INVESTIGATION INTO THE SAFETY OF BABIES IN CARRY-COTS RESTRAINED BY A HARNESS

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1. INTRODUCTION AND INITIAL ASSUMPTIONS

In the Federal Republic of Germany, the wearing of seat belts in both the front and rear seats of passenger cars is compulsory. Children below the age of 12 years are exempted from this legal obligation. The German Road Traffic Regulations (StVO) stipulate merely that children must be carried on the rear seats unless the passenger seat is fitted with a special child restraint device.

Child restraint devices are - depending on the age of the child - carry-cots or baby seats (also called baby shells) for babies and young children, and children's seats of various sizes fitted with tables and/or belts for older children.

Since 1984, ECE-R 44 has been adopted as the regulation for the testing of child restraint systems - i.e. child restraint devices used in conjunction with the vehicle's own seat belts or special harnesses /1/.*

Following the 2nd amendment to this Regulation, child restraint devices of Group 0, for children below 10 kg, were included in the Regulation.
It is planned to incorporate the test in accordance with ECE-R 44 for Group 0 devices also into the 15th Amendment Ordinance to the National Regulations Authorizing the Use of Vehicles for Road Traffic (StVZO)so that after a transitionary period, from 1988 (or possibly 1992), only approved child restraint systems will be available or may be used.

Whereas child restraint systems from the other groups (I, II and III, corresponding to weights of children between 9 and 36 kg) can already be regarded as having been more or less technically perfected, a Swedish investigation into the use of carry-cots in a function as a child restraint system discovered weaknesses /2/. This was the reason for the investigation into the safety of babies in carry-cots restrained by a harness which the Federal Highway Research Institute (BASt) carried out on behalf of the Federal Minister of Transport and in conjunction with the German Association of Automobile

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* Numbers in parentheses designate references at the end of the paper

Seat Belt Manufacturers and the German Association of Pram Manufacturers /3/. Baby seats installed on the passenger seat in the direction of travel were not included in this investigation.

2. ACCIDENT STATISTICS

In 1985, 8,400 people were killed in road traffic accidents in the Federal Republic of Germany. 5.5% of this figure, i.e. 460 deaths, were children below the age of 15 years. When compared with the statistics for other countries, these figures represent a very bad result. Children account for approx. 8% of all car passenger deaths /4/. This figure corresponds roughly to their participation in road traffic (children in the rear of passenger cars approx. 7%).

Table 1 shows a breakdown according to age of the statistics for 1984.

Age	Victims	Deaths	Seriously Injured
0	77	4	28
1	781	18	144
2	800	6	136
3	934	11	155
4	948	8	136
5	929	9	141

Table 1: Accident Statistics Involving Children as Passengers in Cars According to Age (1984)

The accident statistics for the Federal Republic of Germany for the age group to be investigated of 0 - 1 years reveal only 77 accident victims. However, these include 28 seriously injured and 5 deaths.

The reason for this low number of deaths and serious injuries appears to be the unknown, but presumably low participation in road traffic of children of this age.

As regards the use of child restraint systems in cars, the investigation carried out by the Federal Highway Research Institute showed a utilization level of only 26% (1986). No distinction is made here between age and therefore the type of child restraint system.

3. CONTENTS OF ECE-R 44 WITH REGARD TO CHILD RESTRAINT DEVICES OF GROUP 0

Child restraint systems are sub-divided into weight classes (see Table 2), and their areas of use into universal, semi-universal and special categories. Carry-cots restrained by a harness always fall into the universal category, i.e. they are tested on the test slide and not in the complete vehicle.

Weight Class	Body Weight	Corresponding Test Dummies*
0	under 10 kg	P-0 and P-3/4
I	9 - 18 kg	P-3/4 and P-3
II	15 - 25 kg	P-3 and P-6
III	22 - 36 kg	P-6 and P-10

*Note: The figure after the P indicates the corresponding age group of the children.

Table 2: Sub-Division of Child Restraint Systems into Weight Classes in Accordance with ECE-R 44.

For the dynamic test, the smallest and largest test dummy in each weight class should normally be used. For Group 0, however, only the P-3/4 (9 kg) dummy should be used /7/. (In this investigation the P-0 (3.4 kg) dummy was also used /6/).

The carry-cots are secured to the test seat and test slide using the belts specified by the manufacturers, and then tested once in forward direction and once in reverse direction. The test speed for the head-on collision is 48-50 km/h, for the reverse collision 30-32 km/h.

Figure 1 shows the test seat with ramp, Figure 2 shows the deceleration curve of the test vehicle during the head-on test. The actual measured deceleration values must not exceed or fall below this curve during the tests. The stoping distance of the test vehicle should be 650 $\pm$ 50 mm.

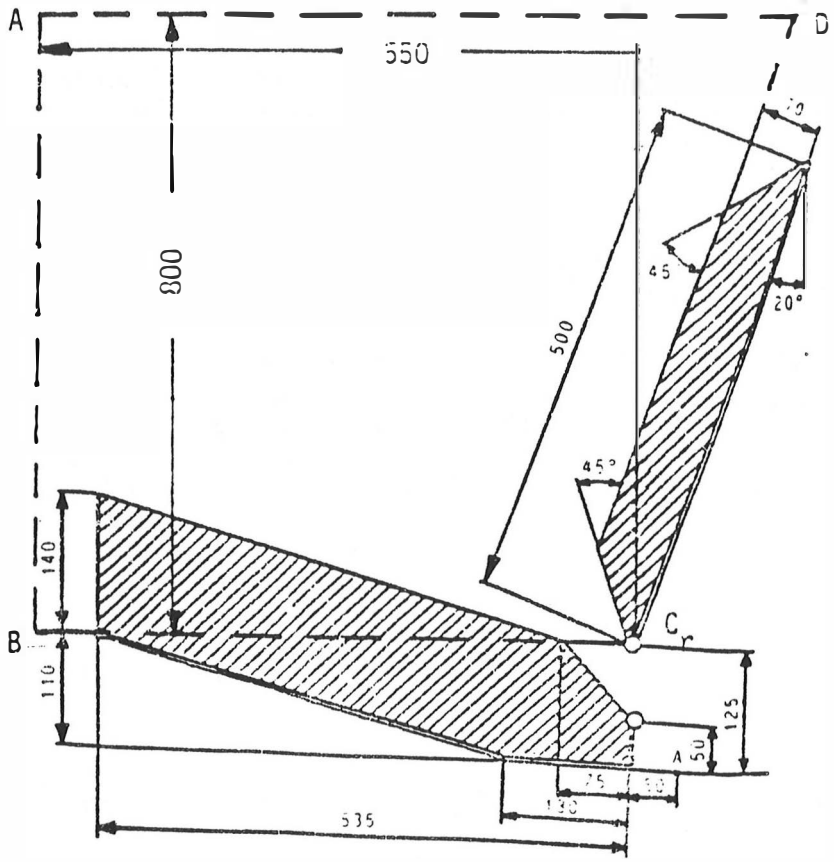

Figure 1: Standard Seat for Child's Car Seat Testing and Limits which Head of Test Dummy Must not Exceed (A,B,Cr,D)

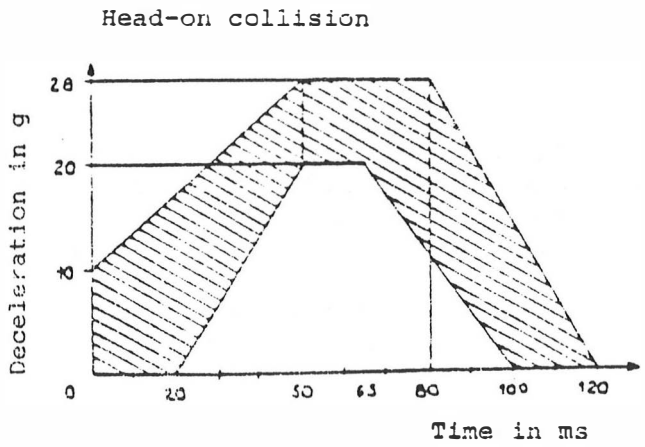

Figure 2: Deceleration Curve of Test Vehicle During a Head-on Collision at 50 km/h

One criterion laid down by ECE-R 44 is that the test dummy must not leave a given area (inside the vehicle, the area between the backrests of the front and rear seats), i.e. the horizontal displacement of the head of the dummy must not exceed 550 mm. In addition, the following dummy test values measured on the P-3/4 dummy (the P-0 dummy has no measurement points) must not be exceeded:

- Resulting chest acceleration (3 ms) < 55 g
- Vertical chest acceleration (3 ms) < 30 g

4. SET-UP AND PERFORMANCE OF THE TEST

Combinations of 6 different commercially available carry-cots* and 4 different harness systems* (two of which, however, were practically identical in design) were tested. The crash tests at 50 km/h were performed only head-on using a rolling carriage on which 2 standardized seats in accordance with regulation ECE-R 44 were mounted. It was assumed that the lower requirements of the test in reverse direction (at 30 km/h) could then be regarded as having been fulfilled. It was possible to observe the deceleration specified by ECE-R 44 within the given limits. Two systems (carry-cot and belt) could therefore be investigated during each crash test. Each system was tested once with the P-0 dummy and once with the P-3/4 dummy. The displacement of the head of the dummy was recorded on film. Head and trunk acceleration measurements were made and recorded on the P-3/4 dummy. A total of 11 tests were available for evaluation.

5. TEST RESULTS

Without going into detail about the various models of carry-cot and the efficiency of the different harness systems - consent of the manufacturers is required before publication, and this has not yet been received - the following points can be noted:

In all tests using the P-0 dummy, the only assessment criterion demanded in ECE-R 44 (horizontal head displacement) was satisfied, with displacements lying below the limit value of 550 mm. In all the tests using the P-3/4 dummy, however, one of the limit values - head displacement or trunk acceleration - was exceeded.

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* Certain of these were kindly supplied to the Federal Highway Research Institute free-of-charge by the manufacturers.

In accordance with ECE-R 44, such systems can only be regarded as being satisfactory if they maintain the permissible limit values for the upper and lower age limits. With a strict interpretation of the regulation, therefore, all the harnesses and carry-cots in the various test combinations failed.

If we differentiate slightly between the test results, depending on whether the harnesses or the carry-cots failed, the following general points can be made:

The majority of carry-cots are obviously not specially designed to withstand the high stresses during an accident. Only one of the carry-cots tested exhibited special constructional measures designed to withstand the stresses occurring in an accident. These measures include being able to place additional padding inside the carry-cot which, although restricting the freedom of movement of the baby, also allow the baby to participate in the deceleration of the vehicle from an early point. In the other carry-cots, the babies have no direct contact with the side wall of the carry-cot. As a result, the baby does not participate in the deceleration of the vehicle in the event of a collision, but is first subjected to a period of free acceleration which results in the baby colliding with the side wall of the carry-cot with a considerably higher impact. In certain cases, the carry-cots are not designed sturdily enough to withstand the collision, so that the side walls collapse and the baby is stopped suddenly by the harness. Where harnesses are used which have two separate belts running over the carry-cot, the baby is restrained at the neck and knees. Although no test values are available, severe injury in the area of the neck must be expected in this case. Figure 3 shows a system of this type during the collision.

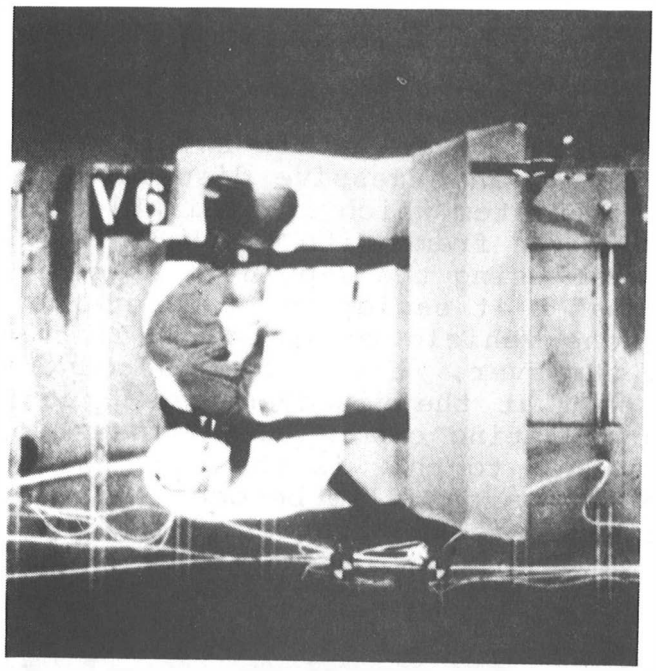

Figure 3: As the side wall of the carry-cot collapses, the baby is restrained by the belts around the neck and legs

In one of the carry-cots tested, practically unpadded steel loops were let into the side walls underneath the material at the level of the baby's head. These steel loops represent an exceptionally high risk of injury. This type of carry-cot must be considered totally unsuitable. ECE-R 44, however, contains no head injury criterion for this Group 0. Typical examples of cases where the baby cannot be catapulted out are the carry-cots with a canopy or where a sleeping bag is attached to the carry-cot.

The results for the harnesses used were rather better than those for the carry-cots, although here again system-specific benefits and disadvantages were discovered. Two special static harness systems are available on the market which are installed on the rear seat instead of the three-point seat belt to restrain the carry-cot. The main difference between these two systems is the positioning of the belts. The one harness system has two belts which pass around the carry-cot and are fastened with two buckles above the baby. The other system has one central fastener in the centre for both belts. Once installed, both harness systems are easy to use.

The 2-fastener system has the disadvantage that as the side wall of the carry-cot collapses - as already described - the baby is constricted around the neck and legs. In the system with the central fastener there is a danger that the unfavourable centre of gravity of the baby (relatively heavy head) may cause the carry-cot to twist out of the harness, thereby permitting an excessive displacement of the head. Another harness system which is available on the market consists of an angular frame with two belts which is installed on the rear seat using the 2-point or 3-point automatic seat belt . This makes it easier to transfer the carry-cot with harness from one vehicle to another. This system is also easy to use. However, it also has one central fastener in the middle, so that the disadvantages described above of the carry-cot twisting out of the harness apply here also (Figure 4). Added to this is the fact that the seat belts and carry-cot belts can also become loosened, so that the displacement also becomes greater.

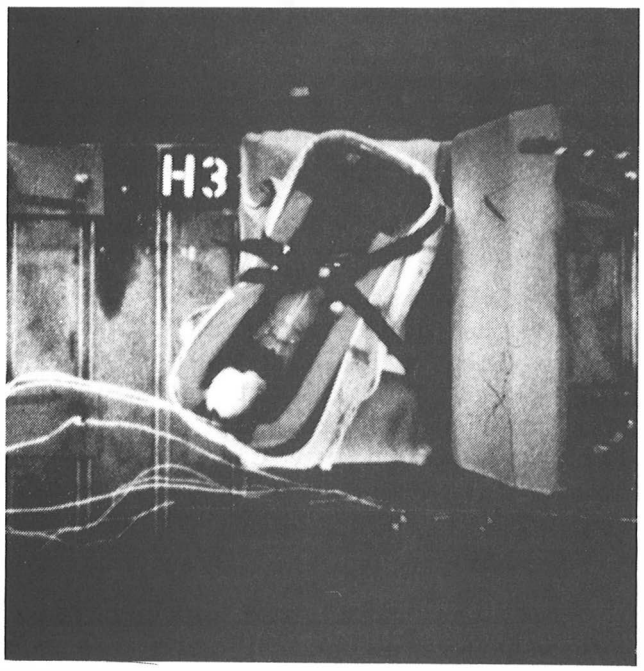

Figure 4: Carry-cot (with lateral padding) twisting out of harness

All the belts tested were completely undamaged even after several tests. The fasteners could be opened without difficulty on all the belts after the tests.

ECE-R 44 defines the safety of child restraint devices only for the pure head-on collision. In the actual accident statistics, however, oblique collisions are encountered far more frequently. In such cases it must be feared that many carry-cots could slip out of the harnesses completely and be catapulted around inside the car (Figure 5).

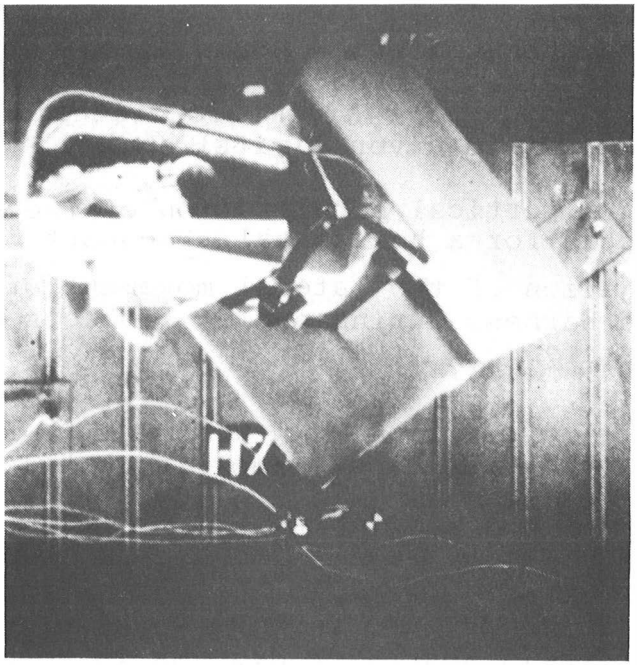

Figure 5: In a collision at an oblique angle (here 35°), the carry-cot is restrained only by the carrying strap

5. SUMMARY OF RESULTS

Six commercially available carry-cots were tested in conjunction with four different harness systems during head-on collisions at 50 km/h in accordance with ECE-R 44.
The following results were obtained:

- All the criteria of the ECE-R 44 were satisfied for the P-0 dummy (new born).

- In all the tests using the P-3/4 dummy (= 9 month old baby), either the trunk acceleration or the head displacement did not satisfy the protection criteria.

- Carry-cots are often not designed for the special case of a collision. The side walls are often too thin and collapse or break; in some cases, hard reinforcements are incorporated into the side walls at unfavourable points.

- All the harnesses stood up to the stresses.

- The carry-cots may slip out of the harnesses sideways in the event of an oblique-angled collision.

As far as the applicability of ECE-R 44 for Group 0 is concerned, the following points can be made:

- A head protection criterion would appear to be necessary, as the head of the test dummy always struck the side wall of the carry-cots. The kinematic criterion alone (head displacement within given limits) is not sufficient.

- The criterion vertical acceleration of the chest < 30 g can be omitted for a horizontal transport.

- An investigation of the lateral movement of the carry-cots in the harness during angled impacts would appear to be necessary.

- It should be examined whether a rear-end collision test is necessary for carry-cots (not for baby safety seats).

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