

## **STATUS REPORT OF IHRA COMPATIBILITY AND FRONTAL IMPACT WORKING GROUP**

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### **ABSTRACT**

The work of this International Harmonised Research Activity (IHRA) group has continued to focus on compatibility research with the prime aim of improving occupant protection in cars by developing internationally agreed test procedures designed to improve the compatibility of structures in front to front, and front to side, impact.

Compatibility is a complex issue but offers an important step towards the better protection of car occupants. To date the group has focussed on frontal performance tests although benefits need not be confined to frontal impact. Group members continue to work actively in research programmes to enhance understanding and develop potential test procedures to assess compatibility.

A number of potential test procedures remain open in the longer term. But, in recent meetings, effort has concentrated on defining key aspects and assessment criteria for a potential phase 1 test as a first step to improve vehicle compatibility. There is a significant degree of common thinking and purpose and, although issues and challenges remain, a phase 1 step should be possible.

### **INTRODUCTION**

It has been recognised for many years that the protection of vehicle occupants is influenced, not only by the characteristics of the vehicle they are travelling in, but also by the characteristics of the vehicle with which it collides. Historically, the emphasis was on mass alone being dominant. But now structural interaction, passenger compartment strength and frontal force are seen as key compatibility factors.

Up to 2001, there were separate IHRA groups for frontal impact and compatibility. In 2001, the IHRA Frontal Group suggested a first step towards frontal impact harmonisation based on using both existing frontal full width and offset impact tests. Future activity in both frontal impact and compatibility areas was combined within one IHRA group from ESV 2001. (The European Union and the European

Enhanced Vehicle-safety Committee (EEVC) has continued to provide the chairman.)

### **AIMS OF THE GROUP AND BROAD APPROACH**

The prime aim of the compatibility work is to develop internationally agreed test procedures designed to improve the compatibility of car structures in front to front and front to side impact, thus improving the level of occupant protection provided in these impacts. A secondary consideration for compatibility is to bear in mind any implications for protection in impacts with pedestrians, heavy goods vehicles and other obstacles. The prime focus up to now has been on front to front impacts (car to car including LTV/SUVs).

Research will continue on improved understanding of side impact compatibility to define the possibility for a side impact test procedure or, at least, to ensure that any front test procedure helps or does not disadvantage side impact protection. Similarly, research will continue to help ensure that steps to improve compatibility help or do not disadvantage frontal impact self-protection.

Car-to-car and car-to-LTV/SUV crashes have been the main area of work, with LTV crashes the dominant concern in North America. Recently the group has concentrated on the development of a potential Phase 1 test procedure and assessment criteria aimed at improving frontal structural interaction. Initially this would mainly influence LTVs but could also influence car design. The addition of further metrics or test procedures in later phases should ideally allow the evaluation of further compatibility aspects i.e. frontal force levels and compartment strength. Vehicles of interest in the different regions represented by members were covered in the last ESV report.

Potential users of any test procedures could vary widely and range from manufacturers wishing to evaluate the compatibility of their products to regulators. The judgements and the administrative process in considering the suitability of any proposed test(s) as a potential basis for regulation would be

individual to each region.

This paper seeks to distil the position of the group and, while it draws on the research of members, it does not attempt to summarise the range of data which individual members have presented. The work of members and their associated organisations appears in individual reports and publications including ESV papers.

## INTERNATIONAL CO-OPERATION

### Membership, Participation And Meetings

Members represent governments in Europe, USA, Australia, Canada and Japan and industry members are nominated by industry in Japan, Europe and USA. In addition individual experts have sometimes attended meetings, particularly when from the host country or group.

Opportunities are sought to have common technical sessions with EEVC compatibility (WG15) meetings. Informal links with the IHRA Side Impact group continue through some common membership and a joint meeting with this group was held after ESV 2003.

### Recent Meetings

Since the last ESV, there have been 7 meetings.  
19<sup>th</sup> meeting 27-28 May 2003 (27 May jointly with IHRA Side Impact Working Group) Tokyo Japan  
20<sup>th</sup> meeting 17-18 September 2003 (17 September jointly with EEVC WG15) Paris France  
21<sup>st</sup> meeting 20-22 January 2004 (jointly with EEVC WG15) Gothenburg Sweden  
22<sup>nd</sup> meeting 13-14 May 2004 (open to wider US attendance) Washington USA  
23<sup>rd</sup> meeting 13-15 September 2004 London England  
24<sup>th</sup> meeting 14-16 December 2004 Paris France  
25<sup>th</sup> meeting 14-15 February 2005 London England

There continues to be an open flow of information on findings between members with normally at least a day spent on presentations of the latest research. Three joint meetings have been held, two with EEVC WG15 and one with the IHRA Side Impact WG. There has been a partial move towards three day meetings, as used when joint meetings are held with the EEVC. This gives more time for presentations and discussions and also offers the prospect of fewer meetings overall. Unusually there were 4 meetings in 2004, mainly linked to the effort towards a phase 1 test outline. EEVC/European industry workshops

were open to members of the group if able to attend. This included one on 23/24 February 2005 on VC-COMPAT results and industry work.

### Co-operation Within Regions

Aside from the links through IHRA, there is a significant amount of co-operation within and between the regional organisations involved in IHRA. Some direct links are outlined below.

EEVC and European industry – Links through industry representation in working groups and industry co-operation with VC-COMPAT

Individual EEVC members – co-operation with Renault, PSA Peugeot Citroen, VW, Ford and others  
NHTSA – co-operation with Ford, Australia, Canada, Europe, MIRA, Cellbond, TRL, Japan, Honda and VW

Australia – co-operation with Subaru, Ford, Renault, NHTSA

Japan – co-operation with JAMA, NHTSA, Australia, UTAC.

### Reviews Of Data

**Structural Survey:** Links continued following earlier structural survey work. Japan had led on this work topic and continued to report to the group both on results and, in addition, those aspects where it had identified differences or inconsistencies between different teams, when using the same VC-COMPAT protocol. Large lateral differences were seen for engine/gearbox data and Japanese measurements of one vehicle were up to 133 mm different to the European data. To resolve this issue, the measurement protocol was revised by UTAC in co-operation with Japan. Points made included determining a reference plane to remove any effects due to suspension ride height differences, investigating point differences and listing the high priority measurements. Liaison on this was mainly direct between the groups involved. It was felt that any issues were worth resolving. NHTSA which has work in this area also wanted to use the most consistent protocol so that results in databases could be used with high reliability in future analyses.

**Accident Review:** Canada presented work on its review of research related to published analyses of accident data, essentially North American sources, including some estimates related to potential casualty benefits. Members were asked to provide accident data related to front, side, belted, unbelted and vehicle class and, if possible, others eg gender and age group to allow further work on its review.

Vehicle types now range from minicar, mini truck, car, small LTV, one box vehicles, small truck and truck and there has been further clarification on accident classes. This work should progress further in 2005. Some regions have submitted statistics although Europe has encountered difficulties in obtaining the desired data. Preliminary analysis of data provided by Japan shows that, in frontal two vehicle crashes, car and minicar fatalities dominate the fatality totals, a high proportion being in car to truck collisions with car to car featuring less strongly. For minicar fatalities, the truck and car are both dominant. For two vehicle side impact, the car and minicar fatalities are dominant with truck and car followed by one box (MPVs and minivans) being the dominant striking vehicles.

### **Outline Of Members' Research Programmes**

Members are actively involved in compatibility research programmes, often with cross-links. The emphasis in programmes tends to reflect regional fleets; for example, the focus is on LTV to car impacts in the USA and on car to car impacts in Europe.

Canada has led on a partially completed review of accident data. In addition, it has reported on some of its side impact work.

European industry work has included studies on reliably detecting the strength of crossbeams, repeatability/reproducibility of test procedures, some modelling work and development work on a deformation based metric. Industry is also contributing resources and some work towards the VC-COMPAT programme.

VC-COMPAT, the European programme on compatibility, has the objective of developing a suite of test procedures to assess and control car structures to improve frontal compatibility and is due to report in 2006. EEVC WG15, which has a steering role in VC-COMPAT, is to make recommendations on frontal impact compatibility test procedures in November 2006. The programme has separate car and truck elements. The car element has four packages (leaders in brackets); structural analysis (UTAC), cost benefit analysis (BASt), crash testing (TRL) both car to barrier and car to car, modelling (TNO) including developing an FE model of one of the barriers and the continued development of a fleet model. The truck element has included several car to truck baseline tests with existing European truck under-run guards (energy absorbing and rigid). In

addition some member states have carried out extra research which supports the work of EEVC WG15.

A new one year European project (IMPROVER) covers diverse topics, one of which deals with SUVs. This element is led by TNO and the aim is to report on the potential effect of an increasing SUV population on safety.

US industry gave general information on some of the US activity aimed at a voluntary approach, including frontal impact compatibility subgroups investigating full width test procedures, possible LTV to car testing (short term) and the use of an MDB (longer term), and a possible supplementary test for secondary energy absorbing structure (SEAS). In addition some findings were presented from car to LTV tests.

NHTSA has reported on LTV to car (mid sized) full frontal and 50% offset tests plus side impact tests with the car as the target vehicle. The LTVs were chosen to reflect different characteristics such as AHOF and initial stiffness. In addition NHTSA have explored vehicle compatibility using a full width test, both with a rigid wall and a deformable element. Limited repeatability work has included a comparison of two car to car tests. Work continues on constructing and validating FE models for the study of car and LTV interaction and to support MADYMO models intended for fleet optimisation. In addition, a load cell wall (LCW) specification has been prepared.

The US car to LTV research by NHTSA and industry is based on the struck car in a full frontal impact experiencing a delta v comparable to that in barrier tests i.e. equal to 56 km/h in a full width test. The same LTV speed is used in the LTV to car overlap tests. In contrast, European car to car (overlap) tests are carried out with each vehicle at a constant speed (56 km/h) but, being car based, they are much closer in mass than the vehicles examined in the US work.

Japan has carried out a series of tests using a full width barrier, both rigid and with a deformable element, using different vehicles (mini, small and medium cars, MPV and SUV). Vehicle to vehicle full frontal tests were carried out for comparison. In addition Japan has carried out analyses related to potential metrics. Other work has included the analysis of various approaches to determine compartment strength based on the interpretation of force levels in an existing offset test.

Australia has reported on an analysis, using the results of earlier Australian PDB tests, to explore

whether compartment strength could be reliably determined from the force level at rebound. More work is planned in this general area. Further car to car and car to PDB tests have also been carried out.

**PHASE 1 PROPOSAL – POTENTIAL FIRST STEP**

In 2004, group effort has been much more sharply focussed on a first step (Phase 1) proposal. This does not change the group's view on longer-term tests. All options remain open for future phases and the longer-term position is covered in a later section (Phase 2).

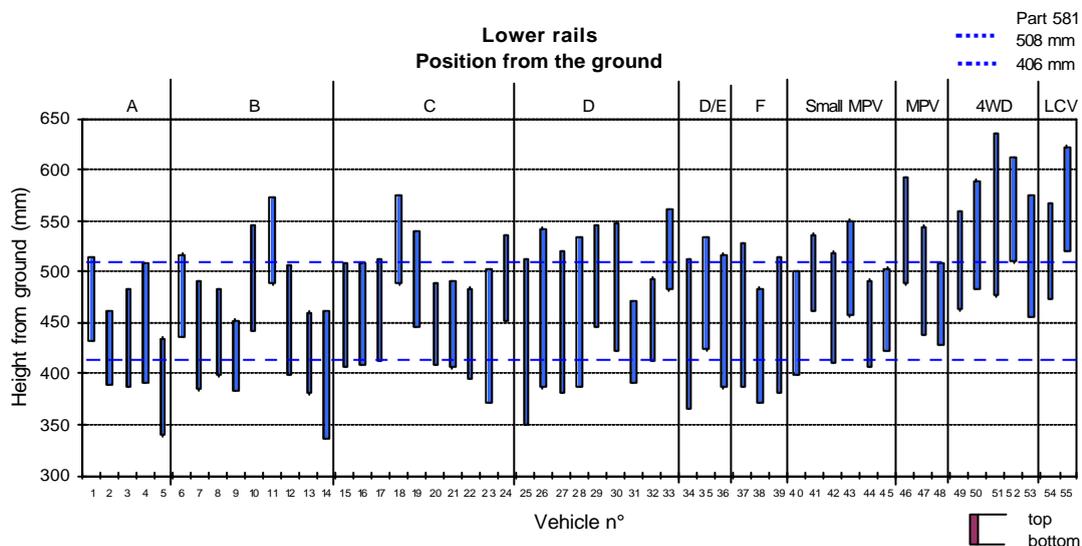
**Introduction To Short Term Proposal**

At the January 2004 meeting, it was agreed that the immediate focus of the group should be supporting the development of a compatibility test procedure that could be implemented in the short term. This step was discussed against a backdrop of the continued need to address LTVs which were the primary and pressing issue for North American members and markets. This is not the situation for all members; for example the EEVC prime interest is car to car compatibility.

benefits in taking advantage of this by ensuring the presence of LTV structures in this zone. An improvement in LTVs would offer the greatest chance of increasing structural interaction in impacts with both current and earlier car models which would be present in the fleet for many years to come. If possible, benefits should also be considered for car to car impacts. The heights of lower rails for vehicles of various classes (cars, MPV, 4WD, LCV) from the European VC-COMPAT structural survey are shown in Figure 1.

The work of the group has remained focussed towards a phase 1 test procedure and addressing in detail associated issues. There has been agreement on defining many of the full width barrier and load cell characteristics, partial evaluation of new metrics, repeatability plus further work on aspects and elements of the proposal.

The structures which a Phase 1 step would encourage on LTVs or cars were felt by industry members to be consistent with possible future vehicle designs if additional improvements in compatibility were introduced.



**Figure 1. Height of lower rails for various vehicle classes in Europe (Source VC-COMPAT)**

An element in subsequent discussion was a view that the vast majority of cars currently generate interaction forces in a similar area, given that most have a cross beam to meet bumper low speed impact standards such as 581. Therefore there should be

**Summary Of Proposed Test For IHRA Phase 1**

In December 2004, the group agreed that, in principle, the outline test procedure described below offers the best way forward for a phase 1 test with a

focus on LTVs. The metrics are recent so they are only partially evaluated and not by all members. This agreement will be reviewed following further investigation of the proposal by group members, including the degree to which it affects the fleet. This applies to the initial step represented by phase 1a. The group hopes to add additional phase 1 requirements in 2005 to further improve compatibility.

**Aims:** The proposal aims

- (a) To improve structural interaction primarily for LTV to car compatibility. One aspect would address crossbeam strength which could also benefit car to car compatibility.
- (b) To minimise the number of tests by adapting the existing full width test by adding a LCW and deformable element while retaining its original function as a self-protection test.

**Scope:** The suggested scope is cars and LTVs (less than 10,000 lbs. gross).

**Test Configuration:** The proposal is a full width test carried out at 56 km/h into a wall equipped with an array of high resolution load cells and a deformable barrier face.

**Load Cell Wall (LCW) Characteristics:** There has been agreement on the definition of many of the characteristics of the full width LCW.

- Height and Width: The LCW should be flat and its height and width sufficient to cover full width and height of all vehicles to be tested.
- Individual Load Cell Size: 125 mm over full wall or subdivisions that can be summed to give 125 by 125 mm units.
- Vertical Position of LCW (on barrier): The group has agreed to use 80 mm ground clearance, the intention being to give a load cell boundary in the centre of the US 581 bumper area.
- A detailed LCW specification with acceptance criteria is being developed. (NHTSA with a few inputs from others.)

**Deformable Face:** A deformable face should cover all of the LCW. The deformable face proposed consists of two layers, each 150 mm deep, front layer 0.34 MPa crush strength and the rear layer 1.71 MPa crush strength, segmented to match the load cells.

**Acceptance Criteria (Metrics) Phase 1a:** The phase 1a vertical and horizontal metrics are intended to encourage sufficiently strong structure in a

common interaction zone. In the vertical metric, target minimum load(s) would be set for (horizontal) rows in the common interaction zone and the metric would address loads lower than this value. The horizontal metric would involve target cell load(s) for cells within a row, based on the total row load. For those cells between the longitudinal rails, the metric would address load values that have lower values than the target cell load(s).

Phase 1a metrics would be based on LCW force measurements and are set out below.

- Vertical: A common interaction zone is defined vertically as 330-580 mm high, essentially the third and fourth load cell rows. For each row, a minimum row load of [100 kN] is proposed.
- Horizontal: The same two rows are examined. A target load would be derived related to the overall load in each row and, based on this, an assessment would be made on the load(s) in the inner cells, likely for [80%] of the vehicle width. A performance limit is to be proposed for this assessment.
- AHOF: NHTSA has shown a correlation between this metric and casualty risk in the existing US fleet. However AHOF alone is not felt to be sufficient, in particular for vehicles with SEAS. A limit would have to be proposed.

#### **Discussion On Some Test Aspects And Choices**

This section discusses some aspects of phase 1a, in some cases giving some background or explanation on the choices made.

**Vertical Position of LCW on the Barrier:** This takes advantage of the degree to which structure is present in this zone for cars. Positioning the ground clearance of the LCW to split the part 581 zone was preferred as this should maximise the sensitivity of a force measurement based approach for movement of relevant structures within this region. A ground clearance of 80 mm, combined with the 125 mm load cell spacing, results in the boundary between rows 3 and 4 being in the center of the 581 zone. Setting metrics for forces in the rows above and below this row boundary can then provide the desired influence.

The ground clearance of individual LCWs in service has varied; the range typically included 50 , 80, 125 and 165 mm, excluding those barriers where the first (lowest) row starts appreciably higher e.g. 250 mm. Some barriers which lend themselves readily to adjustment have changed to this ground clearance for new testing.

**Deformable Face on Barrier:** The deformable face was originally proposed by the EEVC as an improvement over a rigid wall for compatibility evaluation e.g. limiting engine inertial loads so that structural behaviour can be “seen” more clearly while minimising the effect on compartment deceleration pulse; a minimal effect is desirable, given that it is based on a self-protection test. Factors relevant to phase 1 include aiding the detection of SEAS and crossbeam structure which relate to the vertical and horizontal metrics proposed. For example, in recent tests, it detected the presence of SEASs 315 mm and 370 mm rearward of the front rail. There is not a precise distance which the barrier will reach into a vehicle; this will depend on the barrier and the degree and manner of deformation of the main structure (PEAS) before the SEAS becomes involved.

Canada, US, Europe and Australia support the deformable element with emphasis on various factors. For Japan the deformable barrier is an open question. Japan recognises that AHOF can be measured with a rigid barrier, but for extra compatibility information, a deformable element is needed. It has noted some examples of differences between rigid and deformable barriers in the deceleration pulse and structural deformation behaviour in its test program. Different perspectives can be held on whether any differences in these areas, e.g. in early pulse shape, airbag triggering and how structure is loaded, should be regarded as being realistic, favouring a particular barrier or being acceptable. No single test can replicate the range of variations in vehicle accidents for structural loading/behaviour and different high deceleration scenarios, and some differences are linked to characteristics that can have advantages.

**Metrics:** Two relatively new metrics are envisaged for phase 1a. The principle behind them is to encourage all vehicles to have a sufficiently strong structure within a common interaction zone. They consist of vertical and horizontal components. These are complementary but could be applied separately. Work to evolve the metrics has concentrated on the vertical one first and this will be followed by further analysis to propose a performance limit for the second. Both tests may evolve based on feedback from evaluations.

**Vertical metric:** This would particularly influence LTVs and is intended to benefit LTV to car structural interaction. The concept was to (a) set a target row load and (b) calculate the load below the target row for each row in the common interaction zone. The metric addresses areas where the force may be below

a desired level; set out in mathematical terms it limits VNT (vertical (component) negative deviation from target row load). More simply, a minimum row load of [100 kN] is proposed. It is intended to be an indicator that an LTV has structure in alignment with the relevant rows and should also be achieved by cars, without the need to cap or adjust for small cars. TRL (EEVC) and Japanese analysis had suggested a value of about 100 KN. The proposal uses peak cell load values.

**Horizontal Metric:** The aim is to assess if crossbeam(s) or comparable structure on SEAS, have sufficient strength. The metric would encourage a crossbeam strength that tended to match the stiffness of the front of the longitudinal. The concept for horizontal is (a) to set target cell load for the row based on overall (total) row load level and (b) calculate load below target cell load for each cell between the rails for each row in the common interaction zone.

So far analysis has been exploratory. The HNT deviation metric value distinguished stiff and soft bumper crossbeams in limited tests. A question of how strong a bumper crossbeam should be on large vehicles has been raised.

**AHOF:** NHTSA have shown a correlation between this metric and casualty risk in the existing US fleet. However AHOF alone is not felt to be sufficient to monitor some structural changes, in particular SEAS. It continues to be recorded in test work and remains a candidate phase 1a metric. A performance level has not been suggested. Japan has suggested that AHOF at the beginning of impact may be a more indicative measure of vehicle structural interaction potential.

European analysis of AHOF using a deformable face suggests a range of AHOF values with cars typically in the 400 to near 500 mm range. Two modified cars gave lower values than the original car. LTVs ranged from about 490 to 550 mm.

**Repeatability:** Two tests with a large family car were examined for repeatability and, though the peak force was 10% higher on one car, the VNT and HNT deviation metrics showed good repeatability e.g. vertical row (12%), horizontal (higher but on low numbers) for a 16 mm vertical and 14 mm horizontal difference in estimated impact alignment. However, because of the potential for impact alignment sensitivity, and generally, manufacturers have been asked to assess their vehicles to ascertain the robustness of the phase 1 test procedure. (In practice,

at present this means phase 1a.) This could involve modelling as well as analysis of tests.

A pass level for a compatibility metric could be aimed at delivering improvements, while also taking some account of practical test factors. All regarded good control on vertical test accuracy as being important for repeatability. Test results from a number of laboratories were analysed for impact accuracy. Three labs with the closest results in this area currently achieve results inside a +/- 10 mm vertical band which would seem a reasonable target for a specific impact alignment tolerance on this aspect.

Close control of impact alignment in test conditions does not mean that safety performance need be similarly sensitive in practice if the alignment of a vehicle differs on the road. Phase 1a can help in the provision of load bearing structure in an area on LTVs where none may exist at present, helping in LTV to car impacts. In addition, the size or coverage of structures can be influenced in practice due to practical considerations such as crushing a barrier face over a wide enough area to generate a desired force and possibly catering for variation in ride height between model variants.

## Issues

The main issues to be addressed are

- The degree to which the metric affects the fleet and the benefits of changing to meet phase 1
- Robustness of the test procedure (mainly impact alignment sensitivity of vehicles).

In addition there are aspects associated with further defining more specific or detailed aspects of the outline phase 1.

- Confirming the appropriateness of [100 kN], for example for small cars
- Proposing an appropriate value for the horizontal metric
- LCW specification and acceptance criteria (including measurement tolerance)
- Specification of deformable element (acceptance criteria e.g. control of segment strength)

Some will involve manufacturers looking at the degree to which the fleet would be affected and the benefit; this would draw on modelling work/ testing. Similarly, experience of the robustness of the procedure with real world vehicles is important. A

LCW specification being prepared by NHTSA is covered later. The deformable element specification can draw on other hexcell controls.

The results of this work may lead to change or further evolution of the proposal.

## Specification/ Acceptance Criteria For Load Cell Wall (LCW)

NHTSA are drafting a LCW specification and acceptance criteria. This builds on an internal procurement specification and offers a wider harmonised approach to LCW specification; this document was presented to the group. EEVC (UTAC, BAST) and industry fed back comments direct to NHTSA on issues such as dynamic acceptance testing, cell mounting techniques, facing material and resonant frequency. This has involved little group effort. Free air resonant frequency will be part of the specification. NHTSA are also investigating the effect of light and dense wood faces on the load cells.

## Candidate Further Metrics - Phase 1b

A number of approaches could offer candidate metrics for further steps within a first phase. All are aimed at improving structural interaction. They offer either an alternative or supplementary assessments of structural interaction but, if desired, individual metrics could be used in any combination.

Potential Phase 1b candidate metrics are outlined below.

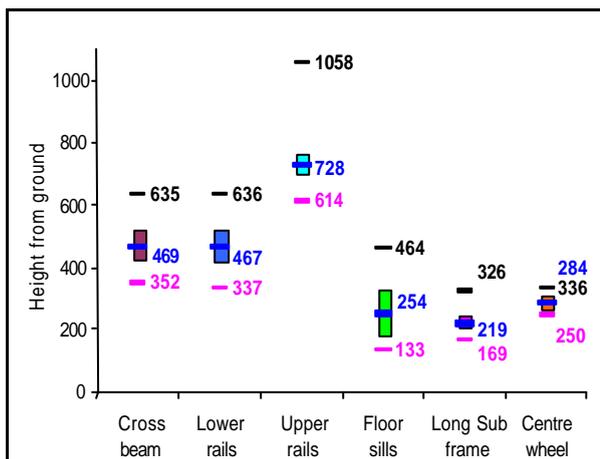
**Relative Homogeneity:** This would control the force distribution over a wider area beyond the common interaction area in Phase 1a, the aim being to encourage the development of structures that behave in a more homogeneous manner. This metric has been used in research analysis in VC-COMPAT and by IHRA members. Areas to be addressed for use as a metric include whether to use peak force or impulse, size of an assessment area and performance limits. (A more detailed discussion of relative homogeneity is in the Phase 2 section under the FWDB.)

**Deformation Based:** This would evaluate the degree to which a vehicle generates “sufficient support” within a common interaction area (same height range as in Phase 1a but width might differ). The proportion of the surface of the stiffer rear layer which is deformed in this area is determined and used as a measure of sufficient support being provided. Also, if this is suitably distributed between the top

and bottom of the common area, then structures below it might be credited. An advantage is that it should be insensitive to impact alignment. An issue could be the accuracy with which the deformation imprint can be determined. The approach is being explored by European industry. An analysis of barriers from earlier tests with weakened, standard and reinforced crossbeams gave progressively higher proportions of the surface deformed (ranging from 23% to 43%). A series of evaluations of the deformation of barriers from earlier tests of standard vehicles is planned.

It is being researched as an alternative assessment technique to a force based assessment as in Phase 1a. However, the overall pattern of barrier deformation might also be considered as a means of obtaining information on the distribution of loads within the interaction area and supplementing a Phase 1a test.

**Alternative Metrics with Assessment Area Extended Beyond Rows 3 and 4:** In principle, any metric which focuses on rows 3 and 4, the common interaction area, could be extended to other rows, particularly row 2 for cars. Any approach should maintain an appropriate level for structural interaction in the common interaction area. The issue is not the concept, simply that the immediate priority in Phase 1a has been the common interaction zone. The two metrics (Relative Homogeneity and Deformation) already cover or can be extended into other rows. The heights of various vehicle structures including crossbeams, upper rails, lower rails and forward (long) subframes, from the European VC-COMPAT structural survey, are shown in Figure 2.



**Figure 2. Height of various vehicle structures including crossbeams, rails, and forward subframes**

### Initial Stiffness

NHTSA obtained a correlation between this metric and casualty risk in the existing US fleet. The deformable element, because of its function, has different initial impact characteristics to a rigid wall and does not give the same initial stiffness value. (NHTSA and Japanese data confirm this.) However this does not mean that a comparable metric could not be derived on a revised basis for the deformable element but initial stiffness is not considered as a candidate phase 1b metric.

### Potential For LCW Improvements (Increasing Resolution)

The (125 by 125 mm) size high resolution load cell continues to be appropriate. However, means of increasing resolution are being investigated with the aim of providing more information about the vehicle's structural characteristics. Three potential routes are outlined.

- Smaller load cells: If specified, this would be likely only in the common interaction zone, currently rows 3 and 4. For example the cell size could be based on 62.5 mm square or an oblong rectangle of 62.5 mm vertical and 125 mm horizontal.
- Measuring moment: Moments might be measurable across a load cell by using existing load sensing sub-elements within an individual load cell and one member is exploring this possibility. In addition NHTSA's simulation work aims to explore the use of this concept and has developed a technique to simulate moment measuring load cells.
- Supplementary deformation measure: This would use the pattern of deformation of the deformable element, in particular the rear layer, to give extra information on the forces applied e.g. whether the force was applied over specific parts or all of an individual load cell. The use of deformation as a supplementary technique was explored using modelling but the benefit was not as great as expected though the model may have been over-pessimistic.

The above deformation measure differs from the "sufficient support" deformation metric which makes an overall assessment of the zone whereas the assessment here was over the area of an individual load cell. However some extra information might emerge from work on the overall metric.

Finally, in addressing any potential advantages of a change to increase resolution, it would be necessary to bear in mind that increasing resolution might also mean a risk of decreasing the reliability of the test. For example, if the number of load cells is increased, apart from the cost, there is a corresponding increase in the risk that the signal output(s) from one might be lost.

## **POTENTIAL PHASE 2 TESTS (OUTLINE)**

### **Outline Of Current Position**

While the group agreed to focus on an IHRA Phase 1, it also wanted all options to remain open for Phase 2. For example Japan stressed the importance of addressing compartment strength. Work in member regions has continued to cover a range of potential tests outlined in this section, though the level and area of activity has varied depending on regional priorities and resources.

The potential tests include a continuation or evolution of a FWDB phase 1 step, extra information from the existing ODB test, a high speed compartment strength test, various PDB proposals and the longer term possibility, probably phase 2+, of an MDB. The position on these is summarised below. Inclusion does not mean that the group view is that a test would be included in any phase 2 proposal. The group intends to review longer term research in developing or evaluating these areas after ESV 2005. Some tests address individual aspects of compatibility. Others are based on an interpretation of an overall result which is influenced by several compatibility aspects of the vehicle. A full width high deceleration test would also feature in phase 2 test scenarios, including those of the EEVC, as a self-protection test. This section outlines the range of compatibility tests and some self protection tests that can offer relevant information or control.

### **Full Width Frontal Test With A Deformable Barrier Face (FWDB)**

This 56 km/h test uses a load cell wall to assess and control the potential for structural interaction between vehicles. (It also offers a high deceleration test.) This is also the proposed phase 1 test configuration but the test metrics used would be developed further and the test could evolve. In the family of associated tests, additional information could be generated from other tests to control (within a range) the peak force generated in a self-protection ODB test and a high speed compartment strength test,

possibly 80 km/h, purely to assess passenger compartment strength.

Evaluation work on the full width deformable barrier (FWDB) has concentrated on the ability to measure the forces generated by the car frontal structure and on the use of metrics to measure these. Currently for phase 1a, different metrics have been proposed. Work on a homogeneity assessment will continue as a possible phase 1b metric or further evolve for phase 2.

The approach being developed to assess the homogeneity of forces in a vehicle footprint, as seen by the barrier, is briefly described. A footprint area, provisionally based on the dimensions of the vehicle being tested, was chosen for the development and evaluation of a possible assessment measure. The method used smoothes the forces from each load cell within the area to minimise the problem of structural members bridging adjacent bad cells, and quantifies the variation between each smoothed load cell force and a derived target load level over the footprint. The work to date has shown how the assessment measure can be used to calculate the variation between rows and columns to give an indication of vertical and horizontal homogeneity.

It can be sensitive to impact alignment accuracy for vehicles which have single load paths or where these dominate and examples have been found. But these are not homogeneous vehicles and this sensitivity should be less of an issue, if higher levels of homogeneity are required. One of the highest levels of homogeneity achieved to date was in a recent SUV test. Also higher LCW resolution could be advantageous in reducing any alignment accuracy sensitivity.

Other issues include determination of the assessment area, whether to use peak force or an impulse based approach. Recent work found impulse gave a similar distribution to that of peak cell force and the effect of localised spikes was reduced. On a more general note, the output lends itself to analysis of a specific aspect (structural interaction) directly. Also the output is available from the beginning of the impact should a particular stage or time factor be relevant.

### **Offset Deformable Barrier (ODB) Test**

This high deformation self-protection test could be used to supply extra information for compatibility purposes using a LCW. (In current ODB tests, speeds range from 56 km/h in regulations to 64 km/h in several consumer tests.) The car's frontal stiffness

could be controlled by specifying that the peak force should lie within a specified range.

Another avenue involves exploring whether data from a 64 km/h ODB test can be successfully used to give an indication of compartment strength.

### **High Speed Compartment Strength Test**

This avenue is an ODB test at [80] km/h purely to assess compartment strength for small cars as there are concerns about the effect on heavy cars. There are no dummy requirements. This has been explored by the EEVC in earlier work, although further work is deferred in the current EEVC programme. Japan has recently reported some further overload tests in the context of a wider exploration of possible approaches.

In terms of the latter, Japan has continued to evaluate possible metrics that might be used to derive appropriate compartment strength information from a 64 km/h ODB test. These included maximum structural force, end of crash force (EOCF) and rebound force, each reflecting barrier force recorded at different points in the impact e.g. EOCF was defined as the barrier force at the time when the engine acceleration is minimum after the engine makes contact with a firewall. At present, there are issues with all the metrics and how to measure compartment strength remains open. Australia has also looked at rebound force in an analysis of some of its earlier PDB tests but this did not give a clear indication of compartment strength.

### **Progressive Deformable Barrier (PDB)**

**Overall Position:** In the last ESV report, the PDB 60 km/h (for partner protection) was part of a second EEVC grouping of tests including a high deceleration 56 km/h full width test (self-protection) and a 60/64 km/h ODB (self-protection, high deformation). However, this could change as France is researching the use of the PDB as a self protection test to replace the current ODB (ECE Reg. 94, 56 km/h) test. This continuing research has been reported via the EEVC for information to the IHRA group. The French proposal is that a change should be made on self-protection grounds before any decision is made on whether the PDB barrier should be used for compatibility. The compatibility metrics are still being researched. There has been no substantial discussion as yet in IHRA, but compatibility and self protection aspects are likely to be part of any future IHRA phase 2 discussions, either as independent or linked PDB options.

The PDB test involves a 60 km/h ODB test with a Progressive Deformable Barrier (PDB) face and 50% overlap.

**PDB for Self-protection:** The latest French research is aimed at modifying the current ODB test (Reg. 94). The modifications proposed by France are to replace the existing (EEVC) deformable element with the PDB deformable element, change the test speed to 60 km/h and overlap to 50%. These are exactly the same conditions as in the compatibility test but now with dummy criteria and also potentially intrusion criteria; there would be no compatibility criteria but a compatibility proposal could be made later. Testing has been performed to compare three cases - regulation 94 (56 km/h), regulation 94 with an increased test speed of 60 km/h as recommended by EEVC WG16 and the French PDB proposal. France saw the main advantage of using the progressive barrier as having the test Equivalent Energy Speed (52 km/h EES) similar for different mass cars, which is not the case for the current EEVC barrier. The approach is aimed at improving the compartment strength of small cars, which would be subject to a more severe impact than at present in regulations, without increasing the severity for heavy cars.

Points raised in brief discussion/clarifications on the presentation included the likelihood that some control on the amount of energy that the barrier absorbs would be needed to ensure that all cars have the intended similar EES in this test. This control could be a mass dependent measure such as limiting the allowable average depth of deformation of the PDB to prevent light vehicles being engineered to take advantage of the large energy absorption capability of the barrier.

**PDB for Partner Protection (Fixed Speed):** The aim of the PDB offset test is to control a car's structural interaction and frontal stiffness up to an equivalent energy speed (EES) of about 52 km/h using measurements of the barrier's final deformation profile.

The PDB compatibility approach seeks to control two aspects by interpreting the final deformation pattern on the PDB face post impact; firstly, depth of deformation level associated with a desired control on maximum force and secondly structural interaction by a variation of depth measurement to reflect local force variations which are in turn linked to a height criteria. (More uniform deformation would indicate a more compatible structure.) The broad appraisal method is outlined below.

The barrier surface is first digitised. Separate areas from different regions of the face, which have the same degree of deformation, are grouped to give a total area for that deformation. A height is then associated with each grouped area. A good compatibility rating would be based on an appraisal which makes an overall assessment of performance, drawing on both deformation (force) and height criteria. The boundary chosen for evaluation excludes the edges of the barrier face, especially the outer edge which suffers additional deformation as the vehicle rotates around the barrier during impact.

Work continues to determine the best way to deal with these derived measures in a numerical appraisal method. The current formula for overall assessment, although available for research, is not ready to be proposed. UTAC is working on medium term measures for three parameters:

- (1) Average Depth of Deformation (Stiffness)
- (2) Average Height of Deformation (Geometry)
- (3) Max deformation of barrier after ADOD line (Homogeneity)

In the medium term a new and different criteria could be a function of all three of these. Current indications are that interim steps would be proposed; the first proposal would be for a single measure which reflects a combination of AHOD and ADOD.

The PDB deformed barrier face (after impact) represents an overall total effect in which several vehicle compatibility factors have combined over the impact. Separating these factors reliably is the subject of the current work.

The PDB generates higher shear in both vertical and lateral planes. (Generating high shear may have advantages in testing structural interconnections between load paths.) Being an offset test, it involves greater structural deformation. Penetration of the barrier outer skin can sometimes occur which can give rise to further damage on removal of the barrier. This would make a rating more difficult but may not occur (or be permitted) if high level(s) of compatibility are specified in a test proposal.

### **PDB Constant Energy**

This Australian approach uses the fixed PDB barrier in a constant energy test, the aim being to stiffen small cars and soften large cars, to control compartment strength and improve structural interaction. The test configuration is with 40% overlap, dummy criteria and a load cell wall behind the barrier. It would be carried out at constant energy with variable speed, equivalent to 48 km/h for 2.5

tonnes and no limit on speed e.g. 74 km/h at 1060 kg. Australia considered that the ODB may still be necessary for cars heavier than [1400] kg as these are not tested at high speed into the PDB.

Essentially this takes compatibility to a further stage in terms of the emphasis on small car occupant protection and compartment strength.

### **Mobile Deformable Barrier (MDB)**

This approach offers the ability to provide for mass and carry out angled (oblique) offset tests. The US regards a mobile deformable barrier (MDB), in conjunction with existing tests, as offering improved coverage of US accidents and in a later phase could be used to address frontal impact and compatibility. The MDB, if considering frontal impact self-protection, would not ensure that all the energy can be absorbed in the vehicle frontal structure unless the MDB mass is increased for heavier vehicles.

There are options of one or both moving (MDB and vehicle). There are however practical considerations such as high test speed (if one moving), test laboratory capability and site approach distances (one or both moving). It would not equalise frontal force but the use of load cells offers information on frontal force and interaction which could be controlled.

There is no specific update on MDB testing since the last ESV report. Past work in Japan had suggested that the current face used could be investigated. Possibilities could include the PDB face. Any programme of MDB development would be a longer term exercise with greatest interest in the US, including a full width MDB; NHTSA pointed out that it could be useful to start early given the long timescales. Other members, despite differing experiences in the past, would also wish this to be included in a review of possible longer term work. However ensuring adequate self-protection for larger vehicles was a concern expressed by European and Japanese industry.

### **SOME ADDITIONAL ASPECTS/ FACTORS**

#### **Specific Test Requirements For Side Impact**

The immediate priority for the group lies with tests to improve frontal compatibility. Improving some aspects of vehicle fronts may help in side impacts but comprehensive requirements aimed at side impact would be complex and a separate exercise, if possible.

## **Insurance Low Speed Damageability Test – Potential Developments**

A presentation was made to the group by a representative from an insurance industry research centre on work by the Research Council for Automobile Repair (RCAR) to update the current low speed damageability test. Although the RCAR group have not yet fixed a bumper test height, the IHRA group felt that there could be a possible conflict on one aspect. If a consequence of the proposed insurance test was higher front bumper beams or associated structure than at present, it was felt that this would create an incompatibility with the lower front bumper beams found in the current fleet and the fact that the IHRA group were building on the use of the 581 zone, either directly or indirectly. If that happened, the result would be an increased risk that new cars with higher bumper or crossbeams would override existing cars with an associated likelihood of increased occupant injury.

## **OUTLINE AREAS FOR RESEARCH PLANS / NEXT STEPS**

The following sets out a structure under which topics can be further discussed after ESV. It is also important to stress that further activities would naturally require agreement by the Steering Committee.

### **Possible Route Map Summary**

The possible route map covers areas of research that could allow the definition of test and assessment protocols over short, medium and long term timescales.

- (1) Within a short term (less than 2 years) timescale: Phase 1 test procedure to enhance structural interaction.

The following further areas were identified and are to be reviewed after ESV.

- (2) Within a medium term timescale:  
These are likely to be fixed barrier tests aimed at improving compartment strength and frontal force matching and further improving structural interaction.
- (3) Within a long term timescale:  
This is likely to be a mobile deformable barrier test.

## **CONCLUSIONS**

### **Phase 1**

The group agreed that, in principle, the outline test procedure described offers the best way forward for a harmonised phase 1 test proposal. The proposal aims to improve structural interaction primarily for LTV to car compatibility.

Recent phase 1 discussion has been mainly on a vertical metric to improve LTV to car compatibility. A later metric could address cross beam strength which could also benefit car to car compatibility but so far analysis has been exploratory.

This agreement in principle will be reviewed following further investigation of the proposal by group members. The main issues to be addressed are:

- The degree to which the metric affects the fleet and the benefits of changing to meet a phase 1.
- The robustness of the test procedure. (mainly impact alignment sensitivity of vehicles)

The use of a deformable element is an open question for Japan.

It is important to keep the outline test procedure for phase 1 in perspective as a potential first step. It must be viewed against a background of much wider longer term research which continues in an effort to develop further compatibility test procedures.

### **Phase 2**

While the group agreed to focus on an IHRA Phase 1 test, it also wanted all options to remain open for Phase 2.

A range of phase 2 options are being explored. For example VC-COMPAT is concentrating on a full width test with a deformable element and a PDB approach; the associated EEVC recommendation is expected at the end of 2006.

The MDB is seen as the longest term option.

A special test or requirement for side impact is some way off although some aspects of a frontal test should help.

### **Wider Comments**

The priorities are structural interaction, followed by compartment strength and control of frontal forces.

EEVC, NHTSA and other research programmes have different emphases but considerable common interest. The close links with the EEVC group work well and industry involvement has been a healthy aspect.

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