EUROPEAN ENHANCED VEHICLE-SAFETY COMMITTEE

EEVC Working Group 13 Report

A REVIEW OF THE INFLUENCE OF GUIDANCE METHODS ON THE PERFORMANCE OF THE FREE MOTION HEAD-FORM, FOR USE IN INTERIOR SURFACE EVALUATION.

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EEVC Working Group 13 report

Abstract

The European Side Impact Regulation 95 includes the assessment of head impact with the EuroSID dummy. It is recognised that this would evaluate only a limited range of the potential head contact locations within the vehicle. EEVC Working Group 13 has undertaken a study of accidents to identify areas of injurious head contact in lateral impact and is developing a potential sub-systems head impact test. Three alternative head-form impactors were evaluated within phase one of a three-phase evaluation programme. Following the phase one the US Free Motion Head-form (FMH) was selected as the preferred impactor. Phase two of the evaluation programme has been performed to evaluate the effect of launch systems, free flight verses linearly guided.

This report presents results of the phase two test programme and compares the relative advantages of free flight and guided impacts, concluding that free flight projection should be adopted.

1. Introduction

EEVC Working Group 13 has embarked upon the development and evaluation of an interior surface head impact test procedure, for side impact head protection. The test procedure is designed to evaluate head protection provided in vehicles over a range of locations identified from detailed accident studies as areas of injury producing head impact. A three phase research programme has been developed to provide the basis for this test procedure which could be used as an annex to the existing full scale side impact Directive [1] or as an extension to an existing Regulation [2].

In the first phase of the EEVC programme [1], three potential head-forms were evaluated (EEVC adult pedestrian head-form, AAMA free flight head-form and the NHTSA Free Motion Head-form (FMH)), in free-flight impact into surfaces representing simplified forms of vehicle structure, that could be impacted by the head. Following part one of the programme the Free Motion Head-form was selected for further evaluation in Phases 2 & 3. The second phase, of the research programme is designed to study the relative merits of different head-form impact test methods, free flight and linearly guided. A third phase of the evaluation programme is being planned in which other aspects of a test procedure will be investigated. Furthermore the test procedure will be fully developed using vehicle structures and the efficacy of various protection strategies, as assessed by the head-form, ascertained.

This report describes phase two of the EEVC Working Group 13 research programme and discusses the merits of the two alternative guidance methods. Issues of sensitivity, repeatability, reproducibility are examined.

2. Test Programme.

Phase one of the EEVC WG13 research programme focused on two basic types of impact [3]; head-form(s) against a flat rigid surface with and without padding and secondly against a yielding structure representing the vehicle 'B' post. The tests included an investigation into the influence of impact angle. In the flat surface tests a slight modification was included in which a hidden rigid hard spot was located within the padding. The test programme described in this report is similar to that used in phase one but with the addition of a third test – that of a cantilever yielding beam rigidly supported at one end. The hard spot test was not included in phase two. Tests were performed at three test institutes (BASt, TNO and TRL), as in phase one. Each institute used their own FMH whereas in phase one a single FHM was used. In addition each institute used a different launch equipment and head-form guidance system.

2.1. Padding materials.

In phase one, two different padding materials were used, polyurethane and polypropylene. Due to manufacturing and supply difficulties the padding materials used in phase two were not identical to those used in phase one. Quasi-static crush and impactor tests suggested that the phase two materials were very similar even though they were manufactured in different ways. It is thought that comparisons could be made between phase one and phase two trials even with the small difference in the padding performance.

2.2. Head form propulsion and guidance systems

The Free Motion Head-form is designed and balanced for free flight projection. In order to test under fully guided conditions the head-form had to be modified. Each institute used their own existing acceleration system that were designed for launch of alternative free flight impactors, thus not only did the head-form(s) require modification but also the launch system.

Each test institute adopted a similar guidance strategy based on the rib piston/cylinder of the EuroSID-1 dummy [4]. This guide is based on a low-mass moving piston running in a fixed cylinder in which rotation is prevented by means of a roller running in a slot. One bearing is located in the end of the cylinder and another on the end of the piston rod, within the cylinder. This two bearing design significantly reduces binding in the system, due to bending forces that could occur in a single linear bearing. The two bearing design creates an effective long length bearing. The EuroSID-1 piston has approximately 55 mm of linear travel. Due to launcher restrictions it was necessary for both BASt and TRL to increase this stroke, thus the two institutes designed and manufactured their own linear guides based on the design principles and size of the EuroSID-1 rib guide unit. In all three institutes the cylinder was attached to the launcher and the piston to the FMH. It was not considered desirable to reduce the mass of the standard FMH to compensate for the piston mass thus the mass of the guided head-form was slightly higher than that of the standard FMH used for free flight. In order to enable comparative assessments to be made the mass of the free flight FMH was increased to the new guided mass, by TNO and TRL. In this phase two programme, the BASt head-form for free flight was 5.078kg and 5.13kg for guided impact. The TNO head-form was the same mass for both free flight and guided impact (5.08kg). The TRL head-form mass was 5.07kg for both types of impact. In phase one of the test programme the three test institutes used only one sample of the FMH (4.5kg). The paddings were obtained and supplied by TRL from a single supplier and from a single batch of material to minimise test variability. The surrogate 'B posts' (test condition 5)[1] tested by TNO were manufactured and supplied by Fiat and the 'B posts' tested by BASt were manufactured and supplied by VOLVO. The cantilever beams (test condition 6) used by TNO and TRL were manufactured within each institute.

2.3. Test conditions

Three generic test conditions were used in this phase of the test programme, Unyielding rigid surface with padding (test condition 2) Figure 1, Surrogate 'B' posts tests (test condition 5) Figure 2 and a Cantilever beam (test condition 6) Figure 3. Some test conditions were repeated in different institutes in order to evaluate reproducibility between test tools and institutes.

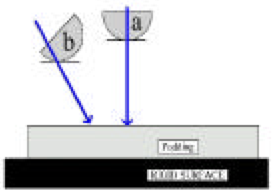

Figure 1 - Condition 2.

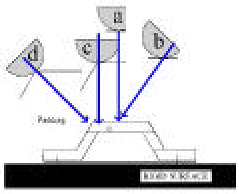

Figure 2 - Condition 5.

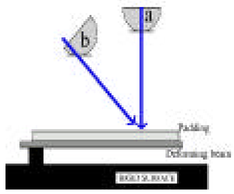

Figure 3 - Condition 6.

In preliminary testing, problems were experienced with the linear guidance systems if the impact angle was set at 45°, as used in phase one, due to bending and friction in the guide. The impact angle was therefore reduced to 60° for test conditions 2b, 5b and 6b. Angled impact, condition 5d, into the simulated 'B posts' was considered to be less severe in terms of induced bending moments in the guide thus the impact angle for this test condition was maintained at 45°. All test results were filtered to channel filter class CFC1000.

[1] The test condition numbers relate to previously planned phase one tests[3]

3. Evaluation of tests and results.

An initial examination of all of the test results (peak head-form acceleration) strongly suggested that a number of inconsistencies existed between test institutes and within test conditions. In order to identify the cause of the apparent inconsistencies and what remedial action should be taken, if any were deemed necessary, the three test institutions jointly examined all the test data. During this review a number of technical problems were identified. Annex A details one possible cause of variability in linearly guided impacts, based on cross axis sensitivity in the head-form accelerometers. The unanimous view of the reviewing group was that some of the test results should be eliminated from the overall analysis of the test programme for valid technical reasons.

The ‘approved’ results are presented in Tables 1-8 and show the mean resultant values for up to four repeated tests, except where stated, at each test condition and the range within the series.

3.1. Test condition 2

Test condition 2 (Figure 1) is the simplest of the three conditions evaluated. Tests were performed at an impact velocity of 2.5 m/s. Tests 2a were impacts normal to the surface (90°) and 2b at 60° rather than the 45° used within phase one. (Due to deficiencies in impact velocity measurement in phase one these results should not be compared with those previous published for phase one).

Table 1 Peak results from tests at condition 2a.

Institute	Polyurethane Padding		Polypropylene Padding	
	Guided	Free flight	Guided	Free flight
	Peak deceleration (range)		**Peak deceleration** (range)	
BASt	65.3 (9.2)	61.6 (0)	-	83.2 (2.1)
TNO	-	70.9 (1.0)	-	93.1 (2.3)
TRL	66.4 (5.4)	61.5* (14.6)	88.3 (12.7)	77.2* (13.2)
	HIC		**HIC**	
BASt	90.6 (17.5)	84.2 (1.4)	-	132 (6.9)
TNO	-	122.5 (5.0)	-	170.0 (10.0)
TRL	97.4 (10.2)	70.3* (46.1)	142.9 (41.6)	102.9* (30.4)

* head mass 4.5kg compared to 5.07kg for other tests

Table 2 Peak results from tests at condition 2b.

Institute	Polyurethane		Polypropylene	
	Guided	Free flight	Guided	Free flight
	Peak deceleration (range)		Peak deceleration (range)	
BASt	53.0 (13.3)	-	66.8 (9.4)	-
TRL	73.2 (3.2)	56.7 (0.7)	-	78.6 (2.6)
	HIC		HIC	
BASt	65.4 (24.6)	-	88.8 (23.5)	-
TRL	98.1 (2.1)	67.3 (1.6)	-	104.3 (4.5)

3.2. Test condition 5

Four ‘B’ post test conditions were examined (Figure 2). When the time histories of some of the angled impacts were reviewed unexpected events or contacts were observed. A two-phase impact appeared to have occurred, with the secondary phase being much higher than the first, identified by a rapid rise in acceleration for the second acceleration phase Figure 4. Film records showed that an unplanned secondary impact had occurred (condition 5d), where the FMH, in free fight mode, had contacted the ‘B’ posts’ rigid support structure. The severity of this contact varied and compromised the validity of the ‘B’ post impact. The cause of the secondary impact was a small misalignment of the head-form with respect to the corner of the B post. This resulted in changes in head-form motion during the impact. Tests, which included this unexpected secondary impact, were removed from the analysis, which then prevented some of the planned for comparative assessments.

In reviewing other angled impact acceleration time histories it was observed that two phases of deceleration had also occurred, with the second phase pulse being the greater, but not characterised by a rapid rise. It was concluded that the first phase of these events was due to the onset of plastic yield and the second to the overall stiffness of the ‘B’ post. Since ‘B’ posts had been sourced from two different centres, and different material stocks it is felt that inter institute comparisons should not be made because of differences in material properties.

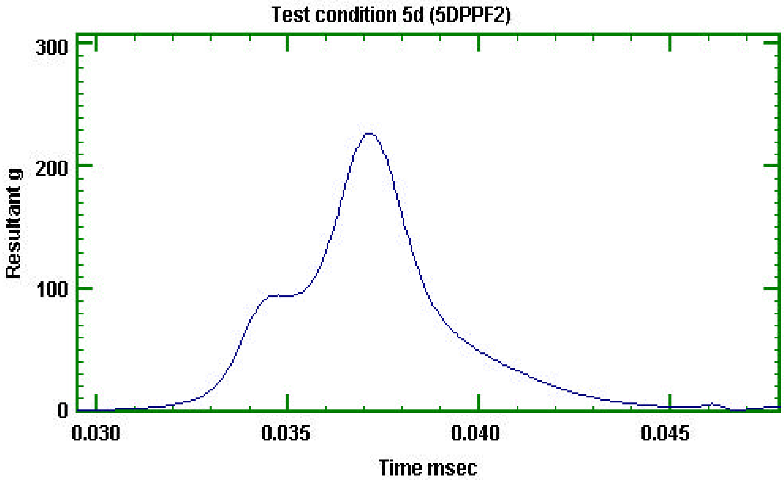

Figure 4 - Example of BAST 5d test, suggesting secondary impact

A superimposed low frequency signal with an amplitude of up 20g appeared in some of the guided angled impact tests acceleration time histories (Figure 5). This type and shape of signal was not present in all angled tests from all of the institutes. It is believed that the oscillation was caused by the design and dynamic performance of one of the linear guides, since the style of oscillations was associated with only one guidance system and only in angled impacts. It should be noted that each institute used a different guidance system and each could have performed differently, even though they were all based on a common design principle. It was considered that the amplitude and frequency of the superimposed signal had so adversely influenced the test results that these particular tests should be eliminated from the analysis. In other tests, from another institute, a low amplitude higher frequency signal was seen superimposed over the expected unimodal impact pulse. This higher frequency signal was also thought to emanate from the guidance system but due to its low amplitude it was not considered to be large enough to eliminate these results from the analysis.

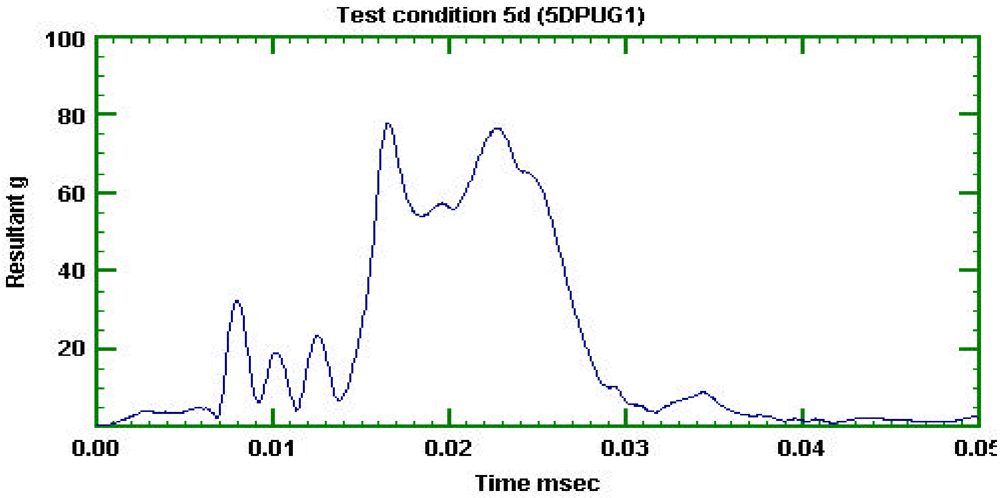

Figure 5 – Test showing low frequency superimposed oscillatory motion. (BASt)

Table 3 Peak results from tests at condition 5a.

Institute	Polyurethane		Polypropylene	
	Guided	Free flight	Guided	Free flight
	Peak deceleration (range)		**Peak deceleration** (range)	
BASt	107.6 (9.8)	140.9 (5.2)	114.9 (3.7)	149.6 (3.1)
TNO	175.8 (7.1)	158.5 (5.0)	172.9 (9.8)	152.7 (3.0)
	HIC		**HIC**	
BASt	606.1 (66.4)	887.3 (75.1)	670.9 (31.0)	1030 (69.8)
TNO	1230.0 (273)	1121.0 (52.0)	1218 (91)	1008.0 (38.0)

Table 4 Peak results from tests at condition 5b.

	Polyurethane		Polypropylene	
	Guided	Free flight	Guided	Free flight
	Peak deceleration (range)		**Peak deceleration** (range)	
TNO	157.6 (13.6)	139 (1.0)	164.6 (13.8)	-
	HIC		**HIC**	
TNO	1075 (104.0)	886 (20.0)	997.0 (55.8)	-

Table 5 Peak results from tests at condition 5c.

Institute	Polyurethane		Polypropylene	
	Guided	Free flight	Guided	Free flight
	Peak deceleration (range)		**Peak deceleration** (range)	
BASt	122.2 (5.2)	-	122.0 (3.7)	124.0 (11.2)
TNO	-	135.1 (6.4)	-	-
	HIC		**HIC**	
BASt	651.8 (45.3)	-	663.0 (37.0)	765.5 (68.7)
TNO	-	895.7 (6.0)	-	-

Table 6 Peak results from tests at condition 5d.

Institute	Polyurethane		Polypropylene	
	Guided	Free flight	Guided	Free flight
	Peak deceleration (range)		**Peak deceleration** (range)	
BASt	*	-	*	91.6**
TNO	-	102.6 (7.5)	-	-
	HIC		**HIC**	
BASt	*	-	*	304.1**
TNO	-	563.3 (35.0)	-	-

* Data eliminated from the analysis due to recordings superimposed by large amplitude low frequency signal thought to be caused by the performance of the guidance system.

* * Only one valid test at this condition

4. Test condition 6

Examination of the time history data from tests performed to condition 6 do not suggest that any results should be eliminated from the analysis due to guidance or uncontrolled noise problems. Even so when the peak data are compared and pulse shapes are examined a level of inconsistency is observed, Figure 5. The general shape of the curves, similar for both perpendicular and angled impacts, suggests differences in the plastic yield characteristics of the beams. As for the 'B' posts the beams were not manufactured by the same organisation therefore some differences in performance could be attributed to differences in material properties.

The clearance between the end of the cantilever beams and the support structure was 20mm. In all of the impacts, angled and perpendicular, the beam 'bottomed out' due to plastic deformation. The various peak readings and inflexion measurements, caused by yield, therefore represent different impact severities. Due to these differences comparisons between test institutes should not be made.

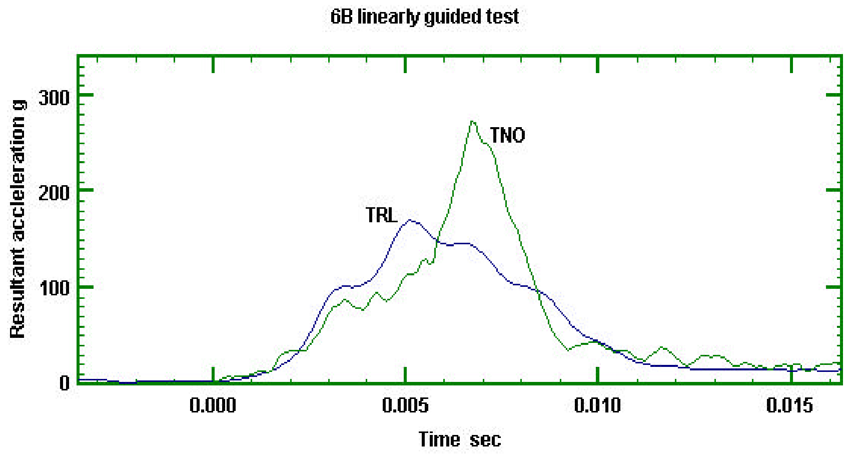

Figure 6. Example of two comparative test results from TNO and TRL for test condition 6b, suggesting beam material plastic yield point differences.

Table 7 Peak results from tests at condition 6a.

Institute	Polyurethane		Polypropylene	
	Guided	Free flight	Guided	Free flight
	Peak deceleration (range)		**Peak deceleration** (range)	
TNO	275.6 (18.1)	-	326.7 (14.4)	-
TRL	221.0 (25.7)	222.8 (16.0)	240.3 (59.9)	287.4 (20.3)
	HIC		**HIC**	
TNO	1738 (408)	-	2355 (292)	-
TRL	1359.5 (152.3)	1480.8 (124.9)	1468 (336.4)	1809.5 (36.1)

Table 8 Peak results from tests at condition 6b.

Institute	Polyurethane		Polypropylene	
	Guided	Free flight	Guided	Free flight
	Peak deceleration (range)		**Peak deceleration** (range)	
TNO	245.3 (15.5)	-	257.5 (40.5)	241.1 (12.7)
TRL	159.3 (3.4)	-	167 (4.2)	-
	HIC		**HIC**	
TNO	1239.3 (129.0)	-	1303.7 (375)	1278.3 (51.0)
TRL	1096.8 (22.0)	-	1039.2 (14.5)	-

5. General discussion

Detailed analysis of the test results obtained in the phase two programme has indicated the presence of unexpected problems. It is believed that these ‘problems’ are associated with the tested materials and head-form guidance systems and not with the performance of the head-form(s) or test procedures. The programme spread the test work across several institutes to permit comparisons not only of test conditions but also inter laboratory differences, if any should exist. It should be noted that each test institute used a different free motion head-form, their own linear guidance and propulsion system. Each institute attempted to test with a common head-form mass for both the guided and free flight tests. Due to the design of the BASt linear guidance system the total kinematic mass for the guided tests was slightly greater than for the free flight tests but the influence of the small additional mass was not considered to be significant (0.05kg).

Detailed analysis of the test results involving energy absorbing (yielding) components (‘B’ post and cantilever beam) have suggested that there were material differences in the tested components thus inter institute comparisons would be inappropriate for these test conditions (conditions 5 and 6). Even so comparisons and conclusions can be made within the test institutes, unless the performance of the guide system itself has compromised the quality of the test, which in some instances was the case.

Analysis of the test data has identified a large number of variables that were assumed to be under control. In reviewing the variability in the data and the number of poorly controlled variables the test institutes have considered that a statistical analysis of peak results would be inappropriate.

The results presented in Tables 1-8 show mean peak head-form deceleration values and Head Injury Criteria (HIC) and also the range within each test condition. Since an in-depth statistical analysis is not considered to be appropriate comments and conclusions have been made on the mean values and quality as assessed by the range.

5.1. Test condition 2

Test condition 2 is the least variable of the three test conditions, as it does not involve plastically deforming sub structures. The only variables are head-form manufacture and performance, launch velocity, padding quality (supplied from the same source and batch), free flight distance between head-form separation from launcher and impact surface and the performance of the linear guidance system. It should be noted that all impacts were performed horizontally thus the influence of gravity on the trajectory and final vector velocity will be influenced by the distance between release point and impact surface, and this would be greater for lower launch velocities.

When considering perpendicular impacts into both types of padding material (condition 2a), there appears to be a high level of agreement between the linearly guided and free flight tests, for the institutes were comparisons are possible. Guided test comparisons are only possible between BASt and TRL for the polyurethane material and good agreement is again observed. Results from free flight comparisons are poor but this in itself may be misleading due to low launch velocities (2.5 m/s) and free flight distances, which varied between institutes.

Preliminary tests results, not presented in this report, indicated that bending moments in the guidance system were unacceptably high for impacts at 45° to the struck surface. To reduce bending moments, to what was considered to be 'acceptable' levels, oblique impacts were performed at 60°. These test results seem to suggest that even at this reduced angle problems are still encountered.

5.2. Test condition 5

Analysis of the test records, both electronic and film, have suggested that there were differences in collapse mode and energy absorbing properties with the surrogate 'B' posts. From an examination of the deformed 'B' posts there is a suggestion that collapse in the central perpendicular tests (5a) was not symmetrical. The effect of this on free flight and guided impacts is therefore likely to be different, not easy to quantify and would add to variability in the test results. In a free flight test the head-form could 'roll' and translate sideways if sub structure collapse was non symmetrical and axial, as might a human head. In a guided impact lateral translation and roll motion would be constrained by the guide and fixation system and bending moments in the guide would be induced. There is also the suggestion that the B posts impacted in this phase of the programme deformed less symmetrically than those used in phase 1, thus comparisons with earlier tests might be inappropriate.

In none of the tests is a good level of agreement observed between free flight and guided impact, within the data that have been deemed to be 'useful'. The performance of one guidance system in oblique impacts highly compromised one set of tests rendering them inappropriate for inclusion in this report suggesting that guided oblique impacts could be a problem, and dependant upon guide performance. As might be expected there are indications that the influence of the different guidance methods is not large for perpendicular impacts. Unfortunately the clarity of this observation is masked due to dynamic behaviour of the 'B' posts. It should be noted that non-symmetrical sub structure failure would induce a lateral loading to the head-form and that these lateral forces would influence head-form response.

Some tests, by BASt, have suggested that free flight impact may be less repeatable due to poor impact alignment and inability to control preciously the free flight trajectory and the final vector of impact. This problem would largely be reduced with full linear guidance. It is thought that the degree of variability, seen in these tests in free flight could be significantly reduced with a good head-form release mechanism and by short free flight distances.

5.3. Test condition 6

The cantilever beam test was designed to test the head-form and guidance system in a second well controlled deforming structure absorbing environment. Examination of the time history records have strongly suggested that the materials used for the deforming beams at the two institutes performing this configuration had different plastic yield properties. In addition the beams deflected sufficiently for the unsupported end to contact the underlying rigid support structure. The severity of this secondary impact varied between the testing institutes due the differences in beam energy absorption rates. Due to these test features comparisons should not be made between the two test establishments, with respect to test reproducibility.

It should be noted that the peak accelerations presented in the Tables 8 and 9 reflect beam 'bottoming out' against the support structure rather than beam failure energy.

Examining tests that compare accelerations measured in free flight and guided impacts indicate a good level of equivalence for both perpendicular and oblique impacts although test variability is somewhat higher than might have been hoped.

6. Comparison of free flight and linearly guided impacts based on peak transducer data.

Previous discussion has highlighted a number of difficulties encountered in the test programme and these difficulties have prevented some of the planned comparisons being made. Even so a limited analysis has been made of matched data sets within test establishments, giving an indication of the differences between free flight and linearly guided control in perpendicular and oblique impact. Comparisons are made by test condition and test institute, Tables 9 and 10.

Table 9 Effect of guidance system on peak measurements – Perpendicular impacts

		Ratio Free flight/Guided	
		Peak FMH acceleration	FMM HIC
2a - Polyurethane	BASt	0.943	0.929
5a – Polyurethane	BASt	1.31	1.46
5a – Polyurethane	TNO	0.902	0.911
5a - Polypropylene	BASt	1.302	1.54
5a - Polypropylene	TNO	0.883	0.828
5c - Polypropylene	BASt	1.016	1.269
6a – Polyurethane	TRL	1.035	1.09
6a - Polypropylene	TRL	1.196	1.23

Table 10 Effect of guidance system on peak measurements – Oblique impacts

		Ratio Free flight/Guided	
		Peak FMH acceleration	FHM HIC
2b – Polyurethane	TRL	0.775	0.686
5b – Polyurethane	TNO	0.885	0.824
6b - Polypropylene	TNO	0.936	0.98

Analysis of the ratios between free flight and linear guided impact for the perpendicular test conditions indicate a large degree of scatter 0.902 to 1.30 but for the oblique impacts all the ratios are one sided in the range 0.936 – 0.775. This suggests that impact guidance systems do influence the severity of the impact and the two test methods are not the same. It might be expected that the ratios associated with perpendicular impacts should be unity with a small symmetrical scatter, due to experimental variation. The large scatter suggests that other factors may be influencing the quantitative assessment. Examining ratios by institute, Table 11, suggests that there may be an institute effect. General examination of each institutes perpendicular guided impact test time histories suggests that the amount of FMH energy consumed in the impact may vary. The BASt pre-impact data indicates pre impact head-form decelerations (release to impact) of between 5-10g, for TRL this is 3-5g and for TNO about 1g. All impacts were performed horizontally, to remove the effect of gravity on the head-form during the actual impact. Pre-impact deceleration must be due to friction in the linear guides since no pre-impact deceleration is observed for the free flight tests. Unfortunately gravity (lateral force in the guide) will influence the performance of any linear guidance system. Gravitation effects create bending moments in the piston, which are constrained by the performance of the plain bearings. The guides used within this programme had a common design base and operated in the reverse mode in which they had been designed. As the piston is withdrawn the effective bearing length reduces, resulting in increased frictional side forces on the bearings. FMH energy will be consumed to overcome this friction the magnitude of which is a function of stroke length and position. Both BASt and TRL had longer stroking pistons, than did TNO thus one might expect greater frictional losses (higher ratio) with BASt and TRL tests, and this is indeed the case.

Table 11 Comparative ratios by institute

Institute	Ratio Free flight/guided			
BASt	1.016	1.31	1.32	0.943
TNO	0.936	0.885	0.902	0.883
TRL	0.775	1.035	1.196	

Note. Each institute used a different guidance system so the different patterns may be more associated to guide rather than institute

Test condition 5a was a perpendicular symmetrical impact but a much larger than expected variation was recorded. On further examination the variation appears to be institute related. It was noted previously that the 'B posts' were made and supplied by different institutes and the fact that plastic deformation was not symmetrical. One explanation for these unexpectedly large variations might be associated with different collapse mechanisms in the B posts. A free flight head-form would rotate and translate sideways in a non-symmetrically deforming impact whilst in a guided impact the guide would try and restrain any lateral movement of the collapsing structure. This would result in increased shear forces and bending moments in the linear guide accompanied by higher frictional losses on the FMH to contact surface plane. Unfortunately there is insufficient information available to study this aspect and confirm the hypothesis.

7. Conclusions.

Test results and the performance of the linear guidance systems used in the programme have not been as well controlled as initially expected and the evaluation of the influence of free flight trajectory verses guidance has been compromised. Even so it is felt that sufficient information has been obtained against which to make valuable judgements.

1. The design and performance of the guidance system has been seen to influence head-form accelerations.

2. Comparative institute results, using linear guidance methods, have been compromised due to differences in test apparatus and associated performance.
3. Phase 2 results have been unexpectedly compromised due to differences in B post and cantilever beam materials.
4. Some Phase 2 oblique impact test results have been ‘fatally’ compromised by secondary impacts of the head-form against support structures caused by small alignment deviations or variations in yield mechanism in the B posts.
5. Both guidance systems have indicated that the polypropylene padding material is stiffer than the polyurethane material.
6. Head-form accelerations, in a linearly guided impact, may be compromised in oblique impact due to the performance of the guide and induced shear force and bending moments.
7. The specification and use of linear guides is considered difficult and unacceptable test variability is envisaged if linear guidance is adopted without adequate specification of the guidance system.
8. External studies seem to indicate that acceleration measurements may be compromised due to cross-axix sensitivities.
9. Based on the three institute’s test results and the general analysis performed by the authors it is strongly felt that free flight launch methods should be recommended.

8. References

1. UN-ECE, Regulation No. 95 - Directive 96/27/EC of the European Parliament and of the Council of 20th May 1996 on the protection of occupants of motor vehicles in the event of a side impact and amending Directive 70/156/EEC, *. 1996: Brussels.*

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9. Acknowledements

Report prepared for EEVC WG13 by P deCoo - TNO, Netherlands, AK Roberts - TRL, United Kingdom, A Seeck - BASt, Germany and agreed by EEVC Working Group 13.

10. Annex A

The Annex summarises an internal report prepared by BASt based on German studies examining perceived problems with acceleration measurements observed in tests with linearly guided impactors.

Brief summary about the acceleration measurement of linearly guided impacts

Undefined vibrations were observed in the signal of a linearly guided impactor. Discussions with other groups in Germany indicated that this was not a unique problem seen only in the BASt. The developer of the BASt impactor test bench[1)] analysed the vibrations in the piston not only for BASt but also for several German car manufacturers in three different ways:

- Simulation of the impactor test bench by a finite element analysis.
- Experimental testing by exciting the piston at a resonant frequency by a external oscillator with feedback.
- Mathematical analysis

In all three analyses the developer detected two different vibration types:

1. A longitudinal vibration. (characteristic oscillation).
2. A flexural vibration, with the maximum amplitude outside of the bearings.

In an impact the impactor accelerometers record the surface impact and both of the oscillation vibrations as they are excited. If the impact surface deforms in a non axial direction then the severity of the flexural vibration could be that much greater.

The flexural vibration depends on the distance between the bearings (guiding length), on the acceleration distance and on the penetration depth of the impactor into the surface. It increases with longer distances between the bearings and with higher penetration depths. The acceleration distances of the impactor are controlled by the design on the launch system and on its acceleration requirements.

The calculations show that the characteristic oscillation does not strongly depend on the material properties. The characteristic oscillation is about 1 kHz and there is no damping effect using the CFC 1000. The measured acceleration signal therefore is influenced by this characteristic oscillation.

Some proposals have been made to eliminate the vibration elements by means of differing filtering strategies but it is felt that this is not a satisfactory method for use in a legislative test procedure.

It is therefore strong suggested that for the head-form impactor a free flight launch system, rather than a guided system, should be adopted.

Annex A References:

1) Personnel communications:

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