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the GRSP Chairperson

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Items 5.4. and 18.1. of the provisional agenda

1998 AGREEMENT

Decisions by consensus vote on those elements of draft global technical regulations that have not been resolved by the Working Parties subsidiaries to the World Forum

Proposal for a draft global technical regulation concerning head restraints

Submitted by the Chairperson of the Working Party on Passive Safety

The text reproduced below was transmitted by the Chairperson of the Working Party on Passive Safety in order to outline the policy decisions needed on the pending issues (ECE/TRANS/WP.29/1058, paras. 78 and 89). The document is based on informal document No. HR-8-5 of the Working Party on Passive Safety's informal group on Head Restraint. This draft gtr is still under consideration by the informal group on Head Restraint.

A. STATEMENT OF TECHNICAL RATIONALE AND JUSTIFICATION

1. THE SAFETY CONCERN

Whiplash injuries are a set of common symptoms that occur in motor vehicle crashes and involve the soft tissues of the head, neck and spine. Symptoms of pain in the head, neck, shoulders, and arms may be present along with damage to muscles, ligaments and vertebrae, but in many cases lesions are not evident. The onset of symptoms may be delayed and may only last a few hours; however, in some cases, effects of the injury may last for years or even be permanent. The relatively short-term symptoms are associated with muscle and ligament trauma, while the long-term ones are associated with nerve damage.

Whiplash injuries are a world-wide problem. In the European Community (EC), there are over 1 million total whiplash injuries a year and the cost of these injuries in the EC is estimated to be €5 to €10 billion per annum and rising (Kroonenburg and Wismans, 1999; EEVC Report No 167). In the United Kingdom the cost of long-term injuries alone has been reported as £3billion. (UK Cost Benefit Analysis: Enhanced Geometric Requirements, EEVC Report, September 2007, http://www.eevc.org) In the Republic of Korea, rear end collisions account for 34 per cent of all car to car collisions and cause 31 per cent of fatalities and 37 per cent of injuries. Additionally, rear impact collisions cause 260,000 neck injuries in 2002 or 57 per cent of all neck injuries in car to car collisions. In Japan, rear impacts account for 31 per cent of collisions resulting in bodily injury. Of these crashes, 91 per cent of the injuries or 309,939 are minor neck injuries. In 2004, among rear impact collisions resulting in bodily injury, 81.7 per cent of male and 88 per cent of female drivers of the impacted vehicles sustained minor neck injuries.

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Based on National Analysis Sampling System (NASS) data, the United States of America (U.S.A.) estimated that between 1988 and 1996, 805,581 whiplash injuries 1/ occurred annually in crashes involving passenger cars and LTVs (light trucks, multipurpose passenger vehicles, and vans). Of these whiplash injuries, 272,464 occurred as a result of rear impacts. For rear impact crashes, the average cost of whiplash injuries in 2002 dollars is $9,994 (which includes $6,843 in economic costs and $3,151 in quality of life impacts, but not property damage), resulting in a total annual cost of approximately $2.7 billion. Although the front outboard seat occupants sustain most of these injuries, whiplash is an issue for rear seat passengers as well. During the same time frame, an estimated 5,440 whiplash injuries were reported annually for occupants of rear outboard seating positions (HR-1-8).

2. UNDERSTANDING WHIPLASH

Although whiplash injuries can occur in any kind of crash, an occupant's chances of sustaining this type of injury are greatest in rear-end collisions. When a vehicle is struck from behind, typically several things occur in quick succession to an occupant of that vehicle. First, from the occupant's frame of reference, the back of the seat moves forward into his or her torso, straightening the spine and forcing the head to rise vertically. Second, as the seat pushes the occupant's body forward, the unrestrained head tends to lag behind. This causes the neck to change shape, first taking on an S-shape and then bending backward. Third, the forces on the

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1/ Non-contact Abbreviated Injury Scale (AIS) 1 neck.

neck accelerate the head, which catches up with - and, depending on the seat back stiffness and if the occupant is using a shoulder belt, passes - the restrained torso. This motion of the head and neck, which is like the lash of a whip, gives the resulting neck injuries their popular name.

3. CURRENT KNOWLEDGE.

There are many hypotheses as to the mechanisms of whiplash injuries. Despite a lack of consensus with respect to whiplash injury biomechanics, there is research indicating that reduced backset will result in reduced risk of whiplash injury. For example, one study of Volvo vehicles reported that, when vehicle occupants involved in rear crashes had their heads against the head restraint (an equivalent to 0 mm backset) during impact, no whiplash injury occurred. 2/ By contrast, another study showed significant increase in injury and duration of symptoms when occupant's head was more than 100 mm away from the head restraint at the time of the rear impact. 3/

In addition, the persistence of whiplash injuries in the current fleet of vehicles indicates that the existing height is not sufficient to prevent excessive movement of the head and neck relative to the torso for some people. Specifically, the head restraints do not effectively limit rearward movement of the head of a person at least as tall as the average occupant. Biomechanically, head restraints that reach at least up to the centre of gravity of the head would better prevent whiplash injuries, because the head restraint can more effectively limit the movement of the head and neck.

In a recent report from the Insurance Institute for Highway Safety (IIHS), Farmer, Wells, and Lund examined automobile insurance claims to determine the rates of neck injuries in rear end crashes for vehicles with the improved geometric fit of head restraints (reduced backset and increased head restraint height). 4/ Their data indicate that these improved head restraints are reducing the risk of whiplash injury. Specifically, there was an 18 per cent reduction in injury claims. Similarly, U.S.A. computer generated models have shown that the reduction of the backset and an increase in the height of the head restraint reduces the level of neck loading and relative head-to-torso motion that may be related to the incidence of whiplash injuries. 5/

With respect to impact speeds, research and injury rate data indicate that whiplash may occur as a result of head and neck movements insufficient to cause hyperextension. Staged low speed impacts indicate that mild whiplash symptoms can occur without a person’s head exceeding the

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2/ Jakobsson et al., "Analysis of Head and Neck Responses in Rear End Impacts - A New Human-Like Model". Volvo Car Corporation Safety Report (1994).

3/ Olsson et al., An In-depth Study of Neck Injuries in Rear-end Collisions. International IRCOBI Conference, pp 269-280 (1990).

4/ Farmer, Charles, Wells, JoAnn, Lund, Adrian, "Effects of Head Restraint and Seat Redesign on Neck Injury Risk in Rear –End Crashes," Insurance Institute For Highway Safety, October 2002.

5/ "Effect of Head Restraint Position on Neck Injury in Rear Impact," World Congress of Whiplash-Associated Disorders (1999), Vancouver, British Columbia.

normal range of motion. This means that our previous focus on preventing neck hyperextension is insufficient to adequately protect all rear impact victims from risks of whiplash injuries. Instead, to effectively prevent whiplash, the head restraint must control smaller amounts of rapid head and neck movement relative to the torso.

In sum, in light of recent evidence that whiplash may also be caused by smaller amounts of head and neck movements relative to the torso, and that reduced backset and increased height of head restraints help to better control these head and neck movements, we agreed to recommend that head restraints should be of sufficient height and positioned closer to the occupant's head in order to be more effective in preventing whiplash.

4. PROCEDURAL BACKGROUND

During the one-hundred-twenty-sixth session of the World Forum for Harmonization of Vehicle Regulation (WP.29) of March 2002, the Executive Committee of the 1998 Agreement (AC.3) adopted a Program of Work, which includes the development of a global technical regulation (gtr) to address neck injuries in crashes. The U.S.A. volunteered to lead the group's efforts and develop a document detailing the recommended requirements for the gtr. The U.S.A. presented an informal document (WP.29-134-12) in November 2004 proposing the work and highlighting the relevant issues to be addressed in the gtr. This proposal was adopted at the March 2005 session of WP.29 (TRANS/WP.29/AC.3/13). The Working Party on Passive Safety (GRSP) developed the head restraint gtr. At its December 2007 session, GRSP concluded its work and agreed to recommend to the Executive Committee the establishment of this gtr into the Global Registry.

5. GLOBAL TECHNICAL REGULATION REQUIREMENTS

5.1. Applicability

The application of a head restraint gtr uses the revised vehicle classification and definitions of Special Resolution No. 1.

There has been extensive discussion of the applicability of this gtr. The application of U.S.A. Federal Motor Vehicle Safety Standard (FMVSS) No. 202 is different than UNECE Regulation No. 17. FMVSS No. 202 requires head restraints in all front outboard seating positions and regulates head restraints optionally installed in the rear outboard seating positions for vehicles up to 4,536 kg. UNECE Regulation No. 17 requires head restraints in all front outboard seating positions of vehicles of category M_1 6/, in all front outboard seating positions of vehicles of category M_2 6/ with a maximum gross vehicle mass (GVM) not exceeding 3,500 kg, and all front outboard seating positions of vehicles of category N_1 6/ and allows for optional type approval of head restraints optionally installed in other seating positions, or in other vehicles.

It was proposed that the gtr, as it pertains to front outboard seats, should apply to vehicles up to 4,536 kg. The U.S.A. presented justification (HR-4-4), developed in 1989, when the

6/ As defined in Annex 7 to the Consolidated Regulation on the Construction of Vehicles (R.E.3) (document TRANS/WP.29/78/Amend.2 at last amended by Amend. 4).

applicability of their regulation was increased to 4,536 kg. By extending the applicability from passenger cars to include trucks, buses, and multipurpose passenger vehicles, there was an estimated reduction of 510 to 870 injuries at an average cost of $29.45 per vehicle (1989 dollars). The U.S.A. presented further analysis (HR-10-3) that showed an additional 348 injuries reduced when the requirements of the gtr are applied to Category 2 vehicles (light trucks) between the range of 3,500 – 4,500 kg GVM. Japan presented 2004 data (HR-4-10) showing the breakdown, by vehicle weight, of crashes resulting in whiplash injuries. They show 7,173 (2.3 per cent) rear impacts involving vehicles with a GVM over 3,500 kg that resulted in bodily injury.

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There is consensus to recommend a wide application in the gtr. Specifically, that head restraints in all front outboard seating positions for Category 1-1 7/ vehicles, for Category 1-2 7/ vehicles with a gross vehicle mass of up to 4,500 kg, and for Category 2 7/ vehicles with a gross vehicle mass up to 4,500 kg.

Given the variability in target population in different jurisdictions, such as the differing data from the U.S.A. and Japan, it was recommended that the gtr should be drafted to have a wide application to vehicles, to maximize the ability of jurisdictions to effectively address regional differences in whiplash crash characteristics. The gtr would establish that if a jurisdiction determines that its domestic regulatory scheme is such that full applicability is inappropriate, it may limit domestic regulation to certain vehicle categories or mass limits. The jurisdiction could also decide to phase-in the requirements for certain vehicles. A footnote was added to the gtr text to make it clear that jurisdictions can decide to limit the applicability of the regulation. This approach recognizes that niche vehicles that are unique to a jurisdiction would best be addressed by that jurisdiction, without affecting the ability or need for other jurisdictions to regulate the vehicles. When a Contracting Party proposes to adopt the gtr into its domestic regulations, it is expected that the Contracting Party will provide reasonable justification concerning the limitation of the application of the standard.

5.2. Purpose

The Working Party of Experts was unable to define a purpose that correlated with injury since the mechanisms are not well understood. Therefore, more general text was developed from the definition of head restraints. The recommended text for the purpose is: "This gtr specifies requirements for head restraints to reduce the frequency and severity of injuries caused by rearward displacement of the head."

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5.3. General Requirements

Due to the high occupancy rates of front outboard seats, it is recommended that head restraints that meet the requirements of the gtr shall be installed. These requirements include dimensional and static evaluations, and may include dynamic evaluations.

7/ As defined in the Special Resolution No. 1 concerning the PTO Common Definitions of Vehicle Categories, Masses and Dimensions (document TRANS/WP.29/1045).

For all other seating positions[1], it is recommended that the installation of head restraints is optional, but if installed these head restraints shall meet most of the requirements of the gtr.[2] Fewer rear seat occupants are exposed to risks in rear impacts because rear seats are much less likely to be occupied than front seats. An analysis of the distribution of occupants by seating position for all vehicle types in 2001 to 2003 U.S.A. National Automotive Sampling System (NASS) shows that 10 per cent of all occupants sit in the second (or higher) row of outboard seats. It is noted that children and small adults derive less benefit from higher head restraints because their head centre of gravity often does not reach the height of 750 mm above the H-point. Therefore, if these data is further refined to include only occupants who are 13 years or older, the relevant percentage is reduced to approximately 5.1. 8/ This conclusion about rear seat occupancy is further supported by U.S.A. data (HR-1-3), which indicate that out of a total of 272,464 annually occurring whiplash injuries, approximately 21,429 (7.8 per cent) occur to the rear seat occupants. In summary, only a small percentage of occupants who are tall enough to benefit from higher head restraints sit in rear outboard seating positions. These percentages are even smaller for front centre and rear centre seating positions.

5.4. Dynamic Test

Ideally, the degree of whiplash injury should be evaluated based on dynamic testing that represents "real world" crashes; that is, based on a vehicle acceleration that occurs in real crashes, a dummy with high biofidelity that reflects the injury mechanism, and injury indices. However, at present, there is still not a sufficient amount of medical data to accurately define the injury mechanism; therefore appropriate injury indices have not been developed. In the interim, AC.3 recommends a dynamic testing option, as an alternative to the static performance requirements in this gtr. A dynamic test option was proposed primarily for two reasons. First, a dynamic test better represents "real-world" injury-causing events and thus is expected to produce greater assurance than the static measurement option of effective real world performance. Second, as explained below, it is believed that a dynamic test will help to encourage continued development and use of "dynamic" head restraint systems[3] because the test is designed to allow a manufacturer the flexibility necessary to offer innovative dynamic head restraint designs.

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Dynamic head restraint systems deploy in the event of a collision to minimize the potential for whiplash. During the normal vehicle operation, the dynamic head restraint system is "retracted." Because an dynamic head restraint system requires a certain range of motion to work effectively,

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1 The Working Party of Experts did not reach agreement on a definition of seating position, and therefore this is left to each Contracting Party or regional economic integration organization.

2 Head restraints at seating positions other than front outboard are not required to meet the backset requirements as explained later in this document.

8/ We further note that approximately 2 per cent of rear seat occupants sit in the centre seating positions.

3 For the purposes of this gtr, "dynamic head restraint system" means a system that is intended to reducs the occupant's injury by moving the head restraint forward during a crash or when the crash is about to occur ("pre-active" systems). The head restraint movement may be obtained by "active" systems whereby the head restraint is activated automatically (e.g. a pyrotechnic head restraint system that utilizes a gas discharge to deploy head restraints) or "reactive", (using the force generated when the occupant loads the seat at the time of rear-end collision) or by some other driving force.

18/ For full details of these tests, please see Docket No. NHTSA–2002–8570–57, 58, 59.

an "undeployed" dynamic head restraint system might not meet the static performance requirements, in particular the backset measurement requirements.

Although the dynamic compliance option is intended to ensure that the gtr encourages continuing development of dynamic head restraint systems, the option is left to the manufacturer and is available to both dynamic and conventional, or "static" head restraint systems. That is, both types of head restraints can be evaluated to either static requirements or the dynamic test option.

The U.S.A. currently has the only regulation with a dynamic testing option. Under the U.S.A. dynamic option, the entire vehicle is exposed to a half-sine deceleration pulse with a target of 8.8g peak and 88 ms duration. The 50th percentile male Hybrid III dummy in each seat must have a maximum head-to-torso rotation of less than 12 degrees and a HIC15 (Head Injury Criteria) of less than 500.

In this gtr under direction from AC.3, when the dynamic test procedure with Hybrid III is allowed, the maximum relative head-to-torso rotation value is limited to 12 degrees with the 50th percentile male dummy in all seats, with the head restraint adjusted vertically midway between the lowest and the highest position of adjustment. The head restraint is to be positioned at one middle position of vertical adjustment because there are concerns with the effects of this gtr on dynamic head restraint systems. As previously stated, there is a need to ensure that the dynamic test option encourages continuing development of dynamic head restraint systems. As discussed below, research indicates that current head restraint systems can meet the head-to-torso rotation limit in this gtr when the head restraint is adjusted midway between the lowest and the highest position of adjustment.

Using published data of low speed rear impact testing of original equipment manufacturer (OEM) seats with Hybrid III 50th percentile male dummies (Viano et al., 2002), and information on whiplash injuries sustained by occupants of these seats, a logistic regression was used to develop a probability of whiplash injury as a function of dummy head-to-torso rotation. The function is shown in Figure 1.

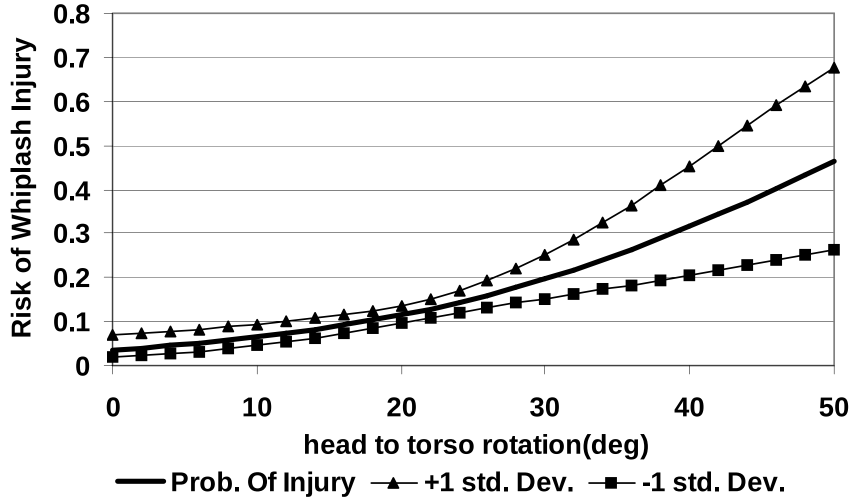

Figure 1
Risk of Whiplash Injury versus head to torso rotation
on the Hybrid III 50th percentile male dummy

A 12-degree head-to-torso rotation corresponds to a 7.3 per cent probability of whiplash. This criterion was selected to ensure adequate protection for occupants who range in stature from shorter females up to and including taller males, for all seats. In evaluating the head-to-torso rotation limit, it was noted that in the past there has not been a consensus among the biomechanics community on how best to measure the potential for whiplash injury. Presently, the relative head-to-torso rotation is the best criterion available, and will assure early head restraint interaction. The goal in selecting performance criterion limits for the dynamic compliance option was to provide a level of safety similar to that provided by the static requirements. However, given the differences in the basic nature of the test requirements, it is not believed to be possible to provide one-to-one correspondence between the two sets of tests. Thus, a particular vehicle may be able to pass one test but not the other.

The U.S.A. performed sled testing as specified in the dynamic compliance option on a specially designed seat to explore how various seat characteristics affect relative head rotation and other dummy injury measures. 18/ An OEM seat with an adjustable head restraint was modified by removing the original recliner mechanism and replacing it with a pin joint free to rotate. The seat back was also reinforced with steel channels that provided the attachment points for a spring and damper system on each side of the seat. Seat back strength in the rearward direction was modified by changing the springs and or their location of attachment relative to the hinge joint. In addition to seat back strength, sensitivity analyses to head restraint attachment strength and seat back upholstery compliance were also performed. Tests were performed with belted 5th percentile female, 50th percentile male and 95th percentile male Hybrid III dummies.

The head restraint height was either 750 mm or 800 mm and the backset was always 50 mm as measured by the HRMD. However, the majority of tests (20 tests) were performed with the 50th percentile male dummy with a 750 mm high head restraint. For all seat back parameters tested with this configuration of dummy and head restraint height, the range of relative head-to-torso rotation was 6 to 16 degrees. HIC15 was measured for half of these tests and ranged from 40 to 75. Nearly half of the seat configurations (9 of 20) met the 12-degree limit placed on the dynamic compliance option for a head restraint in the lowest adjustment position (750 mm). In general, the smallest relative rotations were seen for the baseline seat back strength 19/ and non-rotating seat backs irrespective of the other seat/head restraint parameters. From these tests, it was concluded that the head rotation and HIC limits selected can be met with typical seat back/head restraint designs when appropriate consideration is given to design in terms of height, backset and strength of head restraint attachment.

In a separate set of tests, the U.S.A. subjected a MY 2000 Saab 9–3 seat to the sled pulse of the dynamic test option. A 95th percentile male Hybrid III dummy occupied the seat. The Saab 9–3 has an dynamic head restraint system, and the head restraint was set to its highest position of adjustment. The maximum head-to-torso rotation was 9 degrees. Viano and Davidsson (2002) also sled tested a 9– 3 head restraint at a slightly lower, 16 km/h ΔV, with the seat occupied by a 50th percentile male Hybrid III dummy. With the head restraint in the up position, the relative head rotation was measured at 6.5 degrees. With the head restraint midway between the lowest and the highest position of adjustment, the relative head rotation was 10 degrees at 23.5 km/h ΔV. It is assumed that this configuration would yield an even smaller head rotation at the 17.2 km/h ΔV.

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In summary, research indicates that the head-to-torso rotation limit of 12 degrees will not discourage the development of dynamic head restraint systems. Current systems, such as the one in 2000 Saab 9–3 and the Toyota Whiplash Injury Lessening (WIL) seat (measured 6 degrees of rotation), can meet the head-to-torso rotation limit in this gtr. U.S.A. testing has also shown that current static head restraints/seats need more extensive modification to meet the head-to-torso rotation limits. These changes might include increasing the strength of attachment to the seat for adjustable head restraints and optimization of the seat back upholstery for compliance.

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The gtr requires a HIC15 limit of 500 for the dynamic test option. The gtr does not require the HIC15 limit as a means of limiting whiplash, but instead as a surrogate for the energy absorption test required for the static compliance option. Because HIC15 is easily measured during dynamic testing, it appears to be a more appropriate measuring tool. The HIC15 level of 500 is associated with an 18.8 per cent probability (95 per cent confidence: 1.8 to 32.5 per cent) of moderate (AIS 2+) head injury. 20/ While the 80g limit and the HIC15 limit of 500 are not necessarily equivalent, the two requirements do share the same intent of mitigating potential injury related to the head's striking a rigid or insufficiently padded head restraint. Data was analyzed from FMVSS No. 201 impactor tests on the back of head restraints and also vehicle

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19/ The baseline seat back strength was obtained through static testing of OEM seats and modeling to determine the corresponding amount of seat back rotation. The static testing can be found in Docket NHTSA–1998–4064–2

20/ Eppinger, R., et al. (1999) Development of Improved Injury Criteria for the Assessment of Advanced Automotive Restraint Systems—II. Available at http://www-nrd.nhtsa.dot.gov/pdf/nrd-11/airbags/rev_criteria.pdf seat sled test data. An 80g half sine acceleration was superimposed on the time duration of the impacts from these tests. This resulted in range of HIC15 values from approximately 425 to 800. Accordingly, it is believed a limit of 500 is appropriate. The greatest HIC15 value obtained in testing sled testing using a 50th percentile male dummy was 57. Thus, the HIC15 limit of 500 is practicable. The 500 HIC15 limit will give a strong indication of deleterious effects on the occupant's head and/or neck from deploying head restraints.

In the discussion of the dynamic test, some suggested that a trigger point for a sensor driven deployable head restraint should be included. It was stated that such a specification would be similar to one included in other U.S.A. sled test options, and argued that such a provision should be included in the head restraint standard to ensure objective testing. One participant cited their dynamic head restraint that uses a pyrotechnic design. Once the threshold acceleration is sensed, the pyrotechnic element fires and the head restraint moves about 40 mm to 60 mm forward, depending on the height adjustment, and rotates 9 degrees towards the occupants head. It was argued that the half-sine characteristic of the deceleration pulse is not representative of the pulse that its vehicle would sense in a rear impact and that sensors designed to the half-sine pulse may trigger head restraints unnecessarily. There was a discussion regarding pre-active head restraint systems indicating that a dedicated test protocol may be required to evaluate them (HR-8-10).

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The specified sled pulse is representative of one experienced in a crash when the head restraint is needed to provide protection. The appropriateness of the ΔV and average acceleration of the pulse is supported by a 2002 Swedish study by Krafft and others. This study examined rear impact crashes with crash recorders where crash pulse was a known (66 such crashes). It examined the relationship between whiplash injury risk and parameters such as ΔV, peak acceleration, average acceleration, and average windowed acceleration for 18 ms, 36 ms, and 80 ms. It found that average acceleration best correlated with whiplash injury risk. For most occupants who had whiplash symptoms for longer than a month, the mean acceleration of the crash pulse was greater than 4.5g and above a ΔV of 15 km/h. For this group, the average mean acceleration was 5.3g and the average ΔV was 20 km/h. The crash pulse has a 5.6g average acceleration and 17.3 km/h ΔV. The EEVC have published a review of the latest information available concerning rear impact pulses and their relationship to whiplash and associated disorders (Recommendations for a Low Speed Rear Impact Sled Test Pulse, EEVC, September 2007, http://www.eevc.org). The report was not able to recommend a single specific pulse shape correlating to injury, instead proposing either a bimodal or triangular, with a Δv of 20 km h^{-1} and mean acceleration of 5-6g to address longer-term (symptoms greater than one month duration).[4] Therefore, it is believed that the sensors should be designed to activate the head restraint in such a situation. There is concern that if a trigger point is specified, i.e., specified that the head restraint be activated at a specific point in time as part of the test procedure, there would be no test of the sensors and no assurance that the head restraint would activate during the type of crash simulated by the sled pulse. At this time, the Working Group of Experts does not recommend including a trigger point.

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Research indicates that currently available dynamic head restraints can meet the requirements of this option for the gtr. Given that the Working Party of Experts strongly encourages the development of a future fully developed alternative dynamic test procedure, including dummy

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4 Recommendations for a Low Speed Rear Impact Sled Test Pulse, European Enhanced Vehicle-safety Committee (EEVC) Report, September 2007, http://www.eevc.org

and criteria for evaluating whiplash injuries, that would further encourage innovative dynamic head restraint designs, further discussion of revision of the current dynamic option was suspended. It is expected that research to develop a single dynamic test would supersede efforts to revise the Hybrid III dynamic option. However, if future information led to different conclusions used to develop the existing procedure and criteria (such as the trigger point or head-to-torso angle rotation), amendments could be made to this option.

While the Working Party of Experts is recommending this dynamic test option, there was some criticism associated with the use of the Hybrid III dummy. Although there is a paper by Ford (SAE 973342), which argues that the 50th percentile male Hybrid III neck is sufficiently biofidelic in the rearward direction. The EEVC report "The Use of he Hybrid III Dummy in Low Speec Rear Impact Testing," (September 2007) showed the 50th percentile male Hybrid III neck lacks sufficient biofidelity to be a useful tool for rear impact testing and therefore cautioned against its use. The EEVC also observed that the interaction of the rigid thoracic spine of the Hybrid III with the seat back is not humanlike which might affect the real world performance of dynamic head restraints.

The group was informed of studies conducted by the EEVC concerning the Hybrid III, BioRID II and RID 3D test devices. At this point the EEVC research ("Dummy Measurements and Criteria for a Low-speed Rear Impact Whiplash Dummy" WG12 Report September 2007) has shown that the BioRID II has the highest level of biofidelity of these three candidate dummies.

At the direction of AC3, recognising the desire of some contracting parties to proceed at a different pace, the gtr contains recommendations to permit the use of the Hybrid III dummy in the assessment of dynamic head restraints. Nevertheless, the Working Party of Experts acknowledges the agreement of AC.3 that the option for a dynamic test using the BioRID II test dummy is recognised in this gtr. We also recognise that some contracting parties may wish to adopt alternative measures using the BioRID II dummy as soon as procedures suitable to the needs of their jurisdiction are developed.

The Working Party of Experts therefore recommends that, in the first instance, contracting parties may introduce into their national or regional laws alternative procedures for use in the dynamic assessment of head restraints. At the discretion of the contracting party, these procedures may be used in concert with this gtr. In making this recommendation the Working Group of Experts understands that those contracting parties will bring forward separately, equivalent recommendations for the introduction of these alternative procedures into this gtr.

In anticipation of this development, a section is reserved in the regulatory text to be used for the incorporation of amendments to provide equivalent dynamic assessment criteria for the BioRID II dummy (test procedures, performance criteria and associated corridors).

Last, for those Contracting Parties which would like to encourage the development of "dynamic" head restraints, but are not comfortable with either of these dynamic options at this time, the Working Party of Experts is recommending that they be allowed to exempt "dynamic" head restraints in their national legislation. The exemption would include the backset requirement in

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In addition, based on agreement from AC.3, the option for a dynamic test using the BioRID II test dummy is recognized in this gtr. A section is reserved in the regulatory text to be used for the incorporation of amendments to include test procedures, performance criteria and associated corridors for the BioRID II dummy.¶

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paragraph 5.1.5., but Contracting Parties or regional economic integration organizations could chose to impose any or all of the requirements of paragraph 5.2.

5.5. Seat Set Up and Measuring Procedure for Static Requirements

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There were two proposals under discussions concerning the set-up of the seat for the measurement of height and backset. One proposal is to use the manufacturer's recommended seating position as detailed in UNECE Regulation No. 17. The other is to use the procedure that is outlined in the recently adopted U.S.A. FMVSS No. 202, which positions the seat in the highest position of adjustment and sets the seat back angle at a fixed 25 degrees. The Working Party of Experts recommends that the seat be measured at the manufacturer's design position to allow additional flexibility to account for vehicles with very upright seat back design angles

It was argued that there are several vehicle concepts (e.g., light trucks, minivans, SUV's and full size vans) in which a seat back angle of 25 degrees is not realistic nor feasible, thus leading to a much larger backset using U.S.A.'s procedure as compared to the real world situation. It was stated that SAE J-1100 July 2002 recommends a 22 degree nominal torso design angle.

Also, it was stated that 5th percentile female stature occupants do not sit at 25 degree torso angles, but prefer about 18 degrees and some as little as 14. It argued that this more upright back angle greatly reduces the backset to the point it interferes with the head of some of these occupants, not just the hair.

After considering the arguments, the Working Party of Experts believes the flexibility of using the design seat back angle is appropriate. Additional flexibility is needed to account for vehicles with very upright design angles. As a practical matter, this approach provides some additional backset flexibility for most seats, since the typical design seat back angle is 23.5 degrees. Specifying that such a seat be tested at the design seat back angle instead of 25 degrees is roughly equivalent to increasing the backset limit by 4.5 to 6 mm. Therefore, this helps address possible concerns related to comfort.

It was also noted that while the Head Restraint Measurement Device (HRMD) was designed to be used at 25 degrees, the device has an articulation to allow for adjustment of the head for varying torso angles. The device can therefore be used at different seat back angles. It is relatively rare that a seat can be adjusted to have a seatback angle of exactly 25 degrees. Thus, even prior to the change to specify seat back angle, the standard specified testing in the adjustment position closest to 25 degrees. For these reasons, there should be no problem in testing vehicles at the design seatback angle.

In addition to the set-up of the seat, the method of measuring height and backset was discussed. Some recommend taking all measurements using the R-point as the required reference point. Another proposal is to use the J826 manikin as the primary measurement tool. The use of the R-point allows measurements to be verified to known design points on the vehicle thus improving repeatability. The use of the J826 manikin allows the seat H-point to be measured as it exists in the vehicle. It was argued that options in seat materials and manikin set up can produce recordable differences from one seat to another. UNECE experience shows that the use of the R-point allows measurements to be easily verified on a drawing and is also very repeatable and reproducible when verified in a car. The use of H-point can address differences in measurements caused by seat materials. The Working Party of Experts agreed to recommend that all static measurements, except for backset, will use the R-point as the required reference point. Because of the sensitivity of the backset measurement to seat to seat differences, the Working Party of Experts agreed to recommend that this measurement be taken with the H-point as the required reference point; Contracting Parties may choose to allow backset to be measured with R-point as an alternative and take into account the seat to seat differences by requiring a smaller backset limit (see section 5.8. for further discussion of the backset measuring method and determination of limits). The United States is currently the only country that specifies use of the H-point for static measurements other than backset. The U.S. agreed to specify R-point for these other measurements, based on a belief that it would not change the safety benefits of their existing regulation. If it were shown that use of R-point instead of H-point changes a measurement to such a degree that safety benefits were lost, they may not be able to adopt R-point for that measurement in their national legislation.

5.6. Height of the Head Restraint

The recommendations for the height requirements are intended to prevent whiplash injuries by requiring that head restraints be high enough to limit the movement of the head and neck, even if such movements do not result in hyperextension of the neck. The persistence of whiplash injuries in current vehicles that are regulated to a 700 mm height indicates these designs are not preventing whiplash injuries from occurring. Research has led to the conclusion that prevention of hyperextension alone does not stop whiplash from occurring. Since a 700 mm high head restraint is capable of preventing hyperextension in many occupants, it seems likely that the persistence of whiplash may be the result of the inability of current head restraints to be positioned to sufficiently limit relative head and neck motion in the normal range of motion.

Research has shown that head restraints should be at least as high as the centre of gravity (C.G.) of the occupant's head to adequately control motion of the head and neck relative to the torso. This does not mean that there would be no additional benefits for a head restraint with a height greater than the height of the head C.G. However, this is likely to be controlled by other factors such as backset, head restraint shape and the underlying structure of the head restraint under the upholstery.

The recent IIHS study also suggests that head restraints that are higher in relation to the head centre of gravity and closer to the back of the head provide greater protection against whiplash. The Working Party of Experts notes that head restraints rated "good" by IIHS (integral restraints with a height less than 60 mm below the top to the head and within 70 mm of the rear of the head) reduced the likelihood of whiplash by 36 per cent in females and 10 per cent in males. An 800 mm high head restraint is likely to be high enough to be rated as "good" at all backsets within the "good" range. The Working Party of Experts believes that the proposed requirement for backset, in conjunction with the proposed height requirements, would lead to a significant improvement in safety.

5.6.1. Front Outboard

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Both UNECE Regulation No. 17 and the FMVSS No. 202 Final Rule require front outboard head restraints with a minimum height of 800 mm above the R-point/H-point, respectively. A proposal was made to recommend a minimum height of 850 mm, to accommodate the taller citizens of some countries. Using recent anthropometric research (see HR-3-6 and HR-4-16) it was demonstrated that when considering erect sitting height a 95th percentile Netherlands male needs a head restraint height of 849 mm to give protection equivalent to that of the average occupant. The United Kingdom submitted data (see HR-4-14 and HR-6-11) showing their population is tall enough to need taller head restraints. The United Kingdom also provided an EEVC Cost Benefit Analysis (UK Cost Benefit Analysis: Enhanced Geometric Requirements for Vehicle Head Restraints, European Enhanced Vehicle-safety Committee (EEVC), September 2007, http://www.eevc.org) demonstrating benefits for increasing head restraint height.above 800 mm.

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There are concerns with raising the height of the head restraint above 800 mm at this time. It was noted that with an 800 mm head restraint, it is starting to become a challenge for manufacturers to be able to install seats in the vehicle, and a larger head restraint can also restrict occupant visibility (blocking vision rearward and to the side) (see HR-3-5). Additional data was presented (see HR-3-4) that showed that in small cars, 850 mm head restraints could severely restrict rearward vision in the rearview mirror.

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Additionally, there are concerns that the method in which the height is measured may not reflect the effective height that would be needed to address the safety concerns of taller occupants. The have been some proposals put forth to improve the measurement method, but they were not yet fully developed for inclusion in the gtr. (See section 5.6 for further discussion of this measurement method.)

At this time, AC.3 has directed that the height requirement be limited to 800 mm, but recommends that the discussion on increasing the height requirement and/or revising the measurement method be continued in Phase 2 to this gtr.

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5.6.2. Front Centre and Rear Head Restraints

5.6.2.1. Defining a Front Centre and Rear Head restraint

This gtr provides an objective definition and a test procedure for determining the presence of a head restraint. A vehicle seat will be considered to have a head restraint if the seatback or any independently adjustable seat component attached to or adjacent to the front centre or rear seat back, that has a height equal to or greater than 700 mm, in any position of backset and height adjustment.

This definition is recommended for the following reasons. Based on the survey of vehicles used to determine the cost effectiveness of this gtr, it was found that a 700 mm threshold captured all of the seats that had adjustable cushion components at the top of the seat back; i.e., what the

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general public would probably consider being a head restraint. 10/ Further, this definition of the head restraint will allow the manufacturers to provide a relatively tall seat back (up to 700 mm) without having to comply with rear head restraint requirements. It is anticipated that such taller seat backs might offer some safety benefits to a certain portion of rear seat occupants. Because rearward visibility remains a concern, it is noted that the manufacturer will be able to determine whether providing a seat back structure above 700 mm would be consistent with the amount of rearward visibility they wish to provide.

5.6.2.2. Height of Front Centre and Rear Head Restraints

As stated earlier, the target population using front centre and rear head restraints is considerably less then that for front seats and the occupants of these seats tend to be shorter. It is therefore recommended that optionally installed front centre and rear outboard head restraints have a minimum height of 750 mm. Due to visibility concerns, there is no height requirement for rear centre head restraints.

5.6.3. Clearance Exemption

There were several proposals considered regarding the need for some clearance between the head restraint, when is it as its highest position, and the interior roofline (headliner) or rear window. In some vehicles, the required head restraint height may lead to interaction with the vehicle interior. In addition, in 2 door vehicles where seats need to be rotated in order to allow ingress or egress of the vehicle, the required head restraint height may lead to the need for head restraint or seat manipulation (e.g. lowering the head restraint manually) in order to be able to rotate the seat back, thereby also impeding emergency exit. Without the clearance, the seat could contact the vehicle structure and slow down the egress process. Some delegates do not believe that emergency egress is an issue and no data were presented to justify this position.

One of the proposals considered allows 25 mm of clearance between the head restraint and the interior roofline (headliner) or rear window when the head restraint is in the highest position, the seat is in the lowest position, and the seat back is at design angle. This is based on the safety concern for maintaining the 800 mm height of the head restraint. Another proposal was put forth to allow the clearance exemption be applied when the seat is in any position of adjustment (HR-4-15). It was stated that this exemption was needed to allow the rear seat passengers to exit the vehicle in emergency. Without the clearance, the seat could contact the vehicle structure and slow down the egress process.

Deleted: There were two proposals considered.

There is concern that the clearance exemption could be applied when the seat is in the highest position, thereby allowing head restraints as short as 700 mm. It was stated that reducing the height of a head restraint to less than approximately 780 mm will have an impact on the benefits.

10/ The survey included twelve 1999 model year vehicles (9 passenger cars, 1 minivan, and 2 SUVs). Five of the twelve vehicles featured rear seating systems that fell under our definition of the rear head restraint.

After considering the reduction in safety benefits and a review of the fleet, it was determined that the clearance exemption is not needed for front or rear seats for folding positions and therefore it is recommended that an exemption of 25 mm only be applied in cases of interference with the interior roofline (headliner) or backlight. An exemption of 50 mm for convertible roofs is also recommended to account for the articulation of the folding top mechanism.

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Deleted: With regard to the seat setup, it was discussed that this exemption be applied when the seat is in the lowest position and the head restraint is in the highest position, since this would be the position of the tallest occupant. It is also recommended that the measurement be taken at any point of forward or aft adjustment. An additional exemption of 50 mm for convertible roofs is also recommended to account for the articulation of the folding top mechanism. ¶

5.6.4. Adjustable Front Head Restraints – Front Contact Surface Area

It was initially proposed to include in the gtr the UNECE Regulation No. 17 requirement that the height of the head restraint face be a minimum of 100 mm to ensure sufficient surface for the occupant's head to contact. The UNECE Regulation No. 17 requirement is measured in the same manner as the overall height of the head restraint. There have been concerns expressed that the measurement taken in this manner does not address the effective height of the restraint. In the case of extremely contoured head restraints, the height of the surface that the head would contact is less than the measured height. This is demonstrated in Figure 2.

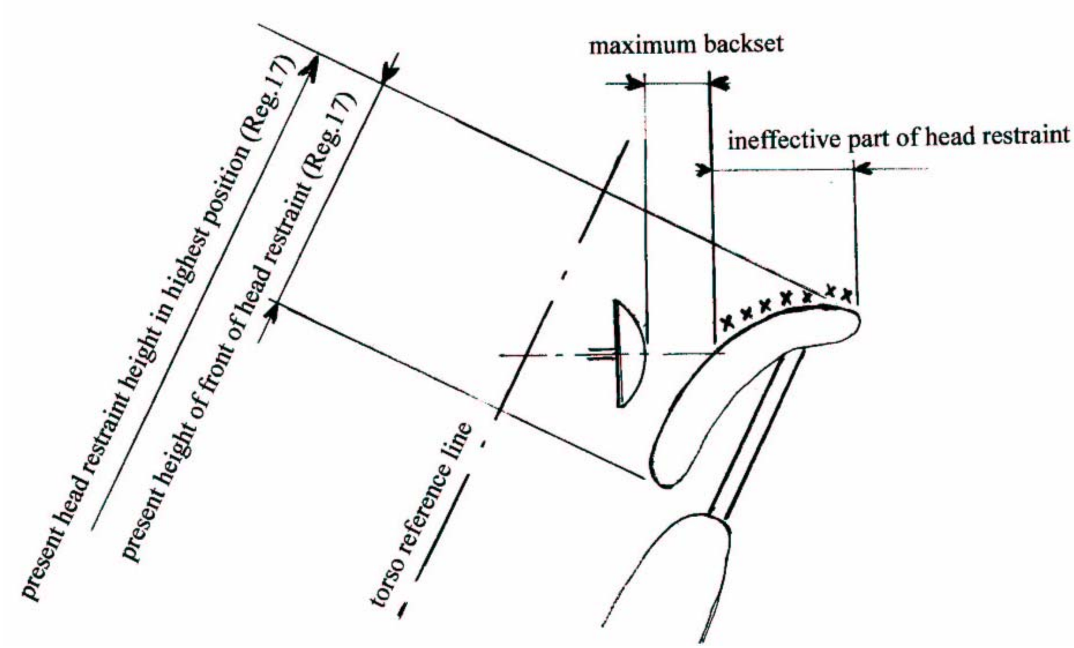

Figure 2 – Ineffective Part of the Head Restraint

To address these concerns, a proposal was made that all seats have a minimum front contact surface area of a head restraint (HR-10-2). This proposal incorporates the dimensional requirements of width, minimum 100 mm height of the head restraint, and backset. This proposal is intended to provide a minimum level of protection for the occupant that is being subjected to the dynamic process resulting from a rear end collision. This front contact surface area is measured in an area bounded by two vertical planes set at 85 mm on either side of the centreline, the rear surface which complies with the backset requirement, and the horizontal plane used to measure the height of the head restraint. This proposal was countered by some as not necessary because the shape of the head restraint is governed by the displacement test, energy absorption test, and other requirements.

Absent a final decision on how the measurement would be made, analysis to determine whether or not such a requirement would add benefits can not begin. At this time, until a fully developed proposal can be evaluated, the Working Party of Experts agrees to recommend that the gtr not include a minimum height requirement for front surface contact area but recommends that the discussion on this issue be continued in Phase 2 to this gtr. Some Contracting Parties may wish to continue regulating a 100 mm minimum height requirement under their current regulation scheme.

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5.7. Head Restraint Width

5.7.1. Front and Rear Seats

It is recommended that all seats have a minimum head restraint width to ensure a minimum level of protection for the occupant in case they do not contact directly on the centreline. 170 mm is an existing standard and is providing appropriate protection for the occupant. Therefore it is recommended that for this gtr, the minimum width of the head restraints in all seating positions be 170 mm.

5.7.2. Bench Seats

There was a proposal to recommend that head restraints have a minimum width of 254 mm when installed in the front outboard positions on bench seats. The need for this requirement has been argued because a bench seat can cause the occupant to sit off-centre from the head restraint (especially if unbelted) therefore a wider head restraint is needed.

There was concern for regulating the wider head restraints because the gtr would be regulating misuse. Others stated this requirement is no longer necessary, because the vehicle bench seat of today is considerably different from the vehicle bench seat of 40 years ago. There is also a concern that wider head restraints could impact visibility.

No justification was provided for this additional requirement for bench seats. This is not a requirement under the UNECE Regulations and it was not shown that bench seats head restraints with a width of 170 mm pose any additional risks to occupants when compared to bench seats head restraints with a width of 254 mm. Therefore this requirement is not recommended for the gtr.

5.8. Backset

The consensus within the biomechanics community is that the backset dimension has an important influence on forces applied to the neck and the length of time a person is disabled by an injury. As early as 1967, Mertz and Patrick first showed that reducing the initial separation between the head restraint and head minimizes loading on the head during a rear impact. 11/ More recently, the Olsson study, which examined neck injuries in rear end collisions and the correlation between the severity of injuries and vehicle parameters, showed that the duration of neck symptoms was correlated to the head restraint backset. Specifically, reduced backset, coupled with greater head restraint height, results in lower injury severity and shorter duration of symptoms. 12/

A different study examined sled tests to determine the influence of seat back and head restraint properties on head-neck motion in rear impacts. The study concluded that the head restraint backset had the largest influence on the head-neck motion among all the seat properties examined. With a smaller backset, the rearward head motion was stopped earlier by the head restraint, resulting in a smaller head to torso displacement. The findings indicated that a reduction in backset from 100 mm to 40 mm would result in a significant reduction in whiplash injury risk. 13/

A study conducted by Eichberger examined real world rear crashes and sled tests with human volunteers to determine whiplash injury risk and vehicle design parameters that influence this risk. The study found a positive correlation between head restraint backset and head to torso rotation of the volunteers and to the reported whiplash injury complaints. The most important design parameters were a low horizontal distance between the head and head restraint as well as the head restraint height. 14/

A study conducted by Dr. Allan Tencer, PhD, used rigid occupant body models enhanced with finite element models of the cervical spine for simulating rear impacts in order to examine the effect of backset on neck kinematics and forces and moments in the neck. The study concluded larger backset correlates to greater displacement between cervical vertebrae and shearing at the facet capsules that are likely associated with whiplash injury. With the head initially closer to the head restraint, the time difference between the occurrences of the peak upper and lower neck shear forces are smaller. At 50 mm backset and lower, the head moved more in phase with the

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11/ Mertz, H.J.; Patrick, L.M.: "Investigation of the Kinematics and Kinetics of Whiplash, "Proceedings of the 11th Stapp Car Crash Conference, Anaheim, California, 1967; pp. 267-317.
12/ Olsson, I., Bunketorp, O., Carlsson G., Gustafsson, C., Planath, I., Norin, H., Ysander, L. An In-Depth Study of Neck Injuries in Rear End Collisions, 1990 International Conference on the Biomechanics of Impacts, September, 1990, Lyon, France. See Table IV and the Appendix.
13/ Svensson, M., Lovsund, P., Haland, Y., Larsson, S. The Influence of Seat-Back and Head-Restraint Proerties on the Head-Neck Motion During Rear-Impact, 1993 International Conference on the Biomechanics of Impacts, September, 1993, Eindhoven, Netherlands.
14/ Eichberger A, Geigl BC, Moser A, Fachbach B, Steffan H, Hell W, Langwieder K. Comparison of Different Car Seats Regarding Head-Neck Kinematics of Volunteers During Rear End Impact, International IRCOBI Conference on the Biomechanics of Impact, September, 1996, Dublin.

torso and extension of the head was reduced indicating a lower risk of whiplash injury. 14/ IIHS, in its studies of head restraints, considers a backset of 70 mm or less to be "good". 15/

Based on this research, it was concluded that adding a requirement specifying a limit on backset would result in reduced angular displacement between the head and torso in a crash. One method used to assess the potential benefits of a backset limit was through a computer modelling study in which the backset dimension was defined as the distance between two vertical lateral planes; one plane passing through the rearmost point on the headform and the other passing through the forward most part of the head restraint at its centreline. A seat model intended to represent a 1986–1994 Pontiac Grand Am was used with the head restraint positioned in 21 different configurations with varying heights and backsets. The vehicle seat, as modelled, was relatively stiff in the longitudinal direction in comparison to those currently on the market. A model of a Hybrid III 50th percentile male was the seat occupant.

For both seat stiffnesses, no head-to-torso angular rotation was greater than 2 degrees for head restraints above 750 mm and backsets 50 mm and closer. At backsets up to 100 mm, all head-to-torso angular rotations were less than 21 degrees for head restraints above 750 mm. At a backset of 150 mm, head rotations of 27 and 44 degrees occurred at head restraint heights of 750 mm and 800 mm, respectively. The computer modelling indicates that the lowest head-to-torso rotation value was seen when the backset was approximately 50 mm.

5.8.1. Backset Measurement Method

5.8.1.1. Measurement of Backset using the Head Restraint Measurement Device

The Head Restraint Measuring Device (HRMD) was proposed as a device to measure backset. The HRMD consists of a SAE J826 three-dimensional manikin with a head form designed by Insurance Corporation of British Columbia (ICBC) attached. The ICBC head form includes a probe that slides rearward until contact is made with the head restraint, thereby measuring backset. The benefit of using the HRMD is that it eliminates the need for obtaining a reference point from the vehicle manufacturer and it measures the actual seat, as it exists in the real world. During the discussion, many raised issues concerning suitability of the HRMD as a test device and the variability in backset measurements when the HRMD is used.

An EEVC report was introduced (HR-10-??) which reported on research efforts to produce a repeatable and reproducible method of measuring head restraint geometry (both height and backset). The research highlighted a number of concerns with the use of the HRMD and H-point manikin including its repeatability and reproducibility. /ref

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The report cited concerns that the geometry of the seat and back pan of the H-point manikin is not well controlled. While discrete points on the surface of these pans are specified, EEVC

14/ Tencer, A., Mirza, S., Bensel, K. Internal Loads in the Cervical Spine During Motor Vehicle Rear-End Impacts, SPINE, Vol. 27, No. 1, pp. 34-42, 2002.
15/ The IIHS head restraint rating criteria is discussed at: Http://www.iihs.org/vehicle_ratings/head_restraints/head.htm.

cautioned that this appears to be insufficient to guarantee that devices from different manufacturers or manufactured to differing versions of particular standards give identical interaction with seats, particularly when the seat is contoured. This could be significant for the accurate determination of torso angle and, in particular, head restraint height and backset when the H-point manikin is used in conjunction with the HRMD.

The Working Group of Experts recommends that it is necessary that the H-point manikin and HRMD machine are considered as a single tool and that they must therefore be calibrated together and remain as a matched pair for use in regulatory assessments. However, the Working Group of Experts has noted that at this time there is no agreed calibration procedure or generally available calibration equipment to ensure compliance with this recommendation. This poses significant risk with respect to reproducibility. It therefore recommends that, a suitable calibration procedure and equipment be incorporated into regulations that use type approval as a method for approval.

Transport Canada conducted a study to verify whether the HRMD is an adequate tool to measure backset. Among other things, the study sought to verify specifications and dimensional tolerances of the HRMD headform and measuring probes. Transport Canada reported that the headform is manufactured to have a mass of 3,150 ± 50 grams, and all linear dimensions of the headform are within ± 0.25 mm of the drawing specifications for the headform size "J" provided in ISO DIS 6220 - Headforms for use in the testing of protective helmets. It also reported that both height and backset probes are within ± 2 mm of the RONA Kinetics drawing specifications, and that conformity with the drawing specifications is accomplished with the specially designed "jig". Dimensional drawings for this headform have been provided in the annex to this gtr.

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The HRMD is a purely mechanical device. Also, unlike a crash dummy, it is not subjected to crash test forces. The Working Party of Experts notes that the International Insurance Whiplash Prevention Group (IIWPG), of which ICBC is a member, has identified that variability between three-dimensional manikins can be an issue when using the ICBC HRMD. To address this issue, IIWPG has developed a "Gloria jig" to calibrate the combination together as one single unit. (Get cite from Canada on Gloria jig.) Although no detailed calibration procedure is included in the gtr text, the group recommends that such procedure is developed.

In a study conducted by the U.S.A. (HR-5-4), variation in backset measurements when using multiple laboratories was examined. This study concluded, among other things, that taking the average of three backset measurements at each of three labs reduced the average measurement range between the labs by about half (from 8.5 mm to 4.5 mm). Using an average of three measurements in each of backset position of adjustment, at a 2 standard deviation (s.d.) (97.7 per cent) level of certainty, the expected variability was 5.64 mm; at a 3 s.d. (99.9 per cent) level of certainty, the expected variability was 8.47 mm. Data was presented by Japan showing a variability of up to 29mm (HR-07-10). Data was presented by International Organization of Motor Vehicle Manufacturers (OICA) showing a variability of up to 11 mm.. (GRSP-41-22)

The Transport Canada study, which used eight vehicles, sought to verify whether the HRMD is an adequate tool to measure backset. It concluded that the HRMD provides repeatable and reproducible results after calibration. It also found that increasing the number of measurements always reduced the backset measurement variability. Using an arithmetic mean of the three

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measurements in each backset position of adjustment, at a 2 s.d. (97.7 per cent) level of certainty, the expected variability was 2.6 mm; at a 3 s.d. (99.9 per cent) level of certainty, the expected variability was 3.9 mm.

Given that both the U.S.A. and Transport Canada studies indicated that increasing the number of measurements reduces backset measurement variability, it is recommended that backset measured using the HRMD is determined by taking the arithmetic mean of three measurements, rather than using a single measurement.

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5.8.1.2. Backset Limit for Measurements using the HRMD

As discussed in section 5.8. above, a backset limit of 50 mm is recommended for optimal reduction in the head-to-torso rotation based on computer modeling. To account for the tolerances of the HRMD (discussed in section 5.8.1.1.), it is recommended to set the maximum allowable backset for front outboard designated seating positions to 55 mm.

5.8.1.3. Measurement of Backset using the R-point as the required reference point

Another proposal was presented separately by OICA and Japan to measure backset using the using the R-point as the required reference point. The test method was developed using the dimensions of the HRMD to develop a measurement apparatus that can fix the R-point to dimensional information provided by the manufacturer. The repeatability of this method has been shown by Japan to have very good variability per individual seat ranging from 0 mm to 1.0 mm in comparison to the backset measured using the HRMD, which ranged from 2.5 mm to 6.0 mm (GRSP-41-3). In the data provided by OICA, an analysis of the measurements across several seats of the same build indicated excellent repeatability, with differences between minimum and maximum measurements on several samples of the same seat model ranging between 0 and 3 mm. These same OICA data indicated a difference of up to 11 mm on the same seats, using the HRMD data. Therefore, it was decided to recommend that the gtr allow Contracting Parties and regional economic integration organizations the option of allowing manufacturers a choice between H-point and R-point, so that manufacturers which did not wish to market their vehicles in other countries would not have to incur potential expenses in retesting their head restraints to measure backset from the H-point.

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5.8.1.4. Backset Limit for Measurement Method using the R-point as the required reference point

While theoretically, the backsets measured using the methods outlined in sections 5.8.1.1. and 5.8.1.3. should produce the same results, a comparison of the two measurement methods performed separately by Japan and OICA showed that on average the backset measured from R-point is less than the backset measured using the HRMD. An analysis, of the data provided by OICA, showed an average offset of 7.9 mm. Japan's analysis showed an average offset of 6.7 mm. Taking into account the variability in the build design discussed in section 5.8.1.3, it is recommended to set the backset limit measured with the R-point method at 45 mm.

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5.8.2. Backset Limit & Comfort

When the U.S.A. benefit analysis for regulating height and backset was examined, it is noted that all the benefits for the front seat passengers come from regulating the backset. These benefits are achieved by improving the current situation. The U.S.A. proposed a backset limit of 55 mm measured at manufacturer's design seat back angle and measured with the HRMD, using the H-point as the initial reference. Others proposed a less stringent backset of 70 mm.

The EEVC Cost Benefit Analysis (UK Cost Benefit Analysis: Enhanced Geometric Requirements for Vehicle Head Restraints, EEVC, September 2007, http://www.eevc.org) considered the potential costs and benefits of introducing a backset limit of between 40 and 100mm. Benefits were determined by the evaluation of potential casualty savings that might occur as a result of a regulatory change with the cost to industry consistent based on the US data. The study used UK data and proposed that significant savings could be achieved through changes to existing head restraint geometry (including the introduction of a backset requirement, Figure X.

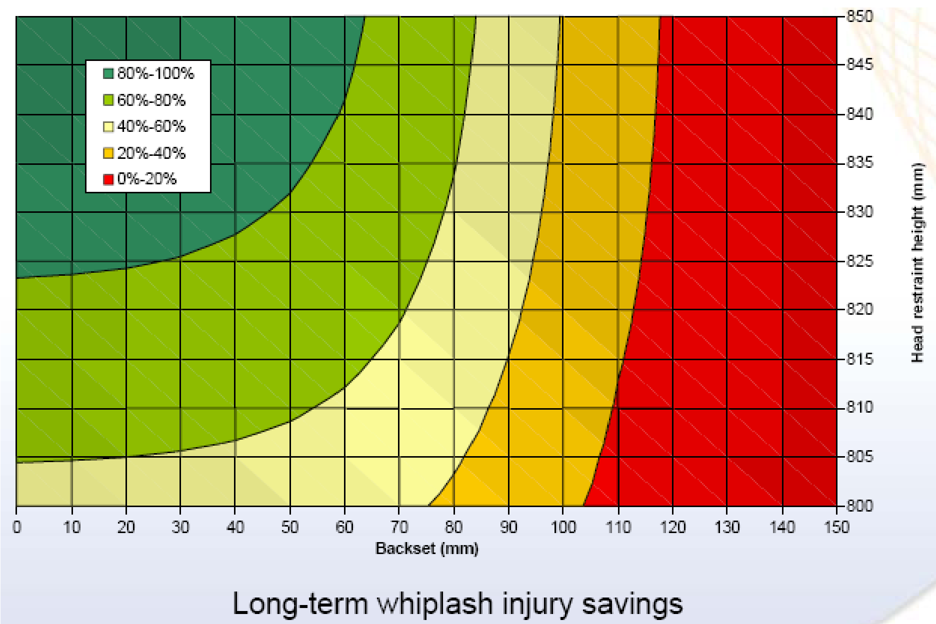

Figure 3 Potential Long-term Whiplash Injury Savings in the UK through increased height and backset requirements.

It has been argued that the 55 mm backset requirement is too aggressive and will create significant customer dissatisfaction. It has been noted that occupants may be intolerant of head restraints very close to the back of their head, and because of differences in the occupants size, posture and seat angle preference, the same head restraint can yield different amounts of backset clearance and thus comfort for different individuals. For instance, it was noted that 5th percentile female stature occupants do not sit at 23° torso angles, but prefer about 18° and some as little as 14°. It was also argued that this more upright seatback angle greatly reduces the backset to the point of interference with the head of some of these occupants, and not just the hair.

The importance of acceptable comfort for all occupants is recognized, including those of short stature. However, it is believed that the available data do not support the view that the 55 mm requirement will create any significant problems for a well designed and well built seat. As indicated by a review of IIHS backst data of 2004 model year vehicles , nearly half of the current vehicles measured had a backset of 55 mm or less, more than 30 per cent had a backset of 45 mm or less, and 25 per cent had a backset of 40 mm or less. Moreover, these calculations were made using a seatback angle of 25 degrees, and the change to design seat back angle will provide additional flexibility to typical vehicles. Thus, a large number of vehicles in the current fleet show that the new requirement can be met without causing significant comfort issues.

Therefore, the Working Party of Experts agreed to recommend a backset limit of 55 mm when measured from the H-point and 45 mm when measured from the R-point. At this limit there are significant benefits and the costs of the regulation are reasonable.

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5.9. Gaps

5.9.1. Gaps within Head Restraint

It is recommended that all gaps within a head restraint are evaluated to ensure a minimum level of protection for the occupant and provide appropriate relief to address rearward visibility concerns. The proposed evaluation requires that if the gap is greater than 60 mm when measured using 165 mm sphere then the gap is tested using the displacement test with the headform applied at the centre of the gap. This is an existing UNECE Regulation No. 17 requirement and is providing appropriate protection for the occupant.

5.9.2. Gaps between bottom of head restraint and top of seat back

There were two proposals on how to address the gap between the bottom of the head restraint and the top of the seat back. One proposed that gaps between the bottom of the head restraint and the top of the seat back have maximum dimension of 60 mm when measured using a 165 mm sphere. The other proposal allows a maximum height of 25 mm when measured using the same method to measure overall height as described in UNECE Regulation No. 17. Requiring a minimum gap is recommended to prevent an occupant from contacting the head restraint posts or other structure when the head restraint is in the lowest position. The Working Party of Experts recommends regulating these gaps using either method. Additionally, the Working Party of Experts recommends that the gap for non-vertically adjustable head restraints should have a maximum dimension of 60 mm.

5.10. Head Restraint Height Adjustment Retention Devices (Locks)

The Working Party of Experts recommends that performance requirements for adjustable head restraints be included in the gtr which are intended to assure that the front head restraints remain locked in specific positions. A 1982 U.S.A. NHTSA study found that the effectiveness of integral head restraints was greater than adjustable head restraints. The study concluded that this difference in effectiveness was due, in part, to adjustable head restraints not being properly positioned. Although one reason for improper positioning is a lack of understanding on the part of the occupant on where to place the head restraint, it also could be due to the head restraint's moving out of position either during normal vehicle use or in a crash. Adjustment locks can mitigate this problem by helping to retain the adjusted position. IIHS has also been critical of adjustable head restraints, especially when they do not provide locks, in their evaluation of head restraints. This criticism has manifested itself in that IIHS, in its rating of head restraints, automatically gave adjustable restraints a lower rating on the assumption that these restraints would not be properly adjusted. In addition, it only evaluated adjustable head restraints without locks in their lowest position. The U.S.A. has received comments during it's regulatory process to update it’s head restraint regulation from consumer groups and vehicle manufacturers supporting adjustable head restraints that lock.

The proposed requirements of this gtr are expected to improve the performance of all adjustable head restraints. The performance of adjustable head restraints may be further improved if steps are taken to ensure that a restraint remains in position after it has been set by the user.

Therefore, the Working Party of Experts is proposing that adjustable head restraints for the front outboard seating positions must maintain their height (i.e., lock) in several height positions under application of a downward force. In addition to locking at a position of not less than 800 mm, they must also lock at the highest adjustment positions. It may be that, for some designs, the highest position is at 800 mm. Adjustable head restraints for the front centre and rear outboard seating positions must lock at the highest position of adjustment above 750 mm, if this position exists. In addition to locking at these specified positions of height adjustment, both front centre and rear outboard head restraints must be capable of retaining the minimum height of 750 mm under application of a downward force. Adjustable head restraints for rear centre seating positions must lock at the highest position of adjustment above 700 mm and be capable of retaining the minimum height of 700 mm under the application of a downward force.

The proposed height adjustment retention lock test begins by applying a small initial load to the head restraint. A headform is used to apply the load and a reference position is recorded. The reference position is measured with this load applied to eliminate variability associated with the soft upholstery of the head restraint. A 500 N load is then applied through the headform to test the locking mechanism. Finally, the load is then reduced to the initial value and the head form is checked against its initial position. In order to comply, the locking and limiter mechanisms must not have allowed the headform to have moved more than 25 mm from the initial reference position.

Concern was expressed that this load was overly severe, the forces were being applied in the wrong direction, and that such a requirement might negatively affect dynamic head restraint system design. Data from Hybrid III dummies was provided on the representativeness of the force levels (HR-2-8). For 23 rear impact crash tests, an average downward force was 539 N. Based on these tests, the Working Party of Experts believes this load is appropriate. Participants have stated that there are advanced dynamic head restraints that, due to their mechanical nature, displace more than 25 mm during the preload of the backset retention test. It was anticipated that there may be advanced designs which, by their dynamic nature, are unable to pass the static

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performance requirements in their undeployed positions. This is why Contracting Parties can allow dynamic systems to meet the dynamic test option or to full or partially exempt the dynamic sytems from the gtr requirements.

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It was also questioned whether to take the measurement at the top or bottom of the head restraint. There was concern at taking the measurement at the top of the head restraint as it does not take into account the foam hysteresis (HR-6-8). Therefore, the Working Party of Experts recommends a test procedure that uses the bottom of the head restraint as reference.

5.11. Removability

The Working Party of Experts is recommending new head restraint requirements to ensure that vehicle occupants receive better protection from whiplash and related injuries. To achieve this purpose, the Working Party of Experts wants to take reasonable steps to increase the likelihood that a head restraint is available when needed. If head restraints were too easily removable, chances are greater that they will be removed. That, in turn, increases the chances that the restraints might not be reinstalled correctly, if at all. By prohibiting removability without the use of deliberate action distinct from any act necessary for upward adjustment, the likelihood of inadvertent head restraint removal will be reduced, thus increasing the chances that vehicle occupants will receive the benefits of properly positioned head restraints. While the Working Party of Experts wants to increase the likelihood that a head restraint is available when needed, it is also important to ensure that head restraints, especially in the rear outboard designated seating positions, can be removed in order to improve rear visibility, child restraint accommodation, and cargo carrying capacity.

5.12. Non-use Positions

The Working Party of Experts is aware of rear seat head restraint designs which have the goal of lessening the rearview obstruction by moving out of the way into non-use positions. The Working Party of Experts is not recommending to specifically compensate for the potential rearview obstruction. However, the Working Party of Experts is recommending language which will allow for folding or retractable head restraints for rear seats if they meet specific criteria. If such a head restraint is adjusted to a non-use position, i.e., any position in which its minimum height is less than that proposed in this document or in which its backset is more than that proposed in this document, it must give the occupant an unambiguous physical cue that the head restraint is not properly positioned by altering the normal torso angle of the occupant by at least 10 degrees, being rotated 60 degrees forward or rearward, complying with the "discomfort metric" which defines the zone the head restraint is in when it is in the non-use position, or it must automatically return to a position where it would comply with all provisions of the regulation when the seat is occupied.

5.12.1. Front Outboard Seats

The Working Party of Experts believed it was important to balance the need to ensure that the head restraint is in the proper position while maintaining the functionality of the seat. In some current designs the head restraint can be placed in a non-use position when the vehicle seat is folded down to increase the cargo capacity of the vehicle. It has been proposed to allow non-use positions in the front outboard seats, as long as they automatically return to the proper position when the seat is occupied. The Working Party of Experts is recommending a test procedure using the 5th percentile female Hybrid III dummy or a human surrogate to evaluate these systems.

5.12.2. Front Centre and Rear Seats

5.12.2.1. Manually adjusted non-use positions

It is recommended regulation of non-use positions in the rear seats, as long as the position is "clearly recognizable to the occupant." There is discussion on how to objectively evaluate this requirement. One proposal is to define "clearly recognizable" as a head restraint that rotates a minimum of 60 degrees forward or aft. There was concern that this definition is too design restrictive as the sole method and additional methods have been proposed (HR-4-13).

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The U.S.A. developed a human factors study to determine if an occupant would be likely to reposition their head restraint as a function of the torso angle change the head restraint produced in the non-use position (HR-5-23). The baseline seat for this study was the second row captain's chair of a 2005 model year (MY) Dodge Grand Caravan. In its original equipment manufacturer (OEM) configuration, the seat created a nominal 5 degree torso angle change between its non-use and in-use positions. The head restraint was then modified by introducing two forward offsets that generated either a 10 or 15 degree torso angle change. One other condition that was used was to attach a label to the head restraint in the 5 degree condition. The label was modified from a label used by Volvo.

Of the participants who adjusted the head restraint, 88 per cent adjusted it immediately after sitting down. The 5 degree condition and label condition were unsuccessful in motivating participants to adjust the head restraint. For the 5 degree condition, only 3 out of 20 participants (15 per cent) adjusted the head restraint. None of the participants (0 out of 20) adjusted the head restraint as a result of the label. The 10 degree condition had a nearly 80 per cent success rate, 19 out of 24. Only four participants were run in the 15 degree condition since the percentage of participants who adjusted the head restraint in the 10 degree condition was high. The 15 degree condition had a 100 per cent rate of adjustment. Based on the results of this study, the Working Party of Experts agreed to recommend the 10 degree torso angle change option as an alternative.

Some representatives and participants support the use of labels since these head restraints are optional, and a label in a non-use position is better than no label at all. Additionally, the need for labels was suggested because the use of the torso angle change method or discomfort metric may be incompatible with the installation on child restraints. Some delegates do not support the use of labels, because there are already too many labels in the vehicles and, based on the U.S.A. study, the labels were ineffective in causing the occupant to move the head restraint out of the non-use position, although 50 per cent of those questioned understood what the label meant, and an additional 30 per cent understood that the head restraint was adjustable. To accommodate all views, in the gtr labels will be recommended as an optional method to be accepted by the

Contracting Party. Based on the available data, Contracting Parties can choose the level of risk they are comfortable with.

Another proposal under consideration is a “discomfort metric” which defines the zone the head restraint is in when it is in the non-use position. It is a method to define objectively the requirement that a non-use position to be “clearly recognizable to the occupant”. To reduce the subjectivity of the UNECE language, a method was developed based on the argument that something which is uncomfortable, e.g. a step in the contour of the seat back, can be considered clearly recognizable. To make the criterion objective and measurable the discomfort metric option defines geometrical requirements, the size and location of the seat back contour, when the head restraint is in the non-use position. In contrast to the “change of torso angle” option, which results mainly in a more upright seating position, the discomfort metric option is focused on discomfort felt in the back of the occupant and therefore results in an overall uncomfortable seating condition.

To determine the appropriate dimensional criteria, several studies were conducted by OICA. One study (HR-8-11) showed that the thickness of the head restraint is more important than the height of the lower edge of the head restraint, as evidenced by the occupant moving the head restraint from a non-use position to an in-use position. The other study showed that, when the discomfort metric dimensions are the same as some current seat designs i.e. so called “shingled” head restraints, a large percentage of small females can recognize the head restraint is out of position.

A third study was conducted (GRSP-41-21) with 79 candidates who represent the body height distribution of the public. The study showed that a shingled head restraint, designed with a thickness of 40 mm and a position of the lower edge of the head restraint in non-use position of 460 mm above the R-point, is sufficient to result in a recognition rate of 92%. While some countries felt these results were optimistic, in that the test conditions may have predisposed participants to concentrate on comfort, all agree that the recognition rate would likely be sufficiently high to justify using these numbers in the GTR.

Apart from thickness and maximum height criteria for the lower edge of the head restraint, there are two additional criteria incorporated in the discomfort metric option: A minimum height of the lower edge prevents a seat design where the lower edge is settled in the area of the seat cushion and cannot be felt by the occupant anymore. Another criterion requires the step in the seat back contour to rise up to the full thickness within a height distance of 25 mm, which assures that it is really a step and not a smooth intersection, which would not be felt by the occupant.

5.12.2.2. Automatically adjusted non-use positions

There is consensus, for the rear seats, to recommend regulation of non-use positions that automatically return to the proper position when the seat is occupied. A test procedure using the 5th percentile female Hybrid III dummy or a human surrogate to evaluate these systems has been added to the gtr.

5.13. Energy Absorption

5.13.1. Impactor

The Working Party of Experts is recommending an energy absorption requirement specifying that when the front of the head restraint is impacted by a head form the deceleration of the head form must not exceed 80g continuously for more than 3 milliseconds. This recommendation is different from the current U.S.A. and UNECE regulations in that it does not specify a type of impactor, but rather a required energy. This would allow either the linear impactor, the free motion impactor, or the pendulum impactor to be used for testing. Studies showed that the results of the test were similar regardless of what type of impactor was used (HR-4-8, HR-5-6).

5.13.2. Radius of Curvature

The Working Party of Experts discussed incorporating the UNECE Regulation No. 17 requirement that designated parts of the front of the head restraint shall not exhibit areas with a radius of curvature less than 5 mm pre- and post-test. There was concern that a breakage could occur during the test which would produce a sharp edge. This sharp edge could harm occupants in a secondary impact. The Working Party of Experts was unable to agree on a test procedure and therefore the requirement was not included in the gtr at this time. Due to these concerns, some contracting parties may wish to continue regulating for radius of curvature under their current regulation scheme.

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5.14. Displacement Test Procedures/Adjustable Backset Locking Test/Ultimate Strength

The Working Party of Experts is recommending the incorporation of requirements to evaluate the head restraint's ability to resist deflection and significant loading. The displacement test requires that a head restraint cannot deflect more than 102 mm when a 373 Nm moment is applied to the seat. Additionally, the seat system must not fail when an 890 N load is applied to the seat and maintained for 5 seconds.

Additionally, the Working Party of Experts is recommending, based on contracting party determination, that head restraints with adjustable backset maintain their position while under load. Some strongly believe that if an occupant adjusts his head restraint backset so that it is less than the requirement, then he should have some assurance that it will maintain that position when loaded. Some further believe, that this requirement should only apply to required head restraints and not those optionally installed. Others strongly believed that the safety needs are met at the requirement. Therefore the gtr was drafted so that a contracting party can designate whether adjustable head restraints will be tested at all positions of backset and to which head restraints this will apply. The test for adjustable head restraints incorporates both the evaluation for total displacement of the head restraint and the evaluation of the locking mechanism for the adjustable backset.

6. LEADTIME

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It is recommended that Contracting Parties implementing this gtr allow adequate lead time before full mandatory application, considering the necessary vehicle development time and product lifecycle.

7. REGULATORY IMPACT AND ECONOMIC EFFECTIVENESS

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In the U.S.A. it is estimated the annual number of whiplash injuries to be approximately 272,464. 251,035 of these injuries involve occupants of front outboard seats, 21,429 injuries involve occupants of rear outboard seats. The average economic cost of each whiplash injury resulting from a rear impact collision is $9,994 (2002 dollars) which includes $6,843 in economic costs and $3,151 in quality of life impacts. The total annual cost of rear impact whiplash injuries is approximately $2.7 billion. Based on a study conducted by Kahane in 1982, the U.S.A. estimates that current integral head restraints are 17 per cent effective in reducing whiplash injury in rear impact crashes for adult occupants, while adjustable head restraints are 10 per cent effective in reducing whiplash injury in rear impact crashes for adult occupants (HR-3-14). The overall effectiveness of current head restraints for passenger cars is estimated to be 13.1 per cent.

It was estimated that upgrading the head restraint requirements would yield the following benefits[5]:

(a) For front seats, reducing the backset to 55 mm increases the head restraint effectiveness 5.83 per cent, resulting in 12,231 fewer whiplash injuries for front seat occupants each year.
(b) For rear seats, increasing the height of voluntarily installed rear head restraints increases the effectiveness of these head restraints by 17.45 per cent, resulting in 1,559 fewer whiplash injuries for rear seat occupants each year.
(c) The total annual reduction in rear impact whiplash injuries is thus estimated at (12,231+1,559) 13,790 or 5 per cent of the annual number of whiplash injuries (272,464).

It can be noted that with respect to whiplash injuries, a 5 per cent reduction in the incidence of whiplash is a significant step forward because the current head restraints only prevent 13.1 per cent of whiplash injuries occurring in rear impact crashes.

There are several reasons to believe that the potential benefits of this regulation are understated. First, a separate analysis of benefits associated with reduced position retention requirement was not performed. Second, in the injury data there is an inherent underestimation of whiplash injury costs due to the underreporting of such injuries. Whiplash injuries are often underreported because of late onset of symptoms. Third, no estimate of the potential reduction of higher-level neck injury more than Average Injury Scale 1 (AIS 1) was made. Although such injuries are much less frequent, their associated costs are much greater.

8. REVIEW OF EXISTING INTERNATIONAL REGULATIONS

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The following existing regulations, directives, and standards pertain to head restraints:

(a) UNECE Regulation No. 17 - Uniform provisions concerning the approval of vehicles with regard to the seats, their anchorages, and any head restraints.

5 These benefits were based on measurements taken from the H-point. Benefits realized from the R-point may be different.

(b) UNECE Regulation No. 25 - Uniform provisions concerning the approval of head restraints (Head Rests), whether or not incorporated in vehicle seats.
(c) European Union Directive 74/408/EEC (consolidated), relating to motor vehicles with regard to the seats, their anchorages and head restraints.
(d) European Union Directive 78/932/EEC.
(e) European Union Directive 96/03/EC, adapting to technical progress Council Directive 74/408/EEC relating to the interior fittings of motor vehicles (strength of seats and of their anchorages).
(f) United States Code of Federal Regulations (CFR) Title 49: Transportation; Part 571.202: Head Restraints.
(g) Australian Design Rule 3/00, Seats and Seat Anchorages.
(h) Australian Design Rule 22/00, Head Restraints.
(i) Japan Safety Regulation for Road Vehicles Article 22 – Seat.
(j) Japan Safety Regulation for Road Vehicles Article 22-4 – Head Restraints, etc.
(k) Canada Motor Vehicle Safety Regulation No. 202 – Head Restraints.
(l) International Voluntary Standards -SAE J211/1 revised March 1995 – Instrumentation for Impact Test – Part 1 – Electronic.
(m) Korea Safety Regulation for Road Vehicles Article 99 – Head Restraints.

Additionally, research and activities being conducted by European Enhanced Vehicle Safety Committee (EEVC) Working Group 12, EEVC Working Group 20, EuroNCAP, and Korea NCAP are also being considered.