RECREATIONAL
OFF-HIGHWAY
VEHICLE
ASSOCIATION

April 18, 2011

Subject: ANSI / ROHVA 1-201X

Ms. Caroleene Paul
Mechanical Engineer
U.S. Consumer Product Safety Commission
4330 East West Highway
Bethesda, MD 20814

Dear Ms. Paul,

The Recreational Off-Highway Vehicle Association (ROHVA) has received your ballot on the proposed American National Standard referenced above. Your ballot was reviewed on March 16, 2011 and April 7, 2011, and this response finalized on April 18, 2011.

Your ballot indicated abstention on the proposed standard and provided comment which is responded to below.

**Comment** – Lateral Stability

The Canvass Draft includes a significant change to the ANSI ROHVA 1-2010 standard in section eight, where a new dynamic test for lateral stability has been added. The added test is a fixed steering dynamic test, similar to the one included in SAE J266, which sets the steering angle to produce a constant turn radius of 25 feet, based on the Ackerman Angle for that radius. [footnote omitted] The test vehicle load, drive line settings, and instrumentation are also specified. The test is conducted on an asphalt surface by driving the vehicle at the set turn radius, while slowly increasing the speed. The test is concluded when the vehicle achieves a corrected lateral acceleration of 0.6 g, or the vehicle encounters either a two-wheel lift condition or a speed limitation.

CPSC staff is encouraged that ROHVA has proposed a dynamic test for the measurement of vehicle lateral stability threshold as a requirement in the standard. Staff agrees that such a test is necessary, that the test should be conducted on asphalt, and that the loading for the test should approximate the condition of a driver, plus a passenger. Further, staff agrees that the proposed data parameters are the correct ones to determine vehicle rollover performance. However, staff does not agree that the specific test method, or the acceptance limits proposed, will be adequate to identify and discriminate problematic vehicle behavior.

ROHVA has proposed a very high steering angle (turn radius of 25 feet) for the fixed steering test. At a very high steering angle, it is possible that a test vehicle will become speed limited before the characteristic of interest is observed. The acceptance limits for the test are set such that a test vehicle that reaches a speed limitation before achieving the minimum acceptable lateral acceleration would be accepted. In addition, any vehicle that experiences oversteer could reach its speed limitations early in the test, which would result in a spiraling-in spin prior to producing data on the lateral stability threshold. Therefore, the dynamic test proposed could accept a vehicle that has the most undesirable combination of characteristics – low lateral stability threshold and oversteer. CPSC staff does not agree with a test method that promotes the design of vehicles with oversteer tendencies. Further CPSC staff believes that the proposed minimum lateral stability threshold of 0.6 g is too low, based on staff's experience with dynamic stability threshold testing of vehicles. CPSC staff recommends a J-turn type test that directly measures the minimum lateral acceleration to achieve vehicle rollover. CPSC staff's experience with this type of test indicates that a relevant value for minimum lateral acceleration at two-wheel lift can be defined.

**Response:** At the urging of CPSC and its staff, ROHVA committed to studying and developing the first-of-its-kind dynamic stability test for off-highway vehicles like ROVs. ROHVA retained Dynamic Research, Inc. (DRI) to research, test and develop the dynamic stability test set forth in Section 8.3. As a result, ROHVA has asked DRI to evaluate and respond to CPSC staff's comments regarding Lateral Stability. Please see DRI's response, attached as Exhibit A to this letter, which is incorporated here by reference.

In the comments, CPSC staff refers to its experience with dynamic testing of ROVs. In its several meetings with CPSC staff regarding ROV standards development, ROHVA has repeatedly requested information and data regarding CPSC's dynamic testing. ROHVA is unable to evaluate and be responsive to some of CPSC's comments without access to CPSC testing information and data.

**Comment** – Vehicle Handling

CPSC staff continues to believe that steady state oversteer is an undesirable and unstable steering control mode for ROVs. Therefore, staff believes that a test to measure steering gradient and an acceptance criterion for handling characteristics is necessary for ROVs. CPSC staff's experience with vehicle dynamic testing has shown that altering the steering characteristics of a vehicle is not difficult. Staff successfully altered the steering characteristics of a vehicle that originally exhibited steady state oversteer, by performing minor modifications to the vehicle's track width and suspension stiffness. The modifications to the vehicle consisted of adding spacers to the rear wheels and removing the rear sway bar (see Figure 1). [Figure 1 omitted.]

The effectiveness of the modifications in improving the vehicle from oversteer (blue lines) to understeer (red and orange lines) is illustrated in the vehicle diagram shown in Figure 2. [Figure 2 omitted.]

**Response:** As you know, nearly two years ago, ROHVA retained DRI to advise ROHVA on issues related to vehicle handling and to evaluate and respond to CPSC staff's comments regarding oversteer/understeer handling characteristics. As a result, ROHVA has asked DRI to evaluate and respond to CPSC staff's most recent comments on this subject. Please see DRI's response, attached as Exhibit A to this letter, which is incorporated here by reference.

In addition, ROHVA notes that the data presented in Figure 2, while not technically wrong in their format, are shown in a manner that seems designed to highlight differences between the data sets rather to allow interpretation of any real-world distinctions in vehicle performance that result from the differences. A better and more objective analysis of the data was provided by Carr Engineering Inc. ("Carr") in its comments to the same presentation of these data sets in an earlier CPSC staff letter. *See* Letter from Caroleene Paul, CPSC, to Thomas Yager, ROHVA, at 3-4 (Dec. 15, 2009). As observed by Carr, the data in fact show that "both vehicles 1 and 2 were controllable to follow the fixed radius path with only minor steering wheel adjustments."

Carr Engineering, Inc., Docket No. CPSC-2009-0087, Comments to Advance Notice of Proposed Rulemaking for Recreational Off-Highway Vehicles, at 32 (Mar. 11, 2010). Specifically, "[v]ehicle 1 required slightly more steering at the maximum test severity than at the lowest severity (31° change)." *Id.* Vehicle 2, in turn, "was able to sustain cornering demands to . . . a very high level of tip-over resistance and controllability and higher than that achieved in the test by vehicle 1." *Id.* at 33. The data for vehicle 2 also confirm, among other things, "that no dynamic change of significance occurred at any cornering severity, let alone one that '. . . can cause unpredictable driver reactions and sudden rollover.'" *Id.* at 34 (emphasis in original).

In the comments, CPSC staff refers to its experience with dynamic testing of ROVs. In its several meetings with CPSC staff regarding ROV standards development, ROHVA has repeatedly requested information and data regarding CPSC's dynamic testing. ROHVA is unable to evaluate and be responsive to some of CPSC's comments without access to CPSC testing information and data.

**Comment** – Occupant Protection

The Canvass Draft includes the addition of an Occupant Retention System (ORS) section to the ANSI/ROHVA 1-2010 standard. Section 11.1 *Seat Belts* requires a minimum of a three-point seat belt; and Section 11.2 *Seat Belt Reminder* requires a visual seatbelt-use reminder that remains active for at least eight seconds. Section 11.3 *ORS Zones* describes four zones that cover operator leg/foot (Zone 1), shoulder/hip (Zone 2), arm/hand (Zone 3), and head/neck (Zone 4) areas.

*Seat Belt Reminder*

CPSC staff does not believe the proposed eight-second reminder light will be as effective in changing user behavior as the seat belt warning requirements for passenger cars in the Federal Motor Vehicle Safety Standards (FMVSS) Standard No. 208 *Occupant Crash Protection*. FMVSS 208 requires an active seat belt reminder that is dependent on the latch status of the seat belt; the user is motivated to latch the seat belt to remove the reminder. In comparison, the eight-second light requirement proposed in the Canvass Daft has no feedback to educate or motivate the users to latch the seat belts.

**Response:** Preliminarily, we note that ROHVA added Section 11.2 and the eight-second reminder light as a mandatory component of the standard, in part, in response to CPSC staff's suggestion in their December 15, 2009 comment letter submitted to ROHVA in connection with the balloting of what became ANSI/ROHVA 1-2010.

An ROV manufacturer may include other features promoting the use of seat belts in addition to the required Owner's Manual, labels, and reminder light. As other features are utilized and demonstrated to be effective, ROHVA will consider adding them to the standard.

**Comment** – *Zone 1 – Leg/Foot*

ROHVA has proposed requirements for the leg/foot area (Zone 1) that can be met by a construction-based permanent barrier that meets specific design criteria. The construction-based method defines the dimensions for a physical barrier and requires that the barrier withstand a horizontal outward force of 50 lbf and have no opening that permits passage of a 3-inch diameter cylinder. ROHVA has not presented the studies, tests, or research that was used in defining the barrier dimensions or its effectiveness. CPSC staff would like to review the research that was used in developing the leg/foot Zone 1 requirements. In addition, the use of a net is specified as an acceptable permanent barrier for Zone 1; CPSC staff does not believe a net is a suitable barrier because it can be cut or removed by the user.

**Response**: The construction-based permanent barrier standard (illustrated below) for Zone 1 provides appropriate and reasonable protection to prevent an occupant's foot or leg extrusion in the event of a vehicle rollover.

CPSC staff does not assert or provide any data or analysis suggesting that the dimensions or the performance standards of the Zone 1 barrier are inadequate, but instead asks to review the information used in developing these requirements. ROHVA is aware that CPSC has conducted occupant retention testing, the results of which presumably form the basis of CPSC staff's comments. In its several meetings with CPSC staff regarding ROV standards development, ROHVA has repeatedly requested information and data regarding CPSC's testing. ROHVA is unable to evaluate and be responsive to some of CPSC's comments without access to CPSC testing information and data.

The ROHVA Technical Advisory Panel (TAP) is comprised of engineers, vehicle designers, and other individuals with collectively decades of experience in designing and testing vehicles, as well as developing vehicle design, configuration and performance standards. As a standards developer, ROHVA is not required to present studies, tests, or research used in establishing standard requirements. Even so, ROHVA considered several different sources of information in establishing the dimensional requirements for Zone 1 raised entryways or permanent barriers. The height of four inches (100 mm) comes from a benchmarking of ROVs currently manufactured by ROHVA members and other ROV manufacturers. Based on the engineering judgment of its members, ROHVA also concluded that a height of four inches balances prevention of inadvertent foot/ankle/leg excursion with the need to avoid creation of a tripping hazard to occupants engaged in frequent egress/ingress activities.

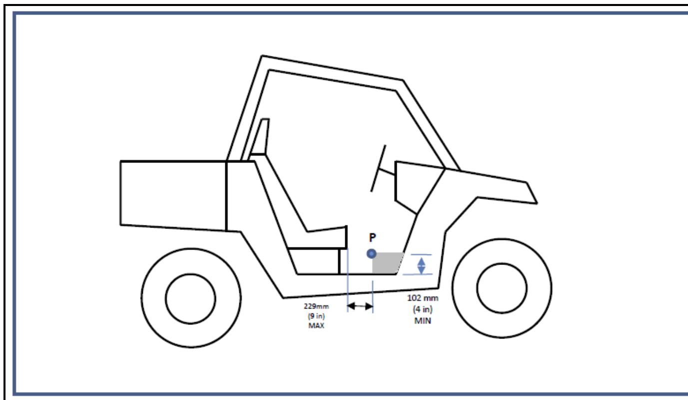


Figure 6.
Zone 1 – Foot/Leg. Both raised entryway and opening area are shown.
Note: Not shown to scale

The maximum permissible opening in Zone 1 of nine inches (229 mm) is based upon the fact that the length a 5$^{th}$-percentile woman's foot when enclosed with appropriate footwear exceeds nine inches in length.[1] ROHVA thereby determined that the 9-inch maximum permissible opening is reasonable and appropriate to reduce the risk of foot and leg extrusion for properly seated ROV occupants.

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[1] Tilley, Alvin R. Henry Dreyfuss Associates. *The Measure of Man & Woman: Human Factors in Design, Revised Edition.* John Wiley & Sons, Inc., New York, NY. 2002. ISBN 0-471-09955-4. (Dreyfuss)

Since this permissible opening (if the ROV is so designed) is behind or toward the rear of the raised barrier, the standard provides for design flexibility to allow ROV ingress and egress without sacrificing Zone 1 retention.

The size of the maximum permissible opening in a barrier in Zone 1 is taken directly from Section 4.16.1 of ANSI/SVIA 1-2010.[2] Seventy-six millimeters has long been successfully used by the ATV industry in defining the maximum opening in the foot environment of such vehicles, including those intended for use by those six years of age and up. Study of anthropometric data also indicated that this measurement was reasonable since knees and foot widths are no smaller than this value.[3]

The requirement that the Zone 1 barrier withstand a horizontal outward force of 50 lbf (222 N) was determined to be reasonable and appropriate by ROHVA based on the engineering judgment of its members and anthropomorphic data. The purpose of the Zone 1 barrier is to prevent inadvertent extrusion of feet and legs in the event of a rollover. The weight of *both* lower legs and feet for a 95$^{th}$-percentile (male) Hybrid-III dummy is less than 32 pounds (14.5 kg).[4] The loading of a Zone 1 barrier resulting from a properly seated and seat belted occupant (with separate torso restraint from the Zone 2 barrier) will therefore not be significantly greater than the weight of the outboard lower leg and foot. The strength criterion of 50 pounds of force (222 N) for the Zone 1 barrier was thereby determined to be appropriate by ROHVA.

**Assembly Weights** ⊟

| Part | Weight (lb) | Weight (kg) |
|---|---|---|
| Head | 10.90 | 4.94 |
| Neck | 3.60 | 1.63 |
| Upper Torso | 49.80 | 22.58 |
| Lower Torso | 66.80 | 30.30 |
| Upper Arms | 12.40 | 5.62 |
| Lower Arms and Hands | 11.60 | 5.25 |
| Upper Legs | 36.20 | 16.42 |
| Lower Legs and Feet | 31.96 | 14.49 |
| Total Weight | 223.00 | 101.15 |

Hybrid-III Component Weights for 95$^{th}$-Percentile Male
(Humanetics Innovative Solutions)

ROHVA believes that nets are an appropriate form of barrier for Zone 1 occupant retention. Several ROHVA members currently use different types of nets and net fasteners due to their ease of use, their effectiveness as a barrier, and their ability to stay fastened and in the correct position notwithstanding vehicle frame flex or rollover. Because nets are normally made with

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[2] ANSI/SVIA 1-2010. American National Standard for Four Wheel All-Terrain Vehicles. Specialty Vehicle Institute of America (SVIA), 2 Jenner, Suite 150, Irvine, CA 92618. Printed January 2011.

[3] Dreyfuss.

[4] Humanetics Innovative Solutions, 47460 Galleon Drive, Plymouth, MI. www.humaneticsatd.com.

fabric, they also serve as a soft barrier that does not become a separate hazard or source of injury in the event of a vehicle rollover or impact.

The term "permanent" as used in this section "means requiring tools for removal, but capable of being serviced or subject to fastening." Annex A11.3.2.3. In addition, during testing "[n]o permanent barrier or fastener damage shall be observed as a result of [the] load application." Section 11.3.2.3(A). This allows for innovation in providing a permanent barrier and avoids unduly design-restrictive requirements. Because virtually any barrier may be susceptible to intentional user bypass or removal through the use of various tools, the potential for bypass or removal of a barrier that otherwise meets the definition of "permanent," as used in this section, is not viewed as an appropriate factor for developing standards criteria.

Ultimately, the use of a net or some other form of barrier is the result of the manufacturer's design and engineering judgment.

CPSC staff has presented no data suggesting that nets (as compared to any other form of barrier) are removed with a frequency that creates an unreasonable risk on injury. Moreover, CPSC staff has presented no data indicating that nets on vehicles currently in the market are not effective. ROHVA therefore concludes that allowing nets to be used as one form of an appropriate Zone 1 barrier provides manufacturers with appropriate design flexibility and allows net and net fastener designs to continue to evolve.

**Comment** – *Zone 2 – Shoulder/Hip*

ROHVA has proposed requirements for the shoulder/hip area (Zone 2) that can be met by a construction-based passive barrier that meets specific design criteria or by a performance-based vehicle tilt test that meets occupant excursion criteria. The construction-based method defines a barrier zone and requires that the barrier withstand a horizontal outward force of 163 lbf. CPSC staff's experience with vehicle rollover simulation tests shows that a 172 lbm occupant ($50^{th}$ percentile male Hybrid III dummy) in a rollover event will impact the shoulder guard with an impact force that is likely to exceed the 163 lbf proposed force. CPSC staff recommends that the ROHVA members perform vehicle rollover simulation tests to determine the minimum force that a shoulder barrier needs to withstand during a rollover event and also determine the effectiveness of the proposed barrier design in retaining the full range of occupants (from $5^{th}$ percentile females to $95^{th}$ percentile males) within the vehicle during a rollover event.

The performance-based method proposed by ROHVA uses a 172 lbm $50^{th}$ percentile Hybrid III dummy that is seat belted into the vehicle. The vehicle is then tilted 45 degrees along its roll axis, and the excursion of the dummy is measured. The dummy cannot extend more than 5 inches outside the vehicle's width to pass the requirement. CPSC staff is concerned that a 45-degree tilt will not simulate accurately the dynamics of a rollover event. The lateral acceleration in a 90-degree, quarter-turn rollover event will most likely exceed the 0.7g that is simulated by the 45-degree tilt angle. Staff also believes that the performance requirements should relate to the hazard patterns identified with ROV-related incidents; namely, full and partial excursion of an occupant's torso during a 90-degree, quarter-turn rollover of the vehicle in a turn. CPSC staff recommends that the ROHVA members perform vehicle rollover simulation tests to determine the effectiveness of the proposed tilt table tests in retaining the full range of occupants (from $5^{th}$ percentile females to $95^{th}$ percentile males) within the vehicle during a rollover event.

**Response**: ROHVA believes that both the construction-based permanent barrier standard and the performance-based standard for Zone 2 provides appropriate and adequate protection to prevent extrusion of an occupant's torso in the event of a vehicle rollover.

Construction-Based Method

The ROHVA TAP is comprised of engineers, vehicle designers, and other individuals with collectively decades of experience in designing and testing vehicles, as well as developing vehicle design, configuration and performance standards. As a standards developer, ROHVA is not required to present studies, tests, or research used in establishing standard requirements. Even so, the force specification of 163 pounds in the construction-based barrier (illustrated below) represents approximately 75% of the weight of a 95$^{th}$-percentile male at 215 pounds.

Although CPSC staff states that its "experience with vehicle rollover simulation tests shows that a 172 lb occupant (50$^{th}$ percentile male Hybrid III dummy) in a rollover event will impact the shoulder guard with an impact force that is likely to exceed the 163 lbf proposed force," it fails to describe that experience, provide any data from rollover simulation tests, or describe the methodology used for those tests. In its several meetings with CPSC staff regarding ROV standards development, ROHVA has repeatedly requested information and data regarding CPSC's testing. ROHVA is unable to evaluate and be responsive to some of CPSC's comments without access to CPSC testing information and data.

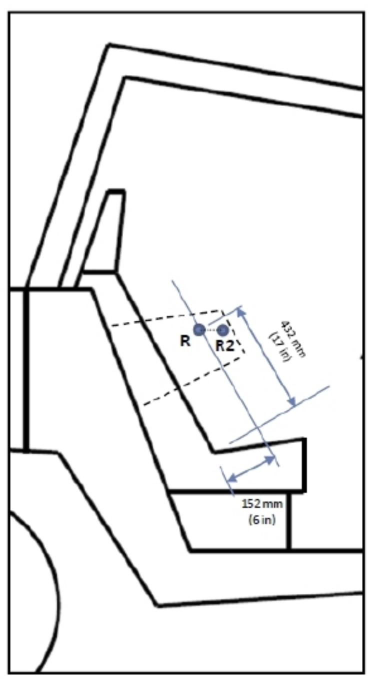


Figure 7.
Zone 2 – Shoulder/Hip. Example barrier and reference point shown.
Note: Not shown to scale

ROHVA agrees with CPSC staff's comment that an unbelted occupant in a rollover event could impact the Zone 2 restraint with an impact force in excess of 163 lbf. But this comment fails to recognize that all components of an occupant retention system ("ORS") work together to decrease the likelihood of occupant extrusion in the event of a vehicle rollover. The Zone 2 barrier will be one of several ORS devices or features absorbing occupant loading in a rollover event. An occupant's usage of the ROHVA-standard-required three-point seat belts is therefore a critical component of the complete occupant retention system.  Any suggestion that the ORS should prevent an unbelted occupant from vehicle extrusion in the event of a rollover fails to recognize the basic nature and function of the ORS.

Performance-Based Method

The purpose of the performance-based Zone 2 alternative method is to provide ROV manufacturers with design flexibility to develop alternative methods of providing protection against torso extrusion in the event of a vehicle rollover.  As a point of clarification, the CPSC staff comment statement that “[t]he dummy cannot extend more than 5 inches outside of the vehicle’s width to pass the requirement” is incorrect.  In fact, the draft standard states that “[t]he *torso* of the test dummy shall not extend more than 127 mm (5 in) outside of vehicle width.” (emphasis added.)  ROHVA believes this performance-based standard, in conjunction with the other mandated ORS features, provides reasonable and adequate protection against the extrusion of an occupant’s torso in the event of a vehicle rollover.

The 45-degree tilt angle was selected to simulate the tipping or rollover point of a vehicle without requiring contact with the ground.  This also allows for repeatability.

Although CPSC staff expresses its concern that the 45-degree tilt used for the performance-based standard will not accurately simulate the dynamics or hazard patterns (full and partial extrusion of an occupant’s torso) of a ROV rollover, it fails to support this concern with any data, testing, or analysis.  In its several meetings with CPSC staff regarding ROV standards development, ROHVA has repeatedly requested information and data regarding CPSC’s testing.  ROHVA is unable to evaluate and be responsive to some of CPSC’s comments without access to CPSC testing information and data.

Based on the engineering judgment of its members and its review of ROV incident data provided by the CPSC, ROHVA concludes that the vast majority of hazard patterns associated with ROV rollovers would be eliminated through proper seat belt use alone.  The performance-based alternative occupant retention standard for Zone 2 provides ROV occupants with additional retention as part of the ORS.

Rollover Simulation Tests

ROHVA appreciates the comments of the CPSC staff regarding rollover simulation tests.  Due to the versatility of the ROV (recreational and utility off-highway use) the wide range of vehicle designs (2, 3, 4, and 6-seat configurations), the different slopes encountered in off-highway conditions, the diverse operating environment (trails, fields, dirt, mud, sand, and snow), and different cargo capacities, it is extremely difficult to determine a typical ROV rollover event for extensive research such as rollover testing.

Since CPSC staff states that it already has experience with these tests, ROHVA again reiterates its request that CPSC to share this data to facilitate the standard development process.  In its ongoing efforts to prospectively revise and maintain the ROHVA standard, ROHVA anticipates reopening the standard after publication to review this issue.

**Comment** – *Zone 3 – Arm/Hand*

ROHVA has proposed requirements for the arm/hand area (Zone 3) that can be met by a construction-based permanent barrier that meets specific design criteria or by a performance-based vehicle tilt test that meets occupant arm/hand excursion criteria.  The construction-based method defines a barrier zone and requires that the barrier withstand a horizontal outward force of 50 lbf and have no opening that permits passage of a 3-inch diameter cylinder. ROHVA has not presented the studies, tests, or research that it used in defining the barrier's dimensions or effectiveness. CPSC staff would like to review the research that was used in developing the arm/hand Zone 3 requirements. In addition, the use of a net is specified as an acceptable permanent barrier for Zone 3; CPSC staff does not believe that a net is a suitable barrier because it can be cut or removed by the user.

The performance-based method proposed by ROHVA uses a 50th percentile male Hybrid III dummy that is seat-belted into the vehicle. The dummy's hands are affixed to appropriate handholds, and the joints are set to simulate the occupant's grip. The vehicle is then tilted to 45 degrees along its rolling axis, and the excursion of the dummy's hand and arm is measured. The dummy's hand and arm cannot extend more than 7 inches outside the vehicle's width to pass the requirement. CPSC staff is concerned that a 45-degree tilt will not simulate accurately the dynamics of a rollover event and that the dummy's hand grip force is not specified with a rationally supported value. Staff also is concerned that a quasi-static test with hand grip forces set at an unrealistically high level will not test accurately the performance of the vehicle in limiting the excursion of an occupant's arm/hand.

**Response**: ROHVA believes that both the construction-based permanent barrier standard and the performance-based standard for Zone 3 provide appropriate and adequate protection to prevent extrusion of an occupant's arms or hands in the event of a vehicle rollover.

Construction-Based Method

The ROHVA TAP is comprised of engineers, vehicle designers, and other individuals with collectively decades of experience in designing and testing vehicles, as well as developing vehicle design, configuration and performance standards. As a standards developer, ROHVA is not required to present studies, tests, or research used in establishing standard requirements. Even so, as indicated in Annex A, the barrier dimensions for Zone 3 (shown in Figure 8) are based on anthropometric data and vehicle operation and configuration factors. The shaded portion in Figure 8 shows the area or "zone" adjacent to the occupant compartment where the potential for arm or hand excursion is to be addressed. The shaded portion does not indicate or represent a specific structure or barrier design, allowing for design innovation and flexibility. Point S in Figure 8 represents the top of a representative occupant's shoulder. The occupant's upper arm is approximately 0.5 meters long from shoulder pivot to elbow, which exceeds the upper arm length of a 95th-percentile male. The line representing the upper edge of the barrier dimension slopes downward in order both to allow visibility for shorter operators and occupants and to provide an unobstructed view to the forward corners of the vehicle. Additionally, the barrier should not invite use as an arm rest, which might contribute to arm/hand excursion in the event the occupant decides to place an arm/hand outside the zone of protection during a rollover. The forward edge of the barrier is perpendicular downward to the seat. The standard allows for no more than 178 mm (7 in) excursion outside of the vehicle within the barrier zone. Together, these zone dimensions reflect an appropriate balance for retention/restraint of occupant arms and hands and vehicle use. Restraining an occupant's upper arm significantly restrains the forearm and hand. Sufficient volume of space and range of occupant motion is needed for proper vehicle operation, use of handholds (which are specified elsewhere in the standard (Section 4.6)) and provide an additional and complementary means of limiting arm and hand excursion) and other motions consistent with the rider-interactive nature of the vehicles, such as bracing or counter-posturing (see concluding paragraph below). These zone dimensions were also developed in conjunction with the additional barriers, restraints and protective measures required for the vehicle (e.g., handholds, Zones 1-2, seatbelts).

The 76-mm diameter probe test was selected based on its successful use, over more than twenty years, by the ATV industry in the ANSI/SVIA standard to limit the size of open areas in the foot well zone of ATVs to address foot environment and excursion, as developed as part of the ATV voluntary standards. Use of the 76-mm probe is appropriate in the analogous context of limiting the size of openings for arm or hand excursion in the specified ROV zone here.

Lastly, "permanent" as used in this section "means requiring tools for removal, but capable of being serviced or subject to fastening." Annex A11.3.2.3. In addition, during testing "[n]o permanent barrier or fastener damage shall be observed as a result of [the] load application." Section 11.3.2.3(A). This allows for innovation in providing a permanent barrier and avoids unduly design-restrictive requirements. Because virtually any barrier may be susceptible to intentional user bypass or removal through the use of various tools, the potential for bypass or removal of a barrier that otherwise meets the definition of "permanent," as used in this section, is not viewed as an appropriate factor for developing standards criteria.

Performance-Based Method

With respect to the performance-based method for Zone 3, the 45-degree tilt angle was selected to simulate the tipping or rollover point of a vehicle without requiring contact with the ground. This also allows for repeatability.

Section 11.3.2.3(B)(5) further specifies that, during performance-based testing, the test dummy's hands "shall be affixed to the appropriate handholds, and the test dummy's joints set, to simulate the occupant's grip appropriate to the handholds in use." Studies indicate that vehicle occupants who are monitoring, observing and experiencing the forces associated with the vehicle's interaction with the terrain during operation utilize active muscular contraction to counter-posture in response to vehicle dynamics, that the forces exerted through the hands and feet during riding are similar to or less than simple physical tasks, and that forces exerted by seat-belted occupants during a 90-degree overturn, in particular, are generally modest and account for only a small percentage of the occupant's total body weight. *See* Michael Carhart, Ph.D. and William Newberry, M.S. – Biomechanical Analysis of Passive and Active Occupant Responses During Rhino Riding and 90-degree Tip-over Events. *Compare* Strength Data for Design Safety – Phase 1 (Government Consumer Safety Research) (United Kingdom, Department of Trade & Industry) (indicating average hand and grip strengths among males and females).

In addition, handholds may be provided in various locations inside a vehicle, including above, in front of, behind, and beside occupants. Some of these handholds may allow for cross-bracing (i.e., an arm across abdomen for increased torso support/retention of occupant). The steering wheel is also a handhold. Different handhold designs and positions may affect the applicable level of grip force. The standard thus specifies that the test dummy's grip must be affixed (e.g., by taping or other means), and its joints set, to simulate an occupant's grip appropriate to the handholds *in use*. As further indicated in Annex A, these setting requirements are to be applied during testing to simulate occupants in the early stages of a rollover. This level of specificity in the standard is appropriate given the modest degree of grip force generally required and the potential variances in handhold designs and placements within different vehicles.

**Comment** – *Zone 4 – Head/Neck*

ROHVA has proposed requirements for the head/neck area (Zone 4) that can be met by recommending that occupants wear seat belts and helmets. Beyond that, no guidance is provided on the content, format, or location of the recommendations. CPSC staff has identified occupant head crush by the vehicle (in many cases, the vehicle's rollover protective structure) as a significant hazard pattern associated with ROV-related incidents. While the benefits of a helmet are not disputed for head impact scenarios, the benefit of a helmet in situations where the occupant's head is crushed by the vehicle is questionable. CPSC staff recommends that the ROHVA members perform vehicle rollover simulation tests to develop a performance-based occupant protection performance test that limits the head excursion of occupants (from $5^{th}$ percentile females to $95^{th}$ percentile males) within the vehicle during a rollover event.

**Response**: The proposed standard specifies that the manufacturer's recommendations that occupants wear seat belts and helmets be contained in the Owner's Manual (Section 4.14.2) and the General Warning Label (Section 4.16.4.5). Figure 15 specifies the format and content of the seat belt and helmet recommendations on the General Warning Label. Beyond these specifications, manufacturers maintain discretion to convey the recommendations using content, format and locations most appropriate for the vehicle.

The benefit of a helmet to prevent or mitigate crushing injuries is clear. A helmet meeting a suitable standard substantially reduces injury risk by limiting the pressure applied to the skull (by the action of the liner), up to deflection where the liner is bottomed and by providing an alternate load path (i.e., a "bridge") around the skull which diverts a portion of the load away from the skull. In laboratory tests of a sample of six typical FMVSS 218 motorcycle helmets, for example, this force bridge can be substantial, e.g., increasing the load at which the skull may be fractured by a 1 square inch mandrel, from 730 lbs (Nahum et al, 1968; Schneider and Nahum, 1972) to approximately 1300-1330 lbs, i.e., for crush loading, a helmeted head has nearly double the force tolerance of an un-helmeted head.

In conclusion, ROHVA is committed to continuing to study occupant retention standards in connection with continued maintenance on the ANSI/ROHVA standard and anticipates reopening the standard after publication.

Thank you for taking the time to participate in the canvass ballot. A revised standard will be re-circulated in the near future that includes all accepted comments.

Regards,

Thomas S. Yager
Vice President

18 April 2011

DRI Replies to CPSC Letter Regarding December 2010 ROHVA Standard Canvass

***<u>CPSC comments related to Lateral Stability</u>***

1. ***p1: "The added test is a fixed steering dynamic test, similar to the one included in SAE J266, which sets the steering angle to produce a constant turn radius of 25 feet, based on the Ackerman Angle for that radius."***

As a point of clarification, SAE J266 describes five different test methods. With regard to test execution, the ROHVA proposed method has some similarities with one of the five methods described in SAE J266. However, that SAE J266 method does not mention Ackermann angle. Moreover, the ROHVA method does not "set a steering angle to produce a constant turn radius." Any non-zero understeer gradient, which virtually all vehicles have to some degree, will result in a variation in turn radius, as speed is gradually increased. Instead, the steering wheel angle is fixed at a value that corresponds to a theoretical (no side-slip) Ackermann front wheel steer angle theoretically corresponding to a 25 ft turn radius.

2. ***p1: "The test is conducted on an asphalt surface by driving the vehicle at the set turn radius, while slowly increasing the speed."***

Again, as a point of clarification, the ROHVA procedure does not involve "driving the vehicle at the set turn radius," but rather driving it at a fixed steering angle." As noted in Reply 1, in general, the procedure generally results in a variation in turn radius, as speed is gradually increased.

3. ***p2: "However, staff does not agree that the specific test method, or the acceptance limits proposed, will be adequate to identify and discriminate problematic vehicle behavior."***

It is unclear what CPSC staff means by "discriminate problematic vehicle behavior." If this means that there are specific lateral stability issues that CPSC staff believes to be "problematic," these issues and any supporting data should be identified so that they can be properly considered.

The ROHVA method will require all future model ROV production to meet robust two-wheel lift stability limits, as suggested by CPSC staff. It is unclear what else one has to do to satisfy any valid desire to "discriminate problematic vehicle behavior."

4. ***p2: "ROHVA has proposed a very high steering angle (turn radius of 25 feet) for the fixed steering test."***

The basis for characterizing the steer angle for a 25 ft turn radius as "a very high steering angle" is unclear. An earlier version of the ROHVA procedure used a larger steering angle (i.e., turn radius of 20 ft) and in response to CPSC comments it was reduced. Currently, it is believed that maneuvers leading to two-wheel lift can and do occur at such steer angles, speeds and turn radii. If CPSC staff is suggesting that even smaller steer angles should be used, this implies the use of even higher speeds and larger turn radii, and there appears to be no basis in the IDI accident data for such higher speeds.

5. ***p2: "At a very high steering angle, it is possible that a test vehicle will become speed limited before the characteristic of interest is observed."***

This is possible, but it depends on the design of the specific vehicle. Only one of the seven vehicles tested by DRI (i.e., one with an open differential) had such a characteristic. This limit occurs for the dynamic stability test because the open differential tends to limit traction and maximum speed in turns and reduces the chances that the vehicle will generate those lateral forces necessary for a rollover.

6. ***p2: "The acceptance limits for the test are set such that a test vehicle that reaches a speed limitation before achieving the minimum acceptable lateral acceleration would be accepted.***

First of all, it is important to keep in mind that in the ROHVA revised draft standard, all vehicles must also pass the operator and passenger Tilt Table performance requirement of 30 degrees which corresponds to a ratio of 0.577 between those forces that are perpendicular to and those forces that are parallel to the tilt table surface. This is very close to the ratio existing between the respective parallel and perpendicular forces in a dynamic stability test at 0.6g. Therefore, all vehicles must have this basic level of geometric lateral stability, which strongly affects the vehicles' dynamic lateral stability, regardless of the details of the dynamic test procedure.

Second, if such a vehicle did reach a speed limitation in the dynamic lateral stability test which prevents it from achieving the otherwise minimum acceptable dynamic lateral acceleration, that would seem to be an appropriate dynamic two-wheel lift resistance feature that ROV designers and manufacturers should be permitted to consider. By acknowledging other limit conditions that prevent dynamic two-wheel lift, the standard encourages future technological innovation that could further reduce the risk of two wheel lift and subsequent vehicle rollovers."

7. ***p2: "In addition, any vehicle that experiences oversteer could reach its speed limitations early in the test, which would result in a spiraling-in spin prior to producing data on the lateral stability threshold."***

In the testing conducted by DRI there were no cases where a vehicle reached a spiral-in limit before exceeding the lateral acceleration criterion of 0.6g. All of the spiral-in limit cases exceeded 0.6g lateral acceleration. Moreover, all of the "spiral-in" limit cases were just that, i.e., they reached a stable turning limit where the maximum thrust that can be provided by the drivetrain equals the large amount of tire drag that occurs at large side slip angles, and this was done on a high friction coefficient surface.

CPSC staff has raised a hypothetical situation which has not been observed. To state that "any vehicle that experiences oversteer…" could do this is to infer a behavior that has not been observed and might not exist.

CPSC staff seems to have equated the terms "oversteer" and "spiral-in limit" when they are not the same thing at all. Oversteering vehicles can reach several types of limit, including a two-wheel lift limit below 0.6g lateral acceleration, a two-wheel lift limit above 0.6g lateral acceleration, and a stable, no two-wheel lift, spiral-in speed limit where the maximum thrust that can be provided by the drivetrain equals the large amount of tire drag that occurs at large side slip angles. "Spiral-in limit" is one of several possible limits of oversteering vehicles, and should not be confused as meaning the same thing as "oversteer."

8. ***p2: "Therefore, the dynamic test proposed could accept a vehicle that has the most undesirable combination of characteristics—low lateral stability threshold and oversteer."***

As noted in Reply7, CPSC staff seems to have mistakenly equated the terms "oversteer" and "spiral-in limit," when they are not the same thing at all. Oversteering vehicles can reach several types of limit, including a two-wheel lift limit below 0.6g lateral acceleration, a two-wheel lift limit above 0.6g lateral acceleration, and a stable, no two-wheel lift, spiral-in speed limit where the maximum thrust that can be provided by the drivetrain equals the large amount of tire drag that occurs at large side slip angles. "Spiral-in limit" is one of several possible limits of oversteer vehicles, and should not be confused as meaning the same thing as "oversteer."

Moreover, there is a difference between linear range understeer or oversteer as measured in a SAE J266 procedure and limit handling behavior. It is unclear which of these conditions CPSC staff is referring to. A vehicle with linear range understeer may have limit oversteer.

No objective basis has been provided for CPSC staff's statement that this "combination of characteristics" is "the most undesirable one." This preference seems to be one of subjective opinion without any basis in fact or data. ROHVA is aware of no data indicating that vehicles with an oversteer characteristic have greater or lesser tendency to reach a two-wheel lift limit, and the DRI test data indicate that both understeer vehicles and oversteer vehicles can reach a two-wheel lift limit, either below or above 0.6g.

The DRI data also indicate that in some cases, a vehicle with an understeer characteristic can reach a tip limit at a lower lateral acceleration than does a vehicle with an oversteer characteristic; and vice versa. There is no relation between understeer/oversteer characteristic and the tip-up limit in terms of lateral acceleration. See Figure 1.

***9. p2: "CPSC staff does not agree with a test method that promotes the design of vehicles with oversteer tendencies."***

The test procedure and associated criteria proposed do not promote the design of vehicles with either oversteer or understeer tendencies. The data in Figure 1 indicate that the two-wheel lift limit is independent of the understeer/oversteer characteristics.

The phenomenon of interest to CPSC and ROHVA is vehicle rollover, and the ROHVA dynamic test measures resistance to that. Fig 1 indicates that rollover resistance is independent of understeer/oversteer characteristic.

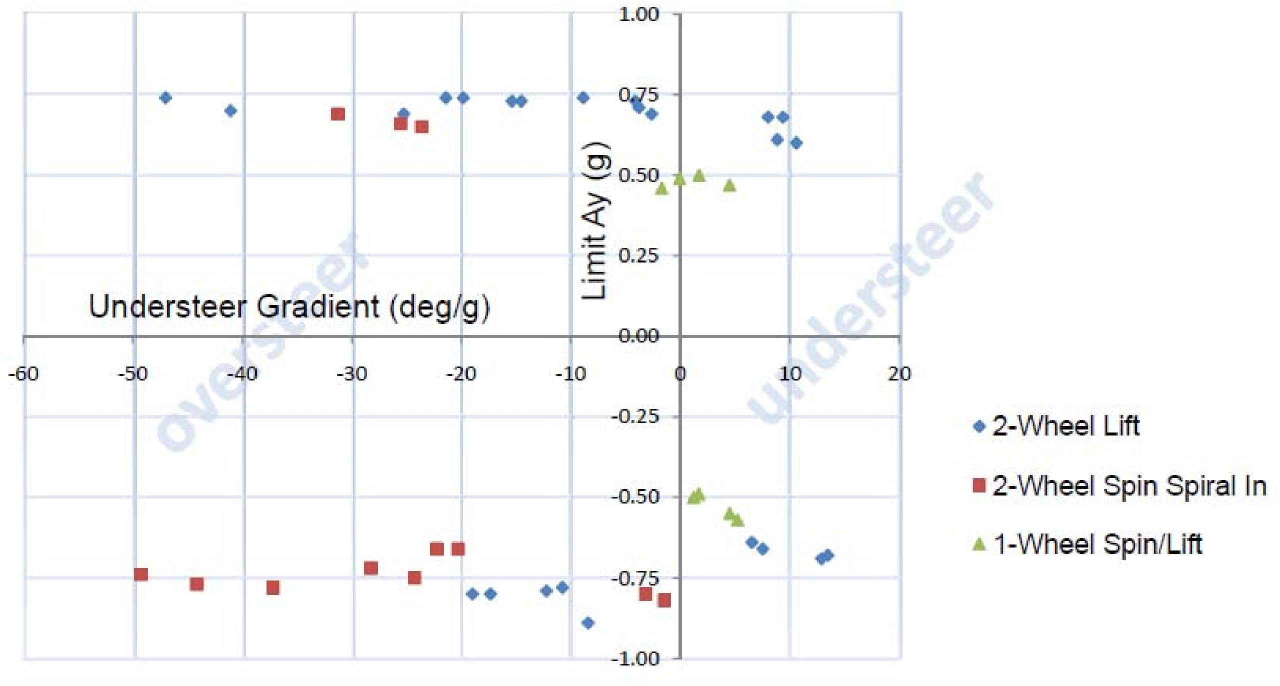


Figure 1. Plot of Limit Lateral Acceleration Values and Understeer Gradient from ROHVA Development Tests

***10. p2: "Further, CPSC staff believes that the proposed minimum lateral stability threshold of 0.6 g is too low, based on staff's experience with dynamic lateral stability threshold testing of vehicles."***

It is unclear what exactly "staff's experience" means. DRI is unable to evaluate and respond to this comment without access to relevant information and data from CPSC's dynamic lateral stability threshold testing.

The proposed minimum lateral stability limit of 0.6g exceeds the average measured tire/soil friction value across approximately 20 public ride sites across the US; and in addition, it has been found that turning maneuvers by typical riders do not generally exceed values in the region of 0.3 g; and that typical riders experience extreme discomfort with lateral accelerations well before reaching the 0.6g criterion.

Using a specially developed measurement device DRI measured tire/soil side force coefficient values for approximately 20 ride areas across the United States. The tire/soil side force coefficient is derived from the ratio of vertical force applied to a rolling tire divided by the side force it can generate under lateral slip, and is representative of the maximum lateral acceleration (in g units) achievable on a given soil. The measured values for eighteen out of twenty soils were between 0.45 and 0.65; the mean value was 0.55.

In addition, a previous study[1] showed that turning maneuvers by typical riders do not generally exceed values in the region of 0.3 g and typical riders experience extreme discomfort with lateral accelerations well before reaching the 0.6g criterion

Based on these data, 0.6 g can be considered to be representative of upper levels of tire/soil side force coefficients likely to be encountered in off–highway operation; and in addition it offers a substantial margin for the typical operator and intended use, as measured in tests with typical riders. It is generally twice the level that typical riders use in normal operation.

***11. p2: "CPSC staff recommends a J-turn type test that directly measures the minimum lateral acceleration to achieve vehicle rollover."***

CPSC does not identify and DRI is unaware of any "J-turn type test that directly measures the minimum lateral acceleration to achieve vehicle rollover." In contrast, the test procedure developed by ROHVA directly measures the lateral acceleration that causes two-wheel lift with a simple, robust, and repeatable method. ROVs are equipped with non-automotive drivelines and tires, which enhance off-highway performance but make it difficult to execute automotive style J-turn tests on asphalt in a repeatable and robust manner. The test procedure developed by ROHVA minimizes the negative effects of testing these vehicles on asphalt, but still directly measures the lateral acceleration that initiates two-wheel lift.

The test procedure developed by ROHVA has several key attributes, one of which is a measured high level of repeatability. In support of the development of this procedure, DRI tested six vehicles in two loading conditions each. Tests were conducted in both directions, and five repeats tests were made for each configuration. Two different approaches were taken to determining the steer angle. These various combinations, with the addition of 8 research conditions, resulted in 56 groups of 5 tests covering all the test conditions. A high level of repeatability was obtained; the average coefficient of variation[2] for these groups of data was 0.020 (i.e., 2.0%), with a minimum of 0.004 (i.e., 0.4%) and a maximum of 0.066 (i.e., 6.6%).

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1 Franz, J.P et al; Comparing Driver Descriptions of Turning to Measures of Off-Road Vehicle Performance; Implications for Driving Instruction and Accident Investigations; Proceedings of the XX Annual International Occupational Ergonomics and Safety Conference, Chicago Illinois, June 2008

2 The coefficient of variation is defined as the ratio of the standard deviation to the mean. In the context of this discussion it represents the standard deviation of results for each set of repeat runs divided by the mean of the results for that set of repeat runs.

The ROHVA test procedure is simple to conduct and is not sensitive to operator skill, technique or timing.

Additionally, the test surface on which the ROHVA test is performed has a surface friction capability that is well in excess of the typical off-highway riding surfaces, and well in excess of the proposed lateral acceleration criterion of 0.6 g. This means that the test results will not be influenced by small changes in test surface friction capability and results should have a high level of reproducibility across different test facilities.

For these reasons, it is expected that the ROHVA test procedure would be highly reproducible, i.e., different test labs or test operators would get very similar results for a given vehicle and configuration (outrigger, ballast placement, operator mass, etc.). Repeatability and reproducibility are key requirements for any objective test procedure, especially where the results may be subject to close scrutiny.

DRI would be very interested in reviewing any data generated by CPSC staff and/or contractors to evaluate the repeatability obtained with respect to the recommended J-turn type test.

***12. p2: "CPSC staff's experience with this type of test indicates that a relevant value for minimum lateral acceleration at two-wheel lift can be defined."***

It is unclear what the basis is of this statement by CPSC staff. If it is based on testing by CPSC or its contractor, DRI is unable to evaluate and respond to this comment without access to relevant information and data regarding this testing.

ROHVA has provided a robust rationale for the use of 0.6g lateral acceleration as the criterion. As stated in Reply 10, the 0.6g limit exceeds the average measured tire/soil friction value across approximately 20 public ride sites across the US; and in addition, it has been found that turning maneuvers by typical riders do not generally exceed values in the region of 0.3 g; and that typical riders experience extreme discomfort with lateral accelerations well before reaching the 0.6g criterion.

If what is meant by "CPSC staff's experience…indicates…" is purely subjective, then such a subjective opinion does not provide a sound basis for a standard.

***<u>CPSC comments related to Vehicle Handling</u>***

***13. p2: "CPSC staff continues to believe that steady state oversteer is an undesirable and unstable steering control mode for ROVs."***

The basis for CPSC staff "continu[ing] to believe" this is unclear, as there are no known test data or accident data that would support such a conclusion. As noted in Reply 9, the data in Figure 1 indicate that the two-wheel lift limit is independent of the understeer/oversteer characteristics. As seen there, either understeering vehicle or oversteering vehicles can pass or fail a two-wheel lift limit criterion of 0.6g lateral acceleration.

There are no known test data indicating that an oversteer characteristic in itself has ever resulted in an actual "loss of control," or in a two-wheel lift for any vehicle. Again, the data in Figure 1 indicate that the two-wheel lift limit is independent of the understeer/oversteer characteristics.

In addition, it is unclear what is meant by "unstable" in this comment. There are many definitions of stability used for various purposes.  For example SAE J670 defines asymptotic stability, neutral stability, divergent instability and oscillatory instability but unfortunately does not provide a definition of "stability."  With respect to vehicle dynamics there are a number of tests and analyses that can demonstrate various types of stability or instability by definition; it is not a judgment or subjective assessment. CPSC's Figure 2 data indicate that the oversteer vehicle is by definition, "stable" up to the maximum lateral accelerations tested (e.g., 0.55 g CW and 0.65 g CCW), since the SAE J266 test is conducted below any stability limit. In addition, there is no evidence that these tests resulted in any type of yaw instability whatsoever.

In addition it is not clear what the bases are for judging oversteer to be "undesirable." There is no evidence that drivers are aware of whether their vehicle understeers or oversteers. This is because, by definition, understeer/oversteer only pertains to whether a vehicle's turn radius increases or decreases as its speed increases, while the steering is held fixed; or whether the required steer angle increases or decreases as its speed increases, on a fixed turn radius. These conditions are unlikely to occur during off-highway operation.  Understeer/oversteer describes the vehicle's turning response to speed changes; when speed is changed, e.g., by changing throttle or braking or accelerating in a turn, the understeer/oversteer characteristic of virtually all vehicles tends to change, and does not remain constant. There are no known experimental, behavioral or other bases or studies which indicate that drivers are aware of these effects, that one value of understeering gradient is more or less "predictable" to them than another, or that they prefer any particular understeer/oversteer characteristic.  What drivers do sense in a sublimit turn is that turning the steering wheel in the direction of the turn increases path curvature, steering out of the turn decreases path curvature, and path-following is accomplished easily. There is no experimental or any other data to suggest that drivers do not adapt immediately to small changes in steering sensitivity with speed or lateral acceleration that result from understeer or oversteer. Further, there is no data to suggest that a typical driver does not unconsciously adapt immediately when transitioning from, for example, an unfamiliar pickup truck to an unfamiliar sports car, which can have quite different steering sensitivities and understeer gradients.

As noted, by definition understeer/oversteer is a sub-limit and steady state characteristic; it does not necessarily correlate to -- and is often confused with -- the limit response of the vehicle which is defined as being one of three possibilities:[3]

**Plow** - The limit condition for vehicle directional response wherein the front *tires* have reached their cornering limit while the rear *tires* have not reached their limit.

**Spin** - The limit condition for vehicle directional response wherein the rear *tires* have reached their cornering limit while the front *tires* have not reached their limit.

**Drift** - The limit condition for vehicle directional response wherein the front and rear *tires* have both reached their cornering limit.

In casual use, the term "oversteer" is often used to describe a behavior that is more appropriately described as "Spin". In this regard it is important to note that a vehicle having steady-state understeer characteristics can still be induced to "spin." This is common with rear wheel drive vehicles under some operating conditions. As throttle is applied, drive torque is developed at the rear axle which is reacted at the tire/soil interface as longitudinal force. This longitudinal force generated by the tires reduces the lateral force capability of the tires. If sufficient throttle/torque is applied while the vehicle is turning the rear tires can reach their cornering limit as a result of the reduction in cornering capability brought about by the generation of longitudinal force. Since the front tires are not providing any drive force their lateral capability is unaffected. If the rear tires reach their cornering limit while the front tires have not, the vehicle is in a "spin" condition. Occurrence of a "spin" condition does not necessarily mean that the vehicle will "spin out" and does not represent a loss of control. In off-highway operation in particular it can be a useful mobility tool by enabling tighter turns to be made at low speeds, as may be demanded by the terrain.

Another point relates to vehicle sideslip, which is often confused with but is in fact unrelated to oversteer/understeer. Under fixed steer conditions, when speed is low, vehicles with front steering tend to exhibit Ackerman steering behavior and the rear wheels track inside of the front wheels. At the vehicle center of gravity, the vehicle's velocity vector points inside of the longitudinal centerline. As speed increases the rear wheels must develop a slip angle in order to produce lateral force and, as a result, move outward from their initial position with respect to the center of the circle. The angle

[3] Anon., Vehicle Dynamics Terminology, Society of Automotive Engineers, Surface Vehicle Recommended Practice J670, January 2008.

between the vehicle's velocity vector and the longitudinal centerline decreases. This angle is defined as the vehicle sideslip angle. As speed increases the vehicle sideslip angle eventually reaches zero, and for further speed increase the magnitude of the sideslip angle increases. This is the case regardless of whether the vehicle is understeering or oversteering. Vehicle sideslip angle is a function of the front to rear weight distribution, turn radius, speed and rear tire cornering stiffness and is not dependent on understeer/oversteer properties[4].

***14. p2: "Therefore, staff believes that a test to measure steering gradient and an acceptance criterion for handling characteristics is necessary for ROVs."***

There are a number of concerns with a test to measure understeer gradient and related acceptance criteria. Briefly:

- There is no basis for the belief that the test and criteria are needed
- There is no basis for selecting an appropriate procedure and conditions
- There is no basis for selecting appropriate criteria

CPSC has not made available any data to support the conclusion that a test to measure steering gradient and an acceptance criterion for handling characteristics is necessary for ROVs. There are no known accident data for on-highway or off-highway vehicles that support a causal relationship between accidents and steering characteristics. NHTSA has investigated this on various occasions during the last 30 or more years, but has been unable to find any such relationship for on-highway vehicles. At this time, there is no sound, sufficiently detailed and extensive, uniformly collected accident database indicating the real mechanisms of actual ROV accidents that could be used to define any cause-effect relationship between accidents and steer properties in any statistically appropriate way. Available reports on ROV accidents are too few in number, and lack sufficient detail and uniformity to be used for that purpose. Furthermore, and as described above, there is no evidence that, in operation, drivers are aware of the understeer/oversteer properties of a vehicle, have a preference in this regard, or find a particular property more or less predictable. Overall, there appears to be no basis, other than assumption, for the belief that a test to measure understeering gradient and an acceptance criterion for handling characteristics is necessary for ROVs. Indeed, DRI understands that in meetings with ROHVA, CPSC staff indicated they had no data that would suggest a correlation between oversteer/understeer and vehicle rollover.

[4] Gillespie, Thomas D. Fundamentals of Vehicle Dynamics, Society of Automotive Engineers, 1992.

A second area of concern involves the specification of any test procedure and conditions for the purpose of measuring the steering properties of vehicles whose intended use is off-highway. Specifically it would be inappropriate and technically misleading to extrapolate steering characteristic data measured on a paved surface to off-highway soils. It is incorrect to assume that a vehicle that has a particular steering characteristic on pavement has the same steering characteristic on any other surface. Measurements of understeer/oversteer made on pavement are simply not applicable to and are not valid for non-pavement surfaces.

Especially for off-highway vehicles, the amount of drive torque required to maintain a steady speed varies substantially depending on the soil, terrain and vegetation conditions (e.g., mud, loose sand, hard clay, tall grass, etc.). The application of drive torque to an axle is reacted by the tires on that axle in the form of longitudinal force between the tire and surface. This reduces the ability of the tires on the drive axle to develop lateral force which in turn can substantially alter the amount of understeer or oversteer of a given vehicle.

ROVs are expressly intended to be operated in off-highway conditions and are not intended to be operated on pavement, and their understeer/oversteer characteristics can vary substantially depending on soil and other operating conditions. The relationship between tire lateral force and slip angle is different for pavement than for soil. For both cases there is generally a linear relationship between slip angle and lateral force over some range of slip angle, though the slope of these would not necessarily be the same for different surfaces or types of soil. On pavement, beyond this linear range, the slope of the curve decreases and can become zero or even negative as slip angle increases. This is not the case on many soils, where, as a result of soil deformation, the lateral force may continue to increase with increasing slip angle. These slip angle-lateral force characteristics are primary contributors to the understeer/oversteer properties of a vehicle. Since the properties are specific to the tire/soil interface in linear, sub-limit and limit cases, the understeer/oversteer behavior of a particular vehicle cannot be expected to be the same for all surfaces and it would thus be inappropriate to require understeer measurement to be made on a paved surface for a ROV that will be used off-highway.

ROHVA has proposed a dynamic tip-stability test procedure to be conducted on a paved surface. This is very different from the case of measuring understeer characteristics. The characteristics that the ROHVA test is intended to measure, dynamic roll resistance, is not dependent on the relative front-rear tire cornering force properties, except that the tire/surface must be capable of providing at least 0.6 g of lateral acceleration. If the tire/surface is capable of providing a higher value, the results of the ROHVA dynamic stability test would not be affected. DRI’s previous research has found that typical off-highway tire/soil side force coefficient values are in the region of 0.55. Since this is below the pass/fail criterion of the proposed ROHVA dynamic stability test, it would not be feasible to perform this test on a representative off-highway surface in order to verify whether two-wheel lift occurs below 0.6g. By contrast, typical paved surfaces can have tire/surface friction coefficient in the range of 0.80 – 0.95. This is not a liability for the ROHVA test, but represents an unrealistic operating condition for a steering characteristic measurement, particularly in light of the very different lateral force-slip angle relationships on soils.

A third area of concern is that the proposal to develop understeer/oversteer acceptance criteria deviates from more than 100 years of vehicle safety practice and standards for all categories of on-highway and off-highway vehicles, for which no such steering characteristic criterion or standard currently exists. It is unclear what the basis for these suggested criteria might be since there appears to be neither a statistical basis to relate steer properties to accident data nor any experimental evidence of a safety-related typical driver subjective preference for a particular steering characteristic.

Understeer tests such as SAE J266 focus on, by definition, sub-limit[5] understeer properties and it is difficult to imagine how steer properties in the sub-limit range of operation could be related to accident mechanisms.

In addition, typical drivers usually operate in the linear, sub-limit range of lateral acceleration in which a given steering wheel movement produces a proportional change in the vehicle's heading. Another way of describing the linear range is that the lateral acceleration versus steering wheel angle relationship remains approximately constant, i.e., the understeer gradient is essentially constant. This is true whether the vehicle has understeer or oversteer properties. As stated above, the Frantz et al study has shown that turning maneuvers by typical ROV drivers do not generally exceed values in the region of 0.3 g, which would be in the linear region of operations under most conditions (a possible rare exception might be extremely slippery surfaces such as ice).

At 0.6 g, ROHVA's criterion for its test, a vehicle would be expected to be well into the nonlinear region of operation, and at or above limit conditions for most riding area soils, which as described above have an average tire/soil friction coefficient of 0.55. The CPSC's suggestion that the lateral acceleration criterion should be even higher than this would be even further into the nonlinear region. It is unclear whether a suggested understeer test and criteria would address the linear, sub-limit or nonlinear, limit range of operation.

[5] SAE J266 states that the test is to be conducted up to the limit of stability or the limit of control, yet does not define these terms or how such limits are to be determined.

With respect to measurement of nonlinear understeer properties, NHTSA noted in the FMVSS 126 Final rule[6]: “Because there are no suitable tests of limit [emphasis added] understeer performance in existence, NHTSA undertook its own preliminary research efforts related to understeer. However, the complexity of such research would require several years of additional work before any conclusions could be reached regarding an ESC understeer performance test”, and further stated that: “NHTSA has carefully examined the existing vehicle dynamics literature including both the SAE and ISO standards. We have been unable to find any test designed to measure the nonlinear understeer gradient over the full nonlinear range of vehicle handling. A variety of theoretical difficulties make it unlikely that such test will ever be developed.”

***15. p2: “CPSC staff’s experience with vehicle dynamic testing has shown that altering the steering characteristics of a vehicle is not difficult. Staff successfully altered the steering characteristics of a vehicle that originally exhibited steady state oversteer, by performing minor modifications to the vehicle’s track width and suspension stiffness. The modifications to the vehicle consisted of adding spacers to the rear wheels and removing the rear sway bar (see Figure 1). The effectiveness of the modifications in improving the vehicle from oversteer (blue lines) to understeer (red and orange lines) is illustrated in the vehicle diagram shown in Figure 2.”***

The issue is not the difficulty, but the relevance. It is agreed that it is relatively simple to change the understeer/oversteer characteristics on paved surfaces. The main issues are, as has been described previously, the irrelevance of such on-highway steering characteristic measurements to off-highway operation on soils (i.e., a vehicle can easily be made by users (or manufacturers) to be understeering on pavement and oversteering on soils, and vice versa); and also the irrelevance of steering characteristics to the tip-up limit (i.e., the test data in Figure 1 indicate that the two-wheel lift limit is independent of the understeer/oversteer characteristics; and that either understeering vehicle or oversteering vehicles can pass or fail a two-wheel lift limit criterion of 0.6g lateral acceleration (or for that matter, any higher lateral acceleration level)).

The data in Figure 1 indicate that understeer/oversteer is not relevant to what occurs in rollover accidents, namely the vehicles’ two-wheel lift lateral acceleration is exceeded by the driver.

In addition, the use of the term “improving” in CPSC staff’s statement that “The effectiveness of the modifications in improving [emphasis added] the vehicle from oversteer…to understeer…” has no objective basis. Many experienced off-highway

[6] 49 CFR Parts 571 and 585, Federal Motor Vehicle Safety Standards; Electronic Stability Control Systems; Controls and Displays; Final rule; Docket No. NHTSA–200727662.

drivers prefer oversteer to understeer, and would not consider this change to be "improving." Most drivers would perceive no difference between sub-limit oversteer and sub-limit understeer. CPSC staff's characterizing such a change as "improving," is subjective and appears to be without foundation.