EUROPEAN ENHANCED VEHICLE-SAFETY COMMITTEE

Development of a European Side Impact Interior Headform Test Procedure

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DEVELOPMENT OF A EUROPEAN SIDE IMPACT INTERIOR HEADFORM TEST PROCEDURE

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ABSTRACT

When the EEVC proposed the full-scale side impact test procedure, it recommended that consideration should be given to an interior headform test in addition. This to evaluate areas of contact not assessed by the dummy. EEVC Working Group 13 has been researching the parameters of a possible European headform test procedure in four phases. Earlier stages of the research have been presented at previous ESV conferences. The conclusions from these have suggested that the US free motion headform should be used in any European test procedure and that it should be a free flight test, not guided. This research has now culminated in proposals for a European test procedure. This paper presents the proposed EEVC side impact interior headform test procedure, giving the rationale for the test and the first results from the validation phase of the test protocol.

INTRODUCTION

EEVC WG13 has been developing a new interior surface test procedure that can be used to enhance the safety afforded in Regulation 95 focused on head injury. The development of this interior headform side impact test procedure was initiated because European accident data indicated the importance of head injuries in side impacts and demonstrated that there was a wide range of head contact location possibilities. However, in the regulatory full scale side impact tests the head of the EUROSID rarely made contact with the vehicle interior and, when it did, only one dummy position in the vehicle was evaluated.

The development programme for the development of a test procedure was planned in four phases. The first phase comprised a test programme to enable the selection of the preferred headform from three possibilities. This was reported at the 15th ESV Conference (Roberts et al, 1996 [1]). The second phase was designed to determine whether a free flight or a guided headform impact was the better choice for such a test procedure. The difficulty in producing sensible and reliable results with the guided system precluded the reporting of this phase at the 16th ESV Conference. However, these difficulties contributed to the evidence for the decision to select a free flight system. Thus the conclusion from Phases I and II were that the preferred system would be a free flight test using the FMVSS 201 Free Motion Headform. This selection had the further benefit of potential harmonisation with the US Standard (FMVSS-201).

The third phase of this work included the correlation between the FMH response and that of EUROSID, the influence of vehicle support on the results, the possibility of a sub-systems approach to testing and the capability of predicting a 'worst case' impact configuration. Furthermore the suitability of using EUROSID for pole impacts with side head airbags present was investigated. An accident analysis to identify the zones within the vehicle liable for head injuries in lateral impacts was also undertaken. The results of the accident analysis and the FMH–EUROSID correlation tests have been reported at the last ESV conference (Lowne et al., 2001 [2]). Since then, the third phase has been completed and a draft test protocol has been established.

This paper discusses the results of the final phase of the development of the interior headform test procedure. In this phase, the draft protocol is validated on a number of vehicles, looking at the feasibility, repeatability, reproducibility and the influence of some of the main parameters.

METHODOLOGY

Test Protocol

The work in the first three phases of the programme has resulted in a draft "EEVC Side impact head protection test procedure" that describes a free flight FMH test with the vehicle lifted from its suspension system and rigidly mounted to the floor. Initial testing to this protocol was carried out on three vehicles in the UK. Some amendments were then made to overcome areas of test and interpretation weakness. The other participating organisations based their studies on the experience gained in the UK. The remaining part of the test programme has been carried out using Version M[1] of the protocol. A summary of this draft protocol (M) is presented ANNEX A.

Test Programme

Vehicles - The test vehicles have been selected based on the vehicle classification as used by Euro NCAP. The objective was to check the feasibility of the draft protocol with a wide range of vehicles and not the compliance of the vehicles themselves which would not have been produced to meet the requirements of the procedure. Tests have been carried out on a small family car (Ford Focus 4 doors, model year 2001), an executive car (Toyota Camry, 4 doors sedan, model year 1997) and a MPV (Renault Espace, 5 doors, model year 2001). All models tested were left hand drive models. Although both the Focus and Camry are sold in Europe and the US, it should be noted that only the Camry model tested has been designed to meet FMVSS-201, the US interior surface test procedure.

Laboratories - The laboratories involved in this test programme were BASt, Cologne, Germany; TNO Automotive, Delft, the Netherlands; VCC, Volvo Car Corporation, Göteborg, Sweden; and Millbrook Proving Ground Ltd., Bedford, United Kingdom, on behalf of the TRL, Crowthorne, United Kingdom.

Table 1.
Test programme for EEVC WG13 IHF test procedure evaluation

	BASt	TNO	TRL	VCC
Focus	EC-0° EC-15° *(1,3)*		EC-0°	EC-0° *(2)*
Camry		US-201	EC-15° *(3)*	
Espace		EC-0°	EC-15° *(3)*	

Note 1: BASt was not able to test locations BP3 & SR2 (the distance between SR2 and SR1 was less than the minimum distance required between targets)
Note 2: Tested right hand side only
Note 3: Tested at 15° due to head positioning problems

Conditions – A comprehensive test programme has been defined by WG13 consisting of the following test conditions:

(1) 'EC-0°': standard tests carried out according to the draft EEVC WG 13 protocol, Version M. At these tests the mounting plate of the headform is perpendicular to the velocity vector;
(2) 'EC-15°': tests identical to the EC/0° test condition with exception of the mounting angle. To avoid chin contact during impact the head is launched with the back plate 15° pitched nose-down relative to the velocity vector. This configuration was included to assess the possibility of ensuring a 'clean' certified forehead contact without significant contact with uncertified parts of the headform;
(3) 'US-201': tests according to the US regulation FMVSS-201 [3]; these tests were included to study the differences between the new EEVC protocol and the US test for FMVSS-201 compliant/non-compliant vehicles.

The complete test programme is summarised in Table 1. For all EC test conditions, the feasibility of the draft protocol to define impact zones and impact locations has been examined. The repeatability of the tests were checked testing the left and right side of the vehicle at identical impact locations, assuming the cars are symmetrical in their performance. Furthermore, the effect of the 15° pitched head to avoid chin contact was studied by comparing the results of the two Ford Focus vehicles tested at BASt. The comparison between the US and EC test conditions was made using the tests with the Toyota Camry carried out at TNO and TRL. Finally, the reproducibility between laboratories was examined using the results of the test with the Ford Focus carried out by BASt and TRL.

Specifications - All the tests have been carried out according to the draft EC protocol or FMVVS-201 with the following detailed specifications.

Instrumentation and data processing were well defined to ensure reproducibility between the test laboratories. The respective parameters recorded during the test programme were: headform impact velocity, headform impact direction, headform acceleration at the CG in three axes with respect to the head co-ordinate system, impact point variation; and exterior vehicle movement, adjacent to the impact point. Electronic data capture, filtering and data process was carried out according to ISO 6487 (1987).

The Head Injury Criteria for the free motion head-form (HICfmh) is calculated with:

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

where 'a' is the resultant head-form acceleration, expressed as a multiple of 'g' (the acceleration due

[1] *Internal EEVC Working Group 13 revision code.*

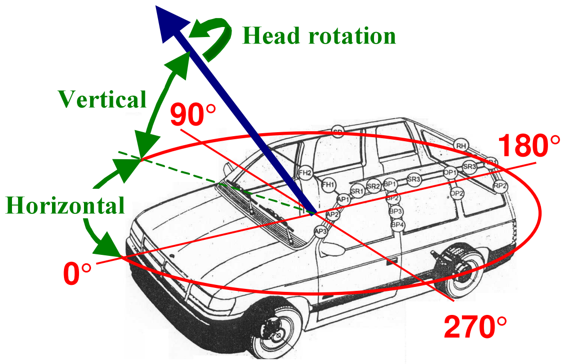

Figure 1. Impact direction definition.

to gravity), and t1 and t2 are any two points in time during the impact, which are separated by not more that a thirty-six millisecond time interval.

Using the HICfmh, the HICdummy is calculated using the same correlation formula as specified in regulation FMVSS-201, namely:

$$HICdummy = 0.75446*HICfmh + 166.4$$

The working group recognises that the correct formula to use with the pitched headform would be different to the standard 0° conversion formula given above. Considering the orientation of the head CG with respect to the contact point, application of the standard formula is likely to change the severity of the head impacts. As the correct conversion formula can only be established through calibration against the 15° test condition and is not available at this time, all results were calculated using the 0° conversion formula.

The actual impact location was recorded e.g. by placing a paint spot on the centre of the contact area on the head or using a sticky target that was placed on the target point. The objective of this measurement was to check the feasibility of the proposed accuracy, a circle with a radius of <10.0 mm of the selected target point, in real test situations.

The proposed test method states that the maximum external vehicle deflection should be not greater then 30 mm. If the vehicle were able to move or flex much more, this would mean that lower HIC values would be achieved and the test would not measure the performance of the safety system in an impact where the exterior of the vehicle could be supported by an external struck object. The laboratories used different methods to measure the maximum exterior deflection. TRL used a metal pointer and plastercine to record the displacement, BASt used two string potentiometers fixed to the outside part of the body and TNO used a simple mechanical system. VCC did not record the exterior vehicle displacement.

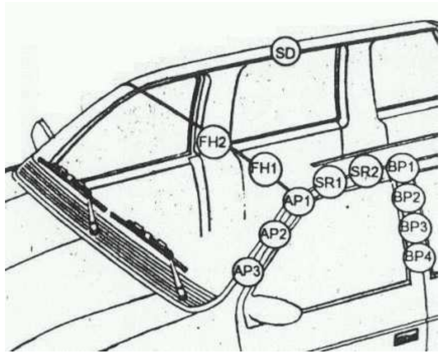

Figure 2. FMH Impact locations.

RESULTS

The impact parameters and calculated HIC values for the various vehicles and test conditions are summarised in Table 4 and 5 in ANNEX B. Three participating labs provided data on the Ford Focus (TRL, Bast and VCC) and two on the Toyota Camry and the Renault Espace (TRL and TNO) respectively. The labels -0°, -15° or 201 indicate that the head tilt nose down 0° or 15° is applied or that the test is performed according to the FMVSS 201 protocol. LHS and RHS refer to driver and occupant side of the vehicle interior, respectively. The HICdummy values given are corrected measured HIC 36 ms values that are comparable with values measured with a dummy in a side impact test.

The impact parameters provide insight in the impact direction selected to hit the interior point and the impact velocity. In Figure 1 the definition for the horizontal, vertical and head angle is given. For target point locations and labelling, see Figure 2.

The achieved impact point accuracy and maximum vehicle displacement per laboratory are given in Table 2 and 3, respectively. The test speed variation for all tests was smaller than the 0.1 m/s tolerance.

Table 2.
Impact point accuracy per test laboratory

Test Lab	**Number of tests**	**Maximum deviation**	**Average deviation**	**Standard deviation**
		mm	*mm*	*mm*
BASt	20	20.6	10.5	4.8
TNO	24	18.0	9.9	5.8
TRL	40	16.0	8.2	4.9
VCC	7	*Not reported*		

Table 3.
Maximum exterior vehicle displacement per test laboratory

Test Lab	Number of tests	Maximum deviation
		mm
BASt	20	4
TNO	24	7
TRL	40	15/5 *(1)*
VCC	7	*Not reported*

Note 1: At Espace location SR1 a displacement of 15 mm was recorded, other results were < 5 mm.

DISCUSSION

Limitation zone definition

The current protocol limits the areas assessed inside the car to those that are likely to be impacted by the driver's head in a side impact. All laboratories have checked the possible impact locations to the proposed limitation zones. Based on this analysis, point AP1 of the Renault Espace was excluded from testing, in particular due to the presence of a double A post. After the initial trial tests in the UK, it was suggested to move the frontal plane 100 mm more forward. This was done to be sure that also the small driver will be taken into account as small occupants will sit much more upright and forward. The extended limitation zone was subsequently used in the other laboratories.

The concept of a limitation zone worked well in this programme as no major inconsistencies were observed between the labs. The practicality of setting the limits in the car was somewhat awkward and time consuming at first, however, it may be expected that as experience grows and/or supporting tools (e.g. based on H-point machine) come available, this will soon be overcome.

Impact location accuracy

The precision at which the targeted points can be impacted is largely dependent of the test equipment, tools and test experience in the various labs. The average deviation in the position of impact point from the required target location in all tests was about 10 mm. The maximum deviation found was a distance of 20.6 mm from the required impact point.

Taken into account that recording of the first contact between two curved faces is not always clear and that test experience is still limited in this prototype test programme, it seems that the tolerance of 10 mm specified, although tight, is achievable and acceptable.

Exterior surface deflection

The proposed maximum exterior deflection of the test vehicle is <30 mm. This value was chosen as an acceptable value after preliminary investigations in the previous phase of the programme. Based on the results of this test program, all values except one are below 10 mm, therefore it should be considered to reduce the tolerance in the protocol to <10 mm.

Repeatability

The vehicles in each lab were tested on the left (LHS) and right (RHS) side to provide data on repeatability of the test protocol. For each lab, the average variation between left and right side test results per vehicle was calculated using the HIC values of all points available. The average of the variation over the vehicles tested in each lab is an indication of the accuracy at which the tests may be repeated in each lab. Figure 3 shows this average variation in HIC, showing that the repeatability is generally acceptable with variations mostly smaller than 10% for identical LHS/RHS tests. It should be noted, however, that if the latter was clearly not the case e.g. because the windscreen broke in the RHS test but not in the LHS or vehicle asymmetry, the data were left out. The differences between the test houses may be attributed to the differences in test expertise and equipment used.

Reproducibility

A distinct difference with FMVSS 201 is that the proposed European test procedure aims to evaluate areas of the car that could result in the highest risk of head injury in side impact. As such, the protocol

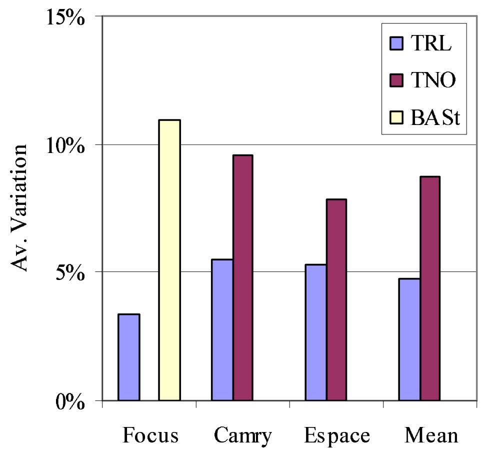

Figure 3. Average variation on HIC values per vehicle for each lab.

advocates the identification and selection of 'worst case points', i.e. points where worst injury risk might occur. It has been anticipated that this may be cause of some variations between test houses not having to clone each other's target point and impact directions.

Comparison of the Focus EC-0° results from TRL, VCC and BASt show that large differences may occur between the impact direction and head orientation chosen (Table 4 and 5). These may or may not lead to significant variations in HICdummy values as Figure 4 shows for those points where a meaningful comparison could be made.

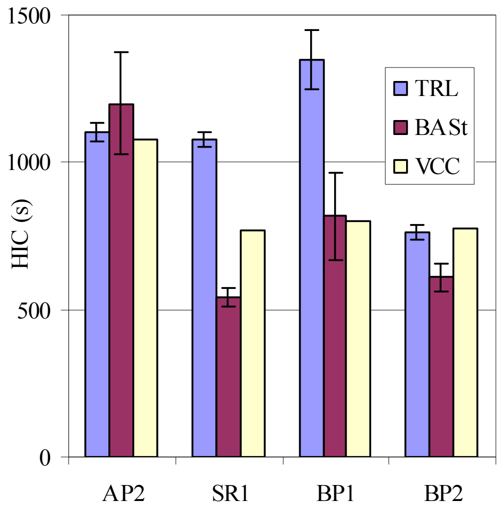

Figure 4. Comparison of HIC values for the Ford Focus; the error bars are based on LHS/RHS testing.

Assuming that all three labs have looked for the worst case situation for all points, the above suggests that this part of the protocol would not be easy to implement consistently at various test houses and leave considerable room for engineering judgement. This situation, however, is not uncommon for regulations, that rely on adequate test experience in addition to the test protocol. It does give the best guarantee that the points of highest risk of head injury are taken into account.

Effect of 15° pitched head

Initial testing suggested that secondary contacts with non-certified areas of the head and/or chin contact could easily occur in some target positions. To overcome this and to ensure a clean contact with the certified forehead contact patch, some tests were performed with the headform pitched forward by 15 degrees.

Both Focus and Espace have been tested in the EC test condition with the headform 0° and 15° pitched forward. Since the correct HICdummy regression equation for a tilted headform is currently lacking, the data were processed with the 0° formula only. Strictly, this means a one-to-one comparison of the HICdummy values is not possible. The trend in HIC as presented in Figure 5 can be compared for the two vehicles.

BASt has tested two Ford Focus vehicles with identical main specifications using identical equipment and test personnel. The test results show differences between the two test conditions, but almost comparable variation between LHS/RHS tests. This seems to indicate that the 15° pitch does not have a major effect on the repeatability.

TNO selected impact locations and angles to be as close as possible to the specifications of the TRL

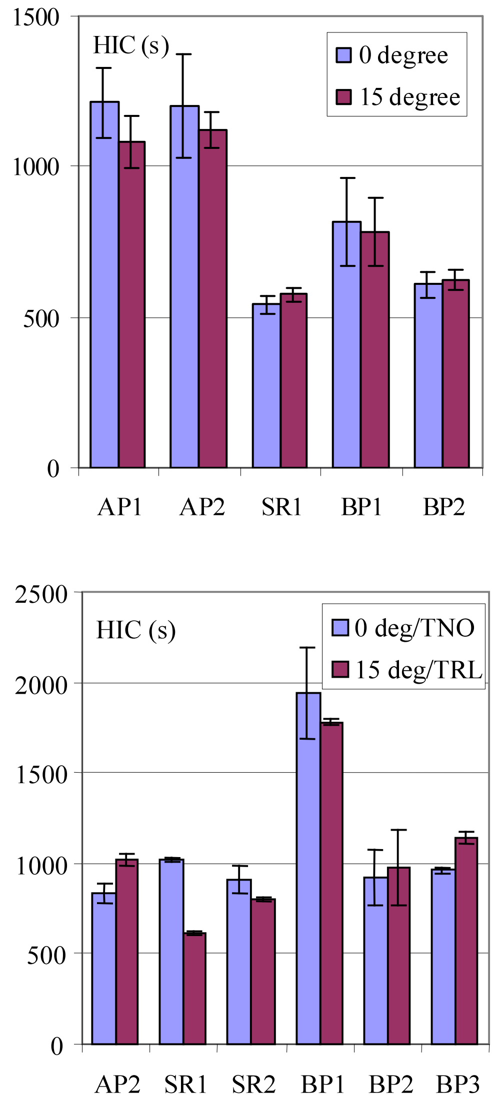

Figure 5. 0/15 deg pitched forward head-form tests on Focus (both tested at BASt) and Espace (tested at TRL and TNO).

tests. For some locations, this turned out to be impossible as the headform was not tilted forward by 15°. Especially for location AP2 and SR1, TNO had to change the angle of impact to have head contact without chin contact first according to FMVSS-201. For the other points the results of the TRL and TNO test show a similar trend.

Further analysis of these data will be undertaken in EEVC WG13 when the correct formula for the 15º pitched forward headform becomes available.

Comparison with US test condition

Of the cars tested in this programme, only the Toyota Camry is thought to have been designed to US standard FMVSS-201. FMVSS-201 specifies exact locations and impact angles based on the possible impact locations of the occupant's head. In contrast, the EEVC protocol specifies a perpendicular impact on a 'worst case' impact location.

A particular concern of WG13 has been that the US protocol allows optimising safety to a test procedure rather than what might happen in reality – i.e. the test procedure could be approved with a unidirectional energy absorption, as that was all that was needed, but in reality an occupants head could impact the surface and almost any angle. The EEVC worst case approach is believed to encourage omni-direction performance of energy absorbing systems.

The Camry was tested by TRL in the EC-15° condition and by TNO according to FMVSS-201 (Figure 6). Part of the differences between the test carried out by TRL and TNO must be attributed to

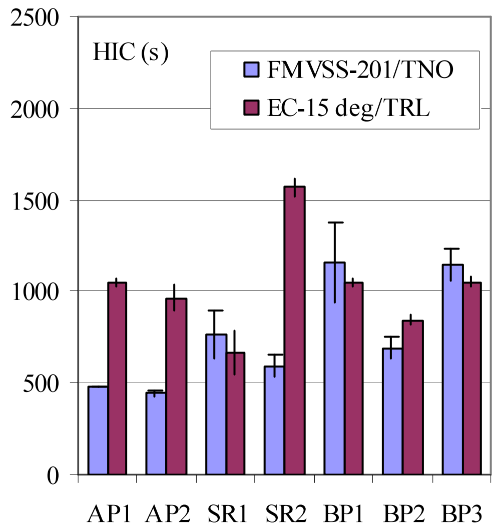

Figure 6. FMVSS-201 and EC-15 deg pitched forward head-form tests on Toyota Camry tested at TNO and TRL respectively.

Figure 7. Roof rail padding of the Toyota Camry after the EC test.

the uncertainty in the calculation of the HICdummy for the 15º pitched forward headform tests.

Especially for the locations on A-pillar (AP1 and AP2) and roof side rail (SR2) the different methods result in higher HICdummy values for the EC test condition. Some of the variation in results from the two comparative procedures may be explained by the energy performance of the padding system used in this vehicle. There is some suggestion that the padding has directional characteristics aligned with the impact directions expected in FMVSS201. When impacted at other directions to padding appears to have collapsed sideways rather than as was designed (Figure 7).

CONCLUSIONS

EEVC WG13 has been developing a new interior surface test procedure that could be used to enhance the safety afforded in Regulation 95 focused on head injury. In the Phase IV of the programme, a series of tests with three different vehicles and in four laboratories has been carried out according to the draft test protocol developed in Phases I to III. Although the test protocol addresses the assessment of active head protection systems, the Phase IV test programme has focussed only on the interior headform tests.

During the evaluation programme some problem areas were identified and modifications were made to the test procedure in an attempt to overcome them, the most notable problem being related to the issue of special vehicle constructions, as observed in the Renault Espace such as the presence of a double A post.

The draft test procedure proposed a number of procedure tolerances, such as impact velocity ±0.1m/s, target accuracy <10mm and external deflection <30mm. Evaluation at four test facilities suggest that of these tolerances, the external deflection could be changed to <10mm.

Initial testing suggested that secondary contacts with non-certified areas of the head could easily occur in some target positions. To overcome this to ensure a clean contact with the certified forehead contact patch some tests were performed with the headform pitch forward by 15º, but this was not subsequently adopted.

The EEVC test procedure aims to evaluate areas of the car that could result in the highest risk of head injury. The identification of such target points has proved to be the most difficult aspect. The variation in test results may reflect this difficulty. However, with familiarisation of the test set-up the procedure proved to be practical and easy to use and the time to carry out is comparable with FMVSS-201 testing. The development of special tools to define the limitation zone must be encouraged.

The evaluation programme has identified a number of areas where some improvement in the test procedure is needed. EEVC WG13 will be amending their proposed test procedure, as appropriate. The new test procedure is also the European contribution to the IHRA discussions on advanced side impact test methods [4] and is forming the core of their interior head protection test procedure .

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3 **Part 571 Crashworthiness**, Federal Motor Vehicle Safety Standard No. 201 - Occupant Protection in Interior Impact

4 **Seyer, K**. IHRA Side Impact Working Group Status Report.. Proc 18th International Technical Conference on the Enhanced Safety of Vehicles, Nagoya, May 2003.

ANNEX A: SUMMARY OF TEST PROTOCOL

Text and values between squared bracket are proposed and to be confirmed before the final issue of the protocol. (Example: [5.3]m/s)

Free Motion Headform Test method

Headform - US Free Motion Headform (FMH)
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 69 mm line 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 100 mm line 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 125 mm line 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 - FMH accelerated under linear control and released for free flight at between [25] and [100] mm of contact point

Impact Velocity - Two headform impact velocities are specified, the higher one for the evaluation of all target points not involving an active Head Protection Systems and the lower one being used for defined areas of the of vehicle, which are protected by an active Head Protection Systems.

- 6.7 m/s ±[0.1] m/s measured <[100] mm from contact point for 'normal' surfaces.
- [5.3] m/s ±[0.1] m/s measured <[100] mm from contact point for areas covered by an 'active protection systems' and for 'secondary impact'

Impact location accuracy - The impact alignment accuracy shall be within a radius of <[10.0] mm of the selected target point.

Impact Environment – The following applies:
- 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

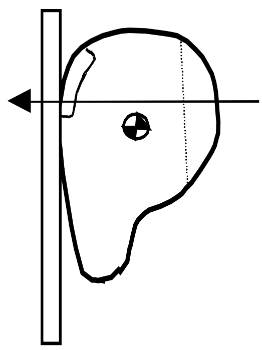

Figure A1. EEVC orientation, 0°.

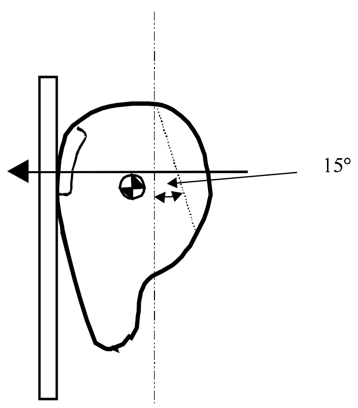

Figure A2. EEVC orientation, 15° forward of vertical

The impact angle, defined as the angle of 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.
The headform should be pitched forward [0° or 15°], see Figure A1 and A2, with respect to the launch velocity vector, to ensure that a clean contact is made with a point in the contact patch of the FMH.

The headform orientation for an impact is determined according to the following procedure, graphically illustrated in the flow chart shown in Figure A3.

The foremost point on the mid-saggital plane on the contact patch should coincide with the impact velocity vector through the contact target.
If the target location point cannot be hit with the head aligned vertically, then the head may be rolled up to 90° in the appropriate direction until a clean contact within the contact patch can be achieved, whilst minimising the potential for other parts of the headform to contact the vehicle during the primary phase of the impact.
If a clean contact is not possible then the headform should be returned to the vertical and yawed by 15deg in the appropriate direction and realigned with the target impact velocity vector. If a clean contact cannot be made following this secondary adjustment then the head may be rolled up to 90° in the appropriate direction.
If the point cannot be impact cleanly then the target point should be moved (again) within the defined limits.

Contact points - The contact points are defined similar as in regulation FMVSS-201 (part 571).

General guidance – The following applies:

'Worst Case' impacts: It is expected that 'worst case' will differ between vehicles, thus each vehicle should be assessed, by examining the drawings or physically, before assuming the padding, fixing or other structure would be the worst case.
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 and joints 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
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 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.
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, including attachment points within a 100mm radius of the target points the padding must be replaced. The 100mm 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 200mm 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 [30] mm. If necessary, the exterior of the vehicle may be 'additionally' supported to limit exterior movement to [30]mm.
If the side window can be opened, tests should be performed with the window fully open.

Approval criteria - FMH Head Injury Criterion
The Head Injury Criterion for the head-form (HICfmh) is calculated according to the following formula:

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

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.

Using the HICfmh, the HICdummy is calculated using the same correlation formula as specified in regulation FMVSS-201, namely:

$$HICdummy = 0.75446\ HICfmh + 166.4$$

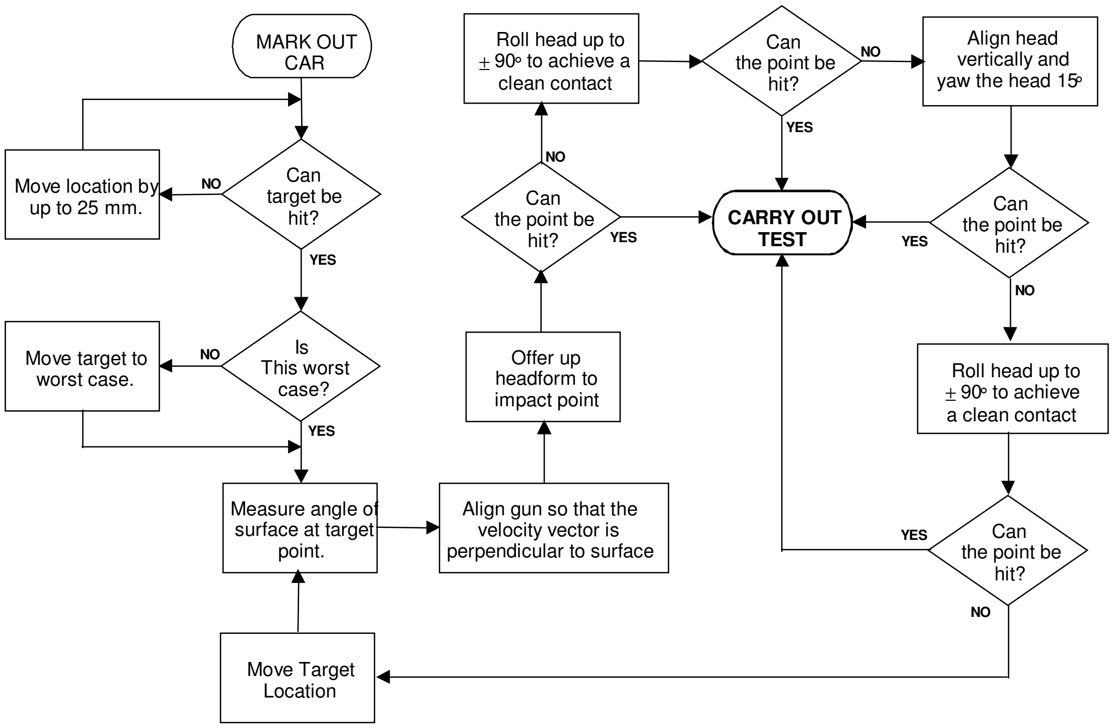

Figure A3. Headform alignment flow chart

ANNEX B: FMH TEST RESULTS

Table 4. Ford Focus results. All 15° HICdummy values were calculated with 0° formula.

Target location		Test laboratory Unit	Impact angles horizontal degrees	vertical degrees	head rotation degrees	Impact Speed m/s	HIC (dummy) s
AP1	**LHS**	**TRL-0°**	0	90	0	6.80	331
	RHS		0	90	0	6.63	850
	LHS	**VCC-0°**					
	RHS		1	48	0	7.06	511
	LHS	**BASt-0°**	273	35	0	6.60	1293
	RHS		87	35	0	6.74	1130
	LHS	**BASt-15°**	273	35	0	6.73	1142
	RHS		87	35	0	6.74	1019
AP2	**LHS**	**TRL-0°**	340	66	90	6.71	1082
	RHS		20	66	-89	6.71	1126
	LHS	**VCC-0°**					
	RHS		21	67	90	7.02	1078
	LHS	**BASt-0°**	273	35	-90	6.62	1207
	RHS		87	35	90	6.60	1322
	LHS	**BASt-15°**	273	35	-90	6.70	1077
	RHS		87	35	90	6.73	1163
SR1	**LHS**	**TRL-0°**	270	65	-9	6.75	1095
	RHS		82	65	9	6.68	1059
	LHS	**VCC-0°**					
	RHS		90	53	0	6.84	766
	LHS	**BASt-0°**	273	35	0	6.60	522
	RHS		87	35	0	6.79	563
	LHS	**BASt-15°**	273	35	-90	6.63	560
	RHS		87	35	90	6.61	591
SR2	**LHS**	**TRL-0°**	270	53	-6	6.69	779
	RHS		90	53	6	6.67	764
	LHS	**VCC-0°**					
	RHS		90	50	0	6.97	803
	LHS / RHS	**BASt-0°**					
	LHS / RHS	**BASt-15°**					
BP1	**LHS**	**TRL-0°**	258	60	-90	6.81	1421
	RHS		102	60	88	6.71	1279
	LHS	**VCC-0°**					
	RHS		118	53	90	6.83	801
	LHS	**BASt-0°**	260	26	45	6.80	922
	RHS		100	26	-45	6.72	711
	LHS	**BASt-15°**	260	26	0	6.61	862
	RHS		100	26	0	6.60	703
BP2	**LHS**	**TRL-0°**	271	21	-90	6.70	745
	RHS		91	21	90	6.67	783
	LHS	**VCC-0°**					
	RHS		103	23	51	6.88	773
	LHS	**BASt-0°**	260	26	45	6.80	577
	RHS		100	26	-45	6.63	640
	LHS	**BASt-15°**	260	26	0	6.62	602
	RHS		100	26	0	6.70	649
BP3	**LHS**	**TRL-0°**	254	6	84	6.76	1082
	RHS		116	6	-84	6.71	1125
	LHS	**VCC-0°**					
	RHS		100	40	90	6.70	857
	LHS / RHS	**BASt-0°**					
	LHS / RHS	**BASt-15°**					

Table 5.
Toyota Camry and Renault Espace results. All 15° HICdummy values were calculated with 0° formula.

Target location		Test laboratory	Impact angles horizontal	vertical	head rotation	Impact Speed	HIC (dummy)
		Unit	degrees	degrees	degrees	m/s	s
Toyota Camry							
AP1	**LHS**	**TRL-15°**	280	48	0	6.74	1035
	RHS		80	48	0	6.70	1063
	LHS	**TNO 201**	300	31	0	6.74	485
	RHS		53	30	0	6.57	482
AP2	**LHS**	**TRL-15°**	260	63	0	6.64	913
	RHS		100	63	0	6.70	1014
	LHS	**TNO 201**	396	20	0	6.71	454
	RHS		67	38	0	6.59	432
SR1	**LHS**	**TRL-15°**	270	35	11	6.68	576
	RHS		90	35	-11	6.77	747
	LHS	**TNO 201**	269	43	0	6.76	853
	RHS		90	34	0	6.50	668
SR2	**LHS**	**TRL-15°**	270	87	0	6.78	1536
	RHS		90	87	0	6.68	1603
	LHS	**TNO 201**	271	32	0	6.70	636
	RHS		90	30	0	6.77	549
BP1	**LHS**	**TRL-15°**	270	45	0	6.69	1060
	RHS		90	45	0	6.73	1029
	LHS	**TNO 201**	264	37	0	6.58	1003
	RHS		97	46	0	6.68	1315
BP2	**LHS**	**TRL-15°**	272	25	0	6.68	827
	RHS		88	25	0	6.69	864
	LHS	**TNO 201**	265	12	0	6.58	733
	RHS		96	2	0	6.47	646
BP3	**LHS**	**TRL-15°**	235	7	0	6.68	1072
	RHS		125	7	0	6.68	1031
	LHS	**TNO 201**	264	1	0	6.74	1083
	RHS		96	-2	0	6.78	1207
Renault Espace							
AP1	**LHS / RHS**	**TRL-15°**					
	LHS / RHS	**TNO-0°**					
AP2	**LHS**	**TRL-15°**	315	38	0	6.69	1000
	RHS		45	38	0	6.70	1040
	LHS	**TNO-0°**	312	41	90	6.59	798
	RHS		44	38	-90	6.51	876
SR1	**LHS**	**TRL-15°**	270	57	0	6.70	607
	RHS		90	57	0	6.72	621
	LHS	**TNO-0°**	270	32	0	6.55	1028
	RHS		90	33	0	6.61	1015
SR2	**LHS**	**TRL-15°**	270	50	0	6.68	789
	RHS		90	50	0	6.68	808
	LHS	**TNO-0°**	270	65	90	6.69	860
	RHS		89	65	-90	6.59	966
BP1	**LHS**	**TRL-15°**	270	57	-90	6.66	1767
	RHS		90	57	90	6.68	1791
	LHS	**TNO-0°**	270	51	-90	6.67	2117
	RHS		94	45	90	6.60	1761
BP2	**LHS**	**TRL-15°**	270	24	90	6.64	825
	RHS		90	24	0	6.72	1124
	LHS	**TNO-0°**	269	26	90	6.63	810
	RHS		89	23	-90	6.60	1029
BP3	**LHS**	**TRL-15°**	270	1	-90	6.72	1113
	RHS		90	1	90	6.73	1165
	LHS	**TNO-0°**	270	1	0	6.74	975
	RHS		90	0	0	6.60	952