C H I L D   R E S T R A I N T   S Y S T E M S

Results from frontal impact tests and proposals for compliance test procedures.

by

Thomas Turbell

National Swedish Road and Traffic Research Institute

Drottning Kristinas Väg 25 S-114 28 STOCKHOLM Sweden

SUMMARY

Frontal impact simulations with 25 different types of child restraint systems have been made with Alderson 3 and 6 years old anthropometric dummies. Impact speed has been 50 km/h and deceleration levels 15-20 g. Electrical measurements, according to SAE J 211a, have included dummy head and chest accelerations, sled acceleration and forces acting on the restraint systems. High-speed photography has also been used.
The most significant difference between various types of systems has been that the resultant head acceleration and the hyperflexion of the neck is considerably lower with rearward facing seats compared with forward facing seats, cushions, shells and harnesses.
It is proposed that, when using the test methods decribed in this paper, the following main performance criteria shall be met:
Maximum resultant head acceleration: 50g
Maximum vertical head acceleration: 20g
This implies that, among the systems existing today, only rearward facing seats can be approved. Behaviourial studies and experience from the 100,000 rearward facing seats used in Sweden confirm that this is a practical and usable design concept for a child restraint system.

INTRODUCTION

A series of investigations on child restraint systems have been carried out at the Road User and Vehicle Division of the National Swedish Road and Traffic Research Institute. Professor Bertil Aldman, Chalmers University of Technology has served as medical consultant and the project has been sponsored by the Swedish Transport Research Delegation.

This paper presents the most important results from the technical part of the investigations /1/. Handling performance of buckles and harnesses /2/ and users'opinions on child seats /3/ have also been studied from behaviourial aspects.

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.

Research and development of child restraint systems was started in Sweden about ten years ago by Aldman /4,5/. These investigations resulted in prototypes of rearward facing child seats intended to be placed in the front seat of the car, supported by the instrument panel. The medical aspects of how to apply great loads on a child's body /6/ are well met by this design concept where the high back of the seat offers an ultimate load distribution at frontal impacts.

Most work on child restraint systems outside Sweden has been concentrated on forward facing systems /7,8,9,10,11/. The rearward facing concept has often been discussed but rejected due to assumed disadvantages of handling convenience, mounting and the risk of the child being sick riding backwards. The results of the behaviourial studies /3/ indicate that these disadvantages are very exaggerated.

These problems have also shown to be very rare in Sweden where about 100,000 rearward facing child seats have been sold. Publicity in press, radio and TV has also led to that Swedish parents are quite aware of the advantages of the rearward facing seats, and approximately every second seat used in the cars today is of this type.

This situation has made it possible for Sweden to accept the international recommendations /12/ on testing child restraints since these recommendations are intended only for forward facing systems.

The test procedures and performance criteria to be presented in this paper will therefore aim at giving the children optimal protection according to the present knowledge of the performance of different systems.

/ / Refers to references at end of paper.

FRONTAL IMPACT TESTS

1 TEST CONDITIONS

This study includes only frontal impact which is the most common and the most severe type of accidents. Impact speed was 50 km/h and the stopping distance approx. 65 cm which implies a deceleration level of 15-20 g. Since a standard car seat was used on the test sled we consider it important to use this moderate deceleration level in order to simulate the real dynamic interactions between the restraint system and the car seat.

Alderson VIP-6C anthropometric dummies, equipped with 3-axial accelerometers in the head and chest, were used.

The complete instrumentation, which was designed to follow SAE Recommended Practice J 211a where applicable, is described in figure 1.

Photographic coverage of the tests was obtained by 5 high-speed motion picture and sequence cameras.

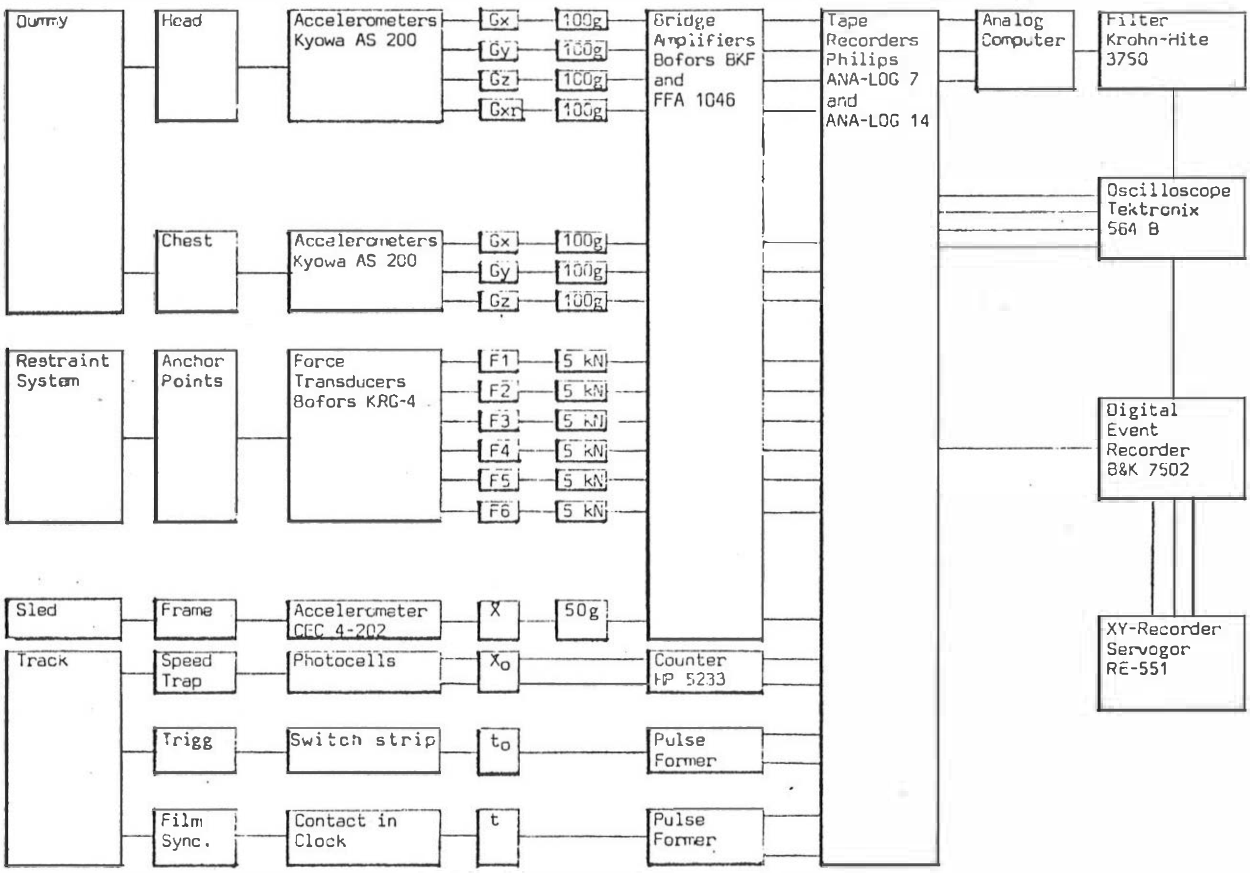


Figure 1. Instrumentation

.2 RESULTS

The impact protection performance of the restraint systems was studied from the following aspects:

A. Head acceleration
B. Chest acceleration
C. Displacement
D. Load distribution
E. Dynamic strength

Based upon the different design concepts and the results from the parameters mentioned above, the restraint systems can be divided into five types:

Type I. Rearward facing seats, front seat.
Type II. Rearward facing seats, back seat.
Type III. Forward facing seats and belts with upper torso straps.
Type IV. Lap belts, shields, cushions and harnesses.
Type V. Hookover seats.

Since the head acceleration is considered to be the most important parameter in these tests, and due to limited space in this paper, only these results will be presented here. The other aspects mentioned above are also partly reflected by the head acceleration.

Type II systems have almost the same performance as Type I and are therefore not included in these results. The systems of Type V were too weak to retain the dummy and are, for that reason, not of any interest in the following.

The graphs presented in Figure 2,3 and 4 show the ranges of head accelerations measured with different types of restraint systems. The following conclusions are drawn from these graphs:
REARWARD FACING SEATS decelerate the head in its initial position. The deceleration starts early and follows the sled deceleration which implies that the resultant acceleration will stay below 40 g. The vertical accelerations are below 10 g.

FORWARD FACING SEATS and BELTS WITH UPPER TORSO STRAPS allow the head to rotate forward before the deceleration starts. The head is then decelerated by hyperflexion of the neck. This sudden rotation is probably an injury-producing factor in itself due to the high rotational accelerations of the brain. These rotational accelerations have been measured and will be reported later. The forces on the neck are at least 3 times as large as with the rearward facing seats. At a later stage of the collision the back of the head will, due to rebound effects, impact the child seat, resulting in very high acceleration peaks.

LAP BELTS, SHIELDS, CUSHIONS and HARNESSES allow the head and torso to rotate forward until they impact the restraint system or the legs. This rotation is rather slow and by the time the head impacts, large relative velocities have developed. The deceleration of the head is therefore accomplished by both a severe facial impact and hyperflexion of the neck. Rebound effects are also quite common with these systems although they will appear at later stages than covered by the graphs in this paper.

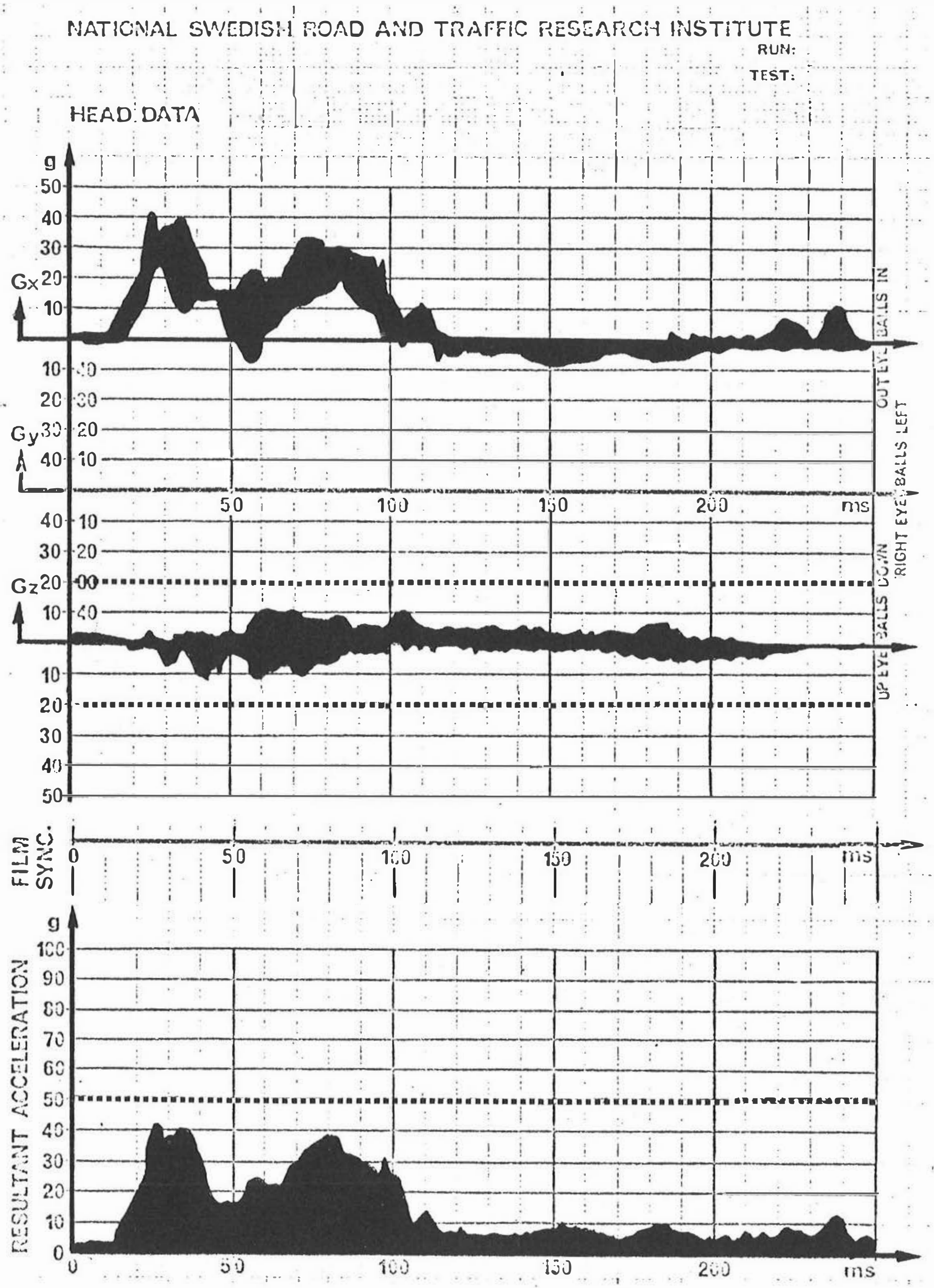


Figure 2 Head accelerations from 5 tests with different REARWARD FACING SEATS in front seat installations. (Dotted lines indicate proposed performance criteria.)

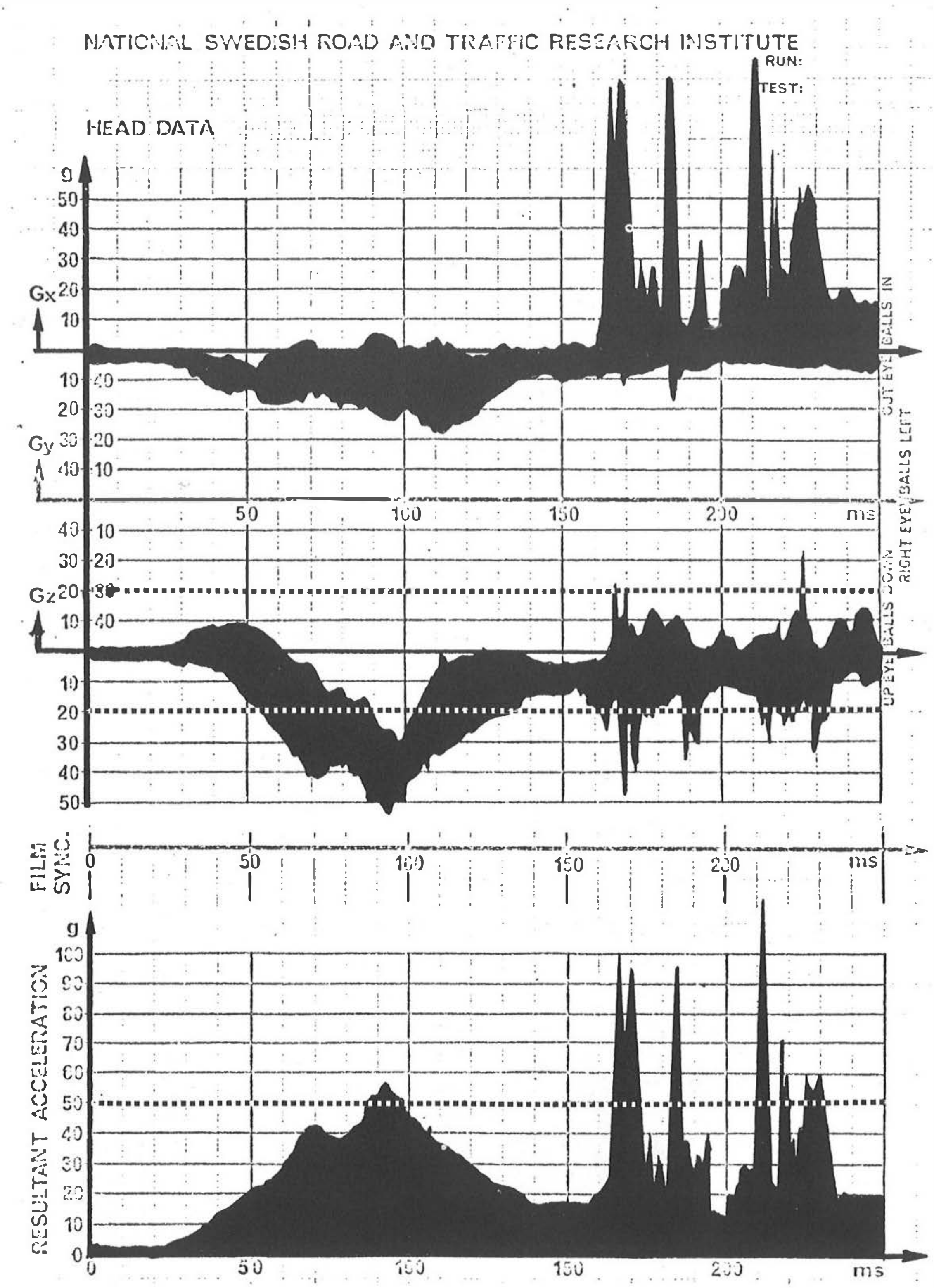


Figure 3 Head accelerations from 9 tests with different FORWARD FACING SEATS and BELTS WITH UPPER TORSO STRAPS. (Dotted lines indicate proposed performance criteria.)

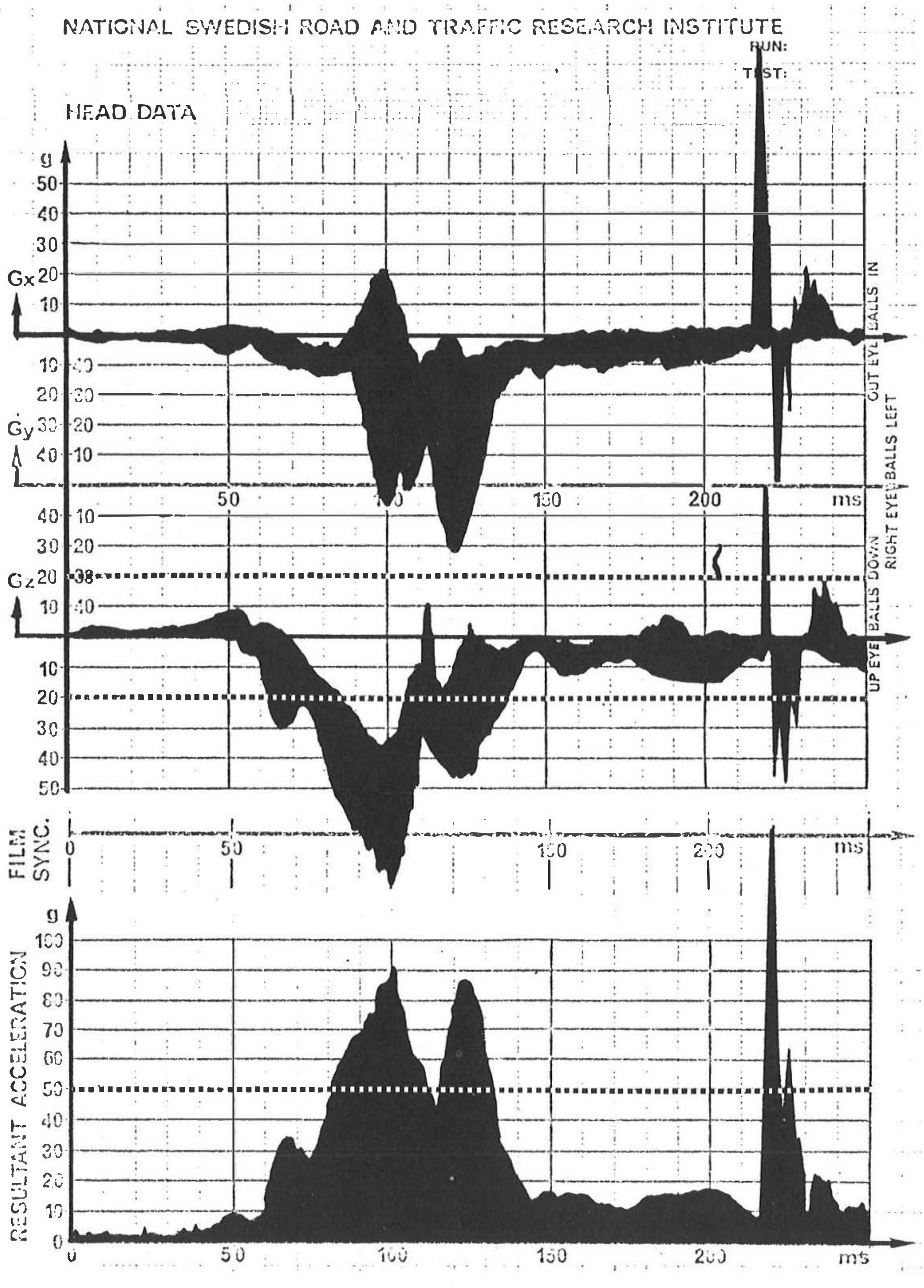
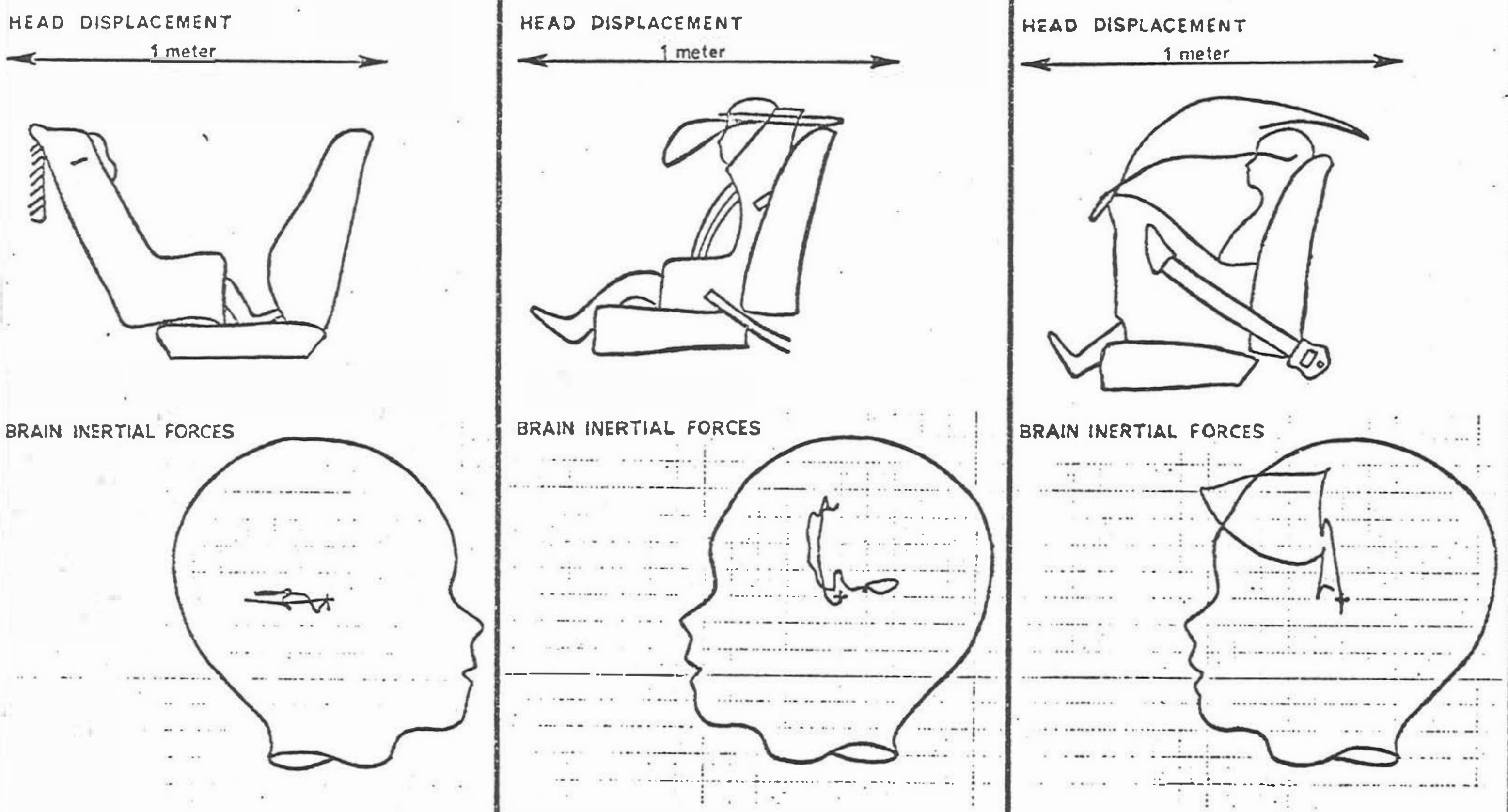


Figure 4 Head accelerations from 5 tests with different LAP BELTS, SHIELDS, CUSHIONS and HARNESSES. (Dotted lines indicate proposed performance criteria.)



REARWARD FACING SEAT
Minor head displacement.
Only linear forces on the brain.

FORWARD FACING SEAT
Moderate head displacement.
Complex linear and rotational forces on the brain and the neck.

SHIELD
Large head displacement.
Complex linear and rotational forces on the brain and the neck.

Figure 5 Typical performance of different types of systems.

3. PROPOSED PERFORMANCE CRITERIA

As has been shown in the previous pages there is a great difference in dummy kinematics between different types of systems. Our opinion, that the head accelerations can be used as performance criteria, is based on the following considerations:

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 represents 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.

Based upon these considerations, 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.
Our proposal for compliance tests with child restraint systems consequently is:
Impact tests as described in this paper with the following limits for the head accelerations as the main criteria:
Resultant head acceleration max 50 g.
Gz (Superior-Inferior) head acceleration max 20 g.
A number of other, more obvious, requirements that also shall be met are presented in the complete report.
This proposal implies that, among the child restraint systems existing today, only rearward facing child seats can be approved. Based upon the psychological investigations performed within this project and the long experience with rearward facing child seats in Sweden, we are convinced that these test methods and performance criteria reflect the present knowledge of how to give our children the best possible protection in car accidents.

REFERENCES

/1/ CHILD RESTRAINT SYSTEMS. Frontal Impact Performance T Turbell National Swedish Road and Traffic Research Institute Report 36A, 1974.

/2/ CHILD RESTRAINT SYSTEMS. Handling Performance of Buckles and Harnesses on Child Seats. P W Arnberg, National Swedish Road and Traffic Research Institute, Report 37A, 1974.

/3/ CHILD RESTRAINT SYSTEMS. Psychological Problems Related to the use of Rearward Facing Child Seats. P W Arnberg, National Swedish Road and Traffic Research Institute, Report 38A, 1974.

/4/ ALDMAN, B. Children´s Protective Devices, Aspects Techniques de la Securité Routiere 16:7, 1963.

/5/ ALDMAN, B. A Protective Seat for Children. 8th Stapp Car Crash Conference, 1964.

/6/ BURDI, A.R., et al. Infants and Children in the Adult World of Automotive Safety Design: Pediatric and Anatomical Considerations for Design of Child Restraints. Journal of Biomechanics. Vol. 2. Pergamon Press. 1969.

/7/ HEAP, S.A., and GRENIER, E.P. The Design and Development of a More Effective Child Restraint Concept. SAE paper 680002.

/8/ ROGERS, R.A., and SILVER, J.N. Elements of an Effective Child Restraint System. SAE paper 680776.

/9/ ROBBINS, D.H., HENKE, A.W., and ROBERTS, V.L. A Study of Concepts in Child Seating and Restraint Systems. SAE paper 700041.

/10/ ROBERTS, V.L. and McELHANEY. Dynamic Performance of Child Seating Systems. SAE paper 720971.

/11/ HONTSCHIK, H., and SCHMID, I. Untersuchung von Einrichtungen zür Sicherung von Kindern in Kraftfahrzeugen. Deutsche Kraftfahrtforschung und Strassenverkehrstechnik, Heft. 226. VDI-Verlag, Düsseldorf, 1972.

/12/ ISO Recommendation R 1713. Restraining Devices for Children in Motor Vehicles ISO/R 1713-1970 (E).