Technical rational for gtr

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.

Based on National Analysis Sampling System (NASS) data, the United States 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. [Insert data from other countries; Japan, Korea, EC]

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 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 requirement 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. Research

indicates that taller head restraints would better prevent whiplash injuries because at heights of 750 to 800 mm, 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 percent reduction in injury claims. Similarly, NHTSA 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 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 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 conclude 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. Global Technical Regulation Requirements

4.1 Applicability

The application of a head restraint gtr will, to the extent possible, use the revised vehicle classification and definitions of Special Resolution 1.

There has been extensive discussion of the applicability of this gtr. The application of US 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[6/], in all front outboard seating positions of vehicles of category M[6/] with a maximum mass not exceeding 3500 kg, and all front outboard seating positions of vehicles of category N[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 United States presented justification (see document No. HR-4-4 of the informal group), developed in 1989, when the 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). Japan presented data (HR-4-10) showing the breakdown, by vehicle weight, of crashes resulting in whiplash injuries. They show

1,540 (0.7%) rear impacts involving vehicles with a GVW over 3,500 kg that resulted in bodily injury.

[Insert final discussion on Category 1-2 and Category 2 vehicles]

There is consensus to recommend that the gtr should recommend 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 [3,500 kg][4,500 kg], and for Category 2[7/] vehicles with a gross vehicle mass up to [3,500 kg][4,500 kg].

4.2. Scope

At the April meeting, scope language was proposed: "This gtr specifies requirements for head restraints to reduce the frequency and severity of [neck injury] in rear end [and other collisions.]" At the June meeting, it was proposed to replace "neck injury" with "whiplash associated disorder".

There was concern about defining the scope using the injuries and the type of accidents in which those injuries occur. The recommended text was for the scope that addresses these issues: "This gtr specifies requirements for head restraints to reduce the frequency and severity of injuries caused by rearward displacement of the head." This text comes from the definition of head restraints.

4.3. 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, static, and dynamic evaluations. These seats can also be tested to an optional dynamic test, which would eliminate the need for an evaluation of backset and some other requirements.

For all other seating positions, it is recommended that the installation of head restraints is optional, but if installed these head restraints must meet the requirements of the standard, except for the backset requirement. Fewer rear seat occupants are exposed to risks in rear impacts because rear seat 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 NASS shows that 10 percent of all occupants sit in the second (or higher) row of outboard seats. We note that children and small adults derive less benefit from taller head restraints because their head center of gravity often does not reach the height of 750 mm above the H point. Therefore, if we further refine these data to include only occupants who are 13 years or older, the relevant percentage is reduced to approximately 5.1 [8/] Our conclusions about rear seat occupancy are further supported by the FRIA data, which indicate that out of a total of 272,464 annually occurring whiplash injuries, approximately 21,429 (7.8%) occur to the rear seat occupants. In sum, only a small percentage of occupants who are tall enough to benefit from taller head restraints sit in rear outboard seating positions. These percentages are even smaller for front center seating positions.

In order to ensure that optionally installed head restraints do not pose a risk of exacerbating whiplash injuries, it is recommended that these head restraints, if installed, must conform to the height, strength, position retention, and energy absorption requirements of this gtr.

4.4. Seat Set Up and Measuring Procedure for Height & Backset

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 US 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 U.S. procedure allows for results of height and backset to be compared from vehicle to vehicle. The UNECE Regulation No. 17 procedure allows the seat to be measured at the same seat back angle that is used to determine other occupant design requirements, such as sight angles and has proved to be very repeatable and reproducible; concerns have been raised that the United States procedure would result in high variations at certification. UNECE Regulation No. 17 also takes into account the difference in seating positions for different vehicle types.

In addition to the set-up of the seat, the method of measuring height and backset is under discussion. Some recommend taking all measurements from the R-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 and when it is under load. 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. [sm1]

4.5. Height of the Head Restraint

4.5.1. Front Outboard

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.

Data was provided showing that the average sitting height for adults in Netherlands and the United States has increased over the last 10 years and a higher head restraint is needed to protect these occupants (see HR-3-6). Japan presented data (see HR-4-10) showing that Japanese females and males are smaller than the United States population and that the current height requirement of 800 mm is appropriate for their population. The United Kingdom also submitted data (see HR-4-14 and HR-6-11) that showed although their population is not increasing in size, they are tall enough to need taller head restraints.

Using the Netherlands and University of Michigan Transportation Research Institute (UMTRI) data for automotive sitting height, it was calculated that a 800 mm height of head restraints is sufficient to protect up to almost a 95th percentile Netherlands male (see HR-4-2). This data was revised to include spine straightening and it still did not support raising the height to 850 mm. The justification for using this measurement calculation is that it incorporates the effect of backset and it measures occupants as they sit in a vehicle.

The justification for the Netherlands data is that it measures erect sitting height and does not need to take in account spine straightening. Some representatives questioned the necessity of taking into account spine straightening. It was stated that spine straightening may not be a factor when there is a reduced backset. Additionally, it was stated that the spine straightening research of Kroonenberg, which showed a T1 z-displacement of 34 mm (SAE paper 983158), was conducted on a standard (cushioned) car seat, and a similar research of Ono (which showed similar effects) was conducted on a rigid board. It was discussed that this phenomenon would not be as pronounced in a cushioned automotive seat.

There are concerns with raising the height of the head restraint above 800 mm. 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 (smaller than mini), 850 mm head restraints could severely restrict rearward vision in the rearview mirror.

The United States reviewed their cost benefits analysis for height and backset and found that there are no benefits to increasing the height to 850 mm (HR-7-11). The benefits calculated are solely influenced by the 55 mm backset. Benefits from height do not come into account until backset is very large.

Based of the benefits calculations from the US and the other concerns expressed, it is recommended that the height of front outboard head restraints be limited to 800 mm.

4.5.2. Front Centre and Rear Head Restraints.

4.4.2.1. Defining a Front Centre and Rear Head restraint.

This gtr recommends an objective definition and a test procedure for determining the presence of a rear head restraint. A vehicle seat will be considered to have a rear head restraint if the seat back, 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 method is recommended for the following reasons. Based on the survey of vehicles used to determine the cost effectiveness of this regulation, we 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 general public would probably consider being a head restraint.9/ 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.

4.5.2.2. Height of Front Centre and Read 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 center head restraints (To be called a head restraint, it must have a minimum height of 700 mm).

4.5.3. Clearance Exemption

There are two proposals being considered. One allows 25 mm of clearance between the head restraint and the roofline or rear window when the head restraint is in the lowest position, the seat is in the lowest position, and the seat back angle measures 25 degrees. 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. (see 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.

Some delegates do not believe that emergency egress is an issue and no data was presented to justify this position. There is also 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 the reducing the height of a head restraint to less than approximately 780 mm will have an impact on the benefits.

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 seats for folding positions and therefore it is recommended that this exemption only be applied in cases of interference with the roofline or backlight. This exemption is currently used for some folding rear seats, and therefore the exemption is still being considered in those cases.[sm2]

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. [sm3]

4.5.4. Adjustable Front Head Restraints – Front Surface Height

It has been 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. It has been proposed that the 100 mm requirement be applied to this effective 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.

For inclusion in the gtr, this requirement needs to be justified and if the method of measurement is to be changed, an objective test procedure will need to be proposed.

[sm4]

4.6. Head Restraint Width

4.6.1. 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 centerline. 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.

4.6.2. 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-center 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 ECE regulations and it was not show 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.

4.7. 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.[10/] 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.[11/]

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.[12/]

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.[13/]

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 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 (2.8 inches) 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 modeling 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 forwardmost part of the head restraint at its centerline. 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 modeled, 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 modeling indicates that the lowest head-to-torso rotation value was seen when the backset was approximately 50 mm. Based on this, it was concluded that this amount of backset is appropriate for front outboard seating positions.

4.7.1. Backset Measurement Method[sm5]

4.7.1.1. Measurement of Backset using the Head Restraint Measurement Device

4.7.1.1.1. 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

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 eliminates the need for obtaining a theoretical reference point from the vehicle manufacturer and it measures the actual seat, as it exists in the real world. This device is readily available and commonly used throughout the world to measure backset. 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.

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 3150 ± 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.

The HRMD is a purely mechanical device. Also, unlike a crash dummy, it is not subjected to crash test forces. Given these considerations, we believe that calibration should really be needed. We note, however, 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.

In a study conducted by the US, 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 laps reduced the average measurement range between the labs by about half (from 8.5 mm to 4.5 mm). The backset measurement variability across laps fit between the estimates made from data presented by Japan and OICA. Using an average of three measurements in each of backset position of adjustment, at a 2 s.d. (97.7 percent) level of certainty, the expected variability was 5.64 mm; at a 3 s.d. (99.9 perecnt) level of certainty, the expected variability was 8.47 mm.

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. It also found that increasing the number of measurements always reduced the backset measurement variability. Using an average of the three measurements in each backset position of adjustment, at a 2 s.d. (97.7 percent) level of certainty, the expected variability was 2.6 mm; at a 3 s.d. (99.9 percent) level of certainty, the expected variability was 3.9 mm.

Given that both the US and Transport Canada studies indicated that increasing the number of measurements reduce backset measurement variability, it is recommended that the backset is determined by taking the arithmetic average of three measurements, rather than using a single measurement. Based on these studies, it is believed that the HRMD is an adequate and appropriate tool to measure backset, providing repeatable and reproducible results.

4.7.1.1.2. Comfort, and Backset Limit, and Seatback Angle.

4.7.1.2. Measurement of Backset using the R-point as the initial reference point

[Add rational when discussion on the method is finished.]

4.8. Gaps

4.8.1. Gaps within Head Restraint.

It is recommended that all gaps with 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 center of the gap. This is an existing UNECE R.17 requirement and is providing appropriate protection for the occupant.

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

It is recommended that gaps between the bottom of the head restraint and the top of the seat back have either maximum dimension of 60 mm when measured using a 165 mm sphere or a maximum height of 25 mm when measured using the same method to measure overall height as described in UNECE Regulation No. 17, and the gap for non-vertically adjustable head restraints should have a maximum dimension of 60 mm.. Requiring a minimum gap was established to prevent an occupant from contacting the head restraint posts or other structure when the head restraint is in the lowest position.

the gap for non-vertically adjustable head restraints should have a maximum dimension of 60 mm. the gap for non-vertically adjustable head restraints should have a maximum dimension of 60 mm.

4.9. Head Restraint Height Adjustment Retention Devices (Locks)

It is recommended that if a device is adjustable for height, then it should hold its position when loaded in the downward direction. This gtr incorporates a test procedure to ensure that the head restraints can withstand the forces associated with normal pressure applied upon the head restraint during ingress and egress, as well as in the event of a crash. The test procedure proposed requires that downward force of 500 N be applied to the top of an adjustable head restraint to ensure the integrity of the height retention device.

The 500 N downward force is representative of the peak loads likely to be encountered in moderate to severe rear impacts. The US reviewed (see HR-2-8) upper neck shear loading from 33 rigid moving barrier, rear impact (48 km/h) US FMVSS No. 301 tests and found the average maximum load caused by the head being loaded in the forward direction with respect to the torso is 351 N. This direction of shear load is a good indicator of head restraint loading on the head and, therefore, head loading on the head restraint. Thus, the 500 N downward force is representative of the peak loads likely to be encountered in moderate to severe rear impacts.

4.10. Removability

It is recommended that gtr include a provision to prevent head restraints from accidentally removed when being adjusted. This is a potential problem when the head restraint is being adjusted in an upward direction but not a downward direction. The recommended requirement allows for removal via a deliberate action distinct from any act necessary for upward adjustment.

4.11. Non-use positions

[Add discussion]

4.12. Energy Absorption

4.12.1. Impactor

[Add discussion]

4.12.2. Radius of Curvature

[Add discussion]

4.13. Displacement Test Procedures/Adjustable Backset Locking Test

[Add discussion]

4.14. Dynamic Test

[Add discussion]

Footnotes:

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

[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.

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).

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).

[8/] We further note that approximately 2 percent of rear seat occupants sit in the center seating positions.

[9/] 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.

[10/] 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.

[11/] 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.

[12/] 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.

[13/] 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.

[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.