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Road vehicles — Side impact testing of child restraint systems — Review of background data and test methods, and conclusions from the ISO work as of November 2005

Véhicules routiers — Essais de choc latéral pour systèmes de retenue pour enfants — Revue des données de référence et des méthodes d'essai, et conclusions du travail de l'ISO jusqu'en novembre 2005

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Foreword

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In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

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ISO/TR 14646 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 12, *Passive safety crash protection systems*.

Introduction

ISO/TC 22/SC 12/WG 1 has been working on the definition of a side impact test procedure for child restraint systems. After meeting the deadline for finalisation of a third DIS version and with disapprovals (by a small margin) of the previous two DIS votings, it was decided to finalise the current project with a Technical Report and to restart the process of developing an international standard.

The aim of this Technical Report is to summarise the work done within ISO, and to compile additional relevant information to form a solid base for the restarted project.

Road vehicles — Side impact testing of child restraint systems — Review of background data and test methods, and conclusions from the ISO work as of November 2005

1 Scope

This Technical Report summarises the work within ISO to define a side impact test method for child restraint systems (CRS). It presents the main background data, and experiences from crash tests carried out during the process of development. Additional relevant data are also presented.

2 Accident statistics

The severity of injuries in side impacts depends on the seating position. It can be noticed that the severity of injuries is much higher for children sitting on the struck side than sitting on the non-struck side. The share of injuries on the non-struck side is comparable to frontal impacts, while the injury probability is much higher in struck side accidents, see Figure 1.

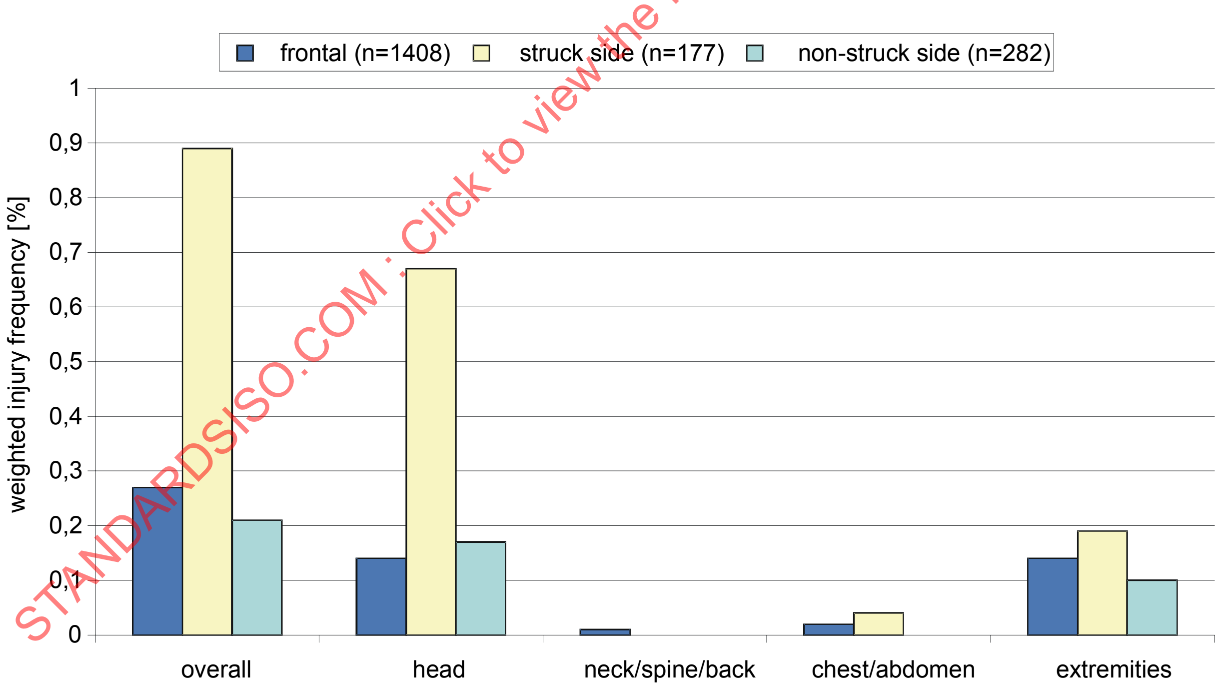


Figure 1 — Injury frequency depending on the impact direction [Arbogast, 2004]

Even when analysing all lateral impact accidents the relative number of children suffering MAIS 2+ injuries is much higher than for other impact directions, see Figure 2.

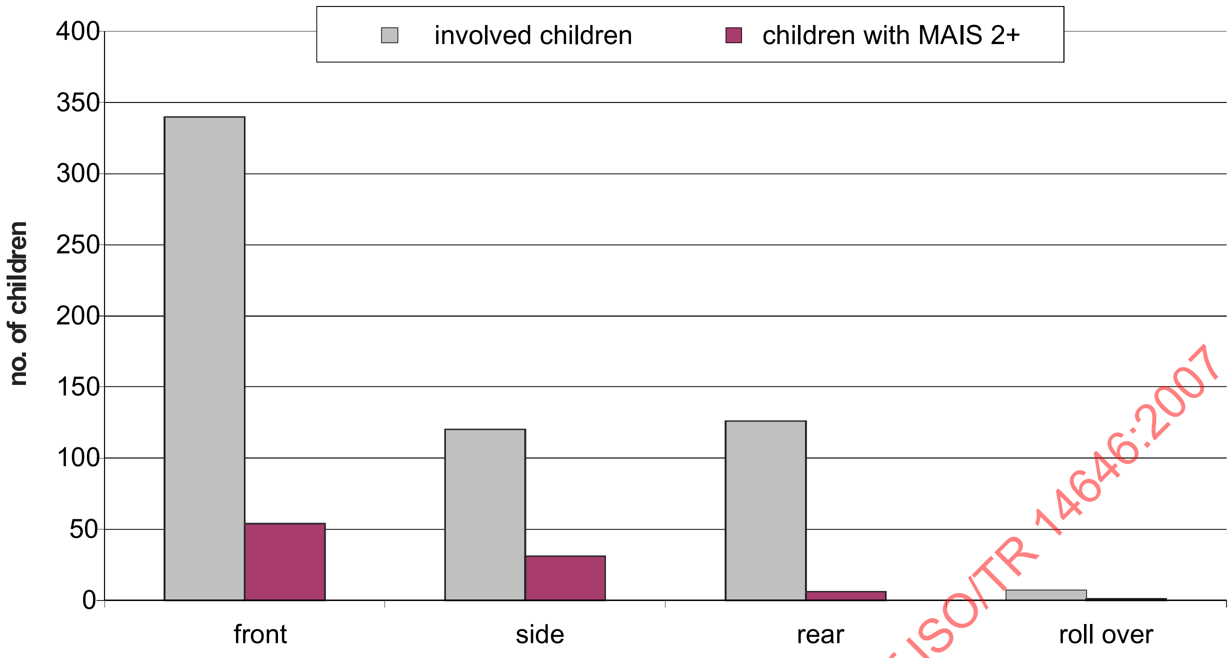


Figure 2 — Share of different impact directions [Langwieder, 2002]

Regarding the different body regions the risk for severe injuries decreases from the head down to the legs. The frequently observed injuries of arms and legs are not of high severity, but may cause long term impairments. The focus for investigations concerning improvements of CRS should be on the head, neck and thorax, see Figure 3.

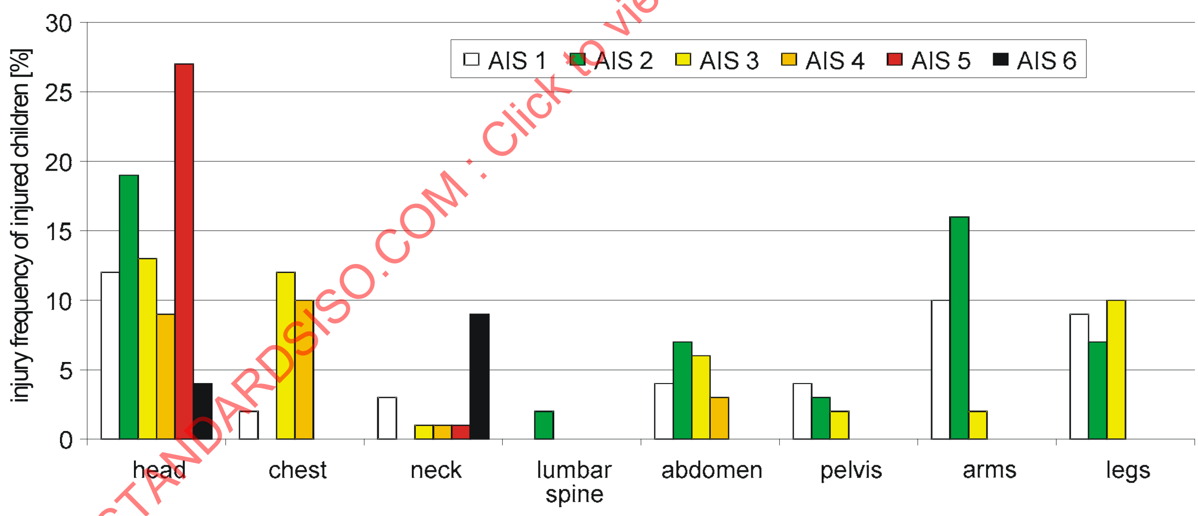


Figure 3 — Injury risk of different body regions of 68 injured children in side impacts [Langwieder, 1996]

Looking at the development of injuries in lateral impacts from 1985 to 2001 it is obvious that the injury probability decreased since 1985 while the risk to suffer neck injuries increased and the chest remained unchanged, see Figures 4, 5, and 6.

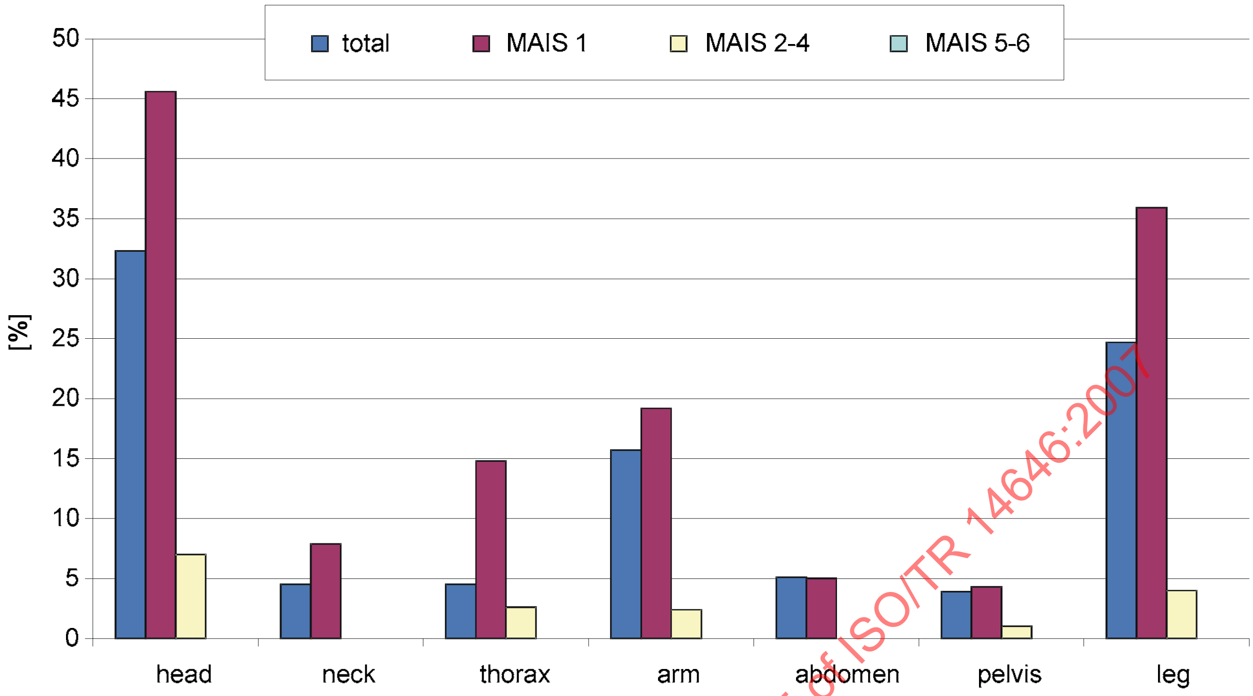


Figure 4 — Injury probability of different body regions in side impact accidents between 1985 and 1990 [Otte, 2003]

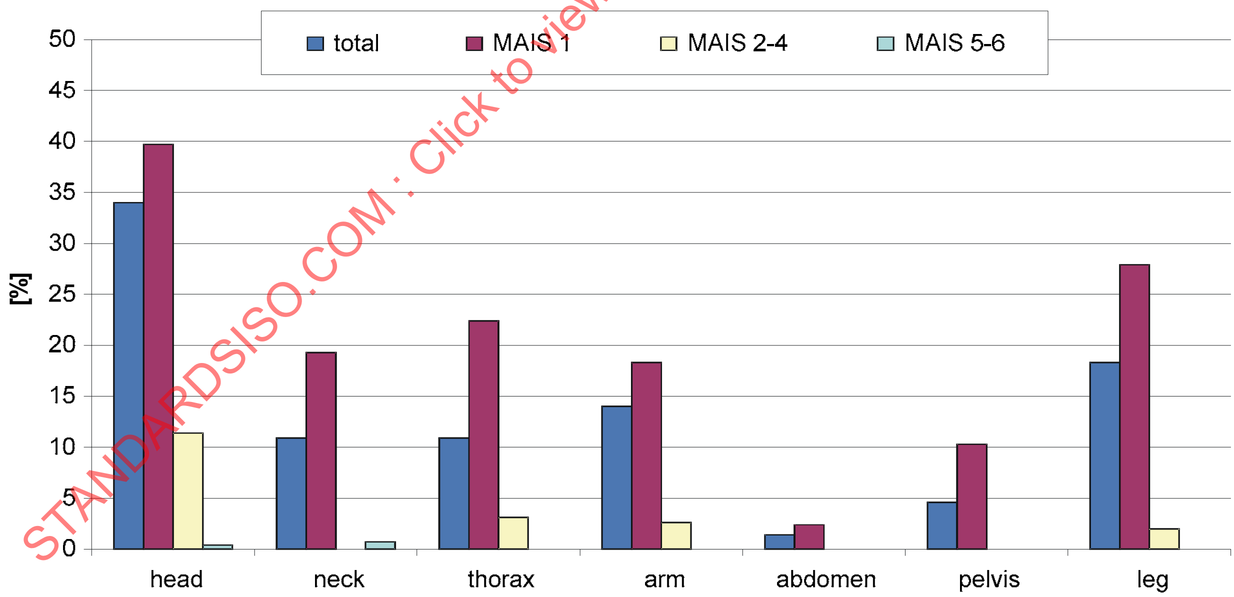


Figure 5 — Injury probability of different body regions in side impact accidents between 1991 and 1996 [Otte, 2003]

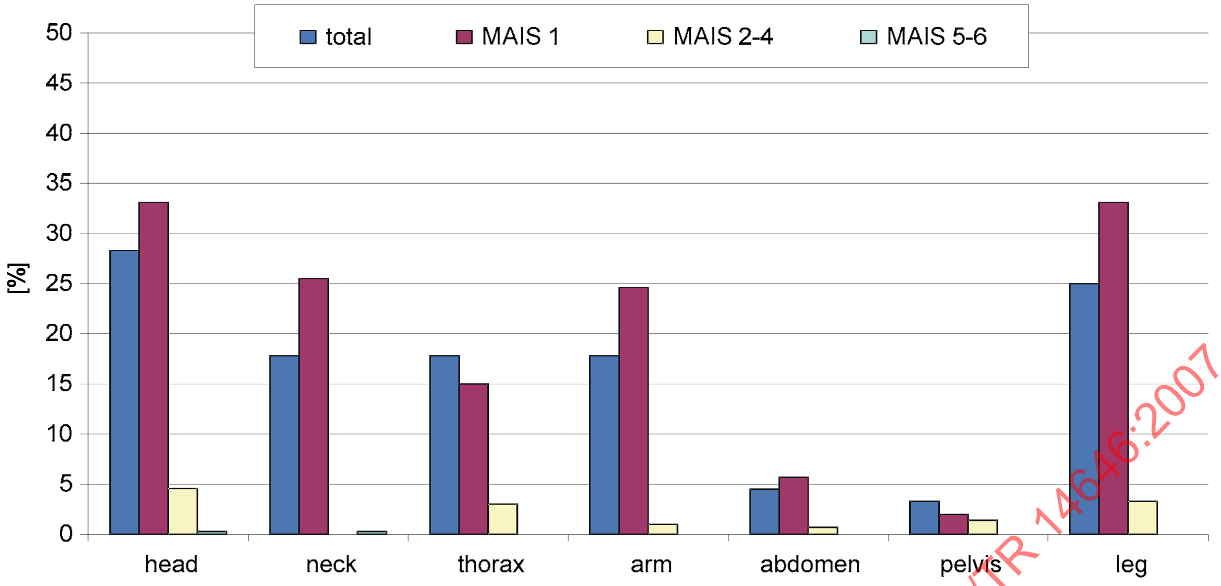


Figure 6 — Injury probability of different body regions in side impact accidents between 1997 and 2001 [Otte, 2003]

The presented accident shows that side impact accidents are severe ones especially for those children sitting at the struck side. Especially head, neck and chest need to be protected.

In a study of Swedish accident situation Jakobsson et al. [Jakobsson, 2005] did not find any moderate-severe (AIS2+) head injuries in children using rear-facing (RF) CRS involved in lateral impact accidents, while children using forward facing (FF) booster seats or the car belt only suffered from moderate-severe injuries (AIS2+) in side impacts. Comparing the injury risk for RF and FF CRS in frontal and lateral impact accidents of NASS Data (US American accident data base) of the years 1988 to 2003 Crandall et al. [Crandall, 2005] observed a ratio of 4,32 in favour of RF seats. The ratio was felt to be larger than expected.

3 Side impact test methods for cars

The full-scale test methods have been validated against the real world accident conditions in the specific regions. We can therefore utilise these test methods in the development of the child side impact test procedure.

3.1 European side impact test methods

In Europe the compulsory side impact test method is described in ECE Regulation No. 95. In addition Euro-NCAP defined a side impact test procedure, which is similar to ECE Regulation No. 95.

3.1.1 ECE Regulation No. 95

A moveable deformable barrier (MDB) strikes the test car with a velocity of 50 km/h in an angle of 90°. The barrier has a weight of 950 kg and a width of 1 500 mm. The deformable element has a ground clearance of 300 mm. The centre line of the MDB should match with the X position of the hip point of the 95-percentile dummy (R-point). A Euro SID dummy is positioned in the driver's seat. No child dummies are prescribed for ECE Regulation No. 95.

3.1.2 Euro-NCAP lateral test

The Euro-NCAP side impact test protocol is in most parts similar to that of ECE Regulation No. 95. The most important differences to ECE Regulation No. 95 are that an ES2 dummy is used in the front driver's position and child dummies are used in the rear. The two following opportunities for the CRS installation are possible:

— P1.5 on the struck side and P3 on the non struck side;

— P1.5 on the middle rear seat and P3 on the struck side.

If a head protection system is available in the car, it can be tested in a pole test. The car travels with a velocity of 29 km/h laterally into a rigid pole with a diameter of 254 mm. No child dummies are used in this test.

3.2 US side impact test methods

The compulsory side impact test method in the US is defined in FMVSS 214. In addition consumer tests are defined by US-NCAP and IIHS.

3.2.1 FMVSS 214

A crabbed barrier hits with a velocity of 54 km/h the stationary test car, see Figure 7. Because of the 27° angle of the barrier the velocity has a component of 48 km/h in the car Y-direction and 25 km/h in car X-direction. The X component should simulate that the struck car is moving in normal lateral accidents. The barriers face has a width of 1 676 mm and a ground clearance of 279 mm. The "bumper part" of the deformable element has a ground clearance of 330 mm. The mass of the trolley is 1 368 kg. US SID dummies are used at the front and rear struck side seat. No child dummies are tested according to FMVSS 214.

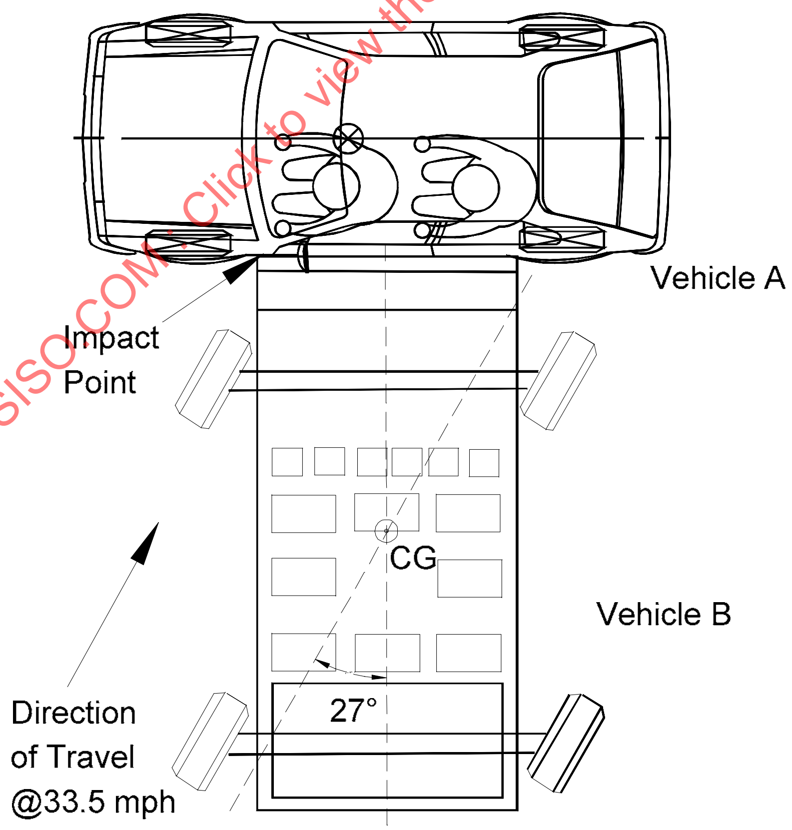


Figure 7 — Impact configuration according to FMVSS 214 [NHTSA, 2003]

FMVSS 201 describes a pole test, which formed the basis for the Euro-NCAP pole test described above.

3.2.2 US-NCAP lateral test

The US-NCAP side impact test procedure is analogous to the FMVSS 214 protocol. The main difference is that the impact speed is 5 mph higher in the NCAP test compared to FMVSS 214. This means an impact velocity of 62 km/h representing 55 km/h in car Y direction and 30 km/h in X direction.

3.2.3 IIHS lateral test

The Insurance Institute for Highway Safety (IIHS) defined a more severe side impact procedure, which should represent accidents with SUV.

A trolley with a mass of 1 500 kg hits the car in a purely lateral impact with a velocity of 50 km/h. The ground clearance of the barrier face is 379 mm, while the ground clearance of the bumper element is 430 mm. The shape of the barrier element shall comply with the front end shape of SUV’s, see Figure 8. Two SID-II dummies are used in the front and rear seats on the vehicle struck side. No child dummies are used in the IIHS side impact test.

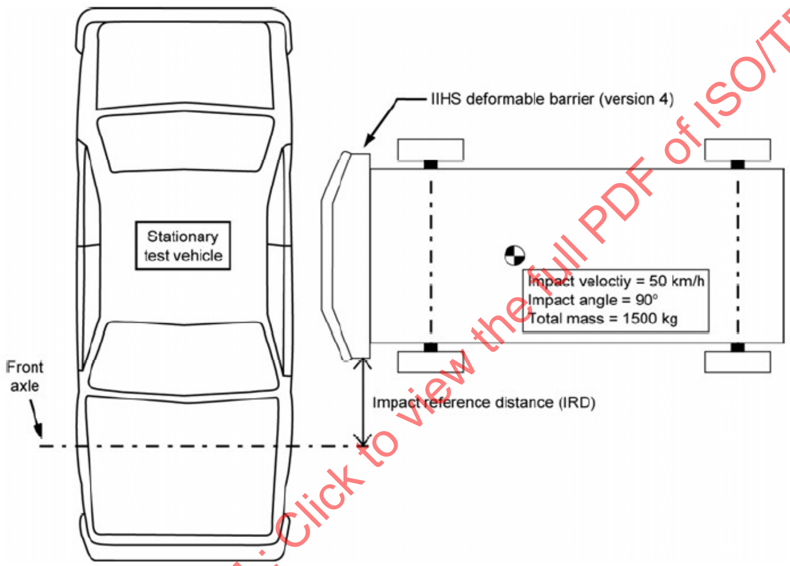


Figure 8 — Test configuration in IIHS side impact test [IIHS, 2005]

3.3 Japanese side impact test method

In Japan, ECE Regulation No. 95 (see above) is used for compulsory side impact tests. J-NCAP utilises Euro-NCAP side impact test method (see above) with some changes. The most important within this context are:

— Test speed is 55 km/h;

— No child dummies are prescribed.

3.4 Australian side impact test method

The compulsory side impact test for cars in Australia is defined by ADR72, which is equal to ECE Regulation No. 95 (as described above). The Australian consumer test programme (ANCAP) follows in most parts the protocols of Euro-NCAP (see above). However, no child dummies are tested in the rear seat.

4 Child related properties of car side impact test methods

4.1 Boundary conditions for a CRS side impact test procedure

In several full-scale crash tests according to regulation ECE Regulation No. 95 performed in the last ten years, dynamic lateral intrusions of front and rear doors were measured. The sample includes super minis, family cars, executive cars and mini multi-purpose vehicles of the model years from 1990 until 2004. Both two-door and four-door cars are included. In the last tests the revised deformable barrier face according to EEVC/WG 13 was used. In all test the lateral intrusion of the inner part of the doors was measured with a string potentiometer or a cross tube positioned at the middle of the door. Intrusion velocities (4.3) were calculated from the intrusion time history diagrams. For comparison, car-to-car test results are analysed in 4.4.

4.2 Door intrusion depth

The maximum intrusion depth of the front door varies from 180 mm to 310 mm, whereas the newer vehicles have lower intrusions (Figure 9).

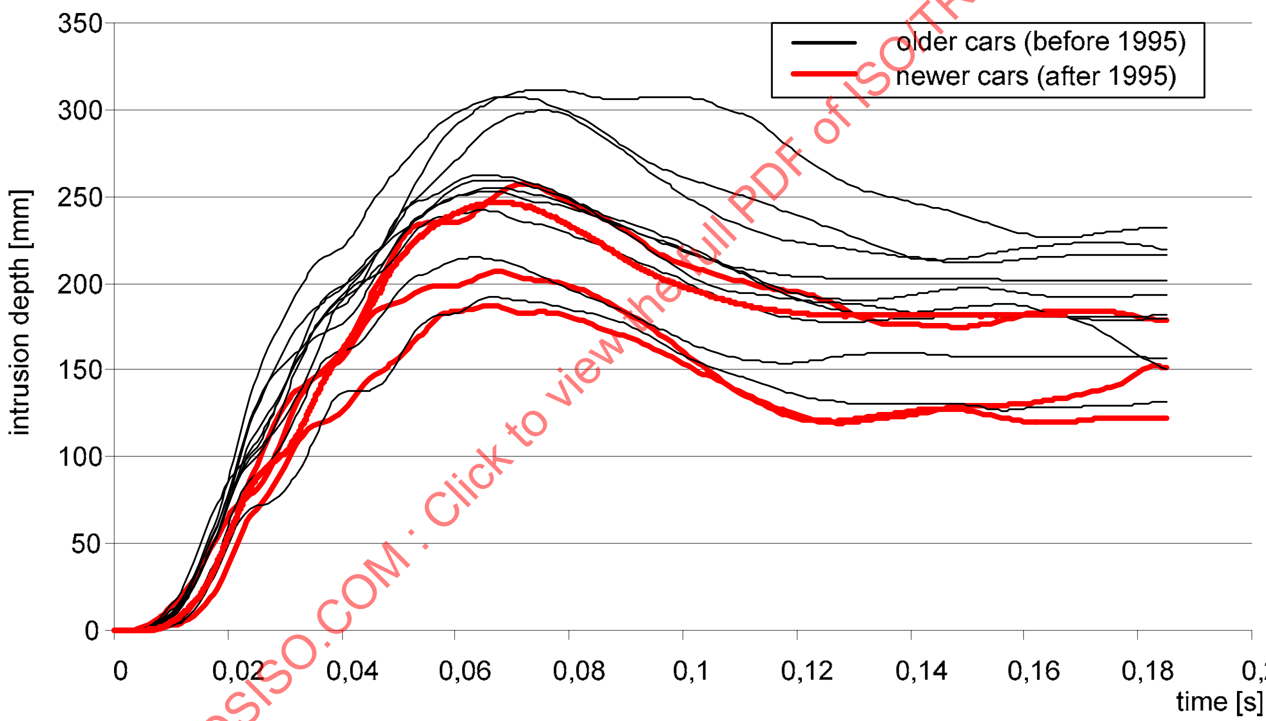


Figure 9 — Front door intrusion depth in side impact tests according to ECE Regulation No. 95 [Johannsen, 2005]

It can be seen that the maximum intrusion depth of the rear door varies from 170 mm to 280 mm, which indicates that the intrusion depth is lower at the rear door compared with the front door (Figure 10).

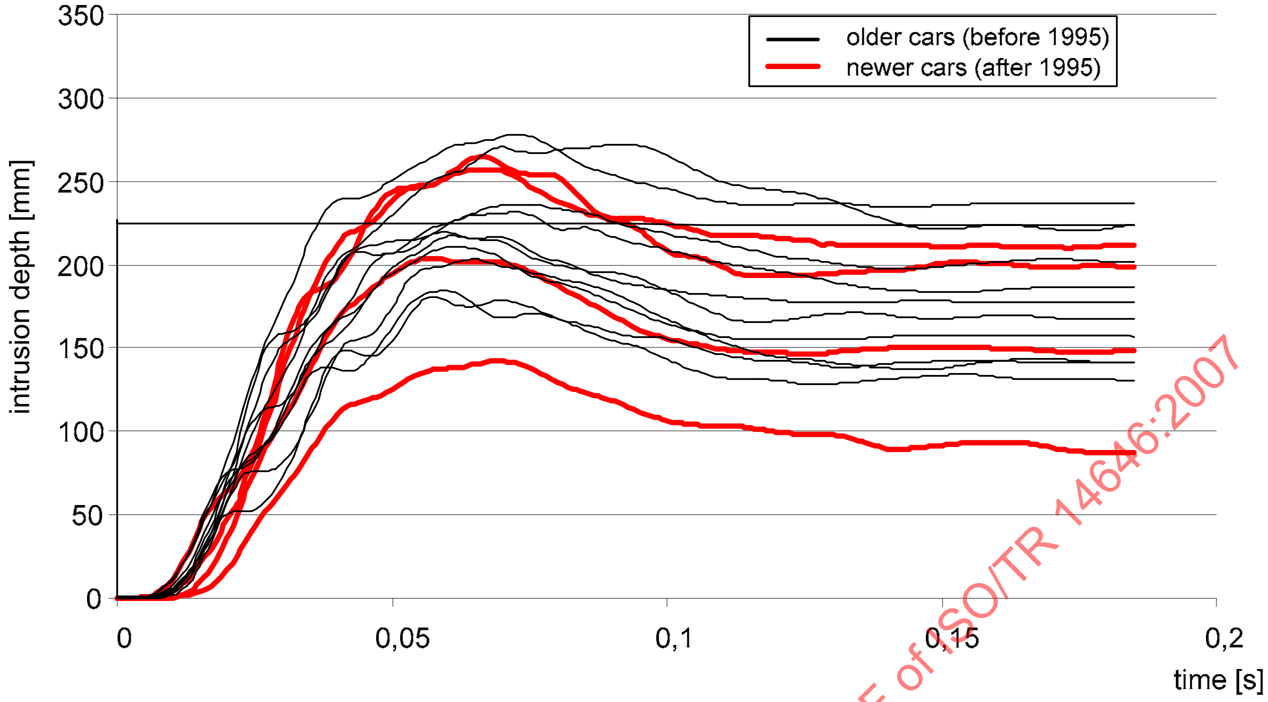


Figure 10 — Rear door intrusion depth in side impact tests according to ECE Regulation No. 95

4.3 Door intrusion velocity from ECE tests

Regarding the intrusion velocity a comparable result can be observed. The intrusion velocity is again lower at the rear door compared with the front door.

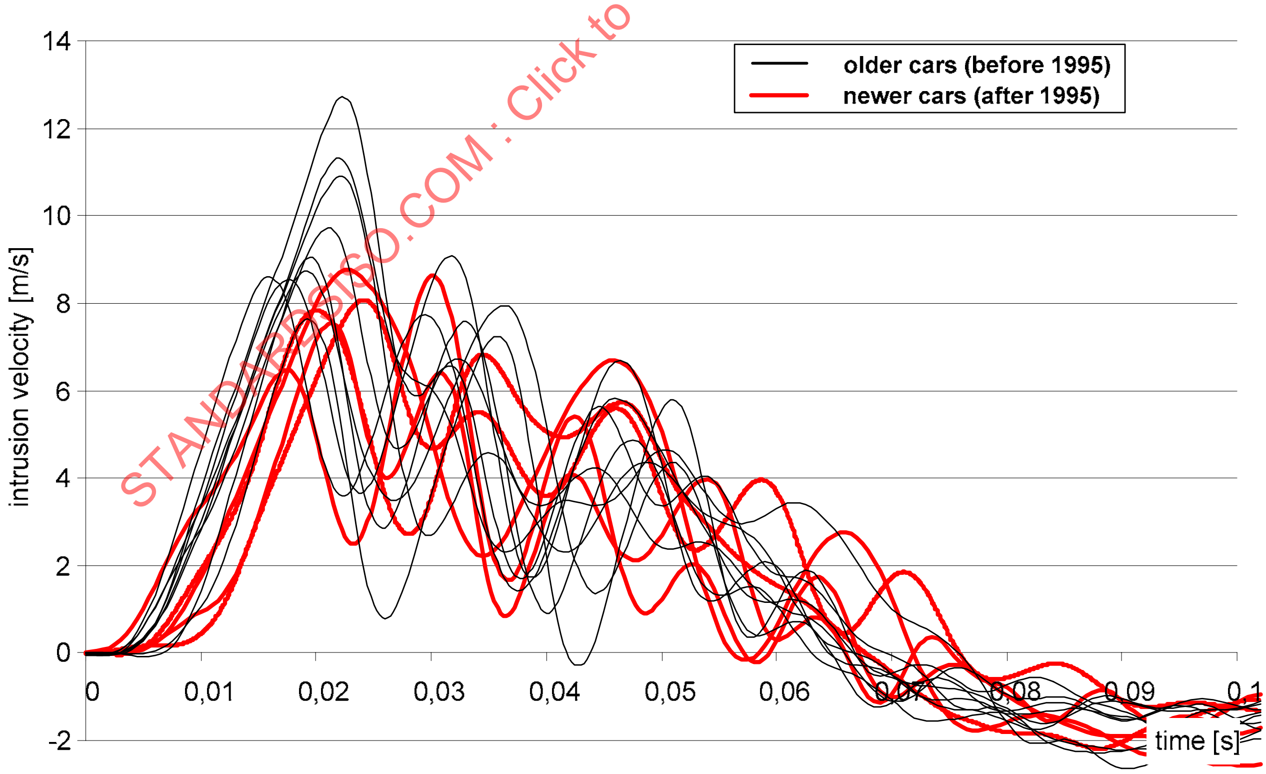


Figure 11 — Front door intrusion velocity in side impact tests according to ECE Regulation No. 95 [Johannsen, 2005]

The intrusion velocity at the front door shows a range between 8 m/s and 13 m/s (Figure 11), while the intrusion velocity at the rear door varies between 7 m/s and 13 m/s (Figure 12).

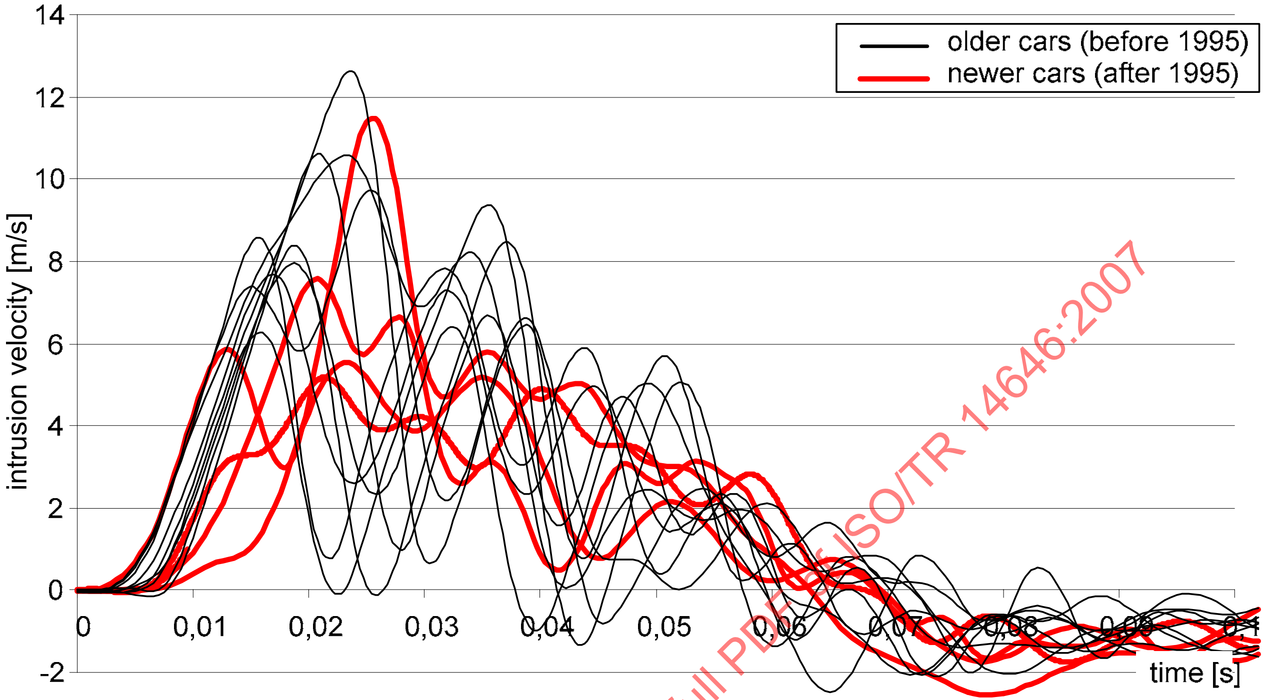


Figure 12 — Rear door intrusion velocity in side impact tests according to ECE Regulation No. 95

Taking into account the difficulties in positioning of the intrusion measurement device especially in smaller cars, a mean difference in intrusion velocity between front and rear door of 10 % can be observed (Figure 13). The difference could be caused either by vehicle design or the test procedure with the centre of impact located more in the front.

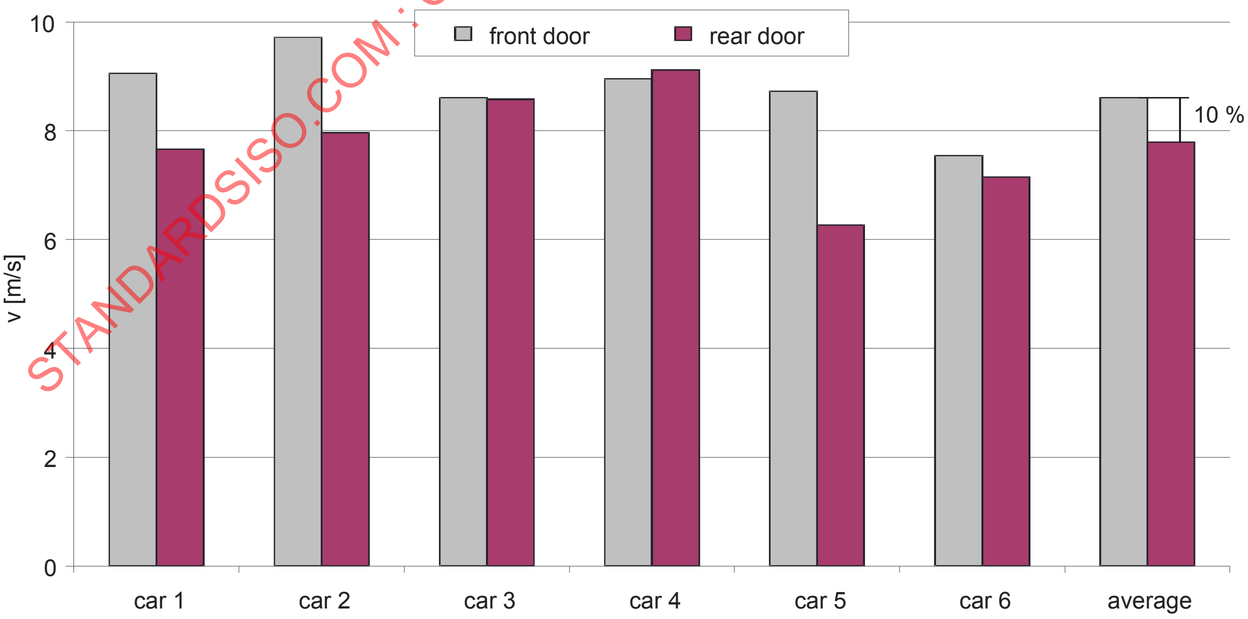


Figure 13 — Comparison of maximum intrusion velocity for front and rear seat

4.4 Door intrusion velocity in car-to-car tests

For the development and assessment of a new European side impact test procedure several car-to-car and MDB-to-car side impact tests were conducted on behalf of EEVC/WG13 [Ellway, 2005]. These data help to analyse real-world side impact accidents, as passenger cars were used as the striking vehicles.

The intrusion measurement data presented below are acquired by acceleration based measurements for the Camry tests (except the AEMDB V2 test) and the Corolla car-to-car tests. For the other tests string potentiometers were used. The intrusion was measured close to the position of the thoraxes of driver and rear seat passenger but without interferences. When comparing acceleration based and string potentiometer based intrusion measurements, Ellway came to the conclusion that the first one tends to deliver higher residual velocity towards the end of the impact.

Figure 14 shows front door intrusion velocity of the inner door panel of an Alfa Romeo 147 running at 24 km/h which was struck by a Toyota Corolla travelling at 48 km/h. In a second test an Alfa Romeo 147 was struck by a Land Rover Freelander. While intrusion velocity in the Toyota test was approximately 6,5 m/s, the Land Rover Freelander caused an intrusion velocity of more than 12 m/s.

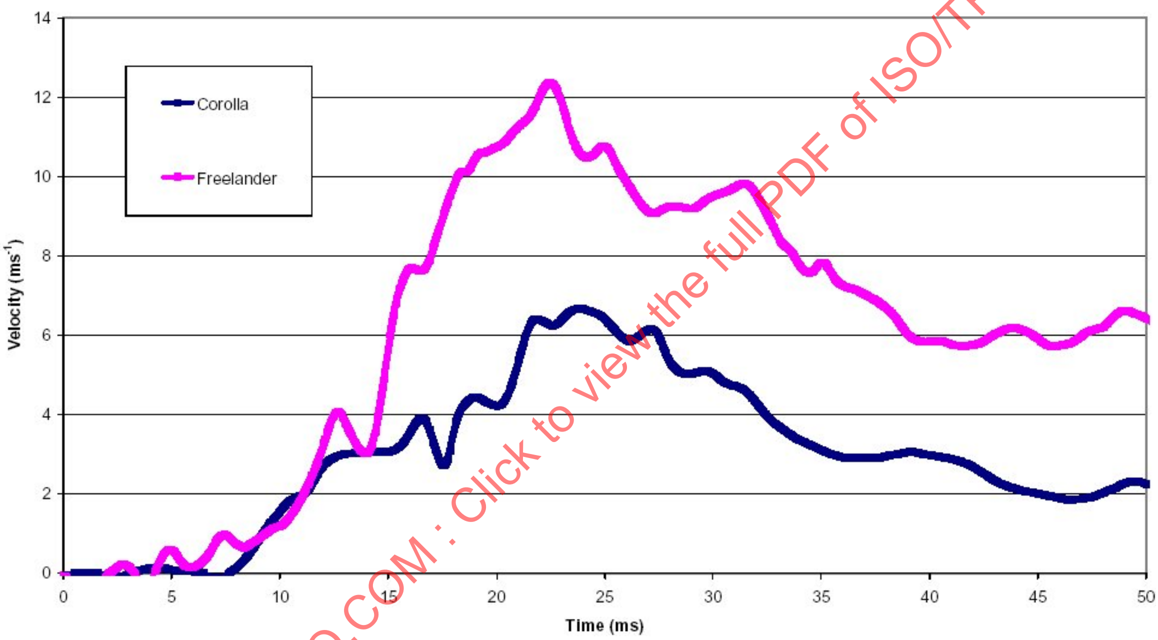


Figure 14 — Comparison of front door intrusion velocity in car-to-car and SUV-to-car test [Ellway, 2005]

Looking at the rear door intrusion velocity of the inner panel these recorded approximately 7,5 m/s in the Corolla test compared to 10,5 m/s in the Land Rover Freelander test, see Figure 15.

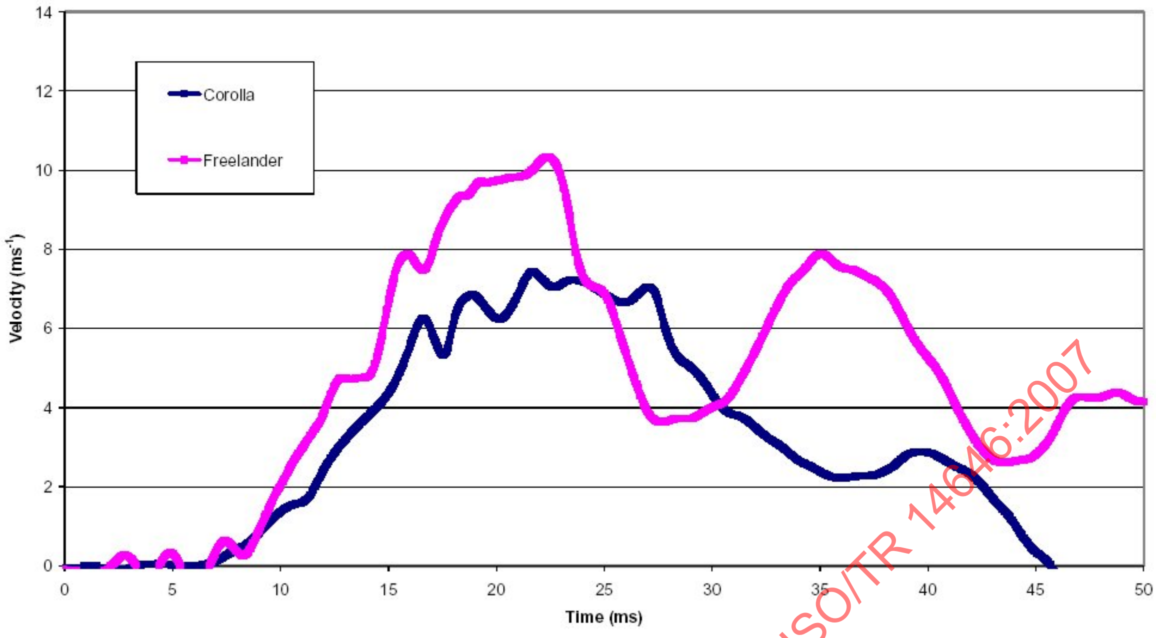


Figure 15 — Comparison of rear door intrusion velocity in car-to-car and SUV-to-car test [Ellway, 2005]

Tests with a Toyota Camry, an executive saloon, showed again considerable differences between car-to-car (in this case a Ford Mondeo was used) and SUV-to-car tests. The intrusion velocities at the front door were approximately 5 m/s for the Mondeo and 9,5 m/s for the Freelander respectively, see Figure 16. For the rear door the intrusion velocities varied between 7 m/s (in the Ford test) and 10,5 m/s (in the Land Rover test, see Figure 17).

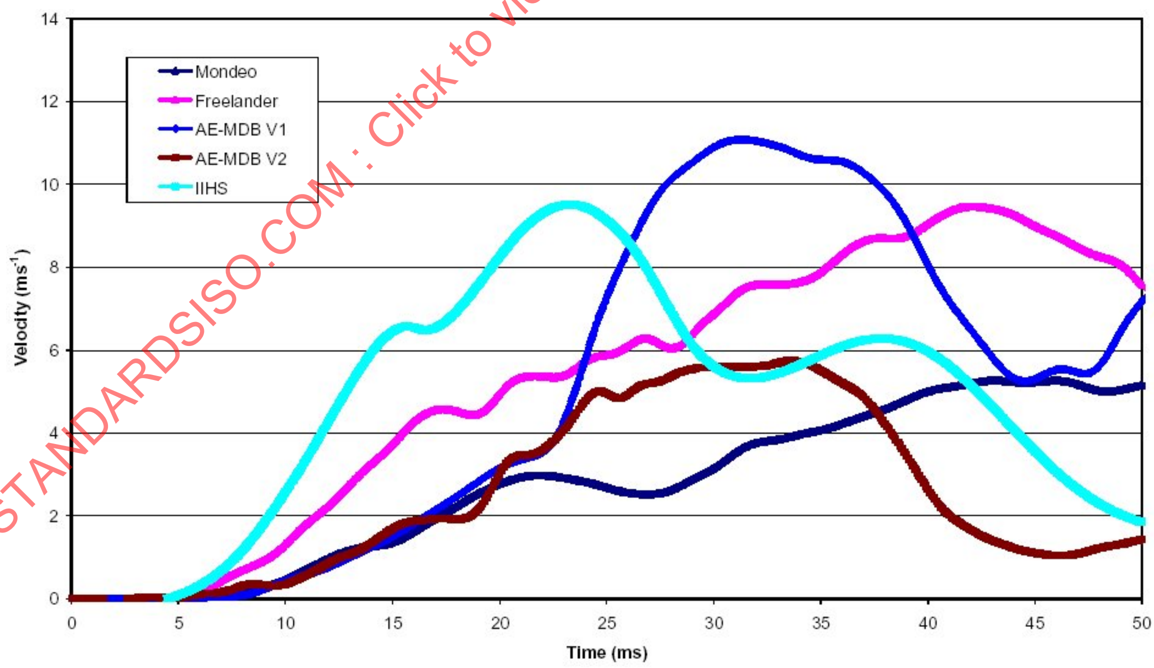


Figure 16 — Comparison of front door intrusion velocity in different side impact tests with a Toyota Camry [Ellway, 2005]

The MDB tests were carried out utilising a barrier face stiffness and geometry (increased ground clearance) different from that of ECE Regulation No. 95. In addition the sled mass was increased to 1 500 kg. These measures should help to represent a more realistic accident severity. The IIHS tests were in accordance to the test procedure described in 3.2.3 above.

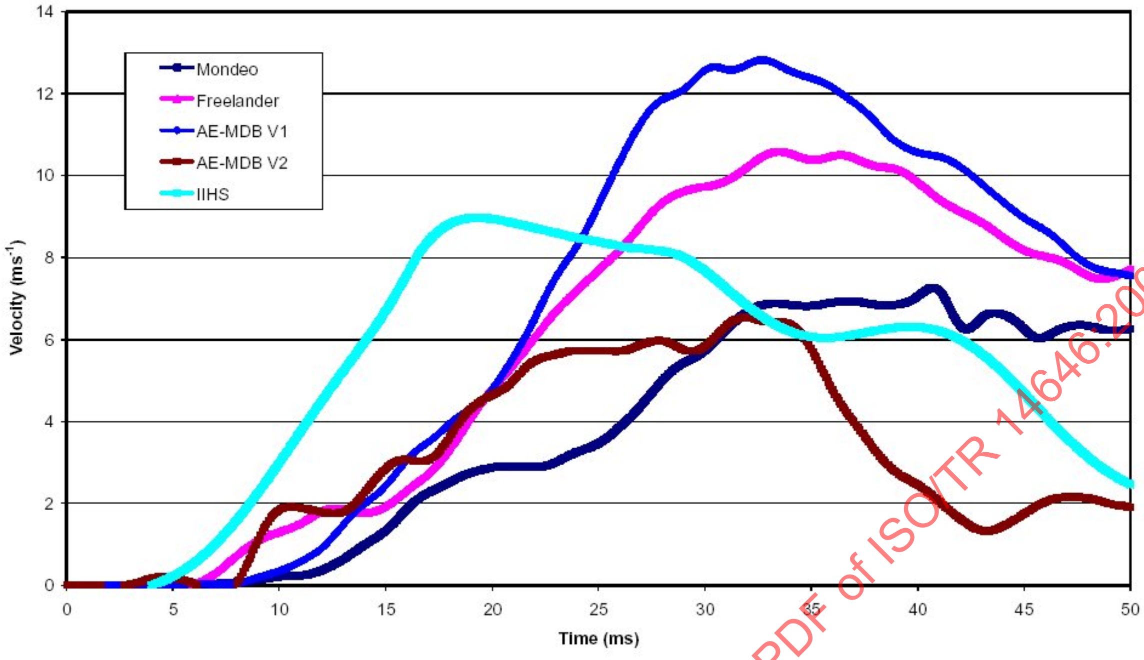


Figure 17 — Comparison of rear door intrusion velocity in different side impact tests with a Toyota Camry [Ellway, 2005]

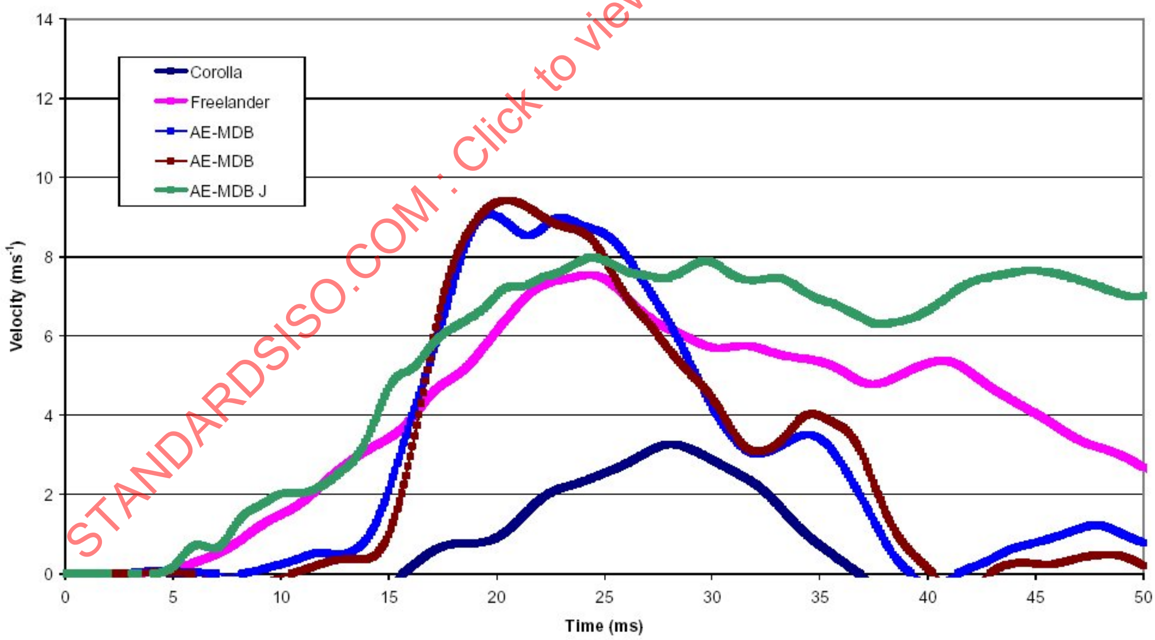


Figure 18 — Comparison of front door intrusion velocity in different side impact tests with a Toyota Corolla [Ellway, 2005]

In the tests with a Toyota Corolla considerable differences between front and rear door are visible, see Figure 18 and Figure 19. While the intrusion velocity in the Corolla-to-Corolla test were relatively low for the front seat (approx. 3,5 m/s compared with 6 m/s at the rear door) this was contrary to the situation for all other tests.

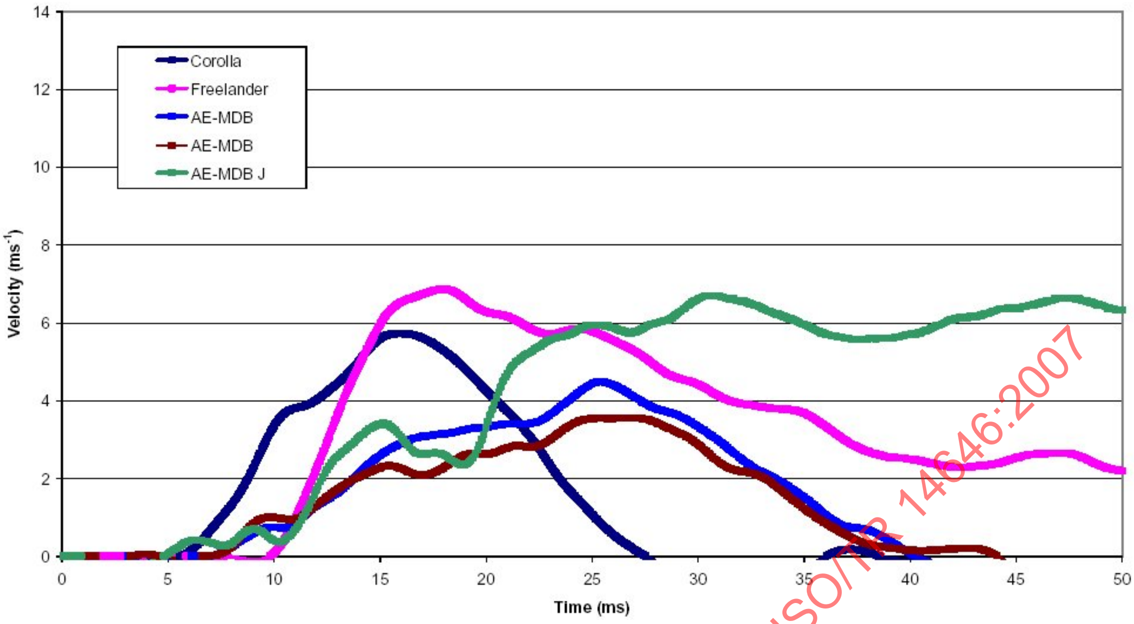


Figure 19 — Comparison of rear door intrusion velocity in different side impact tests with a Toyota Corolla [Ellway, 2005]

4.5 Struck car acceleration and velocity change

In addition to the intrusion of the side structure the struck car experiences a lateral acceleration.

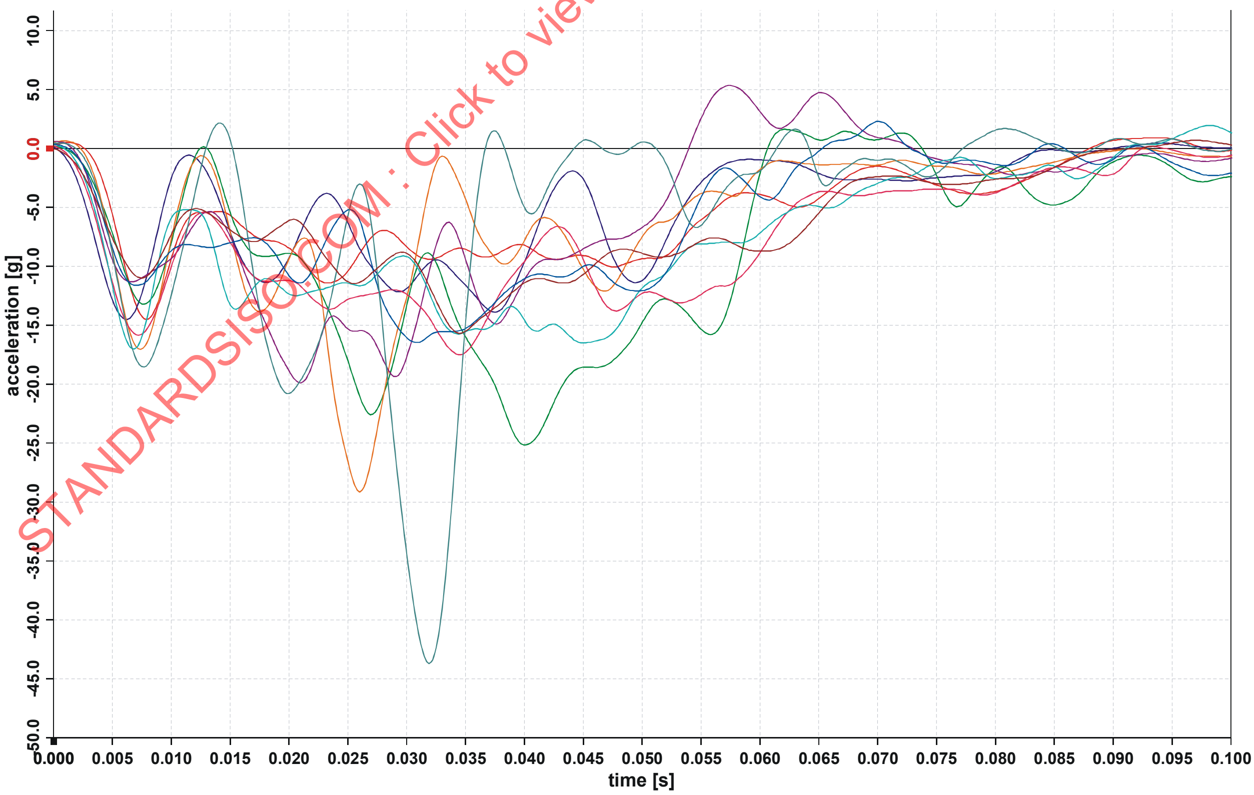


Figure 20 — Acceleration of the struck car in ECE Regulation No. 95 tests [Nett, 2003]

Taking into account the theoretical velocity change for cars of an average weight in ECE Regulation No. 95 tests the struck car will be accelerated up to 22 km/h (Figure 20), which is in line with the derived velocity change from the vehicle acceleration time histories shown in Figure 21.

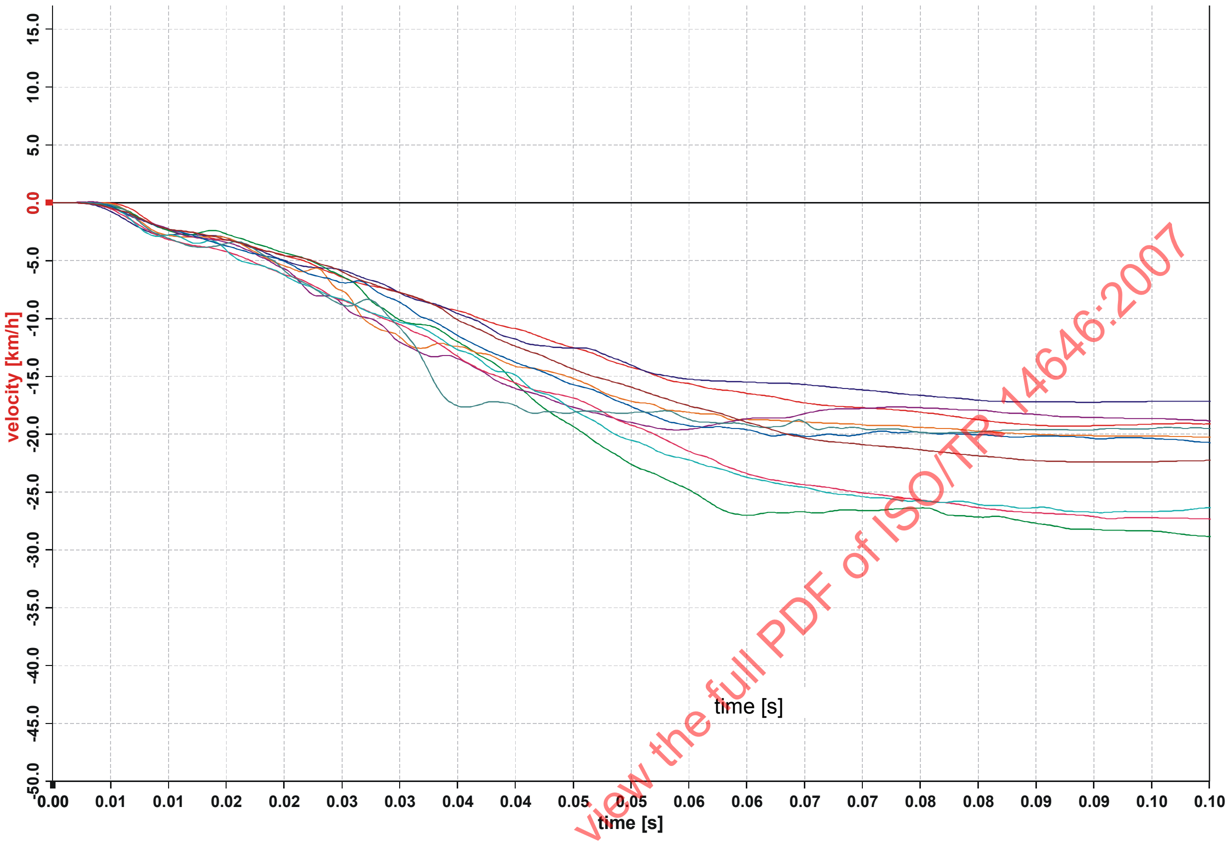


Figure 21 — Velocity change of the struck car in ECE Regulation No. 95 tests [Nett, 2003]

4.6 Deformation profiles

The comparison of static deformation of the struck vehicle from front to rear shows at first an increasing crush over a distance of about 500 mm, then a more or less constant crush over a distance of about 900 mm and then a decreasing trend (Figure 22).

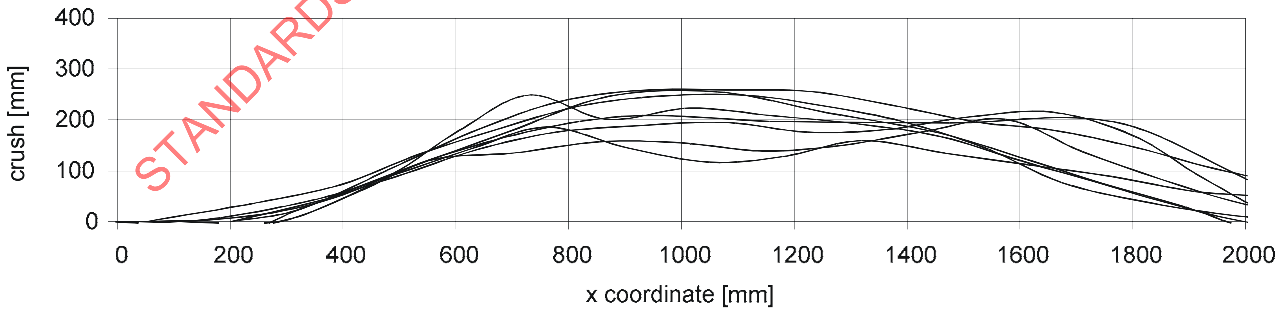


Figure 22 — Static crush of different cars in ECE Regulation No. 95 tests [Johannsen, 2005]

The static crush in the EEVC/WG13 as described above show a comparable static crush as mentioned above, see Figure 23 and Figure 24. The crush distribution across the vehicle height shows significant differences. Again the influence of properties of the striking vehicle can be observed.

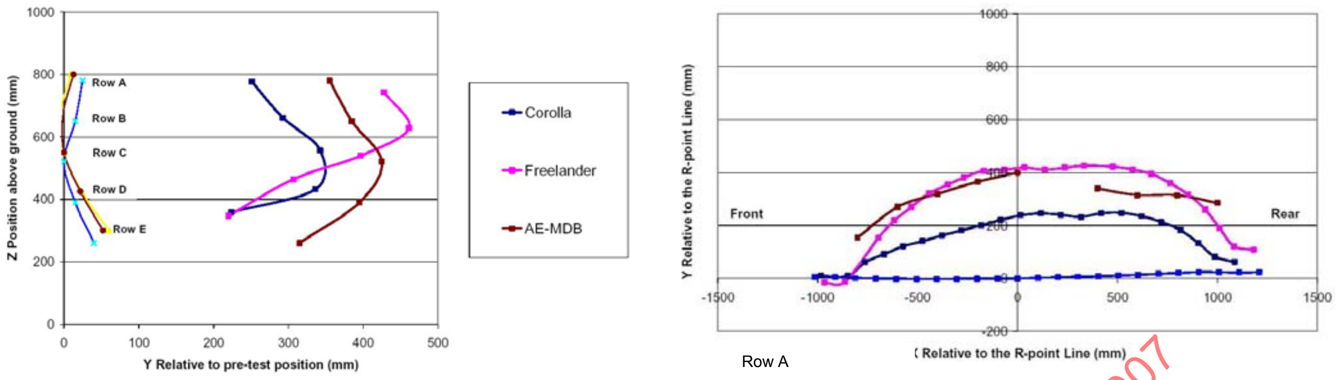


Figure 23 — Static crush of Alfa 147 in several side impact tests [Ellway, 2005]

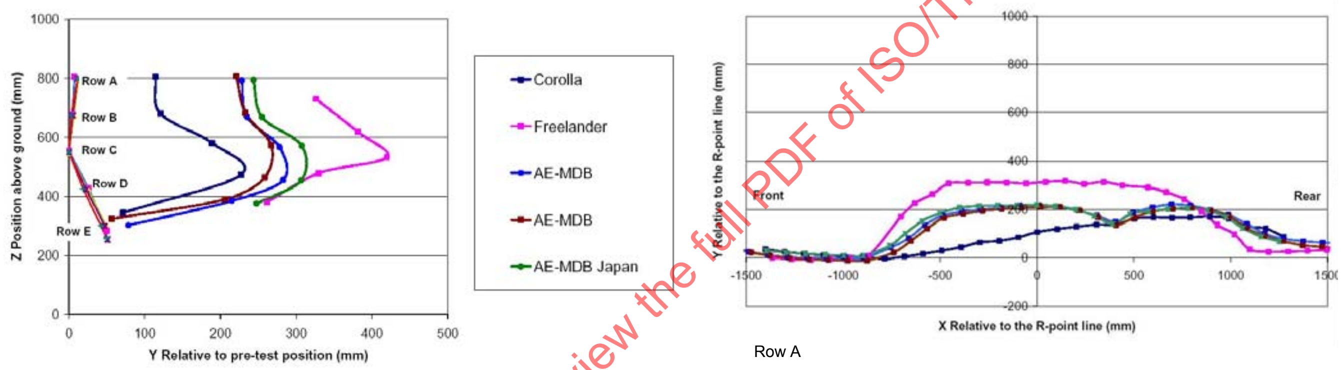


Figure 24 — Static crush of Toyota Corolla in several side impact tests [Ellway, 2005]

4.7 Dynamic force-deflection characteristics of door interior

In addition to the dynamic behaviour, the geometric boundary condition of passenger cars, such as the lateral distance between seat and side structure, the height of the window sill in relation to the CR-point, and the stiffness of the side structure, are important.

The stiffness of the door trim, analysed in pendulum tests, showed considerable differences for different car models and different impact locations, see Figure 25.

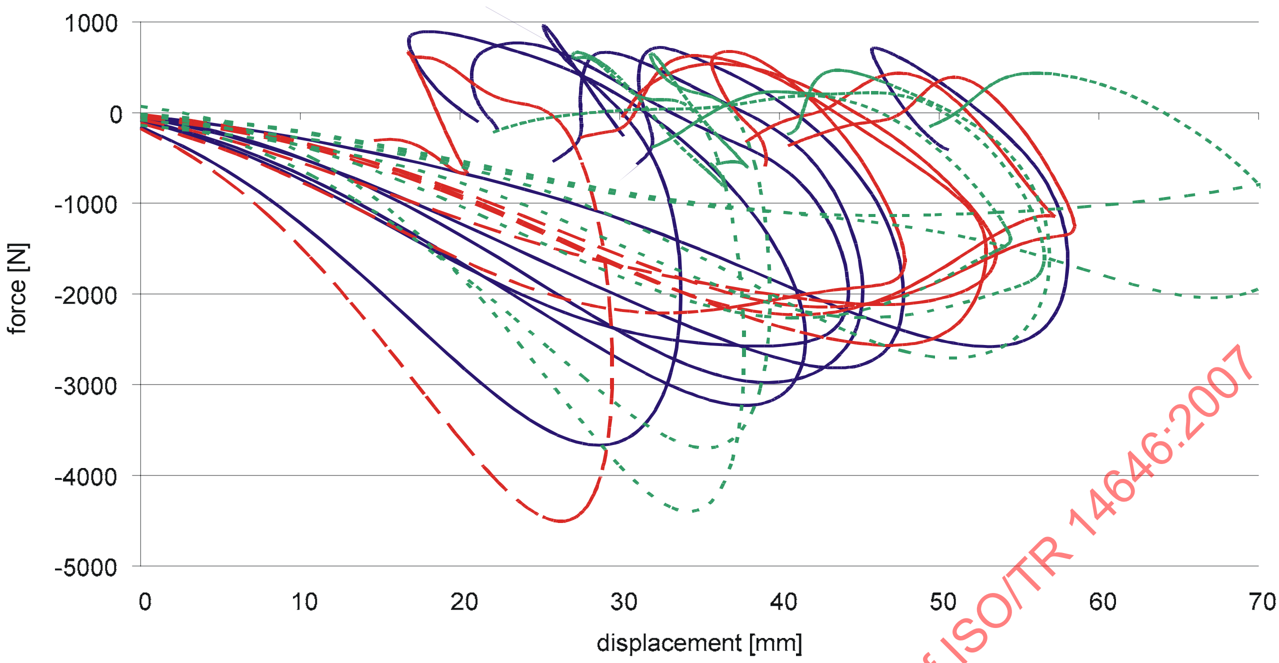


Figure 25 — Door trim force-deflection characteristics of different locations at different doors [Nett, 2003]

4.8 Door window sill height and distance to door trim

Investigation of Nett [Nett, 2003] showed a lateral distance of the CRS centreline to the side structure of 300 mm and a window sill height of 500 mm.

The average window sill height with respect to the CR point is approximately 500 mm [Nett, 2003], Figure 26.

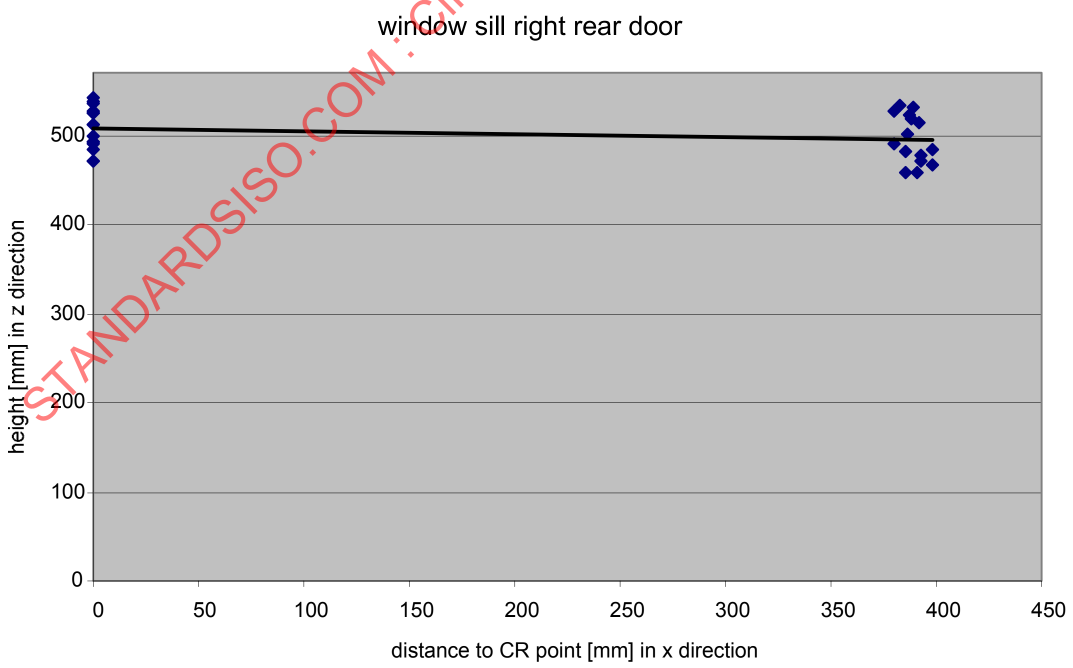


Figure 26 — Height of the window sill in different cars [Nett, 2003]

The CRS centreline has an average distance to the inner door trim of approximately 300 mm [Nett, 2003], Figure 27.

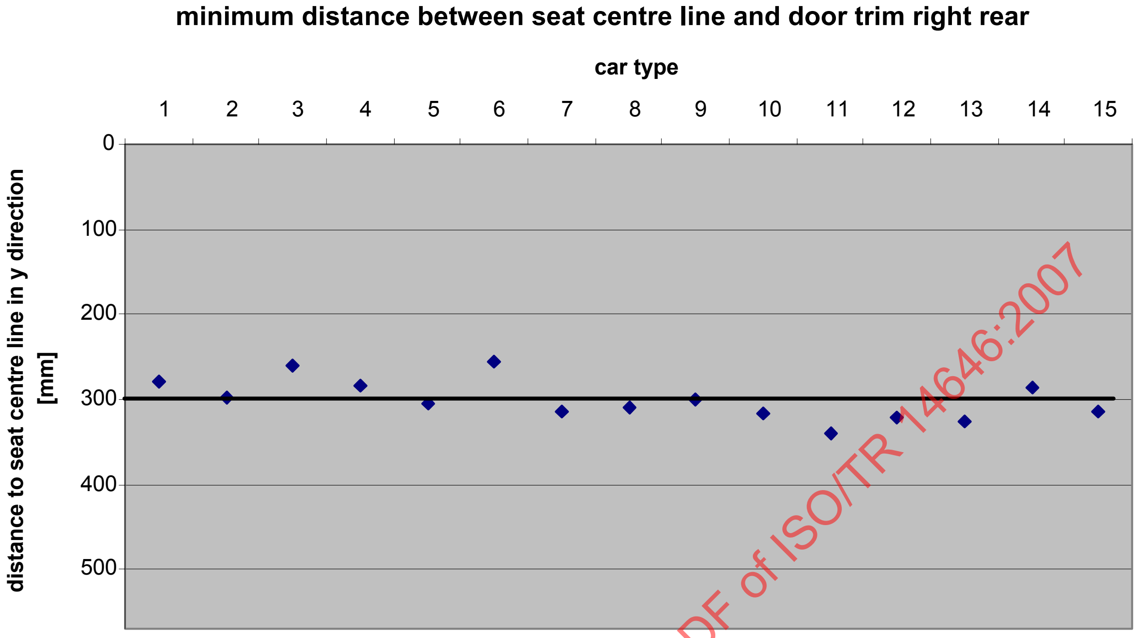


Figure 27 — Lateral distance between CRS centreline and inner door trim [Nett, 2003]

5 Requirements for the side impact test procedure

The requirements of the ISO side impact test procedure for child restraint systems can be divided into the sections; test severity, validation, repeatability and reproducibility, and field of application.

5.1 Test severity

The test severity is defined by sled acceleration, intrusion depth and intrusion velocity (as far as intrusion is simulated), but also by geometrical measurements such as the panel height, distance of the CRS to the panel etc.

Analysis of full-scale side impact tests shows that the performance of current cars has been significantly improved during the last years. However, there are still old cars on the road and the test severity of the full-scale test is subject to several discussions as it is felt to be too moderate. One example for higher severity tests is the IIHS test procedure, where the mass of the barrier as well as the stiffness and shape of the barrier face, causes a more aggressive contact with the car in comparison to ECE Regulation No. 95 and FMVSS 214 test conditions.

Whilst there are no validated biomechanical load limits for children in side impact tests, the dummy readings resulting from the side impact test procedure should correlate with those measured in full-scale side impact tests.

Summing up the results presented in Clause 4 and the statements above, the following properties defining the test severity apply to a majority of cars in use:

- Intrusion velocity range: 7 – 10 m/s
- Intrusion depth: approx. 250 mm
- Sled acceleration range: 10 – 15 g
- Door panel height: approx. 500 mm
- Distance between door and CRS centre line: approx. 300 mm

In addition the padding specification needs to be fully defined.

5.2 Validation

For the validation of the test procedure, the test severity as well as the CRS definition according to the scope (see below) needs to be approved. Concerning the test severity, accident statistics show that the most important body region to protect is the head. Therefore it is necessary to put special emphasis on the validation of head loads and the capability of child restraints to contain the head inside the CRS during the test.

5.3 Repeatability and reproducibility

The most crucial parameters with respect to repeatability and reproducibility are intrusion velocity (magnitude and timing) and dummy and CRS installation. Based on test experience and numerical simulation, variation in sled acceleration do not influence the dummy readings in a similar way as the parameters mentioned above.

5.4 Field of application

Besides the differences of forward facing and rear-facing the fixation of the CRS and the child can be different. The following types can be found in today's world markets: belt fixed CRS with integral harness for the child (FF mainly 5-point-harness, RF mainly 3-point-harness), booster with/without backrest (CRS and child restrained with car belt), ISOFIX connection of CRS and car with integral harness for the child. For the belted CRS the usage of tensioning devices, which reduce the belt slack of the car belt, are becoming more popular. The side impact test procedure has to be able to cope with all these different CRS types. In addition it is important that all these seats are tested with comparably realistic severity.

6 Historical overview

Based on a side impact test procedure developed by TUB (Technical University of Berlin) within the EU funded project Brite ATASED (Advanced Technologies for Automotive Seat Evaluation and Design) TUB started testing CRS in lateral impacts. These tests were conducted in a double-sled arrangement, where the first sled impacted the second one. This double sled approach represents the deceleration and intrusion as recognised in car side impact accidents. In the beginning a real car door was mounted on the striking sled, which impacted a CRS mounted on a car seat. See Figure 28.

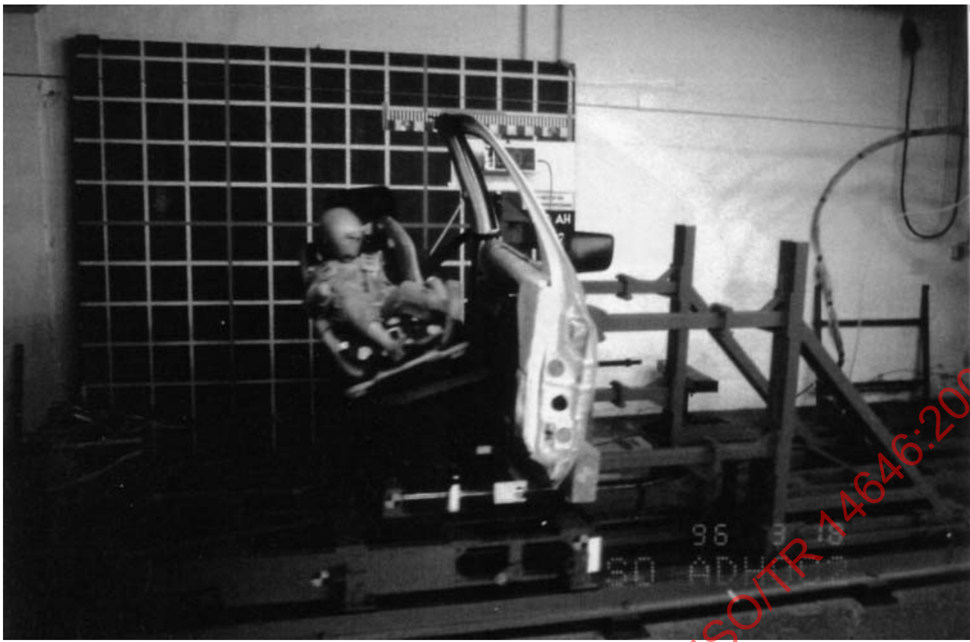


Figure 28 — Double sled test set-up with car door and car seat

In a later evolution a flat panel was used to represent the door and the CRS was mounted at an ECE Regulation No. 44 test bench. See Figure 29.

Figure 29 — Double sled test set-up with flat panel and ECE Regulation No. 44 test bench

It was then proposed by TRL (Transport Research Laboratory) to represent the intrusion with a hinged door. The hinged door was impacted by a 100 kg pendulum mass. Because of the relatively low mass the intrusion depth and intrusion velocity could not be reproduced in a satisfactory manner. Both depended on the CRS fixture, CRS weight etc. However, the principle idea of the hinged door concept seemed to be a good compromise of reproducing vehicle acceleration and intrusion.

As an alternative, the Nordic European countries proposed to use a curved panel as a door, which is fixed at the concrete block. The intrusion velocity in this approach is defined by the initial sled velocity. As the intrusion velocity in lateral impacts is higher than the lateral velocity change of the struck car, the Nordic countries proposed to use a suitable intrusion velocity as initial sled speed. The sled was then decelerated during the contact with CRS and dummy to meet the intrusion depths requirement. This procedure was realised by TNO with a flat panel.

Another proposal, coming from MPA Stuttgart, was to impact the CRS by a panel without reproducing the vehicle movements.

7 Current side impact test procedures for child restraint systems

This clause gives a brief summary of the existing side impact test procedures for child restraint systems.

7.1 ISO/DIS 14646 / TRL test procedure

The child restraint working group of ISO (ISO/TC22/SC12/WG1) started in 1994 the development of a side impact test procedure for child restraint systems. Most of the procedures described in Clause 6 were proposed and discussed within the responsible task group. Finally in the end of the nineties the decision was taken to use a derivative of the hinged door concept as proposed by TRL.

The main problem recognised with the original hinged door concept was the considerable influence of the CRS on intrusion velocity and intrusion depth. This was mainly caused by the relatively low impactor mass. Finally the activating method of the intruding panel was not defined in the protocol but corridors for intrusion velocity and an intrusion depth was fixed.

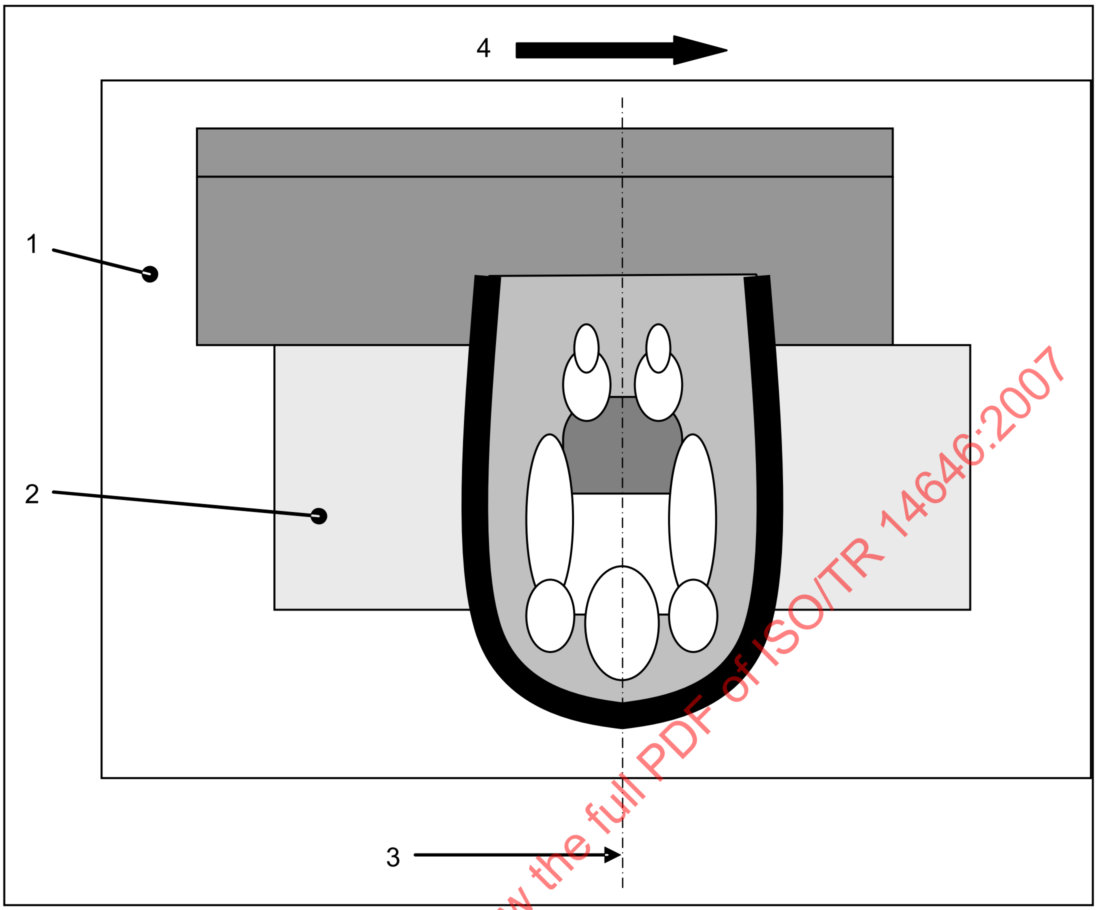
Due to the proposed hinged door method it is important to define the worst-case conditions. The contact velocity between the CRS (child dummy, respectively) and the intruding panel depends on the angular velocity of the panel and the distance of the CRS (defined by the position of the head) to the hinge line. In order to test rear-facing and forward facing CRS with the same test severity, it is necessary to use different hinge line positions with respect to the CR point. Within ISO it was decided to test in worst-case conditions, which means with the maximum intrusion close to the dummy's head, requiring the hinge line far from the dummy's head.

The draft standard was subject to two subsequent DIS votes. After failing the first one, it was decided to improve the draft standard for rear-facing CRS, while defining the details for forward facing CRS in a second part. For the second vote only the part covering RF CRS was presented, the second part should be published as a Technical Report. However the standard proposal was disapproved also during the second DIS vote (by a small margin).

7.1.1 Description of the ISO test method

The drafts for Part 1 (RF CRS) and Part 2 (FF CRS) are attached to this Technical Report as Annex A and Annex B, respectively.

The main property of the ISO/DIS 14646 test procedure is the hinged door concept where an ECE Regulation No. 44 test bench is mounted at an angle of 90° on a sled. To avoid interactions between the intruding panel and the test bench backrest, the latter one is displaced by 100 mm, see Figure 30.



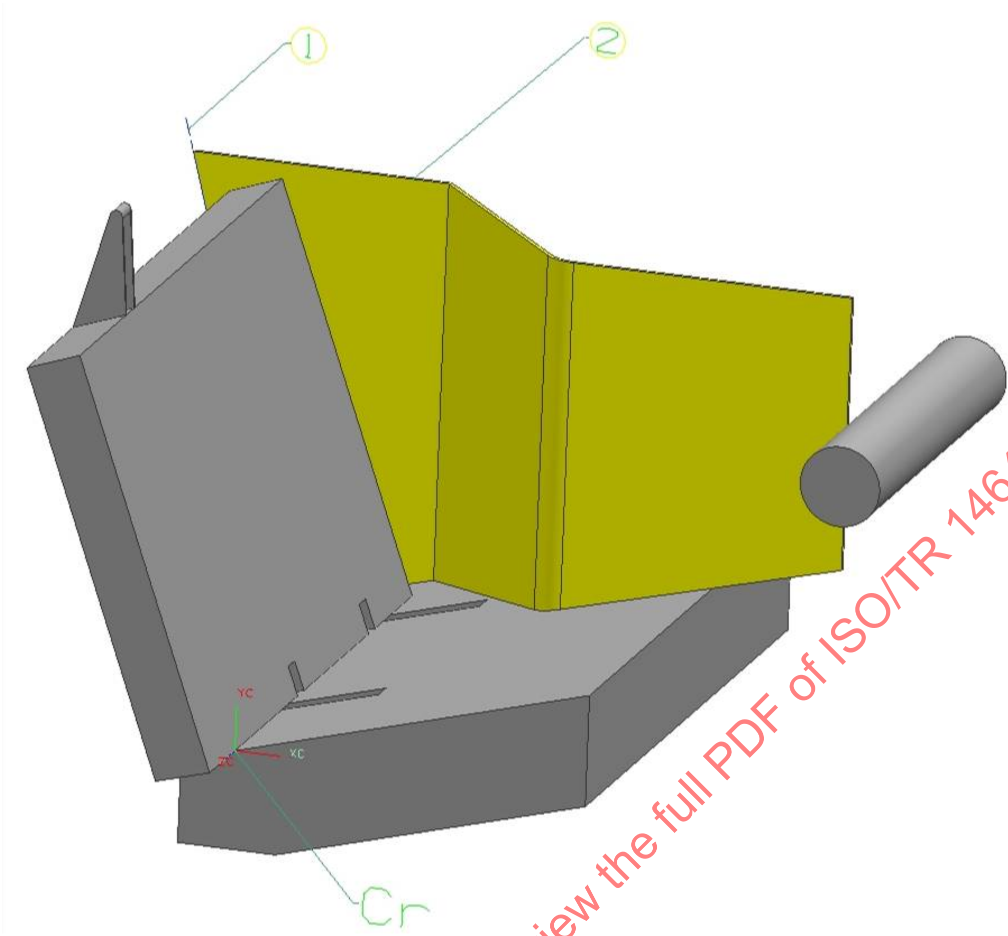
Key

1 sled
2 ECE R.44 test bench
3 CRS centreline
4 travel direction

Figure 30 — General test setup in ISO/DIS 14646

The hinge line of the intruding panel is perpendicular to the seat cushion by means of an angle of 15° to the ground. The simulated intrusion should realise an intrusion depth of 250 mm and a maximum intrusion velocity of 9 m/s.

The panel shape was subject to several discussions within the responsible task group. After initially testing with a flat panel, curved and shaped panels were developed and tested. The main advantage of a shaped panel is the fact that it is possible to define a maximum intrusion, which is not the case with a flat panel. Finally a double shaped panel according to Figure 31 was developed.



Key

1 panel hinge line

2 hinged panel

Figure 31 — Seat bench construction with panel for RF configuration of ISO/DIS 14646

During the sled deceleration the hinged door intrudes. The CRS is positioned with a distance of 300 mm of its centreline from the hinged door. The test procedure takes into account the worst-case scenario for both, RF and FF CRS, by positioning the hinge at the side of the feet of the child dummy. The sled deceleration is defined by a delta-v corridor representing an overall delta-v of 25 km/h. The hinged door concept transfers the translational into a rotational intrusion. The middle angular velocity for RF CRS of 13 rad/s corresponds to a translational intrusion velocity at the point of the head of about 12 m/s.

The test procedure according to ISO/DIS 14646 was implemented at TRL.

7.1.2 Voting results

The draft ISO standard was disapproved in both DIS votes. Numerous comments were provided for both votes. Annex C contains the detailed voting results and comments with observations of the first vote, while Annex D includes the voting results and comments for the second vote.

In the first vote ISO/DIS 14646 was disapproved by five countries (France, Italy, Japan, Netherlands, US). The main reason for the disapproval was the missing validation, especially for the test set up for FF CRS.

During the second vote, again five countries disapproved the proposal. This time France, Germany, Japan, Philippines and Sweden voted against the draft especially because of separate parts describing the test methods for FF and RF seats, and again the missing validation, especially regarding reproducibility.

7.2 TNO test procedure

The TNO procedure is based on an earlier stage of the ISO/DIS 14646. The main difference to ISO is the utilisation of a flat panel and a different padding. In principle the TNO procedure was intended to be used for both, RF and FF CRS, in worst-case conditions, but the set up for FF worst-case has not been realised yet.

7.3 TUB test procedure

The test procedure developed by the Technical University Berlin is again based on the hinged door concept. TUB started the development in 1999 based on the resolutions and decisions taken by ISO WG1.

The main differences with respect to ISO/DIS 14646 are different hinge line orientation, different panel shape and different panel padding. In addition the backrest and upper belt anchorage point in FF configuration are both moveable in the Y direction and firmly connected with the intruding panel representing the seat and b-pillar displacement in full-scale crash tests. The lower ISOFIX anchorages are free to move in Y-direction.

The hinge line in the TUB method is vertical to the ground allowing the same hinge to be used for both test set-ups. The single shaped panel is padded with a thicker and softer material compared to the ISO procedure.

The TUB test procedure was selected to be used for the NPACS Programme (New Programme for the Assessment of Child Restraint Systems) at the end of 2005.

7.4 ADAC test procedure

The ADAC (Germany Motoring Club) tests take place in a body-in-white of a VW Golf [Gauss, 2002]. The body-in-white is mounted on a sled at an angle of 80° and is equipped with a fixed door. The angle of 80° should cause an additional head movement in frontal direction. Therefore it is more difficult to pass the head containment criterion for FF CRS. The body in white is mounted in the same way to the sled for FF and RF CRS. In the ADAC procedure a fixed door is used, i.e. no intrusion is simulated. The sled is decelerated from an initial velocity of 25 km/h at a level of 15 g. The main advantage of this test procedure is that it is considerably simpler, enabling good performance with respect to reproducibility.

7.5 Australian Standard AS/NZS 1754 test procedure

In Australia and New Zealand two different kinds of side impact tests for homologation of child seats have to be used. One test is on a test bench, which is mounted at 90° on a sled, without any door and the second test is with a fixed door, again at 90° angle. The first test assesses for dummy ejection in lateral impacts and has been in the standards for over 20 years while the latter test assesses the head containment capabilities of the CRS. For the door-less tests, selected TNO P series dummies are used for forward facing seats and boosters, while a TARU Theresa dummy is used for infant restraints. Selected TNO P series dummies are used for the tests in which the door is utilised. The sled is calibrated to undergo a velocity change of not less than 32 km/h, with a deceleration of 14 – 20 g. The door used was based on research work from the Child Restraint Evaluation Program with changes to construction of the angle on the top half of the door. This side impact testing with the door was introduced in to the 2004 version of the standard.

7.6 Australian CREP test procedure

The consumer information testing in Australia is known as the Child Restraint Evaluation Program (CREP). There have been three rounds conducted and published. There are two side impact tests, one at 90° and the other at 66° (previously 45°), both with a fixed door structure in place. The test conditions are the same as AS/NZS 1754 (see above), however there are additional assessment criteria. Selected TNO P Series dummies are used for testing. In some instances they are modified to increase their seated height.

8 Conclusions

Accident statistics prove that side impact accidents are dangerous for children travelling at the struck side in passenger cars. Although the number of seriously injured children has decreased during the last decades, there is still a considerable risk especially for head, neck and thorax injuries. Comparing RF and FF CRS there are indications that rear facing seats protect children better in side impact than forward facing child restraint.

Side impact test procedures for cars, which are designed to represent average accident conditions, are mainly MDB tests with a barrier travelling either perpendicular to the struck car or at a crabbed angle. In addition to the direction differences in barrier weight, speed, geometry and stiffness exists. The most severe test procedure seems to be the IIHS side impact test procedure simulating an SUV striking the test car.

When analysing test results of ECE Regulation No. 95 side impact tests it becomes evident that injures are caused by the combination of both structural intrusion and vehicle acceleration. The intrusion is defined by intrusion shape, intrusion depth and intrusion velocity. In addition geometrical properties (such as door panel height, distance between side structure and CRS etc.) of the struck car have a considerable influence. An appropriate side impact test procedure for CRS should be capable to reproduce the following properties:

— Intrusion velocity range: 7 – 10 m/s

— Intrusion depth: approx. 250 mm

— Sled acceleration range: 10 – 15 g

— Door panel height: approx. 500 mm

— Distance between door and CRS centre line: approx. 300 mm

In addition the padding specification needs to be fully defined.

In addition the test procedure should be repeatable and reproducible and should offer the possibility to test all kinds of CRS at a comparable severity level.

The proposed side impact test method for CRS according to ISO/DIS 14646 reproduces vehicle acceleration by a sled and intrusion by a hinged panel. It has been disapproved in two votes; mostly because concerns that additional validation of the procedure would have been necessary.

As a consequence of the disapprovals of the proposed ISO procedure, and taking into account the alternative method development, ISO/TC22/SC12/WG1 adopted the following resolution in November 2005:

"Considering the disapproval of DIS 14646-1.2, and the recent information that NPACS have just decided to use a method similar to the TUB method for side impact CRS rating, WG 1 decided to change direction of the ISO work in recognition of the NPACS decision." *(Excerpt of resolution 180, adopted at the 34th meeting in Arlington (USA), 2005-11-17.)*

Annex A
(informative)

ISO/DIS 14646-1.2: ISO side impact test procedure for rearward-facing child restraint systems

NOTE This annex shows the essential parts of the ISO side impact test procedure as officially circulated for voting as a Draft International Standard on 2005-08-04. The original clause and figure numbering is maintained. The two annexes of the standard proposal (Annex A, Further specifications and instructions for systems attached with belts, and Annex B, Corridor definitions and example curves) are not included in this Technical Report.

0 Introduction

0.1 Objective and notes on the applicability

The objective of this standard has been to create a test method to evaluate the ability of a child restraint system (CRS) to minimise injuries in lateral impacts.

This part of the standard is applicable ONLY to rearward-facing child restraint systems.

It is explicitly stated that it is not possible to compare the performance of forward and rearward facing CRS according to this standard, unless they are each tested in their respective worst case conditions.

The worst case condition means that the maximum intrusion occurs close to the child's head. Taking into account ECE Regulation No. 95 tests, for rearward-facing CRS this applies to the rear seat position, for a forward-facing CRS this applies to the front passenger seat position. In real-world accidents the worst case might occur for both CRS orientation either in the front seat or in the rear seat depending on the impact point.

0.2 Background data and development of the method

This standard has been prepared on the basis of accident data. The standard addresses the struck side impact conditions, which from the research data are shown to be the conditions that in real accidents produce the majority of the fatalities and serious injuries.

A major aim has been to use methods that are relatively inexpensive. Thus, the standard has been developed through a progression of tests from full-scale vehicle impacts, via double sled dynamic tests, to a single sled with a hinged panel, representing the intruding vehicle door, or interior.

The data from the full size tests was first replicated on two sled rigs in which one sled represents the struck vehicle and the second sled represents the striking vehicle and the intruding side structure. The data from this method was analysed and used to develop a close approximation of the side impact event on a single sled. In this procedure, the intruding side structure is represented by a pivoted panel that is rotated in relation to the test seat at a relative velocity within a band of velocities measured in full scale tests. The movement represents the deformation of the inner side structure of the passenger compartment relative to the non-struck side of the vehicle.

1 Scope

This part of the International Standard specifies a test method for rearward-facing child restraint systems in side impact collisions. The test method simulates the conditions in which most of the serious injuries occur, and for which the child restraint characteristics can improve the protection of the child.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 6487, *Road vehicles — Measurement techniques in impact tests — Instrumentation*

ISO 7862, *Road vehicles — Sled test procedure for the evaluation of restraint systems by simulation of frontal collisions*

ISO 13216-1, *Road vehicles — Anchorages in vehicles and attachments to anchorages for child restraint systems — Part 1: Seat bight anchorages and attachments*

3 Terms and definitions

For the purposes of this International Standard, the following terms and definitions apply.

3.1
child restraint system
CRS
any free-standing device intended to provide child vehicle occupants with an approved restraint

NOTE CRSs comprise various categories such as car beds, infant restraints, toddler seats (forward and rearward facing), booster cushions, and booster seats. Combination products may cover two or more of these product categories.

3.2
struck side
side of a vehicle, where a lateral impact occurs

3.3
non-struck side
opposite side to struck side

3.4
hinged panel
impactor to the child seat, which simulates the intruding inner side structure of the passenger compartment in a lateral impact

3.5
intrusion plane
extension upwards of the hinged panel inner surface, adjacent to the dummy head

4 Test method

4.1 General

The test conditions are intended to represent the loadings in full-scale impacts as closely as possible.

When a vehicle experiences an impact to its side by the front of another vehicle, the undeformed part of the struck vehicle (chassis) is subject to a lateral acceleration and a velocity change. In addition, the struck side of that vehicle may intrude rapidly into the passenger compartment, impacting occupants seated on the struck side adjacent to the impact. As regards a child restraint, the chassis acceleration affects the reaction of the anchorages and the inertial displacement of the CRS while the side intrusion affects the direct loading on the CRS.

This complex interaction cannot be replicated entirely in a simple sled test procedure. For this test procedure, the chassis acceleration and intrusion of the inner side structure have been specified independently. The chassis acceleration is reproduced by the sled deceleration. The intrusion is simulated by the motion of a hinged panel mounted on the sled.

For two vehicles of equal mass, the velocity change of the struck vehicle in a side impact will be about one half of the impact velocity of the striking vehicle. Thus this method simulates a side impact of approximately 50 km/h.

In the case of a CRS equipped with ISOFIX, excessive deformation of the ISOFIX attachments on the CRS might occur in this sled test method, compared to full-scale impacts. This damage is not to be included in the assessment of the CRS performance.

4.2 Test facility and equipment

4.2.1 Test rig

The test rig comprises a sled fitted with

- test seat,
- hinged panel,
- standard 3-point belt and ISOFIX anchorages,

as described in Figures 1 to 4.

The sled is equipped with a means of generating a Δv corridor as shown in Figure 5 with a velocity change of 25 km/h.

For the simulation of the intruding door (inner side structure) in side collisions, the hinged panel is moved during the sled deceleration by a means that generates a panel angular velocity as given in Figure 6.

4.2.2 Dimensions and specifications

The design and specifications of the test seat with anchorages is shown in Figures 1 to 4. The design and specifications of the hinged panel are shown in Figure 3.

NOTE The figures show one practical solution, where the seat back of the bench has been moved to avoid conflict with the hinged panel. Alternative solutions may be used to avoid this interaction, as long as the relevant geometry and characteristics of the panel are maintained.

The stiffness and strength of the hinged panel shall be sufficient in order that the panel will remain essentially undeformed during the test and to avoid excessive oscillations of the panel.

The surface of the hinged panel shall be covered with a 35 mm padding according to the following specification:

- On the panel surface: 15 mm of Bolidt compound PU 77.03 (or equivalent);
  - 87 weight units of compound A;
  - 13 weight units of compound B.
- On top of the above: 20 mm of Styrodur 2 500 C (or equivalent).

NOTE Alternative padding with the same characteristics would be acceptable.

4.3 Test dummies

Specification of the dummies allowing adequate measurements in the side impact method is not included in this standard. The most appropriate dummies according to state-of-the-art for this application should be used.

NOTE It is intended to cover the test dummies in a separate part of the standard.

4.4 Instrumentation

The instrumentation shall comply with current ISO standards. The measurement techniques shall comply with ISO 6487.

4.4.1 Instrumentation of the test rig with the hinged panel

The following parameters shall be measured:

— Sled acceleration and velocity change;

— Panel angular velocity.

There shall be a capability of determining head containment within the CRS and head contact with the intrusion plane should it occur, e.g. mechanically or photographically.

The impacting panel surface, covered with the defined padding, should allow the identification and analysis of contact areas between the child dummy and the impactor.

4.4.2 Instrumentation of the dummy

The following parameters shall be possible to measure:

— Head and chest acceleration, by tri-axial accelerometers;

— Neck forces and moments;

— Chest compression (optional);

— Head displacement, e.g. by high speed video or film analysis.

4.5 Test installation

Only new and untested CRS should be used.

The CRS shall be installed with a standard seat belt according to the specifications of Annex A, or with ISOFIX anchorages (see ISO 13216-1) as applicable.

The lateral distance between the centre line of the CRS and the inner panel hinge plane shall be 300 mm.

4.6 Test conditions

4.6.1 Sled motion specifications

The sled velocity change shall be 25 km/h (6,94 m/s) with a tolerance of ± 0,5 m/s.

The sled deceleration shall comply with a Δv corridor as shown in Figure 5.

NOTE 1 See ISO 7862 for general specifications relating to the sled pulse definition.

NOTE 2 For informative purpose, the corresponding sled deceleration corridor is shown in Figure B.1 (Annex B).

4.6.2 Hinged panel motion specifications

— The total angular change shall be 25° (± 0,5°) and the intrusion shall be 250 mm (± 8 mm), see Figure 3;

— The hinged panel shall be maintained at the intruded position, without overshooting;

— The angular velocity curve shall start at point of origin(0/0) and pass through the defined rectangle in Figure 6;

— The angular velocity must not exceed 14 rad/s.

The hinged panel angular velocity profile shall comply with Figure 6, and shall not be affected by contact with the CRS.

NOTE For informative purpose, example angular door velocity profiles are shown in Figure B.2 (Annex B).

5 Parameters to be measured and recorded

The performance criteria have to be specified in relation to the selected dummies. Below is listed what is necessary, and what is desirable, to record.

The following parameters shall be recorded:

— Direct dummy head contact with the intruding panel;

— Head containment within the child restraint system.

The following parameters are recommended to be measured or calculated:

— Head Injury Criterion (HIC);

— Head resultant acceleration;

— Head excursion in relation to the intrusion plane;

— Neck axial tension;

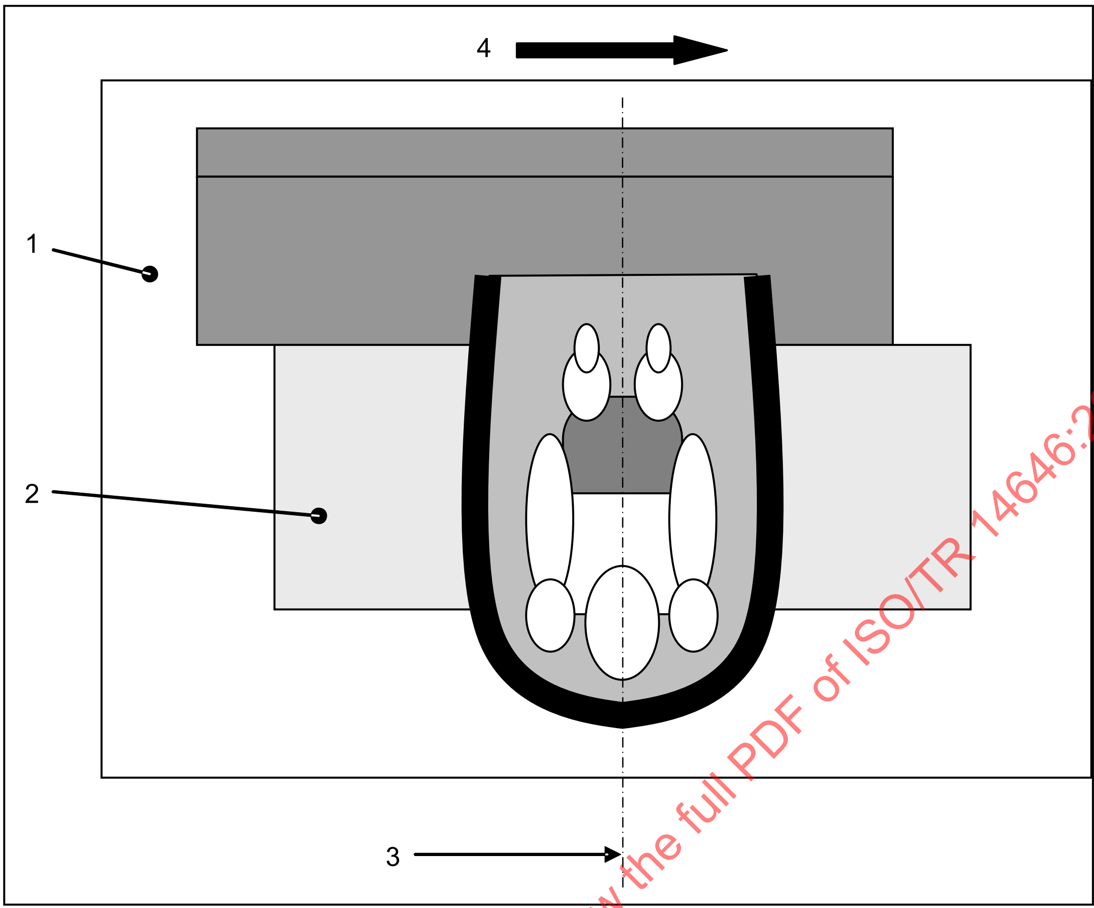
— Neck shear force (lateral component);

— Neck lateral bending moment;

— Chest resultant acceleration;

— Chest compression (if applicable to the dummy used).

NOTE Excessive deformation of the ISOFIX attachments on the CRS is not to be included in the assessment of the CRS performance.



Key

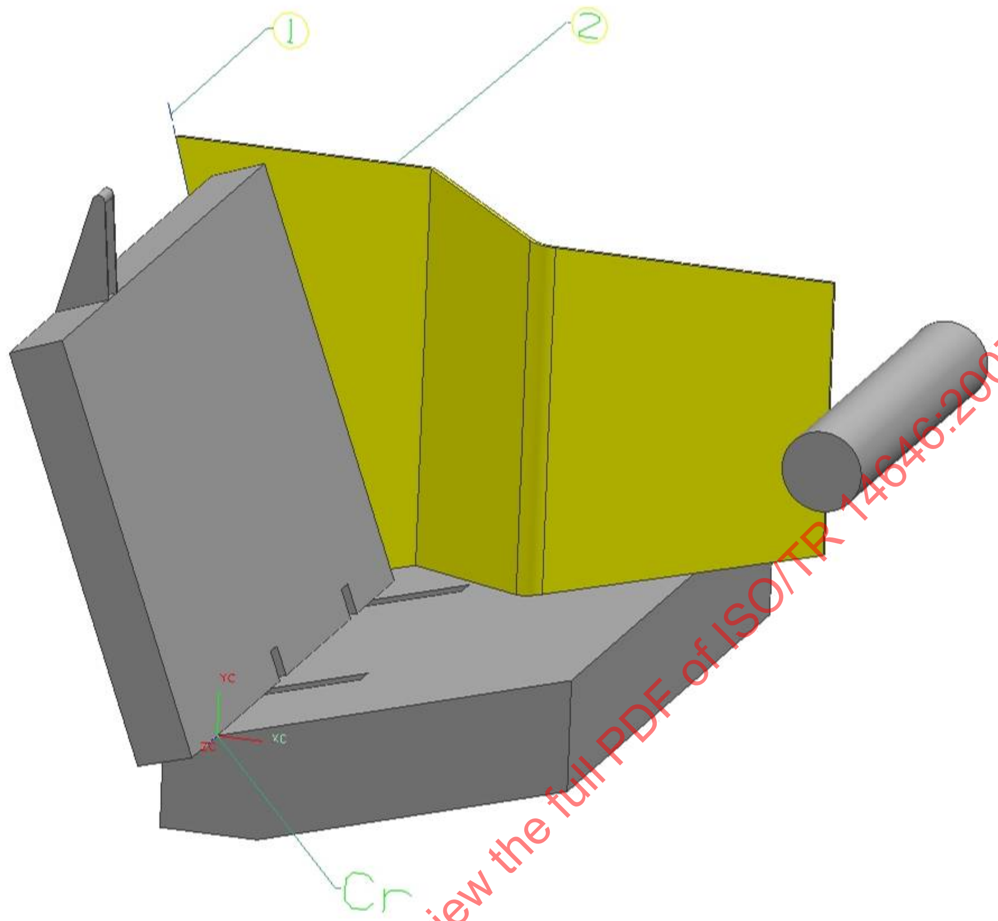
1 sled

2 ECE R.44 test bench

3 CRS centreline

4 travel direction

Figure 1 — Test configuration of a rearward-facing CRS, with ECE R.44 bench prepared for side impact testing



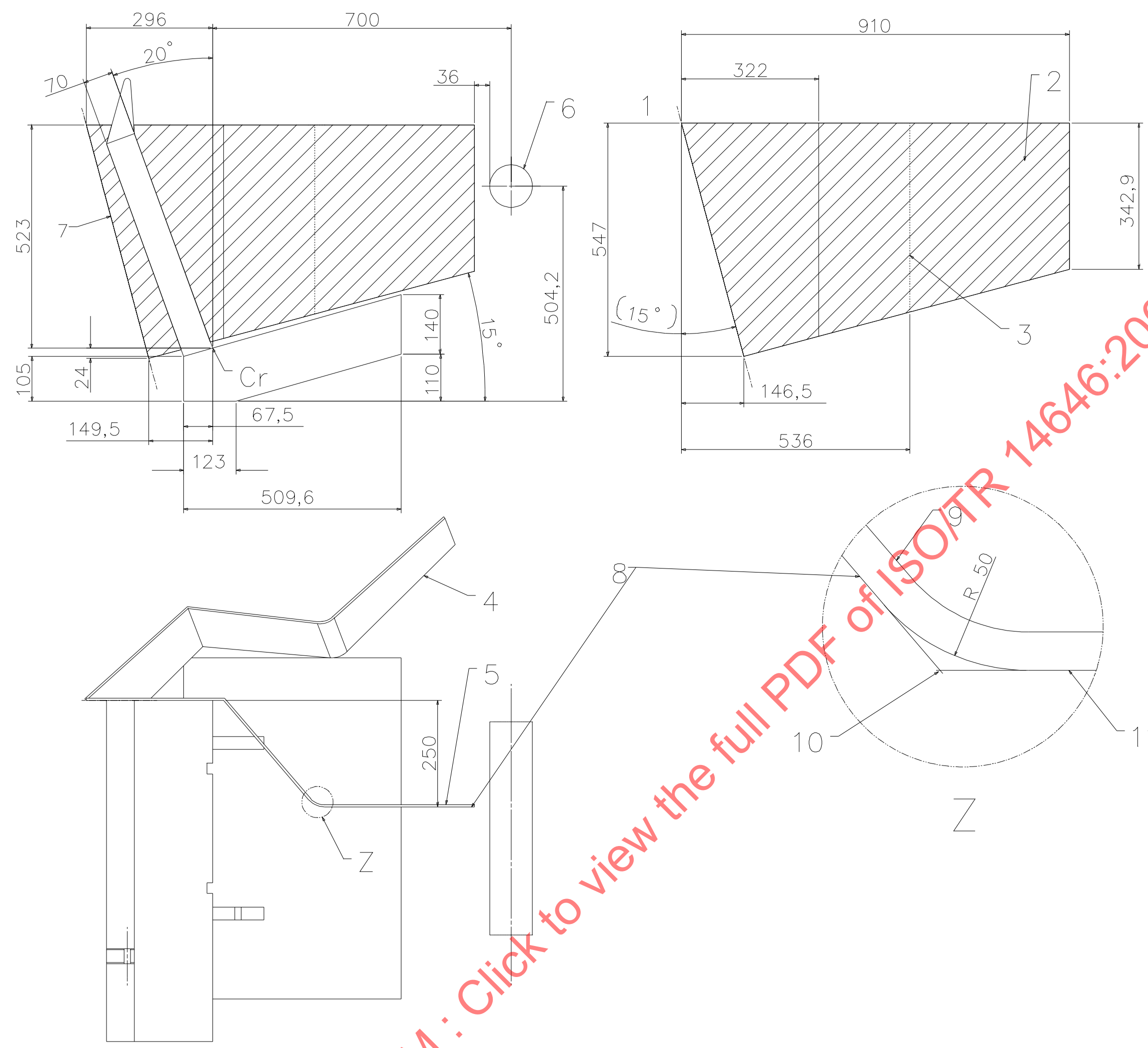
Key

1 panel hinge line

2 hinged panel

Figure 2 — Seat bench construction with hinged panel for testing of a rearward facing CRS

Dimensions in millimetres

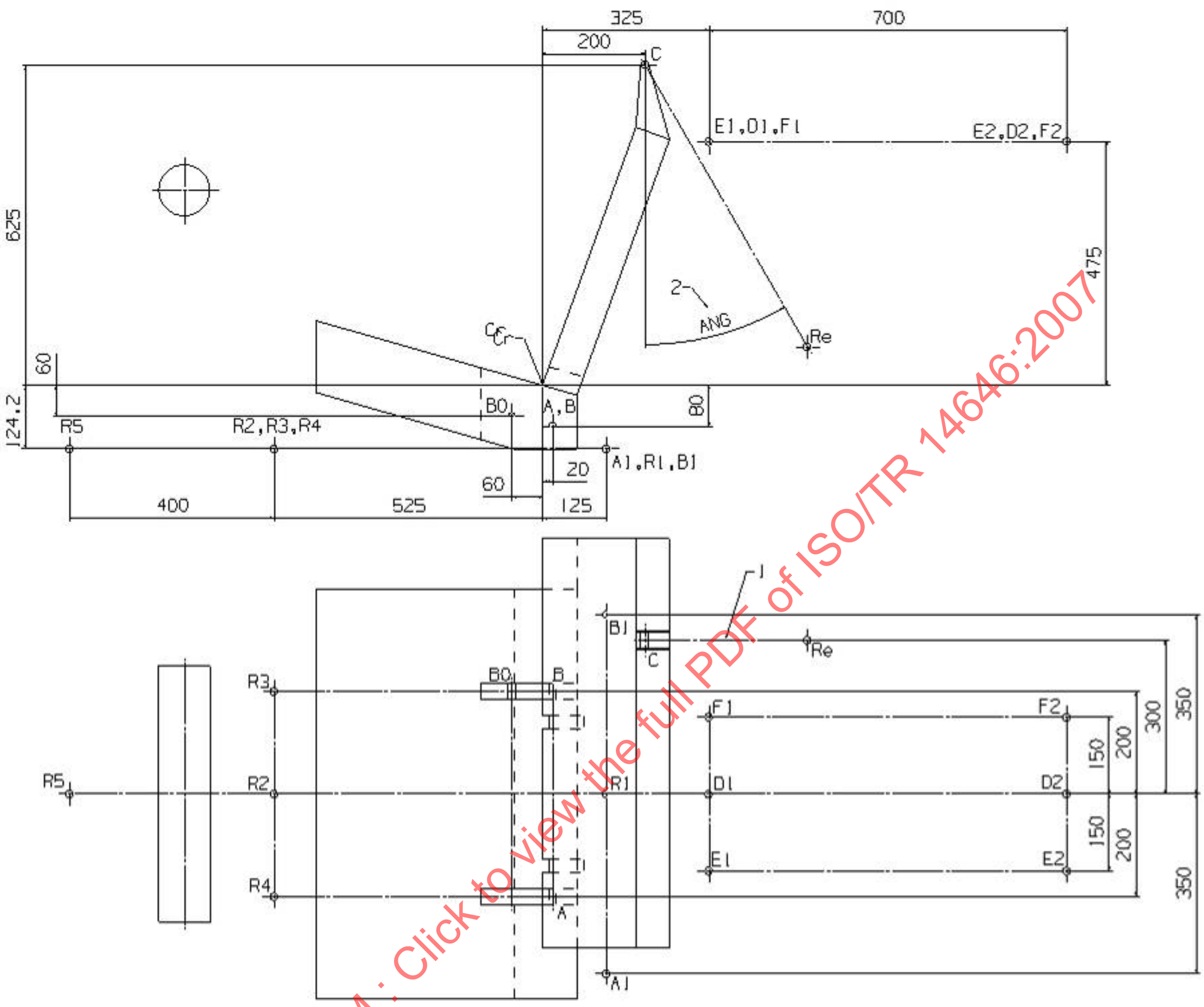


Key

1 door panel dimensions
2 simulated door panel
3 intersection line
4 panel pre-intrusion position
5 panel post-intrusion position
6 ECE R.44 steel tube
7 hinge centreline
8 surface representing the front of the panel
9 rigid plywood
10 intersection line
11 panel padding

Figure 3 — Dimensions of a hinged panel for testing of a rearward facing CRS

Dimensions in millimetres

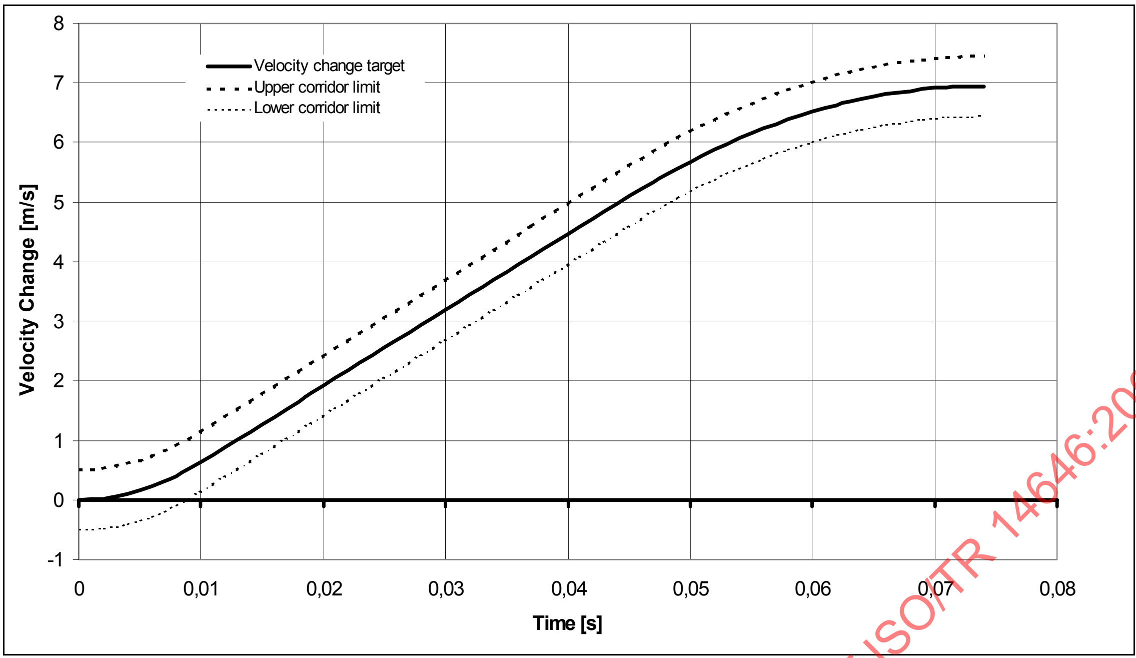


Key

1 distance C – Re = 550 mm

2 angle “ANG” = 30° maximum

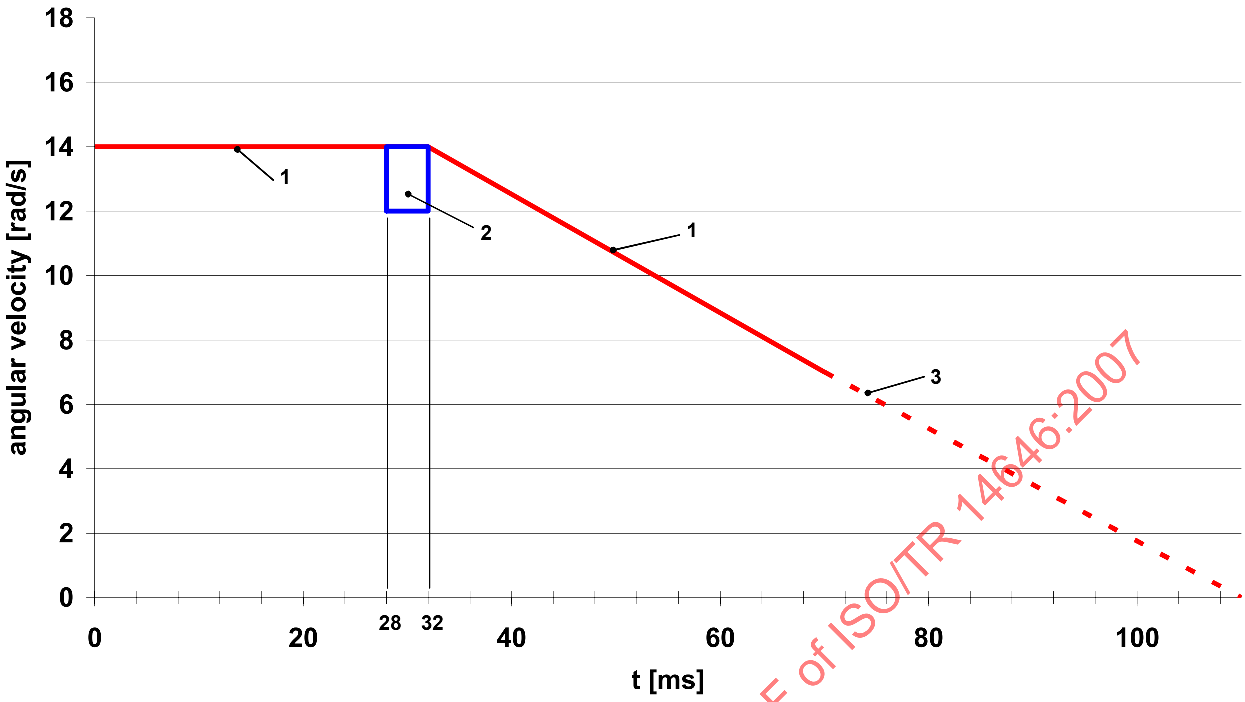
Figure 4 — Seat bench construction with ISOFIX and belt anchorage points



NOTE 1 For the corresponding acceleration data, see Annex B.

NOTE 2 It is important to keep within the velocity change corridor, but not the acceleration corridor. Remaining within the acceleration corridor will not guarantee compliance with the Δv corridor.

Figure 5 — Sled Δv corridor (total Velocity Change = 6,94 ± 0,5 m/s)



Key

1 angular velocity upper boundary line

2 defined rectangle (12-14 rad/s at 28-32 ms)

3 dashed line from 70 ms to 110 ms

The angular velocity curve shall start at point of origin (0/0) and pass through the defined rectangle. It shall be kept below the boundary line, except in the region marked by the dashed line.

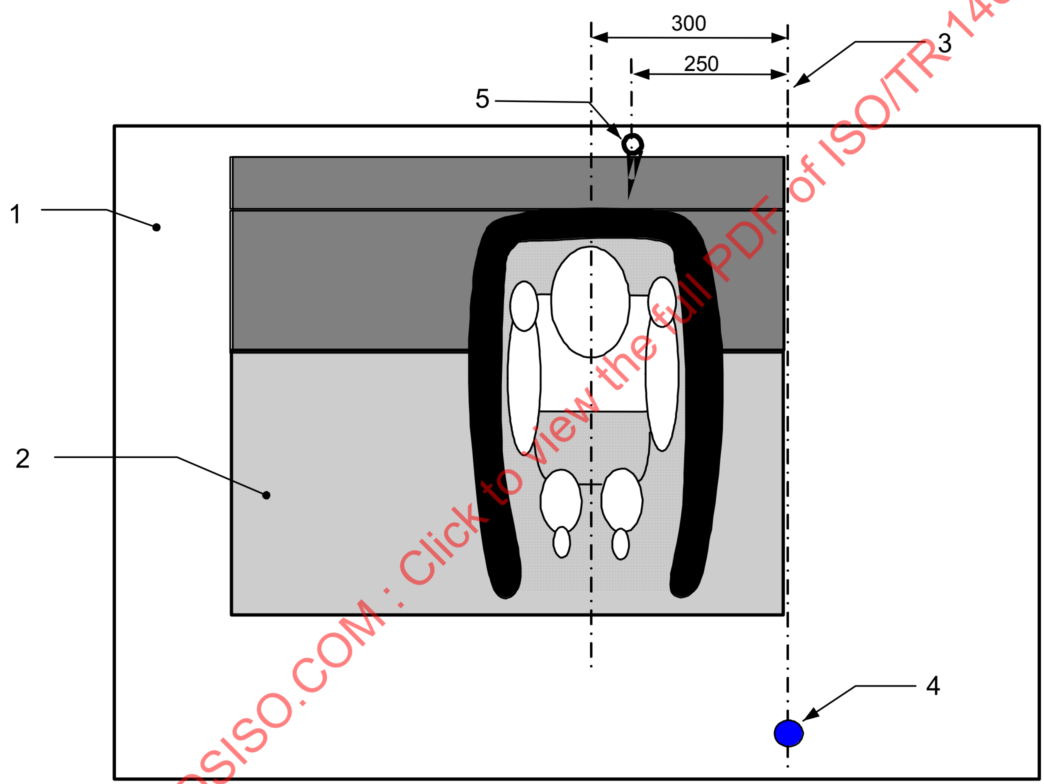
Figure 6 — Hinged panel angular velocity

Annex B
(informative)

Working draft of planned future ISO/TR 14646-2, ISO side impact test procedure for forward facing systems

NOTE In addition to the method for testing of rearward-facing systems shown in Annex A, the original drawings of the test setup and impacting panel to be used for testing of forward-facing systems are shown in this annex, these being the main differences in the test setup. The original figure numbering is maintained.

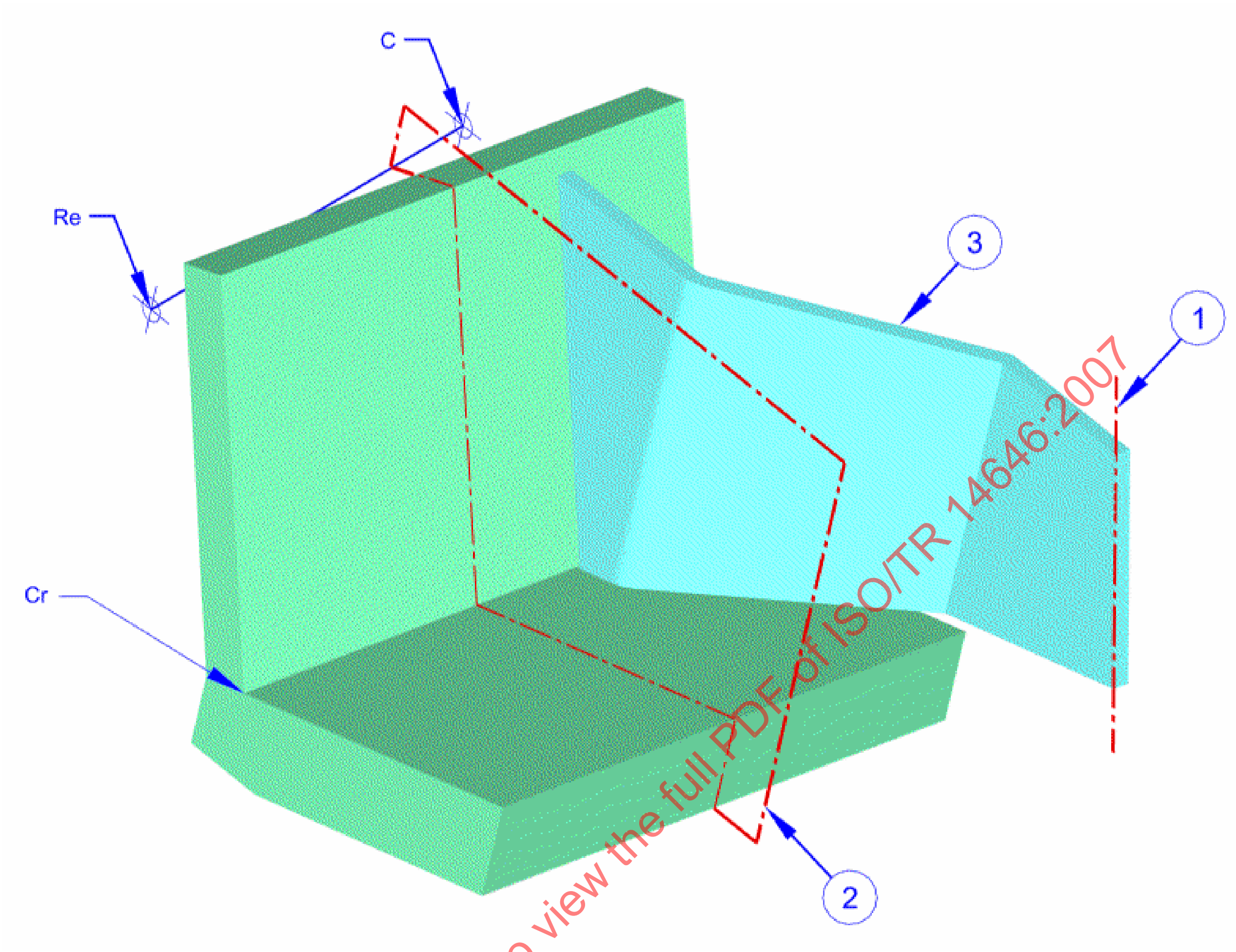
Dimensions in millimetres



Key

1 sled
2 ECE R.44 test bench
3 hinge plane
4 hinge
5 latch

Figure 4 — Test configuration of a forward facing CRS — Worst case condition



Key

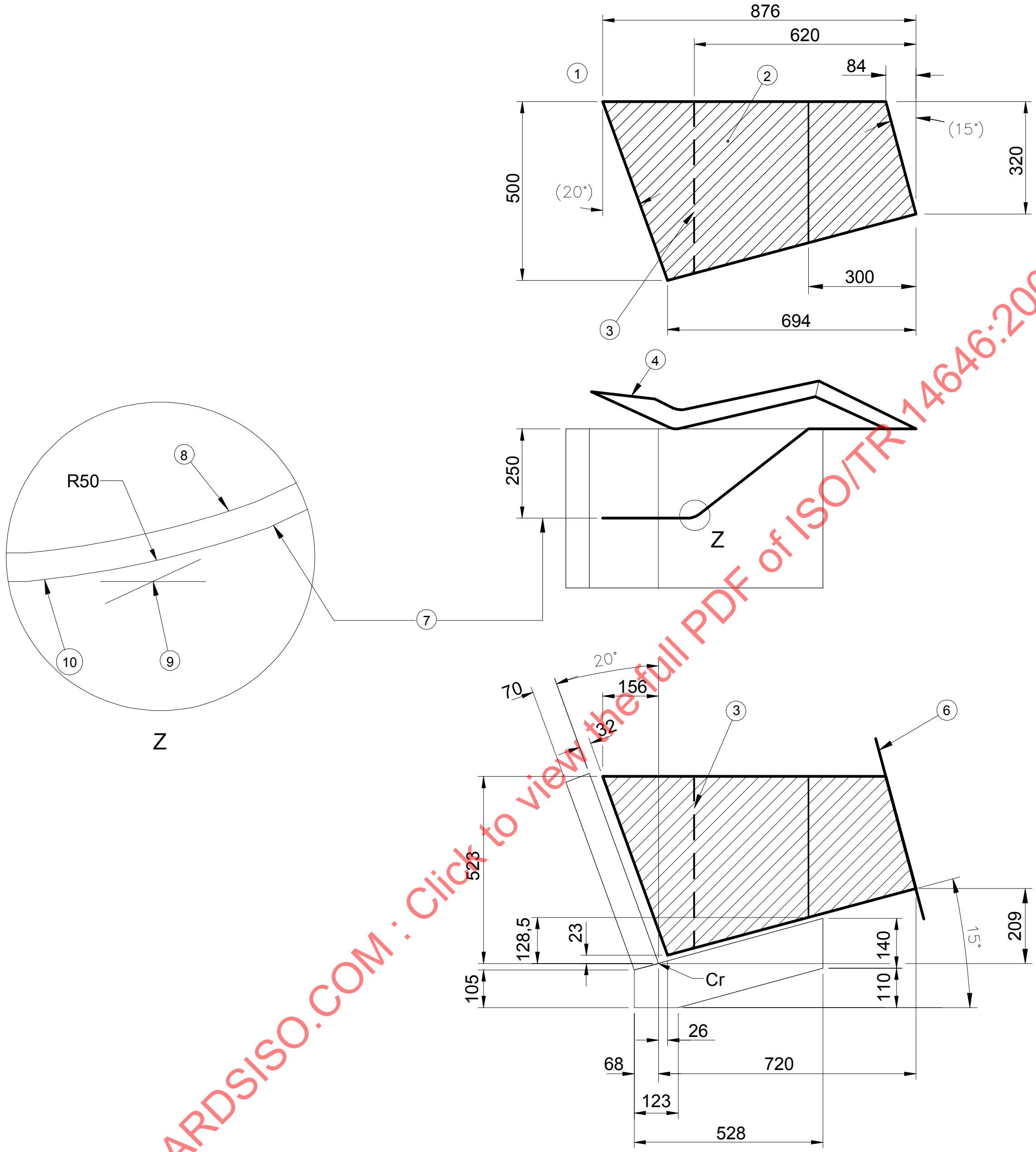
1 door hinge line

2 CRS centreline plane

3 simulated door panel

Figure 5 — 3-D view of seat bench construction with belt anchorage points for testing of forward facing CRS

Dimensions in millimetres



Key

1 door panel dimensions
2 simulated door panel
3 intersection line
4 door open
5 N/A
6 hinge centreline
7 surface representing the front of the door
8 rigid plywood
9 intersection line
10 door padding

Figure 6 — Dimensions of a hinged door panel for testing of a forward facing CRS

Annex C
(informative)

Voting results and comments received on ISO/DIS 14646:2003

P-Members voting: 8 in favour[1)] out of 13 = 61,53 % (requirement > = 66,66 %).

Member bodies voting: 5 negative[2)] votes out of 16 = 31,25 % (requirement < = 25 %).

The following comments were provided (editorial comments are not included here), and subsequently the observations on the comments were given, with help of the Task Force on side impact testing.

MB	Clause No./ Subclause No./ Annex (e.g. 3.1)	Paragraph/ Figure/ Table/ Note	Type of comment	Comment (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
FR	General			At the moment, this test procedure has never been evaluated in forward facing configuration. For rearward facing, only one evaluation has been made with one ECE 95 test. This test has been run with an unknown vehicle and with an unknown CRS. In addition the values measured in this unknown reference test seem to be very high. For instance in this test the head resultant acceleration is 93 g, whereas the mean value obtained with 47 European cars is 41 g (source: from EuroNCAP side impact results phases 5 to 13).	A complete validation for forward facing and for rearward facing is needed. It shall be proved that these rearward facing and forward facing test procedures are representative of the conditions and the results of a real car crash test.	1) Validation criteria will be established. 2) Reference tests for validation of the forward facing configuration are certainly needed. WG1/Task Force side impact is currently investigating the possibilities to gather data of reference tests. 3) In parallel, sled testing in the forward facing configuration will be performed.
SE			ge	The method was originally intended to be a "simple method", but has turned out to be very demanding and expensive considering the hardware and precision requirements. This is especially related to the construction of the door(s) and the system needed to control the door movement. A considerable knowledge has been acquired by the labs involved in the CRS side impact testing, and although there is now almost a total agreement on the dynamic impact issues (including the severity level to introduce to the system) there are still two "competing" door shapes, hinge systems and door actuation systems being used. It seems possible that these two could be developed and tuned to give equal test results.	Investigate the possibility of adding the "TUB test setup" in an annex, with parameters adjusted to give corresponding test results.	A single test set-up is necessary to ensure a uniform standard.
SE			te	The test case with forward facing CRS has not yet been fully evaluated or validated. The method cannot be considered finalised before this has been carried out. In addition, the consequences for Isofix attachments, with the door hitting close to these, have not been fully investigated in the forward facing case.	It may be needed to adjust some parameters in the forward facing test case.	Decision depending on the outcome of further tests of the forward facing case.

1) Australia, Canada, Germany, Israel, Korea (Republic of), New Zealand, Sweden, United Kingdom.

2) France, Italy, Japan, Netherlands, USA.

DE NL		General to the test procedure	ge	This Draft International Standard has not been validated for both proposed test configurations until now. Some results for rearward facing CRS have been presented, but any test with forward facing CRS. The repeatability and reproducibility of test results have not been proven.	Validation of test procedure is necessary before voting.	See reply to FR comment above. Also the rearfacing configuration shall be considered.
UNI			ge	No comment is made on the methodology. Nevertheless, we are not in favour to consolidate a procedure of "Side Impact Test method" because the key-points (i.e. dummies and injury criteria) for the time being are not yet defined or incomplete (e.g. Clause 4.3 "Test dummies"). We accept the work done by TRL (Transport Research Laboratory, UK research centre) to this point in time but more testing needs to be done to set the rig for front and rear seat conditions and forward and rear facing seats. Some European projects are in progress on this matter (e.g. "CHILD") therefore we feel it is premature to continue the work on this item until dummies will be defined.	Freeze this document as it is now and wait for the outcome from European project and/or other national projects and research (e.g. University of Berlin TUB) in the field of dummies and their injury criteria.	This item is addressed in WG 1 resolution 148, asking for assistance from other ISO WG:s concerning dummies and injury criteria. The method will be completed with these items as a second step, when the appropriate information is available.
JP			ge	It is not possible for us to favor or oppose with this DIS. Because we don't believe there is enough data and explanation for correlation between real impact test and sled test.		See replies to the above items related to validation of the procedure. Further validation will be necessary.
US			ge	DIS 14646 specifies all aspects of the test structure except the child seat. This suggests it is a test for the child seat manufacturer, not the vehicle manufacturer.		The scope clearly states that the method is intended for evaluation of the child restraints only.
US			ge	With the door profile, door covering, door angular velocity, seat belt system, and door intrusion fixed within DIS14646; the vehicle manufacturer has no ability to refine the vehicle design to improve child safety.		The test is reflecting the current worst case from vehicles tested according to the ECE R.95 side impact test. Changes in vehicle design may be reflected by changes to the standard.
US			ge	Any regulation aimed at improving safety needs to optimize the performance of the vehicle and safety system. The ultimate goal is to reduce the energy transferred to the test dummy. A safety test should test the safety systems ability to absorb and redirect energy away from the test dummy.		See reply to the above US comment.
US		Introduction states	ge	"this standard has been prepared on the basis of accident data" is the accident data available for review.		The accident data is understood to have been taken from the 1996 Stapp Car Crash Conference. (Langwieder et al.)
FR	1		te	The scope states that the procedure is intended only for CRS suitable for children up to 22 kg	The mass range for the tested CRS should be extended to all types of CRS: child seats suitable for children up to 36 kg.	Raising the mass limit to 36 kg is agreed (but CRS without side protection would be unlikely to pass).
US	3	Section 3.5	te	Window plane; assumes a vertical window. This is not a realistic assumption.		The window plane does not actually simulate a real window, rather a plane marking a significant risk of contact with an intruding object. "Window plane" will be replaced by "intrusion plane".
UK	3.1	Note	te	These categories are not termed this way in the UK.	Delete note.	The comment is noted. However, this general definition of "child restraint system, CRS" is the same for all the ISO CRS standards, and is based on a decision by WG 1. Thus it should not deviate in this standard.

