EUROPEAN ENHANCED VEHICLE-SAFETY COMMITTEE

EEVC WG20 Report – Static Test of Head Restraint Geometry: Test Procedure and Recommendations

WG20 report

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Static Test of Head Restraint Geometry: Test Procedure and Recommendations

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64

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Summary

EEVC WG20 was tasked by the EEVC Steering Committee with developing a static test of head restraint geometry as a first stage in the mitigation of injuries in low-speed rear impacts. The WG was required to validate the repeatability and reproducibility of the test procedure and test tools and to provide a cost-benefit analysis from which recommendations for limits on head restraint back-set and height requirements can be made.

This report summarises the WG20 test procedure and the evaluation of the test procedure, including the rationale for the decision that have lead to the specification of the test procedure. It also summarises the UK cost-benefit analysis that has been developed in support of the test procedure.

A test procedure for head restraint backset has been developed, using a simpler method than that used in existing insurance rating schemes. A backset probe is positioned relative to the seat and head restraint using a portal frame and a co-ordinate measuring machine; the probe is then pushed towards the head restraint with a force of 10 N to measure the backset. The seat back angle is set to the manufacturer's design angle and the R-point is used as the origin for the height measurement, as in existing UN-ECE vehicle regulations. The use of a simple portal frame to position the backset probe avoids a number of problems relating to the reproducibility and representativeness of the 3-D H machine and Head Restraint Measurement Device (HRMD) typically used to measure head restraint geometry.

The draft WG20 backset test procedure has only been evaluated with a small number of seats and at a single laboratory. Wider experience with the test procedure should be gained before it is recommended for regulatory use. In particular, this is to ensure that the wording of the test procedure is interpreted consistently by different laboratories.

The existing Regulation 17 height measurement method was preferred by the WG as it is easy to implement and is well understood. However, it was found that this method overestimates the effective height of the head restraint and therefore the level of protection offered to the vehicle occupant. A proposal for a revised Regulation 17 height measurement method has been developed by the Netherlands that defines the effective height of the head restraint. This retains the advantage of not using the 3-D H machine and HRMD, whilst addressing the concerns regarding the overestimation of the effective height. If possible, this method should be combined with the backset portal method so that only one test apparatus is required to perform both measurements. It is recommended that this draft proposal is evaluated further.

A cost-benefit study has been undertaken based on UK accident data, injury costs and population height distribution. For this study, the following options for making regulatory changes were considered:

1. Doing nothing
2. Increasing the current head restraint height requirement from 800 mm to somewhere in the range of 800 to 850 mm
3. Introducing a limit for head restraint backset somewhere in the range of 40 to 100 mm
4. A combination of the two options for head restraint height and backset

For each of these options the benefits were determined by evaluation of the potential casualty savings that might occur as a result of the regulatory change. A monetary value was applied to the benefit by assigning a cost to each whiplash injury with long-term symptoms. This value, which was based on the willingness to pay model, was £ 61,326. Application of this cost to the 2005 UK casualty data

produced a total cost associated with the long-term whiplash injuries to front seat occupants in frontal and rear impacts of approximately £ 3 billion. The potential casualty savings were calculated as a proportion of this total cost. Long-term injuries that would be mitigated to short-term injuries by improved regulatory requirements were considered to be balance by short-term injuries being mitigated to non-injury; therefore, the cost of short-term injuries was not considered.

A conservative cost-benefit estimate was developed, based on the probability of mitigating long-term neck injury (Figure i) and on estimates of the costs for vehicle seat modifications. The benefit-to-cost ratio is shown in Figure ii. It should be noted that a static geometric head restraint requirement is a first step in mitigating low-speed rear impact injuries, and additional benefit may result from appropriate dynamic seat testing.

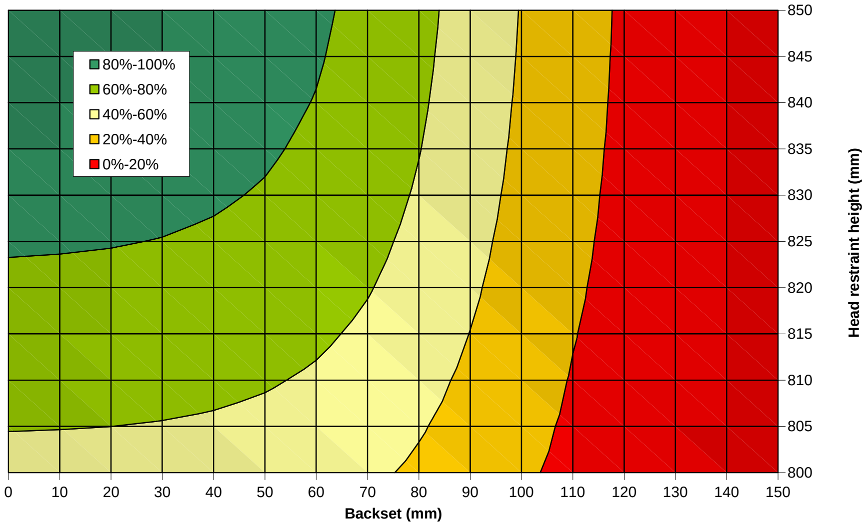

Figure i: Percentage probability of mitigating long-term neck injury based on head restraint height and backset for the UK male population

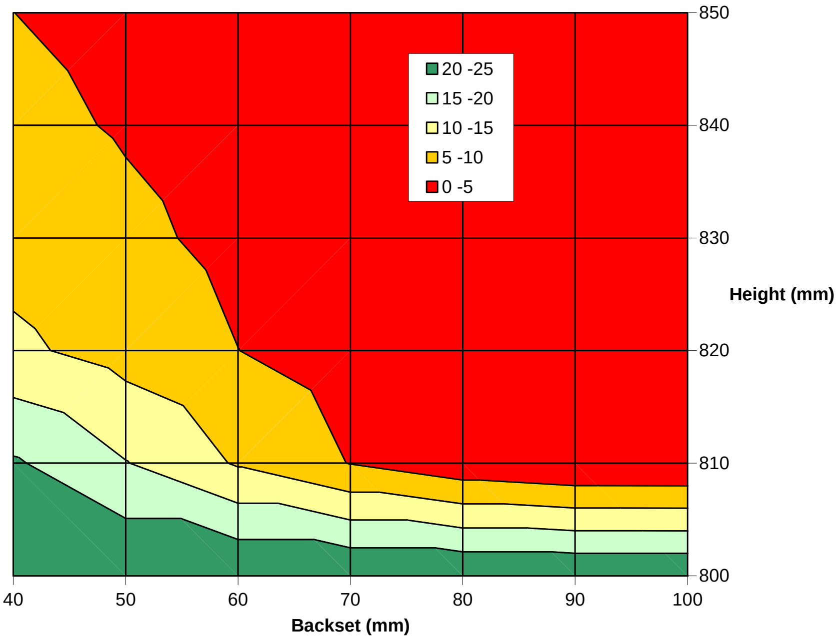

Figure ii: Graphical representation of the benefit divided by cost for the various proposed head restraint height and backset limits

The test procedure does not define a test for head restraint height or backset locking mechanisms, although it is recommended that such locks are mandated and that their strength is assessed.

It is recognised that tilting front seats in three-door cars, which represent approximately 20% of the EU fleet, may need additional consideration so that the head restraint does not prevent access to and egress from the rear seats. No specific test procedure has been developed, but recommendations have been made for how this could be achieved. The cost of vehicle and seat modifications that may be required for these vehicles is currently being collated.

The assessment of active and reactive head restraints was considered by the WG and a separate work item is in progress to develop a dynamic test procedure for these systems. However, it is recommended that consideration is given to applying the same head restraint height and backset requirements to active and reactive head restraints as for passive head restraints. This would ensure a minimum level of performance for active and reactive head restraints, even if the do not deploy as intended. Active and reactive head restraints would then be able to improve upon the minimum level of protection offered by a passive head restraint with the same geometric requirements.

1 Introduction - Static Test of Head Restraint Geometry

From the WG20 Terms of Reference:

> The Working Group shall develop a static test of head restraint geometry as a first stage in the mitigation of injuries in low-speed rear impacts. The WG will validate the repeatability and reproducibility of the test procedure and test tools. A cost-benefit analysis will be undertaken, and, based on this, recommendations for limits on head restraint back-set and height requirements will be made.
>
> *Deliverable: A validated test procedure and cost-benefit analysis.*

This report summarises the WG20 test procedure and the evaluation of the test procedure, including the rationale for the decision that have lead to the specification of the test procedure. It also summarises the UK cost-benefit analysis that has been developed in support of the test procedure.

2 Development of the WG20 Test Procedure

2.1 Initial RCAR-Based Draft Test Procedure

EEVC WG20 developed a draft head restraint geometry test procedure based on the RCAR test procedure used in the insurance industry [RCAR, 2001]. This procedure measures the height (relative to the top of the head) and the backset (the horizontal distance from the back of the head to the front of the head restraint) using the 3-D H machine (also known as the SAE J-826 manikin) and the Head Restraint Measurement Device (HRMD). Refinements were made to the text of the RCAR procedure to improve the consistency with which the test procedure was interpreted and to introduce a small load to the measurement tool to discourage overly soft head restraints.

The draft WG20 test procedure was evaluated for repeatability, reproducibility and usability by four laboratories (TRL, Thatcham, BASt and IDIADA) using three test tools (two manufactured by Automotive Accessories in the UK and one by TechnoSport for the SAE in the US) and four car seats. The test procedure and the evaluation programme were reported in EEVC WG20 document number 123 [Hynd *et al.*, 2006], which is available from eevc.org/publicdocs/publicdocs.htm.

Overall, the results suggested that seat design may be the most important source of test variability, but that it is possible to design a seat that has relatively good test reproducibility as well as a wide range of comfort adjustments.

With a tightening of the torso angle specification from 25° ± 1° to 25° ± 0.5° and improvements in the reproducibility of the 3-D H machine, the results of this test programme indicate that the draft WG20 RCAR-based test procedure could have sufficient repeatability and reproducibility for a Regulatory test procedure. An improvement in the reproducibility of the 3-D H machine may result from the calibration procedure being developed outside WG20 by the insurance industry.

2.1.1 3-D H Machine

During the development of the draft WG20 RCAR-based test procedure, it became apparent from the work presented to WG20 that there a number of concerns regarding the specification of the test tool used in the test procedure (the 3-D H machine). These concerns are discussed in Appendix A. In summary, the main concerns are:

- The geometry of the interface between the 3-D H machine and the seat is not sufficiently well controlled for use in evaluating the geometry of head constraints without additional calibration of the tool being undertaken. This is undesirable for a regulatory test tool, but in practice may not affect the current application of the 3-D H machine in regulation. However, it is not acceptable for measurement of head restraint geometry, which is more sensitive to differences in the geometry of the test tool. It should be noted that additional calibration procedures for the 3-D H machine and HRMD are being developed within the insurance industry whiplash protection initiative.

- The geometry of the interface between the 3-D H machine and the seat is not representative of any particular specification, such as the UMTRI 50th percentile male external geometry, so it is not clear how well it represents any particular occupant group.
- The 3-D H machine has rigid seat and back pans, with just a hip joint representation to allow rotation between the two pans. This means that the tool is unable to conform to the seat in the way that a human occupant would (e.g. to local structures such as lumbar support or narrow side bolsters in a sports-style seat). This means that the measured backset and height may be unrealistic for some seats, which could mean that adequate seat designs (for human occupants) are failed or that inadequate seat designs pass a given test procedure.

Overall, these concerns led WG20 to investigate alternative head restraint height and backset measurement methods that would not require the use of the 3-D H machine, or that would only use it to confirm that the torso angle and the R-point were set to within the required specification (which is how the 3-D H machine is used in current UN ECE regulations). However, it is also recommended that:

- Consideration is given to developing a specification and certification procedure for the external geometry of the seat and back pans of the 3-D H machine in order to better control this regulatory test tool.
- The references for and specification of the 3-D H machine in the regulatory texts is clarified.

2.1.2 Torso Angle

The draft WG20 RCAR-based test procedure used the 3D H machine and HRMD, and adopted a fixed seat back torso angle of 25°. This was considered to be a typical seat back angle adopted by drivers of cars. However, existing UN ECE regulations use the manufacturer's design angle for the seat, which is kept constant for all of the UN ECE regulatory test procedures for a particular vehicle model. For reasons of consistency, it was preferred to maintain the use of the manufacturer's design angle in any new test procedure unless there was a good justification for using a different torso angle. It was found that most cars have a design angle of 25°, but some have a design angle as low as 19°.

The use of design angle or a fixed angle (say, 25°) was discussed further by the WG. Based on the information in Appendix B, the WG found that there does not appear to be an advantage in specifying a fixed torso angle for static geometric testing if the3-D H machine and HRMD is not used. The use of the manufacturer's design angle could, however, be a problem for a matching dynamic test of head restraint geometry as the dummy used may not be stable at steeper torso angles. If a fixed torso angle of 25° was used in a dynamic test of head restraint geometry, and the design angle of the seat was not equal to 25°, the design angle would be expected to be steeper than 25° for the majority of vehicles to be tested. A more reclined seat back typically gives a greater backset (using a 3-D H machine and HRMD), so using a fixed angle of 25° may make a dynamic test or head restraint geometry more stringent than the static test for seats that have a design angle of less than 25°. In this case, reactive or active head restraints would be expected to be used and should be capable of providing a level of protection at least equivalent to that provided by good static geometry.

Recommendation: Use the manufacturer's design torso angle for regulatory compliance testing of head restraint geometry.

2.2 Alternative Test Procedures

As a result of the work summarised above, WG20 decided to investigate alternative methods of assessing head restraint geometry. Some of the alternatives are shown in Appendix C.

2.2.1 Alternative Backset Test Procedures

For backset measurement, the following alternatives were considered:

- Proposed EuroNCAP protocol using
  - SAE H-point manikin (very similar to the 3-D H machine)
  - Head Restraint Measuring Device (HRMD)
  - No preload to head restraint
- Draft EEVC WG20 RCAR-based test procedure
  - Similar to EuroNCAP, but with 10 N preload to backset probe
- Alternative proposal from UTAC (see GTR documents HR-06-03 and HR-06-06)
  - Replaces the 3-D H machine with a simple three-link mechanism located at the H-point
- 3D FARO measurement without HRMD
  - Like UTAC, but seat loaded with SAE manikin
- 3D FARO measurement without HRMD, without SAE manikin
  - Like UTAC without preload
  - Like UTAC with 10 N preload to backset probe

The evaluation of the backset options was reported in WG20 working document WD137 (see Appendix D). This report concluded that:

- The variation caused by the individual seats (one type of reproducibility) and SAE manikin positioning (repeatability) is larger than the deviation caused by a change of measurement method.
- The positioning of the SAE manikin (including seat back angle setting) mainly determines head restraint distance.
- Head restraint distance varies with seat back angle and H-point location. This relation is not similar for all seat types.
- Within the test procedure specifications, small differences in H-point location may result in large changes of the head restraint distance. For example in seat B the H-point location ranges from -3 to +2 mm, but the backset changes from -6 to +9 mm.
- No method gives more accurate results than any other method, so there is no preference for any method with regard to these results.

The following recommendations were also made:

- The measurement method is intended to be used for regulatory testing. This means that an easy-to-use and straightforward method will be preferred by the type approval engineer. The mathematical co-ordinate measurement machine (CMM - e.g. 3D Faro arm) method without the

HRMD and, if possible, even without the SAE manikin is therefore likely to be preferred to the method with manikin and HRMD.

- For this type of measurements (head restraint geometry) there is a need for tighter requirements on the positioning of the SAE manikin; alternatively, a more straightforward point in the car, like R-point, could be used. The latter option does not need an SAE manikin, as long as there are other means to properly verify the seat back angle. Not using an SAE manikin can make the procedures more robust, since errors in positioning are diminished.
- The influence of each of the parameters determining the measured head restraint distance can be investigated more thoroughly using a larger sample size of measurements.

It was noted by the WG that a simple (3D Faro-arm based method) could easily be extended to other occupant sizes, e.g. 95th percentile male. Based on this investigation, the simple CMM method was adopted by WG20 for backset measurement. A draft test procedure for this method has been written (see Appendix E); further experience with this test procedure is recommended by WG20 before the method is proposed for use in vehicle regulations. The test procedure is summarised in Section 3.

Recommendation: Use a simple CMM-based method for backset measurement regulatory compliance testing of head restraint geometry.

2.2.2 Alternative Height Measurement Procedures

For height measurements, the Regulation 17 measurement method was considered [EEVC WG20, 2007]. The WG agreed that the Regulation 17 height measurement method was straightforward to implement and had the advantage of not requiring the use of the combined 3-D H machine and HRMD. However, concerns were raised that the measurement method overestimates the effective height of the head restraint and therefore overestimates the benefit arising from the Regulation (see Appendix B of the UK cost benefit report [EEVC WG20, 2007]; see also GTR documents HR-02-03 from the NL and HR-03-10 from the Alliance of Automobile Manufacturers).

The backset portal could be modified to include a height probe. This would be a simple measurement and would be a better estimate of the effective height of the head restraint than the Regulation 17 method, but it would not be accurate for all head restraint designs (for instance, head restraints with a convex front surface). It would be preferable to define the effective height of the head restraint (the height that will offer whiplash protection to a given height of occupant) and measure this height, either using a modification to the Regulation 17 method or the backset portal.

A revised Regulation 17 height measurement method has been drafted by the Netherlands that defines the effective height of the head restraint (see). This retains the advantage of not using the 3-D H machine and HRMD, whilst addressing the concerns regarding the overestimation of the effective height. If possible, this method should be combined with the backset portal method so that only one test apparatus is required to perform both measurements. The method has only recently become available and should be evaluated more thoroughly before it can be recommended for regulatory testing.

Recommendation: Evaluate the draft proposal for a revised Regulation 17 height measurement method.

2.2.3 R-point vs. H-point

The use of the R-point or the H-point as the origin for the head restraint height and backset measurements was considered by the WG. The evaluation of alternative backset test methods (see Section 2.2 and Appendix C) indicated that reproducibility would be best if the R-point was used, rather than the H-point. With respect to type approval testing, the WG were in favour of using the R-point in preference to the H-point. The WG noted that when tests were to be performed without guaranteed communication with the manufacturer (e.g. for consumer ratings) there could be an advantage in using the H-point, but as this test procedure is for regulatory use this is not an issue.

The existing Regulation 17 height measurement method uses the R-point as the origin for the height measurement. The WG recommended that any updated Regulation 17 height measurement method (see Section 2.2.2) should also use the R-point.

Recommendation: Use the R-point as the origin for height and backset measurements for regulatory compliance testing of head restraint geometry.

3 Overview of the Draft WG20 Backset Test Procedure

The WG20 backset test procedure is based on the UTAC method, which proposed to replace the 3-D H machine and HRMD with a three-link mechanism, the links representing the ‘torso’ of the 3-D H machine, the ‘neck’ of the HRMD, and the ‘head’ of the HRMD respectively. These links placed the backset probe (as found on the HRMD) in the correct position for the backset measurement to be made.

In the WG20 backset test procedure, the UTAC method is simplified further by replacing the physical three-link mechanism with a calculation that defines the location of the backset probe relative to the R-point. The probe is held in place by a framework, known as a portal, that allows the backset probe to translate in a fore-aft direction so that the backset measurement can be made (see Figure 1). The 3-D H machine is installed in the seat only to check that the R-point and seat back torso angle are within the specified limits for the seat.

Figure 1: HRMD backset probe held in position using the adjustable portal arm

The initial position of the backset probe (IPx, IPz) is using the following equations:

IPx	=	[Rx - Tlink *sin(tda- da) - ProbeX]
IPz	=	[Rz + Tlink *cos(tda- da)+ ProbeZ]

where

Rx and Rz	=	the R-point co-ordinates
tda	=	the manufacturer's torso design angle
Tlink	=	505.5 mm
da	=	3°
ProbeX	=	60.5 mm
ProbeZ	=	205 mm

Tlink, da, ProbeX, and ProbeZ are constant values specific for a specific combination of 3-D H machine and HRMD and can be measured or found in manuals. It is recommended that these values are standardised to represent a 50th percentile male vehicle occupant. The R-point and tda are specified by the vehicle manufacturer. A simple spreadsheet to automate the calculation of the initial and final positions of the backset probe, and the backset, has also been developed.

The backset probe is loaded with an axial force of 10 N towards the head restraint. This ensures that overly soft front surfaces on head restraints, which may not be able to support the head effectively, are discouraged. The draft test procedure is reproduced in Appendix E.

3.1 Further Work

The draft WG20 backset test procedure has only been evaluated with a small number of seats and at a single laboratory.

Recommendation: Wider experience with the test procedure should be gained before it is recommended for regulatory use. In particular, this is to ensure that the wording of the test procedure is interpreted consistently by different laboratories.

4 Cost-Benefit

The UK undertook a cost-benefit study of geometric head restraint requirements. The study was based on UK accident data, injury costs and population height distribution, but should be representative of most of Europe. The main exception is The Netherlands, where the mean height of the population is greater than that in the UK. There are three key factors in car seat/head restraint geometry which determine whether whiplash occurs and how serious it is:

- The head restraint height (the height of the head restraint with respect to the head of the occupant).
- The backset of the head restraint (the horizontal distance from the back of the head to the front of the head restraint).
- Whether the head restraint has the ability to remain (or lock) in its set position whilst supporting the neck.

This cost-benefit study is concerned with the first two of these key factors and has been undertaken to determine the justification for making changes to the geometrical requirements for head restraints.

The potential options for making regulatory changes considered in this study were:

1. Doing nothing
2. Increasing the current head restraint height requirement from 800 mm to somewhere in the range of 800 to 850 mm
3. Introducing a limit for head restraint backset somewhere in the range of 40 to 100 mm
4. A combination of the two options for head restraint height and backset

For each of these options the benefits were determined by evaluation of the potential casualty savings that might occur as a result of the regulatory change. A monetary value was applied to the benefit by assigning a cost to each whiplash injury with long-term symptoms. This value, which was based on the willingness to pay model, was £ 61,326. Application of this cost to the 2005 UK casualty data produced a total cost associated with the long-term whiplash injuries to front seat occupants in frontal and rear impacts of approximately £ 3 billion. The potential casualty savings were calculated as a proportion of this total cost. Long-term injuries that would be mitigated to short-term injuries by improved regulatory requirements were considered to be balance by short-term injuries being mitigated to non-injury; therefore, the cost of short-term injuries was not considered.

To evaluate the benefits from decreased backset of the head restraint an injury risk function was developed based on published injury data [Olsson *et al.*, 1990] (see Figure). This is based on relatively old data for accidents and injuries occurring in Volvo cars from the 1980s. Since then, seat back and vehicle stiffness have increased across the vehicle fleet, and both of these factors are associated with an increase in the risk of whiplash injury. Therefore, this backset risk function is considered to be conservative and suitable for use in a cost-benefit study.

The protection offered by the height of the head restraint was evaluated by assuming that if the head restraint is high enough to support the centre of gravity of the head then the protection offered is adequate, otherwise it is inadequate. The height required included an allowance for ramping-up, whereby a person moves up the seat back during a rear impact. This assumption was combined with the height distribution of the UK population to give the proportion expected to be given adequate protection by different head restraint heights. The product of this and the backset risk function gives the injury mitigation distribution shown in Figure .

For each option, costs for Original Equipment Manufacturers (OEMs) to implement each of the proposed changes to the head restraint geometry were also determined. These costs were based on the increase in head restraint height. No response was forthcoming from industry for the costs associated with changing the backset of head restraints in cars, so no backset costs were used in the analysis.

The benefit minus cost value of each option was then calculated along with the benefit to cost ratio (Figure). It was found that the greatest benefit after subtracting the associated cost is expected with a head restraint height of 840 mm and a backset of 40 mm. The greatest benefit to cost ratio should occur with a small change in head restraint height and a backset of 40 mm. The minimum change in regulation expected to yield a benefit to cost ratio of two would be to adopt a backset of 70 mm.

It should be noted that a static geometric head restraint requirement is a first step in mitigating low-speed rear impact injuries, and additional benefit may result from appropriate dynamic seat testing.

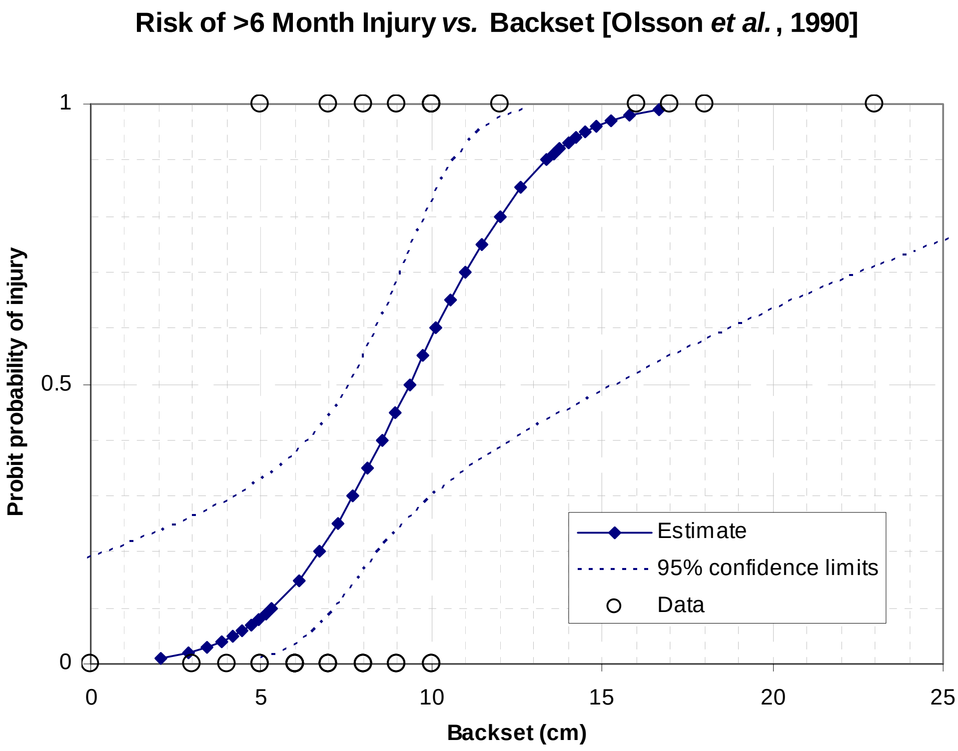

Figure 2: Risk of long-term whiplash symptoms (> 6 months) *vs.* head restraint backset, based on data from Olsson *et al.* [1990]

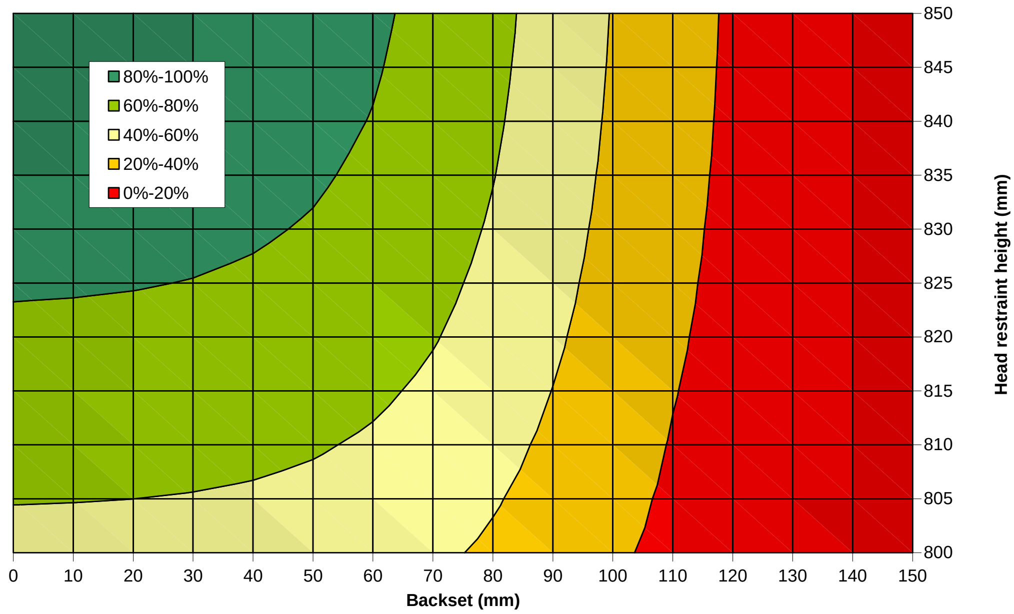

Figure 3: Percentage probability of mitigating long-term neck injury based on head restraint height and backset for the UK male population

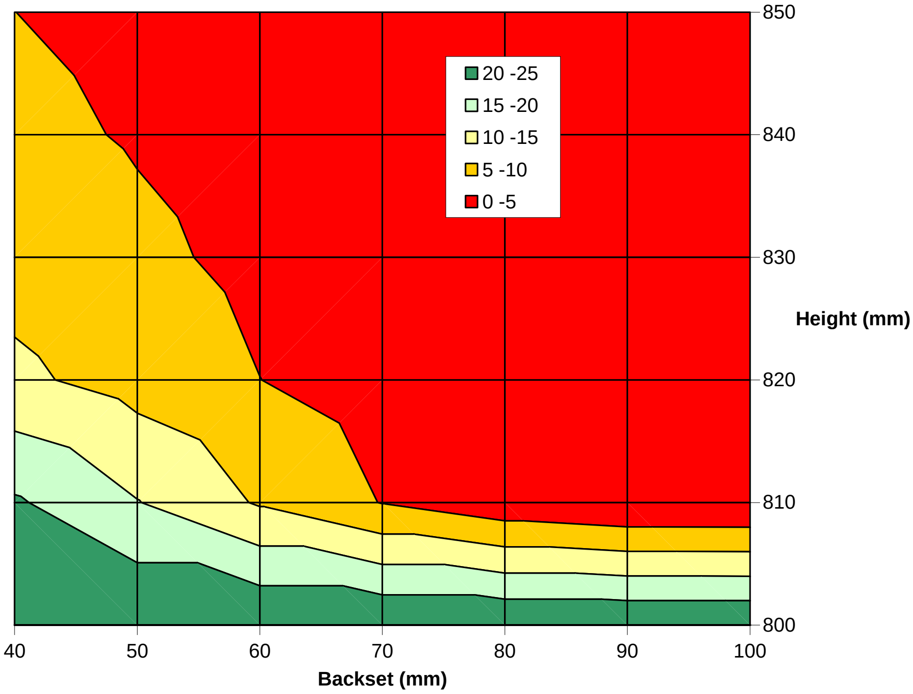

Figure 4: Graphical representation of the benefit divided by cost for the various proposed head restraint height and backset limits

5 Other Issues

5.1 Worst-Casing

Many vehicle models have more than one seat option (one vehicle model is reported to have over 20 seat variations) and approval testing of all possible seat models would be expensive. The WG considered the use of worst-casing to identify the seat with the worst height and backset measurements for each vehicle model and reduce the testing overhead. It is considered to be very difficult for an approval authority to determine the relative performance of different seats without testing them. However, the WG suggested the following approach to identifying the worst-case seat or seats through discussion with the vehicle manufacturer:

> ‘Worst-casing reduces the amount of testing needed across the range of a product type. Manufacturers shall be required to submit technical documentation to the type approval authority that adequately specifies the product (seat system) in terms of elements of the design relevant to the tests to be performed. A meeting shall be held between the type approval authority and the manufacturer in order to consider all of the products to be tested.
>
> ‘There are potentially a wide variety of seat and seat systems that will require inclusion under any approval and it is difficult to provide a specific set of rules to cover the worst case procedure for all approvals. Data may be presented by the manufacturer (including results of in-house testing) in order to assist in the selection of the worst-case seat.
>
> ‘The product variant to be tested will be the one with the expected lowest height and the largest backset. The product variants tested for each of the height and backset criteria may not necessarily be the same.’

5.2 Seat Adjustment

Current UN ECE Regulations define a small number of seat adjustments (see Table 1). Typically these are set to the manufacturer's design position unless there is a particular reason to set a different position (such as the worst, usually highest, position for the head restraint in the Regulation 17 strength test) or if the adjustment is not expected to make a difference to the result of the test (such as the position of the head restraint in the Regulation 95 side impact test). However, most seat adjustments are undefined (see Appendix G for a definition of the typical seat adjustments available in the current fleet). If the manufacturer does not define these adjustments, the approval authority will typically set these adjustments to match a non-adjustable seat of the same type.

For the WG20 test procedure, the same approach is recommended. The seat should be set up according to manufacturer's specifications that were used to set the R-point. As a minimum, the following seat adjustments should be considered where they are available on the seat being tested:

- Seat back angle
- Seat track fore-aft position
- Seat height
- Seat tilt
- Seat cushion height
- Seat cushion tilt
- Lumbar support
- Upper seat back angle

It should be noted that other adjustments are likely to become available and the manufacturer should provide the approval authority with adjustment information for these as appropriate. The seat back (torso) angle should be set to the manufacturer's design angle using the 3-D H machine, unless the manufacturer proposes a more accurate way to determine this angle. In this case, the 3-D H machine should be used to check that the seat back angle is within the required tolerance.

Adjustment	ECE R94 and ECE R95	ECE R17
Seat Track	Middle	Fore and aft
Seat Back Angle	Manufacturer's design or 25° torso angle	Manufacturer's design or 25° torso angle
Seat Height	Manufacturer's design or same position as a fixed seat	Highest and lowest
Seat Tilt	Manufacturer's design	Not defined
Cushion Height	Not defined	Not defined
Cushion Tilt	Not defined	Not defined
Cushion Extension	Not defined	Not defined
Lumbar	Fully retracted	Not defined
Side Bolsters	Not defined	Not defined
Head Restraint Height	Highest or CoG of the head (worst case)	Highest Position (Worst case)
Head Restraint Tilt	Most rearward (no interaction)	

Table 1: Seat adjustments in UN ECE Regulations 94, 95 and 17

5.3 Head Restraint Adjustment

The WG20 geometric test procedure was validated with the head restraint in the mid-height position and otherwise adjusted according to the existing RCAR procedure [RCAR, 2001]. Other possibilities are also possible, but have not been assessed by the WG to date. These include:

- The current Regulation17 approach - using the highest locking position, and using current calculation for the 50th percentile male to set the probe position
- Lowest and most rearward position - measure with calculation for 5th percentile occupant
- Mid position with most rearward position - measure with current calculation for 50^{th} percentile occupant
- Highest with most rearward position - measure with calculation for 95th percentile occupant

5.4 Tilting Front Seats

Three-door cars that have two rows of seats typically enable access to the rear row of seats by allowing the seat back to be tilted forward much more than would be achieved through the normal seat back angle adjustment. Usually, this means that the seat back is moved through the vertical position to a forward-leaning position. This is usually achieved by activating a quick release mechanism mounted on the seat.

Increasing the height requirement for front seat head restraints means that some head restraints in three-door cars may contact the roof of the vehicle during the tilting process, particularly for higher seat height positions, which would prevent access to the rear seats. More importantly, egress from the rear seats in an emergency could be impaired.

ACEA data that has been presented to WG20 shows that the approximately 20% of car sales in the EU are three-door cars. It is not known what proportion of these would be affected by any change to head restraint height requirements. The WG is collating this information, together with the estimates of the cost of possible vehicle and seat modifications that may be necessary for these vehicles.

The WG recommends that consideration is given to specifying a clearance that allows a lower head restraint height for tilting front seats if the regulated head restraint height would interfere with the roof in the manufacturer's design position. However, consideration should also be given to ensuring that adequate protection is available for taller occupants who have the seat adjusted lower than the manufacturer's design position. This could be achieved by, for instance:

- *Specifying that a [to be specified] clearance is allowed for the head restraint in its lowest locking position when the seat is in its highest use position*
- *Specifying that the same [to be specified] clearance is allowed for the head restraint in its highest locking position when the seat is in its lowest use position*
- *Specifying that there should always be a locking, use position of the head restraint that allows the seat to be tilted forward, even when the seat is in its highest adjustment position.*

5.5 Assessment of Active and Reactive Head Restraints

Active head restraints are moved forward (and usually upwards) early in a rear impact crash event to improve the position of the head restraint relative to the head of the occupant. The restraint is triggered by a sensor and actuated by a mechanism such as a spring or pyrotechnic device. There are a number of possible advantages to active head restraint systems, including:

- The head restraint does not need to be close to the back of the head during normal driving, which has comfort and user acceptance benefits. However, it is important to ensure that the head restraint will trigger during *any* crash event that may cause a whiplash injury, and that the actuation of the active head restraint does not itself pose an injury risk.
- During a crash event that may cause whiplash injury, the head restraint can be moved in to the best possible position for whiplash injury prevention. This means that different occupant sizes and postures can be compensated for more effectively than is possible with standard passive head restraints.

Reactive head restraints also move forwards (and usually upwards) in a rear impact event, but they are actuated by the torso of the occupant as it is pressed in to the seat back during the impact. Both active and reactive head restraint systems have the potential to reduce the risk of whiplash injury compared with passive head restraints, by improving, or even optimising, the geometry of the head restraint when it is needed.

There are several options for assessing the geometry of active and reactive head restraints:

- Applying the static test procedures for head restraint height and backset using either:
    - The same height and backset limits as passive head restraints. This option would ensure that the head restraint is as effective as a passive head restraint even if it does not deploy. The active or reactive nature of the head restraint is there to improve upon the protection offered by a passive head restraint with the same initial geometry.
    - Less stringent height and backset limits than required for passive head restraints. This option would assume (in the absence of any other test procedure) that simply being active or reactive would make the head restraint at least as effective as a passive head restraint with more stringent requirements. It is not clear how this would be assessed, so the predicted benefit from head restraint height and backset requirements may not be delivered.
- Assessing the geometry of the active or passive head restraint during a dynamic rear impact test
    - This is a separate work item on the WG20 terms of reference and is not considered further here.

Most types of active head restraints could be triggered and measured statically in their post-deployment position. This would ensure that the geometry was adequate, but it would not ensure that the head restraint would deploy reliably. This could be addressed by requiring the manufacturer to provide evidence that the head restraint will deploy correctly in *any* impact event that may cause a whiplash injury. However, reactive systems could not be assessed in this way as the amount by which they deploy is dependent on the dynamic interaction between the occupant and the seat during the impact.

Recommendation: Apply the static test procedures for head restraint height and backset to all head restraints, regardless of whether they are passive, active or reactive. This option would ensure that the head restraint is as effective as a passive head restraint even if it does not function as intended. The active or reactive nature of the head restraint is there to improve upon the minimum level of protection offered by a passive head restraint with the same initial geometry.

6 Summary

A simple test procedure for the determination of head restraint backset has been developed and has been evaluated with three seat types at a single laboratory. The test procedure uses a simple framework to hold a backset probe at a position calculated to be representative for a 50^{th} percentile male occupant; positions for other occupants could also be developed and tested very easily. The backset measurement is referenced to the R-point of the seat and the seat is set-up to the manufacturer's specification (e.g. the seat back torso angle is set to the manufacturer's design angle). The Head Restraint Measurement Device (HRMD) is not used and the 3-D H machine is only used to verify the R-point and seat back torso angle as per current UN ECE regulations. This means that the biofidelity, repeatability and reproducibility concerns that have been raised regarding the 3-D H machine (when applied to head restraint geometry measurements) are avoided.

It is considered that the test procedure provides a simple, cost-effective and reproducible assessment of head restraint geometry that is appropriate for regulatory approval testing. It should be noted that the use of the manufacturer's specification for seat set-up may make this test procedure less suitable for consumer information testing.

The test procedure does not define a test for head restraint height or backset locking mechanisms, although it is recommended that such locks are mandated and that their strength is assessed.

It is recognised that tilting front seats in three-door cars, which represent approximately 20% of the EU fleet, may need additional consideration so that the head restraint does not prevent access to and egress from the rear seats. No specific test procedure has been developed, but recommendations have been made for how this could be achieved. The cost of vehicle and seat modifications that may be required for these vehicles is currently being collated.

The assessment of active and reactive head restraints was considered by the WG and a separate work item is in progress to develop a dynamic test procedure for these systems. However, it is recommended that consideration is given to applying the same head restraint height and backset requirements to active and reactive head restraints as for passive head restraints. This would ensure a minimum level of performance for active and reactive head restraints, even if the do not deploy as intended. Active and reactive head restraints would then be able to improve upon the minimum level of protection offered by a passive head restraint with the same geometric requirements.

7 Recommendations

Recommendation: Use the manufacturer's design torso angle for regulatory compliance testing of head restraint geometry.

Recommendation: Use a simple CMM-based method for backset measurement regulatory compliance testing of head restraint geometry.

Recommendation: Use the R-point as the origin for height and backset measurements for regulatory compliance testing of head restraint geometry.

Recommendation: Review the proposal for a revised Regulation 17 height measurement method as soon as it becomes available.

Recommendation: Wider experience with the test procedure should be gained before it is recommended for regulatory use. In particular, this is to ensure that the wording of the test procedure is interpreted consistently by different laboratories.

The WG recommends that consideration is given to specifying a clearance that allows a lower head restraint height for tilting front seats if the regulated head restraint height would interfere with the roof in the manufacturer's design position. However, consideration should also be given to ensuring that adequate protection is available for taller occupants who have the seat adjusted lower than the manufacturer's design position. This could be achieved by, for instance:

- *Specifying that a [to be specified] clearance is allowed for the head restraint in its lowest locking position when the seat is in its highest use position*

- *Specifying that the same [to be specified] clearance is allowed for the head restraint in its highest locking position when the seat is in its lowest use position*
- *Specifying that there should always be a locking, use position of the head restraint that allows the seat to be tilted forward, even when the seat is in its highest adjustment position.*

Recommendation: Apply the static test procedures for head restraint height and backset to all head restraints, regardless of whether they are passive, active or reactive. This option would ensure that the head restraint is as effective as a passive head restraint even if it does not function as intended. The active or reactive nature of the head restraint is there to improve upon the minimum level of protection offered by a passive head restraint with the same initial geometry.

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Appendix A 3-D H Machine

A.1 Introduction

EEVC WG20 has been tasked with developing test procedures for the mitigation of injury in low-speed rear impacts, with a prime focus on reducing neck injury. Currently, the WG is following a programme to develop three test procedures:

- a static test of head restraint geometry;
- a dynamic test of head restraint geometry
- a dynamic injury assessment test procedure

Each of these test procedures requires the seat to be set up in a well defined and reproducible way. The seat back angle is usually adjusted to give a particular torso angle with the 3-D H machine, also used to determine the H-point of the seat in Regulation 94 and 95.

The objectives of this appendix are:

- To document WG20's understanding of the test tools (variously 3-D H machine, H-point machine or Oscar) used in several existing and proposed test procedures for the determination of H-points and the measurement of head restraint geometry;
- To document any differences between these test tools, in particular with respect to the measurement of head restraint geometry;
- To document existing and on-going efforts to calibrate the test tools;
- To document any outstanding issues outside existing and on-going calibration efforts;
- To make recommendations to the Steering Committee regarding the resolution of these issues and the future use of the test tool.

A.2 Definitions

A.2.1 Definition of the SAE J826 H-Point Machine

The history of the SAE J826 H-Point machine is as follows:

1. Report of the Body Engineering Committee approved November 1962.

2. Revised by the Human Factors Engineering Committee May 1987.

3. Revised by the SAE Human Accommodation and Design Devices Committee June 1991 and June 1992, rationale statement available, and completely revised July 1995.

4. The description of the H-Point machine was replaced in J826 Jun 2002 with a new H-Point machine known as ASPECT.

5. In February 2004, the ASPECT definition was moved to SAE J4002 and the original H-Point machine was reinstated in SAE J826 (July 1995 version).

J826 1995 calls the device an 'H-Point machine'. It includes a basic description of the machine, which includes a plunger unit to control the force used to locate the buttock unit into the seat, and a headroom probe.

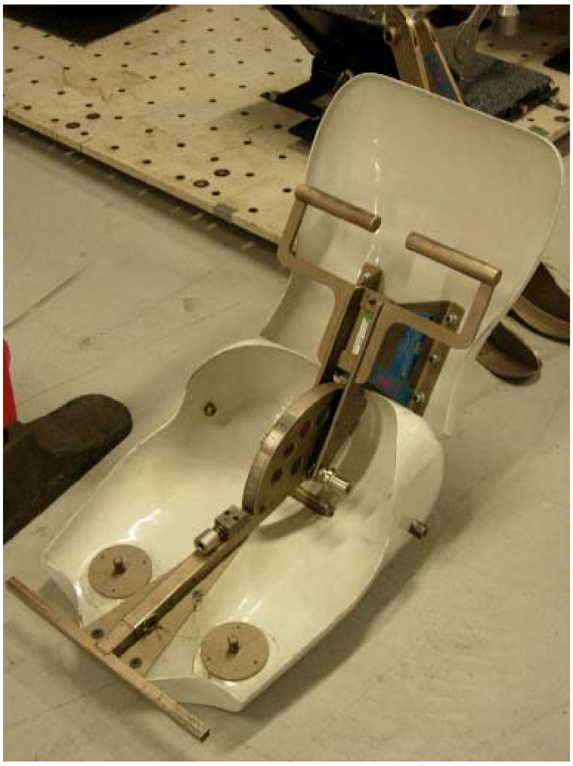

Figure A.1: SAE H-Point Machine manufactured by TechnoSports in the US - shown without weights and headroom probe, but showing the plunger unit

The machine is described as having seat and back pan ‘representations of deflected seat contours of adult males’. The machine provides ‘seat penetration equivalent to a 76 kg (167 lb) male.’ The following is given as a reference of the source of the dimensional data:

> ‘The adult male dimensions were take in part from the 50^{th} percentile data acquired by Geoffrey (SAE paper 267A, 1961). The remaining dimensions were developed from US Department of Health, Education and Welfare data by the Design Devices Subcommittee of the SAE Human Factors Engineering Committee, March, 1969.’

A.2.2 Definition of the 3-D H-Point Machine in ISO

A three-dimensional H-point machine was defined in ISO 6549-1980 and updated in ISO 6549-1999. The definition includes the following reference to the source of the data:

> ‘The torso and seat pans of the three-dimensional H-point machine are representations of average torso and seat contours of an adult male’ with the footnote: ‘Derived from data based on the driving population in the USA.’

No further reference for the data is given.

The machine provides ‘seat penetration equivalent to a 76 kg male’. Unlike the SAE machine, the ISO machine does not include a plunger to locate the buttock unit into the seat. The ISO Standard refers to the SAE for drawings and a videotape of the machine, but no specific standard or reference is given. The Standard notes that for highly contoured seats designed to give special support to the driver during cornering at high lateral forces, the three-dimensional H-point machine may give unrealistic results.

A.2.3 Definition of the 3-D H Machine in UN ECE Regulations

Regulation 94 and 95 refer to the 3-D H machine, with some basic drawings for nomenclature. For detailed information on the construction of the 3-D H machine, the reader is referred to the Society of Automotive Engineers, although no specific SAE standard is referenced. The Regulations also note that the 'machine corresponds to that described in ISO Standard 6549-1980', which appears to be the source for the figures used in the Regulation. The ISO standard refers to the SAE for drawings and a videotape of the H-point machine, but again no specific standard or reference is given. The figures in the ISO standard do not include the plunger unit shown in SAE J826.

Figure A.2: 3-D H Machine manufactured by Automotive Accessories, UK

A.3 Geometry of the 3-D H Machine and SAE J826 Seat and Back Pans

Whilst the source of the geometry of the seat and back pans is not given explicitly, investigations by the IIWPG reported to EEVC WG20 indicate that the geometry is based on a single person, not a representative average. The geometry is not identical to the UMTRI AMVO [Schneider *et al.*, 1983] geometry used in the latest crash test dummies (e.g. WorldSID, THOR-FT, BioRID).

It appears that the geometry of the seat and back pan is not well controlled. Discrete points on the surface of these pans are specified, but this appears to be insufficient to guarantee that the devices made by different manufacturers or at different times give identical interaction with seats, particularly those with more 'sporty' contouring. For most seats this is not expected to be an issue for H-point measurement within the tolerance normally used (±25 mm), but could be significant for the accurate determination of torso angle and, in particular, head restraint height and backset when the H-point machine is used in conjunction with the HRMD.

The Working Group was concerned that the geometry of the seat and back pan appears not to be well controlled and that this is undesirable for a regulatory test tool.

A.4 3-D H Machine and SAE J826 Calibration

The IIWPG and other groups have undertaken work to examine the consistency of the 3-D H machine and HRMD, both individually and when the HRMD is fitted to the 3-D H machine. This is separate from work, such as that undertaken by WG20, to evaluate the repeatability and reproducibility of head restraint height and backset measurements made using these tools.

Thatcham reported that they were able to get up to 16 mm difference in backset measurements by combining the least typical back assembly with the least typical HRMD hanger points and that the alignment of the hanger points is the biggest source of variation in head restraint measurements. They also note that there was a step-change in the geometry of the seat and back pans for J826 tools produced by TechnoSport in the US when they replaced the (worn-out) mould used to produce the parts. Some pans were up to 10 mm narrower at certain points. Whilst the effect of this on head restraint measurement has not been quantified directly, it is expected that it would be significant, particularly for seats with ‘sporty’ bolsters.

The IIWPG have developed a draft calibration procedure, including a specification for a special calibration jig (called GLORIA - see Figure 3). This jig ensures that the skeleton of the 3-D H machine is set up correctly and that the weight hangers are correctly aligned. It also ensues that seat and back pan are perpendicular. The HRMD is then fitted to the 3-D H machine and the backset and height probe measurements checked. If they are outside the defined limits the probes are replaced. If they pass the test, the 3-D H machine, HRMD and probes are marked to ensure that they are only used as a calibrated set. The specification for the GLORIA jig was based on the average geometry of a number of existing 3-D H machines / SAE J826.

Figure A.3: The GLORIA jig for calibrating the 3-D H Machine and HRMD

It is understood that the SAE are developing a calibration procedure for the SAE J826, but details of this are not yet available.

The GLORIA jig controls the relative alignment of the seat and back pans, but it does not control the geometry (the external 3-D profile) of the seat and back pans. It is understood that this will not be fully controlled by the SAE calibration procedure either.

WG20 expect that the GLORIA and SAE calibrations will improve the consistency of the test tools and that this will improve the reproducibility of test procedures that use the tools. However, there is still a concern within the WG that the lack of control of the geometry of the seat and back pans could lead to reproducibility problems with head restraint geometry measurements. It is also considered that this is an undesirable situation for the current use of the 3-D H machine (for H-point and torso angle determination) in existing regulations.

A.5 Recommendations

- It is recommended that consideration is given to developing a specification and certification procedure for the external geometry of the seat and back pans of the 3-D H machine in order to better control this regulatory test tool. To-date, the test tool has been reported as adequate for H-point determination, but the lack of control of the geometry could affect interaction with the seat, especially for narrower sports seats, and was not considered by the WG to be desirable.
- It is recommended that consideration is given to reviewing the Gloria certification jig for possible use in current regulations using the 3-D H machine. This would be most important if the 3-D H machine is used for head restraint geometry assessment.
- It is recommended that the SAE and IIWPG 3-D H machine certification work is reviewed periodically to ensure that the WG is up-to-date and that work is not duplicated.
- It is recommended that the references for and specification of the 3-D H machine in the regulatory texts is clarified.

Appendix B Torso Angles

B.1 Introduction

EEVC WG20 has been tasked with developing test procedures for the mitigation of injury in low-speed rear impacts, with a prime focus on reducing neck injury. Currently, the WG is following a programme to develop three test procedures:

- a static test of head restraint geometry;
- a dynamic test of head restraint geometry
- a dynamic injury assessment test procedure

Each of these test procedures requires the seat to be set up in a well defined and reproducible way. The seat back angle is usually adjusted to give a particular torso angle with the 3-D H machine, also used to determine the H-point of the seat in Regulation 94 and 95. WG20 is currently considering the options for defining torso angle for a static test of head restraint geometry, as discussed below. Some of the issues may also be relevant to the dynamic test procedures that are under discussion and this is also highlighted below.

B.2 Options for Defining Torso Angle

There are two main approaches to setting the torso angle of the seat:

- Defining a fixed angle for all seats (such as the 25° torso angle in the RCAR test procedure used by the insurance industry)
- Using the manufacturer's design angle (as already used in a number of UN ECE Regulations)

A torso angle of 25° is used in the draft WG20 RCAR-based static geometric test procedure and the repeatability and reproducibility this procedure have been assessed by the WG [[Hynd *et al.*, 2006]]. At the 13th WG20 meeting a list of advantages and disadvantages for each torso angle definition was developed, which formed the basis for the list below:

B.2.1 Manufacturer's Design Angle

Advantages

- Consistent with existing UN ECE regulations.
- Works for seats that do not adjust to the specified angle.

Disadvantages

- Design angle may not be typical of occupant seating position.
- Design angle could be chosen to give a good backset measurement (but only at the cost of changing the angle for all other regulatory tests).
- Only one specification of each vehicle model is tested in the Reg 94 and 95 front and side impact tests - how is it ensured that other model variants with other seats have a 'reasonable' design angle? The use of a 'reasonable' design angle is only ensured for one seat option and some vehicle models have over 20 seat options.

- If the design angle is less than e.g. 25°, then a more reclined 'typical' angle would be likely to have a greater backset.
- The design angle is based on a CAD representation of a 95th percentile male occupant and the seat R-point is used as the reference, not the H-point - whereas static geometric test tools are based on a 50th percentile male occupant.
- The test tool in the draft WG20 RCAR-based test procedure (3-D H machine and HRMD) is not stable at torso angles less than ~23° - the test tool must be held in place if the seat back is steeper than this.

B.2.2 Fixed Angle (say 25°)

Advantages

- Guaranteed to be consistent for all variations of a seat in a vehicle model.
- Existing test tools demonstrated to work at 25° (if a 3-D H machine plus HRMD style test procedure is used).
- A fixed torso angle of 25° would be typical of manufacturers' design angles for most cars.
- Less than 25° will typically give smaller backset, but may not be typical of real-world seating positions.
- Reasonably representative of the torso angle set by drivers in the field.

Disadvantages

- 25° may not be typical for e.g. car-based vans - may be less than 25°.
- Not consistent with other UNECE regulations.
- Some seats may not adjust to a torso angle of 25°.

B.3 Manufacturer's Design Angles

Information on the manufacturer's design angle for four European manufacturers' vehicles on sale in Europe have been made available to the WG. This includes 41 cars and 7 vans, representing approximately two-thirds of the total number of models produced by the eight manufacturers. For the cars, 30 of the 41 vehicles had a design angle of 25° for the front seats. The mean was 24.5°, the median was 25°, and the range was 19° to 25°. The torso angle was very manufacturer-specific: some had very consistent torso angles across their models at or near 25°, while others had a wide range of torso angles across their models. For outboard rear seats, the range was 20° to 27°, with a median of 25° and a mode of 27° (26 vehicles reported).

For the vans, the design angle of the front row of seats had a range of 19° to 25°, with only one vehicle having a design angle of 25°. The mean was 21.7°. The rear outboard seats, where fitted, all had a design angle of 21° or 22°.

The data for front seats is summarised in **Figure B.**.

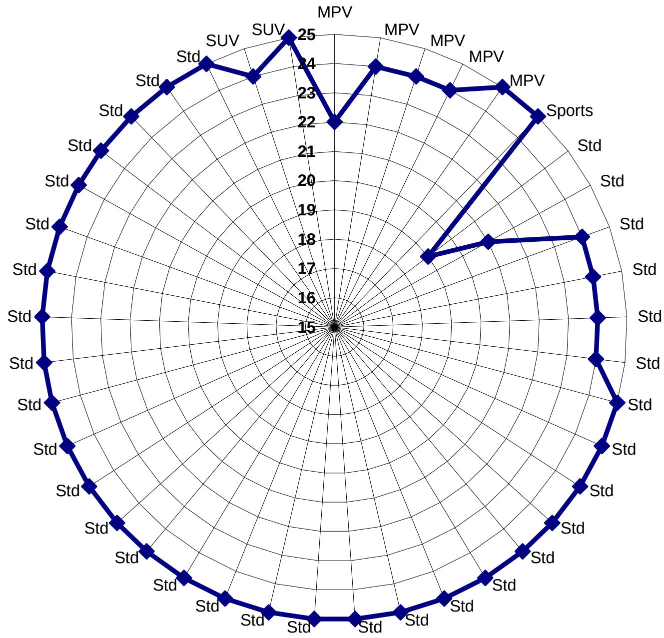

Figure B.1: Manufacturer's design angles for a subset of the cars and vans from the European fleet

B.4 Issues for Consideration

If using 3-D H machine and HRMD based procedure:

- Could opt for 25° or as near as the seat will adjust, but
    - Equipment would not work for some seats and would have to be held in place

If using a UN ECE Regulation 17 style procedure

- Any seat angle could be used, so
    - Could opt for 25° or as near as the seat will adjust, or
    - Could use manufacturer's design angle (but can't guarantee that this will be 'reasonable' for seats not used in Regulation 94 and 95)

A currently unpublished study presented to the WG showed that front seat occupants have poor repeatability of seat-back angle selection, so are likely to use vehicles at a range of angles.

A more reclined seat back typically gives a greater backset (using a 3-D H machine and HRMD), so using a fixed angle of 25° may offer greater protection to those users who set their seat backs more upright than this. By contrast, using a more upright torso angle may offer lower protection to those who use their seat at a more typical angle.

Appendix C Alternative Static Head Restraint Backset Test Procedures

C.1 Introduction

EEVC WG20 has developed a test procedure, based on the RCAR test procedure, for assessing the geometry of head restraints. The WG20 procedure uses the 3-D H machine (used in regulatory and consumer testing to locate the H-point of a seat) and the Head Restraint Measurement Device (HRMD - used in the RCAR test procedure) - see Figure C.1 and Figure C.2. The procedure has been evaluated by the WG and a report on the evaluation is now available [Hynd *et al.*, 2006]. In the time since the WG developed and evaluated this test procedure, several alternatives approaches have been proposed, both within WG20 and other fora. The first is a proposal from UTAC to determine the H-point of the seat using the 3-D H machine, and then to use a simpler tool to measure the geometry of the head restraint Figure C.3 and Figure C.4). The other proposal, from OICA and JASIC, is to use a modified version of the existing Regulation 17 test equipment to measure the geometry of the head restraint relative to the R-point of the seat (Figure C.5).

The pros and cons of the three main static geometric test methods, as currently considered by WG20, are listed in the sections below:

Figure C.1: 3-D H machine and HRMD

Figure C.2: Backset measurement using 3-D H machine and HRMD (EEVC WG20 method)

Figure C.3: 3-D H machine and HRMD

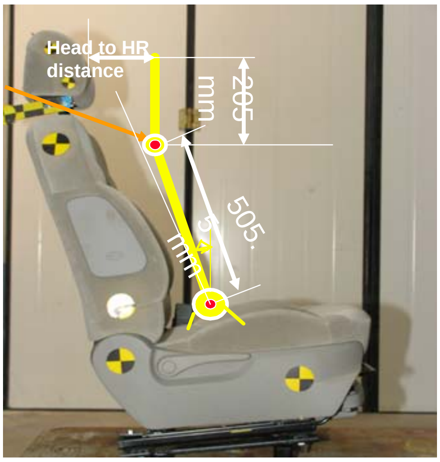

Figure C.4: Schematic of simplified UTAC approach

Figure C.5: OICA / JASIC approach using modified Regulation 17 equipment

C.2 Summary of the Alternative Backset Measurement Methods

C.2.1 3-D H machine and HRMD (current WG20 draft test procedure)

Advantages

- Loads the seat
- Based on H-point - so seat-specific
- Can use with isolated seat, BIW or whole vehicle

Disadvantages

- Geometry of seat and back pan not well controlled and not representative of any particular occupant group (arbitrary shape, which is not defined)
- Relatively high variability in backset and height measurements
- Seat and back pan do not conform to the seat as a human would - not biofidelic - but is this needed? Causes a problem with narrow seats

C.2.2 UTAC

Advantages

- Easy to use, easy to replicate in CAD.
- Don't need additional calibration of the 3-D H machine / HRMD combination (e.g. Gloria calibration rig) because no HRMD used. 3-D H machine is used only for what it was designed to do (i.e. determine the H-point and torso angle).
- Could incorporate the HRMD height probe. Advantage that it is a seat-based measurement, to an extent even if manufacturer's design angle is used.

Disadvantages

- Can’t push probe in to head restraint.
- Still has all the disadvantages of the 3-D H machine interacting with the seat and not having a controlled shape, poor interaction with bolsters etc.
- Doesn’t load the seat back at the time the backset measurement is made

C.2.3 OICA/JARI

Advantages

- No interaction of an uncontrolled part with the seat (assuming simple back plate is defined)
- Makes use of existing Regulation 17 test fixtures, used for height measurement
- Uses the R-point, which is well defined and repeatable
- No effect on the provision of lumbar support

Disadvantages

- Depending on definition of back-plate interface and force applied, could push in to seat back foam more than full human back and give a smaller backset than the human
- Uses the R-point, which may not represent a typical H-point and could be adjusted to improve backset measurement

Appendix D Evaluation of Static Backset Measurement Methods

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TNO report

Comparison of static backset measurement methods

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Contents

1 Introduction

EuroNCAP intends to introduce a static head restraint evaluation method soon for the prevention of whiplash injuries in rear-end crashes. This methods makes use of an SAE-manikin (OSCAR) and a Head Restraint Measuring Device (HRMD) to determine the horizontal and vertical distance between the head and the head restraint. As there are various manikin-HRMD combinations around the world, with somewhat different back shapes it is uncertain how these will influence the measurements. One of the proposals is to certify the shape of the SAE-manikin, to be sure all devices measure the same distances. On the other hand, alternative ways of measuring can be thought of, not using an HRMD at all. A few alternative methods, which should diminish errors due to the the devices used, were evaluated in the current study. The measurements of the EuroNCAP protocol were used as a reference.

2 Methods

2.1 EuroNCAP

In summary, the EuroNCAP protocol specifies that a car seat should be set to the following position prior to testing:
– Seat at mid travel (forward-rearward) and mid height (up-down)
– Seat back inclination to 25 +/- 1 degrees using an SAE manikin
When the SAE manikin is installed in the seat and the seat is set to the required settings, the HRMD is placed on top of it, the head being leveled horizontally, and the head restraint distance is measured in vertical and horizontal (backset) direction. Backset is thought to be most important of these two, since it determines the horizontal travel of the head, which should be limited as much as possible during rear impact.

2.2 UTAC

With the use of different measuring devices from various manufacturers, it was found that the results of the head restraint backset measurements show a lot of scatter. So alternatively, UTAC in France proposed a method for measuring backset only, which does not use a combination of SAE manikin and HRMD. UTAC proposed to use a three link device representing the size of an SAE machine (Figure 1)

Figure 1 – HRMD backset measurement (left) and UTAC three-link bar replacement (right)

The manikin is replaced by three links (Figure 2):
1. From H-point to HRMD rotation point. This link has a length of 505.5 mm and is set at an angle being the seat back angle minus 3 degrees (which is more upright).
2. From HRMD rotation point to probe vertical location, being 205 mm above the HRMD rotation point
3. The probe itself, which now measures 73 mm more compared to a standard backset measurement. In fact the *flat* back part of the head would be 60.5 mm behind the vertical (second) link.

The advantage of this method is its simplicity, the disadvantage is that it still needs an SAE-manikin to find the H-point location and seat back angle. Given the fact that the first two links are set at a predefined length and angles, it is more straightforward to directly calculate at which position the rear flat part of the HRMD head would end up. From that point the distance between the rear flat part of the head and the flat front part of the probe can be measured, which is the head restraint distance (see also Figure 3). In that case the links are not needed and just a few geometrical equations and a 3D Coordinate Measuring Machine (CMM) measurement are needed as will be used in the next paragraphs.

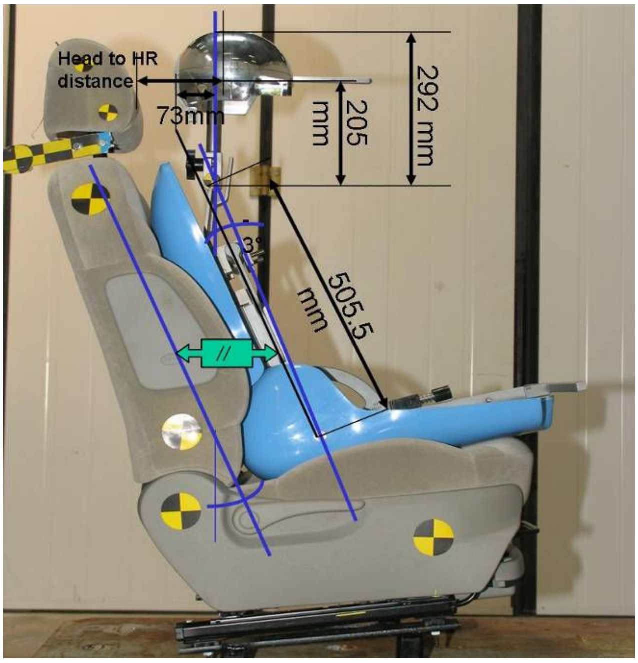

Figure 2 – Dimensions needed from an HRMD for the UTAC three-link bar replacement

2.3 Alternatives

Some alternatives to the UTAC measurement method were evaluated. These were based on an initial seat setting with the SAE manikin, like UTAC did. Then a set of mathematical equations were used to find the virtual location of the HRMD head. This is the mathematical equivalent to the hardware method of UTAC. A set of CMM measurements were used to determine the head restraint distance, as explained below.

Initially the measures as applied in Figure 2 were cross-checked. First a backset measurement was done according to the EuroNCAP method. Taking that measurement as a start, the position of the rear *flat* part of the HRMD head was determined with a 3D CMM measurement. Then, taking the the link lengths and angles from the UTAC method, this position was determined once more on a mathematical basis as in Figure 2. At this point a discrepancy occurred. It was found that the link lengths and angles which were to be used for this specific combination of SAE-manikin and HRMD were different from the ones specified by UTAC. They used a 3 deg angle to find the HRMD rotation point on the torso, while a 1.9 deg angle seemed more appropriate in our case. Also the torso link length was slightly larger (505.9 mm). These two differences caused the backset measurement to change by 15-20 mm between the EuroNCAP measurements and the UTAC method.

There were also differences found in probe height, which makes a comparison of backset measurements at different heights on the head restraint invalid. For that reason the CMM measured height of the HRMD probe was taken from the EuroNCAP measurements and applied in all subsequent test to have a valid comparison. In three of five tests a rectangular portal was made around the seat, which held the backset probe. The height of the probe was adjustable, to be able to obtain the same height as the EuroNCAP protocol. The backset probe was able to slide horizontally at this specific height in order to measure the backset (Figure 3).

Figure 3 – HRMD measurement (left) and measurement without any seated manikin (right). Only the probe is used for backset measurement and the rear part of the HRMD head is calculated from the H-point location using fixed manikin and HRMD dimensions. The arrows indicate the CMM measuring locations.

The backset measurement according to the EuroNCAP protocol was done with a 3D FARO arm (CMM) locating the flat posterior part of the HRMD head and the flat (anterior) part of the probe and subtracting the measurements. In the measurements not using the HRMD head, the rear location of the head was calculated according to the link representation.

$$\begin{bmatrix} R_x \\ R_z \end{bmatrix} = \begin{bmatrix} Hp_x - l\sin(sba - 1.9) - 60.4 \\ Hp_z - l\cos(sba - 1.9) + 205 \end{bmatrix}$$

With:
$[R_x ; R_z]$ = position of the rear part of the head
$[Hp_x ; Hp_z]$ = position of the dummy H-point
l = the length of the first link from H-point to HRMD rotation point
sba = seat back angle in degrees

The following test matrix was applied:

1. EuroNCAP standard proposed measurement with SAE-manikin and HRMD;
2. EuroNCAP standard proposal + SAE manikin + HRMD + 10 N preload to the HRMD backset probe. This is the method as currently proposed by EEVC WG20;
3. Portal with probe measurement, loading the seat with the SAE manikin;
4. Portal with probe measurement without any loading of the seat, nor the head restraint;
5. Portal with probe measurement with 10 N preload applied to the probe.

The first two measurements were done twice: in the current test series (for RDW) and in an earlier test series (for TNO/EEVC). In the second earlier test series the HRMD probe was used for the backset measurement, not the FARO system.

3 Results

The measurements for the various methods are shown in Table 1 in two series, the RDW series and the former TNO/EEVC series. Combining these series gives the averages as given at the end of the table. For the RDW series the results are also shown in Figure 4.

Table 1 – Static measurement results: five methods in the RDW test series, two methods in the EEVC test series.

Test series		H point [mm]		Head restraint distance with FARO [mm] (RDW)				
RDW	Torso Angle [deg]	x	z	HMRD + Manikin + 0 N	HMRD + Manikin + 10 N	No HMRD + Manikin + 0 N	No HMRD + No Manikin + 0 N	No HMRD + No Manikin + 10 N
B1	25.4	70.2	331.4	54.0	58.0	53.6	48.4	51.8
B2	25.3	66.0	332.3	65.7	69.1	65.1	60.6	63.9
B4	25.7	68.1	329.5	62.1	65.7	63.1	56.6	59.0
C3	25.8	204.9	357.5	54.8	59.0	54.4	51.4	54.8
C4	25.9	203.6	354.7	54.2	57.6	53.9	50.9	54.7
C7	25.6	205.3	352.1	55.7	60.1	55.7	52.6	55.4
E10	25.3	27.9	395.3	60.1	62.3	59.3	56.4	59.3
E15	25.1	26.3	395.3	57.1	60.1	58.5	56.9	58.3
E1	24.9	28.2	395.6	54.5	57.6	53.9	52.4	54.4
TNO/EEVC								
B1	25.0	70.0	329.5	55.0	58.0			
B2	24.9	69.0	331.3	54.0	56.0			
B4	25.2	70.2	332.1	51.0	54.0			
C3	24.4	205.4	355.3	47.0	52.0			
C4	24.2	202.7	355.4	46.0	49.0			
C7	24.1	204.0	355.4	52.0	56.0			
E10	25.1	24.2	391.1	62.0	64.0			
E15	25.3	27.9	394.2	62.0	64.0			
E1	25.8	26.2	393.8	62.0	67.0			
Averages	Torso Angle	x	z	0 N	10 N			
Seat B	25.2	68.9	331.0	57.0	60.1			
Seat C	25.0	204.3	355.1	51.6	55.6			
Seat E	25.2	26.8	394.2	59.6	62.5			

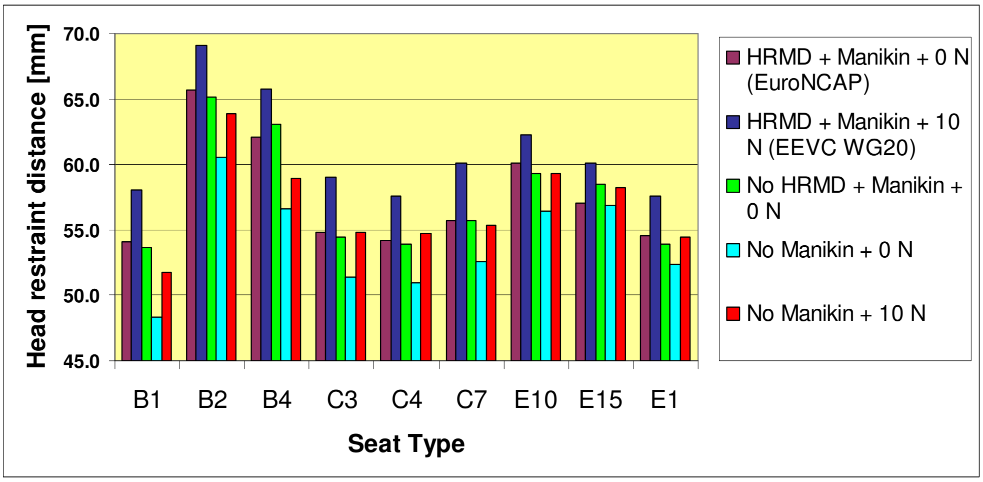

Figure 4 - Head restraint distance (backset) using various methods (note the y-scale starts at 45 mm)

For each seat type the deviations from the average (of six) EuroNCAP measurement were calculated. This result is shown in Figure 5. A few interesting findings can be seen from this figure:

- Applying the 10 N preload always increased the backset on average by 3.5 mm.
- Not using the HRMD, but with the SAE manikin in the seat decreased the head restraint distance by average 0.1 mm (average absolute deviation is 0.6 mm). This result was not significant!
- Taking the manikin out of the seat always decreased the backset (average 3.6 mm); there is no seat back loading anymore.
- Applying a preload of 10 N to the head restraint, while there is no manikin in the seat showed different effects for each seat type, but the backset always increased with respect to the previous measurement (without manikin, without 10 N) by 2.8 mm on average.
- It can be seen that there are large differences between seats of one type. The deviations within each type were even larger than the deviations occurring through the test method used. For instance, the difference between seat B1 and B2 in de RDW standard EuroNCAP measurement was 11.7 mm, while the difference within seat B1 using different measurement methods is only 5.6 mm. The average deviation within one seat type was 3.8 mm (see the ABS AVG bar of the EuroNCAP measurement in Figure 5). The question is where these differences are caused by. For this reason the deviation is plotted against the seat setting parameters: H-point x- and z-location and the seat back angle.

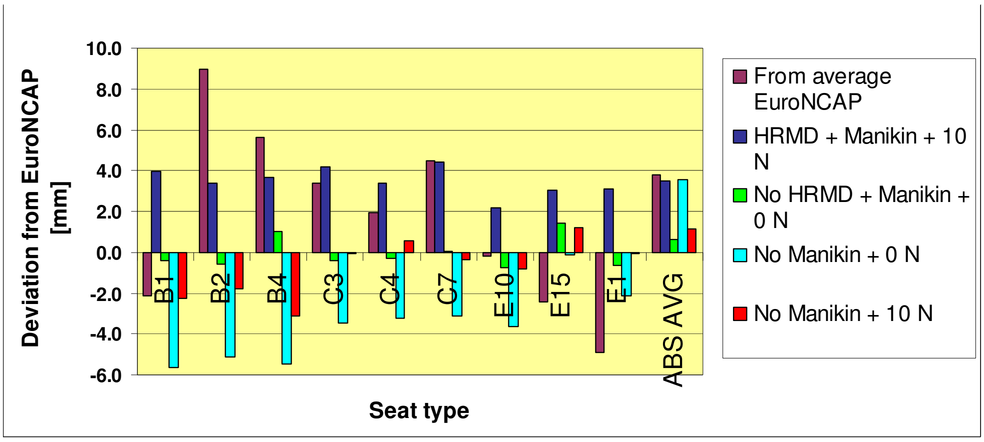

Figure 5 – Deviation of backset from average EuroNCAP measurement using various methods. 3 seats of one type each and 2 measurements per seat were used for the average. ABS AVG means the average of the absolute deviations within one seat type.

For each seat type the average of six measurements were calculated and subsequently the deviations from this average for each individual seat were calculated. Figure 6 - Figure 8 show the deviations from the average backset per seat type against

1. The deviation from the average H-point x-position;
2. The deviation from the average H-point z-position;
3. The deviation from the average seat back angle.

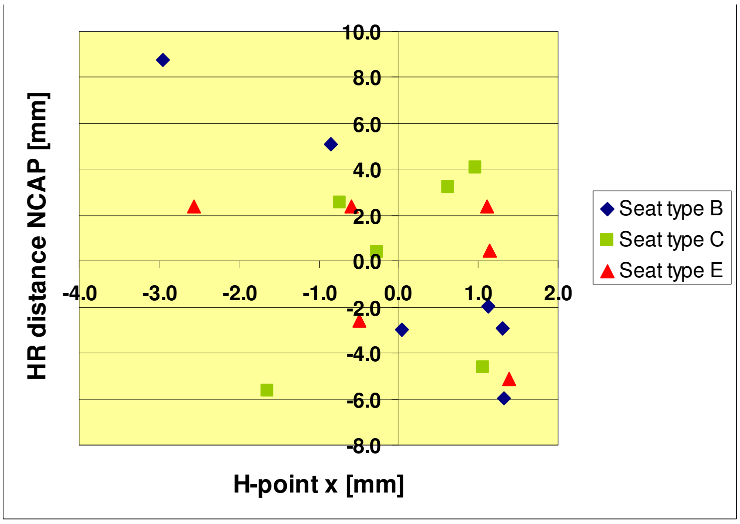

Figure 6 – Relation between the deviation from the average H-point x-position and deviation from the average backset in the EuroNCAP measurement

These figures indicate that:

1 For seat C and E there seems to be no influence of H-point x with backset. In seat B there seems to be a decreasing backset with increasing H-point x-location (Figure 6);
2 For seat B and C there is no influence of H-point z with backset, while for seat E a decreasing backset is observed with increasing H-point z-location (Figure 7);
3 All seat B, C and E show an increasing backset with increasing seat back angle (Figure 8).

However, more measurements are needed to verify these findings. Note also that these relations assume the other parameters to be kept constant, which is not true. So there might also be cross-correlations involved. The influence of each parameter on the result can be analysed with principle component analysis using a larger sample size.

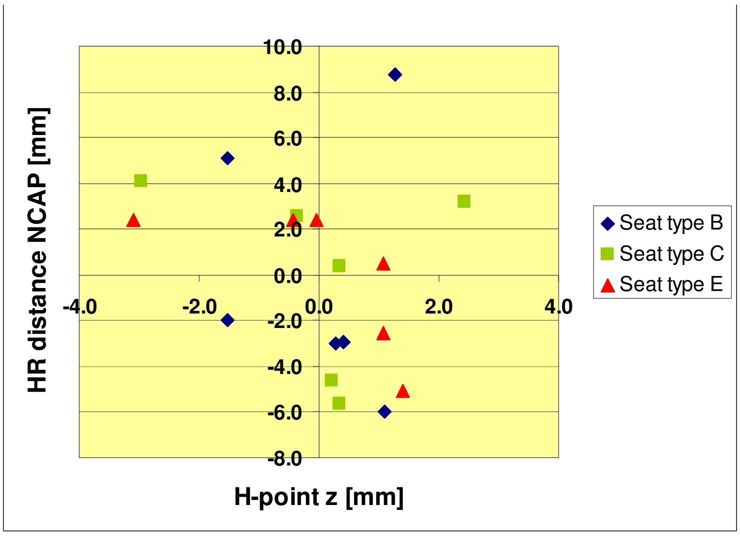

Figure 7 – Relation between the deviation from the average H-point z-position and deviation from the average backset in the EuroNCAP measurement

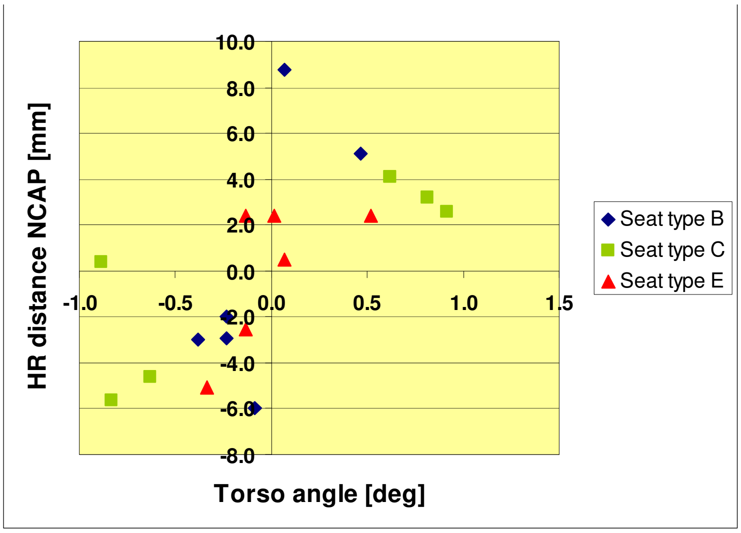

Figure 8 - Relation between the deviation from the average seat back angle and deviation from the average backset in the EuroNCAP measurement

Figure 9 shows the relation between the deviation from the average backset measurement for two methods, the EuroNCAP method and the EEVC method with 10N preload. For each seat type the average backset was calculated and the deviation from this average is plotted in this figure. It shows that the deviations were not dependent on the measurement method (all results are near the straight line, not even biased on one side), but were rather dependent on the individual seats.

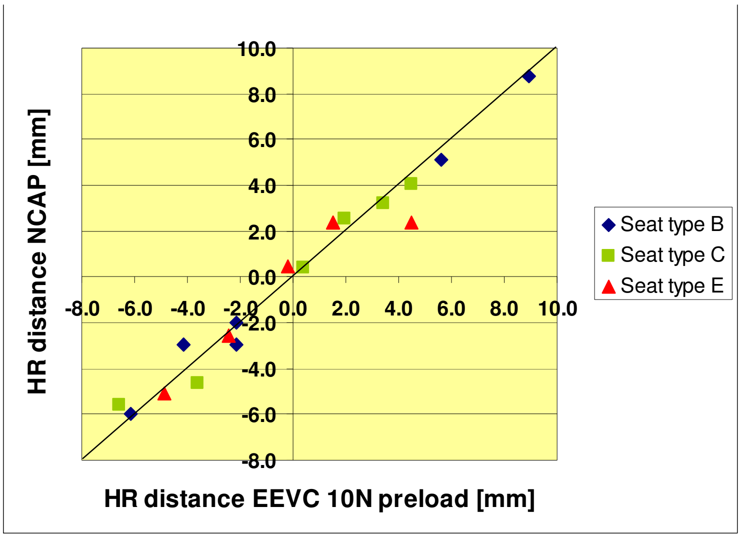

Figure 9 – Relation between the deviation from the average backset EEVC measurement and the deviation from the average EuroNCAP measurement method. Two measurements were done on each of three seats of one type. Averages were calculated for each type of seat.

Some highlights of the results were:

- The deviation caused by the individual seats (of one type: reproducibility) and SAE positioning (repeatability) is larger than the deviation caused by a change of measurement method;
- Head restraint distance varies with seat back angle and H-point location. This relation is not similar for all seat types;
- Small differences in H-point location may result in large changes of the head restraint distance; all measurements were performed within the test procedure specifications. For example in seat B the H-point location ranges from -3 to +2 mm, but the backset changes from -6 to +9 mm.

4 Conclusions and recommendations

On the basis of these evaluations, the following conclusions can be drawn:
- The measurement method is not mainly determining head restraint distance;
- The SAE manikin positioning (including seat back angle setting) mainly determines head restraint distance;

- There is no preference for any method with regard to the results found;
- The UTAC method is more straightforward, not typically more accurate.

Some recommendations can be made on the methods and requirements therein:
- The measurement method will be used for regulatory purposes in the end. This means that an easy-to-use and straightforward method will be preferred by the type approval engineer. The mathematical CMM method without the HRMD and, if possible, even without the SAE manikin is therefore thought to be preferred to the method with manikin and HRMD;
- For this type of measurements there is a need for more tight requirements on SAE manikin positioning or to use a more straightforward point in the car, like R-point. The latter option does not need an SAE manikin, as long as there are other means to properly verify the seat back angle. Not using an SAE manikin can make the procedures more robust, since errors in positioning are dimished;
- The influence of each of the parameters determining head restraint distance can be investigated more thoroughly using a larger sample size of measurements.

Appendix E WG20 Static Backset Measurement Test Procedure

EEVC WG20 Report – Document Number 143

Static measurement protocol

Version: v1

Date
May 2007

Authors
Hans Cappon, Mordaka Justyna

On behalf of European Enhanced Vehicle-safety Committee (EEVC) Working Group 20

Number of Pages 13

CONTENTS

1. Introduction

This procedure enables the user to determine the static backset of a car seat head restraint in order to assess its ability to prevent soft neck injury often called whiplash injury. Recently, several methods have been assessed (Cappon, 2007): the draft EuroNCAP method, UTAC proposal (Minne, 2006) and a more simplified method (TNO) based on the UTAC proposal. The analysis showed that head restraint distance is mainly influence by the SAE manikin positioning not by the measurement method. It was recommended that since the measurement method would be used for regulatory purposes, it should be easy-to-use. The most straightforward method tested by Cappon was the direct Coordinate Measurement Machine (CMM) method and the protocol prescribed here is based on this method.

2. Definitions

R point - "seating reference point" means a design point defined by the vehicle manufacturer and established with respect to the three-dimensional reference system.

H point - means the pivot centre of the torso and thigh of the 3-D H point machine installed in the vehicle seat. The "H" point is located in the centre of the centreline of the device which is between the "H" point sight buttons on either side of the 3-D H machine. The "H" point corresponds theoretically to the "R" point .

3-D H point machine means the device used for the determination of “H” points and actual torso angles (SAE Standard J826, SAE Handbook, Vol 3, 1999) modified according to the RCAR procedure for evaluating head restraints (see item 2.1) The H-Point machine is commonly referred too as an OSCAR but is also known as a SAE Manikin or HPM.

HRMD – Head restraint measuring device. This is a hardware representation of a human neck and head, which is used to measure the static horizontal and vertical distance between the head and the head restraint of a car seat. It was introduced by the Insurance Company of British Columbia (ICBC, Canada) and is used in many static protocols measuring head restraint distance.

HRMD rotation point – This is the adjustable hinge joint (right above the fixed connection between HRMD and 3D H machine). The hinge is used to level the head of the HRMD to the horizontal.

Torso Link (**Tlink**)- distance from R-point to HRMD rotation point. This link has a length of 505.5 mm and is set at an angle being torso design angle minus 3 degrees.[1]

Torso Link angle – means the angle measured between the vertical and the Torso Link.

Difference angle (da) - Torso Link angle minus Torso design (manufacturer) angle. Currently the value of da is set at 3 degrees.

ProbeZ- probe vertical location relative to HRMD rotation point

ProbeX- horizontal distance between the flat back part of the HRMD and Neck Link.

Torso design (manufacturer) angle (tda) - means the angle measured between a vertical line through the "R" point and the torso line in a position which corresponds to the design position of the seat-back established by the vehicle manufacturer.

Seat back design angle (manufacturer) – seat back angle established by the vehicle manufacturer.

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[1] These values were proposed by UTAC for their HRMD. In fact the exact values do not really matter as long as they are consistent and related to a specific body size. The values chosen will only cause systematic errors between the real HRMD measurement and the static measurement proposed here. Thus it is of influence to the accepted backset limits proposed by the procedure.

Initial position of backset probe point (IP) – virtual point corresponding to the mid centreline of flat edge of backset probe or corresponding to point on HRMD from which the backset probe protrudes.

Final backset probe point (FP) – virtual point corresponding to the mid centreline of flat edge of backset probe while the backset is the first contact with the head restraint centreline.

1 Method

The method is based on the UTAC method, which proposes to replace the HRMD and 3DH machine with a three-link mechanism, the links representing the 3DH ‘torso’, the HRMD ‘neck’ and the HRMD head, respectively. The backset measurement was made with the probe taken from the HRMD. In the current method, the UTAC method is more simplified by replacing the links with mathematical equations. The SAE manikin is installed in the seat only to set the seatback angle at the car manufacturer designed angle. The HRMD backset probe is held by an upsidedown U shaped portal and positioned at the height where normally the HRMD probe is found. The portal enables the probe to slide horizontally and vertically. The position of the probe (the rear location of the head) (IPx, IPz) is calculated based on:
R- point coordinates (relatively to fixed seat feature for instance to rail bolts)
tda- design (manufacturer) torso angle
Tlink=505.5mm
da= 3deg
ProbeX =60.5mm
ProbeZ=205mm
IPx [Rx – Tlink *sin(tda- da) – ProbeX]
IPz [Rz +Tlink *cos(tda- da)+ ProbeZ]
Tlink, Nlink, da, ProbeX, ProbeZ are constant values specific for a specific combination of SAE manikin and HRMD and can be measured or found in manuals. In the end these values should be standardised to represent an average male person. The R point and tda are given by the seat manufacturer.

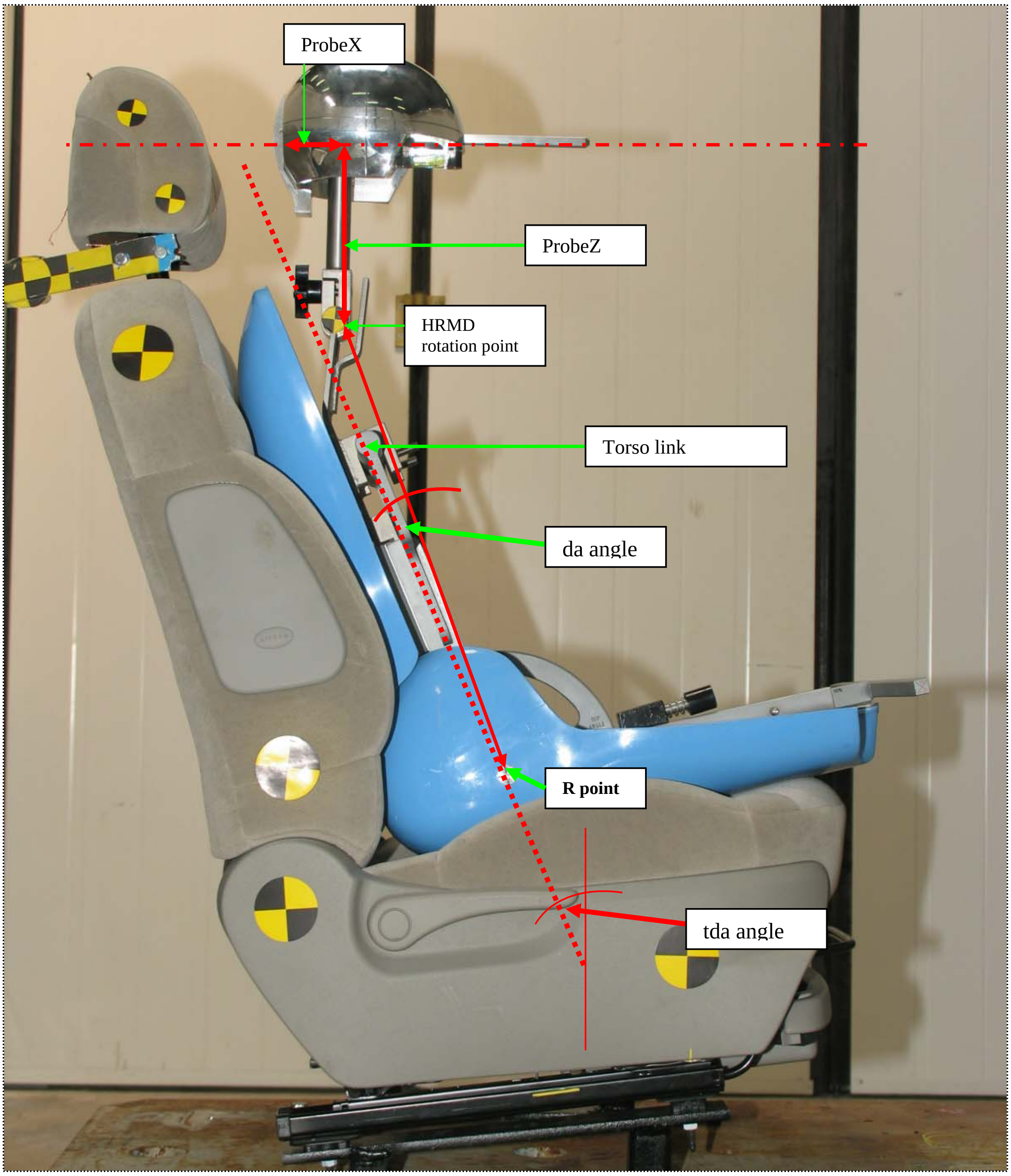


Figure 1 Dimensions needed from an HRMD and SAE to calculate the position of the rear flat part of HRMD (IP)

3. Reference documents and tools required

The following documents and associated equipment will be required to undertake this procedure:

- R point and design torso and seat back angle from a seat manufacturer
- Seat set up specification from manufacturer
- protocol.xls file
- measurement system
- portal with attached backset probe
- force plunger, dynamometer
- SAE manikin (OSCAR)

4. Test coordinate system

Measure	Seat reference
Positive X	Same direction as acceleration forces in a rear impact sled test (forward from seat)
Positive Y	Determined by right-hand rule and based on X and Z definitions, so left lateral.
Positive Z	Vertically upward

SAE J211 definition of coordinate system

5. Seat test position

The seat should be set up according to manufacture specifications which were used to set the R point. Make sure that following adjustments are taken into account (if any):

- *Seat back angle*
- *Seat track*
- *Seat height*
- *Seat tilt*
- *Seat Cushion Height*
- *Seat Cushion Tilt*
- *Lumbar Support*
- *Upper Seat Back*

It is recommended to set the manufacturer seat back angle with SAE manikin by setting manufacturer designed torso angle, unless the manufacturer proposes more accurate way to determine this angle.

6. Seat head restraint test position

Now: mid height etc. according to Euro NCAP procedure.

Other possibilities:

- R17 approach – the highest position using current calculation for 50th percentile

- Lowest position with most rearward position - measure with calculation for 5th
- Mid position with most rearward position – measure with current calculation for 50th
- Highest with most rearward position – measure with calculation for 95th

NOTE: UMTRI does not represent, in terms of height, an average or 50th European or American. This could be easily addressed by changing the neck and torso link values in the calculations to adjust them to the current population.

7. Backset Measurement

1. Set seat and head restraint to the test position described in section 5 and 6.
2. Calculate the coordinates of the required initial position of the backset probe (IP) using the protocol.xls. (This is the position where in theory the flat back part of the HRMD head would be.)
3. Mark a vertical centreline on the head restraint.
4. Set the portal such way that the upper edge of the backset probe ruler corresponds to z-coordinate of the calculated IP (+/- 1 mm) and make sure it slides horizontally (see Figure 2).
5. Slide the probe horizontally till the first contact with the head restraint centreline.
6. Apply 10N force to the probe to ensure that any trim covering material is in contact with the underlying foams, or that the separation of trim material does not provide artificially favourable measurements.
7. Still applying the force, measure the coordinates of the FP point at the flat posterior side of the probe (final backset probe point) (see Figure 3)
8. Write down into indicated cells in protocol.xls the x and z to the coordinates of point FP.
9. The backset will be calculated.

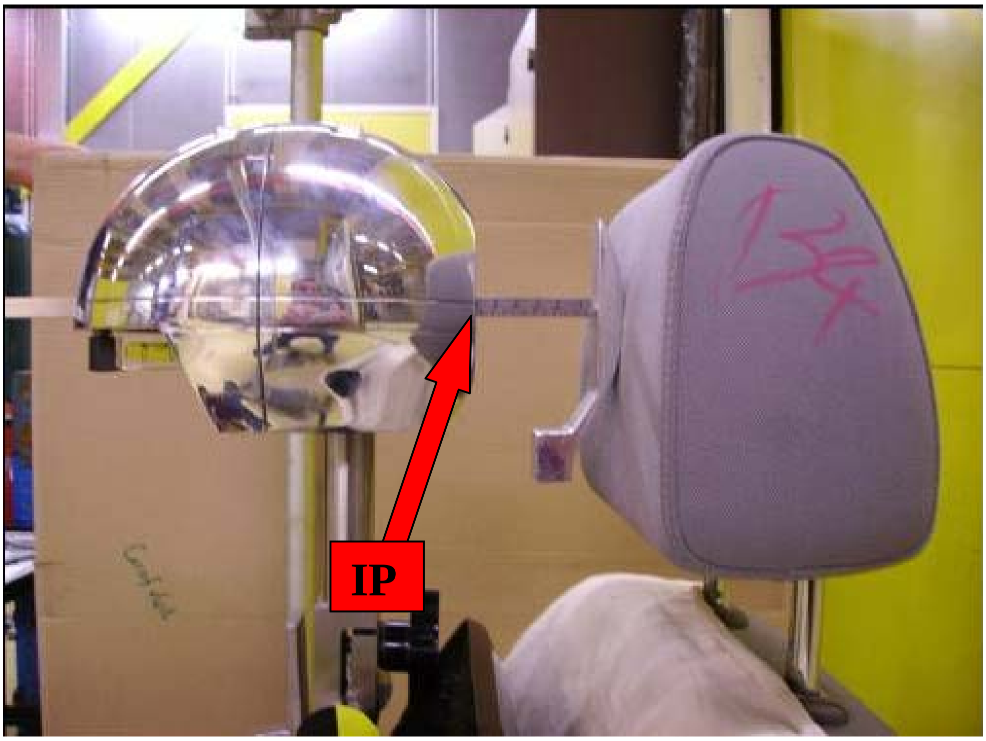


Figure 2 Position of backset probe relatively to the calculated point.

Figure 3 Measurement with the probe attached to portal in test position. The arrow indicates the FP measurement location.

8. References

Cappon H., 2007.*Comparison of static backset measurement methods,* TNO report, 2007.
Minne F. 2006. *HR-6-6*, 2006
Euro NCAP procedure. *EURO NCAP – THE DYNAMIC ASSESSMENT OF CAR NECK INJURY PROTECTION*, VERSION 2.6, 2007.

Appendix F Draft Height Measurement Test Procedure

PROPOSAL FOR DRAFT AMENDMENTS TO DRAFT GTR ON HEAD RESTRAINTS

Transmitted by the expert from the Netherlands

Note: The text reproduced below was prepared by the expert from the Netherlands in order to create a new definition for a Front Contact Surface Head Restraint in the gtr since. The present requirements for height of 100 mm and width of 170 mm (resp. paragraphs 5.6.1. and 5.10. of Reg.17) are not properly taken on board in the gtr, which makes that parts of the head restraint may not contribute to the support of the head during a crash.

ENCOUNTERED PROBLEM

The present definitions of minimum required head restraint height and minimum height of the front of a head restraint seem to be insufficient because certain head restraint shapes are such that a part of the head restraint will not properly function in limiting the rearward displacement of the seated occupant's head. This is clearly demonstrated by the section indicated with crosses on the head restraint in the figure below.

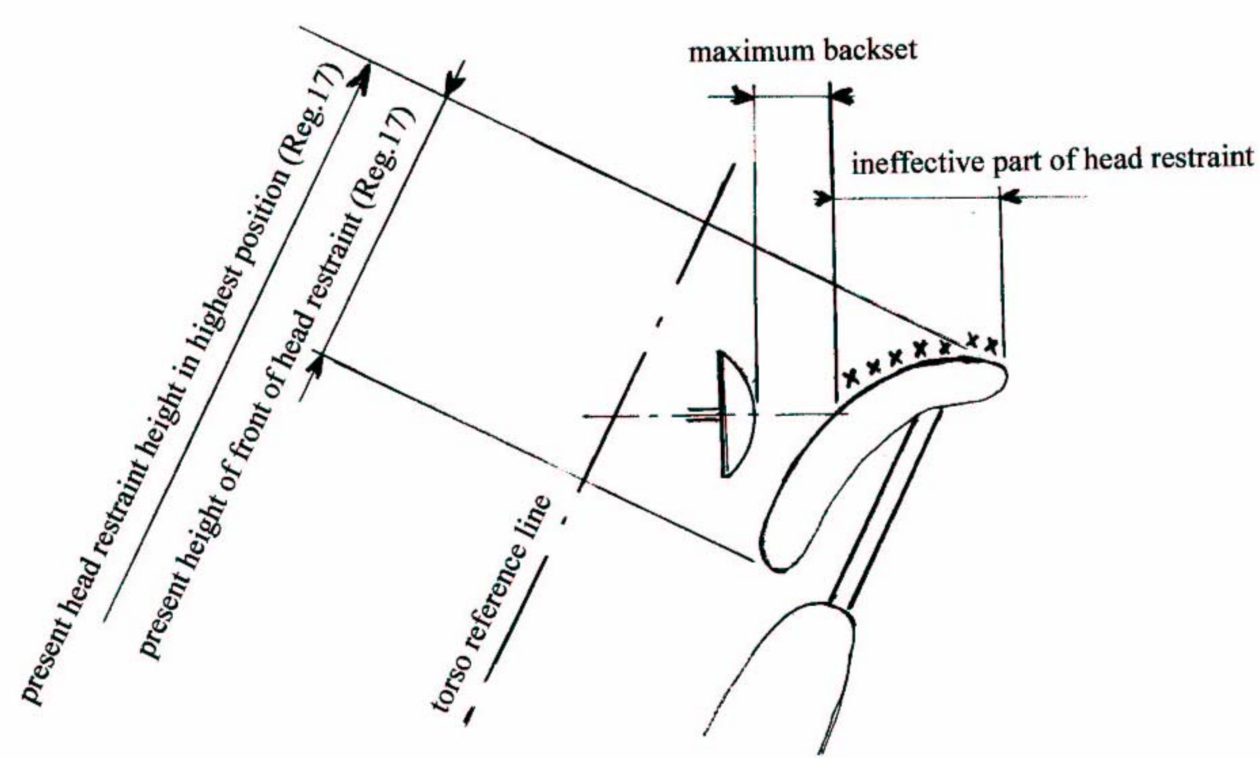


Figure – Demonstrating the ineffective part of head restraint

This problem can be solved by linking the established requirements:

- height of the front of a head restraint (100 mm),
- width of a head restraint (170 mm) and
- head restraint height relatively to the R-point,

and putting them in a new requirement called Front Contact Surface Head Restraint.

To fulfil this new requirement, head restraints shall be checked on the presence of a minimum Front Contact Surface Head Restraint (100 x 170 mm), which meets two conditions, namely: be close enough behind the occupant’s head according to maximum backset requirement ánd the top line of this Front Contact Surface (considered as the effective head restraint height, see figure 12-1) should meet the requirements for minimum height above the R-point.

This concept leads to the following proposal.

PROPOSAL

in Definitions of the GTR:

3.16. Front Contact Surface Head Restraint means the surface intended to support the seated occupant’s head to limit rearward displacement.

in Performance requirements of the GTR:

5.1.6. Minimum area and location of Front Contact Surface Head Restraint. When measured in accordance with Annex 12:

5.1.6.1 a Front Contact Surface Head Restraint shall have at least a minimum area with borders that coincide with the intersections of the following planes with the head restraint:

- two vertical longitudinal planes set at 85 mm on either side of the vertical median plane of the seat,
- two planes perpendicular to the torso line, 100 mm apart, of which the upper plane is located at the highest effective head restraint height. The highest effective head restraint height shall not be less than the minimum required head restraint height that counts for the concerned designated seating position.

5.1.6.2. a Front Contact Surface Head Restraint [of front outdoor seating positions] shall fulfil the backset requirements.

Annex 1, Annex 2 and Annex 3 will be replaced by one single Annex hereafter called Annex 12:

Annex 12
Test Procedure for Verifying the Front Contact Surface Head Restraint

1. Purpose. The procedure described in this Annex is used to verify whether the Front Contact Surface Head Restraint encloses the minimum area and is located as required in paragraph 5.1.6.
2. Tools and use. For the measurements a CMM (Coordinate Measuring Machine) in combination with a HRMD-probe is used. The probe is fixed in a portal construction such that it can be shifted horizontally (X-direction) and can be displaced laterally and vertically (respectively Y-direction and Z-direction).
   During determination of the X-coordinate of the head restraint surface a 10N force is applied to the probe to ensure that any trim covering material is in contact with the underlying foams, or that the separation of trim material will not provide artificially favourable measurements. For the measurements of backset the CMM shall touch the easy accessible rear side (the flat edge) of the probe. The difference between this X-coordinate of the flat edge and its known initial X-coordinate (see Appendix 1 of this Annex) gives the backset measure.

3. Procedure. The seat shall be adjusted such that its H-point coincides with the R-point and the seat back is set at the design seat back angle (if it is adjustable), taking account of the requirements of paragraph 4 of this Annex.
   The head restraint shall be adjusted to the highest position of use. The head restraint shall, if adjustable laterally, be adjusted to the most rearward position.

3.1. The initial position of the HRMD-probe can be calculated taking into account Annex 12 , Appendix 1.

3.2. The vertical median plane of the seat shall be located and/or drawn on the head restraint; this will be considered as the centre line of the head restraint.

3.3. Two vertical longitudinal planes set at 85 mm on either side of the centre line of the head restraint shall be used to locate and/or draw the vertical borders of the minimum area of the Front Contact Surface Head Restraint.

3.4. Establish on the centre line of the head restraint the highest point that fulfils the backset criterion, taking account of Annex 12, Appendix 1.

3.5. A plane through this established point, perpendicular to the torso reference line, shall be used to locate and/or draw a line between the vertical borders.

3.6. Check whether all points, constituting the line determined in paragraph 3.5., fulfil the backset criterion.

If not, start again with paragraph 3.4. by establishing a new point on the centre line at a lower height.

If the backset criterion is fulfilled on this line the so determined line is the upper border of the Front Contact Surface Head Restraint and is considered as the highest effective head restraint height. This height has to fulfil the minimum head restraint height above the R-point that counts for the concerned designated seating position.

3.7. A plane, below and parallel to the plane used to locate the upper border, on a distance of 100 mm (see figure 12-1), shall be used to locate and/or draw the lower border of the Front Contact Surface Head Restraint.

3.8. Determine whether all points, constituting the vertical borders and the lower border of the Front Contact Head Restraint Surface fulfil the backset criterion.

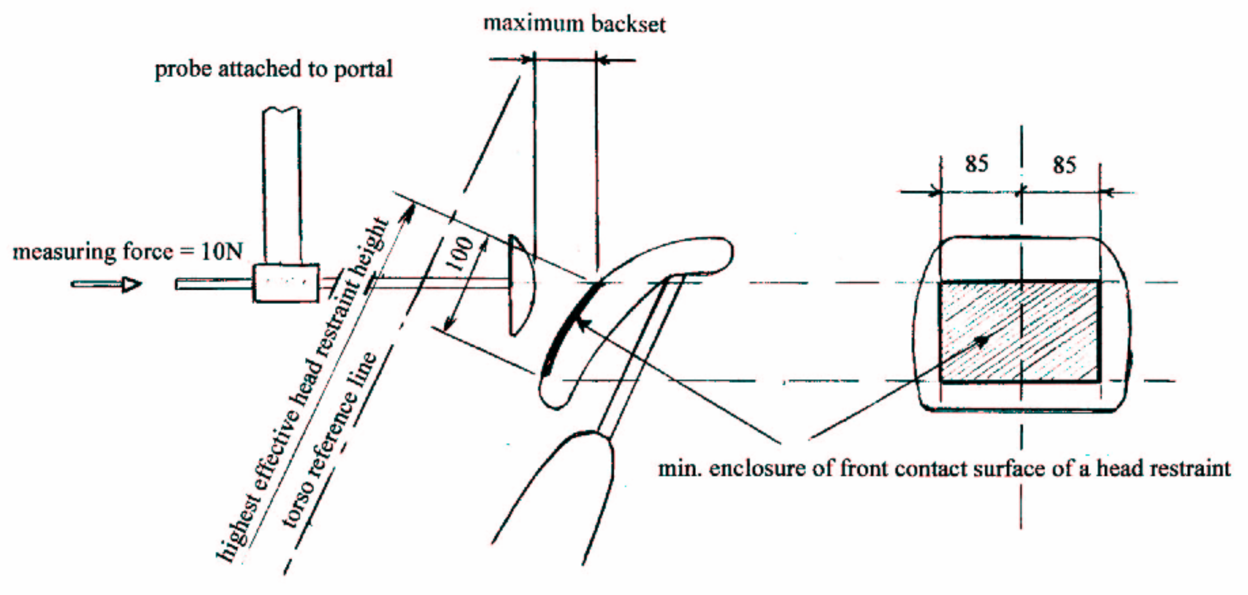


Figure 12-1: Check on compliance of Front Contact Surface Head Restraint to minimum enclosure and location

4. Relationship between the H-point and the R-point .

4.1. When the seat is positioned in accordance to the manufacturer's specifications, the H-point, as defined by its co-ordinates, shall lie within a square of 50 mm side length with horizontal and vertical sides whose diagonals intersect at the R-point, and the actual torso angle shall be within 5 degree of the design torso angle.

4.2 If these conditions are met, the R-point and the design torso angle, shall be used to demonstrate compliance with the provisions of this Annex.

4.3. If the H-point or the actual torso angle does not satisfy the requirements of paragraph 4.1., the H-point and the actual torso angle shall be determined twice more (three times in all). If the results of two of these three operations satisfy the requirements, the conditions of paragraph 4.2. shall apply.

4.4. If the results of at least two of the three operations described in paragraph 4.1. do not satisfy the requirements of paragraph 4., or if the verification cannot take place because the vehicle manufacturer has failed to supply information regarding the position of the R-point or regarding the design torso angle, the centroid of the three measured points or the average of the three measured angles shall be used and be regarded as applicable in all cases where the R-point or the design torso angle is referred to in this Annex.

Annex 12 – Appendix 1

RELATIONSHIP BETWEEN PORTAL APPARATUS EQUIPPED WITH HRMD-PROBE AND 3-D H MACHINE EQUIPPED WITH HRMD-PROBE,

The HRMD-probe is the simulation of the back of the occupant's head.
The original position of this probe is derived from the UMTRI mid-sized male (report nr. UMTRI-83-53-1, Dec.'83), and can be reached by means of a 3-D H machine that is suited to receive the HRMD (see figure 12-2).

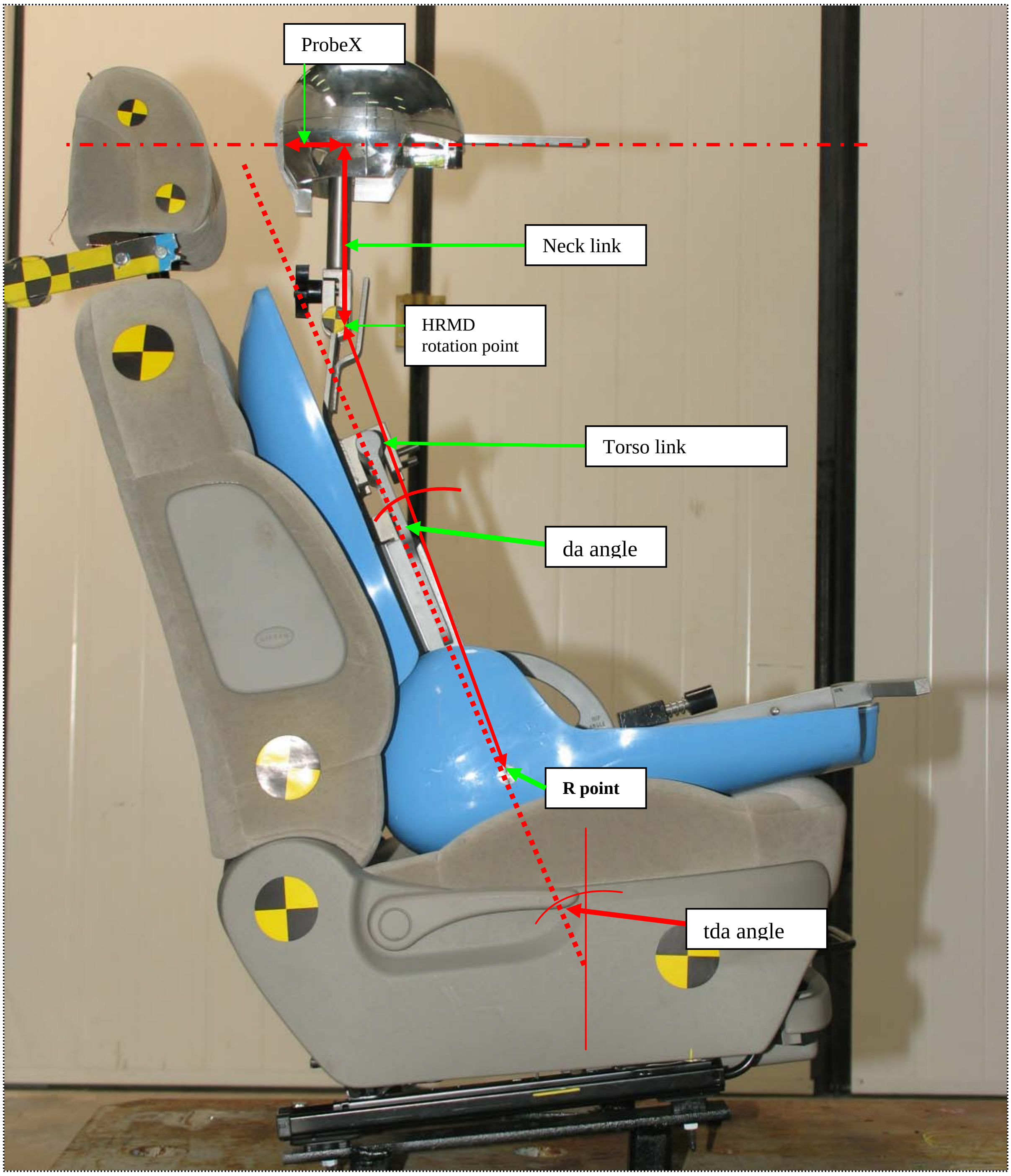


Figure 12-2 Dimensions needed from an HRMD and SAE to calculate the position of the rear flat part of HRMD

Because of restrictions bound to the use of the 3-D H machine, this procedure can cause difficulties.
The portal apparatus equipped with the HRMD-probe (see figure 12-3, shown with HRMD-probe shifted against the head restraint) in combination with a Coordinate Measuring Machine (CMM) excludes the above mentioned difficulties.

Figure 12-3

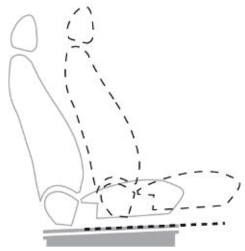
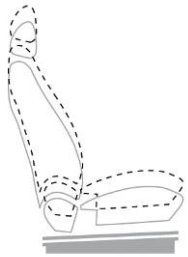
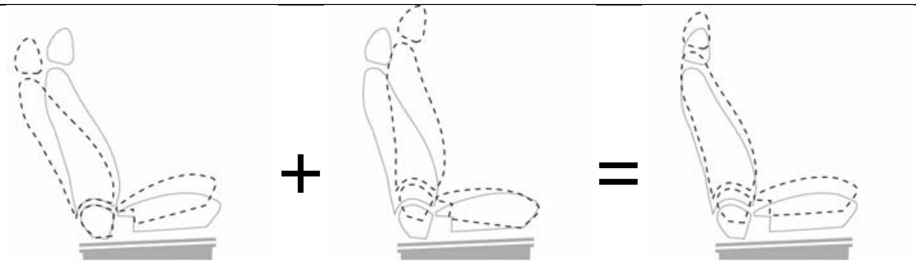
The spherical side of the HRMD-probe in its initial position simulates the back of the head of the UMTRI mid-size male sitting in an automotive posture. This position is dependent upon the design angle of the seat and will be calculated (see below).
The difference between the HRMD-probe in its initial position and the position with the HRMD-probe shifted against the head restraint (measured) will give the backset.
[For ease of accessibility the rear side of the HRMD-probe (the flat edge) will be touched with the CMM in both positions. The difference between these two X-coordinates is the backset.]

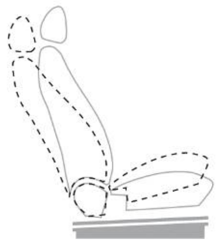
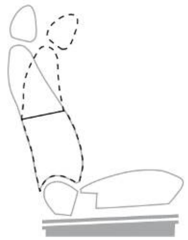
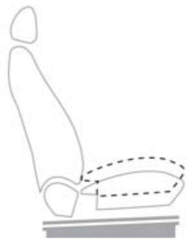
<u>Calculation of the X-coordinate of the flat edge of the HRMD-probe in its initial position:</u>
Constant values:
Torso Link = 505.5 mm, is the connecting link between R-point and HRMD-point
Neck Link = 205 mm, is the vertical link between HRMD-point and centre of head
da angle = 1.9 degrees, is the angle between Torso Link and design torso line
Probe X = 60.5 mm, is the horizontal distance between Neck Link and the flat edge of the proposed HRMD-probe
Values depending of manufacturer's specifications:
R-point = accepted from manufacturer taking account of paragraph 4 of Annex 12, and the X-coordinate of the R-point is taken as zero.
tda angle = design torso angle accepted from manufacturer taking account of paragraph 4 of Annex12

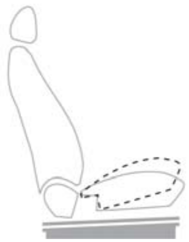
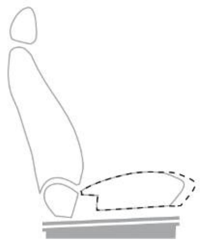
Formula:

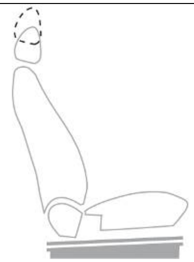
$$X\ coordinate\ \ flat\ \ edge = 505.5 * \left| SIN\ (torso\ design\ angle - 1.9) \right| + 60.5$$

Appendix G Definition of Seat and Head Restraint Adjustments

Seat Track An adjustment that moves the entire seat (seat cushion and seat back) in the fore and aft directions.		
Seatback (Torso) Angle An adjustment that rotates the entire seat back, independently of the seat cushion, about a pivot at the seat back/seat cushion joint, therefore, changing the angle of the seat back relative to the seat cushion.		
Seat Height An adjustment that moves the entire seat vertically (seat cushion and seat back in unison). This adjustment must keep the angle of the seat cushion the same relative to the ground. This can be one control (2-way) that moves the whole seat in unison or a combination of controls (4-way – a toggle or multiple knobs) that, when used together, keep the angle of the seat cushion the same relative to the ground.	 2-way (one control)	 4 way (toggle or multiple knobs) **NOTE: It is not possible to have 4 way seat height AND seat tilt**

Seat Tilt An adjustment that rotates the entire seat (seat cushion and seat back in unison). This adjustment rotates a seat in such a way to significantly change the angle of the seat cushion, relative to ground, from its full-down position. This adjustment can move either the front or rear of the seat in order to change the angle.		
Upper Seat Back An adjustment that rotates only the upper portion of the seat back about a pivot point in the seat back. This adjustment will change the angle of the upper seat back relative to the lower portion of the seat back.		
Seat Cushion Height An adjustment that moves the seat cushion vertically, independent of the seat back, while keeping angle of the seat cushion the same relative to the ground. This can be one control (2-way) that moves the whole seat cushion in unison or a combination of controls (4-way – a toggle or multiple knobs) that, when used together, keep the angle of the seat cushion the same relative to the ground.	 2-way (one control)	 4 way (toggle or multiple knobs) **NOTE: It is not possible to have 4 way seat cushion height AND seat cushion tilt**

Seat Cushion Tilt An adjustment that moves the seat cushion, independent of the seat back, in such a way to significantly change the angle of the seat cushion, relative to ground, from its full-down position. This adjustment can move either the front or rear of the seat cushion in order to change the angle.		
Cushion Extension An adjustment that moves or extends a portion of the seat cushion forward so that the overall length of the cushion can be increased.		
Lumbar Support An adjustment that causes the lower centre portion of the seat back to protrude in order to provide support to the lumbar section of an occupant's spine.		
Side Bolsters An adjustment the moves the sides of the seat back or seat cushion so that the contour of the seat can be changed.		

Head Restraint Height An adjustment that moves the head restraint vertically.		
Head Restraint Tilt An adjustment that moves the head restraint horizontally.		 OR  OR