EUROPEAN ENHANCED VEHICLE-SAFETY COMMITTEE

Report on the work of EEVC WG13
1992-2005
Working Group 13

www.eevc.org

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1992 - 2005

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Chairman of EEVC WG13

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1. Overview

EEVC working groups are created under the umbrella of the EEVC Steering Committee to investigate specific Vehicle Safety issues as deemed needed by the Steering Committee. The Working Groups comprise of nominated Technical Experts, in their relevant files, one from each participating country, to carry out coordinated research that could be used by the EEVC Steering Committee to enhance vehicle safety. Working Group 13 (WG13) was created in 1992 to support and extend the work carried out by the former side impact working group WG9 which started its work in 1988. WG 9 members developed the European Side Impact dummy EuroSID and the side impact test procedure that led to UN/ECE Regulation 95.[1]

The work of WG13 initially focused on supporting UN/ECE Regulation 95 and reviews of various aspects of it, during its first two years. In addition the group was asked to look at a new topic, namely the assessment of internal surfaces struck by the head, in a side impact.

In 1996 a similar broader based organisation to the EEVC was created 'IHRA' (International Harmonisation of Research Activities). In 1999 IHRA took on side impact as an active subject area. Contributions to the IHRA Side Impact Working Group (SIWG), from European Governments, were channelled through the EEVC using WG13. The Terms of Reference for WG13 were amended accordingly. The European Governments representation on the IHRA SIWG came from the WG13 chairman and one other WG13 National member.

2. Terms of Reference

The terms of reference for WG13 were given by the EEVC at the 28th meeting of the Steering Committee. They were amended following recommendations from WG13 at the first meeting of the group and subsequently approved by the Steering Committee. These were:

1) To support the implementation of the Full Scale Side Impact Test Procedure.
2) To consider any related topic which may enhance the protection provided in side impact *particularly regarding a complimentary head-form impact test.*
3) To assess the composite test procedure in relation to the results of the full scale test *and to provide a scientific basis for the comparison of the two procedures.*

The terms of reference were revised 15th June 1999 and a further paragraph (d) added March 1999 to encompass IHRA activities:

(a) The development of a repeatable and meaningful head impact test for the evaluation of head impact protection in side impacts
(b) Studies to reduce the variation in test results of the full scale side impact test due to differing designs of barrier faces and dummy positioning.
(c) Assessment of accident data analyses in support of the EC Side Impact Directive review.
(d) Organise and coordinate the EEVC contributions to the IHRA international working group on Side Impact Test Procedures. *(March 1999)*

The next change was made in June 2000:

(a) Develop a repeatable and meaningful head impact test for the evaluation of head impact protection in side impacts (Propose draft EEVC test procedure by Spring 2001).

(b) Produce and validate a proposal for the design specification of the MDB face for use in the EEVC full scale side impact test. (Propose draft design specification by end 2000, validate by mid 2001)
(c) Provide continuing support for the EC Side Impact Directive review, if requested by the Commission, as and when appropriate.
(d) Organise and coordinate the EEVC contributions to the IHRA international working group on Side Impact Test Procedures.

Item d) was modified in February 2004 to:
(d) Organise and coordinate the EEVC contributions to the IHRA international working group on Side Impact Test Procedures. This will involve technical contribution to the development and assessment of all aspects of the suite of IHRA side impact procedures. The four elements of the test procedure include a Mobile Deformable Barrier (MDB) to car test: a Pole impact test: an Interior surface test procedure and an Out Of Position test procedure.

3. Membership

The EEVC Working Group has been made up of both nationally appointed technical members and by supporting members, largely drawn from the automotive industry, one per county, at the discretion of the national member. Some of the work has a close association with work that had taken place in the US and for some of the time a guest from NHTSA was invited to participate in the meetings as observers. When the scope of the WG13 work encompassed IHRA related activities representatives from Japan were invited to attend as observers.

Membership (as of the last meeting 8th December 2005)
Chairman:
    Mr. Adrian Roberts (UK)
National Members:
    United Kingdom: Mr. James Ellway (also group secretary)
    France: Mr. Jean-Philippe Lepretre
    Netherlands: Mrs. Marian Bosch-Rekveldt
    Germany: Mr. Tobias Langner
    Italy: Mrs. Giuditta Antonetti
    Spain: Professor Luis Martinez
    Sweden: No active member
Support members
    Mr. Peter Janevik (Sweden)
    Mr. Stuart Southgate (UK)
    Mr. Jacques Faure (France)
    Mr. Ton Versmissen (Netherlands)
    Mr. Christoph Mueller (Germany)

Special Invitation:
    for interior surface testing discussions, USA: Dr. William Fan
    for IHRA activities, Japan: T Kreuzinger, T Akiba, M Uneo.

Previous/retired members of WG13.
FRANCE – Mr. C Pichon, Mr. T Bourdillon, Dr. D Cesari, Mr. C Fourgeaud, Mr. P Castaing, Mr. D Pouget
GERMANY – Mr. A Seeck, Mr. E Faerber, Mr. M Piesche, Mr. S Knack
NETHERLANDS – Mr. P deCoo, Mr. J Nieboer, Dr. Michiel van Ratingen

ITALY – Mr. A Benedetto, Mr. S Canali, Mr. F Fossat, Mr. E Becchio
SWEDEN – Mrs. I Skogsmo, Mr J Sameus, Mr. J Oster, Professor P Lovsund, Mr U Lechelt
UK – Mr. W Coates, Mr. P Fay, Miss C Owen, Mr. John Green, Professor R Lowne OBE (ex WG13 Chairman).

4. Work items

During the 1992-2005 period research by WG13 members, was first purely focused on European Activities for the EEVC Steering Committee. Latterly effort was directed into IHRA SIWG to give a European view and to ensure that the procedures were appropriate for possible European Application.

All of the principle reports from the working group were submitted to the EEVC SC, for their approval and when given STEERING COMMITTEE approval, were electronically published on the EEVC web site (www.eevc.org).

Initial progress in WG13 was slow with two years separating the first and second meetings, thus the effective work period covered in this report spans a period of 11 years. In the last few years WG13 was much more active with up to four meetings per year being held with contributions from the industry support members

All of the records of the work of WG13 are located on the EEVC web site within the WG13 domain area. Only a few working documents for the very early years are not archived.

The first meeting of WG13 took place 12th June 1992. Since then the group has met 39 times, the last meeting taking place 8th December 2005.

The following sections detail the specific tasks and achievements of the group with both EEVC and IHRA focuses.

4.1. Work Task – Support for ECE Regulation 95 / Directive 96/27/EC.

This encompassing work item was a task placed on the working group to continue the support given to the EEVC STEERING COMMITTEE and to the Commission previously supplied by Working Group 9, the former side impact group, that had developed the side impact test procedure and the side impact dummy (EuroSID-1) which led to Regulation 95. The two active areas of work focused on the review of the frontal and side impact directives and the specification of the ECE Regulation 95 / Directive 96/27/EC barrier face detailed in Section 4.4 of this report[1].

The initial work, reviewing the directives, was a combined study with WG16, the frontal impact group. The side impact group was specifically asked to address the following issues.

i) test speed
ii) seating position derogation
iii) the barrier height above the ground (termed: ground clearance)
iv) the necessity of a pole test in addition to the side impact requirements of directive 96/27/EC.
v) Viscous criterion

The summary recommendations from his review are presented below and are extracted from the EEVC paper, which is available on the publications page on the EEVC web site, www.eevc.org.

(i) Test Speed. - EEVC Response

'There is an indication from the accident analysis that the overall severity of impact in the test procedure should be raised. The total intrusion seen in accidents is normally greater than that seen in the Side Impact test. However, there are a number of parameters that could influence this, including barrier mass, stiffness, height, in addition to the impact speed. The accident data for two countries indicated that the current test speed included only about 25 per cent of serious injury cases and 10 – 20 per cent of fatal accidents, suggesting a potential benefit from an increased test speed.

Recommendation: It is recommended by EEVC that a research programme be undertaken to establish the performance of cars at higher impact speeds than the current level before any decision could be taken to recommend an increase in the test speed.'

(ii) Front seat position

'The accident review indicted that there were clearly cases of injury due to contact with the B-pillar, particularly to the head but also to the chest and abdomen. However, the frequency of those contacts is not certain. The derogation included in the Directive was introduced because technical solutions to the problem of impact to the B-pillar were unproven when the Directive was drafted. The introduction of side airbags demonstrates that this problem can now be solved. The derogation could now be removed and this would be expected to reduce the incidence of injuries, although the size of the reduction is not clear. If airbags are already being introduced by vehicle manufacturers to meet the current needs, then the cost of meeting the requirement at B-pillar positions should be negligible. It should be borne in mind that the removal of the derogation may result in an effective mandatory fitment of side airbags.

Recommendation: It may be advisable to undertake a research programme regarding the effect of side airbags on out-of-position occupants before making this commitment'

(iii) Ground clearance of MDB Face

'An attempt was made to evaluate the appropriateness of the current MDB face ground clearance from the accident review. From the accident analyses, there was no strong evidence to suggest that the current ground clearance of the MDB face was inappropriate. The mean height of maximum intrusion in EuroNCAP and legislative tests that had been performed at one institute was below that seen in accidents, suggesting that the ground clearance may be too low, but this was not so for another test institute. An associated study of the front and side structures of modern cars suggests that the ground clearance (i.e. the height of the bottom surface of the MDB face) should be raised but not the level of the top of the MDB face. This would not be possible to achieve without a redesign of the whole MDB face.
Recommendation: [1] EEVC recommends that note be taken of this indication that the ground clearance may need to be raised in the future but that no action should be taken in the short or medium term.'

(iv) Pole Test

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[1] This item is being addressed within the IHRA related work and the development of the AE-MDB, Section 4.6.1

‘The accident study indicated that side impacts to poles and narrow objects constitute a significant proportion of MAIS 3+ side impact injury accidents. In the Netherlands, Sweden and the UK, these ranged from 12 percent to 16 percent while in Germany pole or narrow object impacts comprise 53 percent of all such side impacts. If struck side occupants only are considered, these figures are even higher. The accident statistics also show that these casualties are primarily young males, more than half being aged under 30 years.

Recommendation: [2] EEVC recommends that consideration be given to the development of a suitable pole impact test for the longer term.

(v) Injury Criteria (including V*C)

‘No further biomechanical research has been undertaken by EEVC regarding the injury criteria. However an analysis has been made of the results for the viscous criterion from the EuroNCAP tests which use a test procedure based on that specified within the Directive. The results indicate that the current value of 1.0 m/s is achieved by most of the cars that have been subject to the EuroNCAP test since the programme started, and all of the cars except for one ($V*C_{max}$ = 1.01) of the last two phases which primarily includes the more recent vehicle designs. The mean value of $V*C_{max}$ for the last two phases was 0.48m/s.

Recommendation: The recommendation of EEVC is that the existing criteria, including the viscous criterion, should be retained at their current values unless future research indicated a need to refine these.’

4.2. Work Task – Interior Surface Test Procedure

The development of an appropriate internal surface test procedure has been the main work item on the WG13 task list, since its inception. The development covered several defined phases as well as an accident study to define the areas within the vehicle which should be evaluated.[3]

The WG13 research phases were:

Phase 1 – Selection of the impactor
Phase 2 – Determination of the impactor guidance system
Phase 3 – Specification development and validation of the test procedure

4.2.1. Interior Surface Test Procedure Phase 1 – Selection of the impactor

In the early phases of the work of WG13 the group considered three impactors as being possible candidates for use in an interior surface test procedure: The Free Motion Headform (FMH), as was specified in FMVSS 201, A small symmetrical impactor, that was being developed by the American Automobile Manufactures Association (AAMA) and the European adult pedestrian headform impactor, that was being developed by EEVC WG10, for use in a frontal impact pedestrian test procedure. To compare the attributes of the three headforms a collection of component tests were developed using different types of foam padding, with and without hidden hard-spot features beneath the surface of the foam, as well as yielding structures: a cantilever beam and a surrogate ‘B post’. The aim of the programme was to determine the potential of each of the test devices to evaluate the padding systems and

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[2] This item is being partially addressed within the Interior surface test procedure, Section 4.2

[3] It should be noted that a similar procedure was operational in the US, FMVSS201. The EEVC Steering Committee instructed WG13 to develop a procedure that was ‘appropriate for European application and the European accident situation’ and not necessarily propose a clone of the US procedure.

whether they could identify the presence of sub-surface injurious structures. Since the FMH and AAMA impactors were not in common use, by WG13 members, WG13 procured one of each of them for the evaluation. The EEVC pedestrian impactor was being widely evaluated in the European research laboratories thus the US impactors were shared by WG13 members. Variability may have thus have been greater for the EEVC impactor, than for the other two.

No significant differences were identified between the three test devices evaluated in the programme. WG13 selected the FMH for further evaluation based on the knowledge that the FMH was already being used and technically supported in a similar procedure in the US. The results of this evaluation programme were presented at the 15th ESV Conference 1996, Melbourne, Australia. [2]

4.2.2. Interior Surface Test Procedure Phase 2 – Impactor guidance system

FMVSS 201 specifies a free flight launch of the headform to defined target points within the vehicle. WG13 wished to test this limitation and determine whether one could permit guided impact, which members felt could have some benefit in improving impact accuracy and reduce test variability, compared to flight methods.

Suitable linear guidance launch systems for the headform were not readily available thus the different test laboratories carrying out the tests developed their own systems. Unacceptable variability was measured in impacts using the linearly guided impactors, especially when the impact vector was not perpendicular to the target surface and when the surface yielded along a vector that was not aligned with the headform guidance vector. WG13 did not consider that this level of variability could easily be minimised. The evaluation programme thus clearly indicated that free flight launch should be recommended and linearly guided methods should be excluded.

In FMVSS the FMH coronal plan is perpendicular to the launch vector. The contact patch on the FMH, as used in FMVSS configuration, is not aligned with the centre of gravity of the headform thus an impact in FMVSS configuration would induce rotation of the headform following contact. An alternative approach would be to pitch the headform forward such that the centre of gravity of the head: was aligned with the forehead contact patch thus reducing the tendency for the head to rotate during the impact. WG13 carried out some comparative test in both configurations. The results suggested that the severity of the test was greater in the centre of gravity aligned mode, as might have been expected as the headforms tendency to rotate during the impact was reduced. It was decided by WG13 members to adopt the FMVSS orientation (coronal plan is perpendicular to the launch vector) due to ‘harmonisation of the severity of the test’ as there would be great confusion when the same impactor was being used and all other parameters were common and the severity of the test would be different.

4.2.3. Interior Surface Test Procedure Phase 3 – Development and validation of the test procedure

Several issues needed to be addressed during the development and validation of the test procedure:

1. Determination of target areas within vehicles that cause head injury and their associated injury severity. This was focused on side impact but at the request of the EEVC Steering Committee the accident study was extended to include frontal impact as well to determine whether the evolving procedure should be extended to encompass

internal frontal surfaces. This WG13 research combined accident and injury data from several available data sources.

2. The impact velocity of the headform. This was derived from an analysis of laboratory vehicle impacts, based on the Regulation 95 procedure.
3. The definition of the target areas: based on real world contacts *(Point 1)*.
4. Recommendations for ‘worst case point of impact’ to avoid sub-optimisation of impact protection.
5. Orientation of the headform, pre-impact, to give it maximum discrimination capability and minimisation of the severity of secondary impacts, to the nose and chin areas of the headform.
6. Launch vector for the headform with respect to the selected target points and surface.
7. Realistic head impact vectors with respect to where an occupant may sit (5th to 95th %ile occupants).
8. Elimination of unrealistic impacts that might be suggested by vehicle profiles *(Point 3)* and an inability to test physically selected points due to the physical size of impactor launch devices.
9. The equivalence of the FMH measurement of impact severity (HIC) with respect to that which would be measured by the EuroSID dummy in a full scale regulatory test.[4]
10. The assessment of active head protection systems, *head airbags*.
11. Assessment of the firing of the air bag.
12. The bags protection capability in an intrusion test – *full scale pole test.*
13. The assessment of a deployed airbag to ensure equivalent protection for different sizes of occupant and seating positions, to prevent sub-optimisation.
14. Drafting of a procedure that would minimize the risk of interpretation ambiguity and test variability.
15. Enhancement of the procedure to encompass the IHRA extension to rear seat occupants, noting that the original EEVC Steering Committee specification was for front seat occupant protection.

The draft WG13 test procedure was first submitted to the EEVC Steering Committee in 2004. It was subsequently slightly amended following that submission and recommendations from the Steering Committee. It was finally published on the EEVC web site, with the Steering Committees approval, in 2005 and released to the IHRA SIWG and to the EC APROSYS project for evaluation. In a couple of areas the report details alternative approaches to address certain issues since unanimous agreement was not possible within WG13, e.g. two methods of head alignment have been proposed in the procedure. In addition the approach angles are to be investigated and confirmed. Further research is needed to determine which approach should be adopted. Information provided by research activities outside of WG13 will be considered by the group.

The original request on WG13 from the EEVC Steering Committee was for frontal seating positions only, favouring restrained occupants due to the high usage of restraint systems in Europe.

When used within the IHRA framework of procedures coverage for rear seat occupants was added (Section 4.7). This extension in assessed area was added to the document in such a way that if it were to be used only for the front seat occupants selected paragraphs could easily be deleted. It would then stand alone as a frontal position test procedure.

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[4] The FMVSS 201 equivalence factors were derived against the US DoT SID whose head and neck is different to that of the EuroSID (and ES-2) dummy

Since several procedures described in the WG13 report are common with that described in the US procedure thus some sections within the WG13 procedure are cloned from the US standard.

A report of the latest status on the WG13 procedure was presented at the EEVC 2005 conference, in Washington, [3]. All of the reports are available on the EEVC web site www.eevc.org and are included in the Appendix.

It should be noted that the procedure does not include the evaluation of some types or classes of vehicle and further studies and proposals would be needed to include them, e.g. soft topped vehicles or vehicles with removable roofs. Some WG13 members are of the opinion that the users of such specialist vehicles would acknowledge that they would be using a vehicle which would naturally have a higher risk of head injury. Vehicle manufactures have also suggested that full head impact protection, as would be needed to comply with the test procedure, may not be possible in such vehicles. In addition sale volumes of such vehicles are much smaller thus the cost benefit of including full level protection would not be cost effective, even if technically possible. Further studies would be needed to investigate these issues and make appropriate recommendations.

The assessment of active head protection systems, to address all of the issues identified previously, (e.g. air bag firing times, assessment of deployed airbags and coverage) have not been fully investigated in the work that WG13 has been able to undertake to date.

The issue of external body deflection and its magnitude during the test has not been demonstrated. In addition the means by which this deflection is to be assessed has yet to be investigated.

The test procedure has made significant progress since the ESV 2003 but is not at the stage where it could be considered fit for regulatory application without further adjustment and broader based evaluation.

4.3. Work Task: Composite Test Procedure

The Composite Test Procedure (CTP) was a test procedure, initially proposed by Volkswagen and ACEA as an alternative approach to carrying out a full scale side impact test. The CTP work task only covered the first few years of WG13's activity.

It was suggested, by the European automotive industry, that the CTP test could be performed early in the design cycle of a vehicle and would be much more repeatable than the Full Scale Test (FST). Approvals could be granted, under the Type Approval process, much earlier in the design process thus reducing costs. The suggestion was that a vehicle could be 'Type Approved' without having to undergo the proposed Full Scale Impact Test. The CTP procedure underwent several iterations and developments eventually finishing as the CC-CTP procedure (Computer Controlled-CTP). The procedure consisted of mounting the test vehicle off its suspension in 'body in white condition' with appropriate trimming. The crushable regulation barrier face was pushed into the side of the vehicle by large hydraulic rams under closed loop control to intrude into the vehicle structure. As the barrier loaded the outside of the vehicle two more independent rams, with attached body forms replicating the occupants upper and lower body, loaded the inner door structure. The control system balanced the loading of the outside of the vehicle with the occupant body forms movement. The results were then ‘black box’ post processed to give the equivalent dummy test values and thus the approval rating for the vehicle.

The European Commission supported an equivalence programme of FST barrier tests (Regulation 95) and CC-CTP tests. The programme was managed by UTAC, France. Many of the tests were witnessed by a group of ‘side impact experts’ from both the automotive industry and members of the EEVC working group. Three cars were evaluated: Mercedes 190, Renault 19 and the Rover Mini, supplied by ACEA. All the vehicles were sequentially produced to minimise manufacturing variance. Tests were carried out by BASt (FST), MIRA (FST), TNO (FST & CC-CTP), UTAC (FST & CC-CTP) and Volvo (Nedcar, Netherlands CC-CTP). The study did not report equivalence between the two procedures and the CC-CTP ceased to be supported, thus further actions from WG13 did not continue.

4.4. Work Task: Reduction in the variability of the Full Scale Test (FST) procedure, Regulation ECE R95.

The draft version of the ECE Regulation 95 originally defined the MDB face by external shape and dynamic performance corridors, plus energy absorption limits. Later on the specification, when it became a regulation, limited manufacturing materials to ‘aluminium honeycomb’ or ‘equivalent’. In effect only aluminium materials were ever used. During the initial years of using the test procedure, within Type Approval process, it was discovered that barriers made by the different barrier manufactures with their individual manufacturing methods and designs could result in significant variation in FST results which was attributable to the barrier face rather than variability in the vehicle manufacture or procedure. WG13 was tasked with investing this issue and making proposals for a revised barrier specification to reduce the unacceptable level of variability. WG13 developed a range of tests to evaluate the barrier faces to try and determine and assess the causes of variability. Following the initial barrier evaluations a revised specification was developed (see Appendix) in which the design and manufacture was closely controlled whilst keeping the original shape and performance specifications. WG13 facilitated a group of barrier manufactures and WG13 members to develop this specification and then to carry out a validation of the final specification. This revised barrier specification was delivered to the EEVC Steering Committee in 2001. It was subsequently included into Regulation ECE R95 and directive 96/27/EC, as a revision.

4.5. Work Task: Coordinate the contributions of the EEVC to IHRA SIWG

During the lifetime of WG13 a similar broader based organisation to the EEVC was created at the 1996 ESV conference, IHRA – International Harmonisation of Research Activities. Side Impact was not a subject area within the original work programme of IHRA but became one in 1998. European Governmentally focussed contributions to the Side Impact Working Group were channelled through the EEVC and WG13. Two members of EEVC WG13 supported the work of the SIWG. The two representatives were Professor Lowne (the first Chairman of WG13) who was succeeded by Mr. Roberts (the current Chairman) on his retirement and by Dr van Ratingen (the National member for the Netherlands).

The first meeting of the IHRA SIWG took place on 19th September 1998. Since then the SIWG has had 23 meetings, the last taking place in Montréal Canada, 23rd June 2005, just prior to the ESV Conference. All documents related to the work of the IHRA SIWG are located on the ihragroups.org web site.

The mission for the IHRA SIWG was set by the IHRA Steering Committee and renewed every two years at the ESV Conference. The last Terms of Reference was set in June 2003, Table 1.

Table 1 - IHRA SIWG: Terms of Reference

SIWG document 138 - 3/6/2003
IHRA SIDE IMPACT WORKING GROUP: NEW TERMS OF REFERENCE
Objective
Co-ordinate research worldwide to support the development of future side impact test procedure(s) to maximise harmonisation with the objective of enhancing safety in real world side crashes.

Scope
In its first 2-year term, the Side Impact Working Group (SIWG) concluded that new test procedures to address the side impact problem should include:

- A mobile deformable barrier to vehicle test
- A vehicle to pole test
- Out of position airbag evaluation
- Sub-systems head impact test

In its next term, the SIWG will also coordinate research to examine the feasibility of improving side impact protection for occupants on the non-struck side and develop a test procedure to evaluate such protection.

Activities
The SIWG is working towards achieving these goals by:

1. Reviewing any new real world crash data to prioritise injury mechanisms and identify associated crash conditions taking into account likely future trends.
2. Taking into account the need to protect both front seat and rear seat(s) adult and child occupants.
3. Interaction with the IHRA Biomechanics Working Group to monitor the development of harmonised injury criteria.
4. Interaction with the IHRA vehicle compatibility working group to ensure solutions in one area do not degrade safety in another.
5. Monitoring and, as appropriate, providing input to the development of WorldSID and any other side impact dummy.
6. Determining the greatest degree of harmonisation feasible and the design and vehicle safety performance implications of adopting different levels of test severity or the worst case condition.
7. Coordinating the evaluation of proposed test procedures subject to availability of test dummies and injury criteria.

Timeframe
While the progress of the group will be reviewed every 2 years, it is expected that:
The target date for draft final proposal of test procedure(s) is 2003 ESV
The target date for final proposal of test procedure(s) is 2005 ESV.

In its early discussions the SIWG considered that best protection in a side impact would be achieved though a suite of integrated complementary test procedures. Two procedures were to be defined to evaluate the main structure of the vehicle: a mobile deformable barrier test and an intruding pole test. Two further procedures were defined to evaluate areas within the vehicle where a) the occupants head could contact and another b) to evaluate occupant's risk of injury in an 'out of position' condition, when internal air bags deployed. Accident studies were collated in the IHRA Biomechanics and Side Impact working groups and used as the foundation criteria for the SIWG test suite[5]. Further input into this phase came from an EC accident study drafted by TRL, TNO, BASt and VOLVO. [4]

It was noted that vehicle fleets were different across the member regions, in IHRA and that more than one type of MDB face may well be needed to address the range of impacting vehicles. The inclusion of two MDB faces was agreed upon: one reflecting the North American large Sports Utility Vehicle (SUV) or Light Truck (LT) and one reflecting the typical European (and Japanese) car. It was acknowledged that in a regulatory framework it may be inappropriate to require compliance to both MDB tests and the study of whether one MDB test would be more stringent than the other was something that would need to be investigated at a later stage, when the two procedures had been finalised.

In order to encourage adequate protection for all occupants the IHRA procedures would be targeted at evaluating injury risk for both front and rear seat occupants, as was already being required in the US Federal Standards and as was recommended by the former EEVC Working Group 9, when the Regulation 95 procedures were being developed.

Responsibility for the development of each of the procedures was shared across the participating regions. The development of the SUV/LT MDB was to be undertaken by North America and Transport Canada, who had already been working with the Insurance Institute for Highway Safety (IIHS). The car type barrier was the responsibility of the EEVC through WG13. WG13 was already undertaking the development of an advanced interior surface test procedure, for side impact, thus WG13 were also tasked with making proposals for a procedure, but expanded to cover rear seating occupants. The North American car industry was already developing an Out Of Position (OOP) test procedure. They were thus tasked with this procedure, within the SIWG.

Side impact is different to frontal in that there are two sides to the vehicle and the occupants can be seated on the 'struck-side' or the 'non-struck side'. Primary attention within the IHRA groups has been applied to protection of the struck-side occupant, as is already prescribed in existing regulations and standards. This focus was carried over into the IHRA work as being of the highest priority. At the same time it was acknowledged that in the future some focus would have to be applied to the non-struck side (far-side) occupant, but this would not be a focus of activity until struck side procedures had been agreed.

Dummies and assessment criteria

The SIWG was not tasked with making proposals on the dummies that should be used in the full scale test procedures or the assessment criteria that should be used with them. This was the task of the equivalent IHRA Biomechanics group.[6]

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[5] These accident studies have not yet been published.

[6] It should be noted that a new side impact dummy, WorldSID, is being developed outside of full control of IHRA and the EEVC and that this dummy, if shown to be 'fit for purpose', might well be the dummy to be used in the test procedures.

The IHRA accident data was suggesting that the population most at risk of injury in a car or SUV test was of small stature and that the population most at risk of injury in ‘pole type impacts’ was the mid-size male. It was therefore suggested that the MDB test procedure would probably use the 5th %ile WorldSID and the pole test the 50th %ile WorldSID.

The EuroSID-1 and then the ES-2 dummy was used for the European development work on the MDB and interior surface procedures. In North America developments with the Large SUV barrier were undertaken using the 5th %ile SID-IIs dummy, a dummy that is not used in Europe.

4.6. Work Task: IHRA - Development of the advanced mobile deformable barrier face (AE-MDB) appropriate for the European accident situation

The research progress of WG13 concerning the development of the AE-MDB (Advanced European – Mobile Deformable Barrier) face have been reported in two ESV papers, 2003[5] and 2005[6]. The name AE-MDB was adopted to differentiate it from the MDB, used in Regulation 95.

The Regulation 95 barrier characteristics were based on vehicle characteristics of the 1970/80s assessed in flat rigid wall tests. During this period many cars had engines longitudinally placed which meant that the primary stiffness of the vehicle and the inertial mass of the engine was located in the lower central area of the car. Vehicle design has changed with engines now being placed laterally across the car possibly due to the influence of ECE Regulation 94, the frontal offset test procedure and other engineering/spatial reasons. It was agreed by WG13 members that a new more advanced barrier face was needed in an advanced test procedure and that its characteristics should be based on appropriate vehicle stiffness data and on its behaviour in replicating ‘real world’ type loading situations.

In the first phase of research WG13 selected two vehicles as base line target cars (Renault Megane and the Toyota Camry) typical of modern European cars with worldwide appeal. Two other vehicles were chosen representing a typical family car (Ford Mondeo), achieving a reasonable EuroNCAP[7] score and a small European SUV (Landrover Freelander), which could also be classed as a large family car, as bullet vehicles. The accident configuration that was chosen for the base line condition was a perpendicular car to car impact with both vehicles moving 48km/hr (Bullet) and 24/km/hr (Target). The fore and aft alignment was chosen such that both front and rear seat occupants would be loaded. The centre line of the bullet vehicle, at the point of impact, was aligned with the front seat occupant’s H point. Due to the forward motion of the target vehicle the rear seat occupant would move forward into the front of the bullet vehicle. The two target vehicles were chosen from different manufactures to ensure that the results were not influenced by single vehicle impact oddities.

The Version 1 AE-MDB barrier face was based on; load cell wall data from a number of different modern vehicles, the shape of more modern vehicles, the intrusion profiles from the base line impacted vehicles, including the comments made in the accident studies and the desire to load simultaneously both the front and rear occupants, in a perpendicular impact in which the bullet vehicle was not travelling forward, as was used in Regulation 95. In addition the North American (IHRA) SUV barrier face was also tested to see how it would compare and whether it had the potential to be an acceptable barrier for use in Europe, which would have been counter the former view of WG13, which suggested that the barrier was not appropriate for European application. The results from this study were published in 2003 at

ESV [5]. The study confirmed the former views of the WG13 that the American barrier face was inappropriate and that the AE-MDB face and its design principles were moving in the correct direction and that further developments were needed.

4.6.1. Barrier face design: progress since 2003

The barrier faces used in the initial research programme (up to 2003) were concept barriers that did not necessarily meet the proposed stiffness targets, but were ‘good enough for first evaluations’. They were also made from ‘off the shelf’ materials. To minimise development costs and ease production of a new barrier face the honeycomb stiffnesses were chosen to be the same as those that were being used in the Regulation 95 barrier, except for one block area which needed a different stiffness material. Certification stiffness corridors for each of the block areas were developed, following the 2003 ESV paper, based on the standard materials and including the shape of the barrier with sloping sides and cut out areas. The certified ‘outer block areas’ were also increased to compensate for the wider barrier and full width barrier certification. The build specification was enhanced to reflect the revised build details included in the updated Regulation 95 barrier design, Section 4.4. This document was circulated to most/all of the MDB manufactures for comment to ensure that it was defining a product that all of them could manufacture so that it gave no one supplier any preferential status.

During the period (2003-2005) further full scale flat load cell wall test results became available for a number of other vehicles, which confirmed that the stiffness targets set for the AE-MDB specification, in this test configuration, were appropriate. There have subsequently been suggestions, from WG15 and various industry members (Toyota, VW, DaimlerChrysler), that the flat load cell wall test can not fully assess the stiffness of modern vehicles and the presence of laterally placed stiffening structures (cross beams). It is acknowledged in WG13 that the simple flat wall test is deficient in this respect but to date no other information sources are available against which to set better design and certification targets for a barrier face. Some soft-faced load cell wall data is available, from the VC-COMPAT and other programmes. The measured forces on the wall are a combination of the stiffness of the front of the vehicle and the crushing soft face, which behaves like a heavy mechanical filter. It is not possible to extract the vehicle stiffness characterises from the combined data against which to define MDB requirements thus this data can not be used to develop an MDB specification, appropriate for a Regulation. It was suggested that it may be possible to obtain such stiffness data from computer simulations. It was noted in WG13 that such simulations would have to be very complex ones, based on new vehicles and those would probably only be available within vehicle manufactures and would probably be commercially confidential. No simulation based data has been procured by WG13 against which a stiffness distribution (local and global) could be defined.

In the WG13 research AE-MDB to load cell wall testing have been carried out, by a couple of institutes, to confirm the build accuracy and quality of the second generation barriers and to evaluate their variability, (Version 2).[7] Results of the latest load cell wall tests were presented in the 2005 ESV paper. [6]

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[7] It should be noted that WG13 member organisations were not sponsoring an MDB development programme with any MDB manufacturer but the results did show that it was possible to build barriers to the new specification with minimal development and produce barrier faces that were very close the desired specifications.

4.6.2. Further base line tests

Further base line car to car tests were performed during this time period with different target cars, replicating the tests that had been done for the 2003 ESV report. One of the bullet cars was changed in this evaluation, the vehicles being supplied by the industry partners within WG13. The two new target vehicles were the Alpha 147 and the Toyota Corolla, both 3 door cars. The Land Rover Freelander remained the SUV/large family car bullet but the Ford Mondeo was replaced by the Toyota Corolla. The results of these tests: deformation profiles, door intrusion velocity profiles and dummy results were included in the 2005 ESV paper. [6].

4.6.3. Performance of the revised barrier

AE-MDB barriers conforming to the revised specification were tested into the Toyota Corolla and the Alfa 147 by WG13 members. These results were compared to the base line tests and presented in the 2005 ESV paper. The deformation of the Alfa 147 with the AE-MDB V2 was more equivalent to or above the severity of the Freelander.

4.6.4. Further studies of a revised specification

Another approach to obtain deformation data and impact severity data is by means of simulation. Such work was carried out by the car industry, presented by VW and DC. Simulations where run with changed stiffness distributions for the lower row of the AE-MDB. The stiffness distributions were analysed in relation to the stiffness the AE-MDB V2 with and without bumper beam.

Tests of an AE-MDB Version 2, Freelander and VW Golf V vs a VW Golf V were performed by Volkswagen and TNO and presented to WG 13. It was noted that the AE-MDB (Version 2) was more aggressive to the doors than all the other cars.

VW *(supported by other German manufacturers)* have made several proposals to change the stiffness distribution of the AE-MDB so that it engages and loads the B post more (versions 3.4 and 3.6 Table 2)[8]. Their studies have used computer modelling techniques. They have made proposals to reduce the stiffness of the outer lower blocks and increasing the stiffness of the central lower block. Their proposed design also incorporates a beam element[9]. Toyota/JARI has also carried out computer simulations and tests with the Toyota Prius, using a barrier very similar to Version 3.1, Table 2[10].

At the January 2005 meeting of WG 13 a number of different possible designs of barrier face were discussed, Table 2. At that meeting there was no consensus as to the best single barrier face design to investigate further. Of the suggested designs WG13 were of the opinion that versions 3.1, 3.4, 3.6, 3.8 and 3.9 were worthy of further investigation.

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[8] Most of the version 3n barriers include a bumper beam element

[9] Presented to WG13 at the 37th meeting December 2004

[10] Presented to WG13 at the 38th meeting January 2005

Table 2 Possible future barrier designs and preferred (**p**) options by WG13

			Beam construction				Countries							observer	
Name	Description		Plate	Honey	Plate		UK	NL	D	ES	Fr.	I	J	Fr.	D.
V2	V2		mm		mm	deleted in September Meeting									
V3.1		+Bumper	3	214	3	best by Japan investigation	p				p		p	p	
V3.2		+Bumper	5	214	5	deleted in Dec.									
V3.3		+Bumper	0.5	214	3	deleted in Dec.									
V3.4	V2 40/60/40	+Bumper	3	214	3	best by VW, BMW, Porsche, Audi, Merc. Investigations						p			p
V3.5		no Bumper				deleted Jan?						p			
V3.6	V2 70/60/70	+Bumper	3	214	3	alternative middle		p	p	p			p	p	p
V3.7		no Bumper				deleted Jan?									
V3.8	V2 100/ new E/100					TRL suggest to change only the middle block	p				p			p	
V3.9	V2 55/60/55	+Bumper	3	214	3	BASt new middle of 3.4 and 3.6		p	p						p

Several organisations that support the work of WG13 are also members of the APROSYS consortium, Section 4.6.6, and have been carrying out additional tests within that programme. These tests have included new car to car tests, AE-MDB to car tests as well as computer simulation studies. Some of these results have been presented to WG13. The results that have been presented are largely based on the VW Golf V, which includes a substantial bumper beam and is seen to load the B post to a much greater extent than has been observed when compared to the equivalent test using the Version 2 AE-MDB. Simulation studies by VW and other German manufacturers have suggested that for 'Golf V equivalence' the central lower block should be increased in stiffness and the other lower blocks weakened. It has been suggested that a barrier conforming to this force distribution would not meet the WG13 force corridors which have been part of the WG13 design criteria. Further details are presented in Section 4.6.6.

4.6.5. Status of the AE-MDB (Version 2) development *(presented in the ESV 2005)*.

The conclusions presented at the 2005 ESV conference were:

1. The completed review of the stiffness of modern vehicle frontal structures has complemented the previous data studied and presented by WG13, which lead to the current stiffness distribution for the AE-MDB.
2. From baseline vehicle testing, the AE-MDB has, in some areas, been shown to be representative of the baseline deformation profiles but when impacted by some more modern vehicles deformation profiles do not reflect the presence of bumper beams.
3. The deformation produced by the AE-MDB is, in some cases, above that of the baseline tests in the softer areas of the target vehicles (mid doors).
4. In the stiffer areas of the target vehicle (B pillar), the deformation caused by the AE-MDB was less than that applied by the most severe baseline test.

5. Most of the dummy injury parameters were well below the critical values used in the current European regulatory procedure, Regulation 95, even when localised intrusion is greater than that of the severer baseline test.
6. The ongoing research is expected to lead to proposals to update the AE-MDB (Version 2) design specification. However no firm direction has yet been determined by WG13.

At the time of the ESV 2005 conference WG13 were not in a position to make a recommendation on an AE-MDB barrier design for use in an advanced test procedure.

It should be noted that some WG13 members have been investigating alternative block stiffness distributions and that this research is ongoing and is being partially covered within the APROSYS project.

4.6.5.1. JARI contributions

JARI were invited to be participants in the activities of WG13 as it related to WG13's activities in support of the IHRA SIWG (circa 2002). Early on it was known that the Japanese were themselves investigating a revised barrier face. It was subsequently discovered that the new Japanese barrier face was very similar to the one being developed within WG13 thus our efforts were combined and JARI decided to continue their research using the initial WG13 AE-MDB.

JARI have been carrying out tests in a slightly different configuration to WG13 using the EuroSID-1, ES-2, SID-IIs (in the rear) and WorldSID dummies with the test configuration equivalent to that specified in Regulation ECE R95, the barrier being targeted on the front seat H point. In addition their base line tests were not moving car to moving car but into a stationary target vehicle. Latterly they have indicated that post impact gross deformation using the AE-MDB barrier was more than they were hoping for, adjacent to the two occupants and produced a special evaluation barrier which included a beam element across the front of the standard AE-MDB barrier, having removed the front 50mm. Only one test had been reported at the 38th meeting of WG13. They report that they believe that this is a reasonable way forward and that further trials were needed with a modified beam. Reports on any further testing have not been made.

4.6.5.2. The future of the AE-MDB

It is not possible to indicate with any certainty what the final design of the AE-MDB may be. Some of the members of WG13 are participating in the APROSYS project and carrying out some further evaluations on alternative MDB designs. At the time of drafting this report WG13 is not able to make any comments on these developments. There is a general consensuses view that the Specification 2 MDB may need to be modified to include some form of cross linking structure but that there is very little data against which it could be defined in a barrier specification. A change in block stiffness may be needed but what these changes may be to achieve the aims of the EEVC are not clear.

4.6.5.3. AE-MDB test procedure

The AE-MDB test procedure is very similar to that which is defined in Regulation 95. It is a perpendicular test with an increased trolley mass of 1500kg compared to 950kg in Regulation 95. Two side impact dummies are to be used in the struck side seating position. Barrier alignment is 250mm rearwards of the front seat 'R point', to load both the front and rear seat occupants simultaneously. The draft procedure is included in the Appendix.

4.6.6. APROSYS

APROSYS is a 6th Framework EC supported programme of research. Twelve partners[11] are working in Sub-package 1 (SP1), the sub-package dealing with the advanced IHRA test procedures. Five members of WG13 are working within the APROSYS consortium in this work package supported by a number of different organisations.

One of the main activities in SP1 Work Package 1 has been to evaluate the suite of IHRA SIWG test procedures. Since WG13 have not been in a position to make a final recommendation on a AE-MDB design APROSYS members indicated that they could target part of the APROSYS resources into looking at it.

APROSYS members decided to look at two versions of the AE-MDB, which had been discussed at the January 2005 meeting with WG13, version 3.1 and 3.9, Table 2, in full scale testing. Both of the barriers included a lateral beam: version 3.1 with the original block stiffnesses and version 3.9, with block area stiffnesses different to that of the WG13 AE-MDB Version 2 and more aligned with the computer modelled barriers. Further base line tests were performed (Golf V and Freelander to Golf V and Ford Fiesta) and MDB tests (version 3.1 and 3.9) into other vehicles: Golf, Fiesta, Volvo S80, Toyota Prius and Mercedes E-class.

The available results of the APROSYS research were briefly referred to in the oral presentation made on the AE-MDB development, at the ESV 2005 conference.

4.7. Work Task: IHRA - Extension of the Interior Surface Test Procedure for use in rear seating positions

Section 4.2 details much of the work that went into the development of the IHRA version of the interior surface test procedure. The procedure is identical to that which was developed for European application but is extended to include rear seating positions. The research carried out to support this extension covered: an extension to the accident studies, the definition of impact zones and the derivation of impact vectors.

The one area that has not been included is the assessment of the firing of any rear head airbags assuming that firing was triggered independent of frontal systems; i.e. a pole test to a rear seat position.

4.8. Pole test

The EEVC WG13 internal surface test procedure includes the use of a full scale pole test if active head protection systems are included as part of the occupant protection package. Within the EEVC interior surface test procedure a perpendicular pole test is described using the ES-2 dummy. Within the IHRA framework of procedures North America was tasked with proposing an advanced pole based test. The test proposed by NHTSA is different to that being used in the existing Federal Standards and proposed by WG13. The new procedure is an oblique pole test at 75 degrees and at a higher velocity (32km/hr compared to 29km/hr). WG13 has not been able to investigate the merits of the IHRA oblique pole test, as it is not within the group’s terms of reference or resources. The WG13 assumption is made that if the IHRA proposed pole test is shown to be at least equivalent to the defined perpendicular one then the perpendicular test would be substituted with the IHRA oblique version.

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[11] TNO, TRL, Cellbond Composites, CRF (Centre Ricerche Fiat), FIAT, Toyota, VW, INSIA/UPA (University of Madrid), IDIADA (IDIADA Automotive Technology), BASt, TUG (University of Graz), TK-P (Takata-Petri)

4.8.1. Pole test and APROSYS

It is noted that several pole tests and simulations have been carried out within APROSYS and by IHRA SIWG members, but WG13 has not had the opportunity to review this data.

4.9. Out of Position

WG13 has done no work in reviewing the IHRA OOP test procedure. The only discussion that has taken place within WG13 queried whether such a procedure is needed in Europe and whether an OOP problem exists in European vehicles.

4.9.1. OOP and APROSYS

An evaluation of the IHRA OOP procedure is being carried out by partners in the APROSYS project, including WG13 members, with a focus on the European situation.

5. Publications

Eleven documents were published by EEVC WG13, with the approval of the EEVC SC, as well as a suite of test data, video and picture emanating from the test programme. This test data led to the specification of the revised Mobile Deformable Barrier face that was adopted in 19XX in a revision the UN/ECE Regulation 95 and was published to enable computer models of the barrier face to be developed against a common data source. All to the documents are available on the EEVC web site.

1. The Development of an Advanced European Mobile Deformable Barrier Face (AE-MDB), 19th ESV Conference 2005
2. EEVC Research in the Field of Developing a European Interior Headform Test Procedure, 19th ESV Conference 2005
3. EEVC Side Impact Head Protection Test Procedure - Encompassing both front and rear seating positions
4. Development of a European Side Impact Interior Headform Test Procedure - 18th ESV Conference 2003.
5. Progress on the Development of the Advanced European Mobile Deformable Barrier Face (AE-MDB) - 18th ESV Conference 2003.
6. Recommendations for a Revised Specification for the EEVC Mobile Deformable Barrier Face.
7. Research Progress on Improved Side Impact Protection - 17th ESV Conference 2001, Amsterdam.
8. Head Contacts in Side Impact - An Accident Analysis February 2000.
9. The Evaluation of Sub-Systems Methods for Measuring the Lateral Head Impact Performance of Cars. 15th ESV Conference 1996, Melbourne, Australia, Paper No 96-S8-O-07
10. Test Methods for Evaluating and Comparing The Performance Of Side Impact Barrier Faces. ESV Conference 1998, Windsor, Canada, Paper No 98-S8-O-02.
11. A Review of the Influence of Guidance Methods on the Performance of the Free Motion Head-Form, for Use in Interior Surface Evaluation. September 1999.

6. Current Status of WG13 activities

This report was reviewed and approved by WG13 at a special meeting called to review the report on 8th December 2005. The current 'active' terms of reference refer to the interior surface test procedure and 'support for IHRA activities'. A report on the former work topic has now been delivered to the EEVC Steering Committee and awaits Steering Committee direction. IHRA working group activities are under review and await the IHRA steering committee to formulate a forward strategy. When this has been completed it is expected that the EEVC Steering Committee will need to give further direction to WG13, regarding further European Governmental support.

The EEVC Steering Committee has requested that EEVC working groups examine their terms of reference as part of a review process and indicate time scales where activities and reports might be forthcoming. WG13 has not met to discuss these issues but have formulated a range of suggestions for Steering Committee consideration, Section 7.

7. Proposed future activities for WG13

- The EEVC Steering Committee formerly requested that WG13 make proposals for an 'interior surface test procedure' for side impact. A report on this procedure has been submitted to the Steering Committee, accepted and is now publicly available. The procedure described in the report has undergone many changes during its development to reduce ambiguity and variability. Unfortunately the procedure still includes several options, as WG13 members were not unanimous in their views that one method was significantly better than another. The final procedure has not been widely validated. Some issues need further refinement and confirmation. Validation of the procedure is taking place within the EC APROSYS project and by some organisations within the IHRA framework. In the current document references are made to the potential advantages of using a symmetrical headform. This late proposal has not been evaluated by WG13 members[12]. It is suggested that the use of such a test device for interior surface evaluation should be investigated to determine whether its use could remove some of the identified problems thus negating the 'alternatives' in the existing test procedure document. If the alternative impactor were to be an improvement then the test procedure could be simplified and potentially made easier to integrate into new or existing European Regulations.
    - It is proposed that WG13 be asked: To review the evaluations by APROSYS and IHRA members of the current EEVC interior surface test procedure within [1 year].
    - It is proposed that WG13 be asked: To review the potential benefits of adopting a symmetrical impactor, thus overcoming some of the identified issues. A revised improved procedure would then be presented to the EEVC Steering Committee within [1 year].[13] *Issues of harmonisation with FMVSS201 should be included in this review.*
    - It is proposed that WG13 be asked: To quantify the benefits that would be accrued if the procedure were to be incorporated into regulation (for front seat positions), within [1 year].

- The interior surface test procedure does not cover certain types of vehicle, e.g. removable hard tops or soft top vehicles. Further research is needed to decide if such vehicles should be included in the procedure and the procedure that should be used with them.

Proposals for an improved procedure would be presented to the EEVC Steering Committee within [2 years]

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[12] A symmetrical impactor is now is defined for use in the European Pedestrian Regulation.

[13] Times subject to available resources.

- WG13 has carried out research into an advanced barrier-based side impact. In addition other organisations, e.g. within APROSYS, have carried out further research looking at alternative barrier designs. Some questions have also been raised considering the severity of the test, by the EEVC SC and the way different versions of the barrier face load the side of a vehicle and the occupants in WG13.
  - It is proposed that WG13 be asked: To review the updated AE MDB barrier and test procedure as proposed by the APROSYS project and other bodies that have evaluated the barrier and procedure.
  - To liase with WG21 into the severity of the developing test procedure and the way it would encourage the enhancement of occupant protection. A review report should be completed in [18 months], outlining progress and directions forwards in terms of possible advances in regulatory activity

- WG13, as a group, has not investigated at the IHRA (oblique) pole test procedure, which is different to that detailed in the interior surface test procedure.
  - `It is proposed that WG13 be asked: To review the basis of the oblique pole test and the added value of it over the perpendicular test for use in the interior surface test procedure and advise the EEVC Steering Committee accordingly, within [1 year]. *(The main issue being harmonisation)*

- Currently in Europe side impact is only assessed at a regulatory level by the one MDB test (Regulation 95). A narrow intruding test is only proposed, by WG13, if active head protection systems are fitted. A pole test could be used to enhance the assessment of primary safety systems, as is proposed by the IHRA SIWG. WG13 has not been asked to advise the EEVC Steering Committee on this particular test procedure, if applied regardless of the interior surface test procedure. Some assessments have been carried out within APROSYS and by other groups comparing the perpendicular and oblique pole test.
  - It is proposed that WG13 be asked: to evaluate the work carried out in APROSYS and by others and to quantify the potential of the pole test, perpendicular and oblique, if applied outside of the interior surface test procedure, in a regulatory manner and advise the EEVC Steering Committee accordingly within [1 year].

- It is proposed that WG13 be asked: To review the IHRA OOP test procedure and advise the Steering Committee on whether it is needed for European application within [1 year]. This would build upon the work taking place in the APROSYS project, scheduled to be available Sept 2006.

- No study has been carried out into the complimentary nature of the IHRA suite of procedures and the benefits that could be accrued if the regulatory authorities were to adopt the procedures ‘as a suite’ or if they were to be selectively adopted.
  - It is proposed that WG13 be asked: To review the costs and benefits of adopting the proposed suite of test procedures, MDB, Pole, Interior surface and OOP and advise the EEVC Steering Committee accordingly within [1 year]. This would build upon the work taking place in the APROSYS project.

- It is proposed that WG13 be asked: To support any organisation that supersedes the current IHRA framework.

8. References

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7. *EuroNCAP*.

9. Annex: Principle published Reports

9.1. Interior Surface Test Procedure: 15th ESV paper 1996

THE EVALUATION OF SUB-SYSTEMS METHODS FOR MEASURING THE LATERAL HEAD IMPACT PERFORMANCE OF CARS

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Paper No 96-S8-O-07

THE EVALUATION OF SUB-SYSTEMS METHODS FOR MEASURING THE LATERAL HEAD IMPACT PERFORMANCE OF CARS

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Paper No 96-S8-O-07

ABSTRACT

The EEVC Side Impact Test Procedure includes the measurement of head impact with the EUROSID dummy. It was recognised that this would evaluate only a limited range of the potential head contact locations within the vehicle. EEVC commenced a study of accident analysis and the evaluation of potential head impact sub-systems tests. Three alternative headforms have been appraised and the effect of free flight and linearly guided impacts have been examined. The objective was to develop a simple, repeatable and representative sub-system test procedure.

This paper presents progress of the EEVC study and the initial results of the test programme. Proposals are made for a possible test method and for a future validation test programme.

INTRODUCTION

The EEVC developed a new impact test procedure for the evaluation of the protection afforded to struck side car occupants in the event of a side impact to the passenger compartment. The final presentation of this test procedure was given in the EEVC paper to the Twelfth ESV Conference in 1989[1]. EEVC developed a new dummy for use with the test procedure (EUROSID) since there was no dummy available at that time suitable for use in side impact testing. The dummy was designed to be able to detect injury risk in the four areas of the body which were most frequently injured at AIS 3 or greater: the head, chest, abdomen and pelvis.

The test procedure is intended to evaluate the protection for a restrained occupant. Under these conditions, the area of the vehicle which impacts the occupant is in most cases confined to the area adjacent to that body area in the normal seating position and these are the areas that are evaluated in the test procedure. However this is not true for the head. Accident studies demonstrated that the area of the vehicle struck by the head is considerably wider than that adjacent to the head. In many cases of serious injury, the head impacts objects outside the vehicle. However there were a significant number of cases of serious injury to the head from contact with the interior of the vehicle. In typical side impact tests the head of the EUROSID dummy frequently does not make contact with the vehicle interior, passing through the side window which is usually broken before the dummy head reaches it. In those cases where the dummy head does strike the interior, it is at a position alongside the original position of the head. In the EEVC side impact test procedure, the dummy head will not evaluate the wide range of positions that are contacted by occupants' heads in accidents.

The EEVC recognised this situation in the final report of the side impact test procedure[2] and concluded that there was a need to investigate the requirements for a supplementary headform test.

EEVC Working Group 13 are developing a head impact test procedure for evaluating the head protection provided in the range of locations for head impact that have been observed in side impacts based on analyses of detailed accident studies. A three phase research programme has been developed to provide the basis for this test procedure which could be used as a supplement to the current full scale side impact test.

In the first phase, three potential headforms have been evaluated in free-flight impacts to targets representing simplified forms of the internal structures of cars that could be impacted by the head. The second phase will study the relative merits of free flight and linearly controlled impacts, using the preferred headform and the third phase will study the application of the proposed test method to whole vehicles and sub-systems and consider the practical level of improvement possible. One sample of the FMH and AAMA headform was available to the group. Each test laboratory used their own EEVC headform, thus the results for the

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EEVC tests include an additional level of variability not experienced with the other two headforms.

This paper reports on two accident analyses supporting the need for the work and gives the results of the first phase of the study.

ACCIDENT ANALYSIS

Accident investigations have identified head impact as a very important and common source of serious injury in side impacts. Otte[3] showed that over 47% of injuries occurred to the head of a struck side occupant in a side impact compared with only 30% to a driver in a frontal impact. Thomas et. al.[4] reviewed some UK accident data examining injury distribution and severity of injury in side impact. Thomas was able to determine that 41% of all head contacts were to the side glass, 11% were to the B post and seat belt anchorage, 6% to the header rail and 1% to the A post. NHTSA has recognised the importance of head impact and has developed its own subsystems test, although this is intended to cover front impacts and rollover in addition to side impacts. They estimate that 19% of head injuries would be affected if the contacted surfaces were padded.[5]

Table 1 Severity of head injury in TRL and Hannover accident samples (side impacts).

DATA BASE	TRL		Hannover	
AIS	1-2	3-6	1-2	3-6
Sub totals	227	81	285	51
Total	*308*		*336*	

In order to identify better the problems of head impact in side impacts, the data bases to which the working group have access have been interrogated. This analysis has concentrated on examining the severity of head injury against the areas of the vehicle interior that have been identified by the accident investigators as being contacted by the head. The two data bases examined are from TRL, the Co-operative Crash Injury Study (CCIS)[6], and the Hannover data base from Germany[7]. The analysis was restricted to side impacts with a direction of impact coded as 2, 3 or 4 o'clock and 8, 9 or 10 o’clock. The data were examined for both struck-side and non struck-side occupants with and without an occupant seated along side. Table 1 shows the size of the accident sample from which the working group analysis has been made. Tables 2 and 3 give the distribution of injuries against contacts as coded in the data for both struck-side and non struck-side occupants. These results indicate that between 40 and 60 per cent of head contacts were to the interior of the vehicle.

Table 2 Single Head Impact Contacts - Restrained struck-side occupants

CONTACT	TRL		Hannover	
	AIS 1-2	AIS 3-6	AIS 1-2	AIS 3-6
A Pillar	6	2		
B Pillar	21	9	50	21
Windscreen	7	1		
Window frame and roof rail	6	3	33	6
Glass	76	2	120	4
Facia	3	1		
Door	7	6	83	4
Roof	3	2		
Light	1		1	
Steering Wheel	2	1		
Sun visor	1			
Rear Window	1			
Ejection		1		
Other Occupants	4		1	
External object	12	35		
Other Contact	1	3		
Not Known	57	7		
No Contact	1	1		
Total number of cases	*209*	*74*	*238*	*35*

The two data bases show slightly different patterns of contact injury but this can easily be attributed to differences in accident collection strategies. Even so there is a clear indication that the B pillar and structure around the side window is an important area for injury producing contacts. The data also clearly show that potential contacts can occur over a large area of the side of the vehicle. The full scale impact test only evaluates injury severity for the head at one contact location, if head contact occurs at all in the particular test. The large area of possible head injury contacts shown in these studies strongly indicates that there is a need for additional impact evaluations, in order to reduce head injury risk in accidents.

Table 3 Single Head Impact Contacts - Non struck-side occupant with impact on opposite side.

Contact	TRL		Hannover	
	AIS 1-2	AIS 3-6	AIS 1-2	AIS 3-6
A Pillar			5	
B Pillar		2	6	2
Windscreen	1			
Window frame and roof rail	1	1	7	4
Glass	6		9	2
Door	3	3	20	8
External object		1		
Other Contact	1			
Not Known	6			
Total number of cases	*18*	*7*	*47*	*16*

HEADFORM EVALUATION

The aim of the research programme is to develop a reliable and sensitive subsystems head impact test procedure that can be used to reduce the severity of head injury in side impacts. Three headforms are currently available that could be used for evaluating the interior surfaces of vehicles. One is specified for use in the proposed ECE pedestrian test procedure[8] (called EEVC headform in this paper) another is based on the Hybrid III dummy head and is specified for use in FMVSS 201 test procedure[9] and is referred to as the FMH. The third headform, which, like the EEVC impactor, is also spherical, is called the AAMA headform in this report[10]. In order to determine which of the three headforms would be preferred for use in this test procedure, a comparative test programme has been developed within the Working Group.

The objectives of the first phase of the programme are to assess the three head forms in free flight impact by investigating :-

- sensitivity to changes in the structure impacted
- repeatability
- reproducibility

In addition to these parameters, other aspects of the headforms, such as details regarding handling, could be assessed.

The Annex to this paper describes in detail the configurations of impact used in the phase 1 programme.

For an impactor to be useful for determining variations in injury risk it must be able to discriminate between different paddings and be able to detect changes in any underlying yielding or non yielding structure and the presence of any hidden hardspots. Two types of test have been used to study these attributes. The first was based on a rigid surface onto which paddings with different characteristics were attached. In order to determine if the head forms could identify any hidden hard objects, this simple test was enhanced by adding a rigid object, in the form of a 10 mm square section steel bar, below the surface.

It was recognised that, in practice, the impactor would be likely to be used to evaluate padding fixed to yielding structures. Therefore some impact tests were included to check the ability of the head forms to discriminate paddings on a surrogate deformable B-post manufactured specifically for this test programme. For added realism, tests to modified B-posts, weakened by incorporating large holes, were performed to determine the relative effects on these head forms.

Impact tests to the B-pillar simulations were performed at 6.7 m/s while those to the padded rigid surfaces were performed at 2.5 m/s to keep the responses to within reasonable limits.

The simplest test to perform would be a perpendicular impact. However it was recognised that not all surfaces would be impacted normal to their surface in accidents. Therefore additional tests at 45E were performed to determine whether it would be necessary to include an angled impact test into the test procedure in order to be able to distinguish between different structural designs or whether the simple perpendicular impact would be sufficient to characterise the performance at that position. In addition offset tests, where the axis of the impact was not in line with the hidden structure changes, were performed to determine the head forms sensitivity to impact position.

The padding materials were chosen and manufactured specially for this evaluation in order to represent different yet typical automotive paddings. The padding thickness covering the B posts and plain rigid surfaces was 10 mm thick while that for the padded surfaces with a rigid hard spot was 25 mm thick. The stiffness of the B posts sections was calculated to be representative of real B posts and to allow deformation without complete collapse of the pillar. In order to standardise the impact surfaces characteristics all test surfaces were covered with a flexible vinyl covering.

In order to make some assessment of impact repeatability, all of the tests were performed twice except for the three simple certification drop tests from 376 mm onto a rigid surface which were replicated three times with each head form.

PHASE 1 TEST RESULTS

Phase 1 tests can be split into three types. Firstly 'certification' type tests based on tests that are used to verify that the response of dummy heads are within prescribed limits. The second type of tests were very simple flat surface tests which have been designed to evaluate the sensitivity of the head forms to different padding systems and the presence of hidden hard spots buried within the padding. The third test series was closer to the 'in vehicle' situation. These last tests are similar to the second type but in these, the padding was attached to a yielding surrogate 'B post'.

All of the following tables present the data in a similar manner. Since each test was performed more than once the mean value of the repeated tests is present along with the range expressed as a percentage of the mean.

Apart from Table 4, which gives the results of the certification type tests, the mean measurements are then compared for two test conditions. The difference between the mean for the second test condition from the first test condition is expressed as a percentage of the first mentioned mean test result. Since the head forms were instrumented with accelerometers the values of peak acceleration (g) and Head Injury Criteria (HIC) are presented. All data were filtered at Channel Filter Class 1000.

Each test configuration is categorised by a two digit code. The first character refers to the configuration type and the following letter refers to impact alignment. Full details of the configurations and coding are presented in the Annex.

Table 4 shows the results of the certification tests and Tables 5 - 18 the results of the free flight tests into different surfaces.

Certification tests

Each head was dropped three times onto the rigid surface, configuration 1a. The results of these tests are presented in Table 4. Apart from indicating conformance to certification requirements the data can give some measure of repeatability under this simple controlled condition. The coefficients of variation for the test results are given in Table 4, although, as these are based on only three results, they cannot be regarded as reliable.

Table 4 Certification (and repeatability) tests of the head forms

Headform	**AAMA**	**EEVC**	**FMH**	**AAMA**	**EEVC**	**FMH**
	Peak Accel. (g)			HIC		
TRL mean	240.9	251	233	803	863.4	682.3
TRL Std. deviation	24.9	15.9	3.7	130.6	103	22.3
TRL Coef of var (%)	**10.3**	**6.3**	**1.6**	**16.3**	**11.9**	**3.3**
TNO mean	251.3	245.7	227.9	784.8	791.2	608.8
TNO Std. deviation	6.3	4.0	7.5	29.2	22.7	18.9
TNO Coef of var (%)	**2.5**	**1.3**	**3.3**	**3.7**	**2.7**	**3.1**
BASt mean	240.1	218.7	236.4	737	661.9	675.2
BASt Std. deviation	3.5	3.8	2.5	13.4	16.1	11.8
BASt Coef of var (%)	**1.5**	**1.7**	**1.1**	**1.8**	**2.4**	**1.7**

Note - Three repeat tests.
- Single sample of AAMA and FMH head forms

Effect of Padding

Tables 5 - 11 compare the sensitivity of the headforms to different types of padding. Table 5 compares the responses of the headforms in tests with two padding types supported on a flat rigid plate in perpendicular impacts (configuration 2a)

Table 5 Configuration 2a Discrimination of padding material in perpendicular impact

Headform	**AAMA**	**EEVC**	**FMH**	**AAMA**	**EEVC**	**FMH**
	Peak Accel. (g)			HIC		
Polyurethane mean	165.2	95.8	144.3	518.3	201.2	430.9
Polyurethane range	*1.9%*	*4.4%*	*2.1%*	*2.9%*	*10.4%*	*2.1%*
Polypropylene mean	242.7	151.2	200.6	959.5	395.4	684.3
Polypropylene range	*0.3%*	*1.2%*	*1.3%*	*1.3%*	*2.3%*	*3.0%*
Percentage variation from Polyurethane	**47%**	**58%**	**39%**	**85%**	**97%**	**59%**

Tables 6, 7, 8 and 9 show the responses in the presence of a hardspot hidden within the padding in perpendicular and angled impacts (configurations 3a, 3B, 3c and 3d)

Table 6 Configuration 3a Discrimination of padding material in perpendicular impact with hardspot

Headform	**AAMA**	**EEVC**	**FMH**	**AAMA**	**EEVC**	**FMH**
	Peak Accel. (g)			HIC		
Polyurethane mean	82.4	70.3	90.6	231.4	160.9	283.1
Polyurethane range	*2.9%*	*0.3%*	*1.8%*	*0.7%*	*0.1%*	*1.7%*
Polypropylene mean	132.2	74.9	121.1	356	145.1	318
Polypropylene range	*12.3%*	*17.1%*	*10.3%*	*18.0%*	*21.7%*	*13.0%*
Percentage variation from Polyurethane	**60%**	**7%**	**34%**	**54%**	**-10%**	**12%**

Table 8 Configuration 3c Discrimination of padding material in perpendicular impact with offset hardspot

Headform	**AAMA**	**EEVC**	**FMH**	**AAMA**	**EEVC**	**FMH**
	Peak Accel. (g)			HIC		
Polyurethane mean	86.9	70.8	90	247.9	163.8	273.6
Polyurethane range	*0.9%*	*1.4%*	*1.1%*	*0.8%*	*2.1%*	*2.7%*
Polypropylene mean	142.5	71.9	109.5	405.2	140.6	281.3
Polypropylene range	*3.6%*	*11.4%*	*15.7%*	*7.1%*	*16.6%*	*17.4%*
Percentage variation from Polyurethane	**64%**	**2%**	**22%**	**63%**	**-14%**	**3%**

Table 7 Configuration 3d. Discrimination of padding material in oblique impact with hardspot.

Headform	**AAMA**	**EEVC**	**FMH**	**AAMA**	**EEVC**	**FMH**
	Peak Accel. (g)			HIC		
Polyurethane mean	40.1	18.7	43.2	52.9	6.7	45.0
Polyurethane range	*4.4%*	*1.0%*	*4.3%*	*12%*	*0.8%*	*11.1%*
Polypropylene mean	170.8	58.3	108.9	585.9	90.0	246.2
Polypropylene range	*0.2%*	*7.7%*	*4.9%*	*1.3%*	*12.4%*	*8.1%*
Percentage variation from Polyurethane	**326%**	**212%**	**152%**	**1008%**	**1243%**	**447%**

Table 9 Configuration 3B Discrimination of padding material in oblique impact with offset hardspot

Headform	**AAMA**	**EEVC**	**FMH**	**AAMA**	**EEVC**	**FMH**
	Peak Accel. (g)			HIC		
Polyurethane mean	37.6	30.3	38.2	47.9	21.1	39.2
Polyurethane range	*37.2%*	*26.1%*	*32.2%*	*84.8%*	*78.2%*	*78.1%*
Polypropylene mean	24.7	10.6	20.9	25	2.6	13.8
Polypropylene range	*37.7%*	*10.4%*	*17.2%*	*80.8%*	*26.9%*	*44.9%*
Percentage variation from Polyurethane	**-34%**	**-65%**	**-45%**	**-48%**	**-88%**	**-65%**

Tables 10 and 11 compare the responses between padded and unpadded B-pillar simulations.

Table 10 Configuration 4B and 5B Discrimination of padding in oblique impact on B post

Headform	**AAMA**	**EEVC**	**FMH**	**AAMA**	**EEVC**	**FMH**
	Peak Accel. (g)			HIC		
Unpadded mean	108.9	78.5	104	567.4	219	414.9
Unpadded range	*8.2%*	*17.7%*	*5.6%*	*17.6%*	*41.4%*	*14.4%*
Padded mean	108.9	135.0	108.1	548.0	815.6	430.3
Padded range	*6.0%*	*5.3%*	*4.1%*	*7.3%*	*9.0%*	*5.1%*
Percentage variation from Unpadded	**0%**	**-72%**	**-4%**	**3%**	**-272%**	**-4%**

Table 11 Configuration 4a and 5a Discrimination of padding on B-post in perpendicular impact

Headform	**AAMA**	**EEVC**	**FMH**	**AAMA**	**EEVC**	**FMH**
	Peak Accel. (g)			HIC		
Unpadded mean	143.9	112.6	144	926.1	495	924.9
Unpadded range	*5.21%*	*8.0%*	*3.5%*	*12.0%*	*21.6%*	*3.0%*
Padded mean	148.8	161.5	123.4	1054.3	1183.3	669.1
Padded range	*4.2%*	*10.3%*	*2.8%*	*7.8%*	*15.4%*	*7.8%*
Percentage variation from Unpadded	**3%**	**43%**	**-14%**	**14%**	**139%**	**-28%**

Effect of Hardspots within Padding.

Tables 12 and 13 compare the results for impacts directly over with results for tests just adjacent to hardspots hidden within the padding, supported on rigid plates for perpendicular and angled impacts. Two types of padding were used in each condition.

Table 12 Configuration 3a and 3c Discrimination of position of hardspot in perpendicular impact

Headform	**AAMA**	**EEVC**	**FMH**	**AAMA**	**EEVC**	**FMH**
Polyurethane padding	Peak Accel. (g)			HIC		
Direct hardspot mean	82.4	70.3	90.6	231.4	160.9	283.1
Direct hardspot range	*2.9%*	*0.3%*	*1.8%*	*0.7%*	*0.1%*	*1.7%*
Offset hardspot mean	86.9	70.8	90	247.9	163.8	273.6
Offset hardspot range	*0.9%*	*1.4%*	*1.1%*	*0.8%*	*2.1%*	*2.7%*
Percentage variation from direct hard spot	**5%**	**1%**	**-1%**	**7%**	**2%**	**-3%**
Polypropylene padding						
Direct hardspot mean	132.2	74.9	121.1	356	145.1	318
Direct hardspot range	*12.3%*	*17.1%*	*10.3%*	*18.0%*	*21.7%*	*13.0%*
Offset hardspot mean	142.5	71.9	109.5	405.2	140.6	281.3
Offset hardspot range	*3.6%*	*11.4%*	*15.7%*	*7.1%*	*16.6%*	*17.4%*
Percentage variation from direct hard spot	**8%**	**-4%**	**-10%**	**14%**	**-3%**	**-12%**

Table 13 Configuration 3d and 3B Discrimination of hard spot in oblique impact.

Headform	**AAMA**	**EEVC**	**FMH**	**AAMA**	**EEVC**	**FMH**
Polyurethane padding	Peak Accel. (g)			HIC		
Direct mean	40.1	18.7	43.2	52.9	6.7	45.0
Direct range	*4.4%*	*1.0%*	*4.3%*	*12%*	*0.8%*	*11.1%*
Offset mean	37.6	30.3	38.2	47.9	21.1	39.2
Offset range	*37.2%*	*26.1%*	*32.2%*	*84.8%*	*78.2%*	*78.1%*
Percentage variation from direct oblique hard spot	**-6%**	**62%**	**-12%**	**-10%**	**215%**	**-13%**
Polypropylene padding						
Direct mean	170.8	58.3	108.9	585.9	90.0	246.2
Direct range	*0.2%*	*7.7%*	*4.9%*	*1.3%*	*12.4%*	*8.1%*
Offset mean	24.7	10.6	20.9	25	2.6	13.8
Offset range	*37.7%*	*10.4%*	*17.2%*	*80.8%*	*26.9%*	*44.9%*
Percentage variation from direct oblique hard spot	**-86%**	**-82%**	**-81%**	**-96%**	**-97%**	**-94%**

Effect of Angled Impact

Tables 14 and 15 compare the perpendicular and angled impact responses in the presence of a hidden hardspot within the two types of padding and Tables 16 and 17 compare the responses in perpendicular and angled impacts to the padded B-pillar simulations.

Table 14 Configuration 3a and 3d Effect of angle of impact to padded surface with hardspot in direct impact

Headform	**AAMA**	**EEVC**	**FMH**	**AAMA**	**EEVC**	**FMH**
Polyurethane padding	Peak Accel. (g)			HIC		
Perpendicular mean	82.4	70.3	90.6	231.4	160.9	283.1
Perpendicular range	*2.9%*	*0.3%*	*1.8%*	*0.7%*	*0.1%*	*1.7%*
Oblique mean	40.1	18.7	43.2	52.9	6.7	45
Oblique range	*4.4*	*1*	*4.3*	*12*	*0.8*	*11.1*
Percentage difference from perpendicular	**-51%**	**-73%**	**-52%**	**-77%**	**-96%**	**-84%**
Polypropylene padding						
Perpendicular mean	132.2	74.9	121.1	356	145.1	318
Perpendicular range	*12.3%*	*17.1%*	*10.3%*	*18.0%*	*21.7%*	*13.0%*
Oblique mean	170.8	58.3	108.9	585.9	90.0	246.2
Oblique range	*0.2%*	*7.7%*	*4.9%*	*1.3%*	*12.4%*	*8.1%*
Percentage difference from perpendicular	**-85%**	**-84%**	**-81%**	**-96%**	**-98%**	**-95%**

Table 15 Configuration 3c and 3B Effect of angle of impact to padded surface with hardspot in offset impact

Headform	**AAMA**	**EEVC**	**FMH**	**AAMA**	**EEVC**	**FMH**
Polyurethane padding	Peak Accel. (g)			HIC		
Perpendicular mean	86.9	70.8	90	247.9	163.8	273.6
Perpendicular range	*0.9%*	*1.4%*	*1.1%*	*0.8%*	*2.1%*	*2.7%*
Oblique mean	37.6	30.3	38.2	47.9	21.1	39.2
Oblique range	*37.2%*	*26.1%*	*32.2%*	*84.8%*	*78.2%*	*78.1%*
Percentage difference from perpendicular	**-57%**	**-57%**	**-58%**	**-81%**	**-87%**	**-86%**
Polypropylene padding						
Perpendicular mean	142.5	71.9	109.5	405.2	140.6	281.3
Perpendicular range	*3.6%*	*11.4%*	*15.7%*	*7.1%*	*16.6%*	*17.4%*
Oblique mean	24.7	10.6	20.9	25	2.6	13.8
Oblique range	*37.6%*	*10.4%*	*17.2%*	*80.8%*	*26.9%*	*44.9%*
Percentage difference from perpendicular	**-83%**	**-85%**	**-81%**	**-94%**	**-98%**	**-95%**

Table 16 Configuration 4a and 4B Effect of angle of impact to unpadded B-post

Headform	**AAMA**	**EEVC**	**FMH**	**AAMA**	**EEVC**	**FMH**
	Peak Accel. (g)			HIC		
Perpendicular mean	143.9	112.6	144	926.1	495	924.9
Perpendicular range	5.2%	8.0%	3.5%	12.0%	21.6%	3.0%
Oblique mean	108.9	78.5	104	567.4	219	414.9
Oblique range	*8.2%*	*17.7%*	*5.6%*	*17.6%*	*41.4%*	*14.4%*
Percentage variation from perpendicular	**-24%**	**-30%**	**-28%**	**-39%**	**-56%**	**-55%**

Table 17 Configuration 5a and 5B Effect of angle of impact to padded B- post.

Headform	**AAMA**	**EEVC**	**FMH**	**AAMA**	**EEVC**	**FMH**
	Peak Accel. (g)			HIC		
Perpendicular mean	148.8	161.5	123.4	1054.3	1183.3	669.1
Perpendicular range	4.2%	10.3%	2.8%	7.9%	15.4%	7.8%
Oblique mean	108.9	135	108.1	548	815.6	430.3
Oblique range	*6.0%*	*5.2%*	*4.2%*	*7.1%*	*8.7%*	*5.1%*
Percentage variation from perpendicular	**-27%**	**-16%**	**-12%**	**-48%**	**-31%**	**-36%**

Effect of Weakening to B-Pillar.

Table 18 compares the responses of the three headforms between perpendicular impacts to the padded B-pillar simulations with and without a hole cut into the sheet metal below the impact point

Table 18 Configuration 5a and 5a▯ Sensitivity to presence of a hole in the padded B-pillar

Headform	**AAMA**	**EEVC**	**FMH**	**AAMA**	**EEVC**	**FMH**
	Peak Accel. (g)			HIC		
Without hole mean	148.8	161.5	123.4	1054.3	1183.3	669.1
Without hole range	*4.2%*	*10.3%*	*2.8%*	*7.9%*	*15.4%*	*7.8%*
With hole mean	146.1	150.9	125.7	1011	1049	651.2
With hole range	*0.3%*	*3.1%*	*3.5%*	*1.4%*	*5.7%*	*2.6%*
Percentage variation from without hole	**-2%**	**-7%**	**2%**	**-4%**	**-11%**	**-3%**

PHASE 1 DISCUSSION

Phase 1 of the test programme allows many comparisons to be made some of which can be viewed as being of more importance than others.

The AAMA and EEVC head forms are both half spherical balls whereas the FMH head form is of an irregular shape with a clearly defined impact area. Some difficulties were experienced in using the FMH head form in respect of orientation within the test laboratories propulsion systems. It was felt that some difficulties might be encountered when testing complex vehicle interiors due to this lack of symmetry and the test houses ability to be able to fire the head form from existing propulsion systems without major changes. In the hard spot tests the FMH could be aligned in a number of different orientations each possibly giving a different response. In order to simplify the tests and to reduce variability a particular orientation of head form to hard spot was adopted.

Several evaluation criteria must be addressed when determining which of the three head forms is the better one.

Sensitivity

Sensitivity can be assessed by examining combinations of test conditions and the ability of the three headforms to discriminate between the different conditions

a) Sensitivity to padding in simple padding tests

The tests have shown (Table 5) that each of the head forms can discriminate between the selected materials. The indicated changes were of the order of 47% to 97% depending upon the chosen assessment parameter and head form. The EEVC head form indicated the greater difference and the FMH the least for both parameters.

b) Sensitivity to padding in the presence of a hard spot..

In the perpendicular impacts, the AAMA headform showed the greatest sensitivity to padding material and the EEVC headform the least. The HIC measured with the EEVC headform showed the opposite trend from the peak acceleration and the opposite trend to the other two headforms with both parameters

In the oblique impact tests directly to the hardspot (Table 9) all three heads showed a very large increase in response when changing from polyurethane to polypropylene padding but when testing with the hardspot offset from the impact point (Table 8), this change resulted in a decrease in response for all headforms. In this instance the EEVC headform showed the greatest sensitivity.

c) Sensitivity to presence of padding on B-post

In the perpendicular tests, only the FMH showed a reduction in response when the B-post was padded compared with the unpadded condition. (Table 10) The HIC, measured with the EEVC headform showed a considerable increase.

In the oblique tests, only the EEVC headform indicated a reduction in response (Table 11). The other two headforms indicated little difference.

d) Sensitivity to presence of hidden hardspot

In the perpendicular tests the AAMA headform showed the greatest sensitivity to the presence of a hardspot, but it indicted a *reduction* in response when impacting directly over the hardspot although the change was not very large. The FMH was the only headform consistently to indicate an increase in response when directly impacting the hardspot area.

In the angled impact with polypropylene padding, all three headforms demonstrated a large and similar reduction in response when impacting away from the hardspot. However, with the polyurethane padding, the EEVC headform indicated an increase. The other two headforms again showed a decrease, as would be expected, the FMH being slightly the more sensitive.

e) Sensitivity to angle of impact

In the tests with hardspot within padding, all three headforms showed the same sensitivity to angle with polypropylene. Overall, the FMH showed least sensitivity to angle with polyurethane padding. For the test procedure, it is probably desirable to be fairly insensitive to changes in angle.

In the unpadded B-post tests the AAMA headform showed least sensitivity, the EEVC and FMH being fairly similar. In the padded B-post tests the FMH showed least sensitivity for peak acceleration and the EEVC with HIC, although the differences are probably not significant.

f) Sensitivity to weakened B-post

The EEVC headform showed the greatest sensitivity to the presence of a hole in the B-post although the difference between the two B-post results were not very large.

Repeatability

Repeatability is a very important assessment parameter for any test device. All of the head forms have been tested more than once in each of the configurations. This allows some assessment to be made of head form repeatability. All the test results include an indication of repeatability as shown by the range of the responses for a single test condition expressed as a percentage of the mean response. This range value comparison as such is not very robust since it is based for most tests on only two values. However, a consistent difference between headforms over all tests would allow some judgement to be made on this aspect of performance. An initial assessment of repeatability has been made by ranking the headforms by percentage range for each test condition for both peak head acceleration and HIC. For the purposes of this assessment, the headforms were given equal ranking if the differences in the percentage range for two headforms were less than one quarter of the average range for those two headforms. i.e. the rankings were similar if :

The assessment methodology has been applied to the data partitioned between perpendicular and oblique impact directions. No headform appeared to perform consistently better regarding repeatability than the others using this assessment technique. In perpendicular impacts the AAMA appeared to be better than the FMH headform which in turn was better than the EEVC headform, for both peak g and HIC measurements. For oblique impacts the FMH head form was better than both the AAMA and EEVC head forms for peak g and HIC. In these oblique tests, the EEVC head form was better than the AAMA as assessed by peak g but the trend is reversed when assessed by HIC. Overall the data do not show that one head form was notably better than the other two.

Further more detailed analysis of these results will be made before the headform for use in Phase II is selected. This preliminary analysis suggests that there is little to choose between them. If further analysis confirms this conclusion, other reasons, such as potential harmonisation, may dictate the choice of headform for future work.

CONCLUSIONS

The test programme was designed to evaluate the three head forms in a series of well controlled experiments, aimed at testing attributes thought to be important in a sub systems procedure. The initial analysis of the results have shown that there is little to choose overall between the three headforms-

1. The EEVC headform was more sensitive at distinguishing between paddings in the simple padding test and for detecting the presence of a weakened hole in the B-post
2. The AAMA headform was overall more sensitive to padding material in the tests involving the presence of a hidden hardspot.

3 Only the FMH gave a consistent and expected response to the addition of padding to the B-post

4 Only the FMH was consistently able to detect the presence of a hidden hardspot within the padding material.

5 None of the headforms was markedly superior to the others for repeatability in the interim analysis. Those differences that were observed suggests that the FMH and AAMA headforms are a little better than the EEVC,

particularly for HIC, which is important if this is the parameter selected for evaluation.

FUTURE WORK

After further detailed analysis of these results, the preferred headform will be selected for the next Phase of the study. As mentioned above, the test programme consists of three phases. Phase II aims to examine the affect of linearly guided compared with free flight projection and Phase III will examine the performance of the preferred headform and projection system in vehicles. In due course the results of these other two phases will be published.

ACKNOWLEDGEMENTS

EEVC Working Group 13 members participating in this test programme and the work of the group are:-

Current members -

Mr Richard Lowne - Transport Research Laboratory (Chairman)
Mr Adrian Roberts - Transport Research Laboratory (Sec.)
Mr Flavio Fossat - Fiat Auto S.p.A.
Mr Dominique Cesari - INRETS
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Mr A Benedetto - Fiat Auto S.p.A.

Observer
Mr John Green - Rover Group

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ANNEX

PHASE 1 TEST PROGRAMME

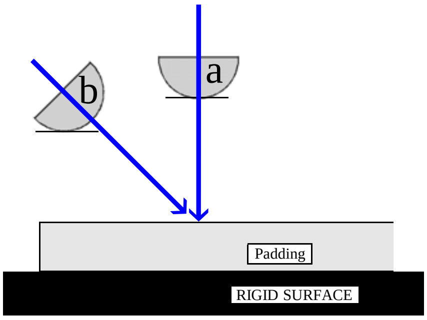
a) Base line tests.
Three impact tests with each of three head-forms on three impact surfaces (rigid surface drop test - to duplicate cadaver and headform test certification conditions {Configuration 1a}, a simulated steel B-pillar {Configuration 4a} and a padded simulated steel B-pillar {Configuration 5a}). All impacts normal to the impact surface from a drop height of 376 mm.

b) Affect of angles of impact.
Three impacts to each of the two B-pillar simulations with each of the three head-forms, all at 45E to the normal to the surface (Configurations 4B, 5B). plus three flat surface padded tests {Configuration 2b}. Impact velocity 2.5 m/s.

c) Sensitivity to hard spots, holes and padding.
Two impacts with each of the head forms onto padded surfaces with a hidden hardspot with two stiffnesses of

padding and two impact positions on each padded surface (one over the hardspot {Configuration 3a} and one adjacent to it {Configuration 3c}), also test {Configuration 3B and 3d}. Two tests onto paddings with different characteristics {Configuration 2a}. The depth of the hard spot is 10mm with a padding cover of 10-12mm thick. Impact velocity 2.5 m/s.

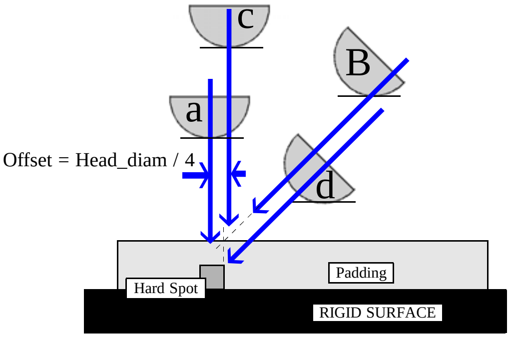
A modified 'padded B post' will be impacted with each of the three head forms, test configuration 5a. The modification to the 'B post' will consist of a 45mm diameter hole in the profiled section of the fabrication, with the hole centred below the point of impact. Each padded 'B post hole test' will be repeated once. Impact velocity 6.7 m/s.



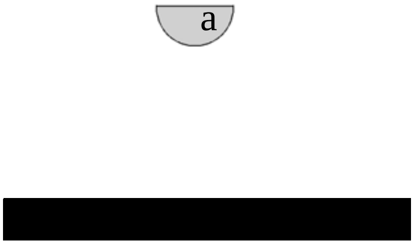
Test Configuration 2 - Padded Surface

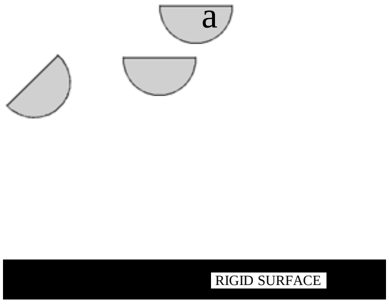
Test Configurations

Angles of impact are 90E and 45E to the rigid surface, the arrows indicating the direction of impact. In the tests shown with lower case letters, the arrow represent the axis of the impactor. - Upper case letters indicate the point of contact of the headform with the surface, and the arrow direction shows the direction of impact only and does not indicate the central axis of the impactor. (None of the configurations is shown to scale).

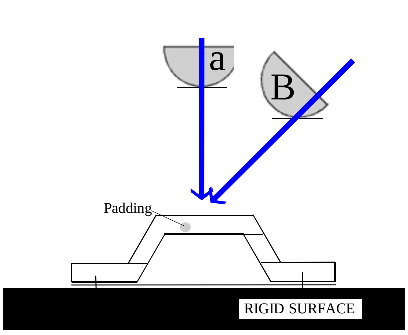


Test Configuration 3 - Padded Hard Spot





Test Configuration 4 - Unpadded B Post



Test Configuration 5 - Padded B Post

9.2. EEVC Research in the Field of Developing a European Interior Headform Test Procedure: 19th ESV paper 2005

EEVC Research in the Field of Developing a European Interior Headform Test Procedure

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Paper No. 158

ABSTRACT

The European Enhanced Vehicle-safety Committee (EEVC) Working Group 13 for Side Impact Protection has been developing an Interior Headform Test Procedure to complement the full scale Side Impact Test Procedure for Europe and for the proposed IHRA test procedures. In real world accidents interior head contacts with severe head injuries still occur, which are not always observed in standard side impact tests with dummies. Thus a means is needed to encourage further progress in head protection. At the 2003 ESV-Conference EEVC Working Group 13 reported the results on Interior Headform Testing. Further research has been performed since and the test procedure has been improved. This paper gives an overview of its latest status. The paper presents new aspects which are included in the latest test procedure and the research work leading to these enhancements. One topic of improvement is the definition of the Free Motion Headform (FMH) impactor alignment procedure to provide guidelines to minimise excessive headform chin contact and to minimise potential variability. Research activities have also been carried out on the definition of reasonable approach head angles to avoid unrealistic test conditions. Further considerations have been given to the evaluation of head airbags, their potential benefits and a means of ensuring protection for occupants regardless of seating position and sitting height.

The paper presents the research activities that have been made since the last ESV Conference in 2003 and the final proposal of the EEVC Headform Test Procedure.

INTRODUCTION

Beside the frontal crash the side crash is the most common crash causing severe injuries. The side impact is loading various body parts. The intruding car structure hits the occupant and can cause severe injuries. In side impact tests in laboratories direct contacts mainly occur with the torso of the dummy. Accident analyses have shown that in real world crashes also head contacts occur with the interior structure of cars. These are only very rarely observed in side impact tests according to European Regulation ECE-R95.

One reason is that real world accidents occur in various impact configurations, which cannot be represented in only one test. To overcome this deficiency in Type Approval evaluations, EEVC WG13 was tasked by the EEVC Steering Committee to develop an Interior Headform Test Procedure for Europe. There already exists a test procedure for head contacts in the interior of cars in the USA (FMVSS 201). The European proposal includes latest research results, in order to obtain a modern test procedure.

It was planned to proceed in four phases to develop this Interior Headform Test Procedure, starting with the selection of the headform impactor. At this time the FMH (Free Motion Headform) was also used in FMVSS 201. No significant advantages were identified in selecting either of the three impactors available. The US FMH, was selected as it was already in use in FMVSS 201. This was presented at ESV 1996. Current research suggests that the use of a symmetrical headform may have a number of advantages in simplifying the procedure and improving test reproducibility. WG13 is not currently in a position to make such a decission and the test procedure still uses the FMVSS 201 headform.

Following the second phase of the research it was decided to specify a non guided / free flight headform impactor. This was presented at the 16th ESV Conference.

After the decision of the impactor type and test method correlation between EuroSID and FMH responses were analysed, resulting in a formula to calculate HIC FMH to HIC EuroSID. Additionally an accident analysis study for side impact crashes was made to identify potential head impact areas. This was presented as result of phase three at the ESV 2001.

A first draft test procedure was developed and its feasibility, reproducibility and repeatability was checked. Several tests in different European and World cars were performed by TRL, TNO, Volvo and BASt. This was published at ESV 2003.

The experience obtained in these tests lead to several further investigations to optimise the test procedure. In the following paragraphs the major investigations and most important changes to the draft test protocol version of ESV 2003 are presented.

DEFINITION OF CLEAN CONTACT AND HEAD ALIGNMENT

It was observed in many cases, that the FMH contacted the interior structure twice, firstly with the calibrated zone (see figure 1) and secondly with the nose or chin part. To avoid or minimise the risk and severity of contact with an uncalibrated area a “clean contact” had to be defined (figure 2)

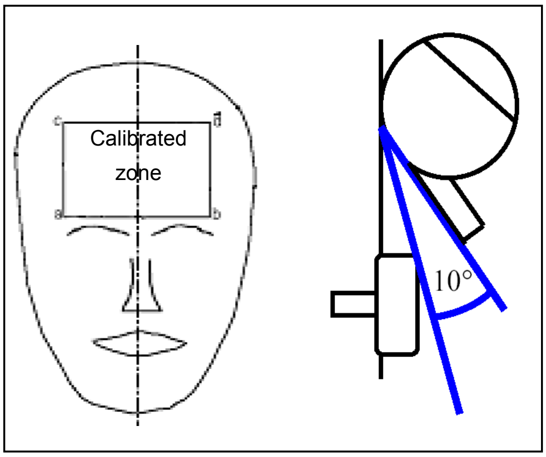


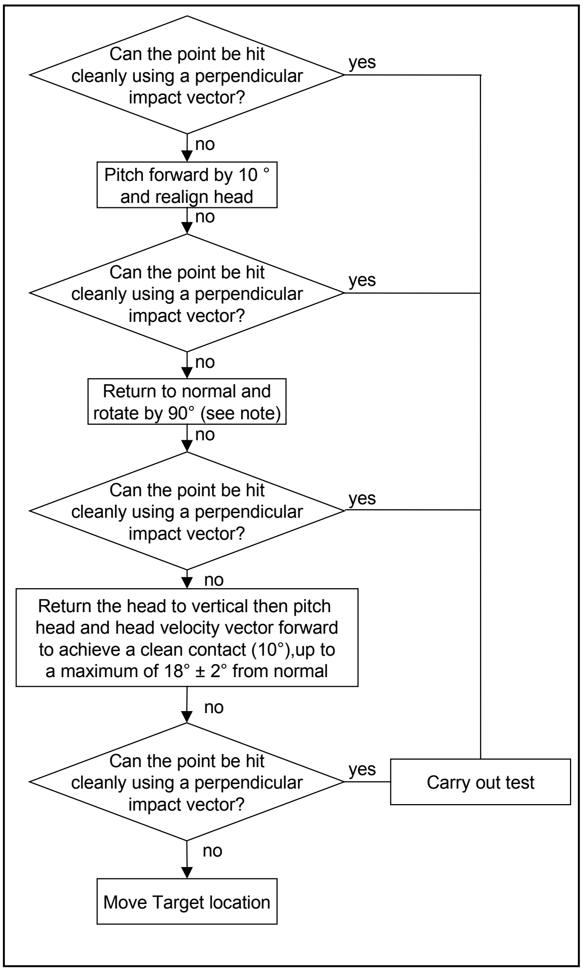
Figure 1: Calibrated zone of FMH

The former draft test procedure proposed to turn the head by up to ± 90°. With the possibility to turn the head to any angle between 0° and 90° the definition could be interpreted in several different ways.

As a result the following flow chart was developed to minimise problems of misinterpretation.

This flowchart was checked by TNO and BASt by aligning FMHs in several cars. Most of the head alignments in same cars at same targets where identical.

Another possibility is to reduce the flow chart in figure 2 by excluding the 90° rotation steps. At this point of time WG13 is not in a position to recommend one as being better than the other.



note: Clarification note on headfrom rotation
FMH axial rotation about the impact vector facing towards the target point.

Target area	Left hand side of the vehicle	Right hand side of the vehicle
A post target points	90° clockwise	90° anticlockwise
Roof rail target points	90° clockwise	90° anticlockwise
B post target points	90° anticlockwise	90° clockwise

Figure 2: Flow chart to obtain “clean contact”

The two proposed possibilities to obtain “clean contact” are more detailed shown in ANNEX A.

Even with this proposed methodology it is possible that secondary impact could still occur. One possibility to minimise further secondary impacts would be to eliminate the flow chart avoiding different interpretations, by the use of a symmetrical impactor as currently used for pedestrian testing in Europe. This has not been investigated further and can not yet be recommended by WG13

NON FRONT SEATING POSITION

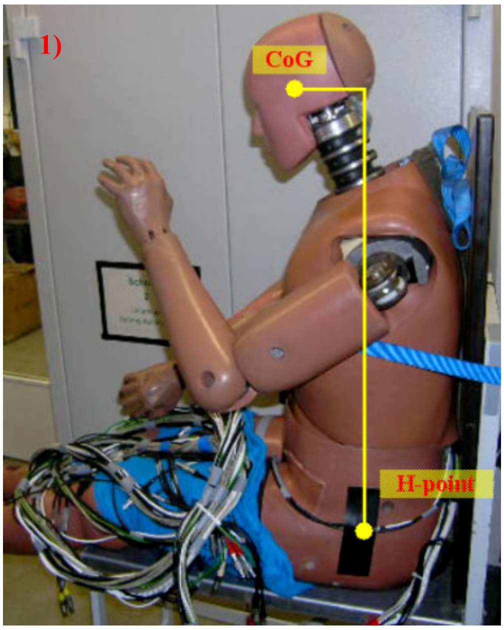
The initial WG13 research focused on frontal seating positions. To contribute a proposal for IHRA (International Harmonisation Research Activities) SIWG (Side Impact Working Group) the test procedure was extended to cover "non front seating positions".

The testing zone for the front seating position was limited to a zone constructed from the CoGs (Centre of Gravity) of a large male in the most rearward and a small female in the most forward seating position.

The procedure to define a limitation zone for the rear seating positions was changed due to different types of seats since rear seats are not usually adjustable at the seat back. Therefore the position of the CoG of different sized occupants could be more easily defined.

Figure 3 explains the procedure:

1) The dimensions from the H-point to the CoG for 5th female and 95th male are known.
2) The torso angle can be determined by the H-point-manikin.
3) The position of the CoGs can now be defined in the car.
4) The four limitation planes are constructed in the car (marked green in figure 3).



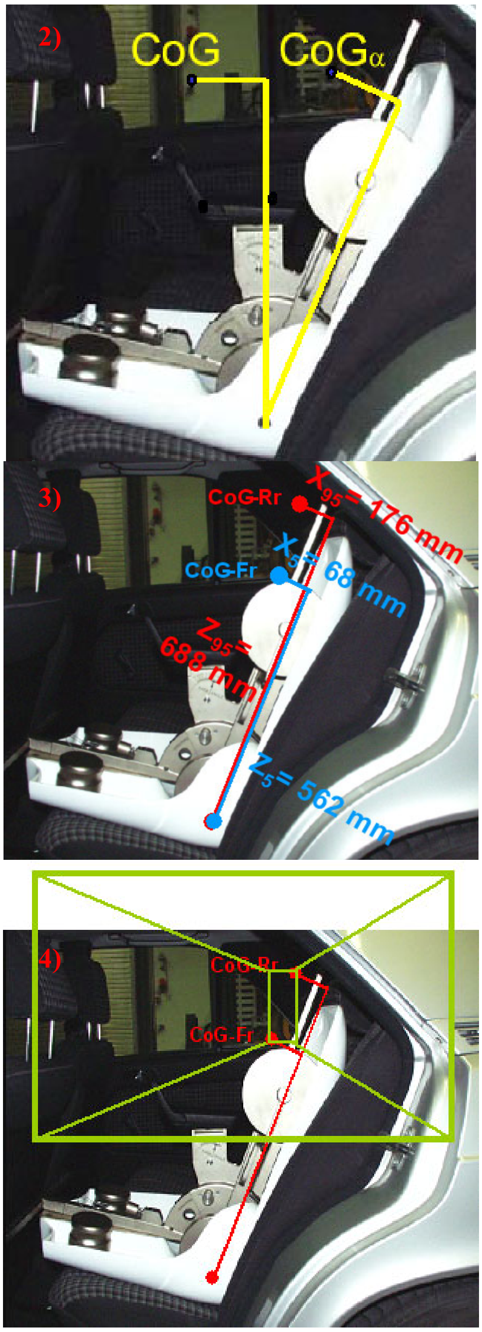
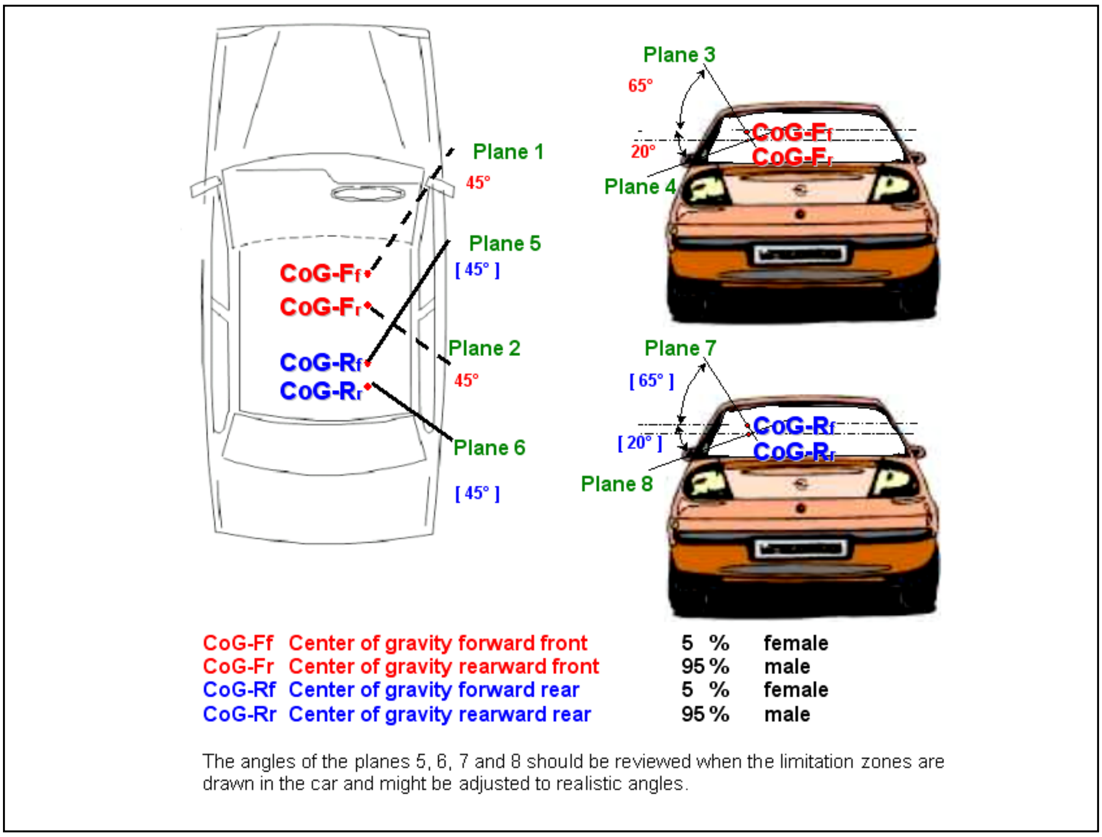


Figure 3: Construction of testing limitation zone for rear seating position

The planes are constructed through the CoGs at the same angles as for the front seating position (see figure 4)



The angles of the planes 5, 6, 7 and 8 should be reviewed when the limitation zones are drawn in the car and might be adjusted to realistic angles.

Figure 4: Planes for limitation zone

The interior testing zone is limited by the yellow line. The areas outside this line are excluded from testing.

Figure 5: Limitation zone in the car

These zones and the methodology to create them will need to be validated in broader based programmes, e.g. the European APROSYS project.

ADDITIONAL TARGET LIMITATION POSITIONS

In addition to the mentioned limitation zones further limitations are necessary since several of the surfaces and possible targets in the limitation window cannot be reached because of the shape of the vehicles interior. It is proposed that any surface within 165 mm of a glazed surface should be excluded form evaluation. This is diagrammatically shown by the application of a sphere of 165 mm diameter in figure 6.

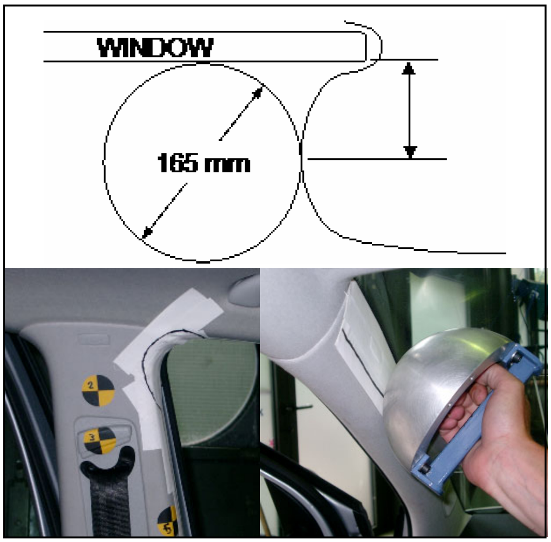


figure 6: additional limitation zone

BENEFIT OF HEAD AIRBAGS

a) Tests outside the car / basic tests

The former test procedure presented at ESV 2003 already included a part dealing with reduction of test velocity due to airbag installation covering the mounting area around the stowed head airbag. The test velocity being 5.3 m/s instead of 6.7 m/s.

WG13 believe that active head protection systems can offer many benefits and should be encouraged as they can give additional head protection. It therefore seems reasonable to enlarge the exception zone to all areas that are adequately protected by head airbag systems, only requiring lower velocity testing to the covered areas. An investigation into methods of evaluating airbags and encourage appropriate performance has been carried out by BASt, within WG13. More details of the BASt study are presented in Appendix 1.

First of all it was analysed whether these tests should be performed on a permanently inflated airbag or a fired airbag. Tests have shown that the variability in performance is marginal if the static pressure is the same as in the fired airbag at the moment of head contact. The adequate airbag pressure (about 0,5 bar) of the different airbags was provided by the airbag manufactures.

Basic tests were made on different designs of head airbags to analyse the different airbag characteristics. All tested airbags and all tested points are shown in figure 7.

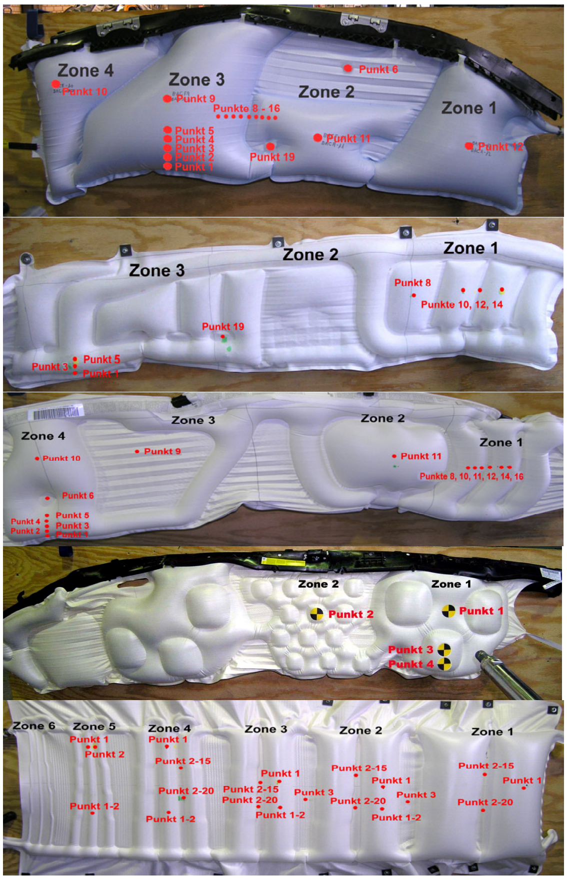


Figure 7: Tested airbags and target points

To eliminate the influence of the vehicle structure behind the bag the airbags were mounted on a homogeneous plate. Therefore a rigid wooden plate was fixed on a rigid steel wall (figure 8). In the research testing in some cases additional foam was attached to the plate, to reduce the HIC to an appropriate level.

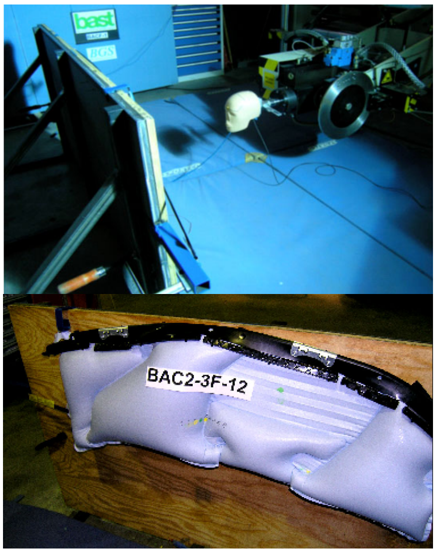


Figure 8: Test set-up – rigid wall

First of all the influence of the impact direction on the airbag was investigated. Figure 9 shows that the influence of the impact direction is marginal, within the range of angles tested, as long as the impactor does not strike through the airbag.

HIC	294 (max)	280	286	276 (min)
Angle	0°	15°	30°	45°

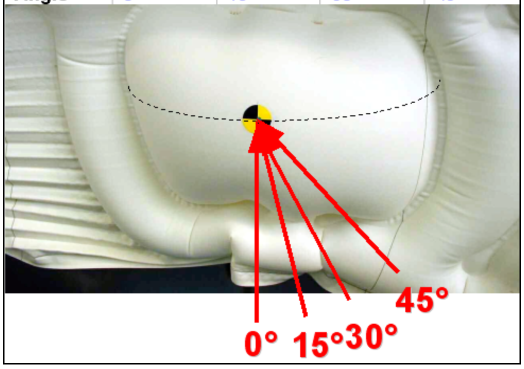


Figure 9: Different impact angles on airbag

To simplify the test procedure into an airbag, it was decided to test perpendicular to the surface below the airbag. The results on the inflated airbags are significant lower than in the tests without inflated airbags on the homogenous plate.

The following figure 10 shows an example of a test on the plate compared to tests on different cushions. The red values are tested with the head at 0° and the yellow values at 10° pitch (see clean contact definition) of the head and velocity vector.

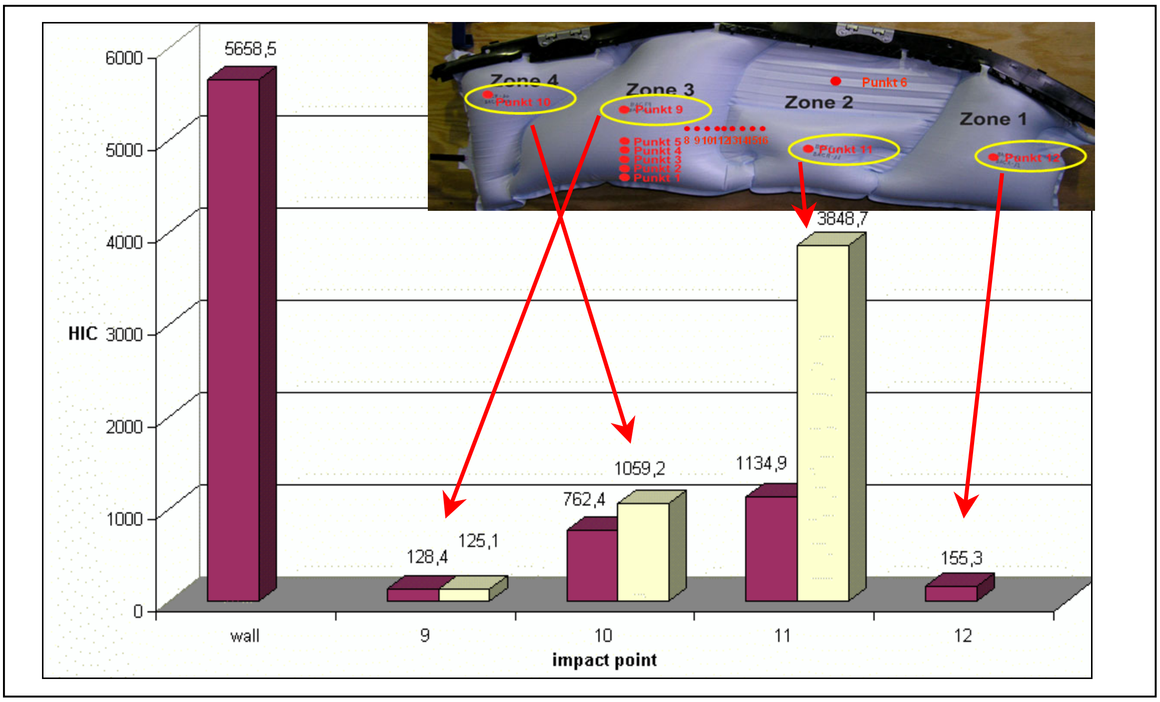


Figure 10: Protection level of different cushions

The critical areas of the airbag where evaluated as indicated in figure 11

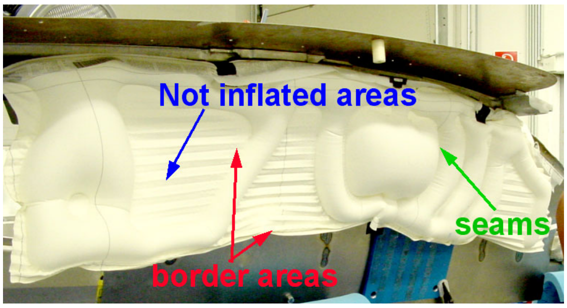


Figure 11: Critical airbag areas

The airbag procedure has been incorporated in the draft EEVC procedure.

- The car would first have to pass a pole test to ensure head airbag triggering.
- The manufacturer has to provide a drawing of areas where the airbag would give the correct level of protection, for example green for adequate protection and red for inadequate protection (see figure 12 and 13)

Figure 12: Marked protection level on airbag

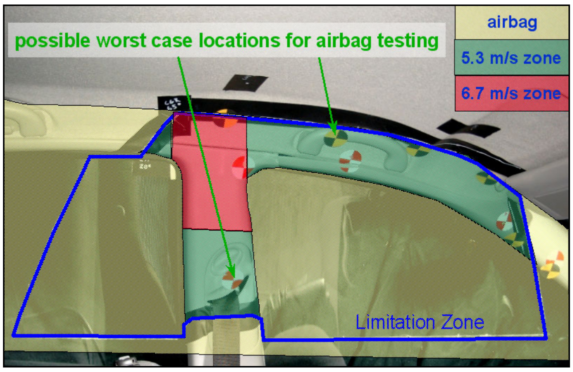


Figure 13: Marked protection level of an airbag on the interior surface

- According to the marked zones the interior structure will be tested at 6.7 m/s in red areas and 5.3 m/s in green areas, without inflated airbag.
- To check whether the determination of the airbag areas in green and red zones is adequate, a minimum of two worst case tests would have to be performed in the green zones on an inflated airbag at 6.7 m/s, in the car. The manufacturer would have to provide information on deployment test pressures and prove compliance.
- The HIC has to be below 1000 in all these tests.

The complete head airbag test proceeding is summarised in the following figure.

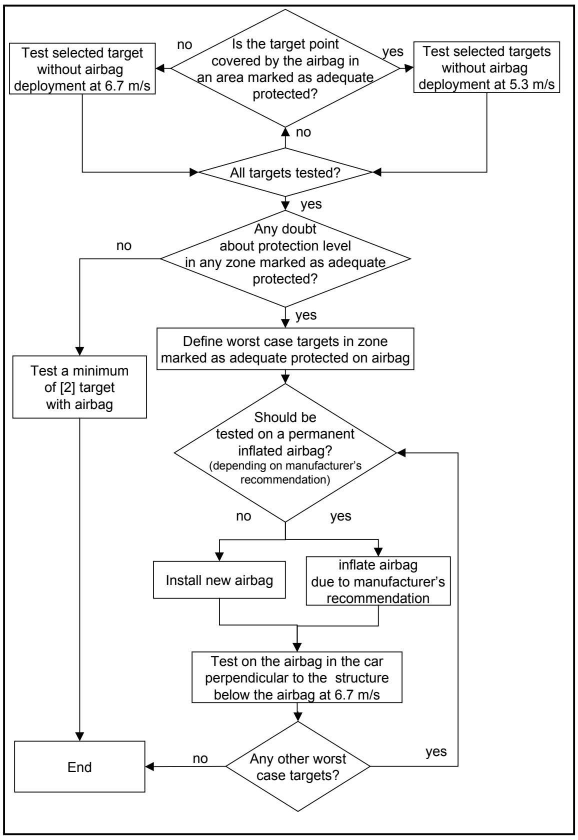


Figure 14: Flow chart for testing with head airbag tests systems

The airbag test procedure is already included in the latest version of the EEVC WG 13 test procedure for interior headform testing.

HEAD IMPACT ANGLE

TNO have carried out a modelling study to investigate reasonable impact directions in side impacts. The testing protocol requires testing of target points perpendicular to the surface structure as worst case direction. It is noted that in some cases this might lead to testing alignments which are very unrealistic compared to real world accidents. Limitation angles had been given in the test procedure, but no closer investigation had been made before the study of TNO to determine impact angles.

Various accident scenarios have been taken into account. More details of this study are given in APPENDIX 2.

Transferred to a general co-ordinate system of a car, this study proposes the following angles:

- **50° < horizontal angle < 115°**
- **-12° < vertical angle < 18°**

The EEVC headform test procedure currently indicates the angles as defined in figure 15, but it does mention the results of the TNO study. It is not yet decided which angles should be recommended in a final European test procedure. The EEVC WG13 test procedure is suggesting that the impact limitation angles should be limited to those shown in Figure 15. In a broader based practical analyse of the test procedure these angles should be examined and verified. This will be done in the European APROSYS project and other evaluation programs.

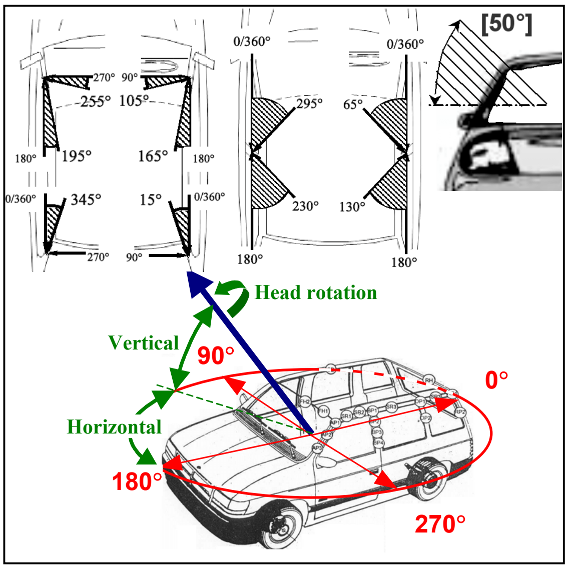


Figure 15: Additional limitation angles co-ordinate system

CONCLUSIONS

It is the aim of EEVC WG 13 to create a robust test procedure that would lead to reduction in injury in real life accidents to all statures of occupant, sitting in realistic seating positions. On one hand the procedure has to test nearly all injury causing possibilities but on the other hand it has to eliminate unrealistic or extreme unlikely tests, without imposing an unmanageable burden on test authorities and vehicle manufacturers.

Repeatability must be ensured in any test procedure that could be used in an approval process. It is also advisable to have a procedure that does not encourage 'single point' optimisation. This means that worst case target point selection should be encouraged and will be the task of the test house, with sound supporting guidance. In addition head alignment should be the same in all test laboratories.

The EEVC WG13 protocol has changed since the last ESV paper in 2003, due the WG13 members research investigations to improve the repeatability of the procedure. A better definition of head alignment has been included to eliminate unrealistic testing conditions.

The test procedure has been extended to evaluate head airbag systems and give credit to manufactures who fit such systems, by reducing the severity of the test to areas of the vehicle that are covered by an appropriate head airbag. Such areas being tested at a lower velocity due to reduced injury risk when undeployed.

The draft test procedure is now at a high stage of maturity.

The procedure will need to be revised further following more extensive evaluations as it includes some alternative testing strategies.

WG13 is of the opinion that it is now at a stage whereby it can be evaluated by the boarder research community.

RECOMMENDATIONS

Further improvements in repeatability and more realistic kinematics may be possible with the use of a symmetrical headform. Head alignment steps as presented in figure 2 would be reduced to a minimum and contacts with uncalibrated zones eliminated. Unrealistic dynamic head rotation would be minimised since the CoG of the test device would be aligned with the target point. Harmonisation in headform impactors in Europe could be achieved if the same impactor were to be adopted, as for pedestrian testing. No tests have been performed in cars with such a test device. Further investigations need to be performed if a symmetrical headform would be preferred to ensure that other unforeseen problems were not introduced. It is noted that a new headform would mean two different test devices for Europe and the United State.

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EEVC WG13 members are:
A K Roberts TRL (Chairman); J Ellway United Kingdom TRL (Secretary); R W Lowne TRL (former Chairman, retired); S Southgate Ford; L Martinez Spain INSIA; G Antonetti Italy Fiat; J-P Lepretre France UTAC; J Faure Renault; D Pouget Renault (retired end of 2004); M van Ratingen TNO The Netherlands; T Versmissen TNO; T Langner Germany BASt; C Müller DaimlerChrysler

APPENDIX 1 Airbag Testing (BASt studies)

Investigations of border areas

An important aspect was the protection level at the border areas of an airbag. All the airbags of figure 7 were tested. Figure A1.1 shows a border marked by the dotted line.

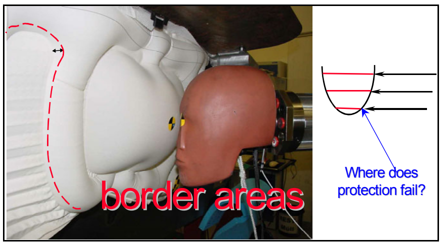


Figure A1.1: Border areas at airbags

An example for border area testing is given in figure A1.2. The result was that at the outer parts of the airbag protection is still provided. It was tested with two different head alignments: 0° (blue) to the horizontal plane and 10° (red) referring to the clean contact definition.

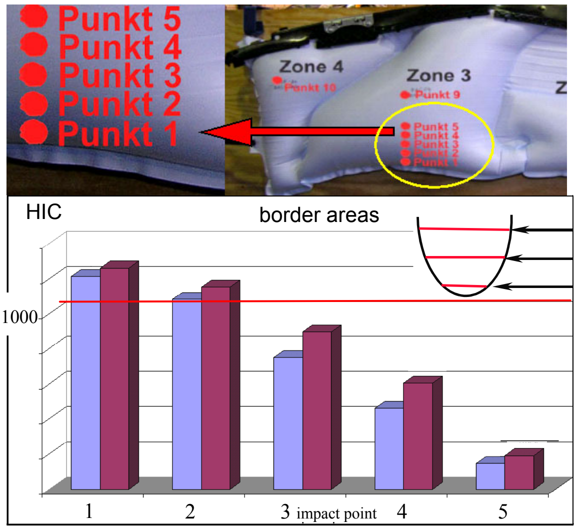


Figure A1.2: Protection level of border areas

Compared to the HIC of about 6000 in figure 10 the HIC values of less then 1300 at the lowest point 1 is quite moderate.

Investigations of seams

Head airbags are made of several airbag cushions to create an adequate shape. Therefore airbags have seams with an airbag thickness of 0 mm (see figure A1.3)

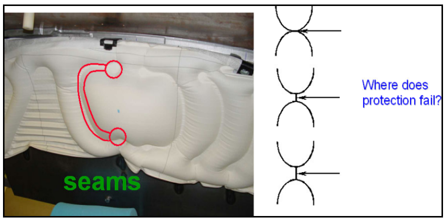


Figure A1.3: Seams at airbags

The questions were: What is the influence of these seams? Is this an area without protection? Several tests have been performed on all airbags of figure 7. Testing was done step by step from one cushion to another cushion by crossing the seam. An example is shown in figure A1.4 testing from a big cushion to a small cushion.
It is surprising that the value of point 12 at the seam with a thickness of 0 mm is still low. The location of the seams cannot be identified by the diagram. The HIC value is rising almost linear.

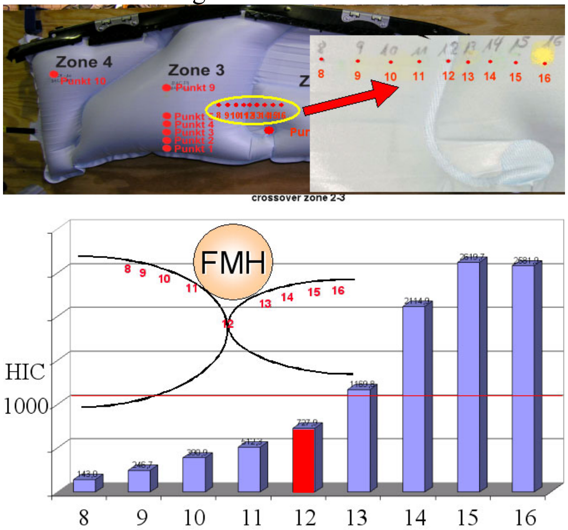


Figure A1.4: Protection level at seams

The explanation for this is: When shooting at the seam, the kinetic energy of the FMH is absorbed by the two bordering cushions (see figure A1.5)

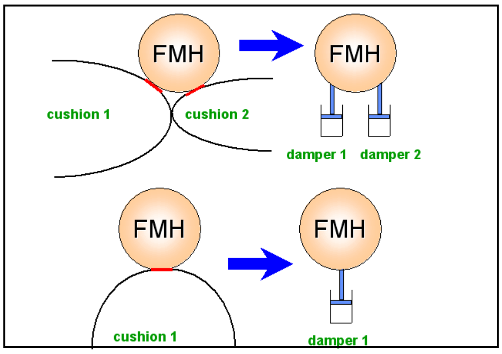


Figure A1.5: Damping effect of cushions

Nevertheless it is possible to avoid 0 mm thickness at airbag cushions. A new weaving technique with multi layer is used in some modern cars (see figure A1.6).

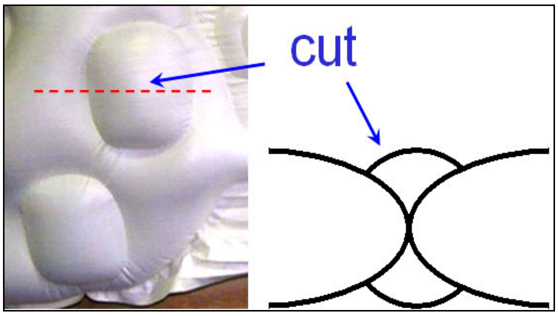


Figure A1.6: Multi layer weaving technique airbag

Special airbag

Further investigations were made of the above mentioned characteristics: cushion thickness and seams. A special woven airbag as shown in figure A1.7 was produced. Here the geometric characteristics could be tested completely isolated in the most comparable way. As shown in figure A1.7 the thickness of the cushion rises from left with Ø 10 mm to right with Ø 150 mm and the seam width from top to bottom from 5 mm to 20 mm.

Influence of airbag thickness at special airbag

First it was investigated whether there is a critical airbag thickness by testing the marked points on the airbag in figure A1.8.

Tests from zone 1 to zone 5 were performed. Point 1 is always the point at the top. Point 1-2 is always at the lower part of each cushion. The thickness is always the same for point 1 and 1-2 on the same cushion. Only the seam width between the cushions is 5 mm for point 1 and 20 mm for point 1-2.

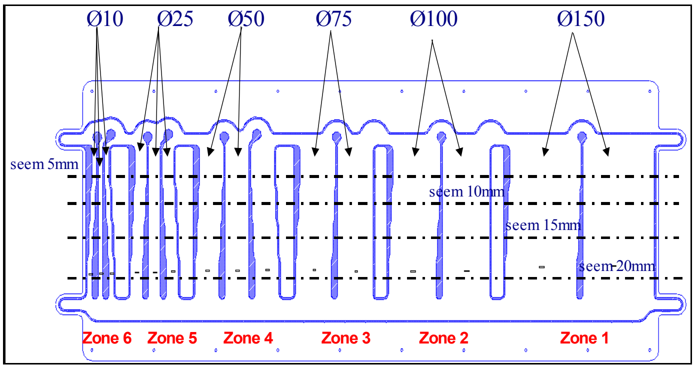


Figure A1.7: Special airbag

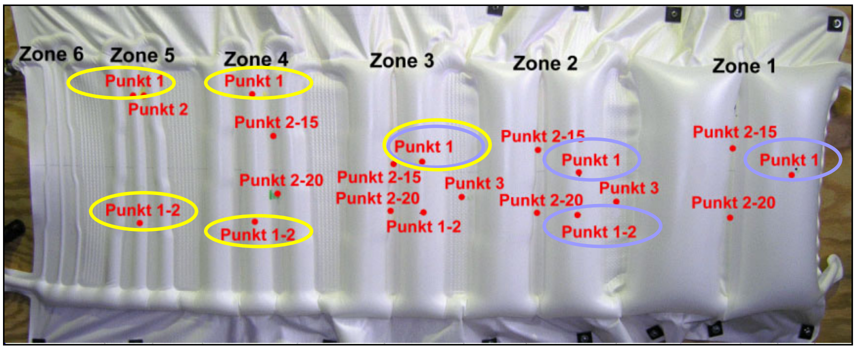


Figure A1.8: Tested points on cushions

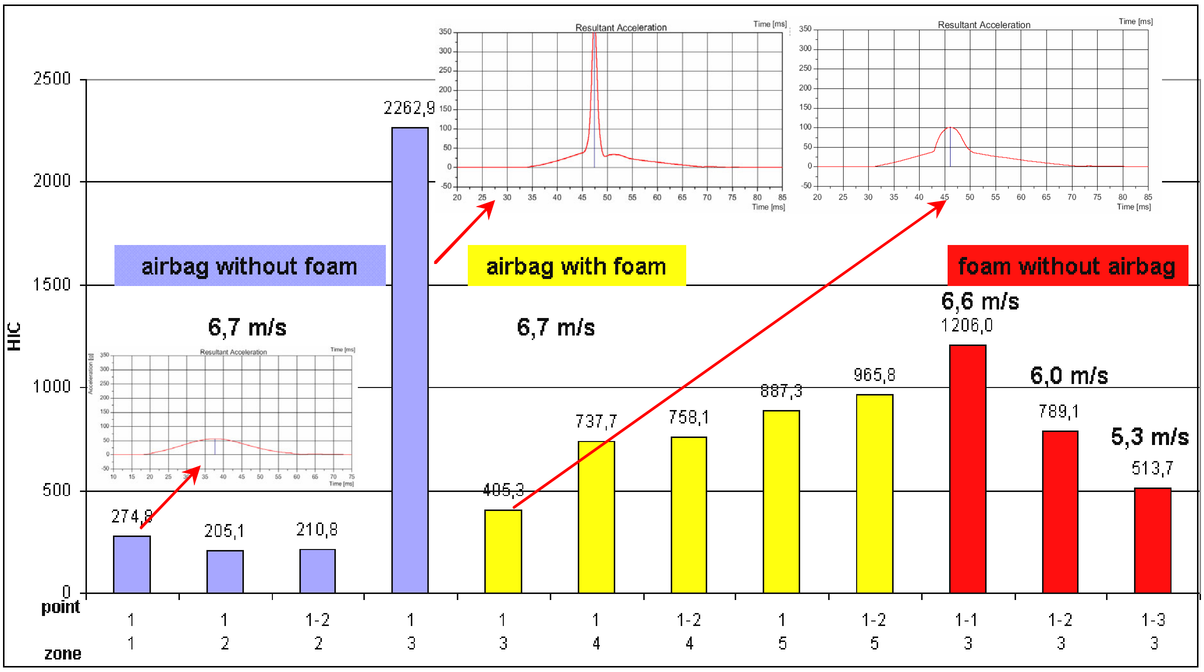


Figure A1.9: Results of cushions testing

The results in zone 1 and 2 show that the airbag thickness has no influence as long as the impactor does not strike through the cushion. The reason is that the kinetic energy was completely absorbed by the cushion. At point 1 in zone 3 the impactor starts to strike through. The critical airbag thickness is under-run. This is visible in the sudden peak in the acceleration curve in figure A1.9. To reduce HICs to an adequate level, further investigations were made with foam underneath the airbag (foam as used in pedestrian testing). Therefore the bars in figure A1.9 are coloured blue when testing without foam and yellow when testing with foam.
After retesting this point with foam underneath, the sudden peak is still visible but is moderated. Further tests from zone 3 to zone 5 show: The thinner the cushion is, the less kinetic energy is absorbed before hitting the structure underneath the airbag.

This study investigated the influence of the thickness completely isolated from any other airbag characteristics. Nevertheless it is impossible to define a certain thickness value where protection fails. There are several other important factors to be taken into account: Volume and air permeability of the cushion, pressure, number of overflow canals, shape and the kind of cushions connected to the tested cushion. Additionally low protection level may be sufficient for a soft structure underneath.

Influence of seam width at special airbag
Now the influence of seams between cushions was investigated.
It was tested from zone 1 to zone 5 at the marked points in figure A1.10, again with foam under the airbag (yellow) and without foam under the airbag (blue).
Only the size of the seams is changing in one zone from top to bottom, indicated by the prefix -15 and -20.
As assumed, the results from zone 1 and 2 are almost identical because the kinetic energy of the head is completely absorbed by the airbag. Therefore it does not make much of a difference if the seam is wide or narrow in this case. In zone 3 the FMH begins to strike through. From here onwards the width of the seams has an influence as shown by point 2-15 and 2-20 in zone 3.

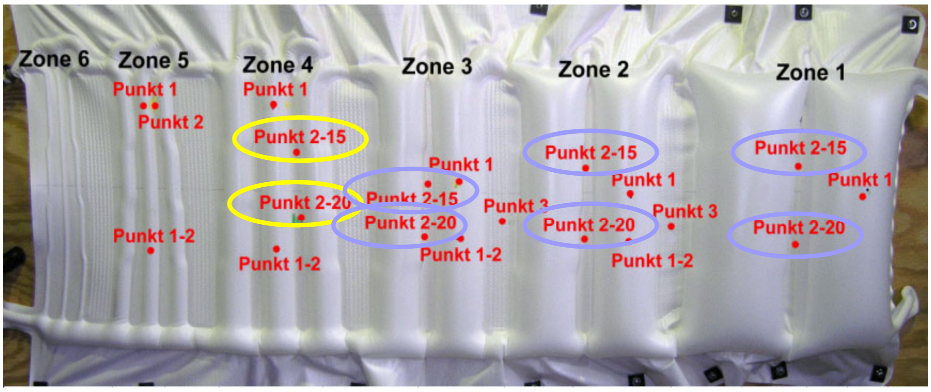


Figure A1.10: Tested points on seems

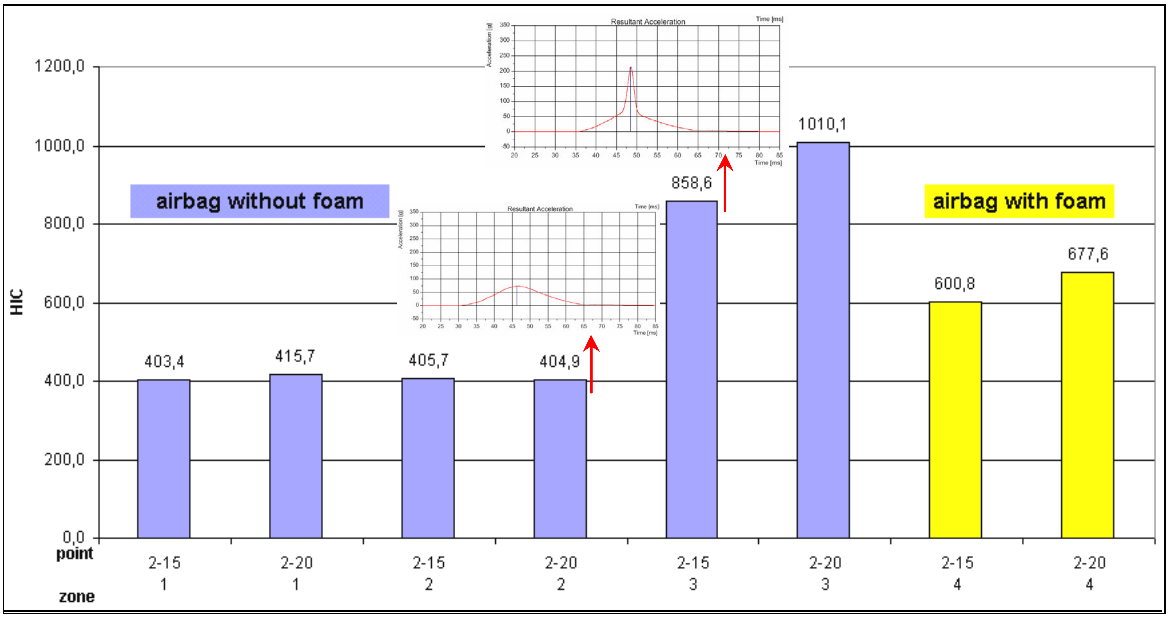


Figure A1.11: Results of seem testing

Looking at figure A1.9 and figure A1.11 it is extremely surprising that the HIC values are higher for zone 1 and zone 2 and lower at zone 3 and 4; tests at seams compared to the cushion values. This indicates that in thin areas where the impactor strikes through, seams offer a better protection than the cushion. The answer is already given in figure A1.5. When shooting at seams the impactor contacts two cushions and is therefore decelerated more effectively.

This means that more energy is absorbed at seams at the same intrusion distance than at cushions.

Result: As long as the impactor does not strike through, the higher deceleration capability of the two cushions leads to higher HICs. In this case the lower deceleration capability with one cushion leads to lower HICs. But more interesting is what happens when the impactor strikes through. The higher deceleration capability by two cushions can absorb more energy before striking on the underlying structure. With only one cushion the HIC value will now be higher because the impactor is hitting the underlying structure with a higher velocity than with two cushion protection.

This should not imply in general that seams are safer than cushions. It always depends on seam width, shape, volume, radius of the bordering cushions etc.

It is been shown that head airbags offer a very good level of protection for head contacts.

Tests inside the car

In this test phase it was analysed how to give benefit to head airbag systems in an “interior headform test procedure”.

Originally the idea was to test the car interior at 6.7 m/s with an exception zone of 5.3 m/s tests, in the area where the head airbag is stored. It is reasonable to enlarge that exception zone to all areas where the head airbag provides adequate protection. This motivates the manufacturers to improve their airbags.

To analyse the effect of airbags in cars, several points on the B-pillar in two different cars where investigated. Three different test scenarios were analysed:

1) without inflated airbag -> 5,3 m/s
2) without inflated airbag -> 6,7 m/s
3) with inflated airbag -> 6,7 m/s

A typical result is shown in figure A1.12.

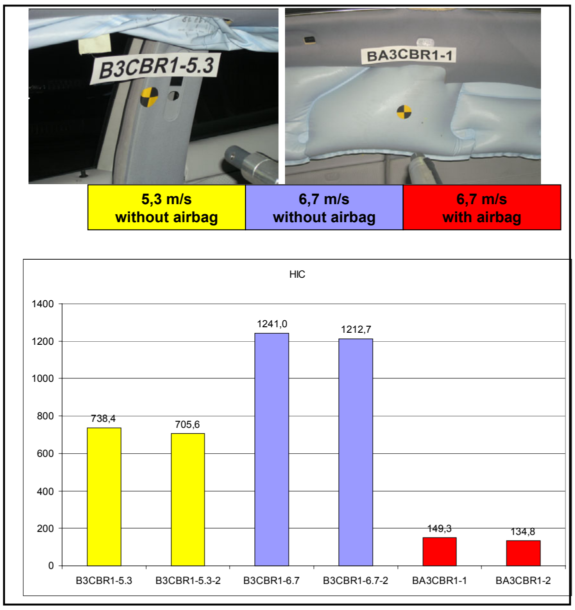


Figure A1.12: Comparison of testing at different velocities and different protections

In some cases the results with 5,3 m/s testing directly on the interior structure were higher than the results with 6.7 m/s testing on the airbag above the interior structure and vice versa, depending on the tested airbag thickness.
Nevertheless again it shows that head airbags can provide a high level of protection.
It should be mentioned that in most tests the airbags were not mounted in their designed positions, because current head airbags are often not equipped with cushions at the B-pillar. The thickest cushion is usually at the position where the pole hits the car in a pole crash according FMVSS 201. Therefore the head airbags have been mounted further backwards. A procedure which gives benefit to head airbags providing an adequate protection, would lead to a better level of protection in the majority of cars.

APPENDIX 2 Impact Angles (TNO studies)

In the TNO study of impact angles in side impacts various accident scenarios were taken into account. The size of cars is responsible for different kinematics and therefore for different severity of accidents. As first scenario a heavy bullet vehicle (Honda Accord) against a relatively light target vehicle (Chrysler Neon) was selected. The second scenario was performed with two heavy vehicles, Honda Accord against Ford Taurus. For mass and size information see figure A2.1.

Model	Category	Test mass [kg]	Length [m]	Width [m]
Chrysler Neon	Medium size	1381	4.36	1.71
Honda Accord	Medium Family car	1636	5.06	1.90
Ford Taurus	Large	1776	5.07	1.86

Figure A2.1: Mass and size information

Additionally different seating positions and occupant sizes were taken into account as described in figure A2.2.

	Target vehicle	Occupant	Initial occupant position
1	NEON	5th percentile female HBM	Normal (fully forward)
2	NEON	95th percentile male HBM	Normal (fully rearward)
3	NEON	50th percentile male HBM	Normal (mid)
4	NEON	50th percentile male ES-2 dummy	Normal (mid)
5	NEON	5th percentile female HBM	Fully rearward *
6	NEON	50th percentile male HBM	Focus on side rail **
7	TAURUS	5th percentile female HBM	Fully rearward *
8	TAURUS	95th percentile male HBM	Normal (fully rearward)

* such that there is highest likelihood of contact with B-pillar (representing a passenger).
** such that there is highest likelihood contact with roof rail.

Figure A2.2: Different seating positions and occupant sizes

Impact angles from 30° to 120° and various impact location at 50 km/h were taken into account (see figure A2.3).

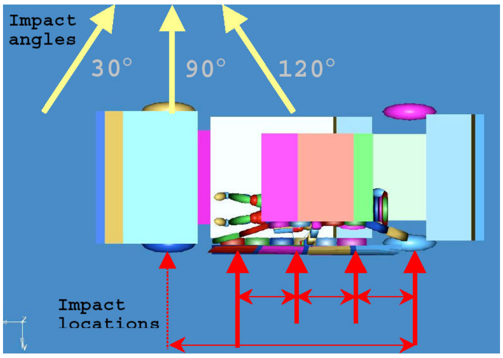


Figure A2.3: Angles and impact locations (top view)

For virtual testing the MADYMO human body occupant model was used because it is more biofidelic than dummy models.

To detect contact between the occupant's head and the interior of the vehicle, a plane was constructed in the car interior by three points. Two points were at the B-pillar and one point at the side roof rail. The plane was not deformable in the simulation but was moved inwards by the crash according to the structure deformation.

For each target car three different planes were used to represent variation in car geometry.

First the base plane was rotated 23° to the vertical and then in addition ± 6° (see figure A2.4)

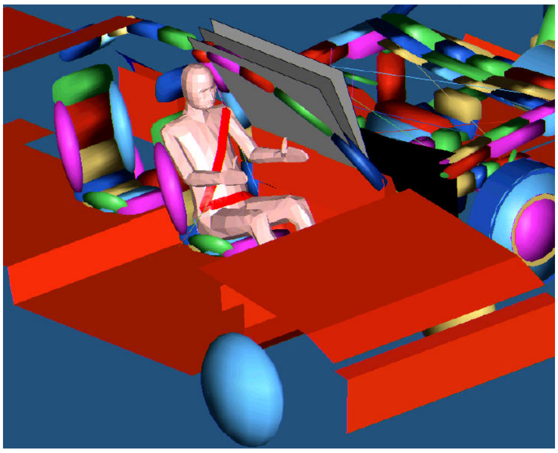


Figure A2.4: Base plane for head contacts

The impact angles are defined according to the constructed plane as shown in figure A2.5.

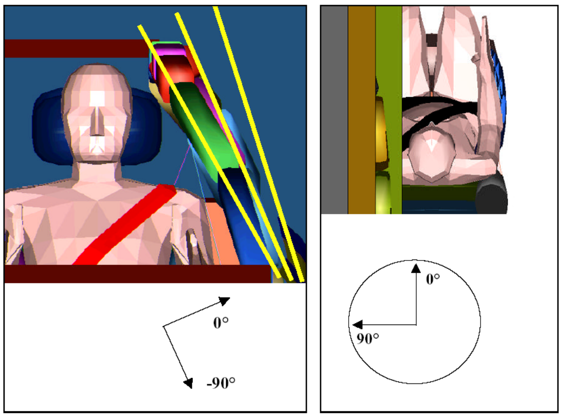


Figure A2.5: Co-ordinate system refereed to base plain

Altogether eight scenarios were simulated: seven with three different sized human models and one with a dummy model in different seating positions. Finally 432 simulations were run.

An example of the head contacts is shown in the following figure A2.6 for different occupant sizes and seating positions for the middle plane (see plane in figure A2.4 and A2.5 rotated at 23°).

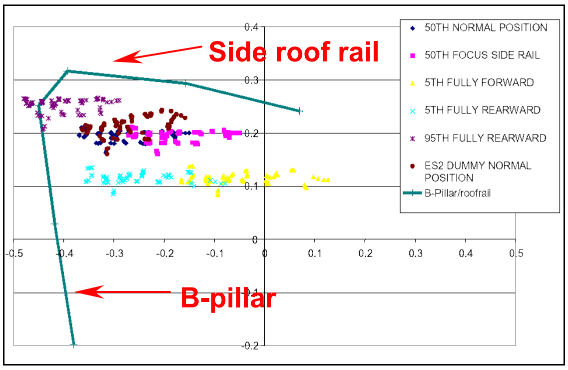


Figure A2.6: Allocation of head contacts for different human sizes

As expected the 95th percentile male has got the highest risk to contact the B-pillar region whereas the 5th female would contact the window area.

The received head impact velocities differ according to occupant size and car mass. The impact velocity is the difference between the velocity of the impact plane and head CoG. A range of 3 to 9 m/s appeared in the simulation. The average was 6.7 m/s, the same as in the interior headform test procedure.
The horizontal and vertical impact angles according to the co-ordinate system in figure A2.7 and A2.8 are also influenced by the seating position and occupant size.

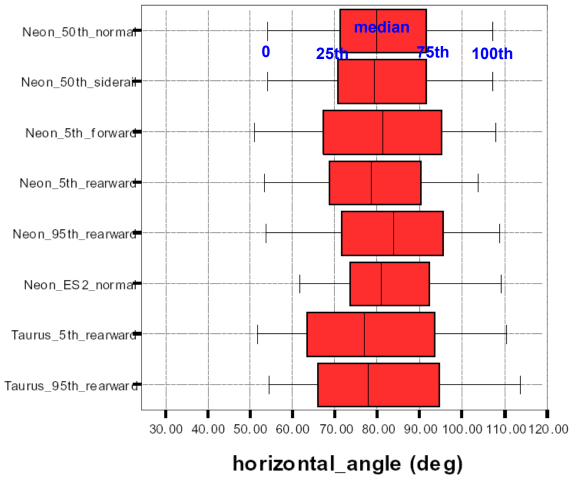


Figure A2.7: Range of horizontal angles

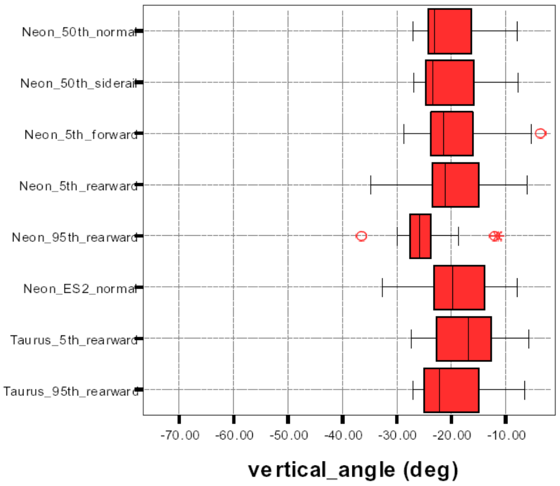


Figure A2.8: Range of vertical angles

The horizontal impact angle is between 50° and 115° and the vertical between –5° and –35° as shown in figure A2.9.

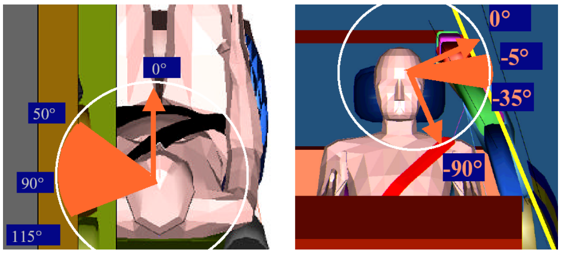


Figure A2.9: Maximum of observed angles

Transferred to a general co-ordinate system of a car, this study proposes the following angles:

- **50° . < horizontal angle < 115°**
- **-12° < vertical angle < 18°**

ANNEX A
SUMMARY OF TEST PROTOCOL

Headform – US Free Motion Headform FMH

Text and values between squared bracket are proposed and to be confirmed before the final issue of the protocol. (Example: [255] degrees)

The headform used for testing conforms to the specifications of FMVSS-201 (part 572, subpart L “Free motion headform”)

NOTE:
The headform shall be re-certified:
- after every [10] tests,
- after each test in which HICdummy > 1000
- after any test in which damage to the head-form flesh is suspected

Forehead impact zone

The forehead impact zone
of the headform is determined according to the procedure specified in sections i to vi below.

i. Position the headform so that the baseplate of the skull is horizontal. The midsagittal plane of the headform is designated as Plane S.
ii. From the centre of the threaded hole on top of the headform, draw a line 69 mm forward towards the forehead, coincident with Plane S, along the contour of the outer skin of the headform. The front end of the line is designated as Point P. From Point P, draw a line 100 mm forward toward the forehead, coincident with Plane S, along the contour of the outer skin of the headform. The front end of the line is designated as Point O.
iii. Draw a 125 mm line which is coincident with a horizontal plane along the contour of the outer skin of the forehead from left to right through Point O so that the line is bisected at Point O. The end of the line on the left side of the headform is designated as Point a and the end on the right as Point b.
iv. Draw another line 125 mm which is coincident with a vertical plane along the contour of the outer skin of the forehead through Point P so that the line is bisected at Point P. The end of the line on the left side of the headform is designated as Point c and the end on the right as Point D.
v. Draw a line from Point a to Point c along the contour of the outer skin of the headform using a flexible steel tape. Using the same method, draw a line from Point b to Point d.
vi. The forehead impact zone is the surface area on the FMH forehead bounded by lines a-O-b and c-P-d, and a-c and b-d.

Free flight trajectory

The FMH must be accelerated under linear control and released for free flight between 25 and 100mm from the point of first contact.

Impact Velocity

Two headform impact velocities are specified, the higher one for the evaluation of all target points not possessing and covered by active Head Protection Systems, and the lower one being used for defined areas of the of vehicle, which are covered by approved areas of an active Head Protection System.
- The standard impact speed is 6.7 m/s ± 0.2 m/s measured ≤ 100 mm from the contact point for ‘normal’ surfaces.
- For areas covered by ‘active head protection systems’, the impact speed is 5.3 m/s ± 0.2 m/s measured ≤ 100 mm from contact point

Impact location accuracy

- The impact alignment accuracy shall be within a radius of ≤ 10.0 mm of the selected target point.

Impact Environment

- The test temperature range shall be between 19 and 26°C
- The relative humidity shall be between 10 to 70%
- The environment shall be stabilised for a period ≥4 hours prior to test
- Time period between repeated tests using the same headform shall not be less than 3 hours

Test location and Head-form orientation

One FMH test should be performed to each test location. These are then restricted to those that lie within the ‘defined’ target area i.e. within an area defined by four planes, two passing through horizontal axes defined by the locations of the heads of large male and small female occupants and two passing through vertical axes also defined by the locations of the heads of large male and small female occupants.
In addition, tests are performed at certain defined structures (taken from FMVSS201u):
- Upper seat belt anchorage
- Seat belt adjustment device, if located above the anchorage point

- Grab handle (located within the defined header rail distance)
- Lighting control unit, coat hook or other such ‘fixed’ vehicle furniture.

Tests at one position must not compromise a test at an adjacent position due to ‘pre-damage’. Although testing will be performed with adjustable windows in the open position, only those contact points, which can be contacted by the headform with the windows closed, will be tested. The impact angle, defined as the angle of the impact velocity vector with respect to the plane tangential to the surface at the point of contact, shall be selected to be the “worst case” as close as possible to perpendicular to the impact surface.

Method 1

Then, for each selected target location, the headform orientation and actual impact location for each test is determined according to the following procedure. For clarity this procedure is illustrated by means of a decision making flow chart in Figure a.

- With the mid-sagittal plane vertical, should coincide with the impact velocity vector through the contact target.
- If a clean contact is not possible without contacting other noncertified parts of the FMH, then the headform and impact velocity vector should be pitched forward with respect to the normal by 10° ± 2° and realigned with the target, figure b.
- If a clean contact cannot be made with the head mid-sagittal plane, aligned vertically following this adjustment then the FMH and velocity vector should be returned to normal to the surface and the FMH be rolled by 90° ± 2° around the velocity vector, as described in the note.
- If the target location point still cannot be hit cleanly, then the headform should be rotated back to its original vertical position and the headform and impact velocity vector should be pitched forwards, with respect to normal, until a clean contact is established up to a maximum allowable pitch of 18° ± 2° to normal. A pitch of 18° reduces the lateral component of the impact vector by approximately 5%.
- If the selected point still cannot be impacted cleanly, then the target point should be moved within the limits defined in Appendix 1, Section 1.3 while still seeking a worst case contactable position.

Method 2

Then, for each selected target location, the headform orientation and actual impact location for each test is determined according to the following procedure.

- With the mid-sagittal plane vertical, the impact velocity vector shall be perpendicular to the surface through the contact target.
- If a clean contact is not possible without contacting other noncertified parts of the FMH, then the headform and impact velocity vector should be pitched downward with respect to the normal by 10° ± 2° and realigned with the target, figure b
- If the target point still cannot be hit cleanly, again the headform and impact velocity vector should be pitched downwards, with respect to normal, until a clean contact is established.
- If the selected point still cannot be impacted cleanly, then the target point should be moved within the limits still seeking a worst case contactable position.

For any method the following exceptions will apply:

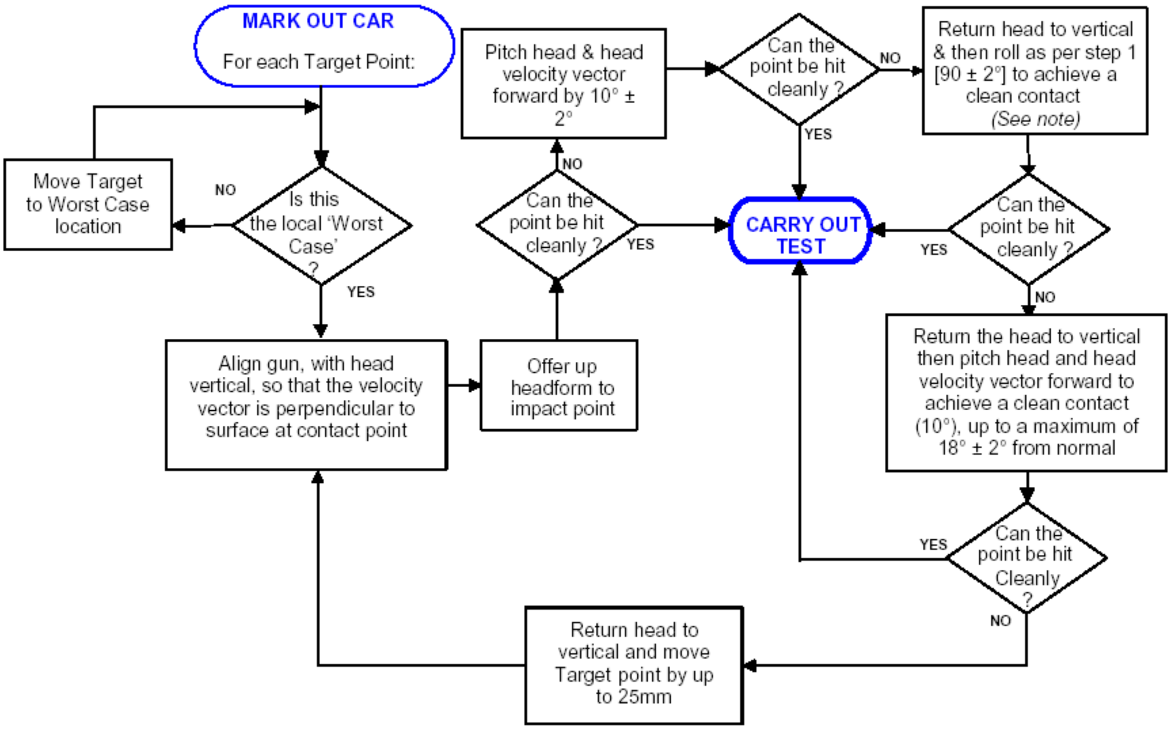
(a) Vertical approach angles will be limited to no more than [50] degrees (as is used in FMVSS 201) for all impacts. (Recent computer simulations has suggested that Vertical approach angles of [-10 to +20] degrees may be more appropriate, see TNO study above)

(b) When testing the A-pillar, the horizontal approach angle will be limited to between [195] and [255] degrees for the left hand side, and [105] to [165] degrees for the right hand side. Figure c. For impacts on the A-pillar only the longitudinal vertical plane passing through the forehead impact zone points O and P shall be perpendicular to the primary axis of the A-pillar at the impact point. Figure d.

(c) When testing side roof structures, B-pillars and other pillars (where applicable), the horizontal approach angle will be limited to between [230] and [295] degrees for the left hand side, and between [65] and [130] degrees for the right hand side. Figure e.

(d) For point BP2, the horizontal approach angle will be limited to [270] degrees for the left hand side and [90] degrees for the right hand side.

(e) When testing the rearmost pillar, the horizontal approach angle will be limited to between [270] and [345] degrees for the left hand side and [15] to [90] degrees for the right hand side. Figure c.



note: Clarification note on headfrom rotation

FMH axial rotation about the impact vector facing towards the target point.

Target area	Left hand side of the vehicle	Right hand side of the vehicle
A post target points	90° clockwise	90° anticlockwise
Roof rail target points	90° clockwise	90° anticlockwise
B post target points	90° anticlockwise	90° clockwise

Figure a: Method 1, headform alignment flow chart

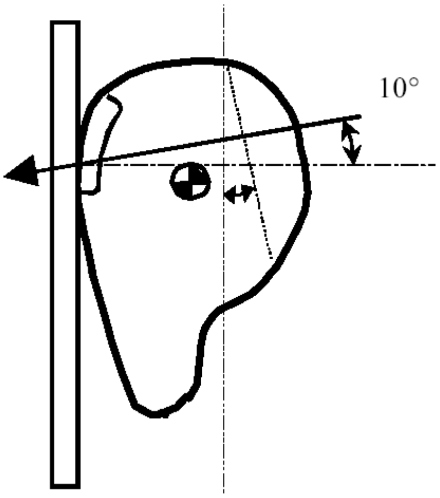


figure b: 10° pitch to the normal

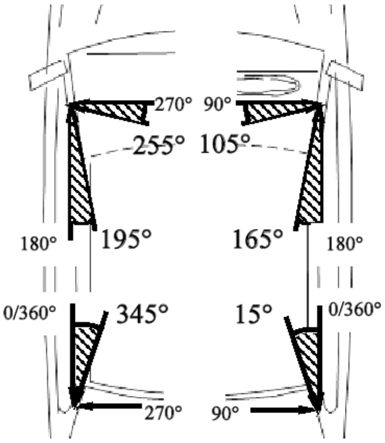


figure c: Horizontal approach angle limitation for A- and rearmost pillar

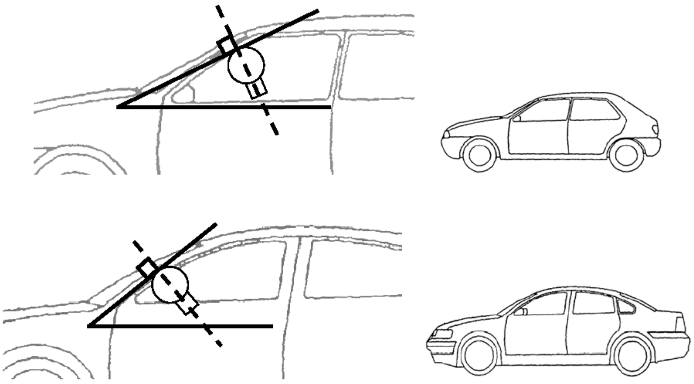


figure d: Perpendicular impact to the A-pillar

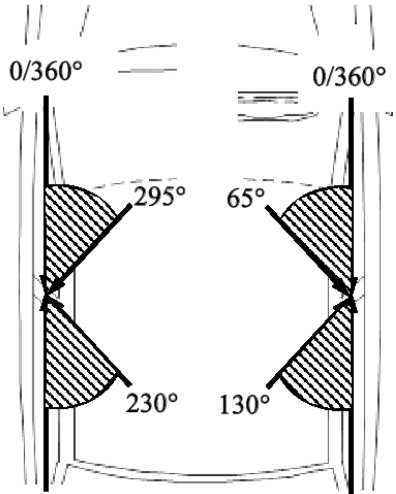


figure e: B-pillar and other pillar horizontal approach angle limitations

Note:

During the first phase of the WG13 research the US FMH was selected as the preferred impactor, thus all of the reported WG13 research has focussed on the use of this test device.

General guidance

- **'Worst Case' impacts**

It is expected that 'worst case' will differ between vehicles, thus each vehicle should be assessed, by examining the drawings or physical inspection, before assuming the padding, fixing or other structure would be a worst case position. An inspection of the trims and underlying structure should be carried out to look for:
- Where the crush depth of padding is minimal.
- The location of fixings and bolts.
- The position of welds, joints or internal webs in the chassis.
- The attachment of padding or other components

The presence of such features could be used to guide a test authority regarding focal point for 'worst case' impacts.

- **Closeness of repeated test**
  - Multiple impacts

  A vehicle being tested may be impacted multiple times, subject to the limitations given below
  - Impacts within 300 mm of each other may not occur less than 30 minutes apart.
  - No impact may occur within 150 mm of any other impact. The requirement within

FMVSS 201 has been increased to 200 mm between points for what is believed to be technical reasons.

The distance between impacts is the distance between the centres of the target circle for each impact, measured along the vehicle interior.

- **Examination of collateral damage**

If other impacts are to be carried out within a 200 mm radius of a previous impact point then any structural damage around and beneath the target point must be assessed. If damage is noted and full repair is not possible then no further adjacent impacts should be performed within the area of damage extended by 200 mm from the target point. Tests at the adjacent points would have to be performed in a different vehicle.

Note – the chin of the headform can contact parts of the vehicle structure 150 mm from the contact point.

Damage assessment

- If any trim or padding has been permanently deformed or show signs of elastic distortion, including attachment points within a 100 mm radius of the target points then the padding must be replaced for adjacent tests. The 100 mm radius could be increased if it is considered that the damage might affect the stiffness of the padding structure in any adjacent impact. All padding and trim attachment points should be examined and assessed for possible collateral stiffness.

- The extent of damage/deformation to structures underlying the padding should be assessed. If any permanent damage is detected the limit of the damage must then be quantified. No adjacent test should be carried out within 200 mm of the edge of the identified structural damage.

Vehicle preparation, including support

The vehicle should be rigidly supported off its wheels with the principle axes of the vehicle being aligned with ground reference co-ordinates. The maximum displacement of the exterior surface of the vehicle, along the axis of the impact adjacent to the point of contact, shall not exceed 10 mm. If necessary, the exterior of the vehicle may be 'additionally' supported to limit exterior movement to 10 mm.

If the side window can be opened, tests should be performed with the window fully open.

Pole impact test Procedure.*

The vehicle impacts a fixed 254 mm diameter rigid vertical pole at an impact speed of 29 ± 2 km/h. The pole is aligned with the centre of gravity of the head of the ES-2 dummy. In order to achieve this impact, the vehicle is placed on a carrier, which can translate freely in the direction perpendicular to the vehicle's longitudinal vertical plane.

* NOTE: The pole impact test procedure is based on that specified in FMVSS 201 with the ES-2 dummy. The specifications for the test procedure defined in Annex 1 have been taken from an edited version of the Euro NCAP protocol, since this also uses ES-2. Elements only used in the derivation of Euro NCAP ratings and items not appropriate for this draft procedure have been removed.

The impact angle should be 90° ± 3°.

The dummy's seating position should be adjusted, if necessary, to ensure that the head presents a target through the side glazing and is not obscured by the B-pillar.

The active system FMH tests and active system sub-structure FMH tests will only be performed where the requirements of the pole impact test are satisfied. The procedure is shown in figure f.

Performance criteria

FMH Head Injury Criterion

The Head Injury Criterion for the head-form (HICFMH) is calculated according to the following formula:

$$HIC_{fmh} = \left(\frac{1}{(t_2 - t_1)} \int_{t_1}^{t_2} ad\ (t) \right)^{2.5} (t_2 - t_1)$$

where 'a' is the resultant head-form acceleration, expressed as a multiple of 'g' (the acceleration due to gravity), and t1 and t2 are any two points in time during the impact, which are separated by not more than a thirty-six millisecond time interval.

$HIC_{dummy} = 0.75446\ HIC_{FMH} + 166.4 * 1000$

Pole Test Head Injury Criterion

In the pole impact test, the Head Injury Criterion (HIC) must not be more than 1000. The HIC is the maximum value of the expression:

$$HIC_{fmh} = \left(\frac{1}{(t_2 - t_1)} \int_{t_1}^{t_2} ad\ (t) \right)^{2.5} (t_2 - t_1)$$

where 'a' is the resultant head-form acceleration, expressed as a multiple of 'g' (the acceleration due to gravity), and t1 and t2 are any two points in time during the impact, which are separated by not more than a thirty-six millisecond time interval.

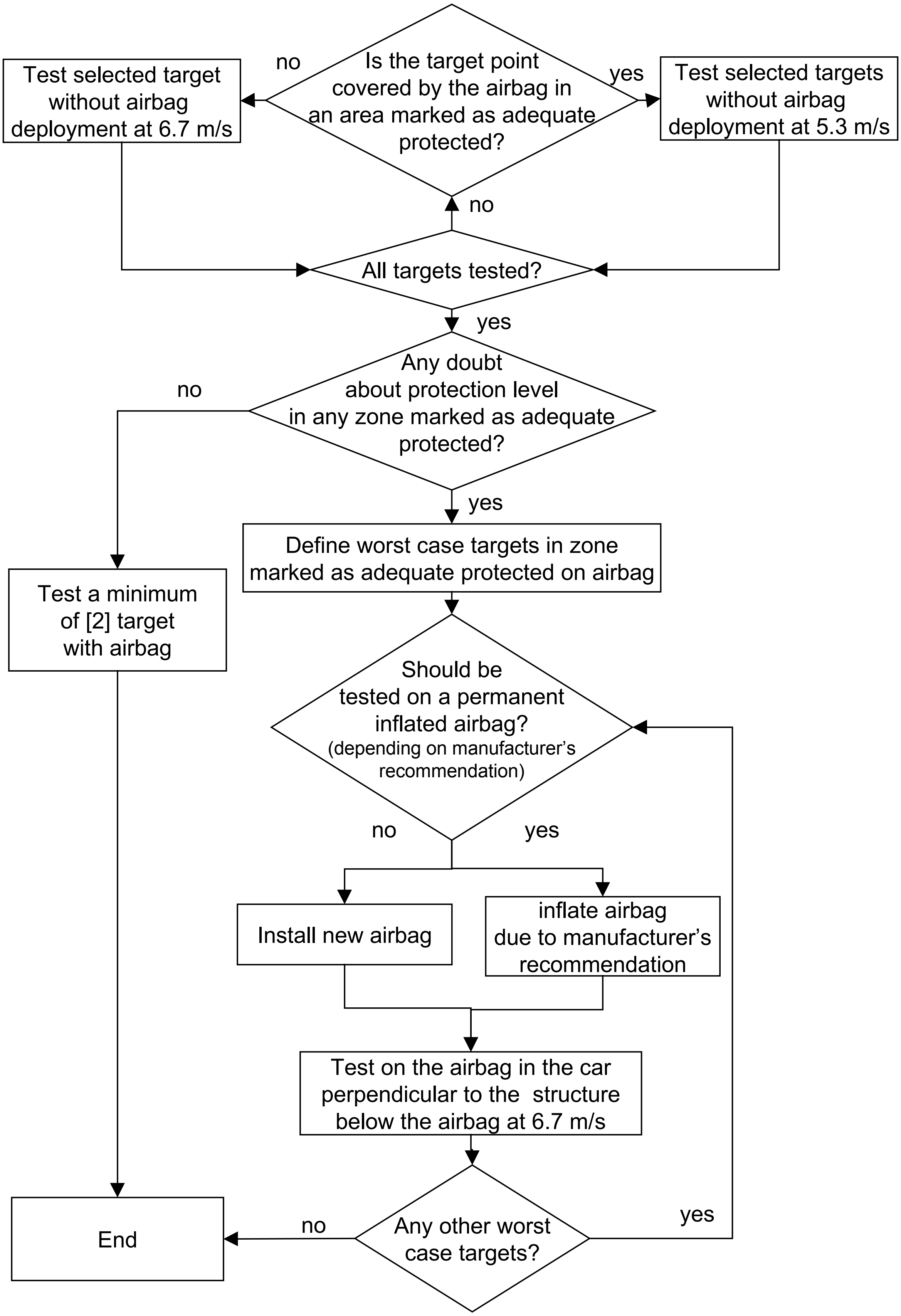


figure f: Flow chart for testing with head airbag systems

9.3. THE DEVELOPMENT OF AN ADVANCED EUROPEAN MOBILE DEFORMABLE BARRIER FACE (AE-MDB): 19th ESV paper 2005

THE DEVELOPMENT OF AN ADVANCED EUROPEAN MOBILE DEFORMABLE BARRIER FACE (AE-MDB)

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TRL Limited (UK) on behalf of EEVC WG13
Paper Number 05-0239

ABSTRACT

The European Enhanced Vehicle safety Committee (EEVC) Working Group 13 (WG13) is working within the IHRA (International Harmonised Research Activities) Side Impact Working Group (SIWG) assisting in the development of a suite of harmonised test procedures for side impact protection. Included in the procedures will be a full-scale barrier based side impact test. This paper presents the current status of a research programme that has been carried out to develop a more appropriate side impact barrier face for use in an advanced side impact test procedure. The Advanced European Mobile Deformable Barrier Face (AE-MDB) test will reflect the ‘car to car type’ accident that is typical in Europe and other regions of the world. The latest research performed by EEVC Working Group 13 in the development of an AE-MDB includes reviews of vehicle force distributions, car to car tests as well as the performance of the current specification AE-MDB tests into a range of vehicles.

It is noted that the European vehicle fleet has developed since the UN-ECE Regulation 95 barrier was first conceived, and as a result an improved test procedure is required. The IHRA procedures are being developed to encourage enhanced protection for both the front and rear seat occupants. The AE-MDB should perform in a way that reflects the current accident situation.

BACKGROUND

The AE-MDB is being developed by EEVC WG13 as part of a contribution to the activities of the IHRA side impact working group, which is co-ordinating worldwide research for various aspects of side impact protection including out of position, interior surface protection, full-scale pole impacts and a full-scale mobile deformable barrier based test procedure. This paper presents the status of the vehicle based AE-MDB test specification and the results of tests performed under the WG13 barrier development programme. It is noted that further research is also being conducted outside of WG13 as part of other research projects including the Advanced Protection Systems (APROSYS) project, and an MDB evaluation in Japan.

There are two MDB based test procedures under consideration by IHRA, one being proposed by the Insurance Institute for Highway Safety (IIHS) and the other by EEVC WG13. The IIHS MDB is representative of an impact by large sports utility vehicles (SUV) and small trucks, which is more reflective of accident severities seen in the US. The AE-MDB is more reflective of the European accident situation, where the MDB is more representative of car-type impacts which form the largest proportion of the European vehicle fleet when compared to SUV type vehicles.

Analysis has shown that the existing ECE Regulatory side impact test procedure (R95), is becoming less representative of the impact severity observed in recent accident data [1]. Overall vehicle intrusion, as seen in real-life side impact accidents is also greater than that seen in laboratory side impact tests, and therefore it has been recommended that the overall side impact test procedure severity should be increased [2]. Edwards et al [1] subsequently proposed several ways to increase the test severity to be able to encourage enhanced occupant protection, which included increasing the speed and/or mass of the MBD and also an increase in ground clearance as supported by data from vehicle structural analyses.

One of the main considerations made by WG13 alongside that of the barrier face specification was that the MDB should be capable of simultaneously loading both the front and rear occupants. This measure was made to ensure that vehicles offer adequate protection to both front and rear seat occupants. This is in line with the original proposal made by EEVC WG9 during the research that led to the development of ECE Regulation 95 and EU Directive 96/27EC, although this aspect was not finally included.

PREVIOUS RESEARCH

The initial development stages of the AE-MDB were reported by EEVC WG13 at the 18th ESV conference held in Nagoya, Japan, 2003 [3]. The barrier development programme was based upon three specific areas for assessment; these were baseline vehicle test results, test and MDB configuration and barrier specification. The test and MDB configuration proposed by WG13 utilises a stationary target vehicle impacted by the MDB travelling at 50km/h. The centreline of the MDB is perpendicular to that of the target vehicle and is aligned 250mm rearward of the target vehicle's R-point. This was set to load both front and rear seat occupants and represent a moving car to moving car side impact; where the initial contact point is aimed at the front seat R-point.

Test and MDB Configuration

As reported previously, EEVC WG13 is of the opinion that from a regulatory perspective a perpendicular test (opposed to angled or crabbed) is the preferred option as it minimises shear loading to the forward honeycomb elements of the barrier face and makes for a less variable test. Furthermore, an analysis of the Co-operative Crash Injury Study (CCIS) database for the UK accidents indicated that perpendicular accidents were equally as frequent as angled impacts [4]. The proportion of casualties that were seriously or fatally injured was 60 percent for perpendicular impacts compared with 45 percent for the angled impacts. This highlights the differences that have been seen between the dummy responses observed in crabbed and perpendicular impacts.

WG13 also believes that a perpendicular impact configuration is the most appropriate for the car based test as suggested by accident data, and is reflective of more than half of the side impact accidents within Europe. These reasons, reinforced by the benefits of repeatability and reproducibility of a stationary target vehicle, formed the basis for the impact configuration of the new test procedure.

Current European side impact requirements are limited to front seat occupants only. The inclusion of a rear seat occupant, as proposed by IHRA, aims to ensure that rear seat occupants are also offered a similar level of safety. This measure requires the AE-MDB impact test to load rear seat occupants appropriately without reducing the loading applied to front seat occupants. Previous studies into the geometrical characteristics of vehicle structures performed by EEVC WG13 indicated that the spacing between the lower rails was similar to the distance between the front and rear seating positions [5]. In order to increase the loading applied to rear seat occupants, the MDB centreline is aimed mid-way between the seating positions. The impact point of the MDB is therefore aimed 250mm rearward of the vehicle R-point.

A measure taken to increase the test severity was to increase the mass of the MDB. The proposed trolley mass was increased from the 950kg specified in R95 to 1500kg. This mass is more representative to that of vehicles in the current vehicle fleet, and is also proposed by IHRA for promotion of harmonisation between test procedures.

Barrier Specification

To increase further the test severity, the initial ground clearance of the AE-MDB face was 350mm. The upper surface of the barrier face is at the same height above ground as that of R95, 800mm, as recommended by Edwards, 2000.

Rigid car to load cell wall (LCW) data, collected from vehicle models dated circa 1970-80s, formed the basis of the stiffness distribution for the R95 barrier face. This measure was based upon force-deflection and energy absorption limits for the individual barrier blocks and the barrier total. The same approach has also been taken to date to develop the AE-MDB corridors. The main source of LCW data available to WG13 prior to the 18th ESV conference (Nagoya) was provided by the Japan Automobile Research Institute (JARI) [3]. The original AE-MDB corridors were subsequently based around these results, and were described by Roberts, 2003. It was proposed that further LCW tests with European vehicles should be performed and compared to the JARI data. WG13 subsequently collected rigid LCW data from seven different vehicle models.

Baseline Vehicle Test Results

The performance assessment for the AE-MDB was based on the results of the 'baseline vehicle test data'. These tests were moving car to moving car perpendicular side impacts; and represented the type of impact that the AE-MDB should be able to replicate. Two different bullet vehicles were used to provide a range of impact scenarios, one being a family sized car and the other a small off road vehicle. Previously, only two target vehicles, a Renault Megane and Toyota Camry, had been used by WG13. It was proposed that the AE-MDB should undergo further evaluation using different vehicle models.

The results from those earlier baseline tests indicated that the AE-MDB performed differently when impacting the Megane than when impacting the Camry. Comparison of the post test vehicle intrusion profiles from the AE-MDB tests with those from the baseline tests indicated that when impacting the Megane, the AE-MDB appeared to be a suitable representation of the European accident situation. However, with the Camry the AE-MDB results were less conclusive suggesting that it may be more suitable for Europe than the IIHS barrier face.

Further baseline car to car and AE-MDB to car tests have been performed since the previous WG13 report. A range of target and bullet vehicles were used in order to provide a broader assessment for the barrier face.

VEHICLE TO RIGID LCW PROGRAMME

The rigid LCW data provided by JARI, gave a clear indication that the frontal stiffness distribution of modern vehicles has changed significantly since the development of the R95 barrier face. WG13 performed additional car to rigid LCW tests in order to confirm that the stiffness distribution in modern European vehicles was comparable to that of the JARI data.

The stiffness distribution; as indicated by JARI and WG13 LCW results together with the AE-MDB version 2 corridors; is shown in Figure 1. The upper frontal structures of the vehicles tested, which align with blocks A, B and C, show a relatively homogenous stiffness distribution and low levels of loading applied. In contrast, the vehicle structures which align with the lower row of blocks do not show such homogeneity. The outer areas are loaded to a greater extent that any other below 350mm of displacement. This load is most likely to have been transferred through the lower rails of the vehicles tested. The centre area (block E) initially indicated large forces after relatively little deformation, it is suggested that this is due to the inertial response from bumper beams and lower rail connecting members. This is exaggerated by the effects of data the filtering processes, which caused loading to be shown prior to vehicle displacement. The load applied to the centre area is, for the most part, lower than that of the outer areas. The loading to this area reaches a similar level to that of the outer areas due to engine loading, which becomes apparent at around 300mm of displacement.

It is accepted that rigid LCW data is unable to clearly highlight the presence of significant lateral connections between lower rails. However, the results are able to provide an indication as to the global stiffness of the vehicles tested. It is currently unclear as to the proliferation of such beam structures throughout the European vehicle fleet, and there is currently no equivalent test procedure which can be used to assess and specify such design, either in terms of barrier design or specification. WG13 has analysed data from LCW tests with a 150mm aluminium honeycomb barrier fitted to the wall. These results were deemed unsuitable for the definition of vehicle stiffness, due to the vehicle structural characteristics being obscured by the presence of the deformable element.

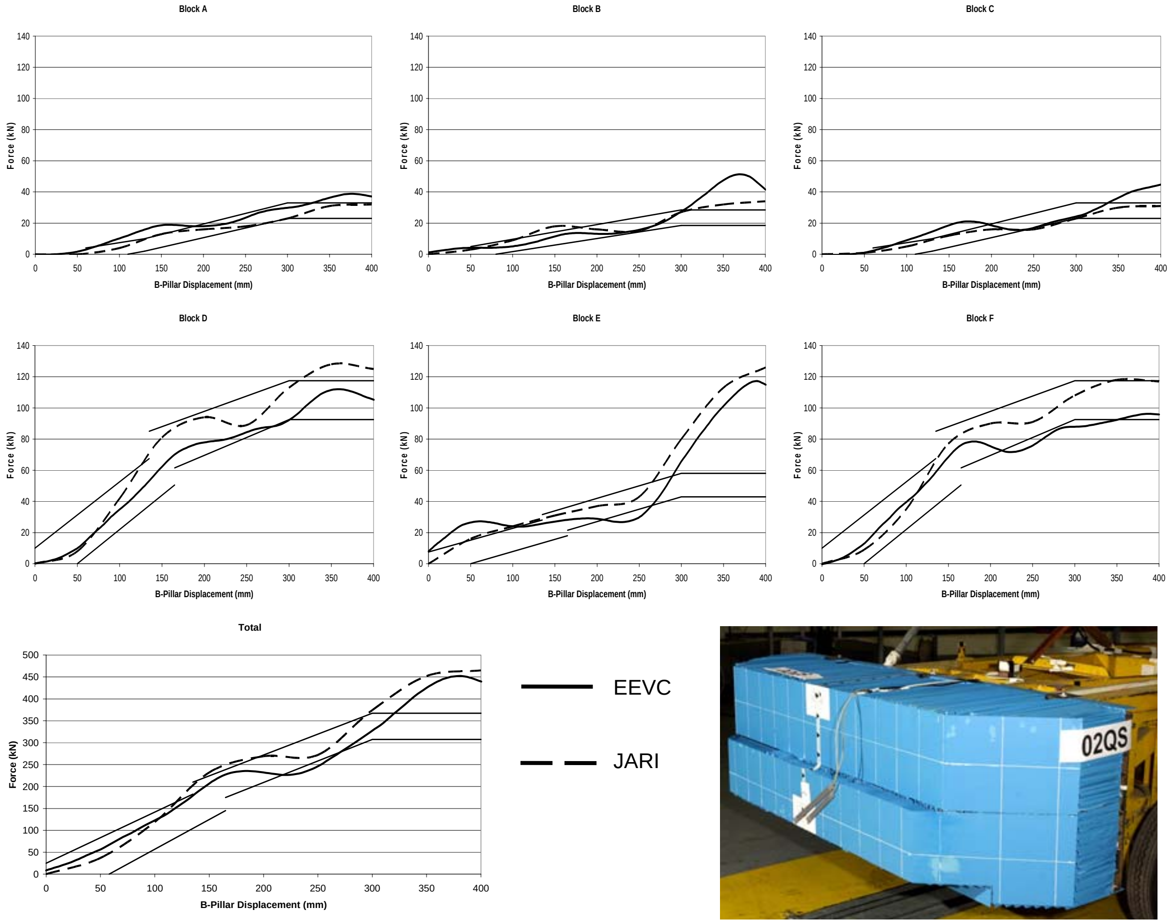


Figure 1 Vehicle to Rigid Load Cell Wall Test Data

Both the Japanese and WG13 data show similar trends across all corridors, and in the case of blocks A, C and E, local and overall force levels are also comparable. For the upper row the WG13 data was slightly above that of the JARI data, whereas the reverse is observed for the lower row. The AE-MDB stiffness corridors have a similar stiffness distribution similar to that of the vehicle data. In general, the total force-deflection traces are very similar and the AE-MDB corridor appears to be a suitable representation of the overall stiffness, up to about 300mm displacement where engine loading becomes apparent.

The information provided by JARI was a 'calculated average' where the force was weighted by vehicle sales data from 1998, with the relative B-pillar displacement normalised. The data was made up from approximately 80 vehicles to LCW tests, and a further analysis based on C-segment vehicle models showed very close similarities between data, which indicated that the full data set was representative of the most common vehicle models. The WG13 data was an averaged force with the relative B-pillar displacement normalised. It was not weighted by vehicle sales, as was the Japanese data, thus any variation could be due to this difference. The WG 13 data was made up of seven vehicle models, and included a small off road model, a multi-purpose vehicle and various D-segment vehicles.

Although the AE-MDB version 2 performance corridors have been modified since those presented at the 18th ESV conference (AE-MDB version 1), the modifications have only been included to make allowance for the geometrical characteristics of the AE-MDB. For example, block E of the AE-MDB utilises the same honeycomb as that of the R95 barrier blocks 1 and 3, subsequently it was given the same corridor in version 1. However, due the step in the AE-MDB, the force applied between 0-150mm displacement is less than that of R95. Therefore the corridor was reduced for this period, and at 150mm the full surface of block E is engaged and the corridor returns to that used in R95. It was the intention that the materials to be used in the construction for the AE-MDB should be based upon those which already exist. In the case of AE-MDB blocks A to C, which form the upper row, the honeycomb to be used was the same as that used for the R95 barrier face block 4.

BASELINE VEHICLE TEST PROGRAMME

Since the previous report at the 18th ESV conference, WG13 has performed four additional baseline tests using two other target vehicle models. In total, eight baseline tests have been performed using four different target vehicles and three different bullet vehicle models. The centreline of each bullet vehicle was aimed at the R-point of each target vehicle, with both vehicle centrelines perpendicular to each other. The speed of each target vehicle was 24km/h, and the bullet vehicles were travelling at 48km/h. This configuration is exactly the same to that of the previous research performed by WG13.

Bullet Vehicle Models

Ford Mondeo – family size vehicle, five-door hatchback. Mark 1 (pre-1996), 1.6l engine, test mass 1390kg.

Land Rover Freelander – small off road vehicle, typical within the European vehicle fleet and available worldwide. 2000 model year, 2.5l engine, automatic transmission, GS model, test mass 1720kg.

Toyota Corolla – small family size vehicle, four-door saloon. 2002 model year, 1.4l engine, test mass 1340kg.

Target Vehicle Models

Renault Megane - small family size vehicle, five-door hatchback. 1998 model year, 1.4l engine, 'AIR' model, test mass 1350kg. Equipped with side airbags.

Toyota Camry – executive four-door saloon available worldwide. 1999 model year, 2.2l and 3.0l engine, test mass for both models 1600kg. Equipped with side airbags.

Toyota Corolla - small family size vehicle, three-door hatchback. 2002 model year, 1.4l engine, test mass 1340kg. Not equipped with side airbags.

Alfa Romeo 147 - small family size vehicle, three-door hatchback. Equipped with side airbags.

The recent baseline tests to a Toyota Corolla and an Alfa 147 were performed using a Land Rover Freelander and a Toyota Corolla. These tests were used to gain further experience of impacts with a small off road vehicle and an average family size vehicle, which provide a representation of the real-world impacts that the AE-MDB procedure should be able to reflect. It was also possible to investigate any differences between three and four/five door vehicles, as the Corolla and Alfa were both three door hatchbacks.

Anthropometric Test Devices

The initial studies by WG13 used the EuroSID-I dummy. Since that research was performed this dummy has been superseded by the ES-2, which is seen as being an improvement over the EuroSID-I. Therefore, WG13 agreed to use the ES-2 and any direct comparison between these evaluations phases should make note of this change.

Toyota Corolla Test Observations
The post test struck side vehicle deformation to the Corolla is shown below in Figure 2 and Figure 3. The Freelander applied loading to the Corolla at a higher level to that applied by the Corolla bullet vehicle, this was indicated by the deformation to the roof and door panel visible just below the height of the door handle. The loading applied by the Corolla was concentrated toward the lower edge of the door and around sill level, in these respective areas, were where the B-pillar was seen to receive most of its loading. There was more door deformation visible in the Freelander test where the lower edge over-rode the sill. There was little sill deformation visible after the Corolla test.

Figure 2 Corolla impacted by the Corolla

Figure 3 Corolla impacted by the Freelander

Alfa Romeo 147 Test Observations
The post test struck side vehicle deformation to the Alfa is shown in Figure 4 and Figure 5. The bullet vehicles applied loading to the Alfa in similar ways to those seen in with the Corolla. Note also that the vertical bend in the door, just rearward of the side mirrors, was pronounced in the Freelander impact, whereas the when impacted by the Corolla this deformation was not present. The form of deformation to the sill and rear panel, beneath the rear window, appeared to be quite similar. In both cases, the lower edge of the driver’s door remained engaged with the vehicle sill. But, the visible rotation of the sill about its primary axis and deformation to the underside, suggests that loading has also been applied to a large proportion of this area.

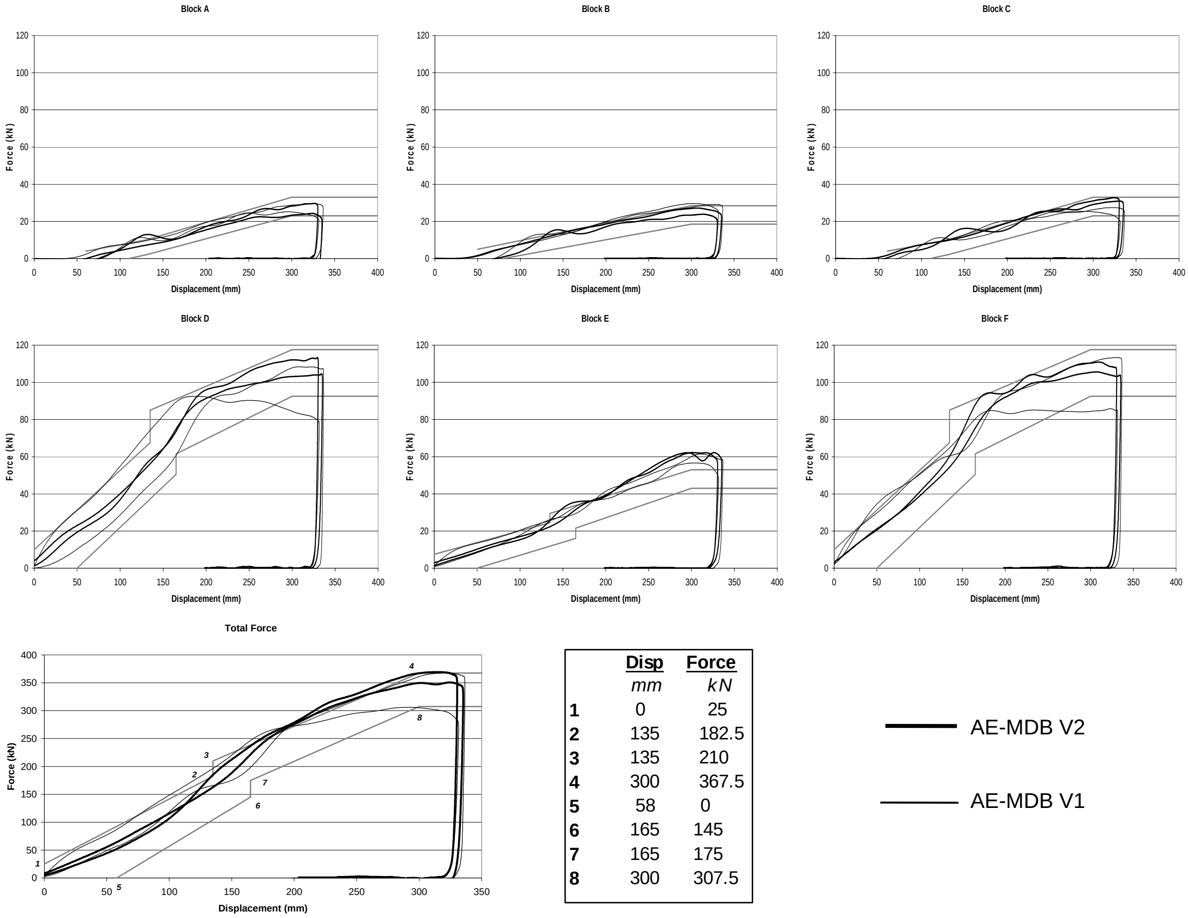
Figure 4 Alfa impacted by the Corolla

Figure 5 Alfa impacted by the Freelander

All of the vehicles impacted by the Freelander indicated that most of the load was being applied approximately midway up the door(s), from observations of vehicle damage. However, the Mondeo and Corolla mostly loaded the target vehicles toward the lower edge of the door(s). With the Freelander, the presence of a high beam connecting the lower rails was evident on each target vehicle. A pre-test measurement of this beam showed it to be positioned approximately 560mm above ground level. With the family sized vehicles, the presence of such beams was not as clear, but measurements of the Mondeo and Corolla located the beams approximately 430mm and 480mm, respectively, above ground level.

AE-MDB TEST PROGRAMME

The current specification of AE-MDB face that has been published is version 2. The barrier version evaluated by WG13 and published at the 18th ESV conference was version 1, the only difference being the build specification to reflect the changes that had been included in the revised R95 barrier face. Prior to the vehicle tests with the AE-MDB V2, two LCW certification tests were performed at two different laboratories in order to ensure that the barriers used met the specification required. The results from the V2 tests, in bold black lines, are shown in Figure 6 alongside those of the V1 tests performed previously by WG13.



	Disp	Force
	mm	*kN*
1	0	25
2	135	182.5
3	135	210
4	300	367.5
5	58	0
6	165	145
7	165	175
8	300	307.5

Figure 6 AE-MDB Certification tests

The certification test results showed that the barriers did suitably meet the design specification, although block E was slightly stiffer than desired after approximately 200mm displacement. Further barriers were subsequently constructed and used for assessment of the specification.

Toyota Corolla Test Observations

The post test deformation of the Corolla after being impacted by the V2 AE-MDB is shown in Figure 7. There was very little roof and upper B-pillar deformation visible. The loading from the barrier was applied over a greater area than that of the Freelander. The lower edge of the doors were deformed in a manner more like that of the Freelander than the Corolla, and subsequently the door over-rode the sill. The level of sill deformation appears to be between that seen in the baseline tests.

Repeatability Evaluation

In an assessment of repeatability; three AE-MDB V2 to Corolla tests were analysed. The results show comparable dummy and deformation results between all of the tests, which were performed at two different laboratories. However, a different trend in door velocity was recorded between laboratories, which can be attributed to different measurement methods.

Figure 7 Corolla impacted by the V2 AE-MDB

Alfa Romeo 147 Test Observations

The post test deformation of the Alfa after being impacted by the V2 AE-MDB is shown in Figure 8. There was less roof and upper B-pillar deformation when compared to that of the Freelander impact, and in this area a closer comparison can be made with the Corolla impact. The most notable differences between the barrier and baseline vehicle impacts is the larger loading to the lower edge of the door, and the lower levels of loading to the sill seen with the AE-MDB. There was no engagement between the door and sill, which did not rotate as it did in the baseline tests, allowing for greater levels of intrusion. In the area of the rear panel the form of deformation was comparable to that of the baseline tests.

Figure 8 Alfa impacted by the V2 AE-MDB

Vehicle intrusion profiles

In all of the tests performed by WG13 the geometrical characteristics of each target vehicle were mapped before and after each impact. A grid was applied to each vehicle with rows at a height of 300, 425, 550 675 and 800mm above ground level. Vertical columns, originating from the Driver's R-point, extended fore and aft at increments of 125mm. The only exception to this was with the AE-MDB to Alfa test, where the grid was measured at 130x200mm increments and do not translate directly to the points measured in the baseline Alfa 147 tests.

Toyota Corolla

The marking scheme for the Toyota Corolla prior to impact is shown in Figure 9. The post test intrusion profile for each row is shown in Figure 10 to Figure 15. The data set contains the two baseline results from the Corolla and Freelander impacts, and also three AE-MDB to Corolla tests.

In general, the deformation produced by the AE-MDB was between the levels of the two baseline tests for all rows. The vertical profile at the R-point position showed the AE-MDB to be mid-way between the baseline tests, which also reflected a similar shape. The B-pillar deformation for rows A to C was almost the same as that from the Corolla baseline test. However, the intrusion either side of the B-pillar was mid-way between that of the two baseline tests. The AE-MDB profiles for rows D and E were higher than that of the Corolla, and at the driver's door the peak intrusion was at a level similar to that of the Freelander. The presence of the stiff B-pillar is clear in all of the AE-MDB profiles, but it is only just visible in the lower Corolla baseline profiles. The B-pillar is not visible for the Freelander profile, which produced 'square shaped' intrusion with the maximum level at row C; 550mm above ground level. The peak level of intrusion for the Corolla test was at row D; 425mm above ground level. The peak level for the AE-MDB tests was at row C; 550mm above ground level.

A comparison between the AE-MDB profiles shows very similar global and local intrusion levels, with similar shaped intrusion.

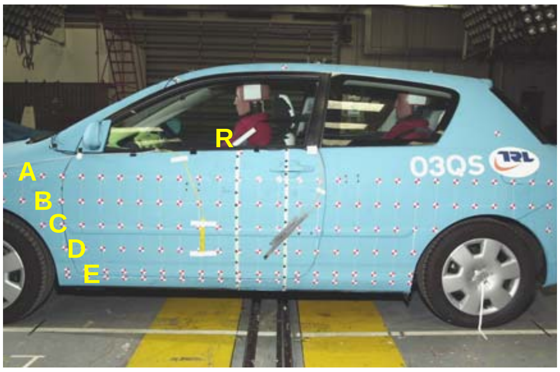


Figure 9 Toyota Corolla Map

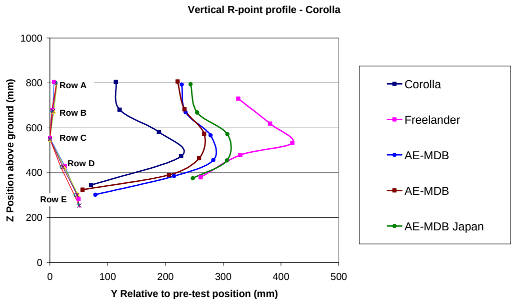


Figure 10 Corolla R-point profile

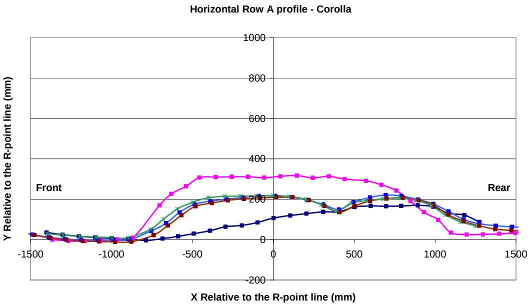


Figure 11 Corolla Row A profile

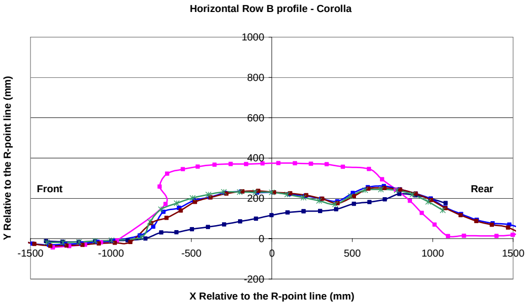


Figure 12 Corolla Row B profile

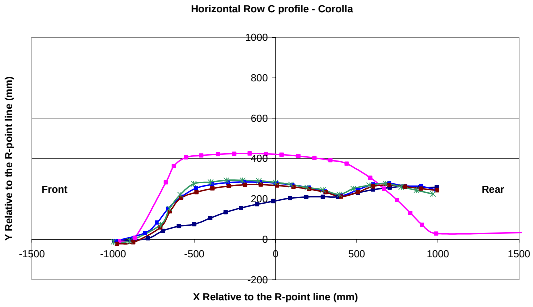


Figure 13 Corolla Row C profile

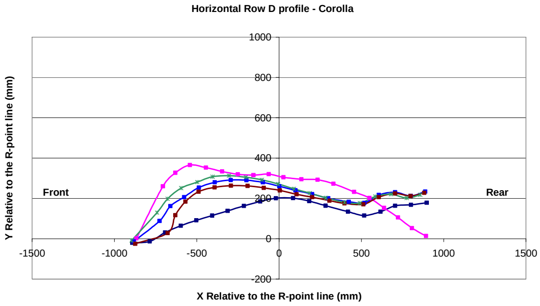


Figure 14 Corolla Row D profile

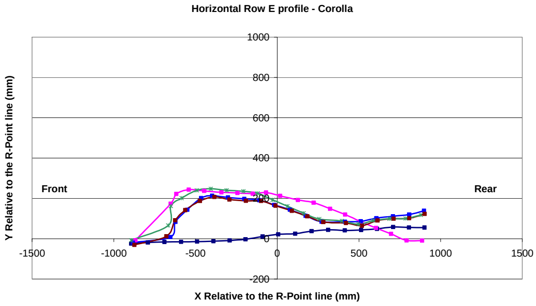


Figure 15 Corolla Row E profile

Alfa Romeo 147

The marking scheme for the Alfa Romeo 147 prior to impact is shown in Figure 16. The post test intrusion profile for each row is shown in Figure 17 to Figure 22.

Rows A to C show the level of AE-MDB intrusion to be similar to that of the Freelander along the driver’s door. Toward the rear of the vehicle, the stiff B-pillar is visible in the barrier profile with lower levels of intrusion. Rows D and F show a similar level of intrusion between the two baseline tests. Whereas the intrusion from the AE-MDB was larger than both of the baseline tests for the full length of the profile. The largest difference was recorded mid-way along the lower edge of the door by 200mm above that of the Freelander. The peak intrusion for the Freelander was at row C; 550mm above ground level, and for the Corolla it was at row D; 425 mm above ground level. The peak intrusion for the AE-MDB was at row D.

Figure 16 Alfa Romeo 147 Map

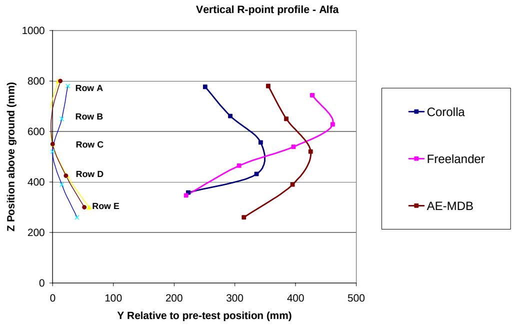


Figure 17 Alfa R-point profile

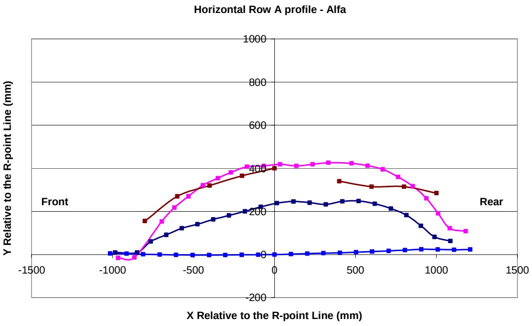


Figure 18 Alfa Row A profile

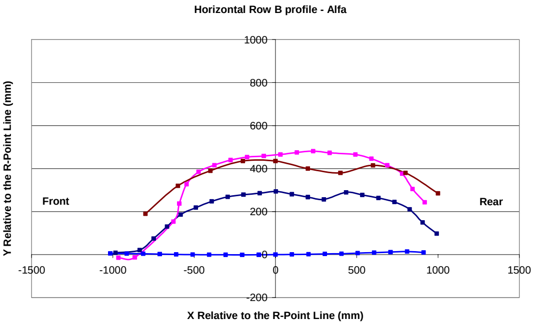


Figure 19 Alfa Row B profile

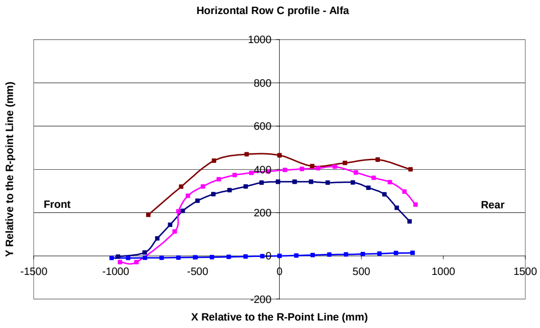


Figure 20 Alfa Row C profile

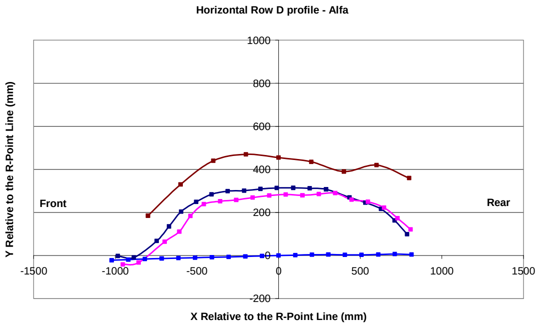


Figure 21 Alfa Row D profile

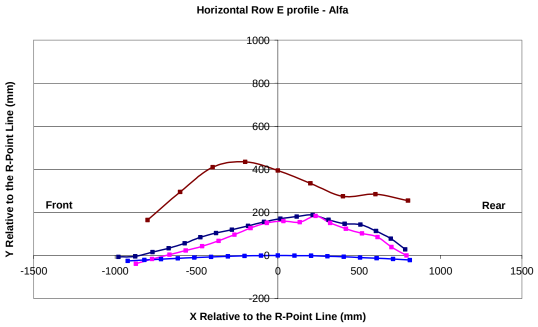


Figure 22 Alfa Row E profile

In reviewing all of the full-scale test data, it is possible to highlight some general trends as assessed by post impact deformation. The baseline tests to all of the vehicles showed that the post impact deformation caused by the Freelander was generally higher than of the Ford Mondeo. In the case of the Megane and Corolla the AE-MDB deformation was between the baseline results. With the Camry the AE-MDB deformation was, in places, above that of the baseline data for rows A, D and E, and for the Alfa this was the case for most rows. Higher levels of door intrusion, in comparison to the B-pillar, were more prominent with the Megane and Camry. A more homogeneous profile was observed with the Corolla and Alfa.

The Freelander has been seen to induce peak intrusion levels at a height of around 550-675mm above ground level on all target vehicles, which is due to the higher level of frontal load paths. Conversely, the family sized vehicles generally loaded around 300-425mm above ground level. The height of AE-MDB peak loading was between that of the baseline vehicles at approximately 425-550mm.

Door intrusion velocity

The importance of door intrusion velocity has previously been highlighted by WG13 as an important measure in determining impact severity as it is the generally door which contacts the occupant and causes injury.

The measurement technique was changed from acceleration based measurement to suitable linear potentiometers, which are believed to be more accurate. Tests to the Megane and Camry used acceleration based measurements, apart from those with the AE-MDB V2, which used potentiometers. The baseline Corolla tests were also acceleration based, and all other Corolla and Alfa tests used potentiometers. One particular characteristic seen with the acceleration based data was higher levels of residual velocity toward the end of the impact. The measurements were taken from the inner door skins at positions close to the driver and rear seat passenger (RSP) dummy thoraxes, but not in a position to interfere with the dummy kinematics. No comparable data was available from the AE-MDB to Alfa 147 test.

The comparative door velocities for all impacts can be seen in Figure 23 to Figure 30. The velocities recorded in the Megane driver and Corolla driver doors show the AE-MDB velocities to be higher than those recorded in the baseline tests. Whereas, in all other positions the AE-MDB V2 barrier was generally between or lower than those of the baseline tests. Peak driver door velocities were not much above 12m/s in the baseline tests and the peak recorded with the AE-MDB V2 was approximately 9m/s using these techniques. For the rear seat passengers, again the largest velocity was recorded at around 12m/s, and 8m/s was recorded with the AE-MDB V2.

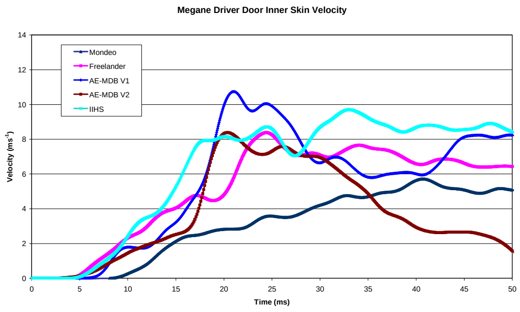


Figure 23 Megane driver door velocities

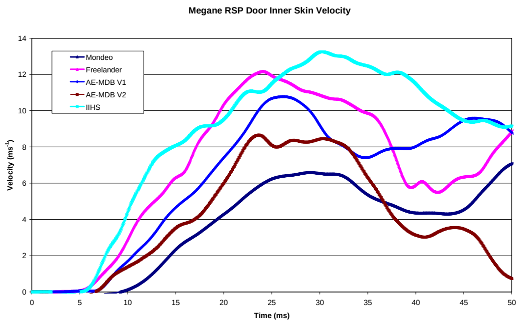


Figure 24 Megane RSP door velocities

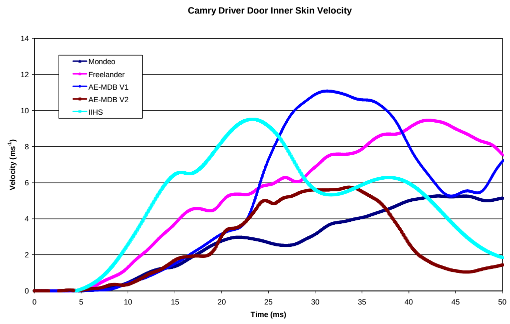


Figure 25 Camry driver door velocities

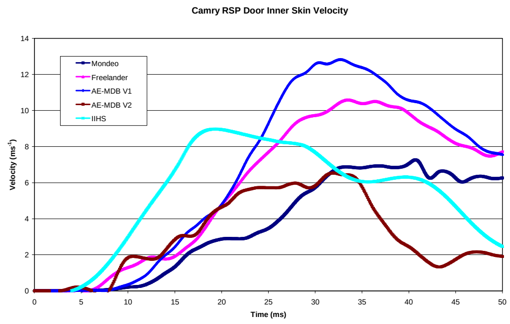


Figure 26 Camry RSP door velocities

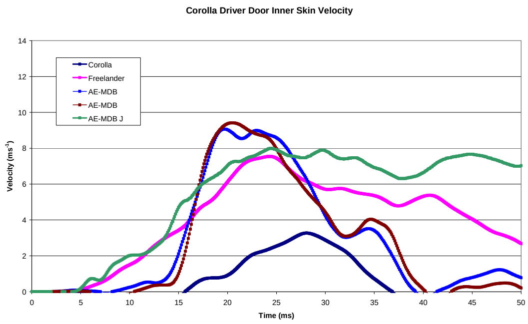


Figure 27 Corolla driver door velocities

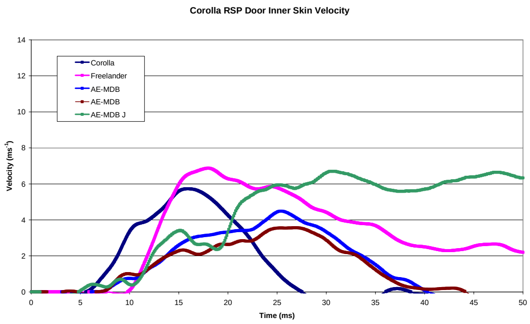


Figure 28 Corolla RSP door velocities

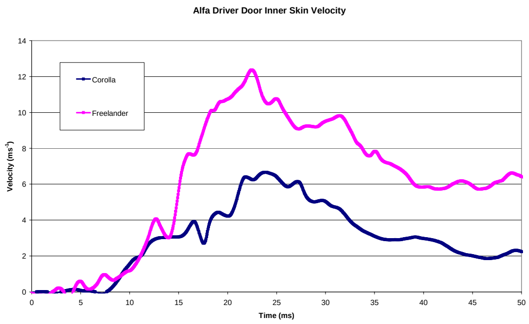


Figure 29 Alfa driver door velocities

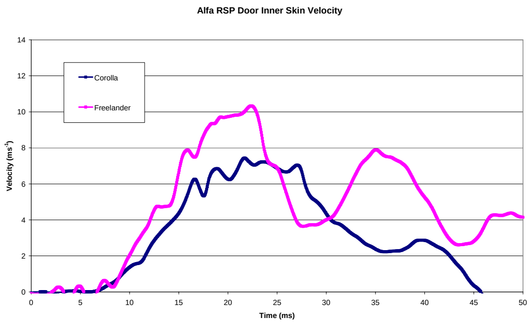


Figure 30 Alfa RSP door velocities

Driver and passenger dummy responses

The test procedure is aimed at encouraging enhancements in occupant protection and reduction in injury risk. It is hoped that if the procedure were to move into a regulatory framework, improved dummies and associated injury criteria would also be adopted.

Throughout the research programme WG13 have used the best ‘tools’ available. In the Megane and Camry tests WG13 used the EuroSID-I and for the latter tests, to the Corolla and Alfa 147, the ES-2 was used. In the case of all Alfa tests, the ES-2RE dummy was used in the driver’s seat and the ES-2 in the rear. These measures can be used to predict the severity of the test based upon current predictions of injury risk. A summary of all WG13 results is shown in Table 1.

		Renault Megane Target Vehicle (EuroSID-I)				Toyota Camry Target Vehicle (EuroSID-I)			
DRIVER		Mondeo	Freelander	AE-MDB V1	IIHS	Mondeo	Freelander	AE-MDB V1	IIHS
HEAD (HIC)		72	250	214	454	98	144	121	266
Rib Deflection (mm)	Upper	6	25	24	45	7	24	20	33
	Middle	7	25	18	48	13	25	24	29
	Lower	10	24	15	49	19	30	31	30
Viscous Criterion	Upper	0.02	0.22	0.27	1.16	0.03	0.15	0.18	0.4
	Middle	0.03	0.22	0.12	1.18	0.06	0.23	0.24	0.29
	Lower	0.07	0.17	0.05	1.27	0.10	0.42	0.40	0.31
Abdomen (kN)		1.2	2.4	1.1	1.6	1.3	2.0	2.2	1.5
Pelvis (kN)		4.3	4.6	4.7	4.5	4.3	4.6	6.2	5.4
Rear Seat Passenger		Mondeo	Freelander	AE-MDB V1	IIHS	Mondeo	Freelander	AE-MDB V1	IIHS
HEAD (HIC)		706	107	38	60	476	39	53	446
Rib Deflection (mm)	Upper	7	7	21	31	8	14	19	25
	Middle	6	4	5	11	4	7	17	16
	Lower	6	11	3	12	4	4	15	14
Viscous Criterion	Upper	0.02	0.02	0.10	0.32	0.06	0.07	0.16	0.27
	Middle	0.01	0.02	0.01	0.06	0.01	0.02	0.12	0.13
	Lower	0.02	0.09	0.01	0.09	0.02	0.00	0.12	0.10
Abdomen (kN)		2.4	4.4	1.6	2.3	1.8	1.7	2.3	2.7
Pelvis (kN)		6.6	7.2	6.4	9.6	4.0	3.3	6.3	5.1

		Toyota Corolla Target Vehicle (ES-2)					Alfa Romeo 147 Target Vehicle (ES-2RE/ES-2)		
DRIVER		Corolla	Freelander	AE-MDB V2	AE-MDB V2	AE-MDB V2 J	Corolla	Freelander	AE-MDB V2
HEAD (HIC)		138	444	353	309	144	68	361	230
Rib Deflection (mm)	Upper	6	21	21	27	23	5	51	50
	Middle	1	11	10	14	12	7	38	39
	Lower	3	3	3	6	6	18	44	47
Viscous Criterion	Upper	0.01	0.24	0.16	0.29	0.20	0.01	0.67	0.61
	Middle	0.00	0.11	0.05	0.09	0.07	0.03	0.65	0.75
	Lower	0.00	0.01	0.01	0.04	0.04	0.17	1.05	0.97
Abdomen (kN)		0.6	2.0	1.3	1.6	1.3	0.7	1.9	1.3
Pelvis (kN)		0.9	5.7	3.7	3.6	3.4	2.5	4.6	4.3
Rear Seat Passenger		Corolla	Freelander	AE-MDB V2	AE-MDB V2	AE-MDB V2 J	Corolla	Freelander	AE-MDB V2
HEAD (HIC)		183	215	394	294	209	86	253	177
Rib Deflection (mm)	Upper	21	29	24	24	25	25	21	12
	Middle	11	24	14	17	14	18	9	3
	Lower	0	13	13	10	11	10	3	9
Viscous Criterion	Upper	0.14	0.15	0.15	0.23	0.21	0.12	0.12	0.07
	Middle	0.04	0.16	0.08	0.14	0.08	0.08	0.03	0.01
	Lower	0.00	0.06	0.07	0.07	0.08	0.03	0.01	0.04
Abdomen (kN)		1.4	0.8	2.3	1.9	2.1	0.1	1.2	1.4
Pelvis (kN)		1.1	1.7	3.2	3.5	3.7	1.7	4.0	5.4

Table 1 EuroSID-I and ES-2 Dummy Results

The driver and rear seat passenger dummy injury parameters for the Corolla and Alfa target vehicles are shown in Figure 31 to Figure 34. These have been calculated as percentages of the critical values as defined in ECE Regulation 95. These levels are as follows:

HIC	1000
Rib deflection	42mm
V*C	1.0m/s
Abdomen force	2.5kN
Pelvic force	6.0kN

The head injury criterion (HIC) recorded by the driver dummy in the Corolla tests showed the response of the AE-MDB tests to be between that of the two baseline tests. This was also the case for abdomen and pelvis. The maximum rib deflection and viscous criterion were at a similar level to that of the Freelander baseline test. For the rear seat passenger, the maximum rib deflection was between that of the baseline tests and the viscous criterion was slightly above. In the case of the abdomen and pelvis, the barrier results were above those of the baseline tests.

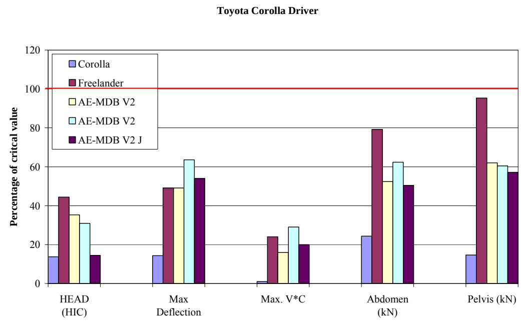


Figure 31 Corolla driver dummy response

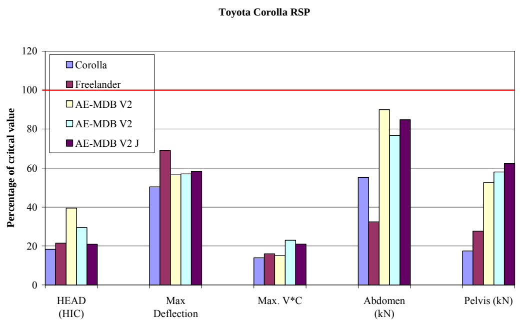


Figure 32 Corolla RSP dummy response

In the Alfa tests, the response of the driver dummy, when impacted with the AE-MDB, was always between the baseline car test results and generally closer to those of the Freelander. The chest deflection was above the critical level specified by R95, signifying a 30% risk of injury ≥ AIS3. For the rear seat passenger, the HIC, rib deflection and viscous criterion of the barrier test were between or below the baseline values, whereas the abdomen and pelvis results were higher.

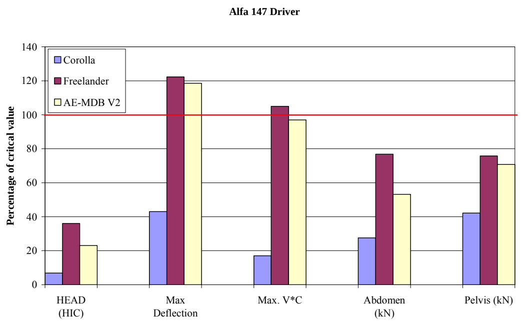


Figure 33 Alfa driver dummy response

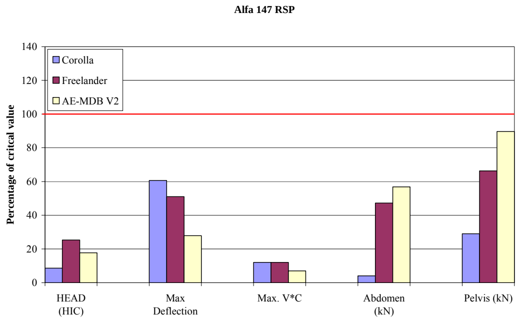


Figure 34 Alfa RSP dummy response

DISCUSSION

The post test intrusion characteristics seen with the AE-MDB show that the barrier is able to replicate, to some extent, the form of deformation seen with the baseline vehicle tests. In the case of the Megane and Camry reported by Roberts et al, which were five and four door vehicles respectively, more intrusion was caused to the front and rear doors than to the B-pillars of the target vehicles. This trend was visible in both the barrier and baseline tests. However, the door deformation with the AE-MDB was generally at a similar level to that of the most severe baseline test, whereas the loading to the B-pillar was similar to that of less severe baseline test. The tests to some of the target vehicles also showed that the form of intrusion with AE-MDB was similar to that of the baseline tests. Similar trends were visible to the deformation and the doors and B-pillar.

In reviewing the biomechanical data from all of the available driver dummy results, the AE-MDB data was often between or slightly higher than that of the baseline data. The areas where the barrier results exceeded the baseline data, and in the case of the Alfa the critical value, were the pelvis in the Megane, the abdomen and pelvis in the Camry and the ribs in the Corolla and Alfa.

For the rear seat passenger, the higher loading was generally seen in the abdominal and pelvic areas. The velocity profiles of all vehicles, where measured, suggest that the AE-MDB loaded the target vehicles at a similar rate to those of the Freelander baseline test, and in the case of the Corolla the peak velocity with the AE-MDB was slightly higher by approximately 1m/s. It should be borne in mind that the measurement method used for the Corolla baseline tests were different to those with the barrier, thus the magnitude of this difference may be less or greater than that recorded.

Based upon the results seen so far, WG13 believes that modifications to the AE-MDB design specification may be needed in order to reduce the post test ‘differential intrusion’ between the doors and B-pillar. The severity of the AE-MDB test procedure was either between that of the baseline tests. In some areas slightly more severe than the baseline tests, but this was not a trend that could be observed in all of the target vehicles.

FUTURE RESEARCH

In order to increase the amount of loading applied by the AE-MDB to the B-pillar, WG13 is considering various modifications to the design specification.

One modification is based upon the application of a ‘beam’ type element being applied across the lower row of blocks. The beam element would be constructed from high strength honeycomb sandwich, which would try to replicate the presence of significant lateral connections between longitudinal frontal structures that are present in some vehicles.

An alternative modification, would be to change the stiffness of block E to be more reflective of the rigid LCW data. The initial block stiffness could be increased along with the stiffness toward the end of the current corridor.

Further modifications that have been discussed are based upon a change in stiffness distribution for the lower row of blocks, along with the inclusion of a beam element as described above.

At the time of this report some numerical simulation of different AE-MDB modifications has taken place to provide guidance to future plans, but no barriers to a revised specification have been manufactured or tested.

CONCLUSIONS

1. The completed review of the stiffness of modern vehicle frontal structures has complemented the previous data studied and presented by WG13, which lead to the current stiffness distribution for the AE-MDB.
2. From baseline vehicle testing, the AE-MDB has been shown to be representative of the baseline deformation profiles in some areas.
3. The deformation produced by the AE-MDB is, in some cases, above that of the baseline tests in the softer areas of the target vehicles (mid doors).
4. In the stiffer area of the target vehicles (B-pillar), the deformation caused by the AE-MDB was less than that applied by the most severe baseline test.
5. Most of the dummy injury parameters were well below the critical values used in the current European regulatory procedure, even when localised intrusion is greater than that of the severe baseline test.
6. The ongoing research may lead to some revisions of the existing AE-MDB design specification. However, no firm direction was available at the time of writing this paper.

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C Müller	Germany, DaimlerChrysler
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9.4. Accident study paper

EUROPEAN ENHANCED VEHICLE-SAFETY COMMITTEE

EEVC Working Group 13 Report.
Head Contacts In Side Impact - An Accident Analysis
February 2001

Head Contacts In Side Impact - An Accident Analysis

An EEVC Working Group 13 Report.

1. INTRODUCTION

In 1989, the European Enhanced Vehicle-Safety Committee (EEVC) proposed a full-scale side impact test procedure in which a vehicle, complete with a EuroSID dummy, was impacted by a mobile barrier onto which was attached a deformable element. Accident analyses have demonstrated that occupants in a side impact often suffer serious or fatal head injuries, some of these being from contact with the interior of the vehicle. A full-scale test can only assess one contact point, assuming head contact on the vehicle structure occurs in the test. Consequently, EEVC recommended that a supplementary interior headform test be developed to evaluate the protection afforded by the vehicle interior at a range of locations that can be contacted in side impact accidents.

This study will assist in defining the parameters required for a European test procedure for interior head protection in side impact.

The objective of this study was to determine the range of head impact locations observed in real world crashes to aid the specification for the impact test locations. Four organisations have supplied data for the study:

1. TRL - Data from the Co-operative Crash Injury Study (CCIS) in the UK,
2. BASt - Medical University of Hannover database in Germany,
3. LAB PSA-Renault - A retrospective accident analysis in France.
4. NHTSA - NASS files in the US.

The data have been analysed to determine the most important impact areas in terms of frequency of contact in accidents. The influence of intrusion on the severity of injuries also has been analysed. Different sampling strategies and contact classifications have been used for each database, therefore it is not valid simply to add the data together to make a single large database. However, each sample can be used to give evidence of the head contact sites observed in side impacts according to its own sampling and categorisation methods. Conclusions can be drawn with greater confidence where the distribution of contacts across more than one of the four samples is similar.

2. SIDE IMPACT ACCIDENT DATA

2.1 DEFINITION OF SIDE IMPACT

The data has been gathered in accordance with a pro-forma developed by the Transport Research Laboratory. Each database was analysed for all non-rollover, single-impact, side-impact accidents, and uses a clock method to describe the principal direction of force. Side impact was classified as an impact occurring between 2 and 4 o'clock, and 8 and 10 o'clock at any point on the side of the vehicle. To eliminate frontal and rear impacts, the point of contact was specified as being to the side of the struck vehicle, Figure 1. The search was confined to accidents, in which occupant(s) sustained a head injury. Front and rear seat occupants were analysed separately. Occupants were predominantly adult, but covered the full range of ages.

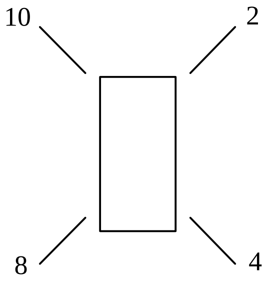

Figure 1 - Clock System used in the CCIS Database

2.2 DATABASE OUTPUTS

The important outputs from the search were:

- Side of Impact (Left/Right)
- Occupant Side (Passenger/Driver)
- Struck Side Occupant (Yes/No)
- Restraint Use (Yes/No/Claimed)
- Collision Deformation Classification (CDC)
- Head Contact (Location)
- Head Severity (In terms of AIS)
- Intrusion (Supported/Unsupported/None)

2.3 DEFINITION OF HEAD IMPACT SITES

The data was analysed for restrained and unrestrained occupants on the struck side, and non-struck side.

The codes used in the databases are explicit, however there are a few exceptions that require further classification:

- **External Object** - The head injury was caused by a contact with an object such as a tree, lamp post, or another vehicle. Three scenarios exist for this code. In the majority of these cases, the occupant would be partially or fully ejected, and the head contact occurred outside of the vehicle. The second scenario is that the external object loads the side of the vehicle, causing the side glass to break. The occupant is not ejected but the head contacts the external object, which has now replaced the position of the side glass. Finally, the head could contact an external object, which has penetrated the vehicle. This code appears in the TRL, BASt and LAB data only (no fully ejected occupants in LAB data).
- **Side Glass –**Head Injury was caused by contact with the side glass. In low severity impacts the glass can remain intact, but during more severe impacts the head contact causes the glass to break. This code was used by the TRL, BASt and LAB databases.
- **Occupant Contact*** – The injury was caused by the occupant's head striking another occupant in the vehicle, and was used by the TRL and BASt databases.
- **Side Other** – This code suggests a contact anywhere on the side of the vehicle that is not already coded. This code usually suggests the door, but is not limited to contacts in front of the B Pillar. This code was used by the TRL, BASt and LAB databases.
- **Unknown** – Injury was caused by a contact, but the contact region could not be identified. Unknown head contact sites were recorded in the TRL and LAB data only.
- **Non-contact injury** – This is separate from an unknown contact region. The injury sustained was not caused by a contact. Only the TRL databases recorded this type of head injury.
- **B Pillar** - This does not include the upper anchorage point, in the TRL and BASt data, where a separate code exists.
- **Window Frame** - This is a code used solely by the Renault-PSA LAB database.

*This code is additional to those used in the TRL (CCIS) database. It was devised for the purposes of this study and evolved from a case by case analysis.

The following groupings have been used:

VEHICLE STRUCTURE	**VEHICLE GLAZING**	**NON VEHICLE**
Airbag	Side Glass	External Object
A Pillar	Flying Glass	Occupant Contact
B Pillar	Windscreen	
Facia Top		
Header		
Head Restraint		
Mirror		
Seat		
Side Roof Rail		
Steering Wheel		
Sunroof		
Roof		
Upper Anchorage Point		
Window Frame		

For each stage of the analysis, the frequency and severity of contacts for each region are presented in the form of tables. The most frequent contacts on the vehicle structure are also presented pictorially to show the specific point of contact, when so recorded. This information was established from individual case reports. Where conclusive forensic evidence of a head contact on the vehicle structure is found, the contact regions are shown graphically. In cases where this type of evidence could not be found, the investigator used all the other circumstantial evidence such as type of injury, and direction of force to establish the most likely contact region. In this instance, the contact region is coded but is not graphically illustrated. Illustrations in the sections that follow show the number of contacts to a specific region. This refers only to the number of contacts in which forensic evidence was found and is therefore often less than the total number of contacts for each region as given in the corresponding tables.

2.4 ACCIDENT SAMPLES

2.4.1 FRONT SEAT OCCUPANTS

Front seat occupant data was obtained from the TRL, BASt, LAB and NHTSA accident databases for occupants that received a head injury in a side impact. In total there are 965 cases for analysis. In 197 of these the occupant sustained a serious head injury. The number of cases, which met the selection criteria, is shown for each database, in Table 1.

DATABASE	TRL		BASt		LAB		NHTSA	
AIS	3+	1+	3+	1+	3+	1+	3+	1+
Totals	89	408	33	93	30	304	45	160

Table 1 - Number of Cases in which Front Seat Occupants Sustained Head Injuries in Side Impact

2.4.2 REAR SEAT OCCUPANTS

Data for rear seat occupants was collected from TRL, BASt and LAB. In this study, a total of 113 rear seat occupants received a head injury in side impact. Of this, 95 occupants sustained minor head injury and 18 incurred serious head injury, shown in Table 2.

DATABASE	TRL		BASt		LAB	
AIS	3+	1+	3+	1+	3+	1+
Totals	10	62	1	6	6	41

Table 2 - Head Injuries to Rear Seat Occupants in Side Impact

3. RESULTS OF ANALYSIS

3.1 GENERAL

This section analyses each individual database, in terms of restraint use and occupant position. This approach was taken as different sampling strategies were used in each database. For example, the TRL and BASt data include injury contacts to a greater range of locations on both the vehicle structure and glazing in addition to non-vehicle contacts. However the LAB data consist of fewer locations on the vehicle structure. It is assumed that those contact sites not covered have been omitted from the recording strategy, for this study. The NHTSA database includes contacts to three locations on the vehicle structure only. All other contact sites were omitted from their investigation.

3.2 FRONT SEAT OCCUPANTS

In Europe, it is a legal requirement that vehicle occupants wear a seat belt at all times with certain limited exceptions. Belt use can only be positively established where conclusive evidence has been found. It should be noted that there are a number of cases in the TRL and BASt data where belt use could not be ascertained. These cases have been excluded from section 3, except where all front seat occupants are considered.

3.2.1 HEAD CONTACT FOR RESTRAINED FRONT SEAT OCCUPANTS

3.2.1.1 Struck Side Occupants

Contacts on the vehicle structure for restrained struck side occupants are listed below, Table 3. The specific points of contact when known, are illustrated on Figures 2-5.

Contact Site	**TRL**		**BASt**		**LAB**		**NHTSA**	
	AIS 3+ No.	**AIS 1+ No.**	**AIS 3+ No.**	**AIS 1+ No.**	**AIS 3+ No.**	**AIS 1+ No.**	**AIS 3+ No.**	**AIS 1+ No.**
Non Contact Injury	0	4	1	2				
Airbag	0	1	0	0				
A Pillar	2	6	1	1	0	0	5	22
B Pillar	1	13	7	11	2	19	16	39
External Object	18	30	5	8	8	13		
Facia Top	0	1	0	0				
Flying Glass	0	11	0	3				
Head Restraint	0	1	0	0				
Side Roof Rail	6	8	0	4	0	10	7	24
Side Glass	2	52	2	6	0	52		
Side Other	3	4	1	4	0	0		
Steering Wheel	1	3	0	1				
Sunroof	0	1	0	0				
Roof	0	0	1	2				
Upper Anch' Point	0	1	0	1				
Windscreen	0	2	0	0				
Occupant Contact	1	1	0	0				
Window Frame					0	8		
Unknown	8	37			0	8		
Total	42	176	18	43	10	110	28	85

Table 3 - Head Contact Regions for Restrained Struck Side Occupants

Shaded areas denote contact site not recorded

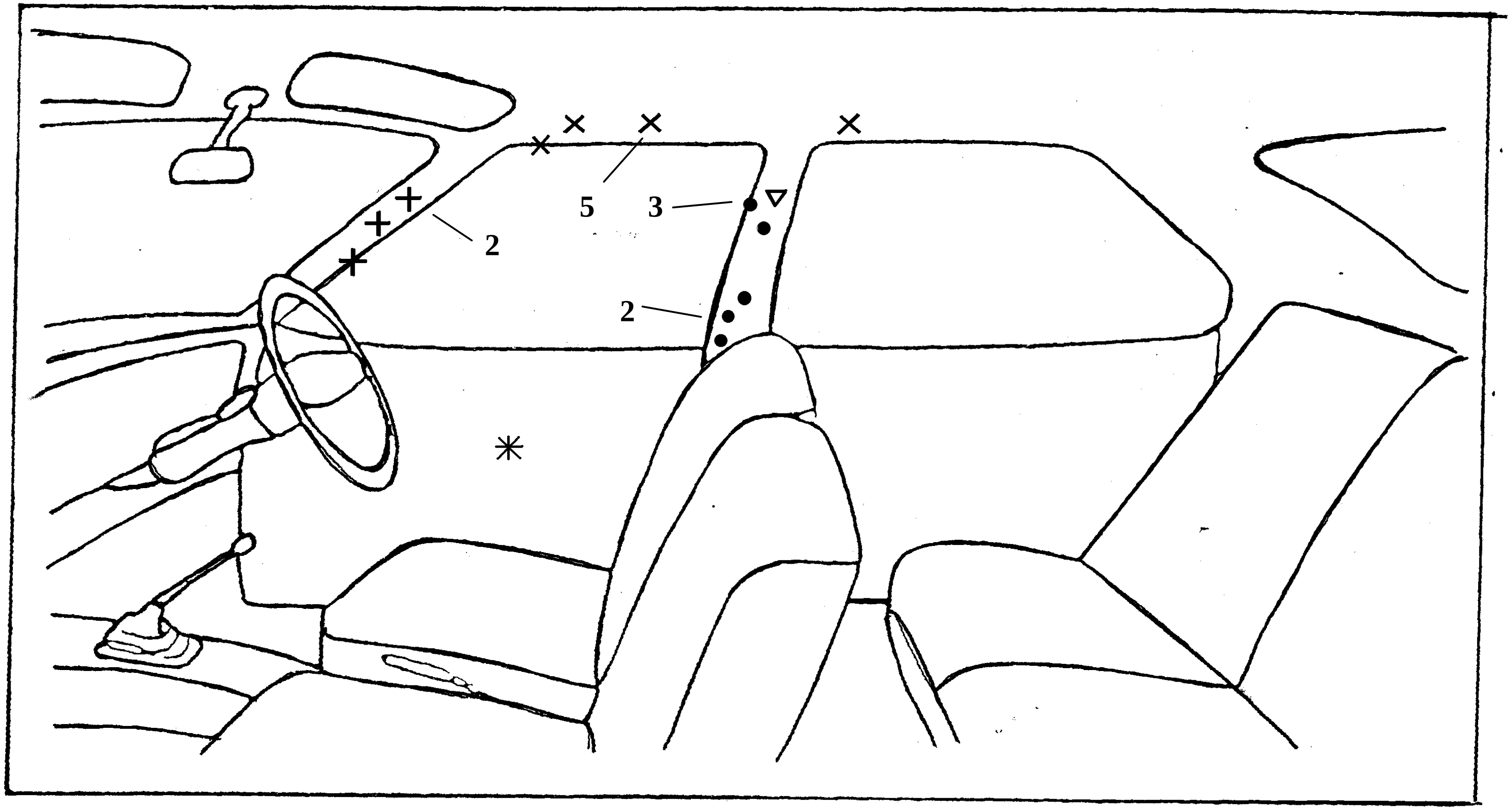

Figure 2 - Graphical Representation of Frequent Head Contact Regions, Front Seat, Restrained Struck Side Occupants - TRL Data

Key	Contact Region	Total in figure	Total no of contacts	Key	Contact Region	Total in figure	Total no of contacts	Key	Contact Region	Total in figure	Total no of contacts
●	**B Pillar**	8	13	▲	**Header**	0	0	∇	**Upper Anchorage**	1	1
✚	**A Pillar**	4	6	#	**Facia Top**	0	1	■	**Steering Wheel**	0	3
	Side Other	1	8	**O**	**Roof**	0	0	♦	**Head Restraint**	0	1
	Side Roof Rail	8	8								

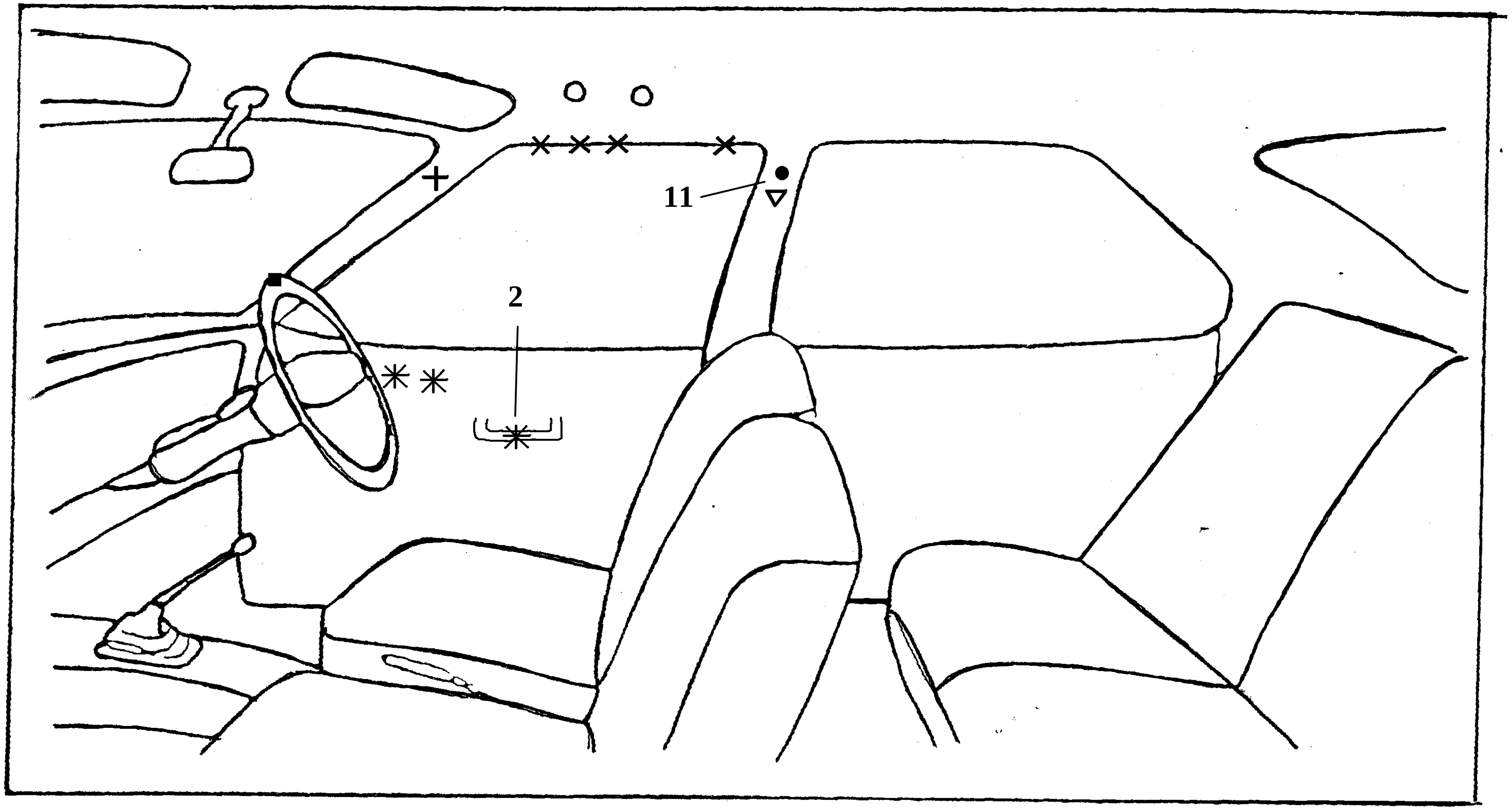

Figure 3 - Graphical Representation of Frequent Head Contact Regions, Front Seat, Restrained Struck Side Occupants - BASt Data

Key	Contact Region	Total in figure	Total no of contacts	Key	Contact Region	Total in figure	Total no of contacts	Key	Contact Region	Total in figure	Total no of contacts
●	**B Pillar**	11	11	▲	**Header**	0	0	∇	**Upper Anchorage**	1	1
✚	**A Pillar**	1	1	#	**Facia Top**	0	1	■	**Steering Wheel**	1	1
	Side Other	4	4	**O**	**Roof**	2	2	♦	**Head Restraint**	0	0
	Side Roof Rail	4	4								

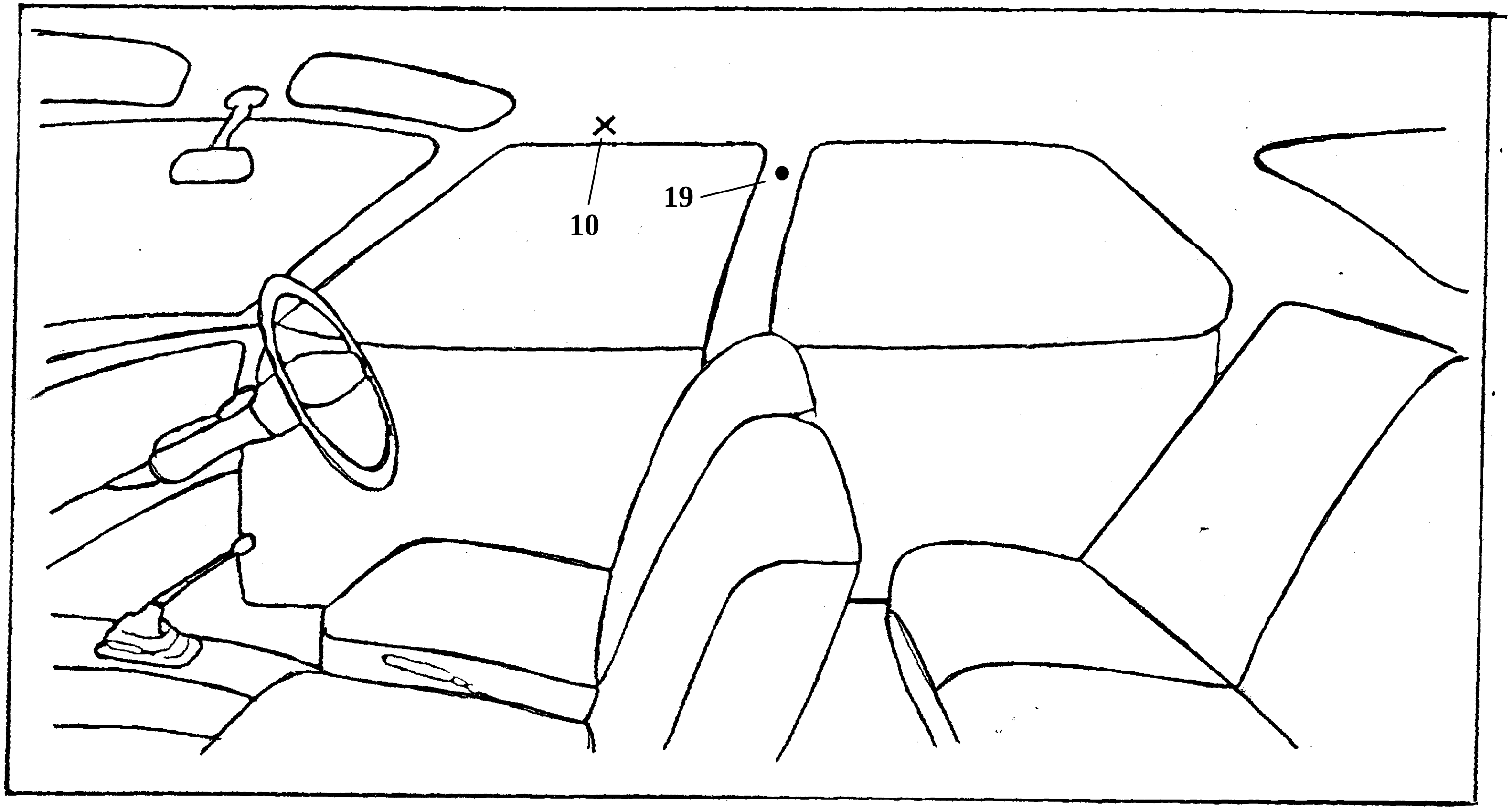

Figure 4 - Graphical Representation of Frequent Head Contact Regions, Front Seat, Restrained Struck Side Occupants - LAB Data

Key	Contact Region	Total in figure	Total no of contacts	Key	Contact Region	Total in figure	Total no of contacts	Key	Contact Region	Total in figure	Total no of contacts
●	**B Pillar**	19	19	▲	**Header**			∇	**Upper Anchorage**		
✚	**A Pillar**	0	0	#	**Facia Top**			■	**Steering Wheel**		
	Side Other	0	0	**O**	**Roof**			♦	**Head Restraint**		
	Side Roof Rail	10	10								

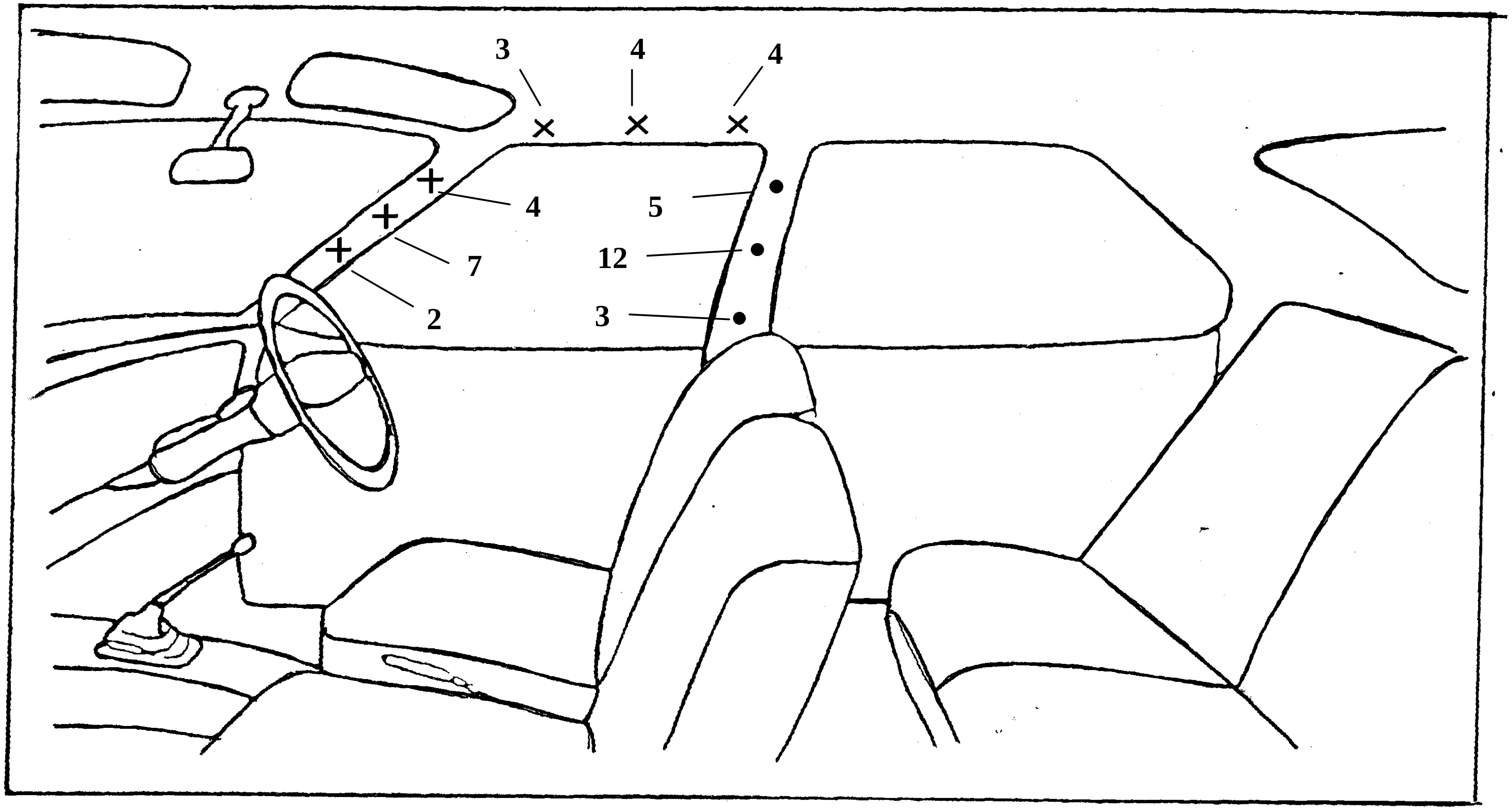

Figure 5 - Graphical Representation of Frequent Head Contact Regions, Front Seat, Restrained Struck Side Occupants - NHTSA Data

Key	Contact Region	Total in figure	Total no of contacts	Key	Contact Region	Total in figure	Total no of contacts	Key	Contact Region	Total in figure	Total no of contacts
●	**B Pillar**	20	39	▲	**Header**			∇	**Upper Anchorage**		
✚	**A Pillar**	13	22	#	**Facia Top**			■	**Steering Wheel**		
	Side Other			O	**Roof**			♦	**Head Restraint**		
	Side Roof Rail	11	24								

3.2.1.2 Non-Struck Side Occupants

Table 4 shows the results for restrained occupants on the non-struck side.

Contact Site	TRL		BASt		LAB		NHTSA	
	AIS 3+ No.	AIS 1+ No.	AIS 3+ No.	AIS 1+ No.	AIS 3+ No.	AIS 1+ No.	AIS 3+ No.	AIS 1+ No.
Non Contact Injury	1	5	0	0				
A Pillar	0	0	0	2	0	2	1	2
B Pillar	1	4	0	2	2	3	2	4
External Object	4	5	0	1	3	4		
Facia Top	0	1	0	0				
Flying Glass	0	8	0	2				
Header	0	1	0	0				
Head Restraint	1	2	1	2				
Mirror	0	1	0	0				
Seat	0	1	0	0				
Side Roof Rail	1	2	2	4	1	7	2	6
Side Glass	1	10	1	6	0	5		
Side Other	4	9	0	2	0	13		
Steering Wheel	1	5	0	5				
Sunroof	0	0	0	0				
Roof	0	1	0	1				
Windscreen	0	0	0	1				
Occupant Contact	0	6	0	0				
Window Frame					1	1		
Unknown	7	40	0	0	0	23		
Total	21	101	4	28	7	58	5	12

Table 4 –Head Contact regions and injury severity for restrained occupants on the non-struck side

Shaded areas denote contact site not recorded.

3.2.1.3 Struck and Non-Struck Side Occupants

Table 5 shows the results for restrained occupants on either side of the vehicle.

Contact Site	TRL		BASt		LAB		NHTSA	
	AIS 3+ No.	AIS 1+ No.	AIS 3+ No.	AIS 1+ No.	AIS 3+ No.	AIS 1+ No.	AIS 3+ No.	AIS 1+ No.
Non Contact Injury	1	9	1	2				
Airbag	0	1						
A Pillar	2	6	1	3	0	2	6	24
B Pillar	2	17	7	13	4	22	18	43
External Object	22	35	5	9	11	17		
Facia Top	0	2	0	0				
Flying Glass	0	19	0	4				
Header	0	1	0	0				
Head Restraint	1	3	0	2				
Mirror	0	1	0	0				
Seat	0	1	0	0				
Side Roof Rail	7	10	2	8	1	17	9	30
Side Glass	3	62	3	13	0	57		
Side Other	7	13	1	6	0	13		
Steering Wheel	2	8	0	6				
Sunroof	0	1	0	0				
Roof	0	1	1	3				
Upper Anch' Point	0	1	0	1				
Windscreen	0	2	0	1				
Occupant Contact	1	7						
Window Frame					1	9		
Unknown	15	77			0	31		
Total	63	277	21	71	17	168	33	97

Table 5 - Contact regions and injury severity for restrained occupants on either side

Shaded areas denote contact site not recorded

3.2.2 HEAD CONTACT FOR UNRESTRAINED FRONT SEAT OCCUPANTS

3.2.2.1 Struck Side Occupants

Table 6 shows the results for unrestrained occupants on the struck side.

Contact Site	TRL		BASt		LAB		NHTSA	
	AIS 3+ No.	AIS 1+ No.	AIS 3+ No.	AIS 1+ No.	AIS 3+ No.	AIS 1+ No.	AIS 3+ No.	AIS 1+ No.
A Pillar	0	3	0	0	0	0	2	18
B Pillar	1	2	2	2	2	8	2	17
External Object	5	13	0	1				
Flying Glass	0	0	0	1				
Header	0	2	0	0				
Side Roof Rail	0	0	0	0	0	5	3	15
Side Glass	0	6	1	1	0	34		
Side Other	0	1	0	0	0	0		
Roof	0	2	0	1				
Windscreen	0	1	0	0				
Window Frame					0	7		
Unknown	0	8			0	5		
Total	6	38	3	6	4	67	7	50

Table 6 - Contact regions and injury severity for unrestrained occupants on the struck side

3.2.2.2 Non-Struck Side Occupants

Table 7 shows the results for unrestrained occupants on the non-struck side.

Contact Site	TRL		BASt		LAB		NHTSA	
	AIS 3+ No.	AIS 1+ No.	AIS 3+ No.	AIS 1+ No.	AIS 3+ No.	AIS 1+ No.	AIS 3+ No.	AIS 1+ No.
Non Contact Injury	0	0	1	1				
A Pillar	0	2	0	0	2	8	3	8
B Pillar	1	1	0	0	1	3	2	4
External Object	3	4	0	0	2	2		
Facia Top	0	0	0	1				
Head Restraint	0	1	0	0				
Mirror	0	1	0	0				
Side Roof Rail	1	1	0	0	1	10	0	1
Side Glass	0	2	0	0	0	2		
Side Other	1	2	0	0	2	13		
Windscreen	0	3						
Occupant Contact	1	2						
Window Frame					0	5		
Unknown	0	8			1	26		
Total	7	27	1	2	9	69	5	13

Table 7 - Contact regions and injury severity for unrestrained occupants on the non-struck side

Shaded areas denote contact site not recorded

3.2.2.3 Struck and Non-Struck Side Occupants

Table 8 shows the results for all unrestrained occupants in a front seat.

Contact Site	TRL		BASt		LAB		NHTSA	
	AIS 3+ No.	AIS 1+ No.	AIS 3+ No.	AIS 1+ No.	AIS 3+ No.	AIS 1+ No.	AIS 3+ No.	AIS 1+ No.
Non Contact Injury	0	0	1	1				
A Pillar	0	5	0	0	2	8	5	26
B Pillar	2	3	2	2	3	11	4	21
External Object	8	17	0	1	4	10		
Facia Top	0	0	0	1				
Flying Glass	0	1	0	1				
Header	0	1	0	0				
Head Restraint	0	1	0	0				
Mirror	0	1	0	0				
Side Roof Rail	1	1	0	0	1	15	3	16
Side Glass	0	8	1	1	0	36		
Side Other	1	3	0	0	2	13		
Roof	0	3	0	1				
Windscreen	0	3	0	0				
Occupant Contact	1	2	0	0				
Window Frame					0	12		
Unknown	0	16			1	31		
Total	13	65	4	8	13	136	12	63

Table 8: Contact regions and injury severity for unrestrained occupants on any side

Shaded areas denote contact site not recorded

3.2.3 HEAD CONTACT BY SEAT POSITION

This section reports the effect of occupant position with respect to side of impact. The tables show the frequency of head contact and severity of injury for each contact region.

3.2.3.1 Struck Side Occupants

Contact Site	TRL		BASt		LAB		NHTSA	
	AIS 3+ No.	AIS 1+ No.	AIS 3+ No.	AIS 1+ No.	AIS 3+ No.	AIS 1+ No.	AIS 3+ No.	AIS 1+ No.
Non Contact Injury	0	5	1	2				
Airbag	0	1	0	0				
A Pillar	2	9	2	3	0	0	7	40
B Pillar	2	18	10	14	4	27	18	56
External Object	24	44	7	12	10	21		
Facia Top	0	1	0	0				
Flying Glass	0	13	0	4				
Header	0	1	0	0				
Head Restraint	0	2	0	0				
Side Roof Rail	8	12	0	4	0	15	10	39
Side Glass	2	69	3	7	0	86		
Side Other	3	5	1	4				
Steering Wheel	1	3	0	1				
Sunroof	0	1	0	0				
Roof	1	3	1	3				
Upper Anch' Point	0	2	0	1				
Windscreen	0	3						
Occupant Contact	1	1						
Window Frame					0	15		
Unknown	10	56			0	13		
Total	54	249	25	55	14	177	35	135

Table 9 - Contact regions and injury severity for all occupants on the struck side

Table 9 shows the results for all struck side occupants (restrained and unrestrained). The specific points of contact on the vehicle structure for struck side occupants, are shown on Figures 6-9

Shaded areas denote contact site not recorded

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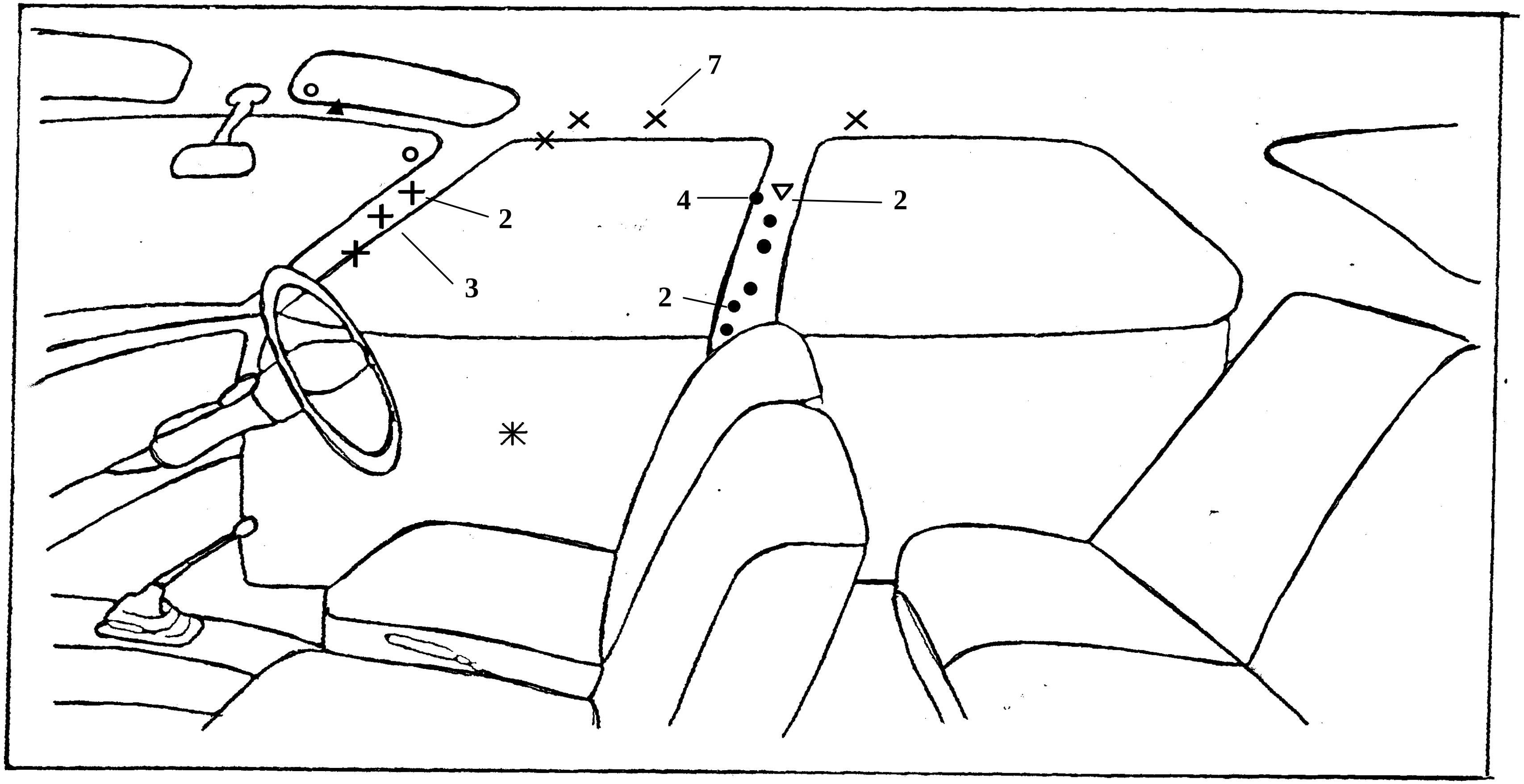

Figure 6 - Graphical Representation of Frequent Head Contact Regions, Front Seat, Struck Side Occupants - TRL Data

Key	Contact Region	Total in figure	Total no of contacts	Key	Contact Region	Total in figure	Total no of contacts	Key	Contact Region	Total in figure	Total no of contacts
●	**B Pillar**	10	18	▲	**Header**	1	1	∇	**Upper Anchorage**	2	2
✚	**A Pillar**	6	9	#	**Facia Top**	1	0	■	**Steering Wheel**	0	3
	Side Other	1	5	O	**Roof**	2	2	♦	**Head Restraint**	0	2
	Side Roof Rail	10	12								

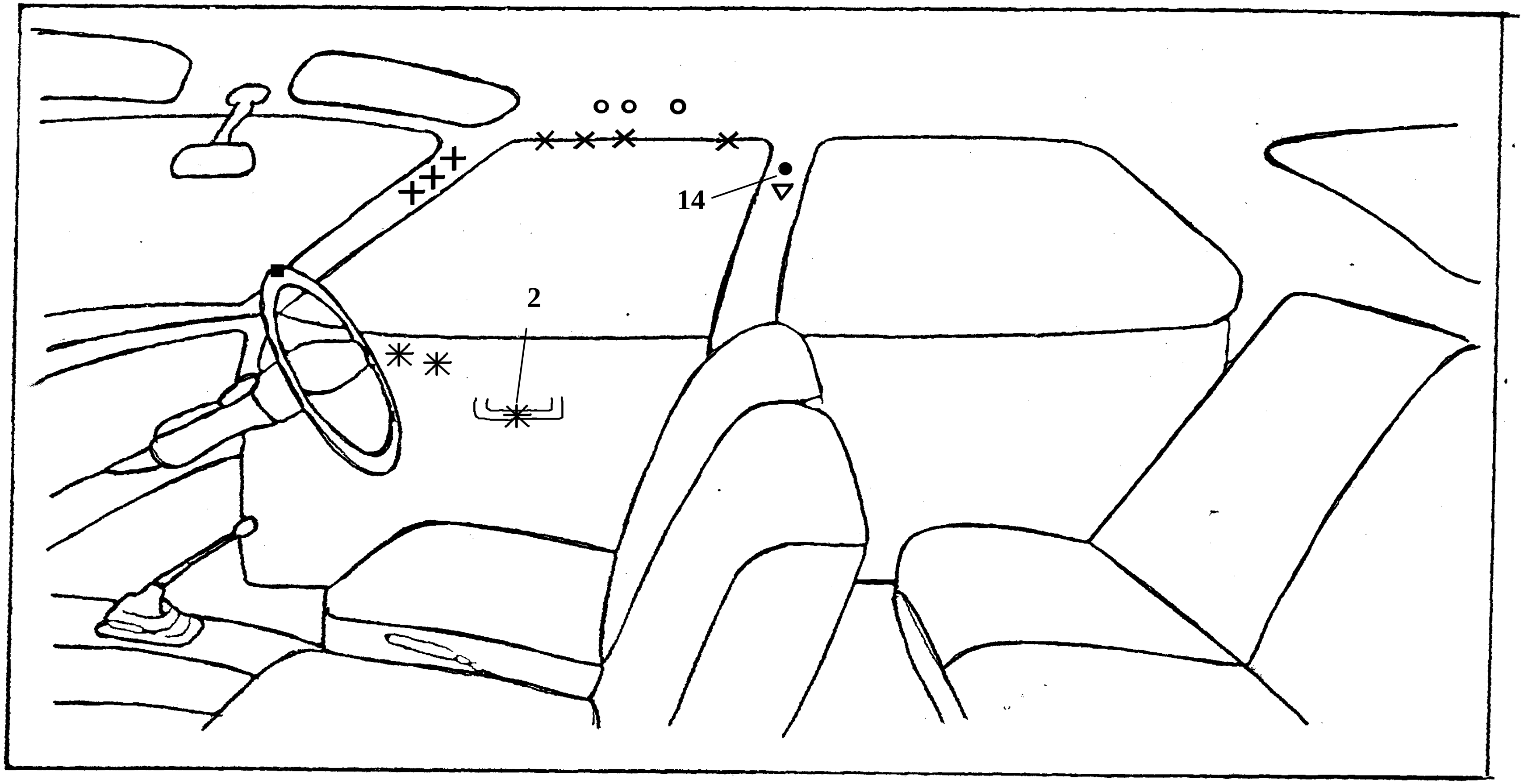

Figure 7 - Graphical Representation of Frequent Head Contact Regions, Front Seat, Struck Side Occupants - BASt Data

Key	Contact Region	Total in figure	Total no of contacts	Key	Contact Region	Total in figure	Total no of contacts	Key	Contact Region	Total in figure	Total no of contacts
●	**B Pillar**	14	14	▲	**Header**	0	0	∇	**Upper Anchorage**	1	1
✚	**A Pillar**	3	3	#	**Facia Top**	0	0	■	**Steering Wheel**	1	1
	Side Other	4	4	**O**	**Roof**	3	3	♦	**Head Restraint**	0	0
	Side Roof Rail	4	4								

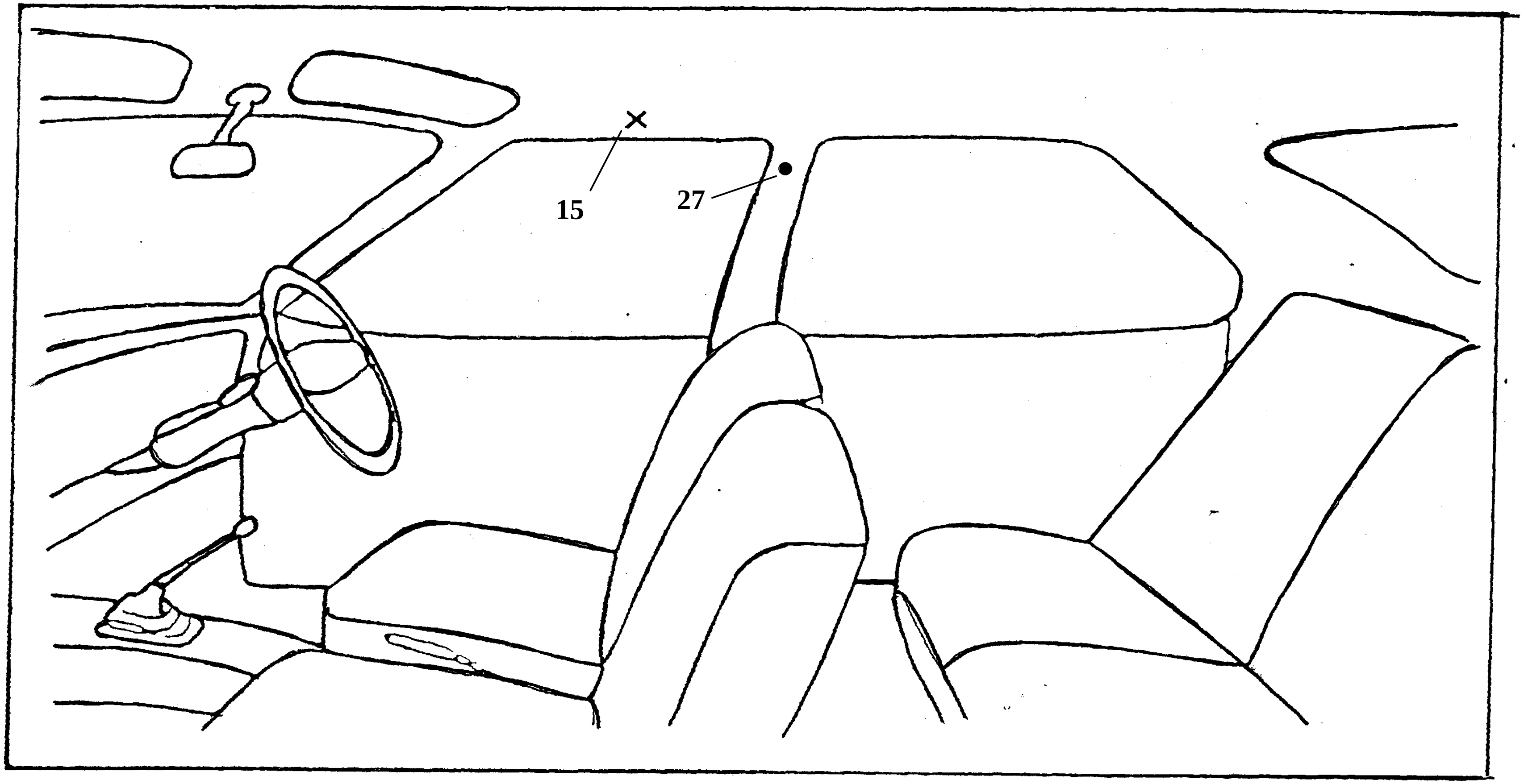

Figure 8 - Graphical Representation of Frequent Head Contact Regions, Front Seat, Struck Side Occupants - LAB Data

Key	Contact Region	Total in figure	Total no of contacts	Key	Contact Region	Total in figure	Total no of contacts	Key	Contact Region	Total in figure	Total no of contacts
●	**B Pillar**	127	27	▲	**Header**			∇	**Upper Anchorage**		
✚	**A Pillar**	0	0	#	**Facia Top**			■	**Steering Wheel**		
	Side Other			O	**Roof**			♦	**Head Restraint**		
	Side Roof Rail	15	15								

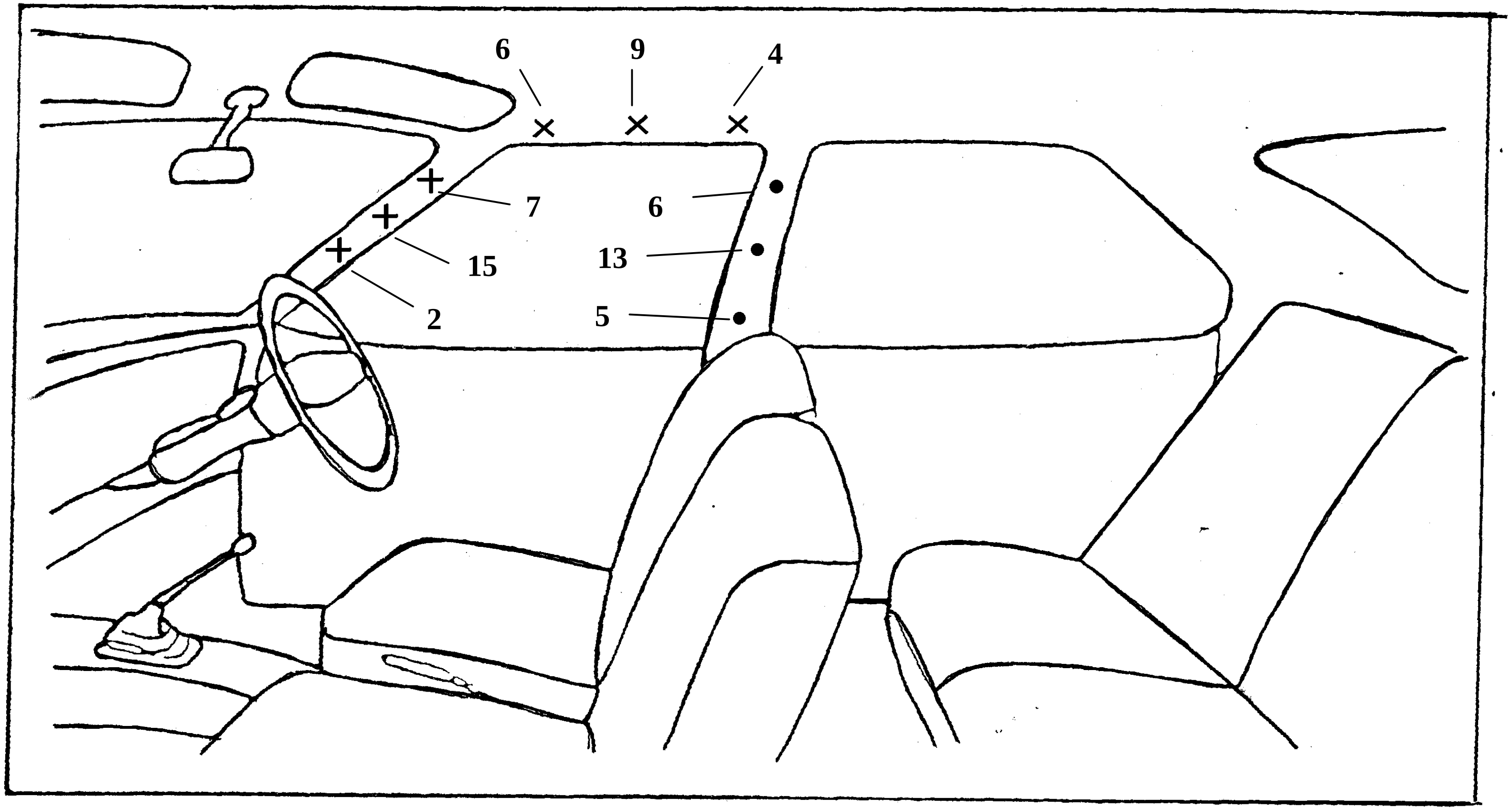

Figure 9 - Graphical Representation of Frequent Head Contact Regions, Front Seat, Struck Side Occupants - NHTSA Data

Key	Contact Region	Total in figure	Total no of contacts	Key	Contact Region	Total in figure	Total no of contacts	Key	Contact Region	Total in figure	Total no of contacts
●	**B Pillar**	24	56	▲	**Header**			∇	**Upper Anchorage**		
✚	**A Pillar**	24	40	#	**Facia Top**			■	**Steering Wheel**		
	Side Other			O	**Roof**			♦	**Head Restraint**		
	Side Roof Rail	19	39								

3.2.3.2 Non-Struck Side Occupants

Contact Site	TRL		BASt		LAB		NHTSA	
	AIS 3+ No.	AIS 1+ No.	AIS 3+ No.	AIS 1+ No.	AIS 3+ No.	AIS 1+ No.	AIS 3+ No.	AIS 1+ No.
Non Contact Injury	2	6	1	1				
A Pillar	0	2	0	3	2	10	4	10
B Pillar	3	6	1	4	3	6	4	8
External Object	8	10	2	3	5	6		
Facia Top	0	2	0	1				
Flying Glass	0	10	0	2				
Header	0	2	0	0				
Head Restraint	1	3	1	2				
Mirror	0	5	0	0				
Seat	1	2	0	0				
Side Roof Rail	2	3	2	4	2	17	2	7
Side Glass	1	14	1	6	0	7		
Side Other	5	11	0	2	2	26		
Steering Wheel	1	7	0	6				
Roof	1	3	0	1				
Upper Anch' Point	0	0	0	1				
Windscreen	0	5	0	2				
Occupant Contact	3	11						
Window Frame					1	6		
Unknown	8	57			1	49		
Total	36	159	8	38	16	127	10	25

Table 10 - Contact regions and injury severity for restrained and unrestrained occupants on the non-struck side

Table 10 shows the results for all non-struck side occupants, (restrained and unrestrained).The specific points of contact on the vehicle structure for non-struck side occupants are shown on Figures 10-13.

Shaded areas denote contact site not recorded

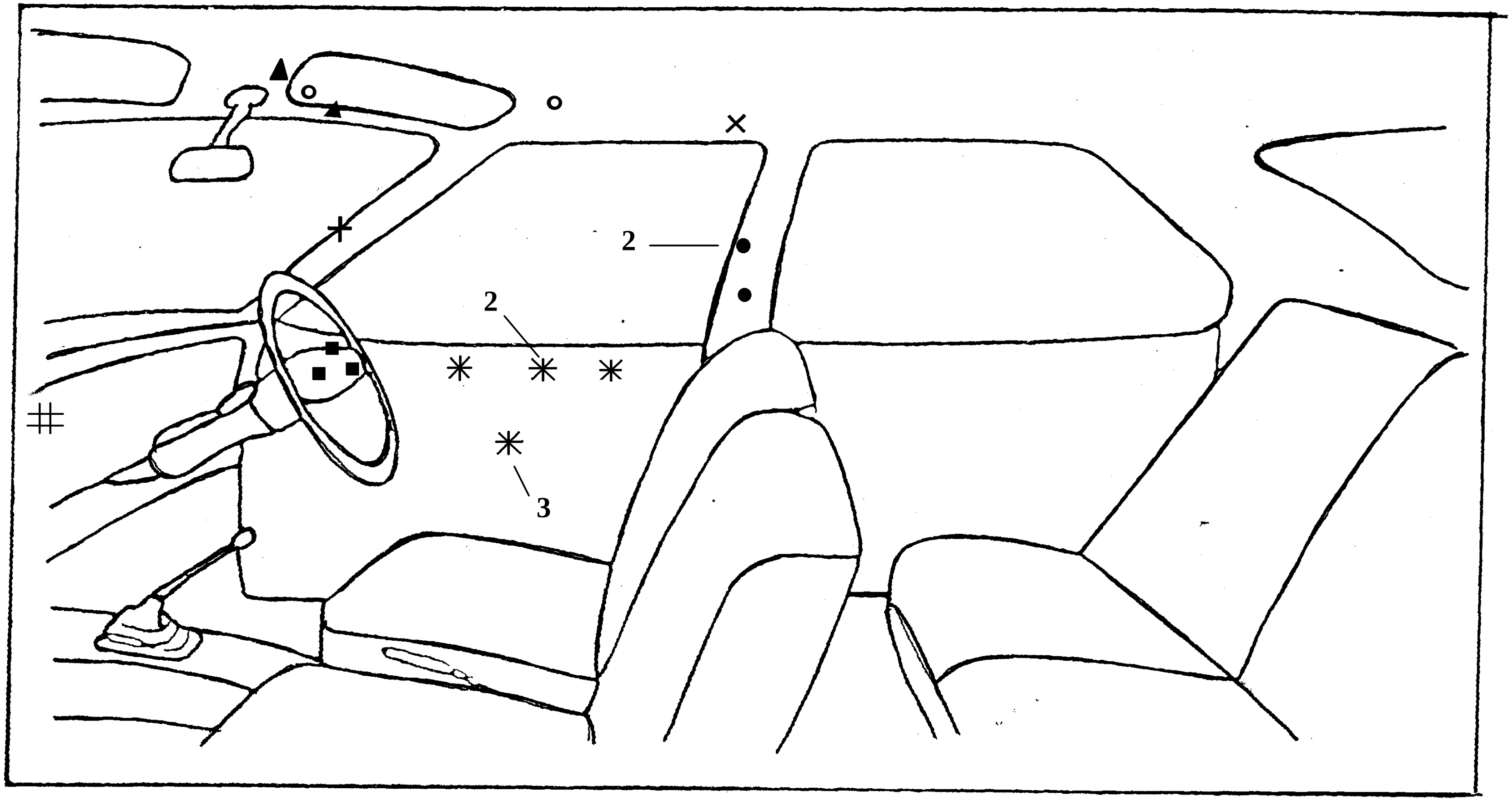

Figure 10: Graphical Representation of Frequent Head Contact Regions, Front Seat, Non-Struck Side Occupants - TRL Data

Key	Contact Region	Total in figure	Total no of contacts	Key	Contact Region	Total in figure	Total no of contacts	Key	Contact Region	Total in figure	Total no of contacts
●	B Pillar	3	6	▲	Header	2	2	∇	Upper Anchorage	0	0
✚	A Pillar	1	2	#	Facia Top	1	2	■	Steering Wheel	3	7
	Side Other	1	3	O	Roof	2	3	♦	Head Restraint	0	3
	Side Roof Rail	1	3								

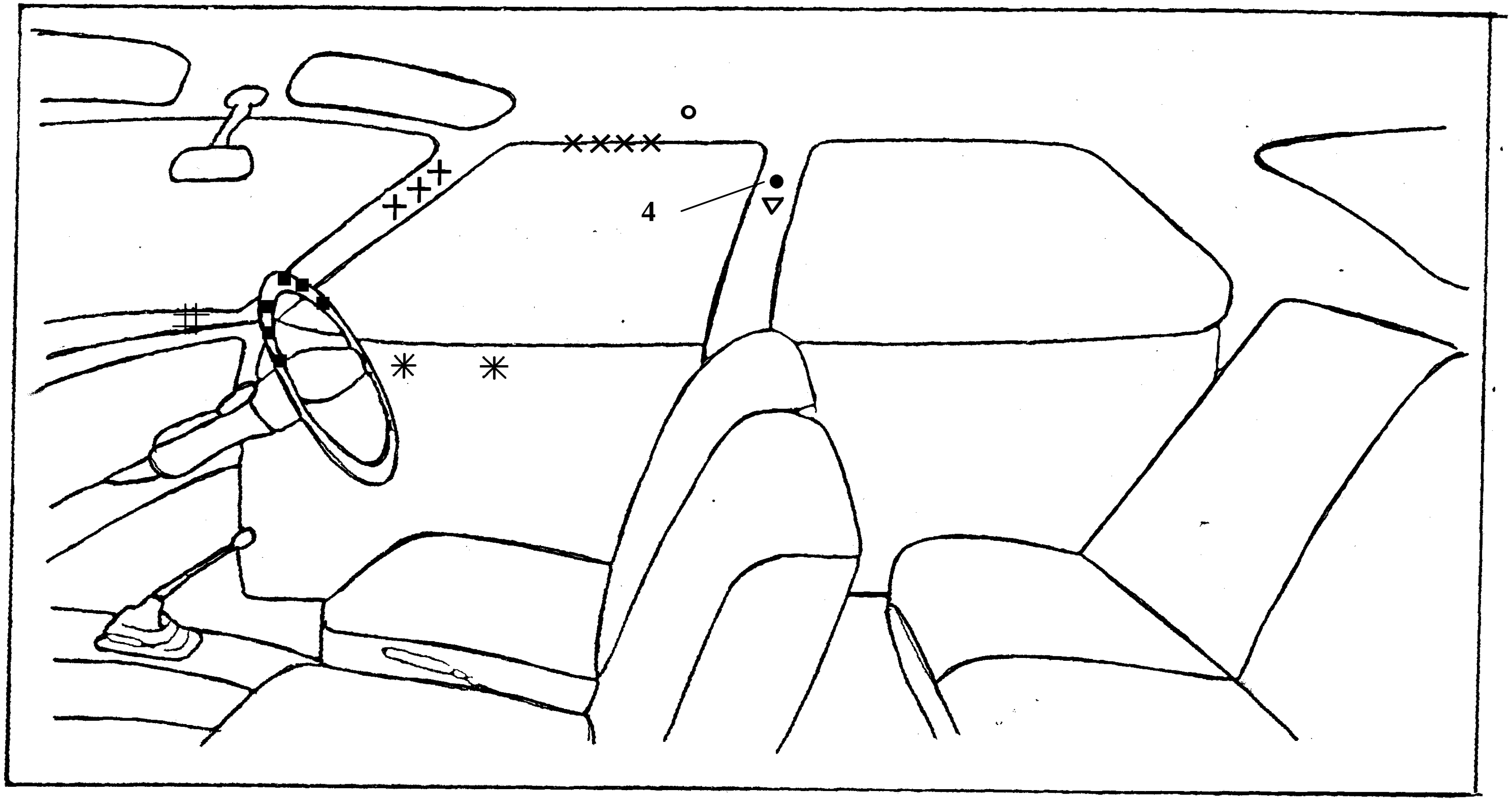

Figure 11: Graphical Representation of Frequent Head Contact Regions, Front Seat, Non-Struck Side Occupants - BASt Data

Key	Contact Region	Total in figure	Total no of contacts	Key	Contact Region	Total in figure	Total no of contacts	Key	Contact Region	Total in figure	Total no of contacts
●	B Pillar	4	4	▲	Header	0	0	∇	Upper Anchorage	1	1
✚	A Pillar	3	3	#	Facia Top	1	1	■	Steering Wheel	6	6
	Side Other	2	2	O	Roof	1	1	♦	Head Restraint	0	2
	Side Roof Rail	4	4								

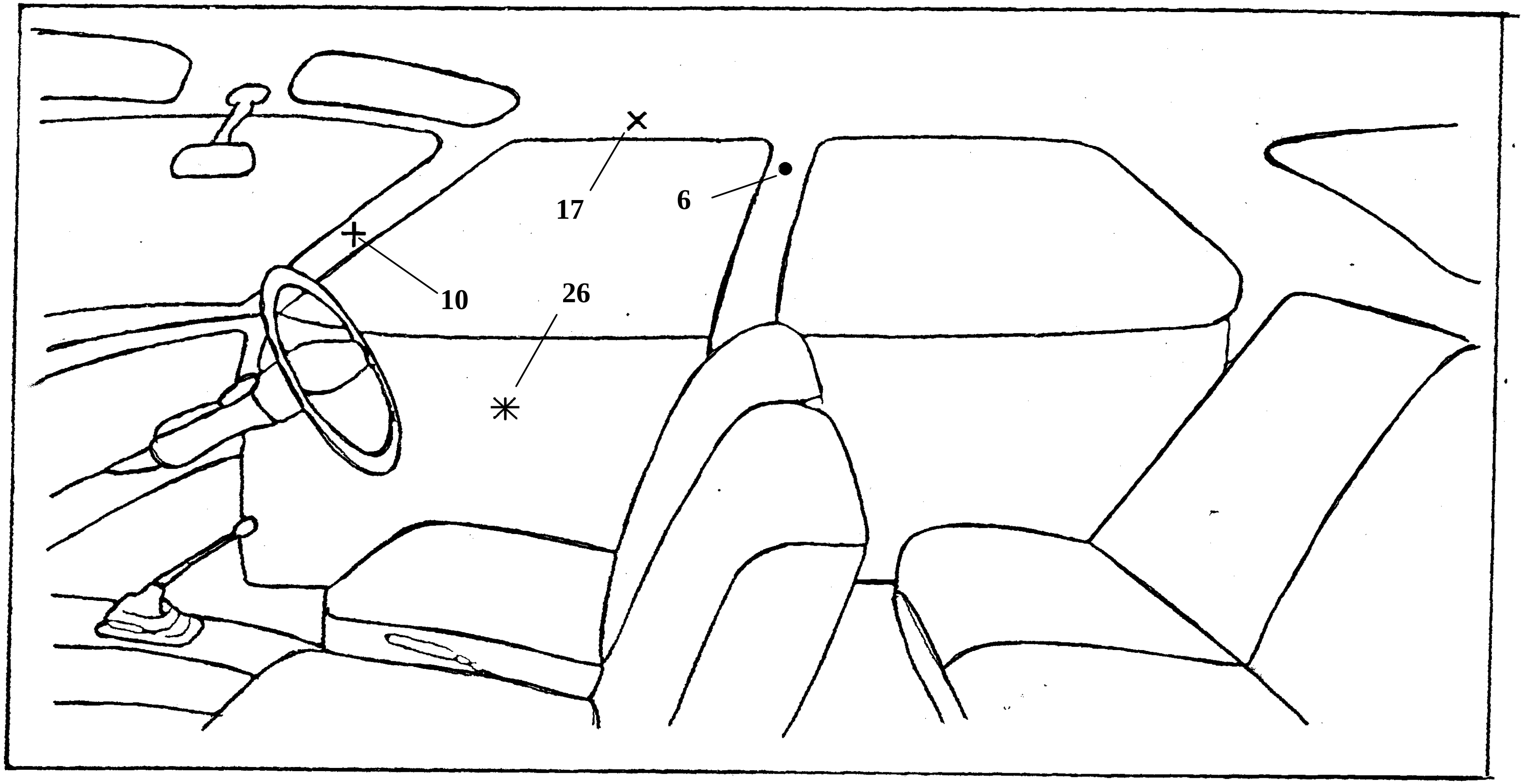

Figure 12 - Graphical Representation of Frequent Head Contact Regions, Front Seat, Non Struck Side Occupants - LAB Data

Key	Contact Region	Total in figure	Total no of contacts	Key	Contact Region	Total in figure	Total no of contacts	Key	Contact Region	Total in figure	Total no of contacts
●	**B Pillar**	127	27	▲	**Header**			∇	**Upper Anchorage**		
✚	**A Pillar**	0	0	#	**Facia Top**			■	**Steering Wheel**		
	Side Other	26	26	**O**	**Roof**			♦	**Head Restraint**		
	Side Roof Rail	15	15								

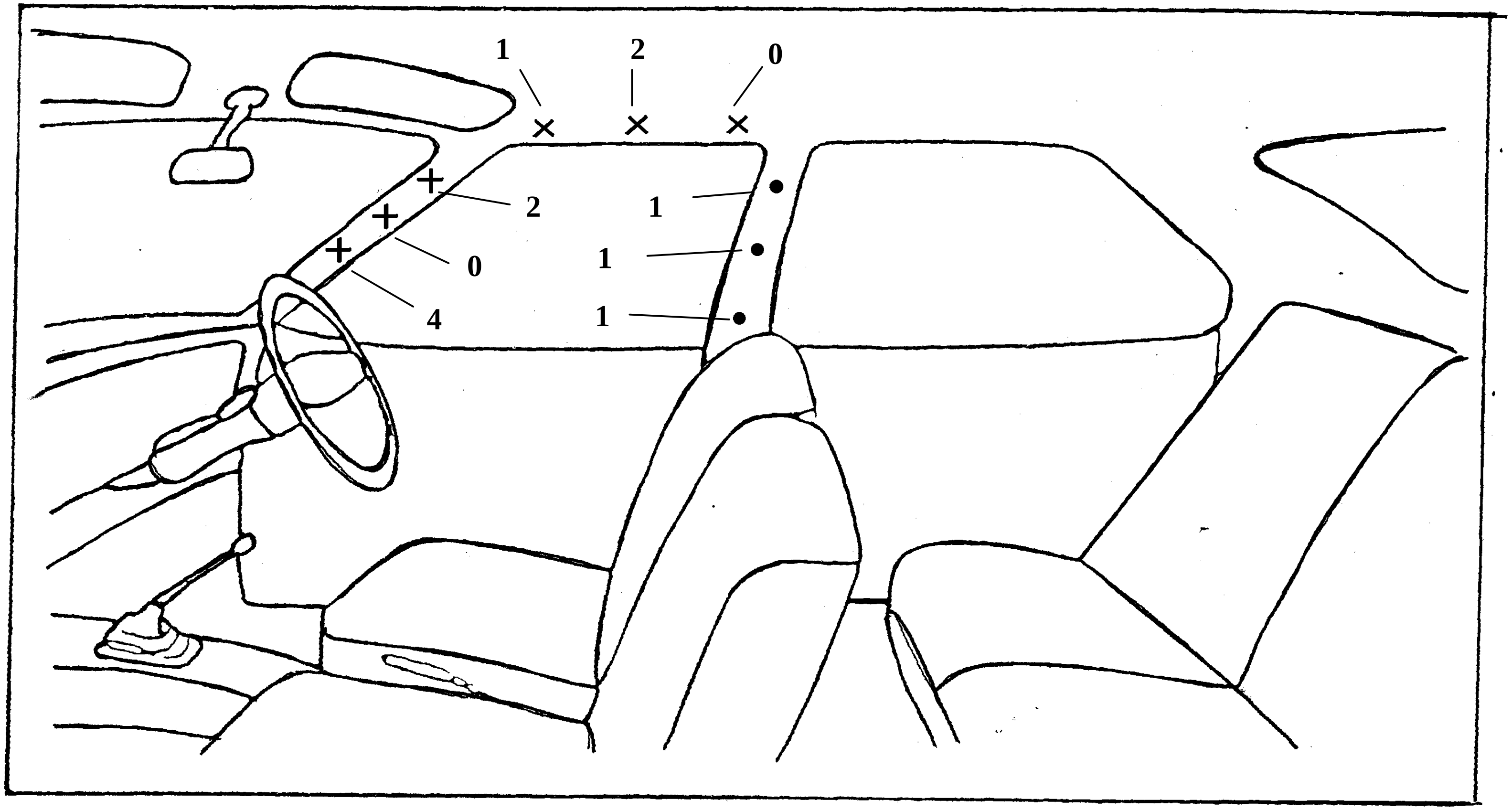

Figure 13 - Graphical Representation of Frequent Head Contact Regions, Front Seat, Struck Side Occupants - NHTSA Data

Key	Contact Region	Total in figure	Total no of contacts	Key	Contact Region	Total in figure	Total no of contacts	Key	Contact Region	Total in figure	Total no of contacts
●	**B Pillar**	3	8	▲	**Header**			∇	**Upper Anchorage**		
✚	**A Pillar**	6	10	#	**Facia Top**			■	**Steering Wheel**		
	Side Other			O	**Roof**			♦	**Head Restraint**		
	Side Roof Rail	3	7								

3.2.4 ALL FRONT SEAT OCCUPANTS

Contact Site	TRL		BASt		LAB		NHTSA	
	AIS 3+ No.	AIS 1+ No.	AIS 3+ No.	AIS 1+ No.	AIS 3+ No.	AIS 1+ No.	AIS 3+ No.	AIS 1+ No.
Non Contact Injury	2	11	2	3				
Airbag	0	1	0	0				
A Pillar	2	11	2	6	2	10	11	50
B Pillar	5	24	11	18	7	33	22	64
External Object	31	54	9	15	15	27		
Facia Top	0	3	0	1				
Flying Glass	0	23	0	6				
Header	0	3	0	0				
Head Restraint	1	5	1	2				
Mirror	0	5	0	0				
Seat	1	2	0	0				
Side Roof Rail	10	15	2	8	2	32	12	46
Side Glass	3	83	4	13	0	93		
Side Other	8	16	1	6	2	26		
Steering Wheel	2	10	0	7				
Sunroof	0	1	0	0				
Roof	2	6	1	4				
Upper Anch' Point	0	2	0	2				
Windscreen	0	8	0	2				
Occupant Contact	4	12	0	1				
Window Frame					1	21		
Unknown	18	113			1	62		
Total	89	408	33	93	30	304	45	160

Table 11 - Contact regions and injury severity all front seat occupants

Table 11 shows the combined results for all front seat occupants (restrained/unrestrained/unknown belt use, occupants on both the struck and non-struck sides). Figures 14-17 show head contact regions on the vehicle structure for all front seat occupants.

Shaded areas denote contact site not recorded

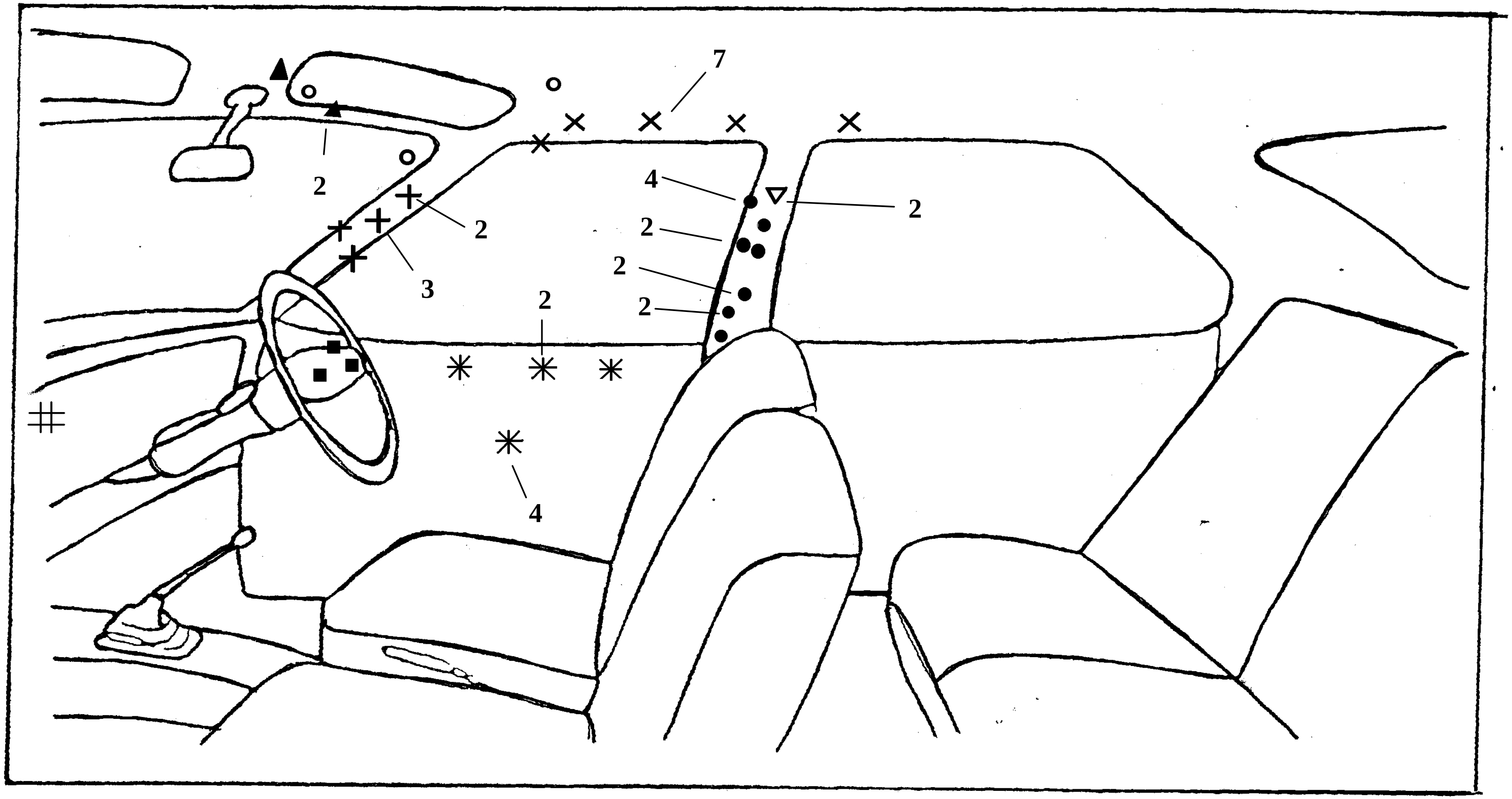

Figure 14 Graphical Representation of Frequent Head Contact Regions, All Front Seat Occupants - TRL Data

Key	Contact Region	Total in figure	Total no of contacts	Key	Contact Region	Total in figure	Total no of contacts	Key	Contact Region	Total in figure	Total no of contacts
●	**B Pillar**	13	24	▲	**Header**	3	3	∇	**Upper Anchorage**	2	2
✚	**A Pillar**	7	11	#	**Facia Top**	1	3	■	**Steering Wheel**	3	10
	Side Other	8	16	O	**Roof**	3	6	♦	**Head Restraint**	0	5
	Side Roof Rail	11	15								

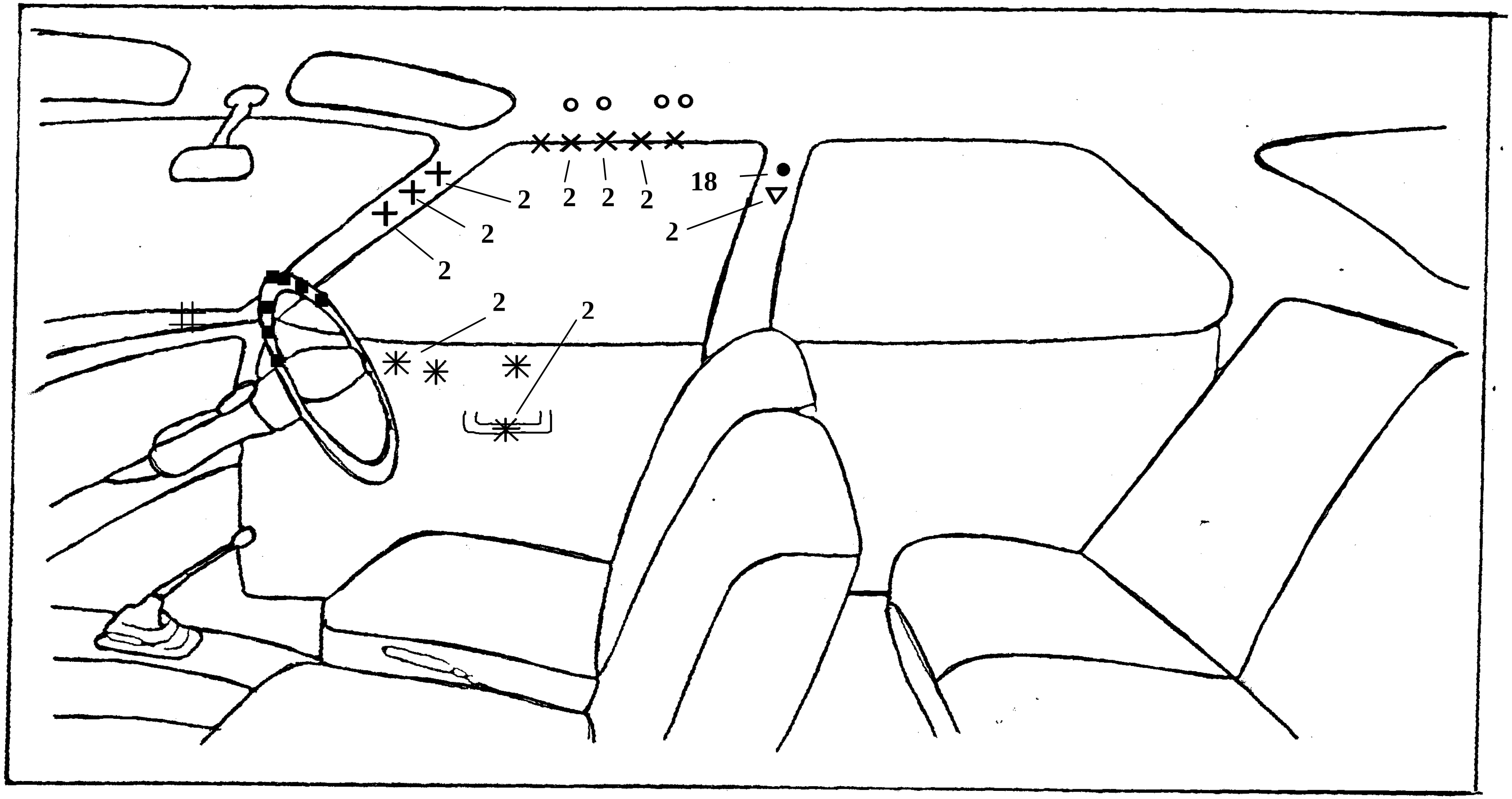

Figure 15 Graphical Representation of Frequent Head Contact Regions, All Front Seat Occupants - BASt Data

Key	Contact Region	Total in figure	Total no of contacts	Key	Contact Region	Total in figure	Total no of contacts	Key	Contact Region	Total in figure	Total no of contacts
●	**B Pillar**	18	18	▲	**Header**	0	0	∇	**Upper Anchorage**	2	2
✚	**A Pillar**	6	6	#	**Facia Top**	0	0	■	**Steering Wheel**	1	7
	Side Other	8	16	**O**	**Roof**	4	4	♦	**Head Restraint**	0	2
	Side Roof Rail	8	8								

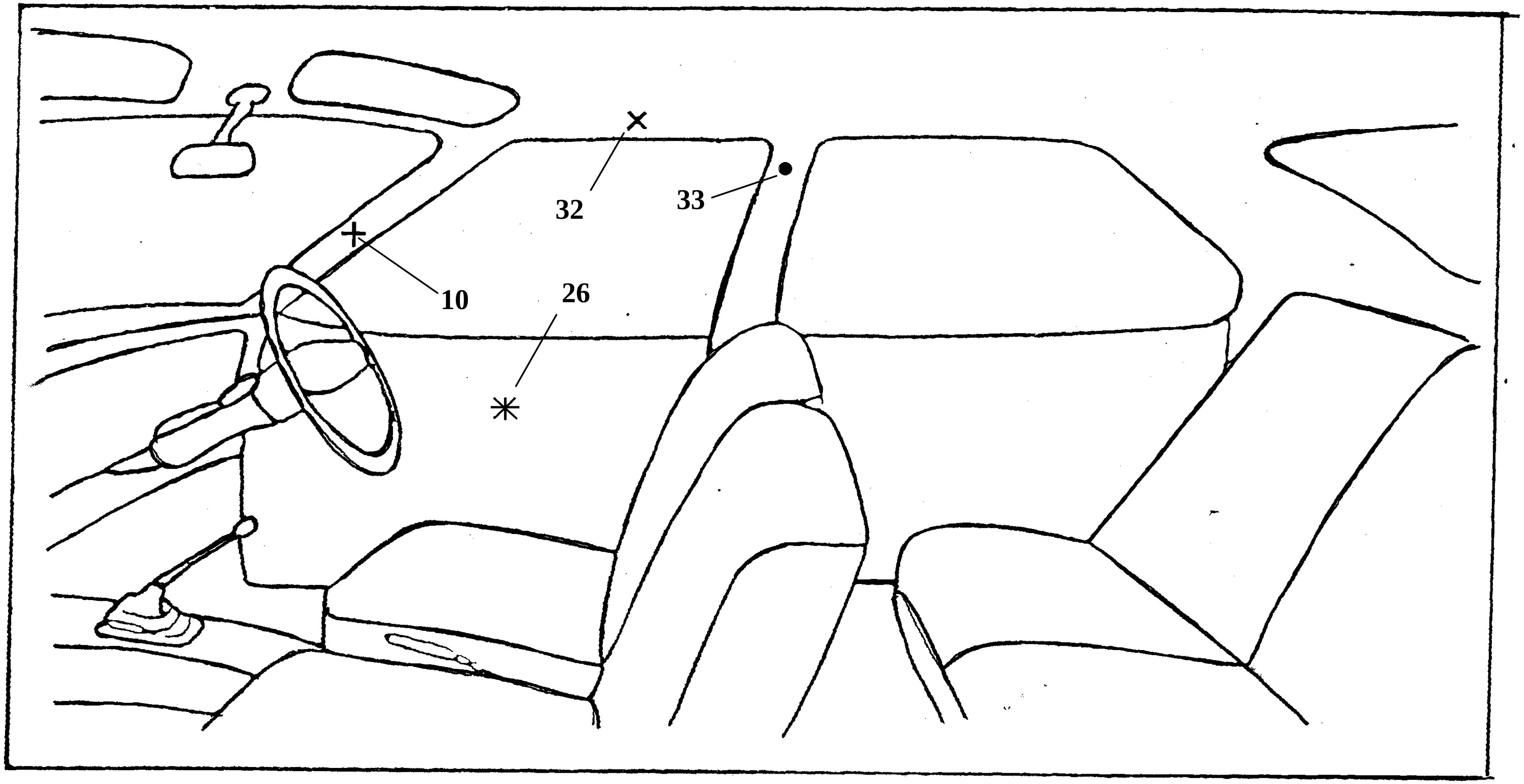

Figure 16 - Graphical Representation of Frequent Head Contact Regions, All Front Seat Occupants - LAB Data

Key	Contact Region	Total in figure	Total no of contacts	Key	Contact Region	Total in figure	Total no of contacts	Key	Contact Region	Total in figure	Total no of contacts
●	**B Pillar**	127	27	▲	**Header**			∇	**Upper Anchorage**		
✚	**A Pillar**	0	0	#	**Facia Top**			■	**Steering Wheel**		
	Side Other	26	26	**O**	**Roof**			♦	**Head Restraint**		
	Side Roof Rail	15	15								

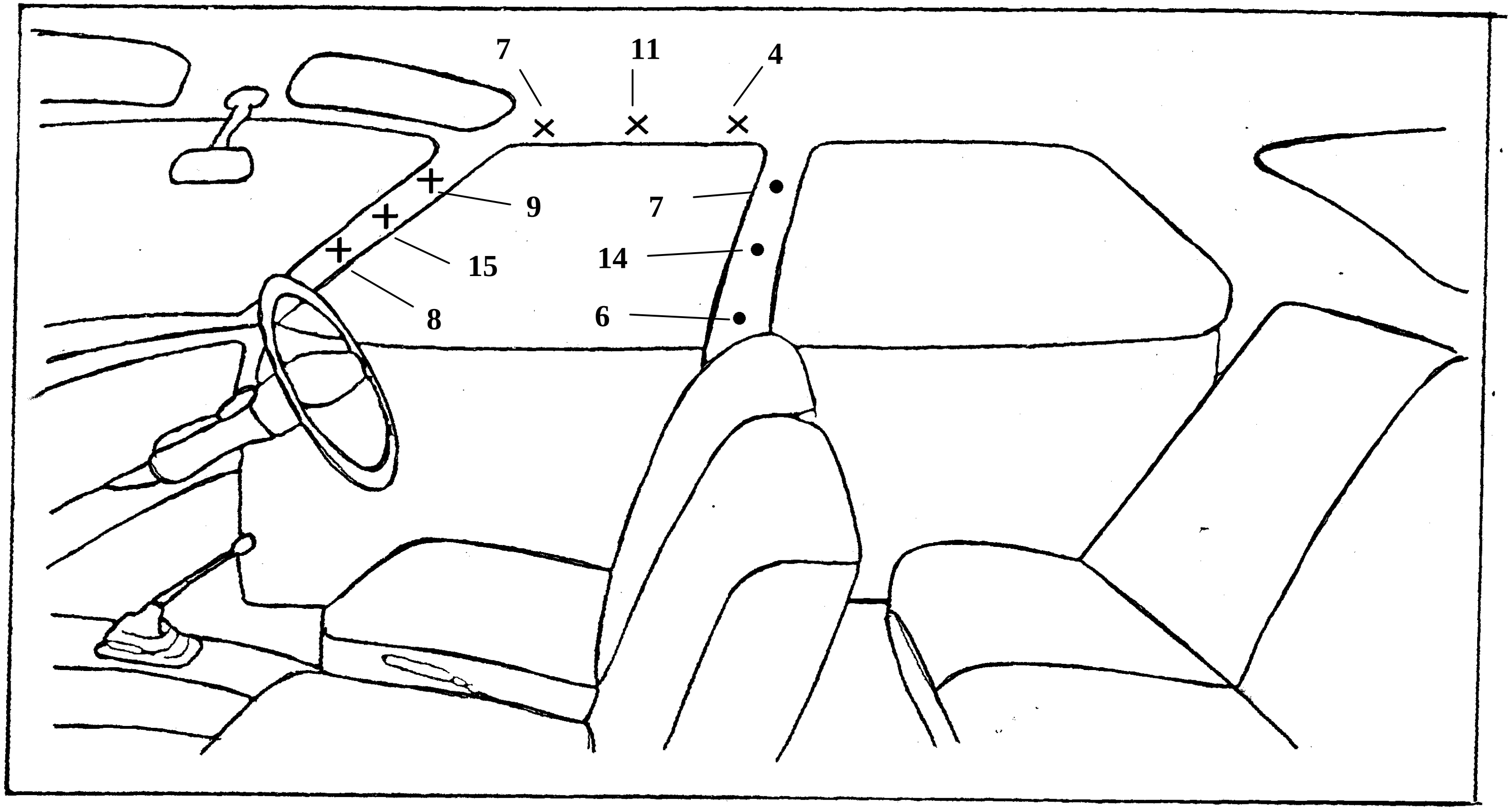

Figure 17 - Graphical Representation of Frequent Head Contact Regions, All Front Seat Occupants - NHTSA Data

Key	Contact Region	Total in figure	Total no of contacts	Key	Contact Region	Total in figure	Total no of contacts	Key	Contact Region	Total in figure	Total no of contacts
●	**B Pillar**	27	64	▲	**Header**			∇	**Upper Anchorage**		
✚	**A Pillar**	32	50	#	**Facia Top**			■	**Steering Wheel**		
	Side Other			O	**Roof**			♦	**Head Restraint**		
	Side Roof Rail	22	46								

3.2.5 INTRUSION –FRONT SEAT OCCUPANTS

This section assesses the effect of intrusion at the point of head contact. This information is only available in the TRL (CCIS) database. There are three categories:

- No intrusion
- Supported intrusion – The contact region was supported by the intruding object, (i.e. bullet vehicle, lamp post, etc).
- Unsupported Intrusion – The contact region was not supported.

The number of cases for each type of intrusion is shown in Table 12 - Table 14. For some cases, the intrusion could not be classified. This category is recorded as 'unknown' and has been excluded from the following tables. Contacts to external objects have been excluded.

3.2.5.1 Struck Side Occupants

Table 12 shows the intrusion types for struck side occupants.

No Intrusion		Supported Intrusion		Unsupported Intrusion	
AIS 3+ No	AIS 1+ No	AIS 3+ No	AIS 1+ No	AIS 3+ No	AIS 1+ No
27	176	15	31	6	17

Table 12 - Intrusion – Struck Side Occupants

3.2.5.2 Non-Struck Side Occupants

Table 13 shows the intrusion type for non-struck side occupants.

No Intrusion		Supported Intrusion		Unsupported Intrusion	
AIS 3+ No	AIS 1+ No	AIS 3+ No	AIS 1+ No	AIS 3+ No	AIS 1+ No
16	112	14	19	2	4

Table 13 - Intrusion – Non Struck Side Occupants

3.2.5.3 All Front Seat Occupants

The type of intrusion for all front seat occupants is shown in Table 14.

No Intrusion		Supported Intrusion		Unsupported Intrusion	
AIS 3+ No	AIS 1+ No	AIS 3+ No	AIS 1+ No	AIS 3+ No	AIS 1+ No
44	288	29	50	8	21

Table 14: Intrusion – All Occupants

This section of the analysis investigates whether the intrusion type affects the severity of the resulting injury. As the aim of this investigation is to define an appropriate test procedure, the effect of intrusion is concerned only with head contacts to the structure of the vehicle. Therefore, contacts with the vehicle glazing, vehicle furnishings and non vehicle contacts are excluded from this analysis. The contact region and severity of injury associated with each type of intrusion is shown below in Table 15 - Table 17.

Contact Site	**TRL**	
	AIS 3+ No.	**AIS 1+ No.**
A Pillar	2	10
B Pillar	1	12
Header	0	2
Side Roof Rail	3	6
Side Other	2	6
Roof	1	4
Upper Anch' Point	0	2
Total	9	42

Table 15 - Contact Regions and Injury Severity with No Intrusion

Contact Site	**TRL**	
	AIS 3+ No.	**AIS 1+ No.**
A Pillar	0	1
B Pillar	3	8
Side Roof Rail	6	7
Side Other	3	6
Roof	1	2
Total	13	24

Table 16 - Contact Regions and Injury Severity with Supported Intrusion

Contact Site	**TRL**	
	AIS 3+ No.	**AIS 1+ No.**
Side Other	1	1
Total	1	1

Table 17 - Contact Regions and Injury Severity with Unsupported Intrusion

3.3 REAR SEAT OCCUPANTS

There are very few cases involving a rear seat occupant, in comparison with the number of front seat occupants. Belt use for rear occupants has only recently become a legal requirement. There are a large number of cases involving occupants where the belt was not used or even not fitted, especially with the LAB data.

3.3.1 RESTRAINED REAR SEAT OCCUPANTS

3.3.1.1 Struck Side Occupants

Table 18 shows the results for struck side restrained occupants.

Contact Site	**TRL**		**BASt**		**LAB**	
	AIS 3+ No.	**AIS 1+ No.**	**AIS 3+ No.**	**AIS 1+ No.**	**AIS 3+ No.**	**AIS 1+ No.**
B Pillar	1	2	0	0	0	1
C Pillar	0	0	0	0	0	1
External Object	0	0	0	0	2	2
Flying Glass	0	1	0	1		
Seat	0	1	0	0		
Side Roof Rail	0	0	0	0	0	1
Side Glass	0	1	0	0	0	0
Unknown	0	8			0	0
Total	1	13	0	1	2	5

Table 18 - Contact regions and injury severity for restrained occupants on the struck side

3.3.1.2 Non-Struck Side Occupants

Results for restrained occupants on the non-struck side are tabulated for all contacts, in Table 19.

Contact Site	**TRL**		**BASt**		**LAB**	
	AIS 3+ No.	**AIS 1+ No.**	**AIS 3+ No.**	**AIS 1+ No.**	**AIS 3+ No.**	**AIS 1+ No.**
Seat	0	2	0	0		
Side Roof Rail	0	1	0	0	0	0
Side Glass	0	1	0	0	0	0
Side Other	0	0	0	0	1	1
Unknown	0	2			0	3
Total	0	6	0	0	1	4

Table 19 - Contact regions and injury severity for restrained occupants on the non-struck side

Shaded areas denote contact site not recorded

3.3.1.3 Struck and Non-Struck Side Occupants

Results for restrained occupants on any side are shown in Table 20.

Contact Site	**TRL**		**BASt**		**LAB**	
	AIS 3+ No.	**AIS 1+ No.**	**AIS 3+ No.**	**AIS 1+ No.**	**AIS 3+ No.**	**AIS 1+ No.**
B Pillar	1	2	0	0	0	1
C Pillar	0	0	0	0	0	1
External Object	0	0	0	0	2	2
Flying Glass	0	1	0	1		
Seat	0	3	0	0		
Side Roof Rail	0	1	0	0	0	1
Side Glass	0	2	0	0	0	0
Side Other	0	0	0	0	1	1
Unknown	0	10			0	3
Total	1	19	0	1	3	9

Table 20 - Contact regions and injury severity for restrained, rear seat occupants on either side

3.3.2 UNRESTRAINED REAR SEAT OCCUPANTS

3.3.2.1 Struck Side Occupants

Table 21 shows the results for unrestrained rear seat occupants on the struck side.

Contact Site	**TRL**		**BASt**		**LAB**	
	AIS 3+ No.	**AIS 1+ No.**	**AIS 3+ No.**	**AIS 1+ No.**	**AIS 3+ No.**	**AIS 1+ No.**
B Pillar	0	0	0	0	1	3
C Pillar	0	0	0	1	1	2
External Object	1	1	0	0	0	0
Head Restraint	0	1	0	1		
Side Glass	0	0	0	0	0	9
Side Other	0	0	0	0	1	4
Window Frame					0	1
Occupant Contact	1	1	0	0		
Unknown	1	4			0	3
Total	3	7	0	2	3	22

Table 21 - Contact regions and injury severity for unrestrained occupants on the struck side

Shaded areas denote contact site not recorded

3.3.2.2 Non-Struck Side Occupants

Table 22 shows the results for all unrestrained occupants on the non-struck side.

Contact Site	TRL		BASt		LAB	
	AIS 3+ No.	AIS 1+ No.	AIS 3+ No.	AIS 1+ No.	AIS 3+ No.	AIS 1+ No.
B Pillar	0	0	0	0	0	3
C Pillar	0	0	1	1	0	0
External Object	0	1	0	0	0	0
Seat	0	4	0	0		
Side Glass	0	1	0	1	0	2
Side Other	0	0	0	0	0	2
Unknown	1	2			0	3
Total	0	4	1	2	0	5

Table 22 - Contact regions and injury severity for unrestrained occupants on the non-struck side

3.3.2.3 Struck and Non-Struck Side Occupants

The results for all unrestrained rear seat occupants are shown in Table 23.

Contact Site	TRL		BASt		LAB	
	AIS 3+ No.	AIS 1+ No.	AIS 3+ No.	AIS 1+ No.	AIS 3+ No.	AIS 1+ No.
B Pillar	0	0	0	0	1	6
C Pillar	0	0	1	2	1	2
External Object	1	2	0	0	0	0
Head Restraint	0	1	0	1		
Seat	0	4	0	0		
Side Glass	0	1	0	1	0	11
Side Other	0	0	0	0	1	6
Occupant Contact	1	1	0	0		
Window Frame					0	1
Unknown	2	6			0	6
Total	4	15	1	4	3	32

Table 23 -Contact regions and injury severity for unrestrained occupants on any side

Shaded areas denote contact site not recorded

3.3.3 POSITION OF REAR SEAT OCCUPANTS.

3.3.3.1 Struck Side Occupants

The results for all struck side occupants in a rear seat are shown in Table 24.

Contact Site	TRL		BASt		LAB	
	AIS 3+ No.	AIS 1+ No.	AIS 3+ No.	AIS 1+ No.	AIS 3+ No.	AIS 1+ No.
B Pillar	1	2	0	0	1	4
C Pillar	0	0	0	1	1	3
External Object	2	3	0	0	2	2
Flying Glass	0	2	0	1		
Head Restraint	0	1	0	1		
Seat	0	1	0	0		
Side Roof Rail	0	0	0	0	0	1
Side Glass	1	6	0	0	0	9
Side Other	0	0	0	0	1	4
Occupant Contact	1	1	0	0		
Window Frame					0	1
Unknown	1	16			0	3
Total	6	32	0	3	5	27

Table 24 - Contact regions and injury severity for restrained and unrestrained occupants on the struck side

3.3.3.2 Non-Struck Side Occupants

The results for all non-struck side occupants in a rear seat are shown in Table 25.

Contact Site	TRL		BASt		LAB	
	AIS 3+ No.	AIS 1+ No.	AIS 3+ No.	AIS 1+ No.	AIS 3+ No.	AIS 1+ No.
B Pillar	0	0	0	0	0	3
C Pillar	0	0	0	1	0	0
External Object	1	2	0	0	0	0
Seat	0	6	0	0		
Side Roof Rail	0	3	0	0	0	0
Side Glass	0	3	0	2	0	2
Side Other	0	1	0	0	1	3
Occupant Contact	0	1	0	0		
Unknown	0	14			0	6
Total	1	30	0	3	1	14

Table 25 - Contact regions and injury severity for restrained and unrestrained occupants on the non-struck side

Shaded areas denote contact site not recorded

3.3.4 ALL REAR SEAT OCCUPANTS

Contact Site	TRL		BASt		LAB	
	AIS 3+ No.	AIS 1+ No.	AIS 3+ No.	AIS 1+ No.	AIS 3+ No.	AIS 1+ No.
B Pillar	1	2	0	0	1	7
C Pillar	0	0	1	2	1	3
External Object	3	5	0	0	2	2
Flying Glass	0	2	0	1		
Head Restraint	0	1	0	1		
Seat	0	7	0	0		
Side Roof Rail	0	3	0	0	0	1
Side Glass	1	9	0	2	0	11
Side Other	0	1	0	0	2	7
Occupant Contact	1	2	0	0		
Window Frame					0	1
Unknown	4	30			0	9
Total	10	62	1	6	6	41

Table 26 - Contact regions and injury severity for restrained and unrestrained occupants on the struck side

The results for all rear seat occupants are shown in Table 26. The specific points of contact on the vehicle structure are shown in figures 18-20.

Shaded areas denote contact site not recorded

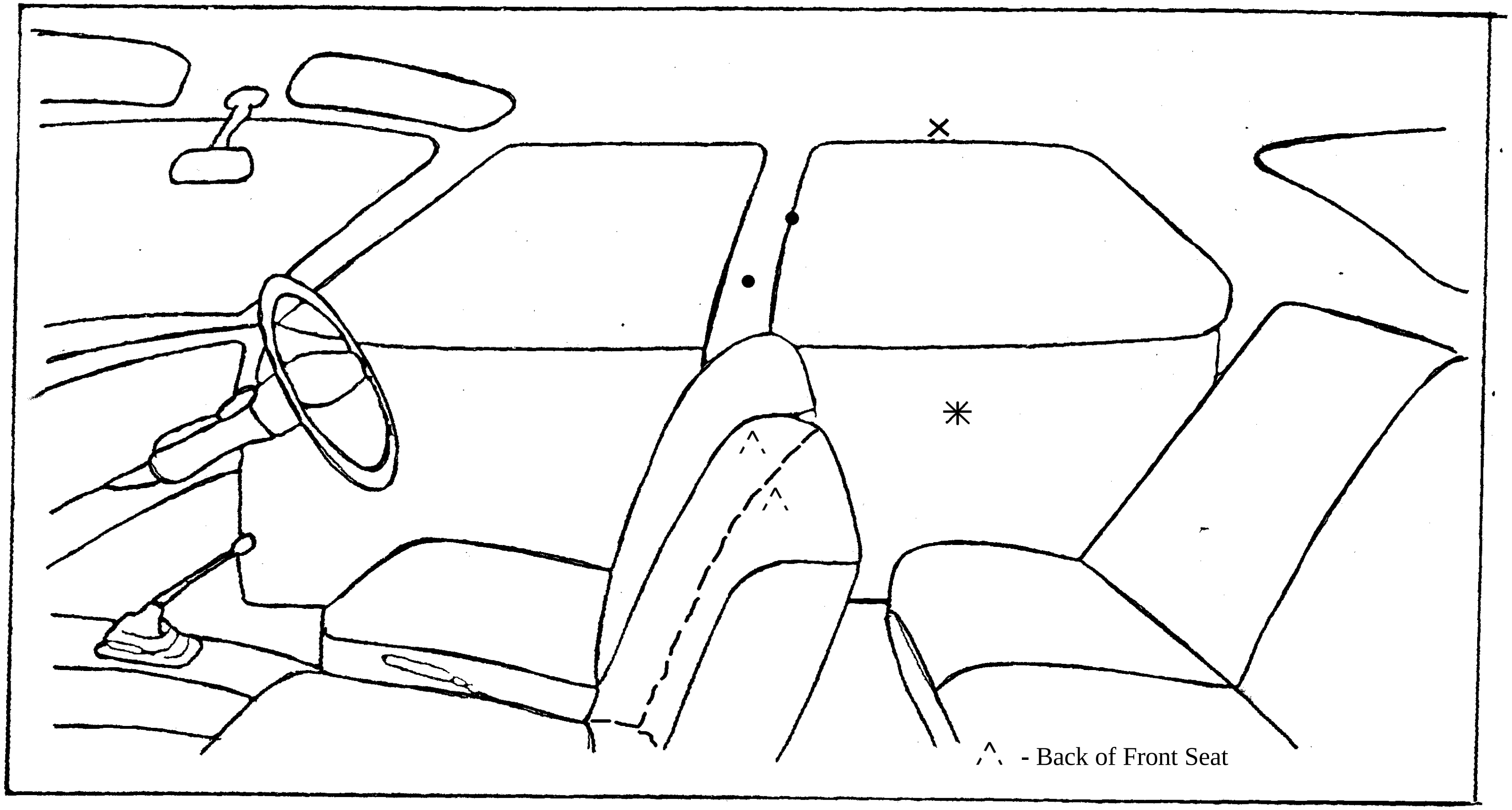

Figure 18 - Graphical Representation of Frequent Head Contact Regions, All Rear Seat Occupants - TRL Data

Key	Contact Region	Total in figure	Total no of contacts	Key	Contact Region	Total in figure	Total no of contacts
●	B Pillar	2	2	^	Seat	2	7
	Side Other	1	1	♦	Head Restraint	0	1
	Side Roof Rail	1	3	ÿ	C Pillar	0	0

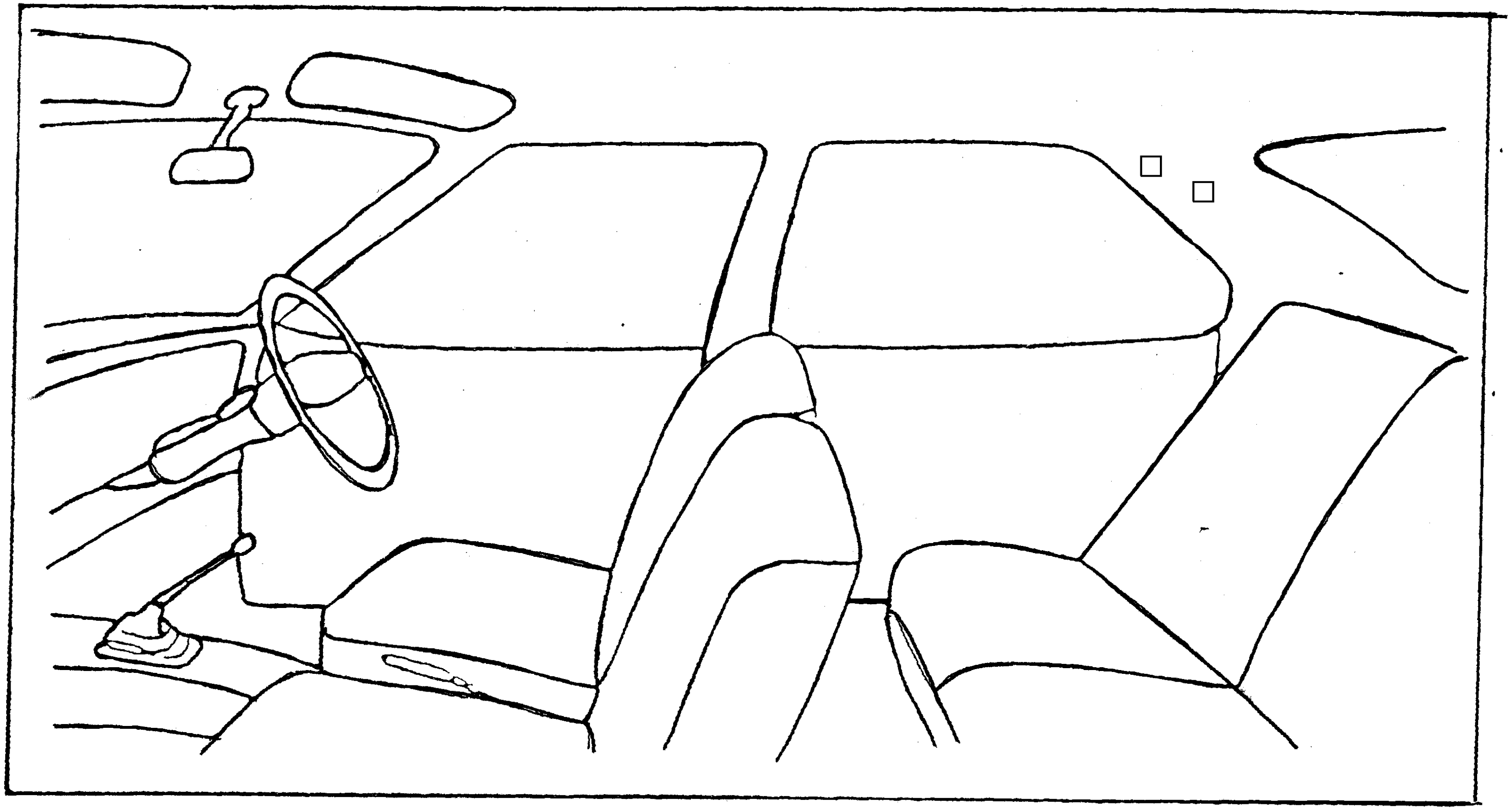

Figure 19 - Graphical Representation of Frequent Head Contact Regions, All Rear Seat Occupants - BASt Data

Key	Contact Region	Total in figure	Total no of contacts	Key	Contact Region	Total in figure	Total no of contacts
●	B Pillar	0	0	^	Seat	0	0
	Side Other	0	0	♦	Head Restraint	0	1
	Side Roof Rail	0	0	ÿ	C Pillar	2	2

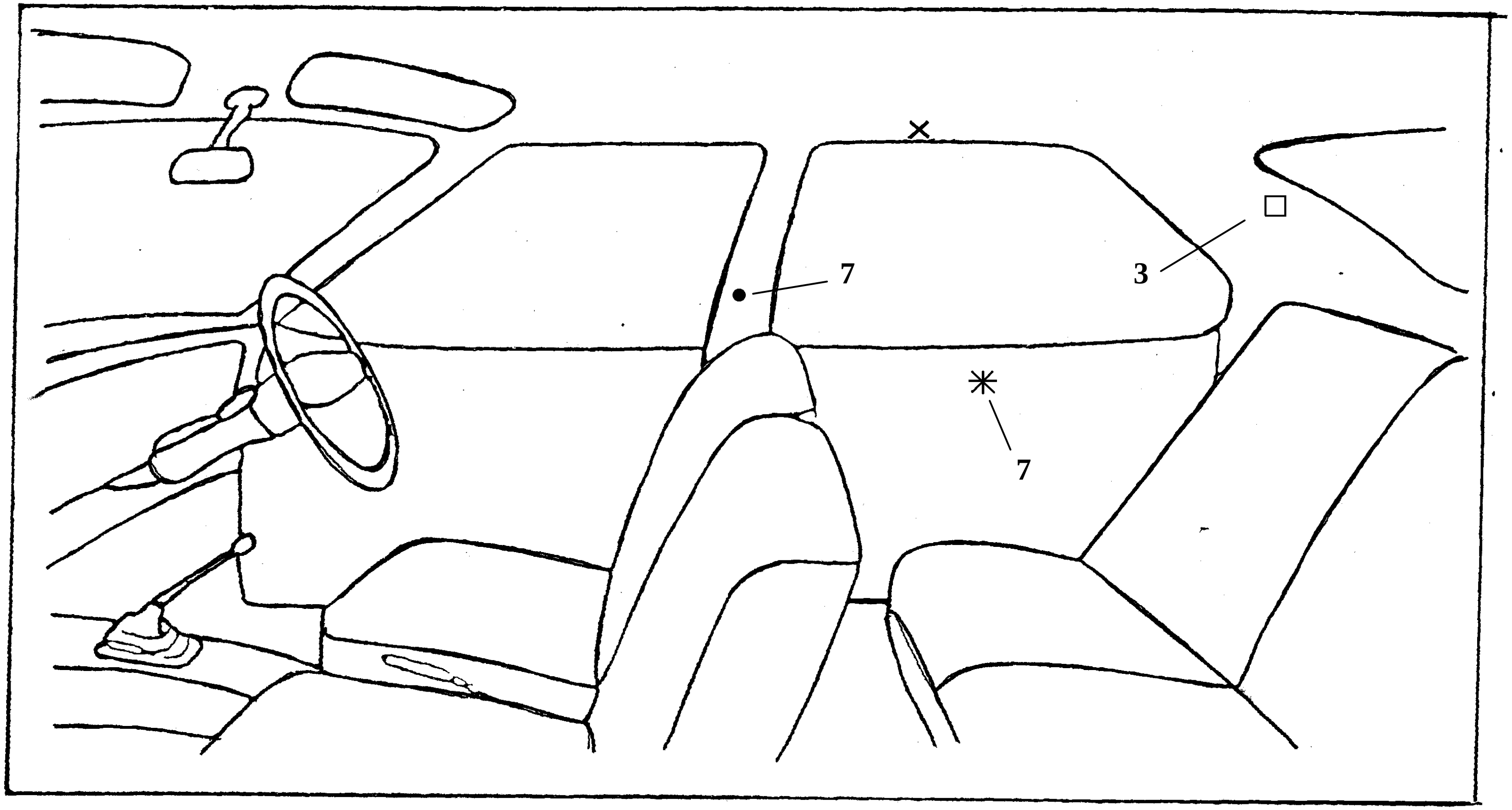

Figure 20 - Graphical Representation of Frequent Head Contact Regions, All Rear Seat Occupants - LAB Data

Key	Contact Region	Total in figure	Total no of contacts	Key	Contact Region	Total in figure	Total no of contacts
●	B Pillar	7	7	^	Seat		
	Side Other	7	7	♦	Head Restraint		
	Side Roof Rail	1	1	ÿ	C Pillar	7	7

3.3.5 EFFECT OF INTRUSION AT POINT OF CONTACT

The final phase of the analysis selected those cases involving rear seat occupants where there was intrusion at the point of contact, and assesses the effect of supported and unsupported intrusion with respect to severity of injury.

No Intrusion		Supported Intrusion		Unsupported Intrusion	
AIS 3+ No	AIS 1+ No	AIS 3+ No	AIS 1+ No	AIS 3+ No	AIS 1+ No
4	43	2	3	0	2

Table 27 –Intrusion – All Rear Seat Occupants

Only a few cases were recorded where intrusion occurred. The severity of injury associated with the type of intrusion is shown below, Table 28 - Table 30, for head contacts with the structure of the vehicle as defined in 3.2.5.3.

Contact Site	**TRL**	
	AIS 3+ No.	**AIS 1+ No.**
Side Roof Rail	0	2
Side Other	0	1
Total	3	40

Table 28 - Contact Regions and Injury Severity with No Intrusion

Contact Site	**TRL**	
	AIS 3+ No.	**AIS 1+ No.**
B Pillar	0	1
Total	0	1

Table 29 - Contact Regions and Injury Severity with Supported Intrusion

Contact Site	**TRL**	
	AIS 3+ No.	**AIS 1+ No.**
Side Roof Rail	0	1
Total	0	2

Table 30 - Contact Regions and Injury Severity with Unsupported Intrusion

4. DISCUSSION

4.1 GENERAL

The primary objective of this analysis has been to establish potential contact zones for the head of car occupants in side impacts. Since any proposed sub-system test is seen as supplementary to the EEVC full-scale side impact test procedure, it should duplicate the occupant condition. Therefore the contact zones for restrained occupants on the struck side form the primary analuses. The contact zones for restrained non-struck side and unrestrained occupants on either side have also been investigated so that the potential for reducing injuries to these occupants might also be considered.

A similar analysis has been performed for rear seat occupants. Clearly the occupancy is much lower than for front seat occupants, so the overall benefits of safety improvement would be commensurably less. Car sharing is currently being encouraged, which may lead to an increase in rear seat occupancy by adults. Rear seat occupants may also feel that they have the right to expect a similar level of safety protection as that afforded to front seat occupants. The results of this analysis can be used to assist in this consideration.

Head contact areas can be divided into three sections:

1. **NON VEHICLE** - External or other occupant contacts. which may suggest the implementation of additional secondary safety systems.
2. **VEHICLE GLAZING -** Including the windscreen, side glass and flying glass, which may also suggest the implementation of additional secondary safety systems.
3. **VEHICLE STRUCTURE** - Rigid members and components on the interior of the car.

Emphasis has been put on contact zones within the vehicle structure, since the aim of this research is to identify regions for a possible interior headform test procedure. External contacts, vehicle glazing, contacts with the other occupant and unknown contact regions have been excluded when defining important contact regions.

Within this study, an unknown contact may occur for two reasons: where the injury was slight, usually AIS 1 and no contact marks were made. In severe impacts usually causing injuries of AIS 5 and 6, the reason would usually have been that it was impossible to identify any contacts due to massive deformation of the vehicle.

The side glass was a frequently struck region but injuries were predominantly minor to moderate, (exclusively in the LAB database). This suggests that, if the glass remains intact, the impact severity is low or if it breaks the impact severity is higher but that injury risk is reduced by glass fracture. All injuries caused by flying glass were minor.

Where external contacts are recorded in the databases, they all agree that this is a particularly common contact site with a high incidence of AIS 3+ injuries. Although contacts to the glazing and external contacts have been shown to be important in terms of frequency and severity of injury, it is not within the scope of this study to discuss them in detail. However, the relatively high incidence of these contacts does suggest that implementation of additional safety systems, such as side window airbags, could substantially reduce the number of injuries which occur during side impact.

The results of this analysis have also highlighted the fact that contacts to the steering wheel, facia top, and head restraint are common in side impact. Impacts to these contact regions are already incorporated into frontal impact assessment and are not discussed in further detail.

Subsequent sections use the term ‘key contact region’ to define those contact sites which the accident data suggests should be considered for any future supplementary interior headform test procedure, for side impact.

4.2 FRONT SEAT OCCUPANTS

4.2.1 GENERAL

The four accident databases are not fully compatible. Thus it was not possible to combine these results, as the sampling strategies and areas of contact defined are different. The following section looks at each database and ranks the contact sites in order of priority (one being the most important) based on the number of AIS 1+ head impacts for each database

4.2.2 RESTRAINED STRUCK SIDE OCCUPANTS

Based on this analysis, Table 31 shows the key contact regions to protect restrained occupants on the struck side.

Contact Site	**Priority in terms of no. of AIS1+ injuries recorded**							
		TRL		**BASt**		**LAB**		**NHTSA**
A Pillar		3		=5		No Contacts		3
B Pillar		1		1		1		1
Side Roof Rail		2		=2		2		2
Side Other		4		=2		No Contacts		
Roof		No Contacts		4				
Upper Anch' Point		5		=5				
Window Frame						3		

Table 31 - Key Contact Regions, Restrained Struck Side Occupants

All four databases agree that the B pillar is the most frequent point of contact for restrained occupants on the struck side, followed by the side roof rail, presumably due to the close proximity of these structures to the occupants' head.

The TRL and NHTSA data place the A-pillar as the third priority while BASt puts ‘side other’ third and LAB the window frame, but this is identified as a distinct contact site only in this database. The BASt sample suggests that the A pillar is of much less importance for restrained occupants on the struck side while the LAB sample has no recorded head contacts to the A-pillar for restrained front seat occupants. In some of the TRL cases with A-pillar contact, there was intrusion which displaced the A-pillar rearwards and inwards. Contact with the A Pillar may occur for restrained occupants on the stuck side, where the direction of force is around 2 o’clock. In this instance, the occupant is able to pivot about the point of interaction between the shoulder and the seat belt and strike the A Pillar. However, taking all samples into account, contact with the A-pillar for restrained struck side occupants is a second order priority for side impact accidents. It may assume a higher priority if all impact directions are considered.

Beyond this the databases are not consistent in identifying one contact site as more important than another. Head contacts identified as side other are recorded only in the TRL and BASt data. This is a recognised site in the LAB database, but no contacts were recorded here. There is evidence from the BASt data that the roof is also a contact region for restrained occupants on the struck side. There was one contact with the upper anchorage point located on the B pillar in the TRL and BASt data.

4.2.3 RESTRAINED NON-STRUCK SIDE OCCUPANTS

Injury head contacts have been shown to occur for restrained occupants on the non-struck side also. If the protection of these occupants is considered important, the following contact regions are a priority, Table 32.

Contact Site	**Priority in terms of no. of AIS1+ injuries recorded**							
		TRL		**BASt**		**LAB**		**NHTSA**
A Pillar		No contacts		=2		4		3
B Pillar		2		=2		3		2
Header		=4		No Contacts				
Side Roof Rail		3		1		2		1
Side Other		1		=2		1		
Roof		=4		5				
Window Frame						5		

Table 32 - Key Contact Regions, Non-Struck Side Occupants

When the study is extended to include restrained non-struck side occupants the range of contact sites increases, this is particularly noticeable in the LAB data. The four databases lack consistency in identifying a single contact site as most important but overall, 'side other' can be considered a priority. Those contact sites identified as important for restrained occupants on the struck side, such as the B pillar, side roof rail and A pillar are also important for restrained non-struck side occupants. Further contacts to the roof and window frame (LAB only) were recorded but they were few in number. An additional contact site, not identified in the analysis of restrained struck side occupants is the header rail. This was identified in the TRL database only. The table ranks only those contact sites at the side of the passenger compartment and ignores internal contacts, such as steering wheel and front header rail

4.2.4 UNRESTRAINED OCCUPANTS –STRUCK AND NON-STRUCK SIDE

A fairly high proportion of those injured in accidents are unrestrained. Contact regions that should be incorporated in a supplementary headform test procedure if the protection of unrestrained occupants is considered important are shown in Table 33 below.

Contact Site	**Priority in terms of no. of AIS1+ injuries recorded**							
		TRL		**BASt**		**LAB**		**NHTSA**
A Pillar		1		No Contacts		5		1
B Pillar		=2		1		4		2
Header		=5		No Contacts				
Side Roof Rail		=5		No Contacts		1		3

Side Other		=2		No Contacts		2		
Roof		=2		2				
Window Frame						3		

Table 33 – Key Contact Regions, Unrestrained –Struck and Non-Struck Side Occupants

It should be noted that in the BASt database there are very few cases involving unrestrained occupant head contact with the vehicle structure. Analysis of the three remaining samples shows the priority in terms of the number of AIS 1+ injuries is less specific for unrestrained occupants. However, taken overall one can observe that the A pillar has become a more important contact site if the protection of unrestrained occupants is to be considered. The roof also has grown in importance when including unrestrained occupants. Those contact sites already identified as important, such as the B pillar, side roof rail, 'side other' are also important for unrestrained occupants. Further contacts to the header rail and window frame (LAB only) are recorded.

Thus, taking all results into account, the first priority areas for protection against head impacts in lateral impacts are the B-pillar and the side roof rail. Second priority areas are ‘side other’ and the A-pillar.

4.2.5 EFFECT OF INTRUSION

The effect of intrusion could only be assessed within the TRL data. Three different scenarios exist when discussing intrusion. Firstly where there was no intrusion at the point of head contact, secondly where there was intrusion but it was unsupported and finally where intrusion occurred and it was supported. The effect of intrusion on the severity of injury was assessed to investigate the need for including such a feature in a test procedure.

No intrusion was the most frequent condition. Supported intrusion occurred in a considerably lower number of cases and the intrusion was unsupported in just a few cases.

In section 3.2.5 , Table 14 shows that where no intrusion occurred, around 10% of cases, were of a serious nature. However when intrusion occurred that was supported by the intruding object, the proportion of injuries that were serious rises to 50%. When unsupported intrusion occurred, 30% of injuries were serious. It should also be noted for the B pillar, side roof rail and 'side other' that not only the proportion but, the absolute number of serious injuries is greater for supported intrusion in comparison with unsupported intrusion.

4.3 REAR SEAT OCCUPANTS

The level of occupancy for the rear seat is much less than that for front seat occupants and therefore any discussion is limited. Nevertheless, across the databases the B pillar, C pillar, side roof rail and seat were identified as head contact sites for restrained occupants on the struck side in the rear seating position. In all databases there is a greater number of unrestrained occupants. If protection of unrestrained rear seat occupants is desired the head restraint (front seat) and 'side other' should also be included.

5. CONCLUSIONS

1. Four databases were reviewed in this study. Each of which had a different sampling strategy, therefore it was not possible to combine the samples. In addition the definition of contact sites was not fully consistent.

2. When each database is compared broadly similar results are obtained.

3. All databases agree that the B Pillar is the principal contact area for restrained occupants on the struck side with the side roof rail as the next most important zone. The A pillar and ‘side other’ are second order priority contact sites. Other head contact sites are; window frame (if treated as a separate contact site), roof, upper anchorage point (if treated as a separate contact site) and head restraint.

4. Analysis of restrained non-struck side and unrestrained front seat occupants, supported this conclusion and suggested that A-pillar contacts become more important and that the header rail becomes an additional head contact site that should be considered for a supplementary headform test for front seat occupants in a side impact.

5. The proportion of severe injuries was higher where the intrusion was supported, than where there was no intrusion. In addition the absolute number of severe injuries from head impact to the B Pillar, side roof rail and 'side other' was greater where the intrusion was supported. To reduce the number of severe injuries in side impact, it would be appropriate to adopt a test procedure, which incorporates a feature to replicate supported intrusion.

6. There were many fewer cases of head contact to rear seat occupants due to the occupancy rate for the rear seat. The cases involving restrained struck side occupants showed that the B and C pillars side roof rail and front seat were contact regions for restrained occupants on the struck side. Analysis of restrained non-struck side and unrestrained occupants showed that it was also possible for the head to contact the head restraint, 'side other' and window frame.

7. It was not possible to draw conclusions on the influence of intrusion for rear seat occupants due to the low number of cases involving intrusion. However, it should be noted that both cases that involved intrusion caused AIS 1-2 type injuries.

6. ACKNOWLEDGEMENTS

This Report was prepared for Working Group 13 by L K Wheeler and C Visvikis from accident data provided by BASt, TRL, LAB and NHTSA

EUROPEAN ENHANCED VEHICLE-SAFETY COMMITTEE

EEVC Working Group 13 Report

Head Contacts In Frontal Impacts

Accident Data Analyse

February 2003

Table of contents

1 Introduction

The Side-Impact Working Group (WG13) of the European Enhanced Vehicle-safety Committee is developing a procedure for head impact testing in vehicle interior.

The ECE-Directive 95 respectively EG-Directive 96/27/EG contains consistent safety conditions for occupants in side impacts. In this impact test procedure (developed by the European Enhanced Vehicle-safety Committee (EEVC)), the passive safety of cars is tested within the scope of European type approval. Test criteria are measured in side impacts on the EuroSID-Dummy sitting in a front seat.

Based on the precisely defined seating position of the dummy the assessment of the passive safety is limited to a few potential injury points in the car interior. In addition to that, the dummy kinematics in an accident are not perfectly humanlike particularly in the head area. While a human's head undergoes strong excursions in a real accident and consequently often hits the car's interior, the dummy's head motions during impact tests are very confined. In order to represent the impact sites of real accidents in a test procedure it is necessary to evaluate the car's interior structure in an additional interior headform test.

Such an additional interior headform test procedure is currently developed by the EEVC working group (WG 13). It is to be introduced supplementary to side impact tests for type approval testing. The development for this test procedure was carried out in a four phase research program that started in 1995.

The first phase covered the choice of a head test device. It was finalised in November 1996.

In the second phase of the research program different candidates for a test procedure were analysed and the free flight procedure was selected. This phase started in December 1996 and ended 1999.

In the currently running third phase test procedures are being developed. Here first impact tests in the car interior are carried out to identify worst-case impact points. The choice of impact points is based on an analysis of accident data from France, England and Germany depicting fequency and injury severity of head impacts in car interiors in side impacts. Additionally in phase three influence of the orientation of head test device, impact direction and angle as well as speed on the impact severity of the impactor are analysed.

Phase four will contain the validation of the test procedure.

The following report presents an additional survey to the already available analysis of head impact points in side impacts. Here accident data from frontal impacts are evaluated. Again frequency and injury severity of head impacts in the car interior are analysed. With this additional report the impact sites resulting from head excursions of belted occupants in lateral, oblique and frontal accidents are identified.

This analysis is based on English and German data from Co-operative Crash Injury Study (CCIS) and the Medical University of Hanover (MUH). In the following chapters the procedure and the results are presented.

2 Objectives

The aim of this study is to identify head contacts in the car interior in frontal accidents. The analysis discriminates between injury frequency and injury severity of head contacts. The following samples are analysed.

Sample 1: Head contacts of unbelted drivers without airbag deployment
Sample 2: Head contacts of unbelted front seat passengers without airbag deployment
Sample 3: Head contacts of belted drivers without airbag deployment
Sample 4: Head contacts of belted front seat passengers without airbag deployment
Sample 5: Head contacts of unbelted drivers with airbag deployment
Sample 6: Head contacts of unbelted front seat passengers with airbag deployment
Sample 7: Head contacts of belted drivers with airbag deployment
Sample 8: Head contacts of belted front seat passengers with airbag deployment

3 Accident Variables for Analysis

All data samples of this analysis meet the following accident variables:

- Impact angle: Between 11 o’clock and 1 o’clock (frontal accidents)
- Accident type: Car to car and car to obstacle, no underrun
- Vehicle age: Manufactured after 1985
- Seating position: Only front seat occupants (driver and passenger)

4 Accident Data Analysis

This chapter contains the analyse of two databases, CCIS and MUH distinguishing between the samples described in chapter 3. The graphs show the percentages of head contacts for the different areas of the car interior for each sample. By this choice of presentation a comparison of the results of both databases CCIS and MUH is possible. Additionally the absolute values of the respective samples are given in each diagramm and the appendix.

All accident data taken for this analysis can be found in the appendix.
In order to make the data from from CCIS and MUH databases comparable the head impact points are summarised in the following 11 areas.

1. Others / Unknown / Frontal Interior / Bonnet:
   Not further specified or unknown head contact points or head contacts outside of the vehicle.
2. Windscreen:
   Head contact against windscreen.
3. Steering Wheel:
   Head contact against steering wheel.
4. 4 Side (Glas / Door / Side Roof Rail):
   Head contact against side structure or side glas of vehicle interior except A-pillar and B-pillar.
5. Dashboard / Facia:
   Head contact against frontal interior like dashboard, facia top or facia.
6. A-Pillar:
   Head contact against A-Pillar.
7. B-Pillar:
   Head contact against B-Pillar including upper seatbelt anchorage.
8. Header:
   Head contact against header or upper roof rail of windscreen.
9. (Sun-) Roof:
   Head contact against the roof or sunroof except roof rails.
10. Seats:
    Head contact against seat.
11. Airbag:
    Head contact against airbag (only for samples with airbag deployment).

4.1 Sample 1: Head contacts of unbelted drivers without airbag deployment

Database	CCIS		MUH	
	N	%	n	%
Head contact AIS 1-2	101	92	126	89
Head contact AIS 3+	9	8	15	11
Total	110	100	141	100

Table 1: Number of cases and percentage distribution of injury severities for both databases sample 1

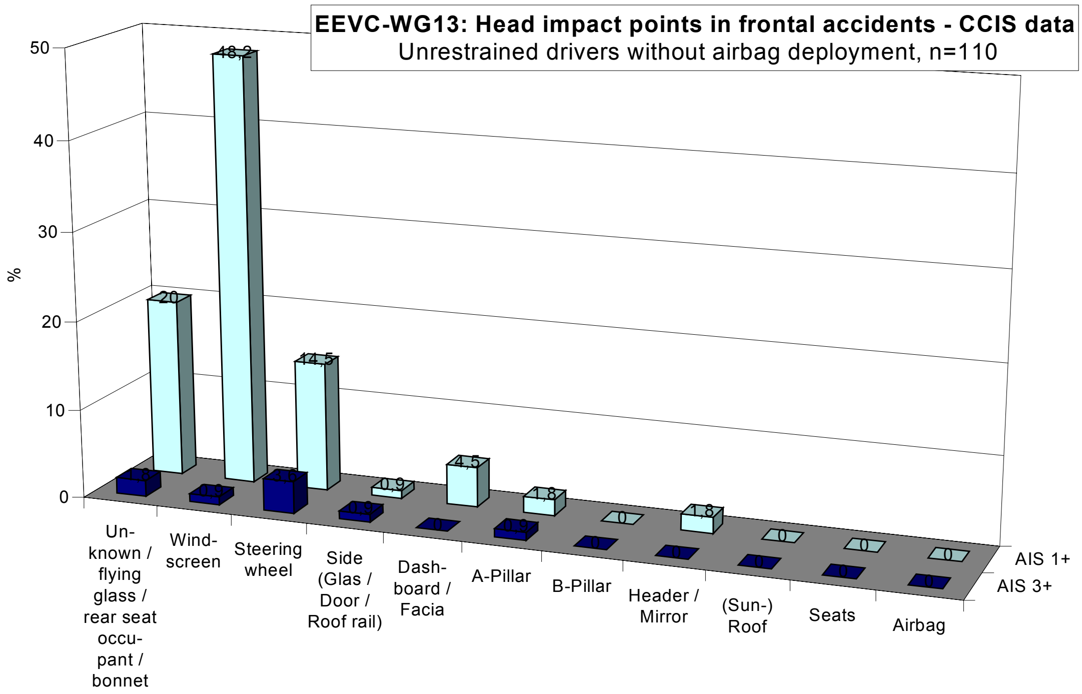

Figure 1: Percentage distribution of head contact areas in frontal accidents for unrestrained drivers without airbag deployment - CCIS database

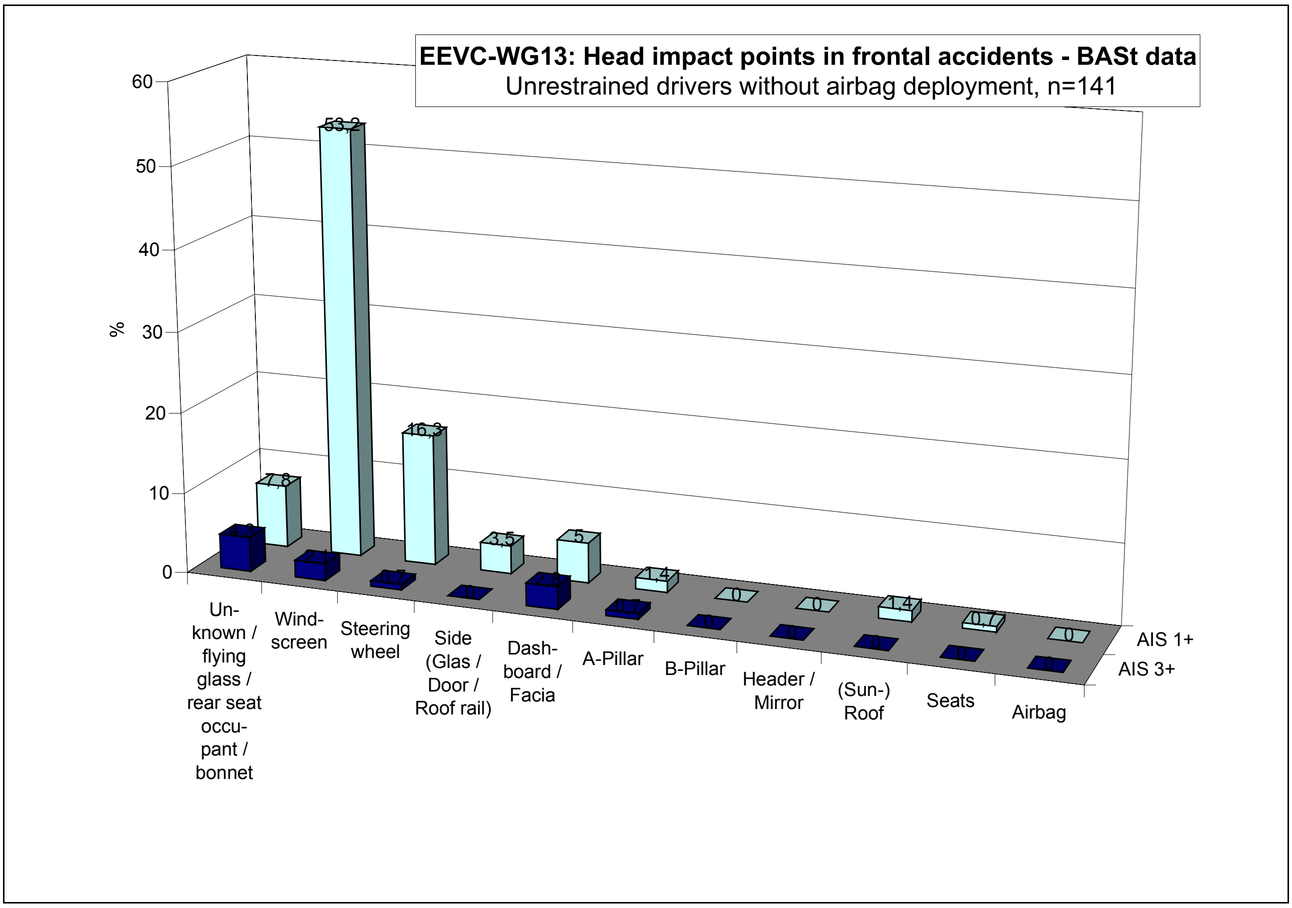

Figure 2: Percentage distribution of head contact areas in frontal accidents for unrestrained drivers without airbag deployment - BASt database

It is obvious, that nearly 50 % of contacts are to the windscreen at AIS 1+ injury severity. This is not surprising because only unbelted drivers are considered.

4.2 Sample 2: Head contacts of unbelted front seat passengers without airbag deployment

Database	CCIS		MUH	
	N	%	n	%
Head contact AIS 1-2	36	97	49	92
Head contact AIS 3+	1	3	4	8
Total	37	100	53	100

Table 2: Number of cases and percentage distribution of injury severities for both databases for sample 2

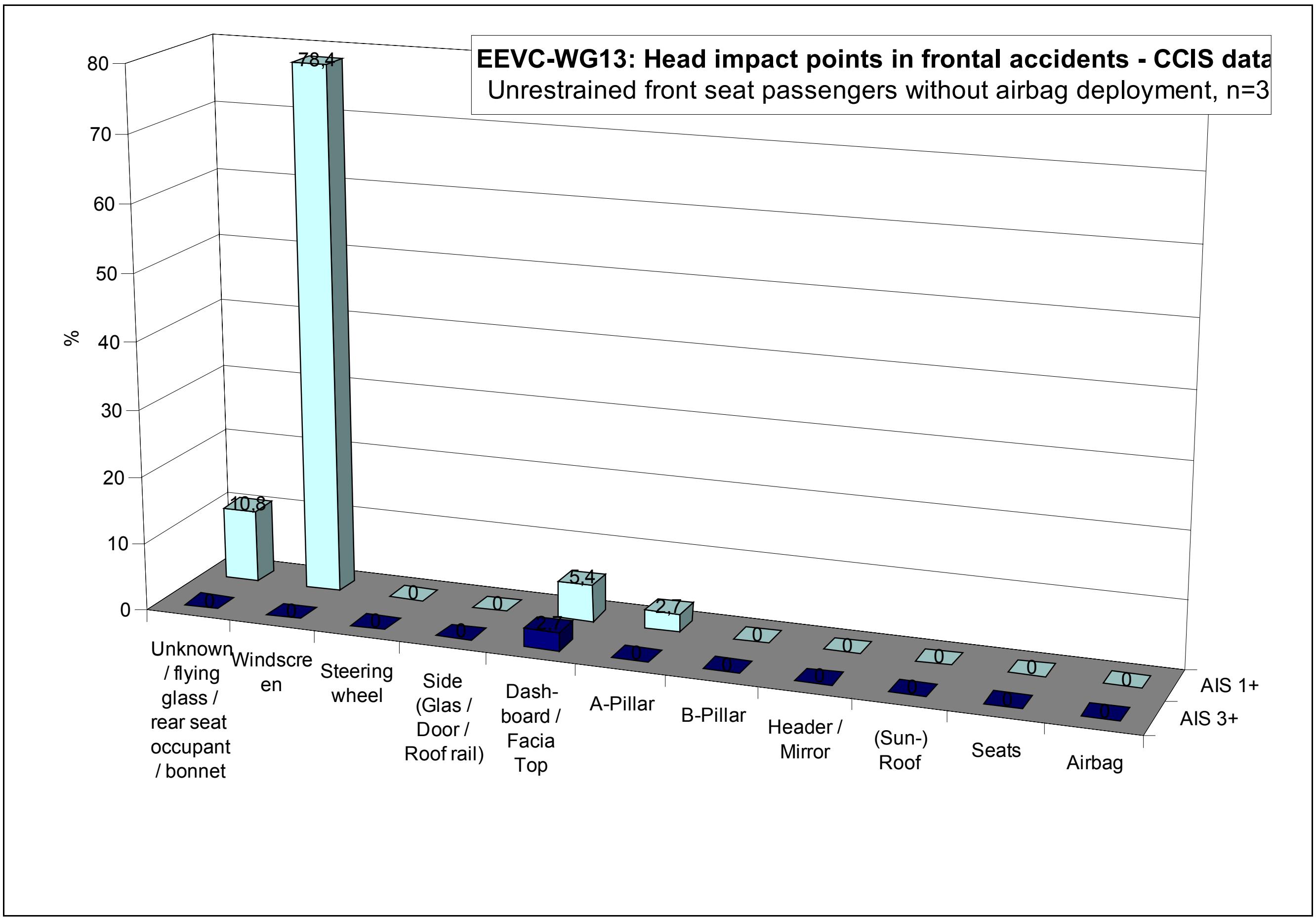

Figure 3: Percentage distribution of head contact areas in frontal accidents for unrestrained front seat passengers without airbag deployment - CCIS database

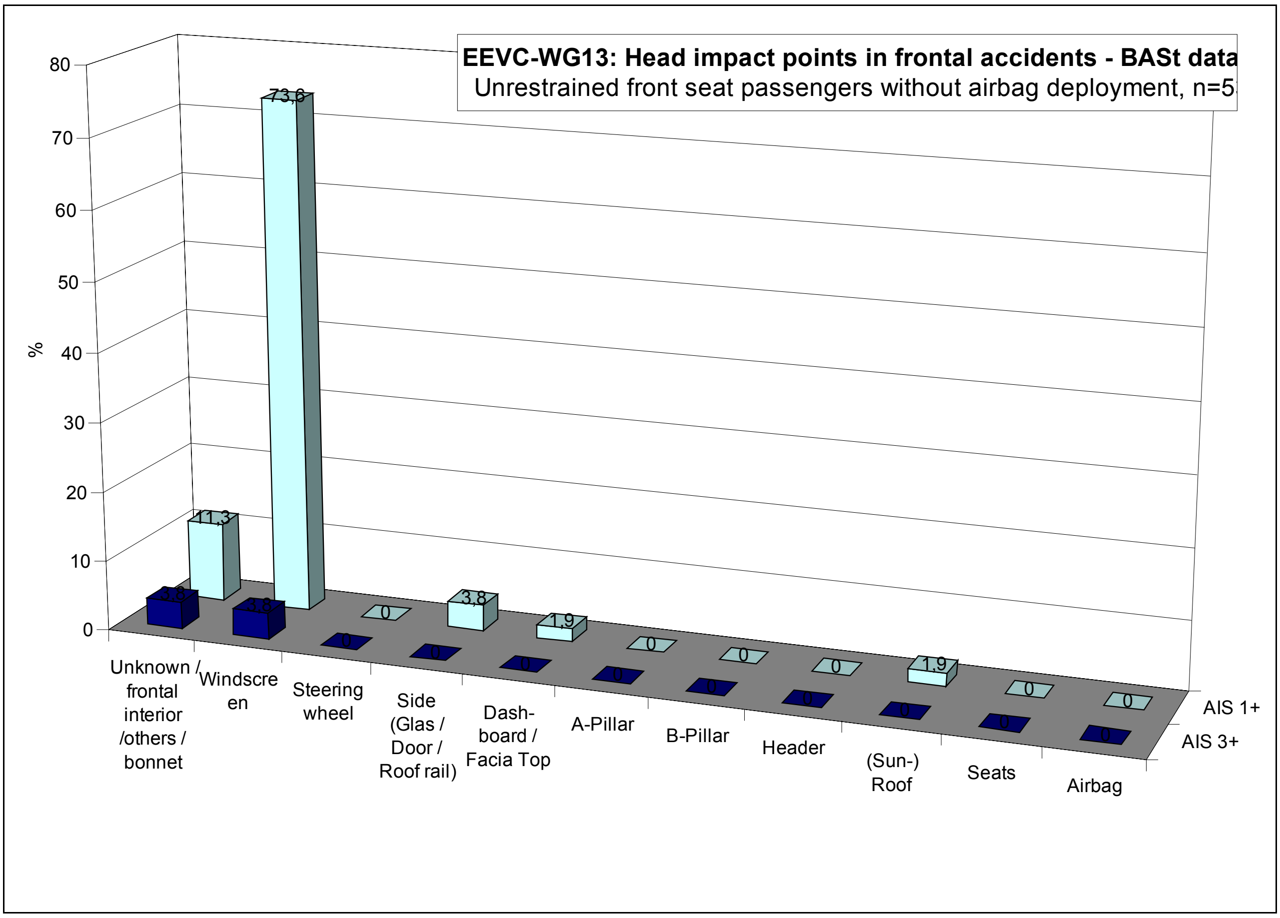

Figure 4: Percentage distribution of head contact areas in frontal accidents for unrestrained front seat passengers without airbag deployment - BASt database

In this sample (unbelted passenger) there is no steering wheel on the passenger side. Therefore the number of windscreen contacts is increased by nearly the percentage of the steering wheel contacts in the previous sample (unbelted driver).

4.3 Sample 3: Head contacts of belted drivers without airbag deployment

Database	CCIS		MUH	
	n	%	n	%
Head contact AIS 1-2	366	91	518	89
Head contact AIS 3+	36	9	65	11
Total	402	100	583	100

Table 3: Number of cases and percentage distribution of injury severity for both databases for sample 3

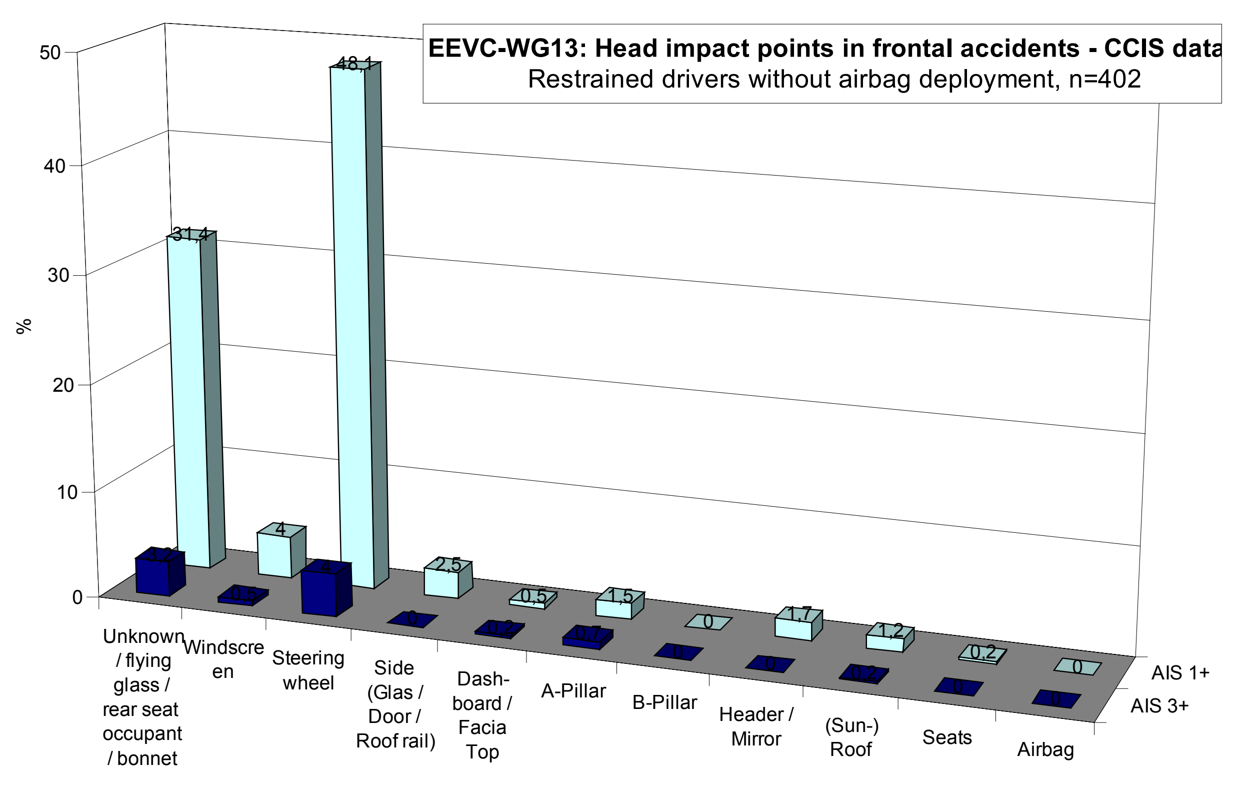

Figure 5: Percentage distribution of head contact areas in frontal accidents for belted drivers without airbag deployment - CCIS database

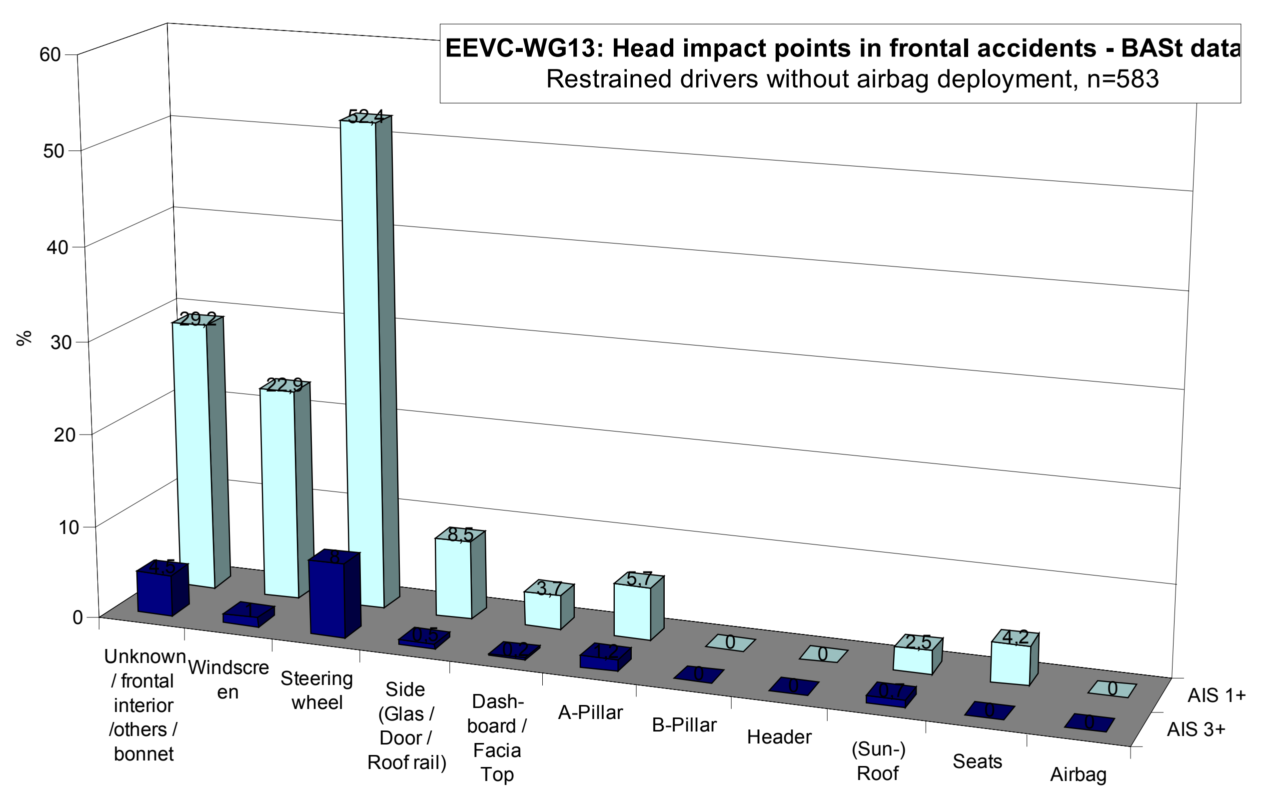

Figure 6: Percentage distribution of head contact areas in frontal accidents for belted drivers without airbag deployment - BASt database

Here the driver is belted. In an accident the belt restrains the chest of the occupant. The head can still move, but the movement is limited. Therefore the number of windscreen contacts is decreasing and the number of steering wheel contacts is increasing. It is remarkable that the number of windscreen contacts differs between the BASt and the CCIS data.

4.4 Sample 4: Head contacts of belted front seat passengers without airbag deployment

Database	CCIS		MUH	
	n	%	n	%
Head contact AIS 1-2	91	91	135	92
Head contact AIS 3+	9	9	12	8
Total	100	100	147	100

Table 4: Number of cases and percentage distribution of injury severity for both databases for sample 4

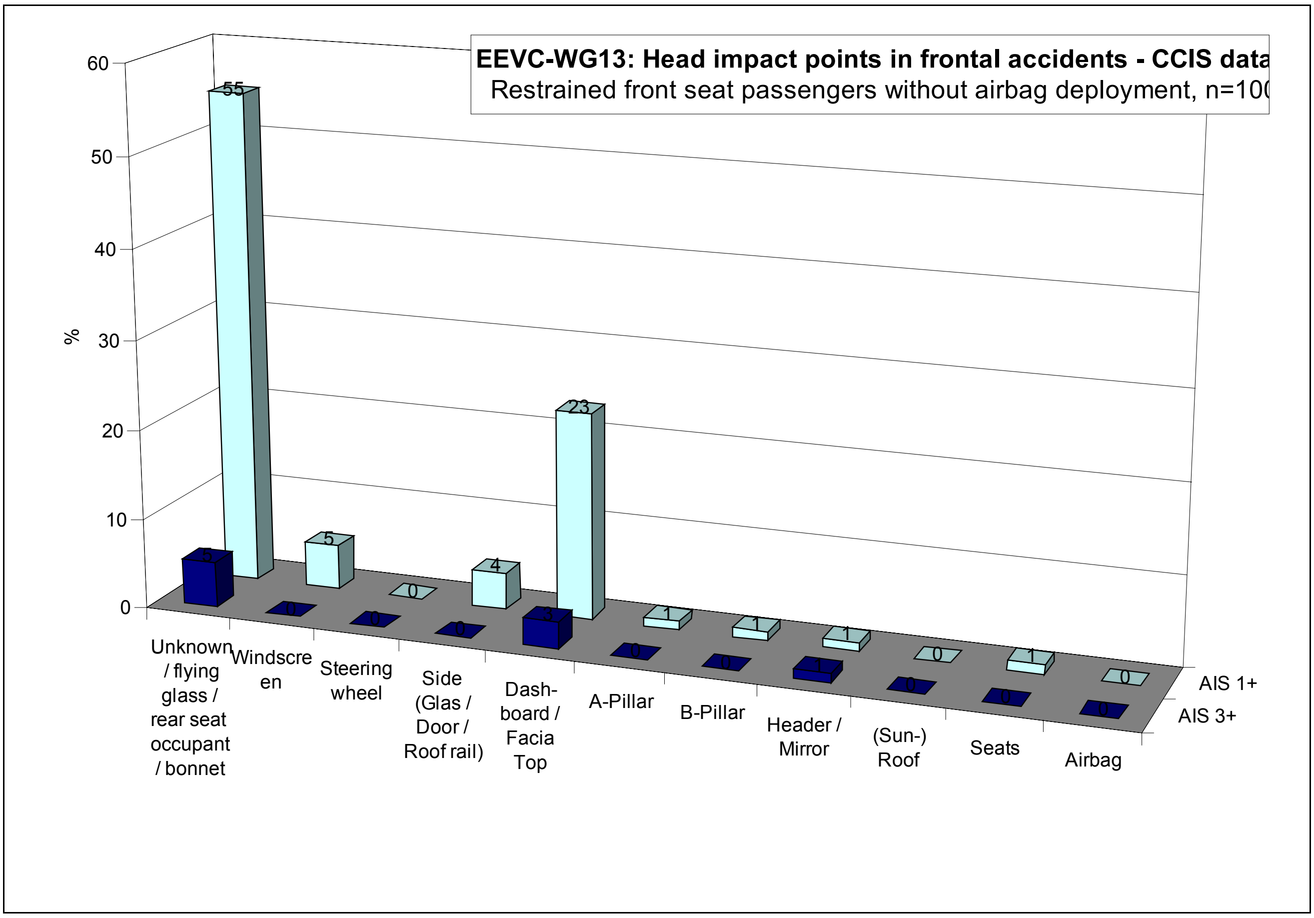

Figure 7: Percentage distribution of head contact areas in frontal accidents for restrained front seat passengers without airbag deployment - CCIS database

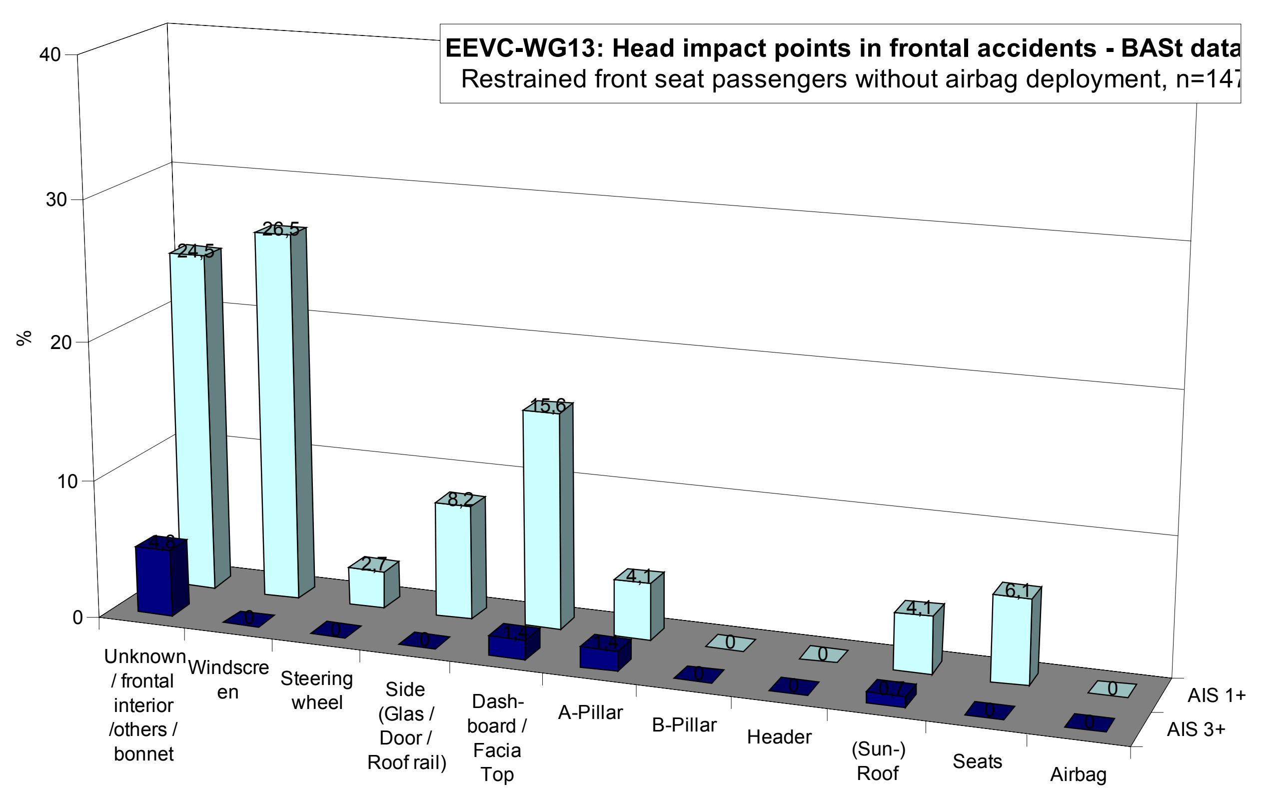

Figure 8: Percentage distribution of head contact areas in frontal accidents for restrained front seat passengers without airbag deployment - BASt database

As in sample 3 the occupant is belted, but he is sitting on the passenger side and there is no steering wheel in front of him. Therefore the steering wheel contacts occur very seldom compared to sample 3. In this sample there are some differences in the data from CCIS and BASt.

4.5 Sample 5: Head contacts of unbelted drivers with airbag deployment

Database	CCIS		MUH	
	n	%	n	%
Head contact AIS 1-2	8	89	2	100
Head contact AIS 3+	1	11	0	0
Total	9	100	2	100

Table 5: Number of cases and percentage distribution of injury severity for both databases for sample 5

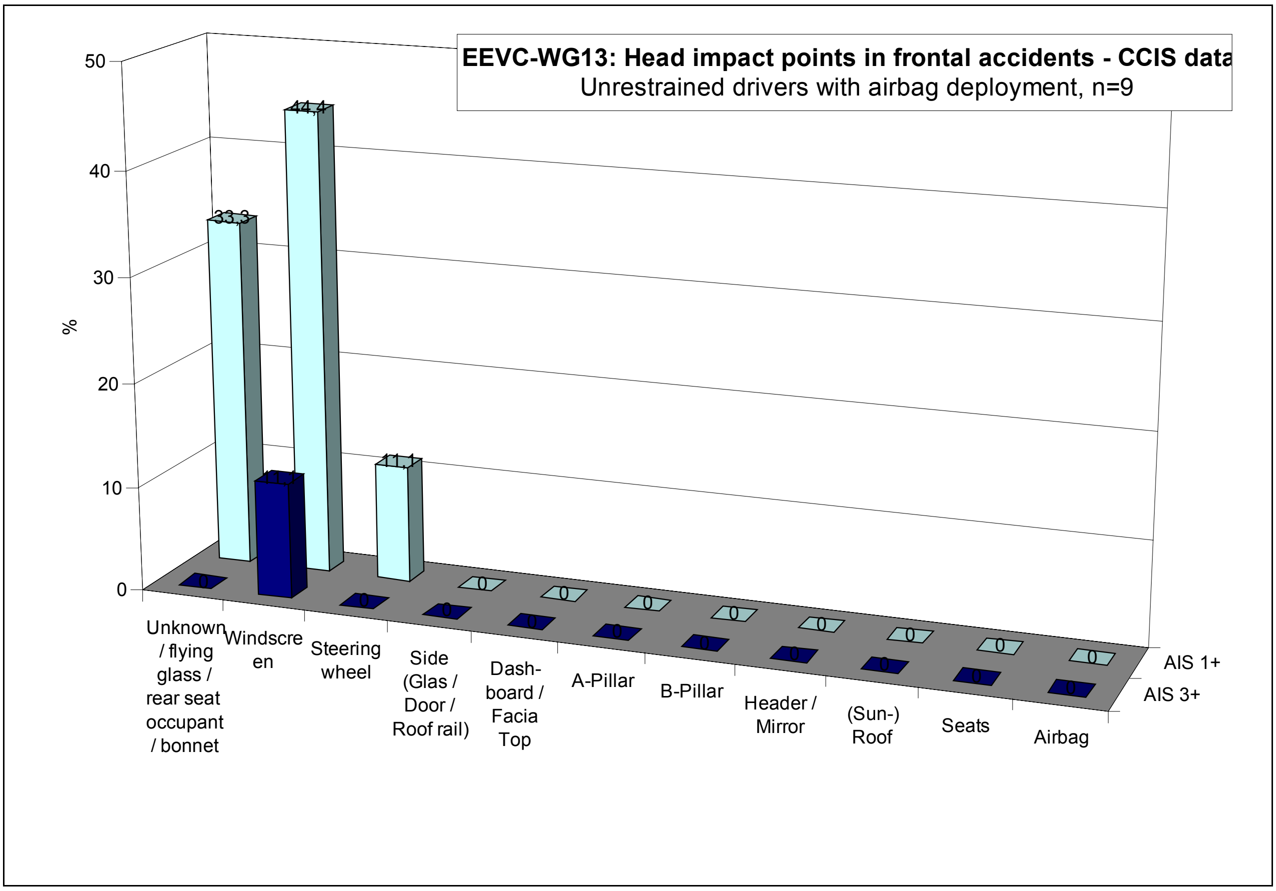

Figure 9: Percentage distribution of head contact areas in frontal accidents for unrestrained drivers with airbag deployment - CCIS database

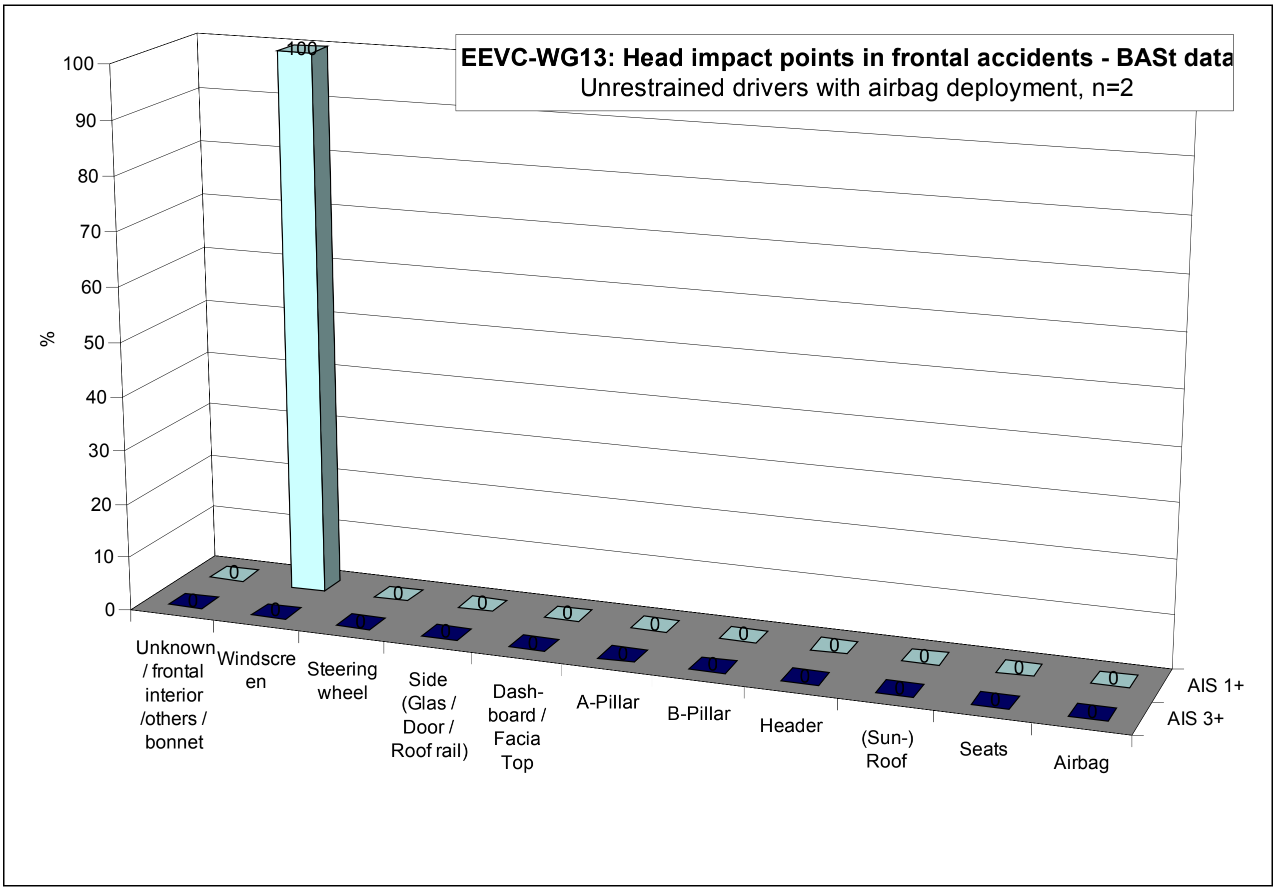

Figure 10: Percentage distribution of head contact areas in frontal accidents for unrestrained drivers with airbag deployment - BASt database

The analysis of this sample is difficult because the number of accidents available for this study is very low. It could be concluded that most contacts occur at the windscreen.

4.6 Sample 6: Head contacts of unbelted front seat passengers with airbag deployment

There is only one accident for unbelted front seat passengers with airbag deployment in both databases. Due to this small number there is no graphical analysis.

Database	CCIS		MUH	
	n	%	n	%
Head contact AIS 1-2	0	-	1	100
Head contact AIS 3+	0	-	0	0
Total	0	-	0	100

Table 6: Number of cases and percentage distribution of injury severity for both databases for sample 6

In this single available case the head gets in contact with the windscreen.

4.7 Sample 7: Head contacts of belted drivers with airbag deployment

Database	CCIS		MUH	
	n	%	n	%
Head contact AIS 1-2	53	90	23	88
Head contact AIS 3+	6	10	3	12
Total	59	100	26	100

Table 7: Number of cases and percentage distribution of injury severity for both databases for sample 7

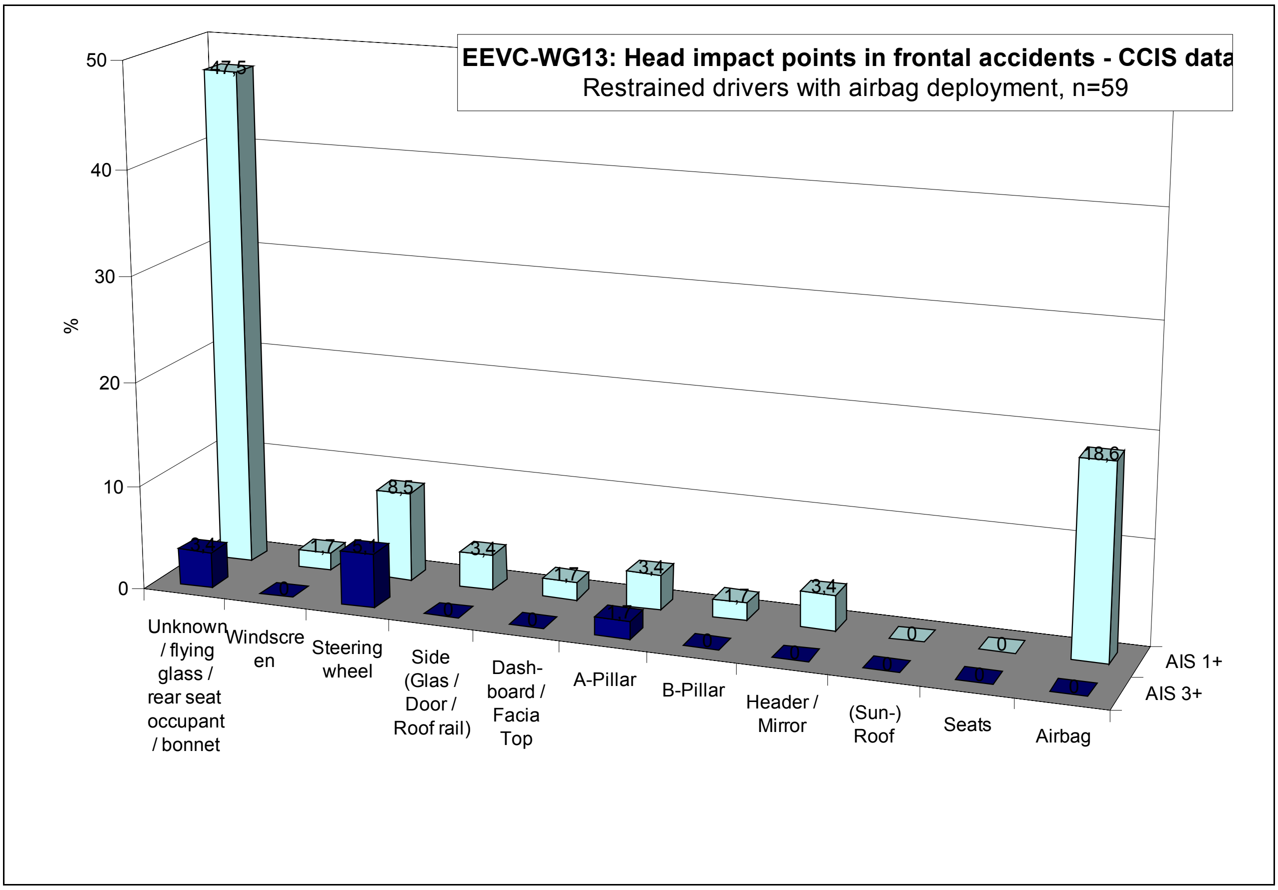

Figure 11: Percentage distribution of head contact areas in frontal accidents for restrained drivers with airbag deployment - CCIS database

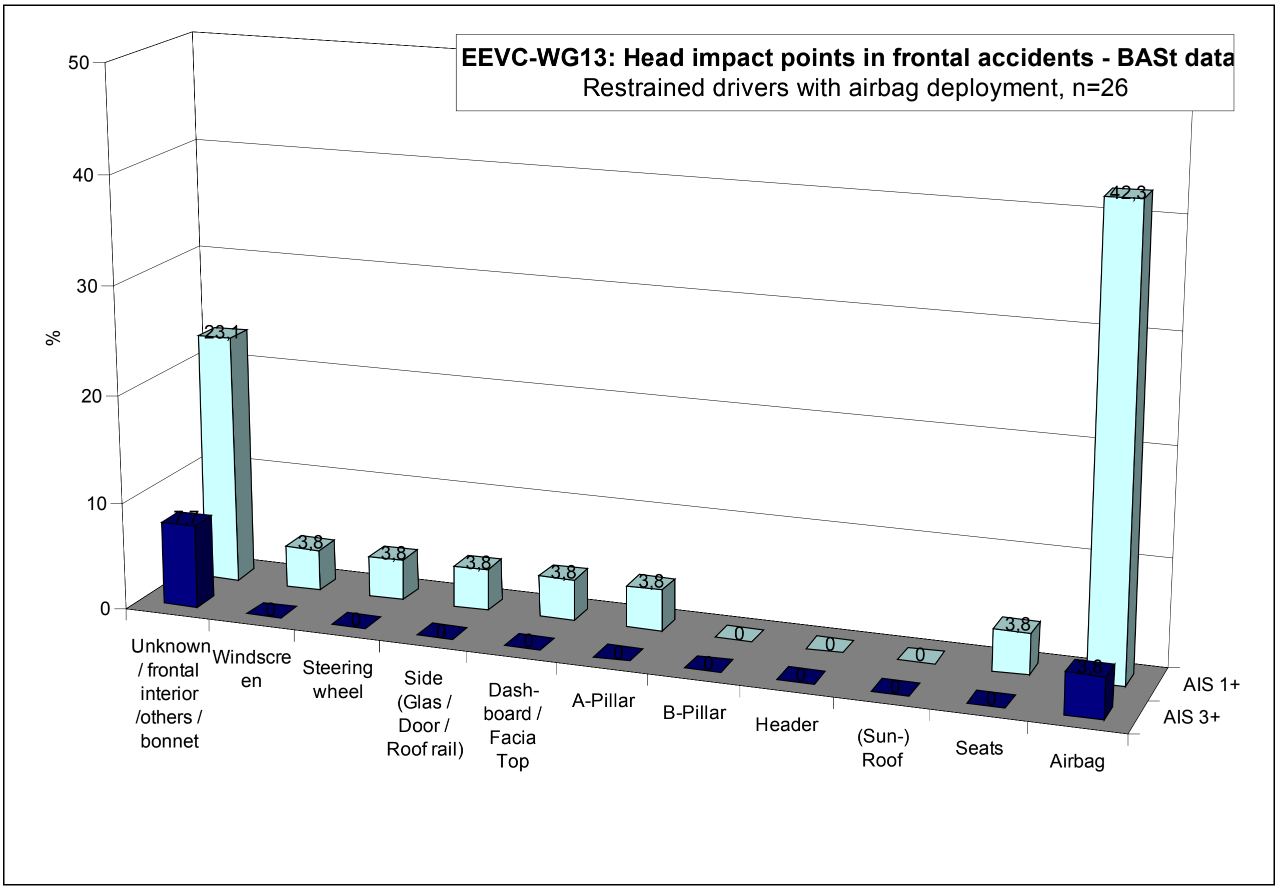

Figure 12: Percentage distribution of head contact areas in frontal accidents for restrained drivers with airbag deployment - BASt database

Contacts with the windscreen and steering wheel are reduced to a minimum. Contacts with the airbag (and not specified or unknown) are dominating.

4.8 Sample 8: Head contacts of belted front seat passengers with airbag deployment

Database	CCIS		MUH	
	n	%	n	%
Head contact AIS 1-2	4	80	4	80
Head contact AIS 3+	1	20	1	20
Total	5	100	5	100

Table 8: Number of cases and percentage distribution and injury severity for both databases for sample 8

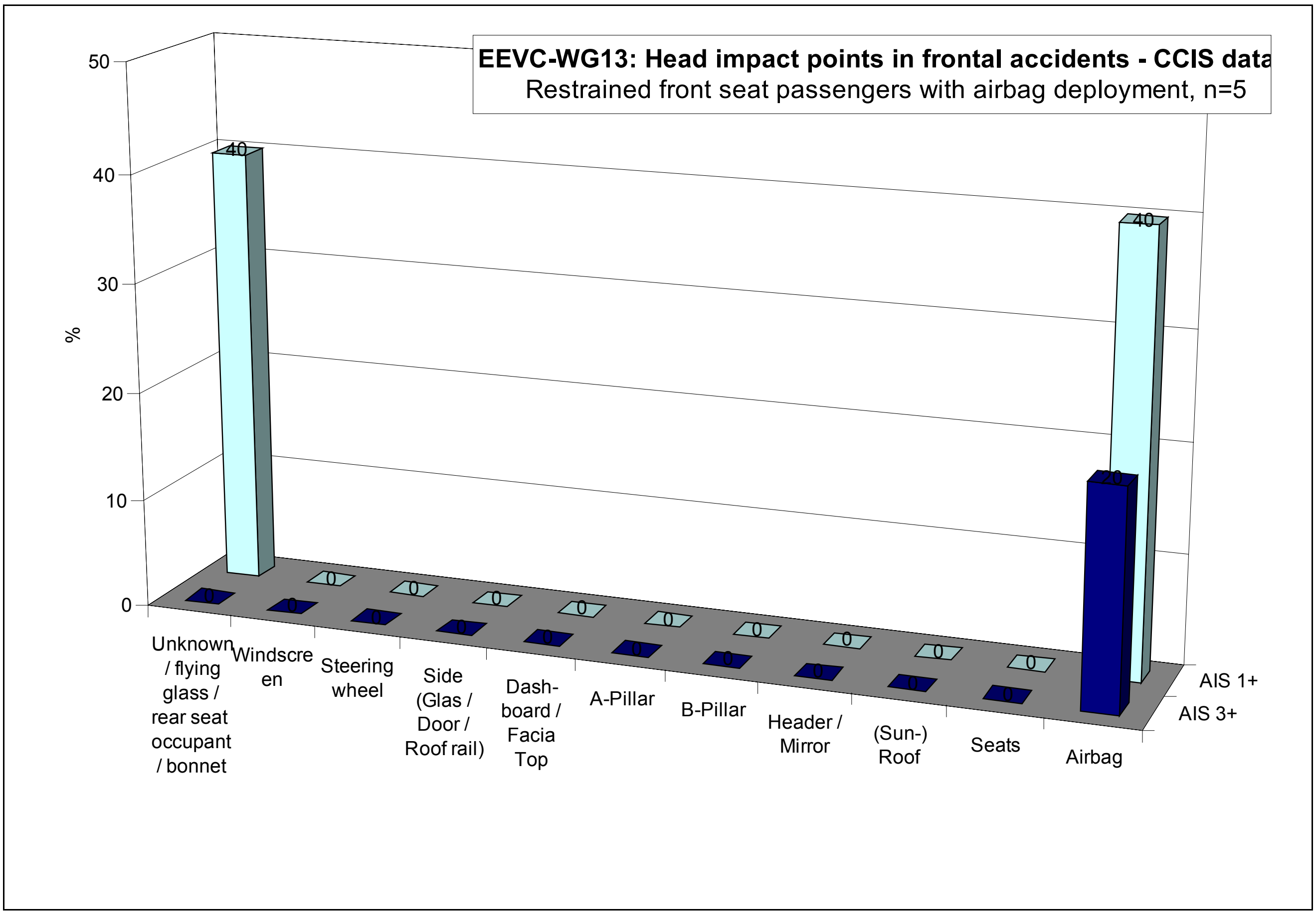

Figure 13: Percentage distribution of head contact areas in frontal accidents for restrained front seat passengers with airbag deployment - CCIS database

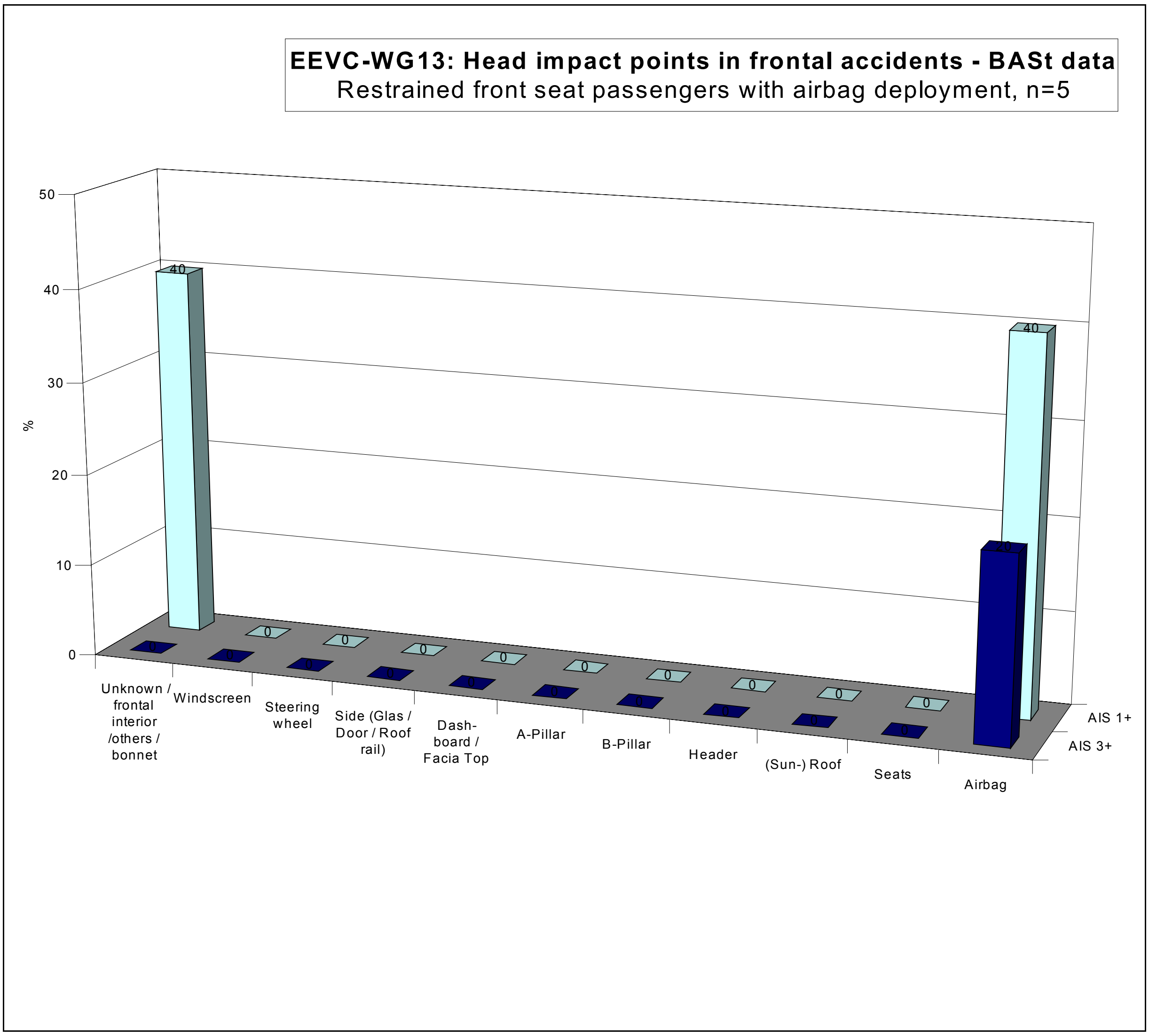

Figure 14: Percentage distribution of head contact areas in frontal accidents for restrained front seat passengers with airbag deployment - BASt database

Although the number of data is very limited the result is nearly similar to the data of sample 7. The airbag is the most frequent impact point in the car.

5 Summary

In the following the results of the accident analysis of both databases are summarised and the main contact zones in the car interior are presented according to their frequency of head contacts.

The head contact areas have different impact frequencies. In the following tables the frequencies are shown by a ranking. 1 is the most frequently hidden point, followed by 2 and so on.

5.1 Unbelted Occupants

Head Contact Area	**Unrestrained Driver without Airbag**		**Unrestrained Driver with Airbag**		**Unrestrained Passenger without Airbag**		**Unrestrained Passenger with Airbag**	
	CCIS	**BASt**	**CCIS**	**BASt**	**CCIS**	**BASt**	**CCIS**	**BASt**
Windscreen	1	1	1	1	1	1		1
Steering Wheel	2	2	2					
Side (Glas / Door / Roof Rail)		4				2		
Dashboard / Facia	3	3			2	=3		
A-Pillar	=4	=5			3			
B-Pillar								
Header / Mirror	=4							
(Sun-) Roof		=5				=3		
Seats								
Airbag								

Table 9: Ranking of head contact areas for AIS 1+ head injuries

Head Contact Area	**Unrestrained Driver without Airbag**		**Unrestrained Driver with Airbag**		**Unrestrained Passenger without Airbag**		**Unrestrained Passenger with Airbag**	
	CCIS	**BASt**	**CCIS**	**BASt**	**CCIS**	**BASt**	**CCIS**	**BASt**
Windscreen	=2	2	1			1		
Steering Wheel	1	=3						
Side (Glas / Door / Roof Rail)	=2							
Dashboard / Facia		1			1			
A-Pillar	=2	=3						
B-Pillar								
Header / Mirror								
(Sun-) Roof								
Seats								
Airbag								

Table 10: Ranking of head contact areas for AIS 3+ head injuries

5.2 Belted Occupants

Head Contact Area	Restrained Driver without Airbag		Restrained Driver with Airbag		Restrained Passenger without Airbag		Restrained Passenger with Airbag	
	CCIS	**BASt**	**CCIS**	**BASt**	**CCIS**	**BASt**	**CCIS**	**BASt**
Windscreen	2	2			2	1		
Steering Wheel	1	1	2			6		
Side (Glas / Door / Roof Rail)	3	3	=3		3	3		
Dashboard / Facia		6			1	2		
A-Pillar	4	4	=3			=5		
B-Pillar								
Header / Mirror	5		=3					
(Sun-) Roof	6					=5		
Seats		5				4		
Airbag			1	1			1	1

Table 11: Ranking of head contact areas for AIS 1+ head injuries

Head Contact Area	Restrained Driver without Airbag		Restrained Driver with Airbag		Restrained Passenger without Airbag		Restrained Passenger with Airbag	
	CCIS	BASt	CCIS	BASt	CCIS	BASt	CCIS	BASt
Windscreen	3	3						
Steering Wheel	1	1	1					
Side (Glas / Door / Roof Rail)		5						
Dashboard / Facia					1	=1		
A-Pillar	2	2				=1		
B-Pillar								
Header / Mirror					2			
(Sun-) Roof		4				2		
Seats								
Airbag				1			1	1

Table 12: Ranking of head contact areas for AIS 3+ head injuries

The results in figure 1 and 2, figure 3 and 4 and 13 and 14 are very similar in both accident studies. But some differences are in comparison of figure 5 and 6, 7 and 8, figure 9 and 10 as well in figure 11 and 12.

6 Conclusion

Almost all new cars are equipped with frontal airbags. These airbags are designed to protect restrained drivers and restrained passengers in accidents.

Most structures which would have been tested in an “interior headform test” for frontal crashes are covered by the airbag in a crash. The exception to this may be the lower part of the A-pillar and this may not be included in the proposed side impact headform test procedure. The need to test this lower part of the A-pillar has not been demonstrated so far from this accident analysis.

Additionally to the most common airbag contacts, some impacts were located as “Unknown, flying parts and rear seats”. Presumably “Unknown” locations are most likely airbag contacts, too. “Flying parts” and “rear seats” cannot be tested in an “interior headform test”.
Only a few contacts with other frontal interior parts were mentioned in the CCIS and BASt data, but for example part of the A-pillar and the B-pillar are already included in the “interior headform test” for side impacts.

It is quite difficult to concentrate on low speed crashes, in which the airbag may not deploy,, because this accident analyses only takes accidents with injured frontal occupant into account. Within this analyse it is impossible to assume the percentage of head injuries caused by interior contacts. But looking at the MUH / BASt data from the year 1990 on with 1073 analysed occupant injuries only two head injuries with AIS2+ can be detected, if the EES (Energy Equivalent Speed) is lower than 20 km/h and no frontal airbag deployed.

Restrained occupant with airbag deployment:
An additional “interior headform test” for frontal crashes does not seem to be necessary if concentrating on restrained drivers and restrained passengers. However it may be advisable to explore further the AIS3+ cases with unknown contacts.

Restrained occupant without airbag fitted:
Current regulations are providing adequate protection for driver and front seat passenger.

Unrestrained occupant:
The principal injurious contacts for unrestrained occupants are to the windscreen. No additional tests are proposed for this condition.

7 Acknowledgements

This report was prepared for Working Group 13 by St. Knack and T. Langner from accident data provided by MUH and CCIS.

9.5. AE-MDB Test Procedure (IHRA SIWG proposal)

AE-MDB COLLISION TEST PROCEDURE

1. INSTALLATIONS

1.1. Testing ground

The test area shall be large enough to accommodate the mobile deformable barrier propulsion system and to permit after-impact displacement of the vehicle impacted and installation of the test equipment. The part in which vehicle impact and displacement occur shall be horizontal, flat and uncontaminated, and representative of a normal, dry, uncontaminated road surface.

2. TEST CONDITIONS

2.1. The vehicle to be tested shall be stationary.

2.2. The mobile deformable barrier shall have the characteristics set out in Section 8. The mobile deformable barrier shall be equipped with a suitable device to prevent a second impact on the struck vehicle.

2.3. The trajectory of the mobile deformable barrier longitudinal median vertical plane shall be perpendicular to the longitudinal median vertical plane of the impacted vehicle.

2.4. The longitudinal vertical median plane of the mobile deformable barrier shall be coincident within ∀ 25 mm with a transverse vertical plane parallel to and 250mm. behind the transverse vertical plane passing through the R point of the front seat adjacent to the struck side of the tested vehicle. The horizontal plane passing through the intersection between the upper row (A-C) and the lower row (D-F) of the MDB face (Figure 1), limited by the external lateral vertical planes of the front face shall be, at the moment of impact, within two planes determined before the test and situated 25 mm above and below the horizontal plane 550mm above ground level.

2.5. Instrumentation shall comply with ISO 6487:1987 unless otherwise specified in this Regulation.

2.6. The stabilised temperature of the test dummy at the time of the side impact test shall be [22 ∀ 4]EC.

3. TEST SPEED

The mobile deformable barrier speed at the moment of impact shall be 50 ∀ 1 km/h. This speed shall be stabilised at least 0.5 m before impact. Accuracy of measurement: 1 per cent. [However, if the test was performed at a higher impact speed and the vehicle met the requirements, the test shall be considered satisfactory.]

4. STATE OF THE VEHICLE

4.1. General specification

The test vehicle shall be representative of the series production, shall include all the equipment normally fitted and shall be in normal running order. Some components may be omitted or replaced by equivalent masses where this omission or substitution clearly has no effect on the results of the test.

4.2. Vehicle equipment specification

The test vehicle shall have all the optional arrangements or fittings likely to influence the results of the test.

4.3. Mass of the vehicle

4.3.1. The vehicle to be tested shall have the reference mass which is the unladen mass of the vehicle increased by a mass representing the mass of the two side impact dummies and [25]kg instrumentation. The mass of the vehicle shall be adjusted to ∀ 1 per cent of the reference mass.

4.3.2. The fuel tank shall be filled with water to a mass equal to 90 per cent of the mass of a full load of fuel as specified by the manufacturer.

4.3.3. All the other systems (brake, cooling, etc.) may be empty; in this case, the mass of the liquids shall be offset.

4.3.4. If the mass of the measuring and data recording apparatus on board of the vehicle exceeds the 25 kg allowed, it may be offset by reductions which have no noticeable effect on the results of the test.

4.3.5. The mass of the measuring and data recording apparatus shall not change each axle reference load by more than 5 per cent, each variation not exceeding 20 kg.

5. PREPARATION OF THE VEHICLE

5.1. The side windows, at least on the struck side, shall be closed.

5.2. The doors shall be closed, but not locked.

5.3. The transmission shall be placed in neutral and the parking brake disengaged.

5.4. The comfort adjustments of the seats, if any, shall be adjusted to the position specified by the vehicle manufacturer.

5.5. The front seat containing the dummy, and its elements, if adjustable, shall be adjusted as follows:

5.5.1. The longitudinal adjustment device shall be placed with the locking device engaged in the position that is nearest to midway between the foremost and rearmost positions; if this position is between two notches, the rearmost notch shall be used.[*]

5.5.2. The head restraint shall be adjusted such that its top surface is level with the centre of gravity of the dummy's head; if this is not possible, the head restraint shall be in the lowest position.

5.5.3. Unless otherwise specified by the manufacturer, the seat-back shall be set such that the torso reference line of the three-dimensional H point machine is set at an angle of 25 ∀ 1E towards the rear.

5.5.4. *All other seat adjustments shall be at the mid-point of available travel; however, height adjustment shall be at the position corresponding to the fixed seat, if the vehicle type is available with adjustable and fixed seats. If locking positions are not available at the respective mid-points of travel, the positions immediately rearward, down, or outboard of the mid-points shall be used. For rotational adjustments (tilt), rearward will be the adjustment direction which moves the head of the dummy rearwards. If the dummy protrudes outside the normal passenger volume, e.g. head into roof lining, then 1 cm clearance will be provided using: secondary adjustments, seat-back angle, or fore-aft adjustment in that order.*
[Needs to be considered and, possibly, aligned with other MDB test procedure)

5.6. Unless otherwise specified by the manufacturer, the other front seats shall, if possible, be adjusted to the same position as the seat containing the dummy.

5.7. If the steering wheel is adjustable, all adjustments are positioned to their foremost travel locations.

5.8. Tyres shall be inflated to the pressure specified by the vehicle manufacturer.

5.9. The test vehicle shall be set horizontal about its roll axis and maintained by supports in that position until the side impact dummy is in place and after all preparatory work is complete.

5.10. The vehicle shall be at its normal attitude corresponding to the conditions set out in paragraph 4.3. above. Vehicles with suspension enabling their ground clearance to be adjusted shall be tested under the normal conditions of use at 50 km/h as defined by the vehicle manufacturer. This shall be assured by means of additional supports, if necessary, but such supports shall have no influence on the crash behaviour of the test vehicle during the impact.

6. SIDE IMPACT DUMMIES AND THEIR INSTALLATION

6.1. The side impact dummies shall comply with the specifications given in [XXX] and be installed in the front and rear seats on the impact side according to the procedure given in Section [Y].

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[*] It is proposed that the seating position be defined for the 5th percentile female in exactly the same way as the definition used for the other MDB test procedure

6.2. The safety-belts or other restraint systems, which are specified for the vehicle, shall be used. [Belts should be of an approved type, conforming to Regulation No. 16 or to other equivalent requirements and mounted on anchorages conforming to Regulation No. 14 or to other equivalent requirements.]

6.3. The safety-belt or restraint system shall be adjusted to fit the dummies in accordance with the manufacturer's instructions; if there are no manufacturer's instructions, any height adjustment shall be set at lowest position.

7. MEASUREMENTS TO BE MADE ON THE SIDE IMPACT DUMMIES

7.1. The following readings of the measuring devices and performance criteria are to be recorded or calculated if using a EuroSID dummy. *Alternative readings will be specified when a different dummy (e.g. SID-IIs) is used. The required results of the tests will be specified after consultation with the IHRA Biomechanics Working Group.*

7.1.1. Measurements in the head of the dummy

The resultant triaxial acceleration referring to the head centre of gravity. The head channel instrumentation shall comply with
ISO 6487:1987 with:

CFC: 1000 Hz, and
CAC: 150 g

7.1.2. Measurements in the thorax of the dummy

The three thorax rib deflection channels shall comply with
ISO 6487:1987

CFC: 1000 Hz
CAC: 60 mm

7.1.3. Measurements in the pelvis of the dummy

The pelvis force channel shall comply with ISO 6487:1987

CFC: 1000 Hz
CAC: 15 kN

7.1.4. Measurements in the abdomen of the dummy

The abdomen force channels shall comply with ISO 6487:1987

CFC: 1000 Hz
CAC: 5 kN

7.2. HEAD PERFORMANCE CRITERION (HPC)

When head contact takes place, this performance criterion is calculated for the total duration between the initial contact and the last instant of the final contact.

HPC is the maximum value of the expression:

$$(t_2 - t_1)\left(\frac{1}{t_2 - t_1}\int_{t_1}^{t_2} a\,dt\right)^{2.5}$$

where a is the resultant acceleration at the centre of gravity of the head in metres per second square divided by 9.81 recorded versus time and filtered at channel frequency class 1000 Hz; t_1 and t_2 are any two times between the initial contact and the last instant of the final contact.

7.3. THORAX PERFORMANCE CRITERIA

7.3.1. Chest deflection: the peak chest deflection is the maximum value of deflection on any rib as determined by the thorax displacement transducers, filtered at channel frequency class 180 Hz.

7.3.2. Viscous criterion: the peak viscous response is the maximum value of V*C on any rib which is calculated from the instantaneous product of the relative thorax compression related to the half thorax and the velocity of compression derived by differentiation of the compression, filtered at channel frequency class 180 Hz. For the purposes of this calculation the standard width of the half thorax rib cage (EuroSID) is 140 mm.

$$V * C = \max\left[\frac{D}{0.14} \cdot \frac{dD}{dt}\right]$$

where D (metres) = rib deflection

The Viscous Criterion, V*C, is calculated as the instantaneous product of the relative compression (D/0.14) and the rate of deflection of the rib. Both are derived from the measurement of rib deflection. The rib deflection response is filtered once at Channel Frequency Class 180. The compression at time (t) is calculated as the deflection from this filtered signal expressed as the proportion of the half width of the EuroSID chest, measured at the metal ribs (0.14 metres):

$$C_{(t)} = \frac{D_{(t)}}{0.14}$$

The rib deflection velocity at time (t) is calculated from the filtered deflection as:

$$V_{(t)} = \frac{8[D_{(t+1)} - D_{(t-1)}] - [D_{(t+2)} - D_{(t-2)}]}{12\partial t}$$

where $D_{(t)}$ is the deflection at time (t) in metres and Mt is the time interval in seconds between the measurements of deflection. The maximum value of Mt shall be 125.10^{-6} seconds.

7.4 ABDOMEN PROTECTION CRITERION

The peak abdominal force is the maximum value of the sum of the three forces measured by transducers mounted 39 mm below the surface on the crash side, CFC 600 Hz.

7.5. PELVIS PERFORMANCE CRITERION

The pubic symphysis peak force (PSPF) is the maximum force measured by a load cell at the pubic symphysis of the pelvis, filtered at channel frequency class 600 Hz.

8 MOBILE DEFORMABLE BARRIER CHARACTERISTICS

8.1. CHARACTERISTICS OF THE BARRIER

8.1.1. The total mass shall be 1500 ∀ 20 kg.

8.1.2. The front and rear track width of the trolley shall be 1,500 ∀ 10 mm.

8.1.3. The wheel base of the trolley shall be 3,000 ∀ 10 mm.

8.1.4. The centre of gravity shall be situated in the longitudinal median vertical plane within 10 mm, 1,000 ∀ 30 mm behind the front axle and 500 ∀ 30 mm above the ground.

8.1.5. The distance between the front face of the impactor and the centre of gravity of the barrier shall be 2,000 ∀ 30 mm.

8.2. CHARACTERISTICS OF THE IMPACTOR

8.2.1. Geometrical characteristics

8.2.1.1. The impactor consists of six independently defined zones whose forms, sizes and positioning are shown in Figure 1 and Figure 2.

8.2.1.2. The deformable impact face shall be 1,700 ∀ 10 mm wide and 500 ∀ 5 mm high.

8.2.1.3. The initial ground clearance shall be 350 ∀ 5 mm measured in static condition before impact, measured at the front surface of the barrier face.

8.2.1.4. There shall be six deformable zones, divided into two rows, three zones made from a single element in the top row (A – C) and three zones of one element each in the lower row (D – F). All the elements shall have the same height (250 ∀ 3 mm); the element of the upper row shall be 440 ∀ 5 mm deep and 1700 ± 5mm wide and those of the lower row 500 ∀ 5 mm deep, the outer elements being 600 ± 3 m wide and the central element 500 ±3mm wide.

8.2.1.5 The characteristics of the material for zones A to F are (currently) given by dynamic force- deformation corridors. The dimensions of the load cell wall plates are given in Figure 3, labelled to match the AE-MDB zone labels.

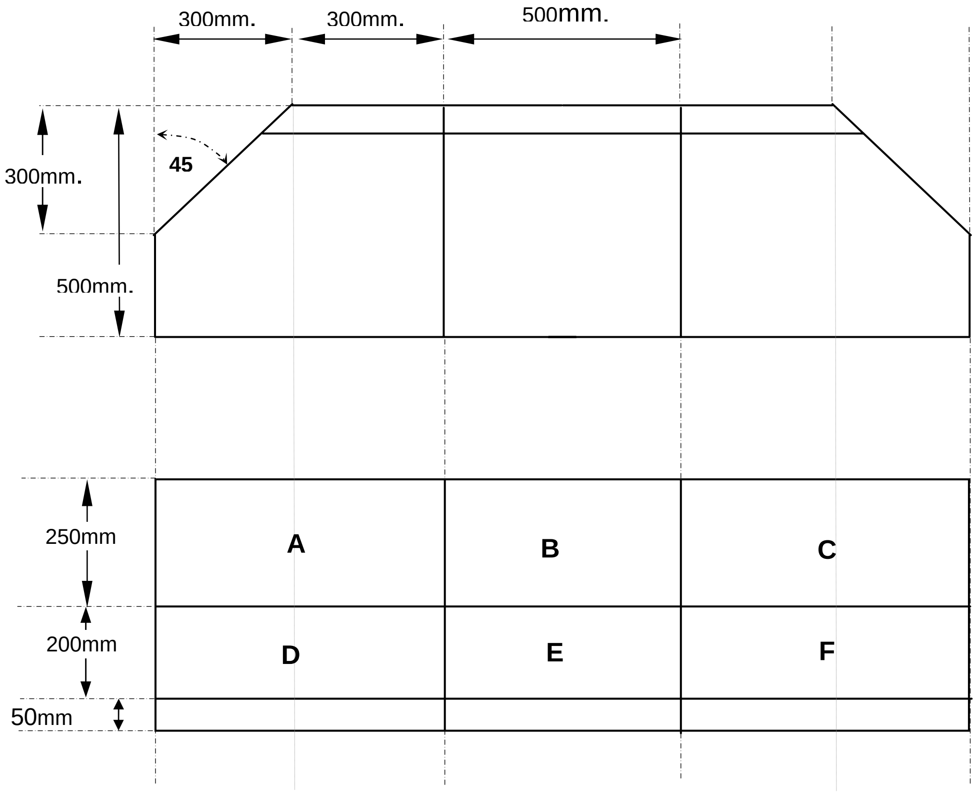


Figure 1 Dimensions of the Deformable Face

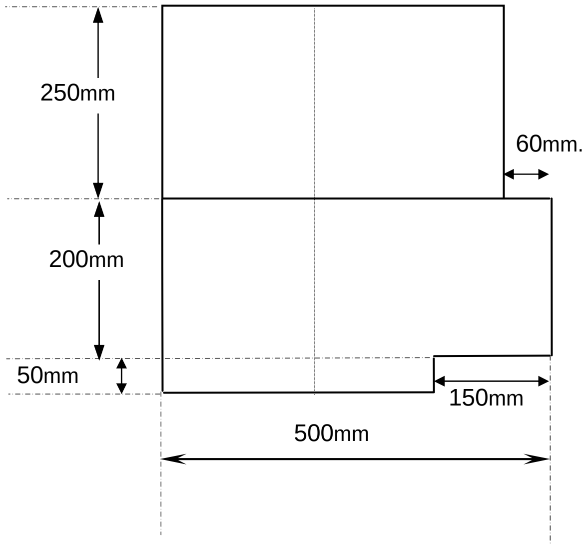


Figure 2 MDB Face - Side View

8.2.1.6 All of the MDB face zones in the top row (A – C) are made from the same material while zones F and D, which are identical, are made from stiffer material than zone E, which itself is stiffer than the material of zones A - C. The force deformation corridors for the load cell plates when impacted by this MDB (Mass 1500kg, impact speed 35km/h), are given in Figure 4.

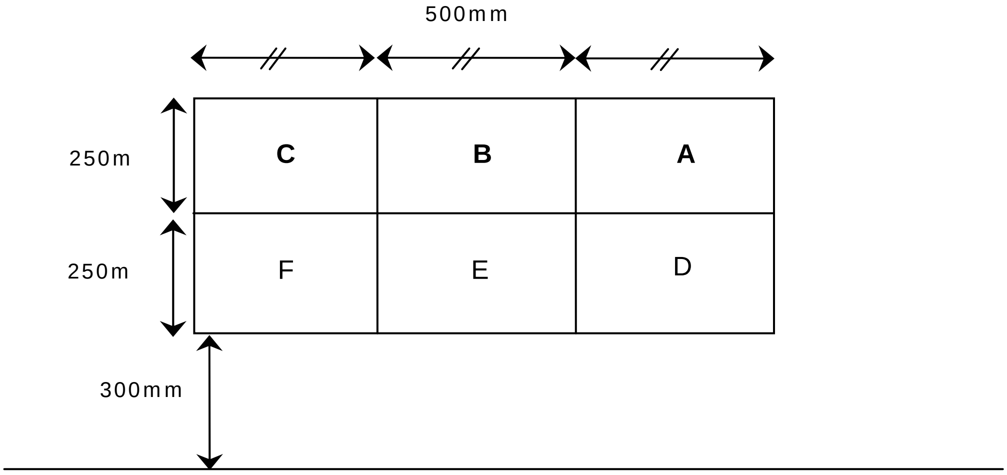
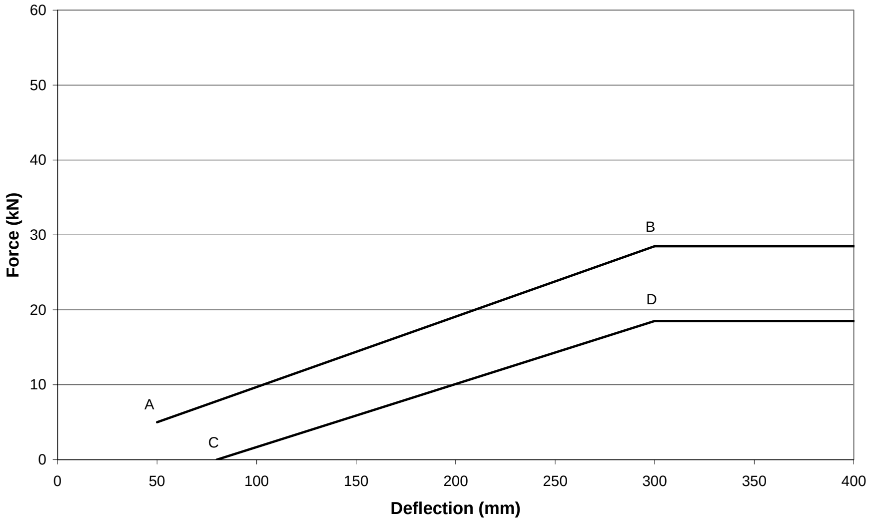


Figure 3. Load Cell Wall plate configuration and dimensions

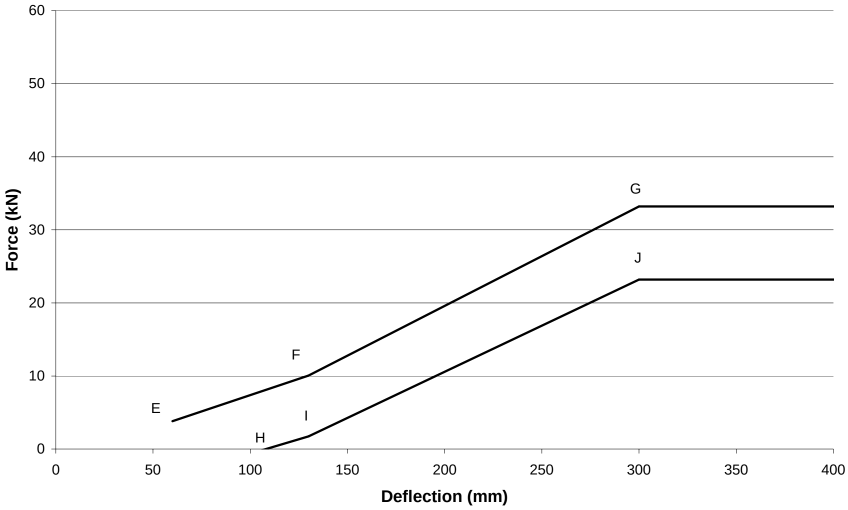
Block B
Figure 1a



d = Deflection (mm)
f = Force (kN)

	d	f
A	50	5
B	300	28
C	80	0
D	300	19

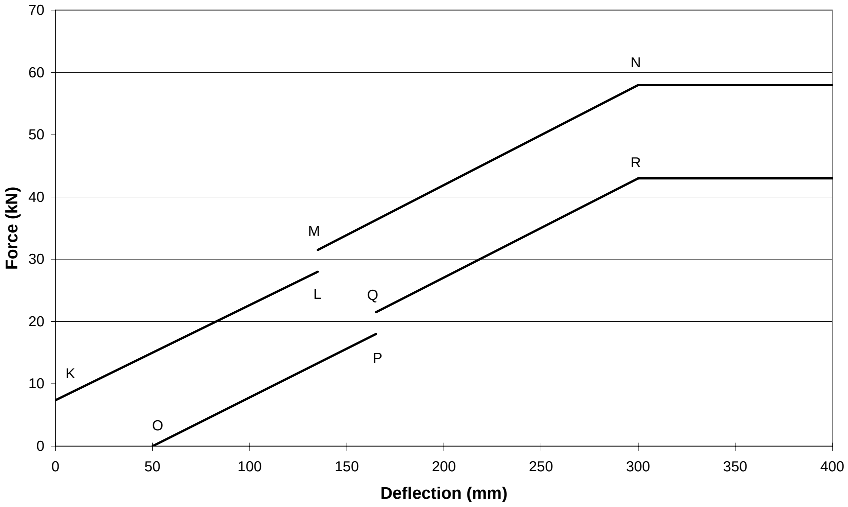
Blocks A & C
Figure 1b



d = Deflection (mm)
f = Force (kN)

	d	f
E	60	4
F	130	10
G	300	33
H	110	0
I	130	2
J	300	23

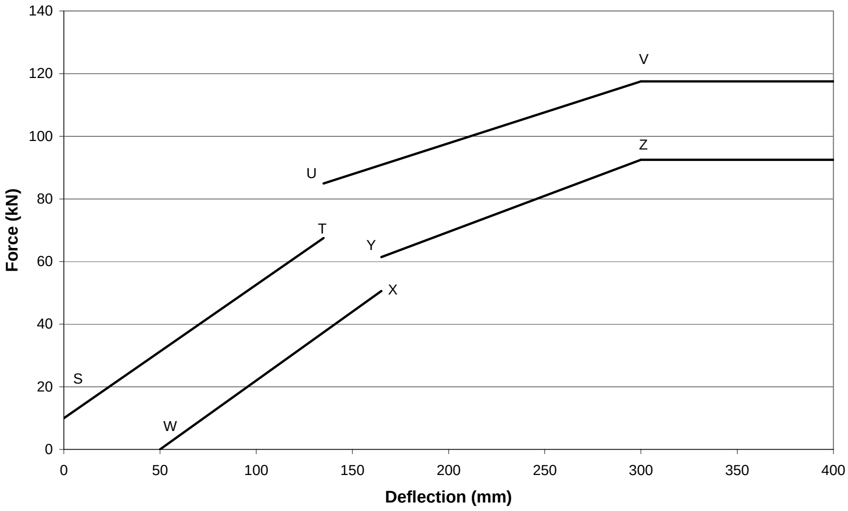
Block E
Figure 1c



d = Deflection (mm)
f = Force (kN)

	d	f
K	0	7
L	135	28
M	135	31
N	300	58
O	50	0
P	165	18
Q	165	21
R	300	43

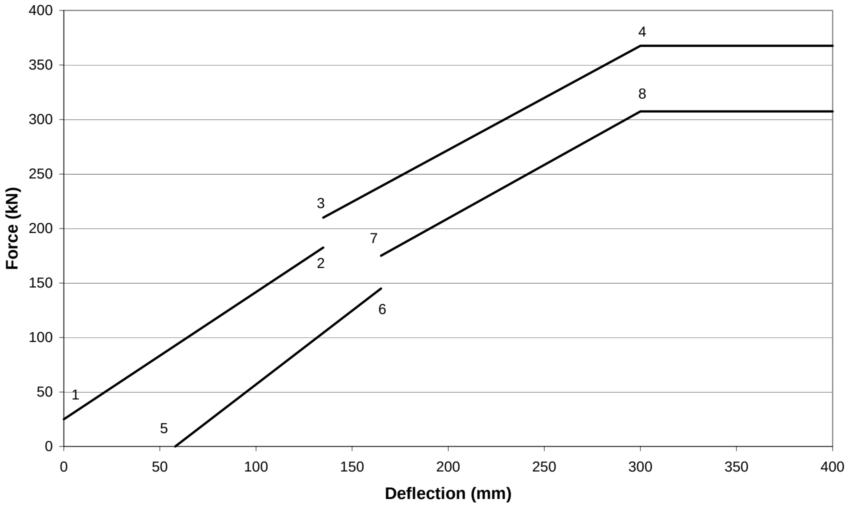
Blocks D & F
Figure 1d



d = Deflection (mm)
f = Force (kN)

	d	f
S	0	10
T	135	67
U	135	85
V	300	117
W	50	0
X	165	51
Y	165	62
Z	300	93

Total
Figure 1e



d = Deflection (mm)
f = Force (kN)

	d	f
1	0	25
2	135	182
3	135	210
4	300	367
5	58	0
6	165	145
7	165	175
8	300	308

Figure 4 Force-deformation corridors for AE-MDB

8.2.1.7 The barrier should be built on a ventilated back plate and mounted on a ventilation frame on the trolley.

9.6. Interior surface test procedure (version 3r).

EEVC

EUROPEAN ENHANCED VEHICLE-SAFETY COMMITTEE

EEVC SIDE IMPACT HEAD PROTECTION TEST PROCEDURE

Encompassing both front and rear seating positions

DRAFT 3r

March 2005

EEVC INTERIOR SIDE IMPACT HEAD PROTECTION

TEST PROCEDURE

DRAFT 3r

(March 2005)

1. INTRODUCTION

The EEVC side impact working group WG13 has been tasked by the EEVC Steering Committee to propose appropriate test procedure(s) that could be used to evaluate interior surfaces of the vehicle that could case head injury in a side impact. EEVC WG13 has focussed most of its research on a subsystems test procedure. With the advent of active head protection systems WG13 has also examined the need for exemptions for certain areas covered by the un-deployed system, the assessment of areas covered by a deployed system and a complementary full-scale impact test based on a pole impact.

The proposed EEVC interior side impact head protection test procedures are designed to evaluate interior surfaces that have been identified as areas that can cause injury to an occupant's head in a lateral impact. The procedures comprise two elements; firstly the evaluation of static (fixed) surfaces, with the exception of glazing, single skin roof panels and secondly active elements, such as air bags that deploy during the early phases of a side impact. Injurious head contacts have been observed in accident data on both front and rear door waistlines, this test procedure does not make any recommendations for the evaluation of this area.

It was the intention that the test procedure would be appropriate for all passenger cars. It has only been validated against vehicle with a fixed/hard roof. It's application to other vehicles such as vehicles with detachable and collapsible roofs will need further research and validation. It is considered that the application to the roof areas of vehicles with detachable and collapsible roofs would be excessively problematic, although it would be appropriate for any fixed A-pillar within the defined zone.

2. BACKGROUND

In three phases of research EEVC WG13 established several details pertaining to a possible EEVC interior headform test procedure. Firstly regarding the choice of headform for the test procedure; of the three headforms available and evaluated by WG13, in the mid 1990s, the US Free Motion Headform (FMH) was the preferred impactor. Secondly a free flight launch system should be adopted, excluding any possibility of using a linear guidance system, and finally a range of issues pertaining to the definition of the test procedure were studied. The third phase included a detailed accident study to assist in the definition of the contact zones.

In recent years vehicle manufactures have introduced a range of new 'active safety systems' ('head area' side air bags) to enhance the protection given to an occupant in a side impact. The provision of such protective devices is seen as potentially very beneficial as they could not only provide protection for head contact internally within the vehicle, but also in the event of head contact with external objects, through the window aperture. However, in the areas where these systems are installed, it may prove difficult, due to space limitations, to provide the full energy absorption requirements. In the equivalent US Standard, FMVSS201, exemption from testing at the full headform test speed is provided for the areas in which these undeployed systems are stored, provided it is demonstrated that the systems do, indeed, provide the protection claimed. This is achieved by subjecting these vehicles to a pole impact test and measuring the dummy head response. [1].

WG13 wishes to include similar exemptions. It now includes relevant features of a pole impact test procedure, based on the pole test defined in FMVSS 201, but using the ES-2 dummy, based on the specification gleaned from the Euro NCAP consortium, which itself uses this FMVSS201u test but with ES-2.

The incorporation of these active systems and their efficacy should be monitored.

The EEVC procedure attempts to encourage head protection of all areas of the side of a vehicle that a human head could impact.

3. IHRA - SIDE IMPACT WORKING GROUP

The proposed procedure was initially designed to address head protection for the front seating positions only, since Regulation 95 only encourages protection for this seating location. The IHRA Side Impact Working Group decided to adopt new research of EEVC WG13 as the foundation for an interior surface test procedure for their suite of advanced side impact test procedures. The work of EEVC WG13 can easily be expanded to cover the extended area of concern, namely protection for the rear seat occupant. To address this need the zones that should be evaluated have been extended in this procedure and are currently undergoing evaluation and validation (Section 1.4.2).

4. PROPOSED TEST PROCEDURES

Two test procedures are described. Firstly the main subsystem headform test to evaluate appropriate internal surfaces that would be impacted by an occupant's head, (Section 4.1.9.2) and secondly the subsidiary pole test that would be used if a deploying head protection system is used in the vehicle under test (Section 4.2). The pole test is based on a full vehicle test involving a pole impact and would assess systems that are designed to protect an occupant's head from external contacts as well as assess the firing mechanism of active head protection systems.

Note: For application within Europe and to be aligned with the scope of protection required in ECE Regualation 95, all references to rear seating zones and targets should be disregarded. For application into IHRA test procedures both front and rear seating positions should be included in the assessment. Further studies will be needed in order to apply the procedure to large occupants in rear seating positions, in particular for smaller vehicles.

4.1 Free Motion Headform (FMH)

EEVC WG13 carried out a dynamic test programme on the three 'most promising' head-forms, available at the time :-

- the EEVC (WG10) adult pedestrian head-form
- the AAMA headform and

- the FMVSS 201[3] Free Motion Head-form (FMH).

The EEVC head-form was being used within the evolving EEVC pedestrian test procedure for exterior surface testing. The FMH, based on the Hybrid III head, was already in use in the US for interior surface testing (FMVSS201). The AAMA headform was one that had been developed by the US auto industry as an improvement on the FMH. The WG13 tests were carried out under closely controlled conditions into a range of impact surfaces, examining padding stiffness, the presence of hard spots within the padding, impact angle and responses to deforming sub structures. For the purposes of this Phase 1 evaluation, a free flight impact was used. The report of the WG 13 'Phase 1' test programme [4] concluded that the Free Motion Head-form (FMH) was the preferred impactor, partially based on harmonisation issues and any further studies should be based on this impactor.

4.1.1 Headform orientation

The Free Motion Head-form can be orientated for impact in a number of different ways. EEVC WG13 have tested it in two orientations with respect to the designated forehead contact patch and the FMH's centre of gravity. The FMVSS201 orientation is such that the mid-sagittal plane of the head-form is vertical and perpendicular to the contact surface and the headform skullcap plate plane is perpendicular to the impact direction Figure 1. Thus the contact patch is not coincidental with the axis parallel to the direction of impact, passing through the FMH centre of gravity (C of G). In such an orientation, impacts tend to be offset to the edge of the certified area. The second orientation evaluated was with the FMH centre of gravity directly behind the forehead contact patch in the direction of impact Figure 2.

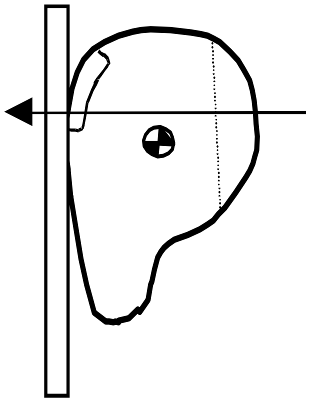


Figure 1 FMVSS 201 alignment

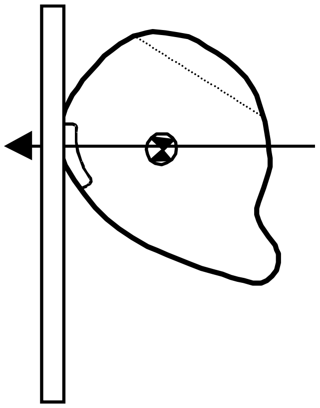


Figure 2 C of G alignment

Tests have shown that, in the 'centre of gravity aligned' mode, the tendency for the head-form to rotate and spin off the struck object is minimised (Figure 2). The severity of this Centre of Gravity aligned test is slightly higher due to the fact that more energy is being absorbed by the struck surface with less being converted to rotational motion of the headform. It was also seen to penetrate deeper into the impacted structure. Thus the FMVSS 201 orientation tends to induce more head-form rotation and a less severe impact.

The coefficient of variation was found to be less for the centre of gravity aligned impacts but the correlation with tests with the EuroSID-1 dummy was better for the FMVSS201 alignment. For this reason and in the interests of harmonisation, WG13 recommended that the FMH be used in the FMVSS201 orientation.

4.1.2 Launch system

As noted above, WG13 based its selection of the preferred head-form in a free flight test environment. In order to determine whether it was necessary or advisable to specify the launch system in any proposed test procedure, EEVC WG13 carried out a comparative test programme with the FMH being used in free flight and fully guided modes. This second phase of the EEVC WG13 research programme found significant practical problems with a test procedure based on a guided impact. The tests clearly demonstrated that a ‘free flight’ launch system should be recommended excluding any possibility of allowing tests to be performed with a fully guided launcher. The phase 1 and 2 programmes also identified a need to specify the distance of free flight between the head-form release and contact to minimise gravitational influences. In addition, a close specification of the period when the impact velocity should be measured was noted as well as a need to specify a clean head-form release from the launch system.

4.1.3 Impact zones from accident studies

To guide the specification of the impact zones for the EEVC test procedure positions contacted by the population involved in real world accidents were studied. An analysis of several in-depth accident databases from France, Germany and the UK identified a range of interior and exterior surfaces contacted by occupants’ heads in side impact accidents, for both front and rear seating positions in side impacts. These data were also compared to similar US data. The accident data were not collected according to the same strategy in all databases but they yielded similar results. From each accident study, struck surfaces were ranked in order of contact frequency.

Table 1 presents the ranked results for restrained struck side occupants and Table 2 for restrained non-struck side occupants. Impacts to other external objects were noted in the study.

Table 1 – Key Contact Regions, Restrained Struck Side Front Seat Occupants

Contact Site	**Priority in terms of no. of AIS1+ injuries recorded**			
	BASt	**LAB**	**TRL**	**NHTSA**
A Pillar	=5	No Contacts	3	3
B Pillar	1	1	1	1
Side Roof Rail	=2	2	2	2
Side Other (inc. door)	=2	No Contacts	4	
Roof	4		No Contacts	
Upper Anch’ Point	=5		5	
Window Frame		3		

(Shaded cells indicate zones that were not included as separate categories in that database)

From these results, the B-Pillar and Side Roof Rail are priority areas for evaluation when considering only the struck side occupants. Side other and the A-Pillar are second order priority areas and are also important areas for the non-struck side occupants.

Table 2 – Key Contact Regions, Restrained Non-Struck Side Front Seat Occupants

Contact Site	**Priority in terms of no. of AIS1+ injuries recorded**			
	BASt	**LAB**	**TRL**	**NHTSA**
A Pillar	=2	4	No contacts	3
B Pillar	=2	3	2	2
Header	No Contacts	▨	=4	▨
Side Roof Rail	1	2	3	1
Side Other (inc. door)	=2	1	1	▨
Roof	5	▨	=4	▨
Window Frame	▨	5	▨	▨

(Shaded cells indicate zones that were not included as separate categories in that database)

In a ‘Type Approval’ regime it is not practical to test all conceivable impact points within the identified areas, thus it will be necessary to specify how the impact locations and impact directions should be selected and defined, preferably taking into account the ‘worst case’ condition. EEVC WG13 has undertaken such an evaluation and has developed a set of guiding principles.

4.1.4 **Test zones**

One FMH test should be performed to any structure within each ‘defined’ target area. The precise location of the impact point is initially specified, based on FMVSS201 target points. These are then restricted to points that lie within a cone based on potential head trajectories in side impacts. To ensure that due care is taken of areas between the individual specified target points, the option is given to test at points between the specified target points if these are deemed to be ‘worst case’, within the guidance given in Section 4.1.3. In addition, certain defined structures are specified as focal points for the FMH test, as they are in FMVSS201.

The Defined structures are:
- Upper seat belt anchorage
- Seat belt adjustment device, if located above the anchorage point
- Grab handle (located within the defined header rail distance)
- Lighting control unit, coat hook or other such ‘fixed’ vehicle furniture.

Some parts of the defined structures may be obscured from head contact by other vehicle trim, e.g. Fascia or fixed seats. Areas so obscured will not be tested with the head-form.

In the interests of keeping the burden of the cost of testing to a minimum, it would be desirable for a number of the tests, if not all, to be performed in the same vehicle. In such an environment collateral damage must be avoided. The test at one position must not compromise a test at an adjacent position due to any ‘pre-damage’. Guidance must therefore be given concerning the spacing of adjacent impact points and the monitoring of damage. Information to support such guidance will be obtained from the ‘in-vehicle’ tests.

4.1.5 **Door Impacts**

The accident data have indicated that injurious contacts with the door can occur to non-struck side occupants. They have been noted to occur even to restrained struck-side occupants. This proposal does not include tests to these locations unless they lie within certain restricted boundaries, but they could be considered in any future amendment.

4.1.6 **Impact velocity**

The severity of the head-form test should be matched to that in the full-scale test. BASt and TRL carried out an analysis of head velocities observed in side impact tests for EEVC Working Group 9 (WG13, WD2). This study indicated that the maximum 'mean head velocity' in the lateral direction was 7.9 m/s. From high speed film analysis it was deduced that this velocity fell to approximately 6.7 m/s by the time the head contacted an interior surface or passed through 'the side window aperture'. It was therefore proposed by EEVC WG 9 and accepted by WG13 that the head-form test should be based on a head impact velocity of 6.7m/s.

4.1.7 **Impact angles and head-form orientation**

Due to the complex motion that occurs in side impact accidents, potential impact angles onto the vehicles interior struck surfaces can be wide ranging and be influenced by impact type and direction, occupant stature and occupant seating position. It is perceived that the most severe injury would be sustained in an impact perpendicular to the struck surface. Unfortunately accident data are not able to give guidance as to actual impact vectors and head orientations at the point of impact. It is realised that impacts perpendicular to the surface may not always be physically possible to achieve or in some cases realistic.

One method of defining impact vectors would be to use the 'H point' manikin and assume a linear path between the normal head position and the contact point. However, the motion of the head of a restrained occupant in a real side impact accident is far from linear. The motion of the vehicle body is complex and it is likely that an occupant would be in a position that differed from this 'standard' position, prior to an impact, particularly if the vehicle rolls or yaws in the impact. Thus a vector definition based on the angle of impact onto the surface, taking into account the worst case consideration, would be more appropriate.

Clearly, only contact locations and impact velocity vectors that can be achieved within the vehicle should be specified. As the FMH is a non-symmetrical impactor with a defined contact patch in the forehead region, it will be necessary to adjust the headforms orientation to permit an impact to the selected target point, with this contact patch. It is proposed that the head-form be preferentially used with the mid-sagittal plane in a vertical mode. It is important that the main contact should be within the certified FMH contact zone.

Two methods for achieving a clean contact have been discussed. The first method (1) permits pre-defined rotation steps (of 90 degrees) of the mid-sagittal plane about the horizontal fore-aft head axis, which is supported by the majority of WG13 members. The alternative method (2), allows the mid-sagittal plane to be pitched forward vertically and perpendicular to the test surface by the required amount to achieve a clean contact.

Method 1
If it is not possible to achieve a clean contact (as defined in Appendix 1, Section 1.1.1) within the specified contact zone of the FMH, with the headform mid-sagittal plane vertical and perpendicular to the surface, without also contacting other (uncertified) parts of the FMH, then the headform and impact vector should be pitched forward by 10° and the contact conditions re-examined. However, it would also be reasonable to permit rotation of the mid-sagittal plane about the horizontal fore-aft head axis to obtain a clean impact and reduce impacts to non-certified areas of the headform. To reduce the number of different impact possibilities, and hence improve reproducibility, it is proposed that the impact vector pitch angle should initially be limited to 0° and 10° only. Rotation about the impact vector is limited to 90° increments only and intermediate values should not be used. If a clean contact cannot be established after rotation the free motion headform should be rotated back to its original vertical position and the impact vector should be pitched from 10° until a clean contact is established, up to a maximum of 18°. If these conditions can not be met the impact point should be moved.

Method 2
If it is not possible to achieve a clean contact (as defined in Appendix 1, Section 1.1.1) within the specified contact zone of the FMH, with the headform mid-sagittal plane vertical and the velocity vector perpendicular to the surface, without also contacting other (uncertified) parts of the FMH then the headform and impact vector should be pitched downward until a clean contact (according to 1.1.1 Appendix 1) is established and the approach angle is within the ad-hoc range as defined in 6.1.7. If these conditions can not be met the impact point should be moved.

4.1.8 **Worst case evaluation**

To achieve the best level of protection for an occupant's head, the vehicle should be evaluated in a 'worst case' or 'most injurious' manner. If surfaces are evaluated in such a mode then the levels of injury saving, when they are struck in a less severe manner or orientation are likely to be maximised. Worst case features are likely to be related to the stiffness of the padding and the underlying structure being impacted – seams, folds, welds and structural components as well as impact direction and head orientation.

4.1.9 **Vehicle preparation and support structures.**

Two types of interior test are possible. One involving the full vehicle, appropriately trimmed and prepared and the other using sections of the vehicle in a sub-component test.

4.1.9.1 Vehicle based test

The test procedure must be repeatable and reproducible. Thus it is important that there are adequate controls in place to minimise test variability and ambiguities in interpretation. To foster improved repeatability and to reduce the variation in ride height caused by operators moving within the vehicle during set-up, the vehicle should be supported on a rigid support off its normal suspension.

The WG13 accident studies have shown that many head injuries are sustained when the intruding or struck object supports the exterior of the vehicle. For the B-pillar and side roof rail, most of the serious injuries occur with support behind the impacted area. Therefore to be effective, the energy absorption should be built into the vehicle structure and trim. External support would prevent any exterior deflection of the vehicle and encourage the provision of energy absorption within the trim and inner structure of the vehicle adjacent to the head impact position.

This could be achieved either by ensuring that the surface is fully and rigidly supported (externally), as was implemented in the 'Composite Test Procedure' [5], or by specifying a maximum movement of an external vehicle reference point, along the axis of the impactor. The definition of any support system that would be reproducible is difficult. Consequently a limit on external motion is preferable. The accident data do not give any guidance on such a deflection criterion. However, test results give an indication of 'normal' motion. Since the purpose of the support is to avoid gross movement., a limit of a point 'P' of 10 mm of external body deflection is proposed, with respect to the vehicle, along the axis of the impact, Figure 3.

If the side window can be opened tests should be performed with the window fully open. However, only points which can be contacted by the FMH with the window(s) closed should be tested.

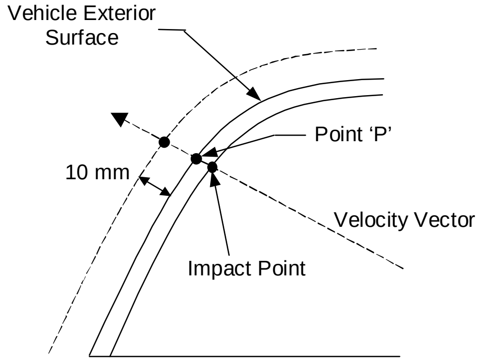


Figure 3 Measurement of external movement

4.1.9.2 Sub-component test

The accident data have shown that many injuries are sustained at positions within the vehicle which are 'externally supported'. Thus a sub-component test of the relevant structure resting on a solid support might provide a good representation of a full-scale vehicle in which the impacted position is externally supported.

However, tests by WG13 with separated B-pillars at the sub-component level demonstrated considerably greater variability than the equivalent car tests. This was considered to be due to the difference in attachment control of the interior trim when only the sub-component was present. On the basis of these results, sub-component tests are not proposed as part of the EEVC test procedure. They may still prove to be of worth in design and development testing if appropriate care is taken regarding trim attachment and stability.

4.1.10 **Deployable or active safety systems**[1]

It is recognised that active head protection systems are being developed and implemented in a number of vehicles and that such systems could afford special or additional protection to the occupant's head. Indeed they may be the only way of protecting the head against external objects. It may prove difficult to achieve adequate performance from the interior headform impact at the standard speed in the area covering the deployment system.

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[1] The assessment of deployed systems is a recent WG13 development and will need further validation.

The EEVC Interior Headform Test Procedure should not discourage such advanced safety developments. A pole impact test is added to ensure that the assumption of 'an effective head protection system' is justified. EEVC WG13 proposes to adopt this approach, but using ES-2 in place of the special Hybrid-SID dummy used in FMVSS 201. This makes the assumption that the occupant's head would not contact these zones at the full impact speed (6.7 m/s) since the head protection system will have been deployed in accidents of that severity. However, to ensure that head injury risk is not exacerbated at impact speeds lower than those, that would trigger deployment, the headform test is performed at a lower impact speed for these defined areas (5.3 m/s). A pole impact test is added to ensure that the assumption of 'an effective head protection system' is justified. EEVC WG13 proposes to adopt this approach, but using ES-2 in place of the special Hybrid-SID dummy used in FMVSS 201. Experience with pole impacts using both EuroSID-1 and ES-2 has shown that it reacts normally with a pole and is capable of distinguishing the presence of protective measures in the head area.

4.1.10.1 Active system FMH tests:

Where the requirements of the pole test (defined in Annex 1) are satisfied, additional tests are included to assess further the performance of the active head protection system to check that adequate protection is given over the whole of the deployed area. The areas of an active system, which are capable of providing adequate protection to the head, will be subjected to FMH tests at the full impact speed (6.7m/s). Those areas are to be nominated by the manufacturer and will be their decision whether the tests are performed with the system statically inflated or triggered and deployed.

4.1.10.2 Active system sub-structure FMH tests:

Satisfactory results would indicate that the occupant's head would not contact the vehicle structures underlying the active system at the full impact speed (6.7 m/s) since the head protection system will have been deployed in accidents of that severity. However, to ensure that head injury risk is not exacerbated at impact speeds lower than those, that would trigger deployment, the headform test is performed to the underlying structures of those defined areas at a lower impact speed (5.3 m/s). The underlying structures of the remaining areas, which are not designated as providing adequate protection, will be tested at the full impact speed (6.7 m/s).

4.1.10.3 Risk from deployment

A transition period exists between the active device being undeployed and fully deployed. During this period a time exists when the occupant can have their head close to the deploying system. Such a scenario is often termed 'Out of Position' (OOP). WG13 is of the opinion that consideration should be given to the need for an evaluation of such a situation but a proposal for a test procedure for this is not included in this report.

4.1.10.4 Head protection coverage area

It is observed that an active head protection system can consist of a collection of pockets or zones. Each of the zones may afford differing levels of protection dependant upon where the occupants head contacts the system. WG13 believes it is important to ensure that a minimum level of protection is given to the occupant, independent of contact position. The areas of an active system, which are capable of providing adequate protection to the head, are defined as ensuring a HIC_{dummy} <1000 when impacted at 6.7m/s. The area(s) that offer the least protection will be evaluated, these could include seam connection/kissing points or areas having the least airbag depth, also the shape and stiffness of underlying structures should also be considered. If there is sufficient doubt as to the ability of certain areas to provide adequate protection, then 'worst case' points will be selected (within the defined area(s)) and evaluated with the *active system FMH tests*.

4.1.10.5 Deflation

Consideration is needed to allow for possible second impacts, on how to evaluate devices that are designed to deflate after the initial impact.

4.1.11 **Application of procedure**

This procedure does not currently include any consideration for convertible or coupé-cabriolet vehicles. It is expected that WG13 will make recommendations on how such vehicles can be suitably assessed in the future.

4.2 Pole impact test

The full-scale pole test procedure, being considered by EEVC WG13, mainly duplicates that specified in FMVSS201u and adapted by Euro NCAP. The dummy to be used in the procedure will be adopted based upon the advice of EEVC WG12, which is currently the ES-2 dummy [10].

5. ASSESSMENT CRITERIA

5.1 Headform test

Any test procedure must include tolerances on the test conditions to reduce test variability. Table 3 details a range of appropriate tolerances, based on the experiences of impact testing gained within the WG13 test institutes.

Table 3 FMH Impact tolerances

FMH • Impact velocity *(in the direction of launch.)*	• Measurement to be taken ≤ 100 mm from the impact point along the primary impact vector • Max free flight distance from release to impact 100 mm • Impact velocity accuracy ± 0.2 m/s
Vehicle • Alignment	• Impact alignment accuracy ≤ 10.0 mm radius of the target point. • Conical alignment ± 5.0° from the intended velocity vector
• Exterior surface deflection	• ≤ 10 mm along the axis of the impact, coincident with the input target

It is generally accepted that HIC, whilst having some deficiencies, is the most appropriate injury criterion for use in an interior head-form test procedure. The FMH is a free-flight test device whose dynamic measurements and injury predictions have been correlated with full-scale test results, which in Europe is currently based on the EuroSID-1 dummy and its ‘side certified head’.

For FMVSS 201, the dynamic performance of the FMH was compared to the Hybrid III dummy, in impacts to the front of each head and a suitable dummy to free motion headform HIC factor was developed. For the EEVC Interior Headform Test Procedure, comparative sled tests with impacts to the certified side of the EuroSID-1/ES-2 dummy head and free flight tests with impacts to the forehead of the FMH, into a range of structures, were carried out by TRL. These tests yielded a linear regression relationship of:

$$\mathbf{Y = 0.6499\ X + 260.32}.$$

This compared well over the important 500 – 1500 HIC range with the correlation trend line given in FMVSS 201 of:

$$\mathbf{Y = 0.75446\ X + 166.4}.$$

To assist in harmonisation and reduce confusion EEVC WG13 agreed to adopt the FMVSS 201 regression relationship, thus:

$$\mathbf{HIC_{dummy} = (0.75446)*HIC_{FMH} + 166.4}$$

In conformity with the full-scale regulatory test [1] the appropriate requirement would be:

$$HIC_{dummy} = \leq 1000 \qquad (\text{or } HIC_{FMH} = \leq 1105)$$

For consistency with ECE Regulation 95, the 36 msec values for HIC would be calculated.

5.2 Pole impact test

The assessment criteria that should be applied to the pole test should be the same as that used for the ES-2 head in the MDB test procedure, defined in ECE Regulation 95.

5.3 Instrumentation and data processing

Instrumentation and data processing must be well defined to ensure reproducibility between test establishments. Factors that must be recorded in the test procedure are:

a) Head-form impact velocity
b) Head-form acceleration (three mutually perpendicular axes through the centre of gravity of the head-form) and
c) Exterior vehicle movement adjacent to the impact point along the impact vector.

Data capture, filtering and data process must conform to the requirements of ISO 6487:1987.[6]

Head Injury Criteria for the head-form (HIC_{FMH}) is calculated according to:

$$\left(\frac{1}{(t_2 - t_1)} \int_{t_1}^{t_2} a\,d_t \right)^{2.5} (t_2 - t_1)$$

Where ‘a’ is the resultant head-form acceleration, expressed as a multiple of ‘g’ *(the acceleration due to gravity)*, and t_1 and t_2 are any two points in time during the impact, which are separated by not more that a thirty-six millisecond time interval.

And then factored to HIC_{dummy} according to:

$$HIC_{dummy} = 0.75446\ HIC_{FMH} + 166.4$$

Note: The measurement of impact test velocity is an important parameter within the test procedure. It is important that measurement systems used are appropriate to the level of accuracy required in the test procedure.

6. SUMMARY OF PROPOSED TEST PROCEDURE.

6.1 Free Motion Headform Test method

6.1.1 **Headform – US Free Motion Headform FMH [7]**

The headform used for testing conforms to the specifications of Appendix 1 Section 2

NOTE:

The headform shall be re-certified

- after every [10] tests,
- after each test in which $HIC_{dummy} > 1000$
- after any test in which damage to the head-form flesh is suspected

The headform used for testing must conform to the specifications of Appendix 1. Section 2

6.1.2 **Forehead impact zone**

The forehead impact zone of the headform is determined according to the procedure specified in 6.1.2 paragraphs I to vii below

i. Position the headform so that the baseplate of the skull is horizontal. The midsagittal plane of the headform is designated as Plane S.

ii. From the centre of the threaded hole on top of the headform, draw a line 69 mm forward toward the forehead, coincident with Plane S, along the contour of the outer skin of the headform. The front end of the line is designated as Point P. From Point P, draw a line 100 mm forward toward the forehead, coincident with Plane S, along the contour of the outer skin of the headform. The front end of the line is designated as Point O.

iii. Draw a 125 mm line which is coincident with a horizontal plane along the contour of the outer skin of the forehead from left to right through Point O so that the line is bisected at Point O. The end of the line on the left side of the headform is designated as Point a and the end on the right as Point b.

iv. Draw another line 125 mm which is coincident with a vertical plane along the contour of the outer skin of the forehead through Point P so that the line is bisected at Point P. The end of the line on the left side of the headform is designated as Point c and the end on the right as Point D.

v. Draw a line from Point a to Point c along the contour of the outer skin of the headform using a flexible steel tape. Using the same method, draw a line from Point b to Point d.

vi. The forehead impact zone is the surface area on the FMH forehead bounded by lines a-O-b and c-P-d, and a-c and b-d.

6.1.3 **Free flight trajectory**

The FMH must be accelerated under linear control and released for free flight between 25 and 100mm from the point of first contact.

6.1.4 **Impact Velocity**

Two headform impact velocities are specified, the higher one for the evaluation of all target points not possessing and covered by active Head Protection Systems, Section 4.1.10, and the lower one being used for defined areas of the of vehicle, Appendix 1 Section 1.3, which are covered by approved areas of an active Head Protection System.

- The standard impact speed is 6.7 m/s ± 0.2 m/s measured ≤100 mm from the contact point for 'normal' surfaces.
- For areas covered by 'active head protection systems', which satisfy the requirements of Annex 1 Section 1.4.3, the impact speed is 5.3 m/s ± 0.2 m/s measured ≤ 100 mm from contact point

6.1.5 **Impact location accuracy**

- The impact alignment accuracy shall be within a radius of ≤ 10.0 mm of the selected target point.

6.1.6 **Impact Environment**

- The test temperature range shall be between 19 and 26°C
- The relative humidity shall be between 10 to 70%
- The environment shall be stabilised for a period ≥4 hours prior to test
- Time period between repeated tests using the same headform shall not be less than 3 hours

6.1.7 **Test location and Head-form orientation**

One FMH test should be performed to each test location.

Initially, the Target Points are determined according to the specification in Appendix 1
These are then restricted to those that lie within the 'defined' target area. (Appendix 1, Section 1.4 below) i.e. within an area defined by four planes, two passing through horizontal axes defined by the locations of the heads of large male and small female occupants and two passing through vertical axes also defined by the locations of the heads of large male and small female occupants.

To ensure that due care is taken of areas between the individual specified target points, the option is given to test at points between the specified target points if these are deemed to be 'worst case', within the guidance given in Section 4.1.3 above.

In addition, tests are performed at certain defined structures (taken from FMVSS201u):

- Upper seat belt anchorage
- Seat belt adjustment device, if located above the anchorage point
- Grab handle (located within the defined header rail distance)
- Lighting control unit, coat hook or other such 'fixed' vehicle furniture.

Tests at one position must not compromise a test at an adjacent position due to 'pre-damage'.

Although testing will be performed with adjustable windows in the open position, only those contact points, which can be contacted by the headform with the windows closed, will be tested.

The impact angle, defined as the angle of the impact velocity vector with respect to the plane tangential to the surface at the point of contact, shall be selected to be the “worst case” as close as possible to perpendicular to the impact surface. Both methods are included as previously discussed in Section 4.1.7.

Method 1
Then, for each selected target location, the headform orientation and actual impact location for each test is determined according to the following procedure. For clarity this procedure is illustrated by means of a decision making flow chart in .

- With the mid-sagittal plane vertical, (Section 6.1.2) should coincide with the impact velocity vector through the contact target.
- If a clean contact, as defined in Section 1.1.1, is not possible without contacting other non-certified parts of the FMH, then the headform and impact velocity vector should be pitched forward with respect to the normal by 10° ± 2° and realigned with the target, Figure 5.
- If a clean contact cannot be made with the head mid-sagittal plane, aligned vertically following this adjustment then the FMH and velocity vector should be returned to normal to the surface and the FMH be rolled by 90° ± 2° around the velocity vector, as described in the note.
- If the target location point still cannot be hit cleanly, then the headform should be rotated back to its original vertical position and the headform and impact velocity vector should be pitched forwards, with respect to normal, until a clean contact (as defined in Appendix 1, Section 1.1.1) is established up to a maximum allowable pitch of 18° ± 2° to normal. A pitch of 18° reduces the lateral component of the impact vector by approximately 5%.
- If the selected point still cannot be impacted cleanly then the target point should be moved within the limits defined in Appendix 1, Section 1.3 while still seeking a worst case contactable position.

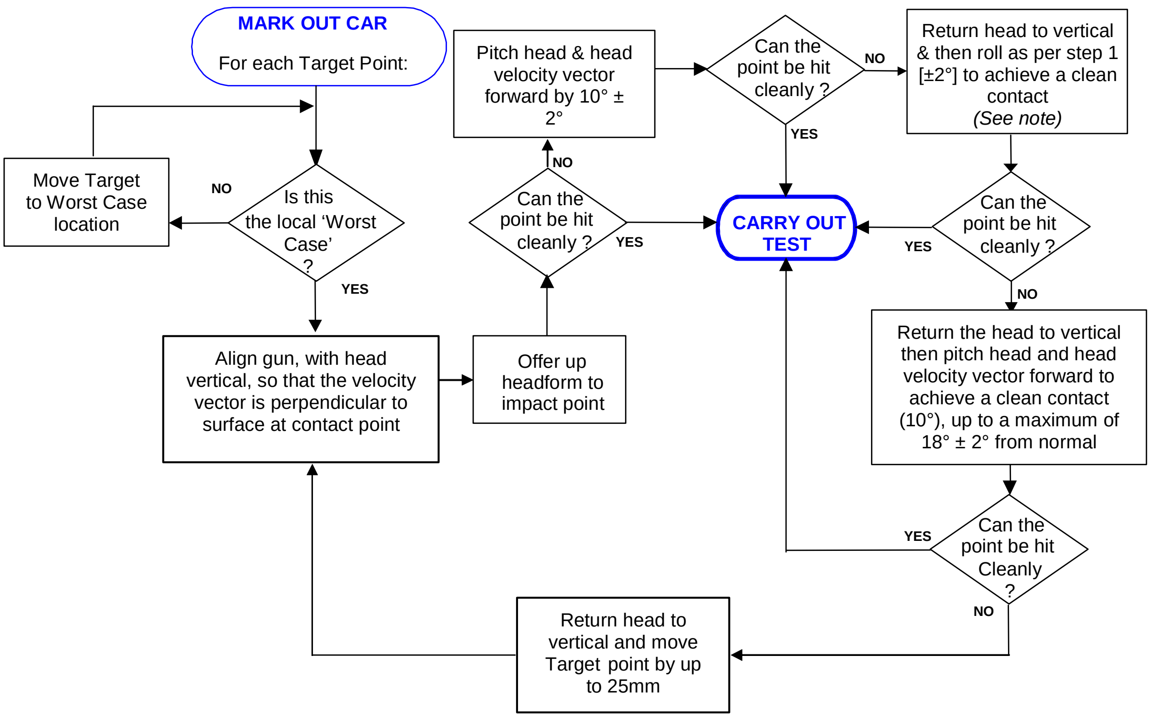

Figure 4 Method 1, Headform alignment flow chart

Note: Clarification note on headform rotation

FMH axial rotation about the impact vector facing towards the target point.

Target area		**Left hand side of the vehicle**	**Right hand side of the vehicle**
Step 1:	**A post target points**	90 degree clockwise	90 degree anticlockwise
	Roof rail target points	90 degree clockwise	90 degree anticlockwise
	B post target points	90 degree anticlockwise	90 degree clockwise

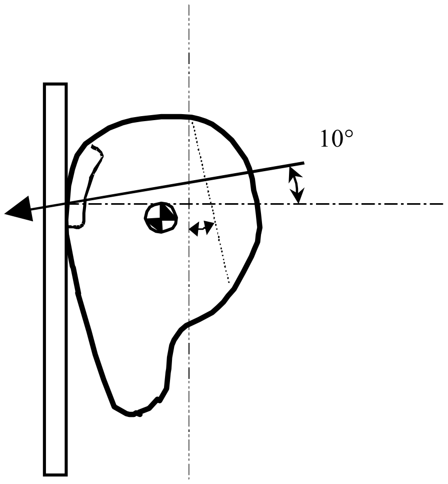

Figure 5 Method 1, orientation 10° forward of perpendicular

Method 2

Then, for each selected target location, the headform orientation and actual impact location for each test is determined according to the following procedure.

- With the mid-sagittal plane vertical, (Section 6.1.2) the impact velocity vector shall be perpendicular to the surface through the contact target.
- If a clean contact, as defined in Section 1.1.1, is not possible without contacting other non-certified parts of the FMH, then the headform and impact velocity vector should be pitched downward with respect to the normal by 10° ± 2° and realigned with the target, Figure 5.
- If the target point still cannot be hit cleanly, again the headform and impact velocity vector should be pitched downwards, with respect to normal, until a clean contact (as defined in Appendix 1, Section 1.1.1) is established.
- If the selected point still cannot be impacted cleanly then the target point should be moved within the limits defined in Appendix 1, Section 1.3 while still seeking a worst case contactable position.

For any method the following exceptions will apply:

(a) Vertical approach angles, as defined in Section 1.1.13, will be limited to no more than [50] degrees (as is used in FMVSS 201) for all impacts. (Recent computer simulations has suggested that Vertical approach angles of [-10 to +20] degrees may be more appropriate).

(b) When testing the A-pillar, as defined in Appendix 1 Section 1.1.9, the horizontal approach angle will be limited to between [195] and [255] degrees for the left hand side, and [105] to [165] degrees for the right hand side. Figure 6. For impacts on the A-pillar only, the longitudinal vertical plane passing through the forehead impact zone points O and P, as defined in Section 6.1.2, shall be perpendicular to the primary axis of the A-pillar at the impact point. Figure 7.

(c) When testing side roof structures, B-pillars and other pillars (where applicable), as defined in Appendix 1 Section 1.1.9, the horizontal approach angle will be limited to between [230] and [295] degrees for the left hand side, and between [65] and [130] degrees for the right hand side. Figure 8.

(d) For point BP2, as defined in Appendix 1 Section 1.3.2.2, the horizontal approach angle will be limited to [270] degrees for the left hand side and [90] degrees for the right hand side.

(e) When testing the rearmost pillar, as defined in Appendix 1 Section 1.1.9, the horizontal approach angle will be limited to between [270] and [345] degrees for the left hand side, and [15] to [90] degrees for the right hand side. Figure 6.

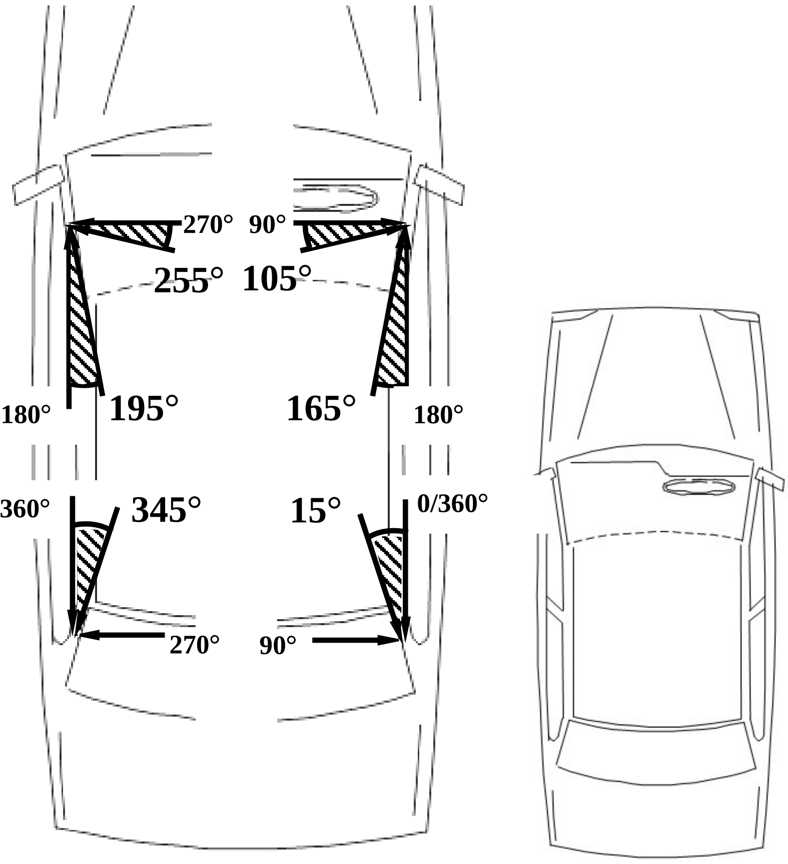

Figure 6 A-pillar and rearmost pillar horizontal approach angle limitations

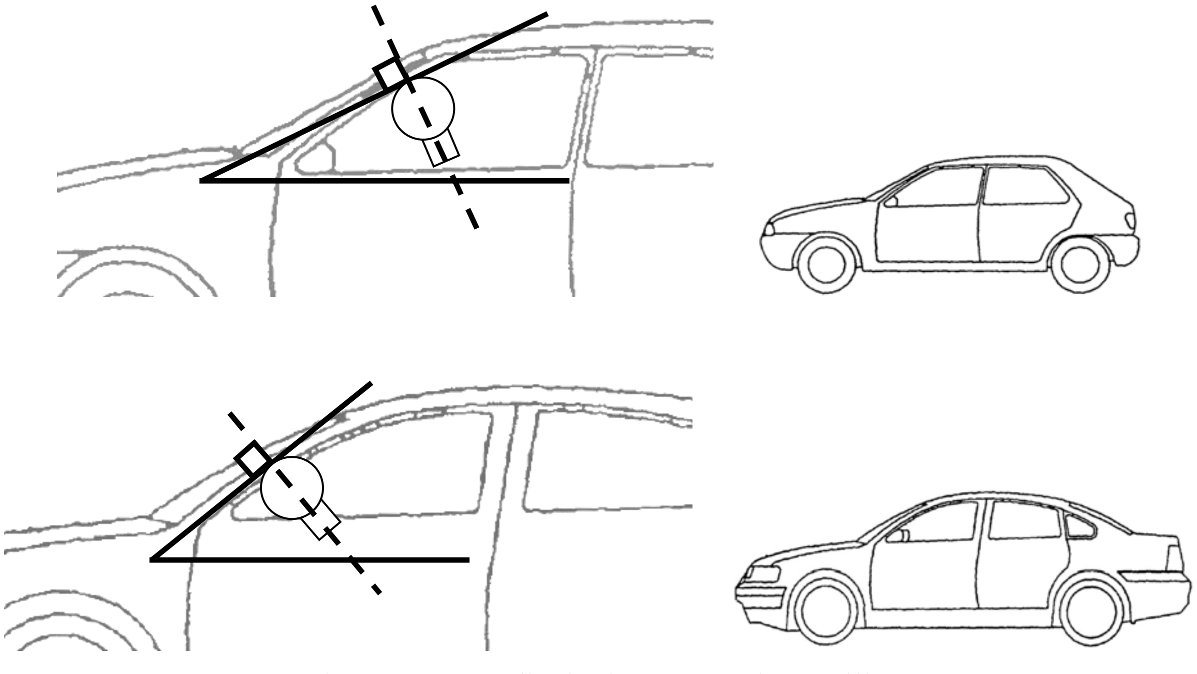

Figure 7 Perpendicular impacts to the A-pillar

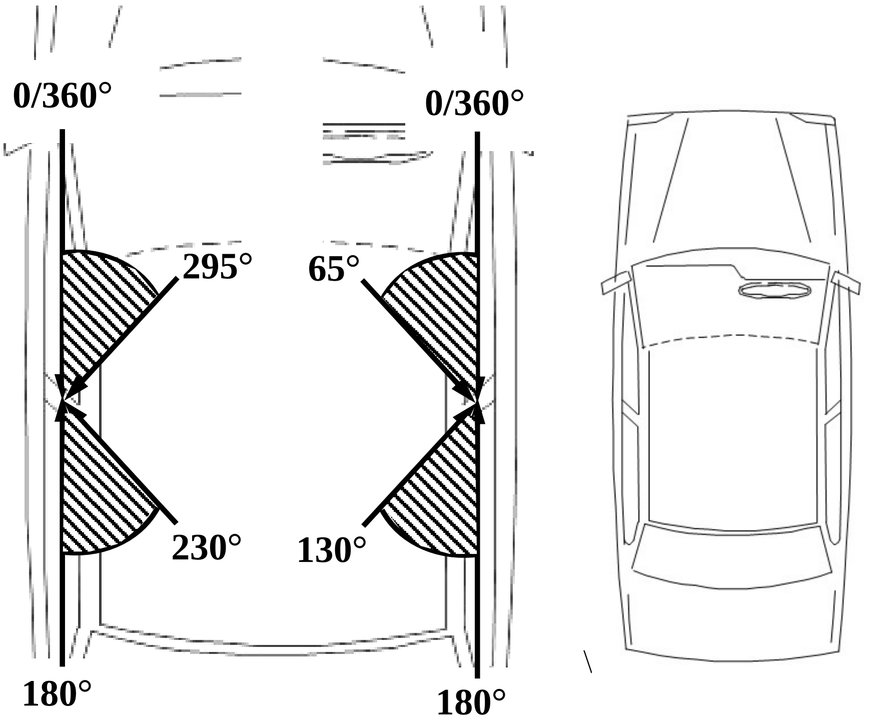

Figure 8 B-pillar and other pillar horizontal approach angle limitations

Note:
During the first phase of the WG13 research the US FMH was selected as the preferred impactor, thus all of the reported WG13 research has focussed on the use of this test device. Much of the intervening WG13 research effort has been directed towards minimising test variability and potential miss-interpretation of the test procedure to create a test procedure that would evaluate worst case conditions and encourage enhanced safety. Both of these issues have been made difficult to achieve due to the non-symmetrical shape of the selected impactor and the alignment of the headform, with the centre of gravity of the headform not being coincidental with the contact point on the headform. As was noted earlier one of the prime reasons for selecting the FMH was based on harmonisation with FMVSS 201. Within Europe the EEVC headforms used in the Pedestrian test procedures have been further developed and is now incorporated within European Directives [8][9]. WG13 believes that many of the more complex issues described in this report, that are designed to achieve clean contacts without ambiguities in interpretation would not be needed if a symmetrical headform were to be adopted. WG13 is of the opinion that the procedure could be much simpler, not needing to include headform pitching and rotation, if an alternative headform were to be used but it would have to be rigorously evaluated to ensue that other complications were not introduced. Some of the alternative options expressed with WG13 would cease to be valid using such an impactor (Annex 3). At this time WG13 is not in a position to indicate whether the use of this headform, now suitable for use within regulation, would be appropriate for internal surface testing since it has not undergone such scrutiny in the in-vehicle environment [4].

6.1.7.1 General guidance

- 'Worst Case' impacts

It is expected that 'worst case' will differ between vehicles, thus each vehicle should be assessed, by examining the drawings or physical inspection, before assuming the padding, fixing or other structure would be a worst case position.

An inspection of the trims and underlying structure should be carried out to look for :-
- Where the crush depth of padding is minimal.
- The location of fixings and bolts.
- The position of welds, joints or internal webs in the chassis.
- The attachment of padding or other components

The presence of such features could be used to guide a test authority regarding focal point for 'worst case' impacts.

- Closeness of repeated test

. Multiple impacts

A vehicle being tested may be impacted multiple times, subject to the limitations given below
- Impacts within 300 mm of each other may not occur less than 30 minutes apart.
- No impact may occur within 150 mm of any other impact. The requirement within FMVSS201 has been increased to 200mm between points for what is believed to be technical reasons.

The distance between impacts is the distance between the centres of the target circle for each impact, measured along the vehicle interior.

- Examination of collateral damage

If other impacts are to be carried out within a 200mm radius of a previous impact point then any structural damage around and beneath the target point must be assessed. If damage is noted and full repair is not possible then no further adjacent impacts should be performed within the area of damage extended by 200mm from the target point. Tests at the adjacent points would have to be performed in a different vehicle.

Note – the chin of the headform can contact parts of the vehicle structure 150mm from the contact point.

Damage assessment

- If any trim or padding has been permanently deformed or show signs of elastic distortion, including attachment points within a 100mm radius of the target points then the padding must be replaced for adjacent tests. *The 100 mm radius could be increased if it is considered that the damage might affect the stiffness of the padding structure in any adjacent impact. All padding and trim attachment points should be examined and assessed for possible collateral stiffness.*

- The extent of damage/deformation to structures underlying the padding should be assessed. If any permanent damage is detected the limit of the damage must then be quantified. No adjacent test should be carried out within 200 mm of the edge of the identified structural damage.

6.1.8 **Vehicle preparation, including support**

The vehicle should be rigidly supported off its wheels with the principle axes of the vehicle being aligned with ground reference co-ordinates. The maximum displacement of the exterior surface of the vehicle, along the axis of the impact adjacent to the point of contact, shall not exceed 10 mm. If necessary, the exterior of the vehicle may be ‘additionally’ supported to limit exterior movement to 10 mm.

If the side window can be opened, tests should be performed with the window fully open.

6.2 Pole impact test Procedure.[♣]

The vehicle impacts a fixed 254 mm diameter rigid vertical pole at an impact speed of 29 ± 2 km/h. The pole is aligned with the centre of gravity of the head of the ES-2 dummy. In order to achieve this impact, the vehicle is placed on a carrier, which can translate freely in the direction perpendicular to the vehicle’s longitudinal vertical plane.

The impact angle should be 90° ± 3°.

The dummy’s seating position should be adjusted, if necessary, to ensure that the head presents a target through the side glazing and is not obscured by the B-pillar.

The *active system FMH tests* and *active system sub-structure FMH tests* will only be performed where the requirements of the pole impact test are satisfied. The procedure is described in Annex 2.

6.3 Performance criteria

6.3.1 **FMH Head Injury Criterion**

The Head Injury Criterion for the head-form (HIC_{FMH}) is calculated according to the following formula:-

$$\left(\frac{1}{(t_2 - t_1)} \int_{t_1}^{t_2} a\,d_t \right)^{2.5} (t_2 - t_1)$$

where ‘a’ is the resultant head-form acceleration, expressed as a multiple of ‘g’ *(the acceleration due to gravity)*, and t_1 and t_2 are any two points in time during the impact, which are separated by not more than a thirty-six millisecond time interval.

$$HIC_{dummy} = 0.75446\ HIC_{FMH} + 166.4 * 1000$$

[♣] NOTE: The pole impact test procedure is based on that specified in FMVSS201 with the ES-2 dummy. The specifications for the test procedure defined in Annex 1 have been taken from an edited version of the Euro NCAP protocol, since this also uses ES-2. Elements only used in the derivation of Euro NCAP ratings and items not appropriate for this draft procedure have been removed.

6.3.2 **Pole Test Head Injury Criterion**

In the pole impact test, the Head Injury Criterion (HIC) must not be more than 1000. The HIC is the maximum value of the expression:

$$\left(\frac{1}{(t_2 - t_1)} \int_{t_1}^{t_2} a d t \right)^{2.5} (t_2 - t_1)$$

where ‘a’ is the resultant head-form acceleration, expressed as a multiple of ‘g’ *(the acceleration due to gravity)*, and t_1 and t_2 are any two points in time during the impact, which are separated by not more than a thirty-six millisecond time interval.

7. REFERENCES

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10. EEVC Working Group 12 Technical Report. *Dummy Specified in the European Pole Test as Part of the EEVC Interior Headform Test Procedure.* June 2003.

APPENDIX – 1

Free Motion Headform test

1. LOCATION OF IMPACT POINTS

1.1 Definitions

1.1.1 Clean contact

Means a minimum of 10 degrees between any part on the face of the free motion headform and any structures that could be contacted by the face at the time of first contact. (
Figure 9)

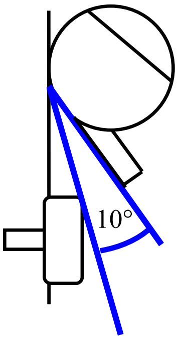


Figure 9 clean contact

1.1.2 Co-ordinate reference system

Means the terminology to be used when describing the impact vector for the free motion headform in relation to the vehicle. An orthogonal reference system consisting of a longitudinal X axis and a transverse Y axis in the same horizontal plane and a vertical Z axis through the intersection of X and Y is used to define the horizontal direction of approach of the headform. The X-Z plane is the vertical longitudinal zero plane and is parallel to the longitudinal centreline of the vehicle. The X-Y plane is the horizontal zero plane parallel to the ground. The Y-Z plane is the vertical transverse zero plane that is perpendicular to the X-Y and X-Z planes. The X coordinate is negative forward of the Y-Z plane and positive to the rear. The Y coordinate is negative to the left of the X-Z plane and positive to the right. The Z coordinate is negative below the X-Y plane and positive above it. (Figure 10).

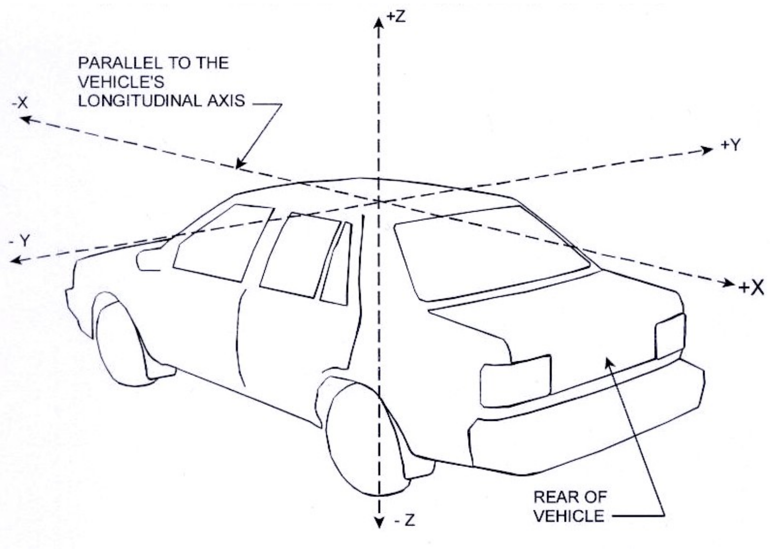


Figure 10 Orthogonal reference system

1.1.3 **Daylight opening**

Means, for openings on the side of the vehicle, other than a door opening, the locus of all points where a horizontal line, perpendicular to the vehicle longitudinal centreline, is tangent to the periphery of the opening. For openings on the front and rear of the vehicle, other than a door opening, daylight opening means the locus of all points where a horizontal line, parallel to the vehicle longitudinal centreline, is tangent to the periphery of the opening. If the horizontal line is tangent to the periphery at more than one point at any location, the most inboard point is used to determine the daylight opening.

1.1.4 **Door opening**

Means, for door openings on the side of the vehicle, the locus of all points where a horizontal line, perpendicular to the vehicle longitudinal centreline, is tangent to the periphery of the side door opening. For door openings on the back end of the vehicle, door opening means the locus of all points where a horizontal line, parallel to the vehicle longitudinal centreline, is tangent to the periphery of the back door opening. If the horizontal line is tangent to the periphery at more than one point at any location, the most inboard point is the door opening.

1.1.5 **Forehead impact zone**

Means, the part of the free motion headform surface area that is determined in accordance with the procedure set forth in Section 6.1.2.

1.1.6 **Horizontal approach angle**

Means, the angle between the X axis and the headform impact velocity vector projected onto the horizontal zero plane, measured in the horizontal zero plane in the counter-clockwise direction. A 0 degree horizontal vector and a 360 degree horizontal vector point in the positive X direction; a 90 degree horizontal vector points in the positive Y direction; a 180 degree horizontal vector points in the negative X direction; and a 270 horizontal degree vector points in the negative Y direction.

1.1.7 Free motion headform (FMH)

Means, a test device which conforms to the specifications of Section 2 of this Appendix.

1.1.8 Midsagittal plane of a dummy

Means, a longitudinal vertical plane passing through the centre of the dummy such that it divides the dummy into two equal mirror images and, for the purposes of this document, passes through the seating reference point of a designated seating position.

1.1.9 Pillars

Means any structure, excluding glazing and the vertical portion of door window frames, but including accompanying mouldings, attached components such as safety belt anchorages and coat hooks, which (1) supports either a roof or any other structure (such as a roll-bar) that is above the driver's head, or (2) is located along the side edge of a window.

(a) A-pillar means any pillar that is entirely forward of a transverse vertical plane passing through the seating reference point of the driver's seat. The top of the A-pillar is defined as being the point adjacent to the windscreen at the most rearward or highest point of the glazing, where there is a connection with the header/side rails and roof panel.
(b) B-pillar means the forward most pillar on each side of the vehicle that is, in whole or part, rearward of a transverse vertical plane passing through the seating reference point of the driver's seat, unless there is only one pillar rearward of that plane and it is also a rearmost pillar.
(c) Other pillar means any pillar which is not an A-pillar, a B-pillar, or a rearmost pillar.
(d) Rearmost pillar means the pillars at the rear of the vehicle which are most rearward from the seating reference point.

1.1.10 Seat belt anchorage

Means, any component involved in transferring seat belt loads to the vehicle structure, including, but not limited to, the attachment hardware, but excluding webbing or straps, seat frames, seat pedestals, and the vehicle structure itself, whose failure causes separation of the belt from the vehicle structure.

1.1.11 Seating reference point

Means, the unique design H-point which establishes the rearmost normal design driving or riding position of each designated seating position, which includes consideration of all modes of adjustment, horizontal, vertical, and tilt, in a vehicle.

1.1.12 Sliding door track

Means, a track structure along the upper edge of a side door opening that secures the door in the closed position and guides the door when moving to and from the open position.

1.1.13 Vertical approach angle

Means, the angle between the horizontal plane and the velocity vector, measured in the midsagittal plane of the headform. A 0 degree vertical vector coincides with the horizontal X-Y plane and a vertical vector of greater than 0 degrees makes an upward angle with that plane.

1.1.14 **Windscreen trim**

Means a moulding of any material between the windscreen glazing and the exterior roof surface, including material that covers a part of either the windscreen glazing and the exterior roof surface.

1.1.15 **Active Head Protection system**

Means, an air bag or active padding system that is deployed from a concealed part of the vehicle very early in an impact to protect the head of the occupant from internal or external ‘hard’ contacts.

1.2 Definition of Targets

1.2.1 **Target circle**

The area of the vehicle to be impacted by the headform is marked with a solid circle 12.5 mm in diameter, centred on the targets specified in Section 1.3 using any transferable opaque colouring medium.

1.2.2 **Location of head centres of gravity (Front outboard designated seating positions)**

Suffix ‘f’ relates to front seat positions e.g. CG-R_f

1.2.2.1 Location of rearmost CG-R_f

For front outboard designated seating positions, the head centre of gravity with the seat in its rearmost normal design driving or riding position (CG-R_f) is located 205 mm rearward and 680 mm upward from the seating reference point. If the seat is adjustable for height, it should be in its lowest normally used position. (Figure 13)

1.2.2.2 Location of forward most CG-F_f

For front outboard designated seating positions, the head centre of gravity is located 70 mm rearward and 580 mm upward from the seating H-point with the seat in its forward most adjustment position. If the seat is adjustable for height, it should be in its highest normally used position. *[NB this is subject to current review based on the seating position of a 5th percentile female driver]* (Figure 13)

1.2.3 **Location of head centres of gravity (Rear outboard designated seating positions)**

Suffix ‘r’ relates to ANY rear seating position e.g. CG-R_r

1.2.3.1 Location of rearmost CG-R_r

For rear outboard designated seating positions, the head centre of gravity with the seat in its rearmost normal design position (CG-R_f) is located 205 mm rearward and 680 mm upward from the seating reference point. If the seat is adjustable for height, it should be in its lowest normally used position. (Figure 16)

1.2.3.2 Location of forward most CG-F_r

For rear outboard designated seating positions, the head centre of gravity is located 70 mm rearward and 580 mm upward from the seating H-point with the seat in its forward most adjustment position. If the seat is adjustable for height, it should be in its highest normally used position. *[NB this is subject to current review based on the seating position of a 5th percentile female driver]*(Figure 16)

1.3 Target Locations

Two methods of deriving target points are proposed. The former, Method 1, is to be used if the vehicle manufacture does not supply information on the location of the target points and is extracted from FMVSS201. If the manufacture does supply information on the target points, as defined in FMVSS201 then Method 2 is recommended.

(a) The target locations specified in Sections 1.3.1 to 1.3.7 and are located on both sides of the vehicle and, except as specified in (b), are determined using the procedures specified in those paragraphs.

(b) For each target location – if it is not possible to contact the target point with the forehead impact zone of the free motion headform, with the side glazing closed, for any of the headform orientations within the range specified in Section 4.1.7, then that target is moved to any location within a sphere with a radius of 25 mm, centred on the centre of the original target, which the forehead impact zone can contact. The radius of the sphere may be increased by 25 mm increments until the sphere contains at least one point that can be contacted at one or more combination of angles.

(c) Targets lying outside the zones defined in 1.4 are not included in those to be tested for side impact.

1.3.1 A-pillar targets (front seat positions)

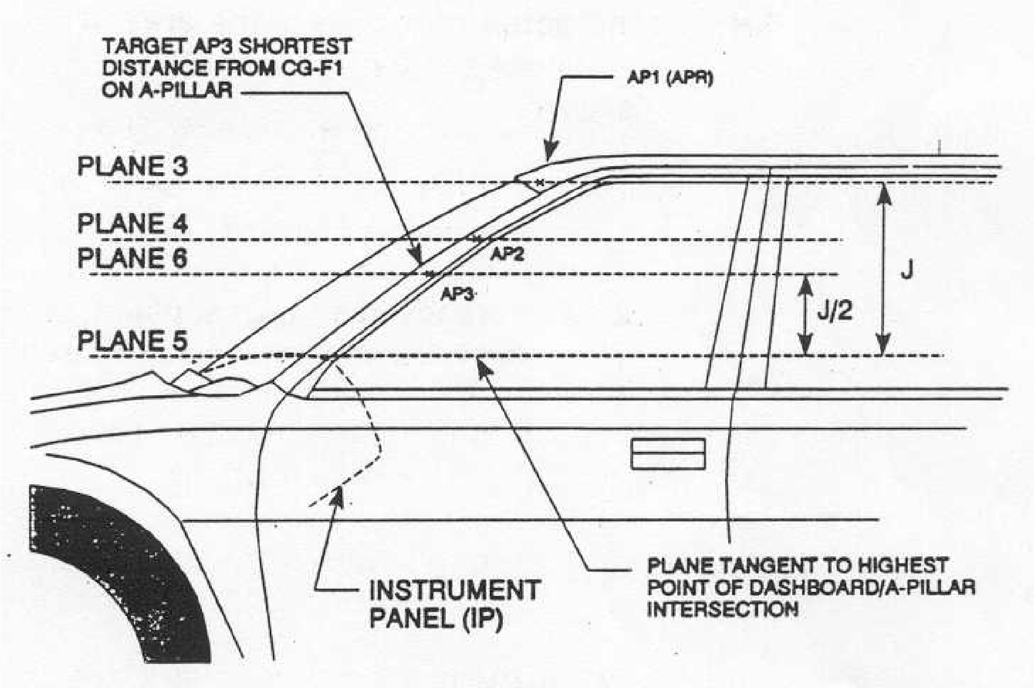


Figure 11 ‘A Pillar’ targets

1.3.1.1 A-pillar reference point and target AP1

On the vehicle exterior, locate a transverse vertical plane (Plane 1) which contacts the rearmost point of the windscreen trim.

Note: if there are two or more pillars each side according to the definition of A-pillar (Appendix 1, section 1.1.1) and the door is attached to or closes onto the rearmost of these pillars, all of the glazing forward of this pillar may be treated as a divided windscreen for the purposes of defining plane 1. The intersection of Plane 1 and the vehicle exterior surface is Line 1. Measuring along the vehicle exterior surface, locate a point (Point 1) on Line 1 that is 125 mm inboard of the intersection of Line 1 and a vertical plane tangent to the vehicle at the outboardmost point on Line 1 with the vehicle side door open. Measuring along the vehicle exterior surface in a longitudinal vertical plane (Plane 2) passing through Point 1, locate a point (Point 2) 50 mm rearward of Point 1. Locate the A-pillar reference point (Point APR) at the intersection of the interior roof surface and a line that is perpendicular to the vehicle exterior surface at Point 2. Target AP1 is located at point APR.

1.3.1.2 Target AP2

Locate the horizontal plane (Plane 3) which intersects point APR. Locate the horizontal plane (Plane 4) which is 88 mm below Plane 3. Target AP2 is the point in Plane 4 and on the A-pillar which is closest to CG-R_f for the nearest seating position.

1.3.1.3 Target AP3

Locate the horizontal plane (Plane 5) containing the highest point at the intersection of the dashboard and the A-pillar. Locate a horizontal plane (Plane 6) half-way between Plane 3 and Plane 5. Target AP3 is the point on Plane 6 and the A-pillar which is closest to CG-F_f for the nearest seating position.

1.3.2 **B-pillar targets (front seat positions)**

1.3.2.1 B-pillar reference point and target BP1

1. Locate the longitudinal vertical plane C at the leftmost point at which a transverse vertical plane, located 300 mm rearward of the A-pillar reference point described in 1.3.1.1, contacts the interior roof (including trim).
2. Locate the longitudinal vertical plane D at the rightmost point at which a transverse vertical plane, located 300 mm rearward of the A-pillar reference point described in 1.3.1.1, contacts the interior roof (including trim)
3. Measure the horizontal distance (D2) between Plane C and Plane D.
4. Longitudinal vertical planes G and H are located at a distance of (0.35*D2) to the left and right respectively of the vehicle longitudinal centreline, measured horizontally.
5. Locate the point (Point 3) on the vehicle interior at the intersection of the horizontal plane passing through the highest point of the forward most door opening and the centreline of the width of the B-pillar, as viewed laterally. Locate a transverse vertical plane (Plane 7) which passes through Point 3. Locate the point (Point 4) at the intersection of the interior roof surface, Plane 7, and plane G or H, as appropriate, defining the nearest edge of the upper roof. The B-pillar reference point (Point BPR) is the point located at the middle of the line from Point 3 to Point 4 in Plane 7, measured along the vehicle interior surface. Target BP1 is located at Point BPR.

1.3.2.2 Target BP2

If a seat belt anchorage is located on the B-pillar, Target BP2 is located at any point on the anchorage. For the test the anchorage will be placed in the position that is most likely to provide additional support to the structure being tested. Where required re-positioning of the anchorage is permissible in order satisfy spacing requirements between impact points.

1.3.2.3 Target BP3

Locate a horizontal plane (Plane 8) which intersects Point BPR. Locate a horizontal plane (Plane 9) which passes through the lowest point of the daylight opening forward of the pillar. Locate a horizontal plane (Plane 10) half-way between Plane 8 and Plane 9. Target BP3 is the point located in Plane 10 and on the interior surface of the B-pillar, which is closest to CG-R_f for the nearest seating position.

1.3.2.4 Target BP4

Locate a horizontal plane (Plane 11) half-way between Plane 9 and Plane 10. Target BP4 is the point located in Plane 11 and on the interior surface of the B-pillar which is closest to CG-R_f for the nearest seating position.

1.3.3 **Side roof targets (front seat positions)**

1.3.3.1 Target SR1

Locate a transverse vertical plane (Plane 25) 150 mm rearward of Point APR. Locate the point (Point 11) at the intersection of Plane 25 and the upper edge of the forward most door opening. Locate the point (Point 12) at the intersection of the interior roof surface, Plane 25 and the plane, described in 1.3.6.1 7, defining the nearest edge of the upper roof. Target SR1 is located at the middle of the line between Point 11 and Point 12 in Plane 25, measured along the vehicle interior.

1.3.3.2 Target SR2

Locate a transverse vertical plane (Plane 26) 300 mm rearward of the APR or 300 mm forward of the BPR (or RPR in vehicles with no B-pillar). Locate the point (Point 13) at the intersection of Plane 26 and the upper edge of the forward most door opening. Locate the point (Point 14) at the intersection of the interior roof surface, Plane 26 and the plane, described in 1.3.6.1 7, defining the nearest edge of the upper roof. Target SR2 is located at the middle of the line between Point 13 and Point 14 in Plane 26, measured along the vehicle interior.

1.3.3.3 Other side rail target (target SR3)

1. Except as provided in 4 below, target SR3 is located in accordance with this paragraph. Locate a transverse vertical plane (Plane 27) 150 mm rearward of either Point BPR or Point OPR. Locate the point (Point 15) as provided in either 2 or 3 below, as appropriate. Locate the point (Point 16) at the intersection of the interior roof surface, Plane 27 and the plane, described in 1.3.6.1 7, defining the nearest edge of the upper roof. Target SR3 is located at the middle of the line between Point 15 and Point 16 in Plane 27, measured along the vehicle interior surface.

2. If Plane 27 intersects a door or daylight opening, the Point 15 is located at the intersection of Plane 27 and the upper edge of the door opening or daylight opening.

3. If Plane 27 does not intersect a door or daylight opening, the Point 15 is located on the vehicle interior at the intersection of Plane 27 and the horizontal plane through the highest point of the door or daylight opening nearest Plane 27. If the adjacent door(s) or daylight opening(s) are equidistant to Plane 27, Point 15 is located on the vehicle interior at the intersection of Plane 27 and either horizontal plane through the highest point of each door or daylight opening.

4. Except as provided in 5 below, if a grab handle is located on the side rail, target SR3 is located at any point on the anchorage of the grab-handle. Folding grab-handles are in their stowed position for testing.

5. If a seat belt anchorage is located on the side rail, target SR3 is located at any point on the anchorage.

1.3.3.4 Sliding door track target (target SD)

Locate the transverse vertical plane (Plane 29) passing through the middle of the widest opening of the sliding door, measured horizontally and parallel to the vehicle longitudinal centreline. Locate the point (Point 19) at the intersection of the surface of the upper vehicle interior, Plane 29 and the plane, described in 1.3.6.1 7, defining the nearest edge of the upper roof. Locate the point (Point 20) at the intersection of Plane 29 and the upper edge of the sliding door opening. Target SD is located at the middle of the line between Point 19 and Point 20 in Plane 29, measured along the vehicle interior.

1.3.4 **B-pillar targets (rear seat positions)**

1.3.4.1 Target BP5

Locate a horizontal plane (Plane 8) which intersects Point BPR. Locate a horizontal plane (Plane 9) which passes through the lowest point of the daylight opening forward of the pillar. Locate a horizontal plane (Plane 10) half-way between Plane 8 and Plane 9. Target BP5 is the point located in Plane 10 and on the interior surface of the B-pillar, which is closest to CG-R_r for the nearest seating position.

1.3.4.2 Target BP6

Locate a horizontal plane (Plane 11) half-way between Plane 9 and Plane 10. Target BP4 is the point located in Plane 11 and on the interior surface of the B-pillar which is closest to CG-R_r for the nearest seating position.

1.3.5 **Other pillar targets (rear seat positions)**

1.3.5.1 Target OP1

1. Except as provided in 2 below, target OP1 is located in accordance with this paragraph. Locate the point (Point 5), on the vehicle interior, at the intersection of the horizontal plane through the highest point of the highest adjacent door opening or daylight opening (if no adjacent door opening) and the centre line of the width of the other pillar, as

viewed laterally. Locate a transverse vertical plane (Plane 12) passing through Point 5. Locate the point (Point 6) at the intersection of the interior roof surface, Plane 12 and the plane, described in *1.3.2.1 4*, defining the nearest edge of the upper roof. The other pillar reference point (Point OPR) is the point located at the middle of the line between Point 5 and Point 6 in Plane 12, measured along the vehicle interior surface. Target OP1 is located at Point OPR.

2. If a seat belt anchorage is located on the pillar, Target OP1 is any point on the anchorage.

1.3.5.2 Target OP2

Locate the horizontal plane (Plane 13) intersecting Point OPR. Locate a horizontal plane (Plane 14) passing through the lowest point of the daylight opening forward of the pillar. Locate a horizontal plane (Plane 15) half-way between Plane 13 and Plane 14. Target OP2 is the point located on the interior surface of the pillar at the intersection of Plane 15 and the centre line of the width of the pillar, as viewed laterally.

1.3.6 **Rearmost pillar targets (rear seat positions)**

1.3.6.1 Target RP1

1. Locate the transverse vertical plane A at the forwardmost point where it contacts the interior roof (including trim) at the vehicle centre line.

2. Locate the transverse vertical plane B at the rearmost point where it contacts the interior roof (including trim) at the vehicle centre line. Measure the horizontal distance (D1) between Plane A and Plane B.

3. Locate the vertical longitudinal plane C at the leftmost point at which a vertical transverse plane, located 300 mm rearward of the A-pillar reference point described in 1.3.1.1, contacts the interior roof (including trim).

4. Locate the vertical longitudinal plane D at the rightmost point at which a vertical transverse plane, located 300 mm rearward of the A-pillar reference point described in 1.3.1.1, contacts the interior roof (including trim).

5. Measure the horizontal distance (D2) between Plane C and Plane D.

6. Locate a point (Point M) on the interior roof surface, midway between Plane A and Plane B along the vehicle longitudinal centre line.

7. The upper roof zone is the area of the vehicle upper interior surface bounded by four planes. A transverse vertical plane E located at a distance of (.35 D1) forward of Point M and a transverse vertical plane F located at a distance of (.35 D1) rearward of Point M, measured horizontally. And, a longitudinal vertical plane G located at a distance of (.35 D2) to the left of Point M and a longitudinal vertical plane H located at a distance of (.35 D2) to the right of Point M, measured horizontally.

Locate the point (Point 7) at the corner of the upper roof nearest to the pillar. The distance between Point M, as described in 6 above, and Point 7, as measured along the vehicle interior surface, is D. Extend the line from Point M to Point 7 along the vehicle interior surface in the same vertical plane by (3*D/7) beyond Point 7 or until the edge of a daylight opening, whichever comes first, to locate Point 8. The rearmost pillar reference point (Point RPR) is at the midpoint of the line between Point 7 and Point 8, measured along the vehicle interior. Target RP1 is located at Point RPR.

1.3.6.2 Target RP2

8. Except as provided in 3 below, target RP2 is located in accordance with this paragraph. Locate the horizontal plane (Plane 16) through Point RPR.

9. 2. Locate the horizontal plane (Plane 17) 150 mm below Plane 16, target RP2 is located in Plane 17 and on the pillar at the location closest to CG-R_r for the nearest designated seating position.

10. If a seat belt anchorage is located on the pillar, Target RP2 is any point on the anchorage.

1.3.7 **Side roof targets (rear seat positions)**

1. Except as provided in 4 below, target SR3 is located in accordance with this paragraph. Locate a transverse vertical plane (Plane 27) 150 mm rearward of either Point BPR or Point OPR. Locate the point (Point 15) as provided in either *(2)* or *(3)* below, as appropriate. Locate the point (Point 16) at the intersection of the interior roof surface, Plane 27 and the plane, described in *1.3.6.1 7*, defining the nearest edge of the upper roof. Target SR3 is located at the middle of the line between Point 15 and Point 16 in Plane 27, measured along the vehicle interior surface.

2. If Plane 27 intersects a door or daylight opening, the Point 15 is located at the intersection of Plane 27 and the upper edge of the door opening or daylight opening.

3. If Plane 27 does not intersect a door or daylight opening, the Point 15 is located on the vehicle interior at the intersection of Plane 27 and the horizontal plane through the highest point of the door or daylight opening nearest Plane 27. If the adjacent door(s) or daylight opening(s) are equidistant to Plane 27, Point 15 is located on the vehicle interior at the intersection of Plane 27 and either horizontal plane through the highest point of each door or daylight opening.

4. Except as provided in 5 below, if a grab handle is located on the side rail, target SR3 is located at any point on the anchorage of the grab-handle. Folding grab-handles are in their stowed position for testing.

5. If a seat belt anchorage is located on the side rail, target SR3 is located at any point on the anchorage.

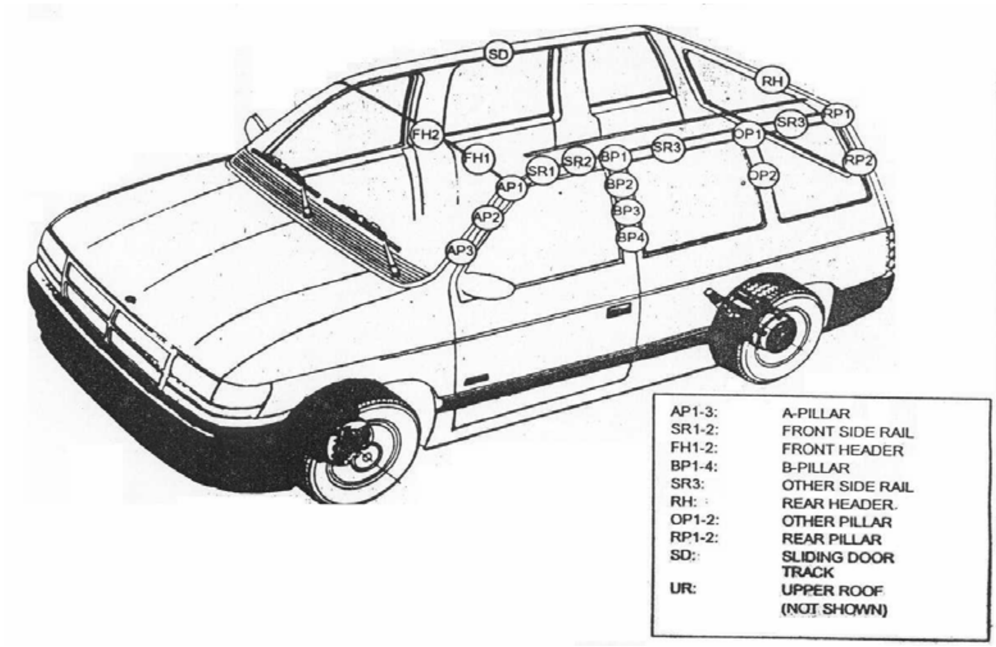


Figure 12 Defined targets, from FMVSS 201.

1.3.8 **Worst Case locations**

If there is a worst case location on the structure containing any of the defined targets and between those targets, with the exception of the seat belt anchorage target, or any other structure other than glazing within the contact zone defined in 1.4, then the test authority may test the “worst case” location instead, provided the FMH can make contact with this location with the side glazing closed.

1.4 TARGET Limitation Zone Definition

1.4.1 **Front Seating Positions**

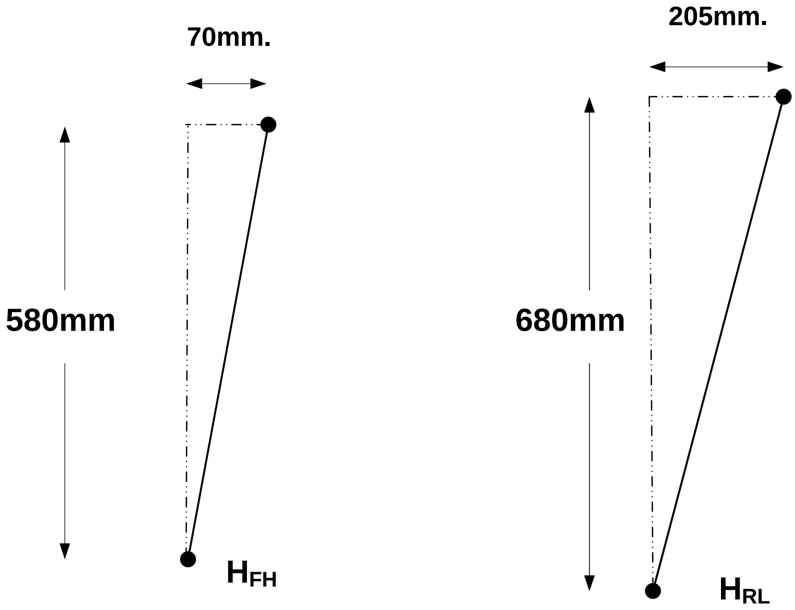
1.4.1.1 For each front outboard designated seating position locate two head centre of gravity positions, CG-F_f and CG-R_f

1.4.1.2 CG-F_f is located 70 mm rearward and 580 mm upward from the seating H-point, as determined by the H-point Manikin procedure as described in ECE Regulation 95, with the seat in its foremost normal design driving or riding position. If the seat is adjustable for height, it should be in its highest normally used position. (Figure 13).

1.4.1.3 CG-R_f is located 205 mm rearward and 680 mm upward from the seating reference point (R-point), with the seat in its rearmost normal design driving or riding position. If the seat is adjustable for height, it should be in its lowest normally used position. (Figure 13).

1.4.1.4 Locate vertical plane P, passing through CG-F_f, which is 45° from the {fore-aft} mid sagittal plane of the dummy. (Figure 14).

1.4.1.5 Locate vertical plane Q, passing through CG-R_f, which is 135° from the {fore-aft} mid sagittal plane of the dummy.



H_{FH} is the H-point at the foremost and highest normal driving or riding position
H_{RL} is the H-point at the rearmost lowest normally used driving or riding position

Figure 13 CG-F_f, CG-R_f and CG-F_r, CG-R_r locations

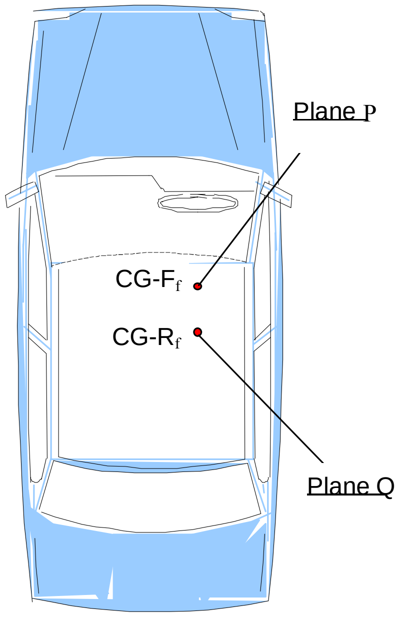


Figure 14 Plan view of planes

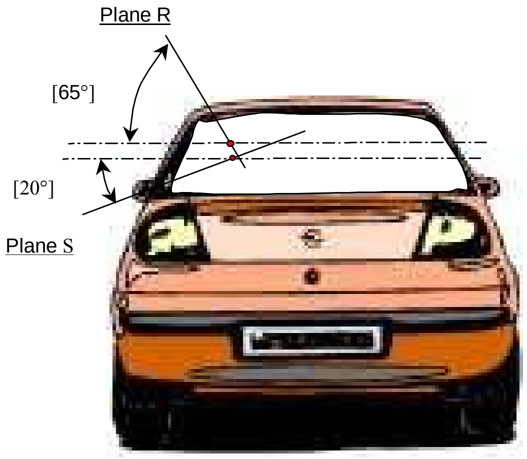


Figure 15 Front view of planes

1.4.1.6 Locate plane R, passing through a horizontal axis through CG-R_f at an angle of 65° from the horizontal plane. (Figure 15)

1.4.1.7 Locate plane S, passing through a horizontal axis through CG-F_f at an angle of -20° from the horizontal plane. (Figure 15)

1.4.1.8 The potential impact locations are located on the inner surfaces of the vehicle within the zone bounded by the line of intersection of these four planes.

1.4.2 **Non Front Seating Positions**

If the rear seats are adjustable, like front seats (especially the seatback angle) the CoG will be defined as for the front seats.

1.4.2.1 For the rear seat(s), the forward and rearward extent of the potential contact zones are limited by two vertical planes, one set at 45° forward of the lateral axis and passing through CG-R_F (Plane T) and the other set at 45° rearward of lateral passing through CG-R_R (Plane U), where CG-R_F and CG-R_R are the locations of the centres of gravity of the small female and large male sitting in the rear struck side seating position, Figure 16.

1.4.2.2 In order to determine the points CG-R_F and CG-R_R for non-front seating positions the H-point manikin, as defined in ECE R94, should be used. Locations for the CG-R_F and CG-R_R are defined with respect to the torso angle, as measured by the H-point manikin. For the 95th percentile CG-R_R lies 688mm along the torso line, above the H point, and 176mm perpendicularly forward of the torso plane. For the 5th percentile CG-R_F lies 562mm along the torso plane and 68 mm forwards of it, Figure **17** - In small cars the 95th percentile CG-R_R may be located outside the car. In this case the CG-R_R should be lowered so to a position within the vehicle [100mm] below the inside surface of the roof vertically below CG-R_R.

1.4.2.3 If the rear seats are adjustable in two different positions the rearmost normal design driving or riding position will be used for the 95th percentile male and the most forward normal design driving or riding position for the 5th percentile female. If the rear seats are adjustable like the front seat (especially the seatback angle) the CoG will be defined like for front seats.

1.4.2.4 If the rear seat were adjustable for the fore-aft position, CG-RF would be determined with the H-point manikin positioned with the seat in the fully forward position and CG-RF for the fully rearward position, in the normal design riding positions. Where the seat back is adjustable, the H-point manikin will be positioned with the torso angle seat to the design position recommended by the vehicle manufacturer.

1.4.2.5 Similarly the upper and lower limits for the contact zone are created by planes passing through fore-aft horizontal axes through CG-RF and CG-RR (not shown) equivalent to that for the front seating positions.

1.4.2.6 In vehicle with low roofs, CG-RR may be theoretically positioned outside of the vehicle. In such cases the location of CG-RR shall be lowered until there is a vertical clearance of [100mm] between CG-RR and the interior surface of the roof.

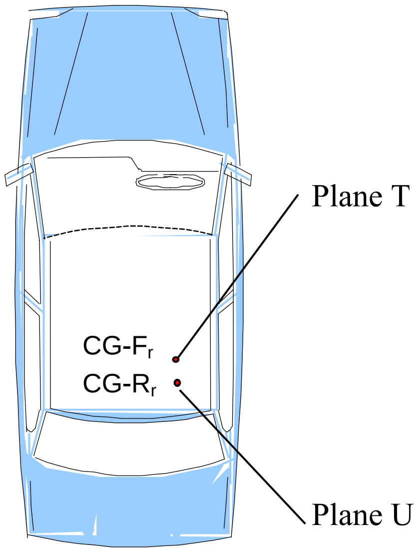
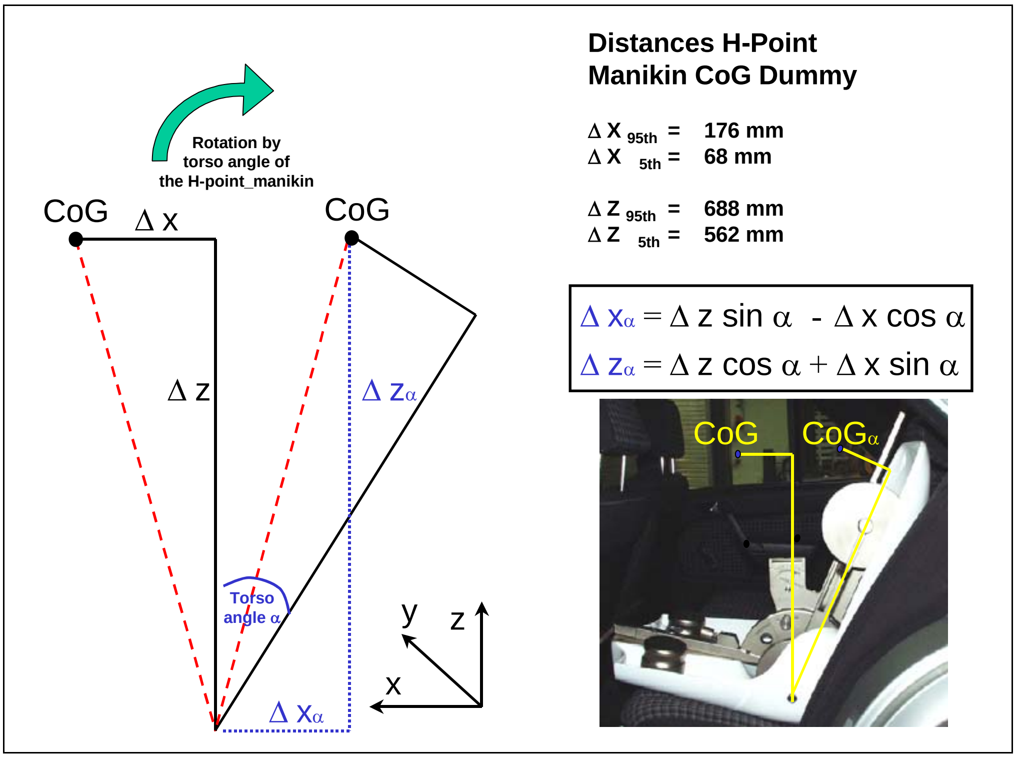


Figure 16 Plan view of planes – Rear seating position



Distances H-Point Manikin CoG Dummy

ΔX_{95th} = 176 mm
ΔX_{5th} = 68 mm

ΔZ_{95th} = 688 mm
ΔZ_{5th} = 562 mm

$$\Delta x_\alpha = \Delta z \sin\alpha - \Delta x \cos\alpha$$
$$\Delta z_\alpha = \Delta z \cos\alpha + \Delta x \sin\alpha$$

Figure 17 CoG using the H-point manikin, non-front seating positions

1.4.3 **Additional exemption area for low velocity testing for vehicles equipped with a deployable protection system, all struck side seating positions.**

1.4.3.1 Locate the periphery of the stowed system projected perpendicularly onto the vehicle interior surface, including mounting and inflation components but excluding any cover or covers that are not deployed or displaced, when the head protection system is deployed.

1.4.3.2 Define an area in the inside of the vehicle 50 mm from the periphery defined in Section 1.4.1.1.

1.4.3.3 Target points found within this area can be impacted at the lower impact velocity defined in Section 6.1.4.

1.5 TARGET Edge Exclusion Zone Definition, (EEZ)

Specific surfaces, within the area bounded by Planes P, Q, R and S, are defined in which impact targets should not be located. The EEZ areas are defined by the use of a 165 mm spherical ball-and applied to every area defined by planes P, Q, R, S.

1.5.1 Place a 165 mm diameter sphere against the vehicles glazed area and the adjacent interior surface, with the window closed and door shut. The surface which cannot be contacted by the spherical ball shall not be tested (EEZ).

1.5.2 The surfaces between the scribed line and the glazing forms the EEZ in which no targets are located, as shown in Figure 18.

1.5.3 Some parts of the defined structure may be obscured from head contact by other vehicle trim, e.g. Fascia or fixed seats. Areas so obscured will not be tested with the head-form.

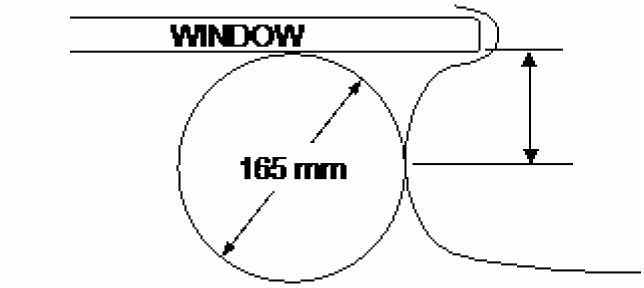


Figure 18 Derivation of Edge Exclusion Zone

2. FMH – TEST DEVICE

2.1 Apparatus

This section describes the anthropomorphic test device (ATD) that is to be used for testing vehicle upper interior components. The device is a modified head component of the Part 572, Subpart E – Hybrid III Test Dummy that is used by the National Highway Traffic Safety Administration (NHTSA), U.S. Department of Transportation, for compliance testing of motor vehicles and motor vehicle equipment with motor vehicle safety standards. The ATD is a free-motion-headform (FMH) that is depicted in the U.S. Code of Federal

Regulations – 49 CFR Chapter V (10-1-95 edition); Part 572 – Anthropomorphic Test Devices; Subpart L – Free Motion Headform.

2.2 Apparatus description.

2.2.1 Drawings

The drawings and specifications referred to in paragraph 2.3 of this section are incorporated in the FMH by reference. These materials are thereby made part of this regulation. Copies of the materials may be inspected at NHTSA’s Docket Section, 400 Seventh Street, S.W., room 5109, Washington, DC, U.S.A. or at the Office of the Federal Register, 800 North Capitol Street, N.W., Suite 700, Washington, DC, U.S.A.

2.2.2 Incorporated material:

Drawing number 92041-001, “Head Form Assembly,” (November 30, 1992); drawing number 92041-002, “Skull Assembly,” (November 30, 1992); drawing number 92041-003, “Skull Cap Plate Assembly,” (November 30, 1992); drawing number 92041-004, “Skull Cap Plate,” (November 30, 1992); drawing number 92041-005, “Threaded Pin,” (November 30, 1992); drawing number 92041-006, “Hex Nut,” (November 30, 1992); drawing number 92041-008, “Head Skin without Nose,” (November 30, 1992, as amended March 6, 1995); drawing number 92041-009, “Six-Axis Load Cell Simulator Assembly,” (November 30, 1992); drawing number 92041-011, “Head Ballast Weight,” (November 30, 1992); drawing number 92041-018, “Head Form Bill of Materials,” (November 30, 1992); drawing number 78051-148, “Skull-Head (cast) Hybrid III,” (May 20, 1978, as amended August 17, 1978); drawing number 78051-228/78051-229, “Skin-Hybrid III,” (May 20, 1978, as amended through September 24, 1979); drawing number 78051-339, “Pivot Pin – Neck Transducer,” (May 20, 1978, as amended May 14, 1986); drawing number 78051-372, “Vinyl Skin Formulation Hybrid III,” (May 20, 1978); and drawing number C-1797, “Neck Blank, (August 1, 1989); drawing number SA572-S4, “Accelerometer Specification,” (November 30, 1992), are available from Reprographic Technologies, 9000 Virginia Manor Road, Beltsville, MD 20705.

2.2.3 Users manual.

A user’s manual entitled “Free-Motion Headform User’s Manual,” version 2, March 1995, is available from NHTSA’s Docket Section at the address in paragraph 2.1. of this section.

2.2.4 Instrumentation – SAE J211

The U.S. SAE Recommended Practice J211, OCT 1988, “Instrumentation for Impact Tests,” Class 1000, is available from the Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096, U.S.A.

2.2.5 General descriptions:

The free motion headform consists of the component assembly which is shown in drawings 92041-001 (incorporated by reference; see § 572.100), 92041-002 (incorporated by reference; see § 572.100), 92041-003 (incorporated by reference; see § 572.100), 92041-004 (incorporated by reference; see § 572.100), 92041-005 (incorporated by reference; see § 572.100), 92041-006 (incorporated by reference; see § 572.100), 92041-008 (incorporated by reference; see § 572.100), 92041-009 (incorporated by reference; see § 572.100), 92041-011 (incorporated by reference; see § 572.100), 78051-148 (incorporated by reference; see §

572.100), 78051-228/78051-229 (incorporated by reference; see § 572.100), 78051-339 (incorporated by reference; see § 572.100), 78051-372 (incorporated by reference; see § 572.100), C-1797 (incorporated by reference; see § 572.100), and SA572-S4 (incorporated by reference; see § 572.100).

Disassembly, inspection, and assembly procedures, and sign convention for the signal outputs of the free motion headform accelerometers, are set forth in the Free-Motion Headform User's Manual (incorporated by reference; see § 572.100).

The structural properties of the headform are such that it conforms to this section in every respect both before and after being used in the test specified in the ECE Regulation No. 21.

The outputs of accelerometers installed in the headform are recorded in individual data channels that conform to the requirements of the U.S. SAE Recommended Practice J211, OCT 1988, "Instrumentation for Impact Tests," Class 1000 (incorporated by reference; see § 572.100).

2.3 Headform drop test – calibration test.

2.3.1 **Performance requirements.**

When the headform is dropped from a height of 376 mm in accordance with paragraph 2.3.2 of this section, the peak resultant accelerations at the location of the accelerometers mounted in the headform as shown in drawing 92041-001 (incorporated by reference; see § 572.100) shall not be less than 225g, and not more than 275g. The acceleration/time curve for the test shall be unimodal to the extent that oscillations occurring after the main acceleration pulse are less than ten percent (zero to peak) of the main pulse. The lateral acceleration vector shall not exceed 15g (zero to peak).

2.3.2 **Test procedure.**

Soak the headform in a test environment at any temperature between 19 degrees C. to 26 degrees C. and at a relative humidity from 10 percent to 70 percent for a period of at least four hours prior to its use in a test.

Clean the headform's skin surface and the surface of the impact plate with 1,1,1 Trichloroethane or equivalent.

Suspend the headform as shown in Figure 50 of the U.S. 49 CFR, Part 752.102. Position the forehead below the chin such that the skull cap plate is at an angle of 28.5 ± 0.5 degrees with the impact surface when the midsagittal plane is vertical.

Drop the headform from the specified height by means that ensure instant release onto a rigidly supported flat horizontal steel plate, which is 51 mm thick and 508 mm square. The plate shall have a clean, dry surface and any microfinish of not less than 0.2 microns and not more than 2.0 microns.

Allow at least 3 hours between successive tests on the same headform.

2.5 Test conditions and instrumentation.

Headform accelerometers shall have dimensions, response characteristics, and sensitive mass locations specified in drawing SA572-S4 (incorporated by reference; see § 572.100) and be mounted in the headform as shown in drawing 92041-001 (incorporated by reference; see § 572.100).

The outputs of accelerometers installed in the headform are recorded in individual data channels that conform to the requirements of SAE Recommended Practice J211, OCT 1988, "Instrumentation for Impact Tests," Class 1000 (incorporated by reference; see § 572.100).

Co-ordinate signs for instrumentation polarity conform to the sign convention shown in the Free-Motion Headform User's Manual (incorporated by reference; see § 572.100).

The mountings for accelerometers shall have no resonant frequency within a range of 3 times the frequency range of the applicable channel class.

2.6 Facility certification

It is important that inter test house variability is kept to a minimum. It is suggested that a systems certification test be developed and carried out which would include the evaluation of the launch facility, headform, instrumentation and data processing in a very repeatable and reproducible manner. No proposals are made describing such a test.

Annex – 1

POLE SIDE IMPACT TEST ♣

1. VEHICLE PREPARATION

The vehicle should be prepared as specified in ECE Regulation R95.

1.1 Impact location

The impact reference line is a line on the striking side of the vehicle, on the exterior of the vehicle, where a transverse vertical plane passes through the centre of gravity of the head of the dummy seated in accordance with Section 1.2.1.

1.2 Overview of settings

The seat should be positioned in the mid adjustment position and at the lowest vertical adjustment

1.2.1 **Dummy positioning**

The ES-2 dummy should be set up according to procedures defined in the ECE Regulation R95, with both arms of the dummy placed at the click stops corresponding to 40° angle between the arms and the torso reference line

1.2.1.1 Position of the head

1. Locate the horizontal plane passing through the dummy head centre of gravity. Identify the rearmost point on the dummy head in that plane. Construct a line in the plane that intersects the front door daylight opening at the same horizontal location and is perpendicular to the longitudinal vehicle centreline. Measure the longitudinal distance between the rearmost point on the dummy head and this line (see Appendix 1, section1.1.3). The door daylight opening must be measured when the door is closed.

2. If the distance is less than 50 mm or the point is not forward of the line, then the seat and/or dummy position shall be adjusted as follows. First, the seat back angle is adjusted, a maximum of 5 degrees, until a 50 mm distance is achieved. If this is not sufficient to produce the 50 mm distance, the seat is moved forward until the 50 mm distance is achieved or until the knees of the dummy contact the dashboard or knee bolster whichever comes first. If the required distance cannot be achieved through movement of the seat, the seatback angle shall be adjusted even further forward until the 50 mm distance is obtained or until the seat back is in its full upright locking position.

3. After positioning the dummy measure and record the dummy position and determine the impact location as described in Section 1.1.

♣ *The principles of the pole impact test procedure are based on the EuroNCAP protocol, which is based on FMVSS 201. Whereas FMVSS201 uses an adapted US SID dummy the EuroNCAP procedure used the EuroSID dummy. The EuroNCAP test procedure has been edited and simplified for the purposes of this document by removing the elements specific to EuroNCAP.*

1.3 Carrier

The test vehicle shall be placed on a carrier which has a horizontal flat surface with a sufficiently large area to allow unobstructed longitudinal displacement of the vehicle of about 1000 mm and rotation of the vehicle during the deformation phase of the impact.

To minimise effects of friction between the tyres of the test vehicle and the surface of the carrier this friction is reduced to a minimum by placing the vehicle with each tyre on two sheets of PTFE.

To avoid vehicle movement prior to the impact, the vehicle may be fixed to the carrier until 5 m before the point of impact. The impact speed should be reached 10 m before the point of impact.

Crumple tubes or a comparable device will decelerate the carrier not earlier than 12 ms or 100 mm after the moment / point of impact.

Position the vehicle on the carrier to achieve that the impact reference line is aligned with the centre line of the rigid pole.

The horizontal impact accuracy should be ± 38 mm.

1.4 Pole

The rigid pole is a vertical metal structure beginning no more than 102 mm above the lowest point of the tyres on the striking side of the test vehicle when the vehicle is loaded as specified in Section 1 and extending at least 100 mm above the highest point of the roof of the test vehicle.

The pole is 254 ± 3 mm in diameter and set off from any mounting surface, such as a barrier or other structure, so that the vehicle will not contact such a mount or support at any time within 100 ms of the initiation of the vehicle to pole contact.

Mark a line along the vertical centreline of the pole, which may be used to check the alignment of the test vehicle on the carrier.

1.5 Impact Speed

TARGET SPEED = 29 ± 0.5 km/h – During the acceleration phase of the test, the acceleration of the carrier should not exceed 1.5 m/s^2.

1.6 Impact Angle

The impact angle should be 90°± 3°. Align the vehicle on the carrier so that the angle between the vehicle’s longitudinal and the direction of movement of the carrier is 90°.

2. AFTER TEST

2.1 Calculation of Injury Parameters

The Head Performance Criterion should be derived as specified in ECE Regulation 95 and in 6.3.2 above.

Annex – 2

[ACTIVE SYSTEM TEST PROCEDURE]

2.1 Pre-requisites

Where the requirements of the pole test are satisfied, additional tests are included to assess further the performance of the active head protection system.

The vehicle manufacturer should indicate which areas of the active head protection device provide an adequate level of protection, and are capable of producing a HIC <1000 when impacted by the FMH at 6.7m/s. In addition a recommendation should also be made as to whether the test(s) should be performed with a statically inflated airbag or if the active system is to be fired/deployed during the test(s). The relevant information for either of the aforementioned methods should be provided so as to facilitate the test(s). The testing will be performed as described in the flow chart in Figure **19**.

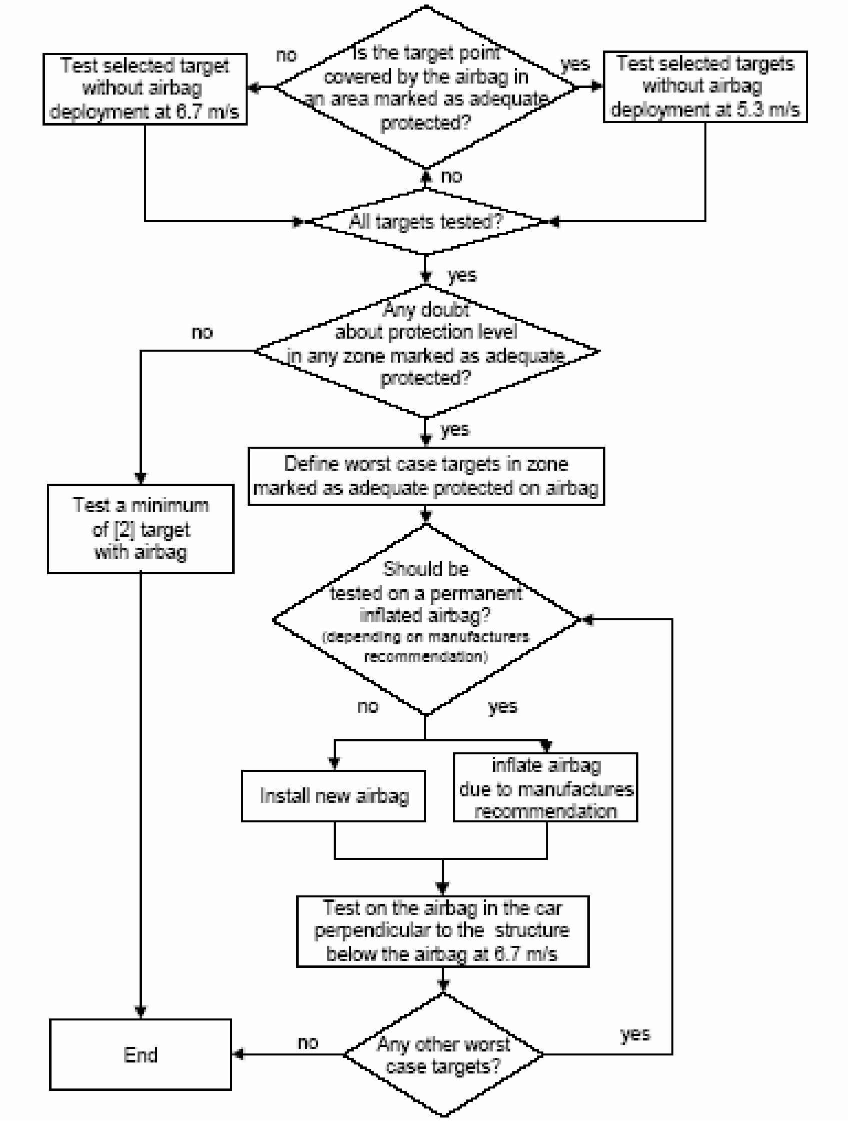


Figure 19 Active system test flow chart

2.2 Active system sub-structure FMH test procedure

2.2.1 **Pre-requisites**

The points as defined in Appendix 1, Section 1.3 will be tested on the vehicle sub-structure(s) with an impact velocity of 5.3m/s if defines as having areas of adequate protection as in Section 2.1. The remaining areas of the vehicle sub–structure, which are not adequately protected by the active device, will be tested with a velocity of 6.7m/s.

2.2.2 **Test conditions**

The criteria defined under Sections 6.1.1, 6.1.2, 6.1.3, 6.1.5, 6.1.6, 6.1.7, 6.1.8 shall also apply to the active system tests.

2.2.3 **Target point locations**

The points defined in Appendix 1, Section 1.3 that are covered by the areas of the active head protection device, as defined in Annex 2, Section 2.1, shall be tested.

2.3 Active system FMH test procedure

2.3.1 **Test conditions**

The criteria defined under Sections 6.1.1, 6.1.2, 6.1.3, 6.1.5, 6.1.6, 6.1.7, 6.1.8 shall also apply to the active system tests.

2.3.2 **Target point locations**

The points defined in Appendix 1, Section 1.3 that are covered by the areas of the active head protection device which have been highlighted by the vehicle manufacturer as providing adequate protection, as defined in Annex 2, Section 2.1, shall be tested. However, if the aforementioned point(s) are not worst case when considering the airbag geometry and construction, then a worst case point will be selected with a deployed airbag.

The test house should test worst case points on the deployed airbag at 6.7m/s until the protection offered by the airbag in the area(s) nominated by the vehicle manufacturer are clearly shown to be adequate. There shall be a minimum of [two] tests to the deployed airbag.

2.4 Performance criteria

The performance criteria as defined in Section 6.3.1 shall also apply to both assessments within the active system test procedure.

Document version Notes

Version 3j (July 2002)

1. Incorporates the pole impact test procedure. The wording is adapted from the EuroNCAP consortium Pole Impact Test Procedure, edited to remove elements not needed for WG13 proposal.
2. Definitions of areas and associated testing related to areas of the vehicle protected by active head protection systems.
3. The introduction section has been amended and sections renumbered to bring consistency to a 'two test' procedure document.

Version 3h (June 2002) (version not distributed to WG13 members)

1. Incorporates several minor modifications related to the orientation of the headform to overcome problems identified by TRL during the first phase of validation testing on the Ford Focus and Toyota Camry as well as a flow chart to reduce interpretation variability.

Version 3m
Not generally issued

Version 3n (May 2003)

1. Revised head orientation to be perpendicular to velocity vector, and limits the range of changes on head orientation to achieve clean impacts.
2. Revised flow chart and definition of forward and rearward seating positions.
3. Minor editorial changes that did not affect the test procedure.
4. Amendments to impact velocity tolerance 0.1 m/s to 0.2 m/s and external deflections (30 mm to 10 mm).
5. Definition of head contact points with window closed, tested with window open.

Version 3o (Feb 2004)

1. Definitions for A-pillar, clean contacts, co-ordinates reference system, horizontal approach angles and vertical approach angles added.
2. A-pillar, B-pillar and BP2 horizontal approach angle limitations added.
3. Vertical approach angle limitations added.
4. Principle of 10 deg clearance for a clean contact.
5. Revision of the head orientation flow chart to remove the 45 degree step, and add further pitching of headform to a maximum of 18 deg from normal.
6. Replacing of EuroSID-1 with ES-2.
7. Mention of the assessment of evaluating a deployed HPS.

Version 3ors (April 2004)

1. Applications within Europe and IHRA.
2. Includes rear seat zone definitions and target points.

Version 3p (October 2004) Submitted to EEVC SC

1. Addition of window bag procedure [BASt].
2. Vector limitations [TNO].

(November 2004)

3. Incorporation of alternative viewpoints.

(December 2004)

4. Finalisation of alternative viewpoints.