAD DISPLACEMENT: 0.67 m

BEFORE TEST

AFTER TEST

0 ms 50 ms 100 ms
150 ms 200 ms 250 ms

TIME AFTER IMPACT
SUMMARY DATA SHEET
SYSTEIN: LAP BELT

SLED VELOCITY: 49.7 km/h
STOPPING DISTANCE: 67 m
MAX HEAD DISPLACEMENT: 67 m

TYPE: IV
TEST: C 110
DUMMY: VIP-3C

HEAD DISPLACEMENT

BRAIN INERTIAL FORCES
TYPE: IV  TEST: C 132
DUMMY: VIP-6C
SLED VELOCITY: 48.9 km/h
STOPPING DISTANCE: .72 m
MAX HEAD DISPLACEMENT: .67 m

SUMMARY DATA SHEET
SYSTEM: LAP BELT
MANUFACTURED BY: -

BEFORE TEST

AFTER TEST

0 MS

50 MS
TIME AFTER IMPACT

100 MS

150 MS

200 MS

250 MS
TYPE: IV  
TEST: C 132

DUMMY: VIP-6C
SLED VELOCITY: 48.9 km/h
STopping DISTANCE: .72 m
MAX HEAD DISPLACEMENT: .67 m

HEAD DISPLACEMENT

1 meter

BRAIN INERTIAL FORCES

NATIONAL SWEDISH ROAD AND TRAFFIC RESEARCH INSTITUTE

CHest DATA

HEAD DATA

MAX HEAD DISPLACEMENT: .67 m
SUMMARY DATA SHEET  
SYSTEM: SAFETY HARNESS  
MANUFACTURED BY: SEARS ROEBUCK AND CO  
USA  

TYPE: IV  
TEST: C.119  
DUMMY: STUNT-3  
SLED VELOCITY: 49.9 KM/H  
STOPPING DISTANCE: .63 M  
MAX HEAD DISPLACEMENT: .60 M
TYPE: IV
TEST: C 119
DUMMY: STUNT-3
SLED VELOCITY: 49.9 km/h
STOPPING DISTANCE: .63 m
MAX HEAD DISPLACEMENT: .60 m

HEAD DISPLACEMENT

BRAIN INERTIAL FORCES

NOT MEASURED

Chest Data

NOT MEASURED

Foot Data
SUMMARY DATA SHEET

SYSTEM: SAFETY HARNESS
MANUFACTURED BY: SEARS ROEBUCK AND CO USA

TYPE: IV
TEST: C 120
DUMMY: VIP-3C
SLED VELOCITY: 50.1 km/h
STOPPING DISTANCE: .67 m
MAX HEAD DISPLACEMENT: .52 m

BEFORE TEST

AFTER TEST

TIME AFTER IMPACT
0 ms
50 ms
100 ms
150 ms
200 ms
250 ms
TYPE: IV  
TEST: C 120

DUMMY: VIP-3C

SLED VELOCITY: 50.1 KM/H
STOPPING DISTANCE: .67 M
MAX HEAD DISPLACEMENT: .52 M
SUMMARY DATA SHEET
SYSTEM: SAFETY HARNESS

NATIONAL SWEDISH ROAD AND TRAFFIC RESEARCH INSTITUTE

TYPE: IV
DUMMY: VIP-6C
TEST: C 134
SLED VELOCITY: 49.0 KM/H
STopping DISTANCE: .68 M
MAX HEAD DISPLACEMENT: .58 M

HEAD DISPLACEMENT

5.0
4.0
3.0
2.0
1.0
0.0

BRAIN INERTIAL FORCES

CHEST DATA

HEAD DATA
SUMMARY DATA SHEET
SYSTEM: NIKI-ASTRO-JET
MANUFACTURED BY: DIE STORCHENMÜHLE GERMANY

TYPE: V
TEST: C121
DUMMY: VIP-3C
SLED VELOCITY: 49.9 KM/H
STOPPING DISTANCE: .66 M
MAX HEAD DISPLACEMENT: >.67 M

BEFORE TEST

AFTER TEST

0 MS 50 MS 100 MS
150 MS TIME AFTER IMPACT 200 MS 250 MS
SUMMARY DATA SHEET
SYSTEM: NIKI-ASTRO-JET

TYPE: V
TEST: C 121
DUMMY: VIP-3C
SLED VELOCITY: 49.9 km/h
STOPPING DISTANCE: .66 m
MAX HEAD DISPLACEMENT: >.67 m
SUMMARY DATA SHEET

SYSTEM: A-STOLEN
MANUFACTURED BY: BRUDERNA WARNELOV AB
SWEDEN

TYPE: V
TEST: C 126
DUMMY: STUNT-3
SLED VELOCITY: 50.2 km/h
STOPPING DISTANCE: .67 m
MAX HEAD DISPLACEMENT: > .54 m

BEFORE TEST

AFTER TEST

TIME AFTER IMPACT
0 ms
200 ms
50 ms
250 ms
100 ms
300 ms
SUMMARY DATA SHEET
SYSTEM: A-STOLEN

NATIONAL SWEDISH ROAD AND TRAFFIC RESEARCH INSTITUTE

TYPE: V  TEST: C 126
DUMMY: STUNT-3
SLED VELOCITY: 50.2 km/h
STOPPING DISTANCE: 1.67 m
MAX HEAD DISPLACEMENT: >.54 m
SUMMARY DATA SHEET

SYSTEM: VT

TYPE: V
TEST: C 127
DUMMY: STUNT-3
SLED VELOCITY: 50.4 km/h
STOPPING DISTANCE: 6.66 m
MAX HEAD DISPLACEMENT: ∞

HEAD DISPLACEMENT

1 meter

NATIONAL SWEDISH ROAD AND TRAFFIC RESEARCH INSTITUTE

CHEST DATA

HEAD DATA

NATIONAL SWEDISH ROAD AND TRAFFIC RESEARCH INSTITUTE

FORCES

ACCELERATION

NOT MEASURED

NOT MEASURED