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Development of Test Procedures for Lower Interior Rear Seat Occupant Protection

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16. Abstract

NHTSA has conducted research with the objective to develop test procedures and assessment criteria to address injuries from impacts with lower interior surfaces in the rear seat area, focusing on head and face injuries due to contacts with seat backs, head restraints, and lower B-pillars. To evaluate the head injury potential of production vehicles as rear seat occupant heads contact lower B-pillars and seat backs, vehicles were tested using a methodology based on the upper interior test procedure of FMVSS No. 201. Seat back impact locations were chosen using engineering judgment that targeted various hard spots. Three targets were chosen on the seat back and one on the head restraint for each seat model. Tests series were completed on seat backs to refine the research test procedures, and it was found that there were elevated HIC results from contact to these surfaces and that countermeasures were feasible to implement into the seat back designs. It was also found that a loaded seat back condition, which is more realistic to a crash environment, produced more repeatable HIC36 responses than an unloaded seat back condition and was possible to incorporate into a free-motion impact test setup. For lower B-pillars, a procedure was developed for a new impact location lower on the B-pillar toward the rear of the vehicle. This new location was at the height of Plane 9 that is the lowest plane defined when establishing the B-pillar coordinate system in the upper interior test procedure of FMVSS No. 201. The plane is at the height of the lowest point on the bottom edge of the front window. Tests series were completed on lower B-pillars to refine the research test procedure, and it was found that there were elevated HIC results from contact to this location, that countermeasures were feasible to implement into the B-pillar trim, and that having the door closed and adjacent trim installed, which is more realistic to a crash environment, was possible to incorporate into a free-motion impact test setup.

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Executive Summary

The National Highway Traffic Safety Administration has conducted research with the objective to develop test procedures and assessment criteria to address injuries from impacts with lower interior surfaces in the rear seat area, focusing on head and face injuries due to contacts with seat backs, head restraints, and lower B-pillars. To evaluate the head injury potential of production vehicles as rear seat occupant heads contact lower B-pillars and seat backs, vehicles were tested using a methodology based on the upper interior test procedure of FMVSS No. 201 with both the free-motion headform (FMH) defined in FMVSS No. 201 (201HF) and a hemispherical adult-sized pedestrian free-motion headform (APHF). All FMH testing used the Head Injury Criterion (HIC) calculated from the resultant acceleration time histories and HIC36 (36-millisecond limit) as a measure of the potential for injury. FMVSS No. 201 defines a HIC transformation called HIC(d) as the injury criterion for the 201HF that was also calculated for applicable tests.

Seat back impact locations were chosen using engineering judgment that targeted various hard spots. Three targets were chosen on the seat back and one on the head restraint for each seat model. Several tests series were completed on seat backs to refine the research test procedure, and it was found that there were elevated HIC results from contact to these surfaces and that countermeasures were feasible to implement into the seat back designs. It was also found that a loaded seat back condition, which is more realistic to a crash environment, produced more repeatable HIC36 responses than an unloaded seat back condition and was possible to incorporate into a free-motion impact test setup.

For lower B-pillars, a procedure was developed for a new location lower on the B-pillar toward the rear of the vehicle (P9-R). This new location was at the height of Plane 9 that is the lowest plane defined when establishing the B-pillar coordinate system in the upper interior test procedure of FMVSS No. 201. The plane is at the height of the lowest point on the bottom edge of the front window. The impact location on this plane was chosen as it is the closest point to the CG-R location that represents the rear occupant’s head. The underlying structure beneath the trim at the impact location is sheet metal. Tests series were completed on lower B-pillars to refine the research test procedure, and it was found that there were elevated HIC results from contact to this location, that countermeasures were feasible to implement into the B-pillar trim, and that having the door closed and adjacent trim installed, which is more realistic to a crash environment, was possible to incorporate into a free-motion impact test setup.

1.0 Introduction

NHTSA has conducted research with the objective to develop test procedures and assessment criteria to address injuries from impacts with lower interior surfaces in the rear seat area, focusing on head and face injuries due to contacts with seat backs, head restraints, and lower B-pillars (Louden, 2017; Wietholter, 2019). To evaluate the head injury potential of production vehicles as rear seat occupant heads contact lower B-pillars and seat backs, vehicles were tested using a methodology based on the upper interior test procedure of FMVSS No. 201 (62 FR 16725; NHTSA, 2016) with both the free-motion headform (FMH) defined in FMVSS No. 201 (201HF) and a hemispherical adult-sized pedestrian free-motion headform (APHF). All FMH testing used the Head Injury Criterion (HIC) calculated from the resultant acceleration time histories and HIC36 (36-millisecond limit) as a measure of the potential for injury. FMVSS No. 201 defines a HIC transformation called HIC(d) as the injury criterion for the 201HF that was also calculated for applicable tests.

2.0 Development of Seat Back and Head Restraint Test Procedures

2.1 Background

The FMH testing described in this report used the 201HF and the International Harmonization Research Activities/Global Technical Regulation (IHRA/GTR) APHF.

The 201HF is a modified Hybrid III dummy head weighing 9.92 lb (4.5 kg) and measuring 5.9 inches (15 centimeters) wide. It is nose-less to reduce potential interference from the nose contacting the impact surface during the test. When striking a selected target, the first contact must occur within the 201HF's forehead impact zone (Figure 1) according to FMVSS No. 201, Section 8.13.3.

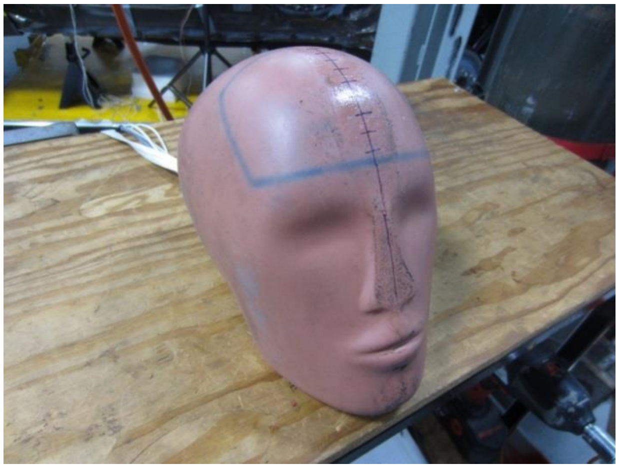


Figure 1. FMVSS No. 201 headform

The APHF is shown in Figure 2. It weighs 9.92 lb (4.5 kg) and consists of an aluminum headform covered with a 0.55-inch (14-millimeter (mm)) thick synthetic skin, with the headform and skin having a total diameter of 6.5 inches (165 mm). The diameter is considered to represent the forehead portion of the 50th percentile adult male. This headform has a spherical contact surface with the accelerometer and center of gravity within 0.39 inch (10 mm) of the geometric center of the sphere.

Figure 2. Adult pedestrian headform

Throughout the testing, the polarities of the headforms were setup as shown in Figure 3, with +X-axis being forward for the headform, +Y to the right of the headform, and +Z being downward per SAE J211.

Figure 3. Headform polarities

Seat back impact locations were identified by deconstructing the seat back for each model tested to expose the metal framework. Locations were chosen using engineering judgment that targeted various hard spots. Three targets were chosen on the seat back and one on the head restraint for each seat model. Generally, a target was placed on the frames uppermost part of the transverse member at the centerline of the seat (SB1), on the top corner of the frame (SB2), over a weld or other hard spot on the vertical side structure (SB3), and at the center of the assembled head restraint height over the left or right vertical metal post (HR1). For SB2 and SB3, the targets were identified on both sides of the seat back for possible testing. The impact locations are shown in Figure 4. A coordinate measuring machine (CMM) was used to measure the targets' X, Y, Z coordinates. The Y and Z coordinates were then transferred to the intact passenger side seat for testing.

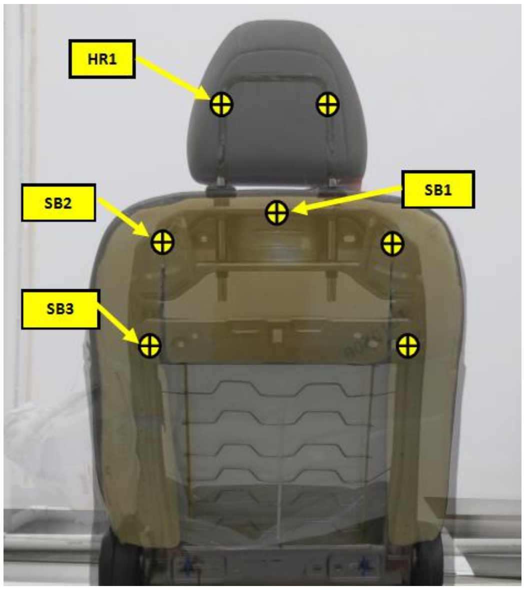


Figure 4. Seat back impact locations

Based on the upper interior test procedure of FMVSS No. 201, the methodology involved in conducting a test included determining impact locations and approach angles. The FMVSS No. 201 standard states that the approach angles should represent the most severe test condition. The actuator launches the 201HF to contact the forehead impact zone on a vector normal to the impact surface at the desired impact velocity. The injury criterion in FMVSS No. 201 when using the 201HF is a HIC transform called HIC(d) that is less than or equal to 1000 where HIC(d) is defined as in Equation 1.

$$HIC(d) = 0.75446*HIC(36) + 166.4 \quad (1)$$

Vertical and horizontal approach angles, with respect to the vehicle coordinate system, must be within a range specified for the interior components covered in FMVSS No. 201. The vertical approach angle range for the A-pillars and B-pillars is -5 to 50 degrees and -10 to 50 degrees, respectively, where a negative value denotes the headform is propelled downward.

2.2 Initial Test Series (CDB Nos. C01378 to C01468)

An initial seat back test series was conducted on front passenger side seat components of a 2014 Honda Odyssey and 2011 Jeep Grand Cherokee at 20 and 25 mph (32 and 40 kph) and at several horizontal and vertical approach angles. Impact locations were chosen using engineering judgment that targeted various hard spots. Three targets were selected on the seat back over the metal framework below the seat padding and one on the head restraint over the metal post. Images of the seat backs tested can be found in Appendix B. This initial test series was conducted to explore the approach angles. The test data can be found in the NHTSA Component Database (CDB)[1] and is tabulated in Appendix A, Table A1. The evaluation showed that: the Honda Odyssey seat back generally produced higher HIC values compared to the Jeep Grand Cherokee and exceeded the injury assessment reference value (>1,000) in several tests, and the APHF generally produced higher HIC values at the seat back impact locations compared to the 201HF for the two seats tested. And, HIC results roughly doubled when the impact speed increased from 20 to 25 mph.

2.3 Fleet Test Series (CDB Nos. C01486 to C01605)

The objective of the fleet test series was to evaluate a fleet of recent model year (MY) vehicles on seat back and head restraint impact locations. This section details the test method and results of impacts on seat backs and head restraints using the 201HF and APHF to evaluate the head injury responses of rear seat occupants in recent MY vehicles.

2.3.1 Test Matrix

Six vehicles were selected to represent the U.S. fleet and are listed in Table 1. Vehicle types include passenger cars, SUVs, and a truck. The vehicles were obtained from NHTSA's inventory of crashed vehicles that were tested with the moving deformable barrier (MDB) into the driver side. Passenger side front row seats were tested in this series.

[1] NHTSA Database. www.nhtsa.gov/research-data/databases-and-software

Table 1. Fleet study test vehicles

Test Vehicles
2016 Chevrolet Cruze (VIN# 1G1BC5SMXG7242432)
2016 Mazda CX-5 (VIN# JM3KE4BY4G0669264)
2017 Toyota Corolla (VIN# 2T1BURHEXHC750301)
2016 Chevrolet Malibu (VIN# 1G11B5SA2GU116636)
2016 Ford F-150 (VIN# 1FTEW1CG7GKD30154)
2016 Nissan Rogue (VIN# KNMAT2MV6GP613626)

The six seats in the fleet study were similar in design; all incorporated a metal frame with vertical side members connected by a transverse member at the top of the seat back and fastened with welds. Images of the seat backs tested can be found in Appendix B. The frame geometries were rectangular, except for the Mazda CX5 that incorporated a tubular geometry. Variations in frame design were observed in the height and cross-sectional area of the transverse member; this affected the location of a hard spot (SB3) on the vertical member produced by the weld. The underlying frame was covered with foam padding that varied in type and thickness across the test vehicles. A thin seat cover was placed over the foam.

The head restraints were also similar in design for the six seat models. An underlying U-shaped metal frame with a tubular geometry consisted of two vertical members and a transverse member at the top half of the head restraint. The frame was encased in a foam that varied in composition and thickness for the six seat models. The Chevrolet Cruze, Chevrolet Malibu, and Ford F-150 incorporated a hard-plastic cover immediately over the metal frame, underneath the foam. The foam was covered with a thin outer fabric.

2.3.2 Test Method

Vehicle seats were removed and mounted to a solid platform prior to impact testing. The platform was stabilized using 500 lb weights on both sides, and the seat was pre-loaded with a water dummy weighing 175 lb to simulate a 50th percentile male occupant sitting in the seat. The seat back angle was set to 25 degrees using the SAE J826 manikin and the head restraint was in the full down position during testing. An example of the seat back test setup is shown in Figure 5.

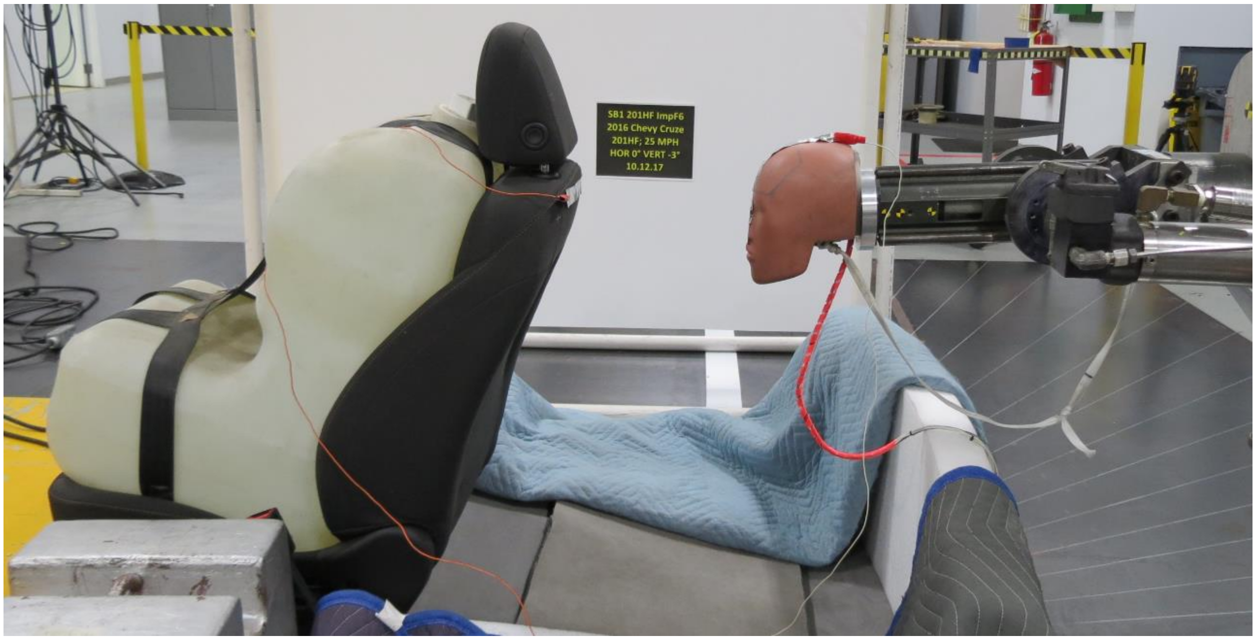


Figure 5. Seat back impact test setup

For this test series, there were no restrictions to the vertical approach angles. This differs from the initial test series on two vehicles (Section 2.2) that limited the horizontal and vertical angles to specific ranges for the different interior structures. For each impact location, the headform was positioned to make the velocity vector as near to normal to the struck surface as possible. The difference in headform design and seat back contours often resulted in unique approach angles for a given impact location.

2.3.3 Results

HIC results are given in Appendix A, Table A2 for all the impact locations: SB1, SB2, SB3, and HR1. HIC36 values exceeding the injury assessment reference value (IARV) of 1000 are shown in red and values above 80 percent are in orange; this is the IARV used in IHRA/GTR No. 9 "Pedestrian Safety." In addition, the HIC(d) transform was computed for all testing with the 201HF. Similarly, HIC(d) values exceeding the IARV are shown in red and values above 80 percent are in orange. Since FMH tests to seat backs and head restraints are not currently specified in upper interior test procedure of FMVSS No. 201, and to provide a more direct comparison to HIC responses from the APHF, only HIC36 responses from impacts to these components were used in this analysis.

Test comparisons showed that the APHF generally produced higher HIC values at the seat back impact locations compared to the 201HF. However, elevated HIC values (>800) were produced by the 201HF for tests conducted on the head restraint at 25 mph on every seat model. As expected, the impact speed affected trends in the results. Elevated HIC values were seen in 36 of 48 tests conducted at 25 mph compared to 2 of 48 tests conducted at 20 mph. The bar charts shown in Figure 6 through Figure 9 compare the HIC values across the seat back and head restraint impacts in the six vehicles. The 2016 Chevrolet Cruze seat back produced higher HIC values overall compared to the other vehicles and exceeded the IARV in 6 of 8 tests at 25 mph.

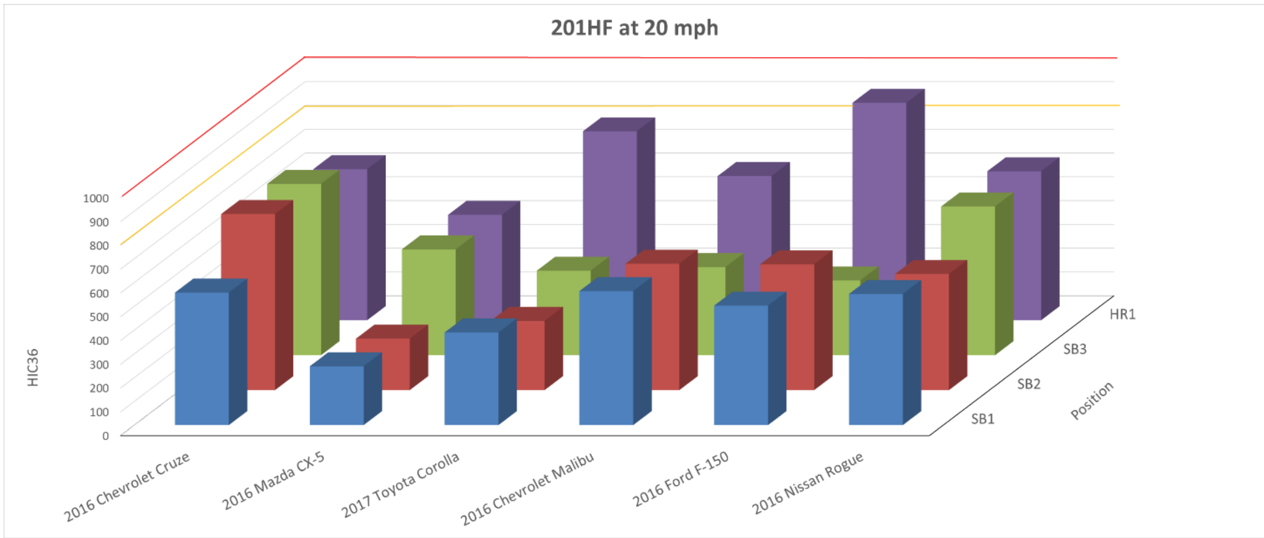


Figure 6. HIC results by impact location and vehicle – 201HF at 20 mph

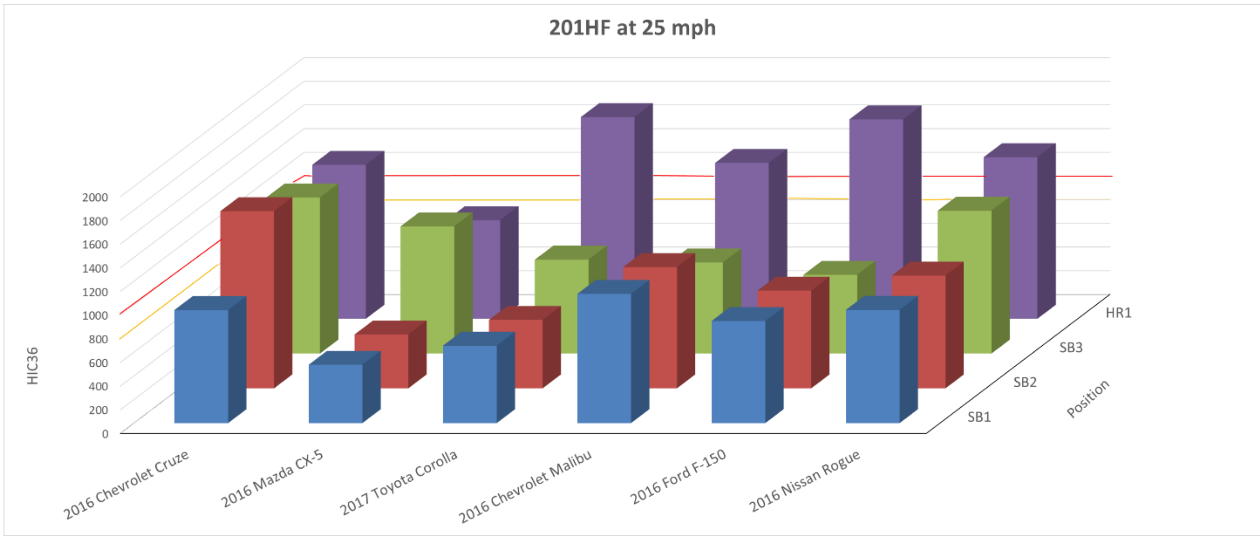


Figure 7. HIC results by impact location and vehicle – 201HF at 25 mph

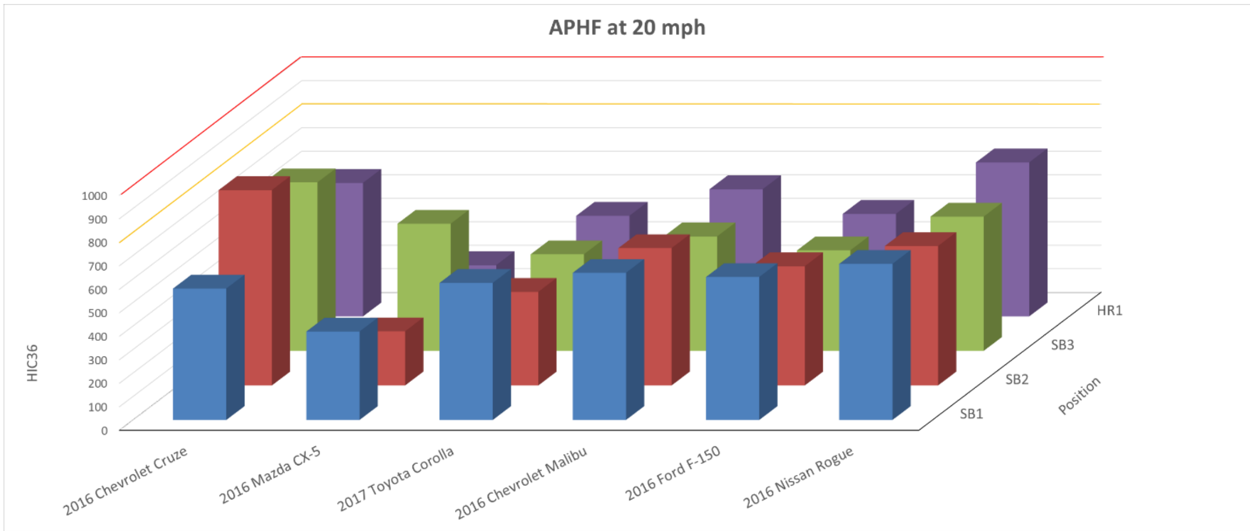


Figure 8. HIC results by impact location and vehicle – APHF at 20 mph

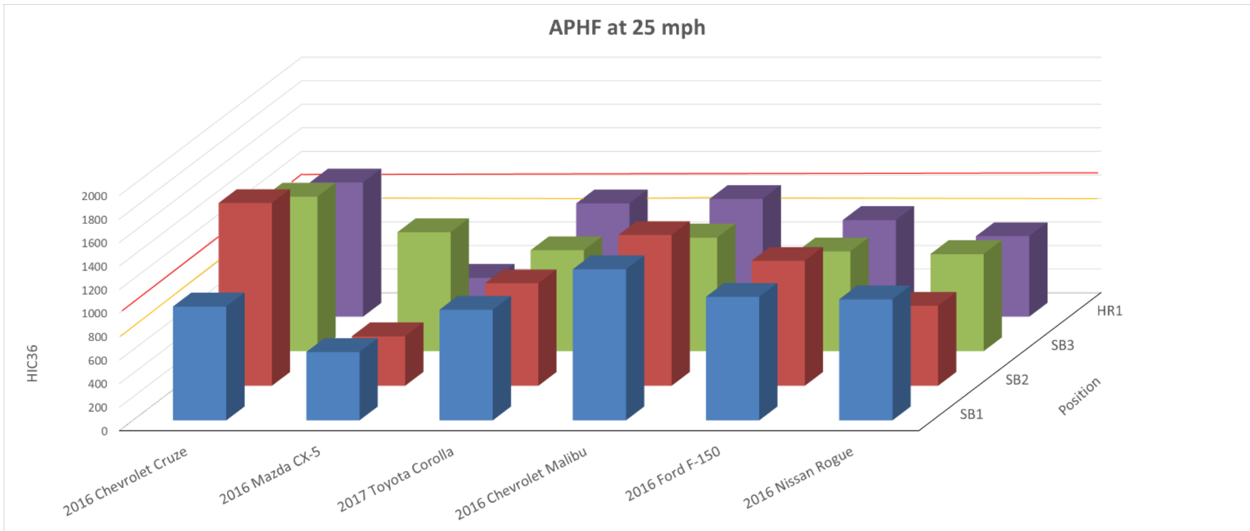


Figure 9. HIC results by impact location and vehicle – APHF at 25 mph

2.3.4 Discussion

The fleet test series showed that the head restraint impact location (HR1) generally had the highest HIC results. The trend was not expected when observing the kinematics during the impacts on head restraints. The headform forces the head restraint forward; therefore, the head restraint would not be expected to provide as rigid of a reactionary surface as the seat back structure. A possible, but untested explanation, is that the head restraint engages the top of the water dummy resulting in a more severe reactionary surface later in the event.

2.4 Countermeasure Test Series (CDB Nos. C01606 to C01697)

A study was then initiated to investigate countermeasures that absorb enough energy to lower the baseline HIC values found in the fleet test series. The objective of the countermeasure test series was to find a countermeasure that lowers HIC to less than 800 for each impact location. Three of the vehicles with the highest baseline results from the fleet study were selected for the seat back countermeasure test series. The tests were performed at the same angles and impact locations tested in the fleet study.

2.4.1 Countermeasure Materials

The countermeasure materials tested in this series were promoted by their manufacturers as appropriate materials to pad the upper interiors in vehicle for FMVSS No. 201.

Extruded Polystyrene (EPS)

A foam known as IMPAXX, shown in Figure 10, was obtained from Coastal Automotive in densities of 2.3 pounds per cubic foot (lb/ft^3) (36.8 kg/m^3) named IMPAXX 300, 2.7 lb/ft^3 (43.3 kg/m^3) named IMPAXX 500, and 2.8 lb/ft^3 (44.9 kg/m^3) named IMPAXX 700. IMPAXX exhibits friable characteristics when struck, and it is used in headliner and pillar trims in the automotive industry. IMPAXX is easily cut to a desired shape. The thickness tested ranged from 0.98 inch (25 mm) to 2.95 inches (75 mm). IMPAXX was obtained for approximately $2.15 per 3.75-inch by 3.75-inch piece tested. Note, material obtained in larger quantities would likely cost less.

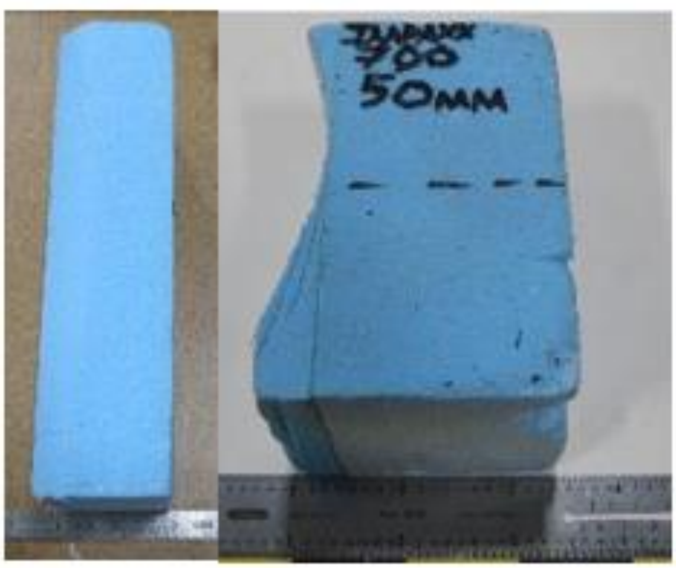


Figure 10. IMPAXX 700

Expanded Polypropylene

The Jeep Grand Cherokee tested in the initial series incorporated expanded polypropylene (EPP) foam bezels around the seat back frame shown in Figure 11. Research testing showed the foam to be a good energy absorber. Sections were cut from the top part of the bezel and thickness ranged from 1.4 inches (35 mm) to 1.5 inches (38 mm). Bezels were obtained for approximately $65 each.

Figure 11. Jeep Grand Cherokee seat back foam bezel

Energy Absorbing Tubing

O-Flex supplied energy absorbing square and rectangular tubing that is constructed with aluminum foils held together with cardboard, shown in Figure 12. The tubing comes in a variety of aluminum thicknesses and compositions. The product literature states that certain thicknesses have been tested and showed that a HIC of less than 800 can be achieved. Thicknesses between 0.9 inch (23 mm) and 2.2 inches (56 mm) were tested in this series. O-Flex can be obtained for approximately $1.40 per 4-inch length.

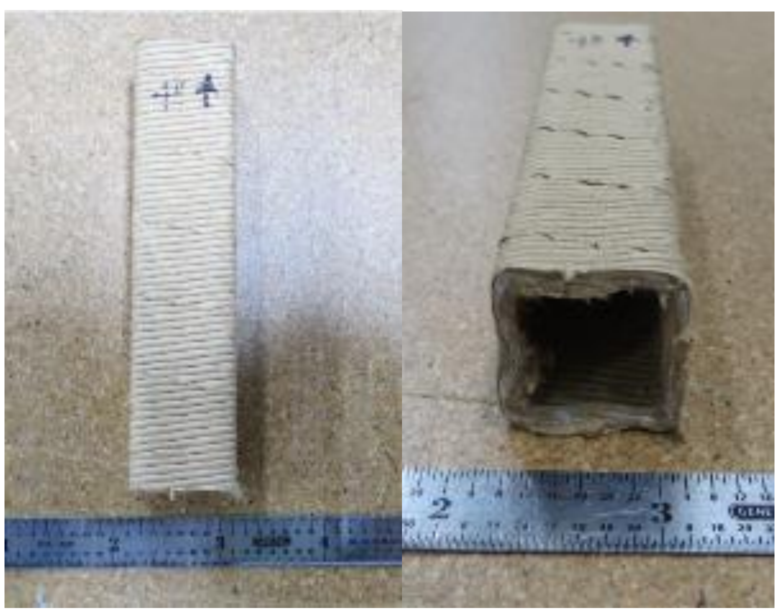


Figure 12. O-Flex tubing

2.4.2 Test Matrix

Three vehicles with the highest HIC values in the fleet study were chosen for the baseline testing in the countermeasure series. The vehicles, listed in Table 2, also encompassed a range of vehicle types: sedan, cross-over, and truck. Front passenger seats tested in the fleet study series were used in the countermeasure study. The head restraint angle was monitored, and the seat was replaced if it could not be kept within approximately three degrees of the original untested angle. The seats were also monitored for visual damage or deformation and were replaced as necessary based on engineering judgement.

Table 2. Countermeasure test vehicles

Test Vehicles
2016 Chevrolet Cruze (VIN# 1G1BC5SMXG7242432)
2016 Ford F-150 (VIN# 1FTEW1CG7GKD30154)
2016 Nissan Rogue (VIN# KNMAT2MV6GP613626)

2.4.3 Test Method

The impact locations determined in the fleet study were tested in the countermeasure series. In some instances, a location did not show elevated HIC values with one of the headforms and was therefore not tested. Horizontal and vertical approach angles established for the 201HF and APHF in the baseline fleet study were used in the countermeasure test series. The impact velocity used was 25 mph, since only 2 tests at 20 mph showed elevated results in the fleet series.

To place the countermeasure material, the seat back and head restraint were deconstructed to expose the underlying metal seat frame and head restraint post. The countermeasures were affixed to the seat back frame and head restraint posts with double-sided tape. Duct tape was used to stabilize the countermeasure. Several countermeasures were used in some tests to prevent chin and lip interaction between the 201HF and the metal frame, as shown in Figure 13.

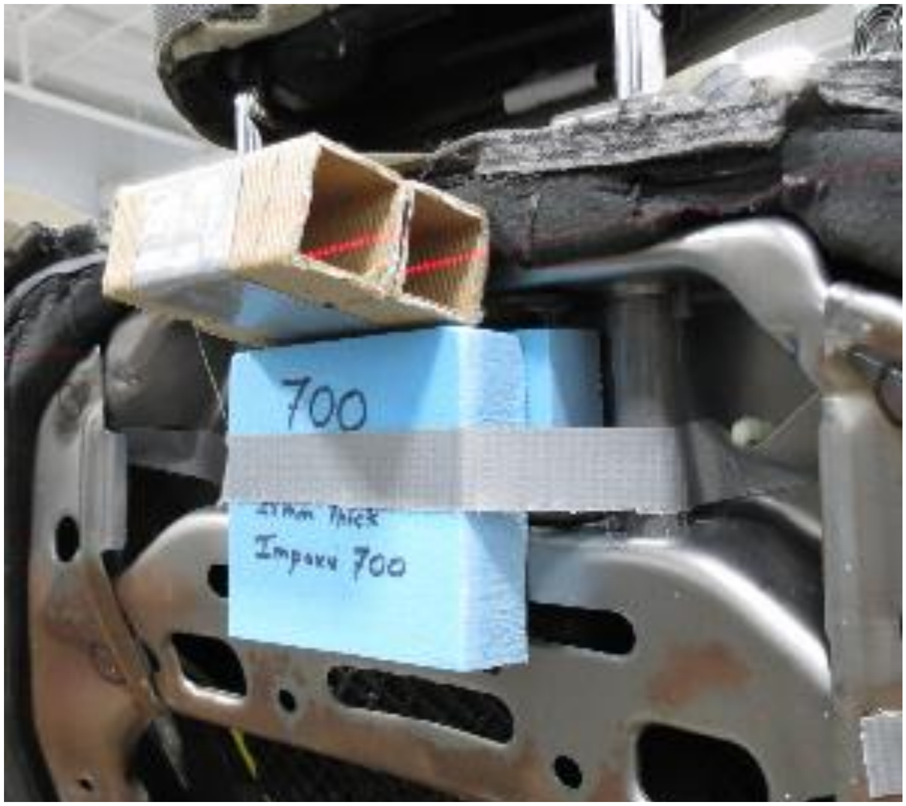


Figure 13. Example of countermeasures use

2.4.4 Results

The results from impacts to the seat back using countermeasures are given in Appendix A, Table A3. Due to unfamiliarity with the countermeasure response, a trial and error approach was taken with the Chevrolet Cruze, the first vehicle tested in the series. This resulted in a high number of tests on this vehicle. With the gained experience, the process was streamlined for the two other vehicles.

The results are shown graphically in Figures 14 and 15. The darker shade of color represents the baseline test and the lighter shade of color shows the lowest achieved HIC with countermeasures regardless of countermeasure used. Baseline HIC36 values were reduced to less than 800 for both the 201HF and APHF, and a reduction in HIC36 values below 800 was achieved in 27 of the 65 (42 percent) impacts performed; some level of HIC reduction was observed in 9 other tests.

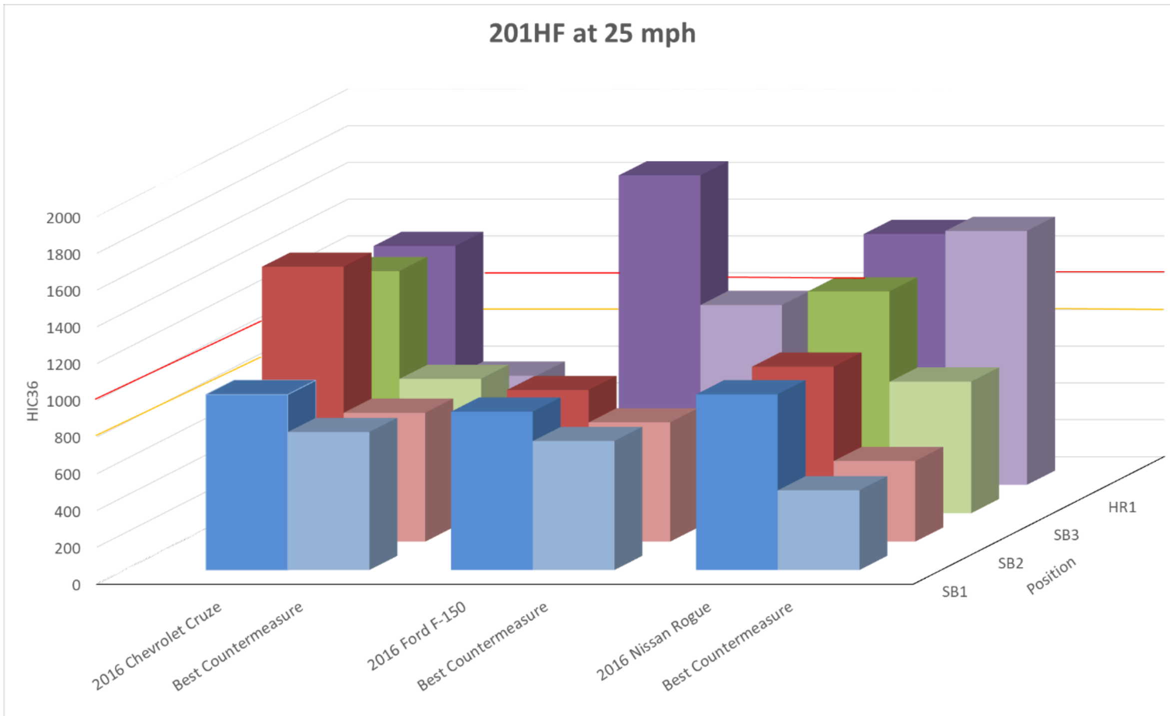


Figure 14. Countermeasure results by impact location and vehicle – 201HF at 25 mph

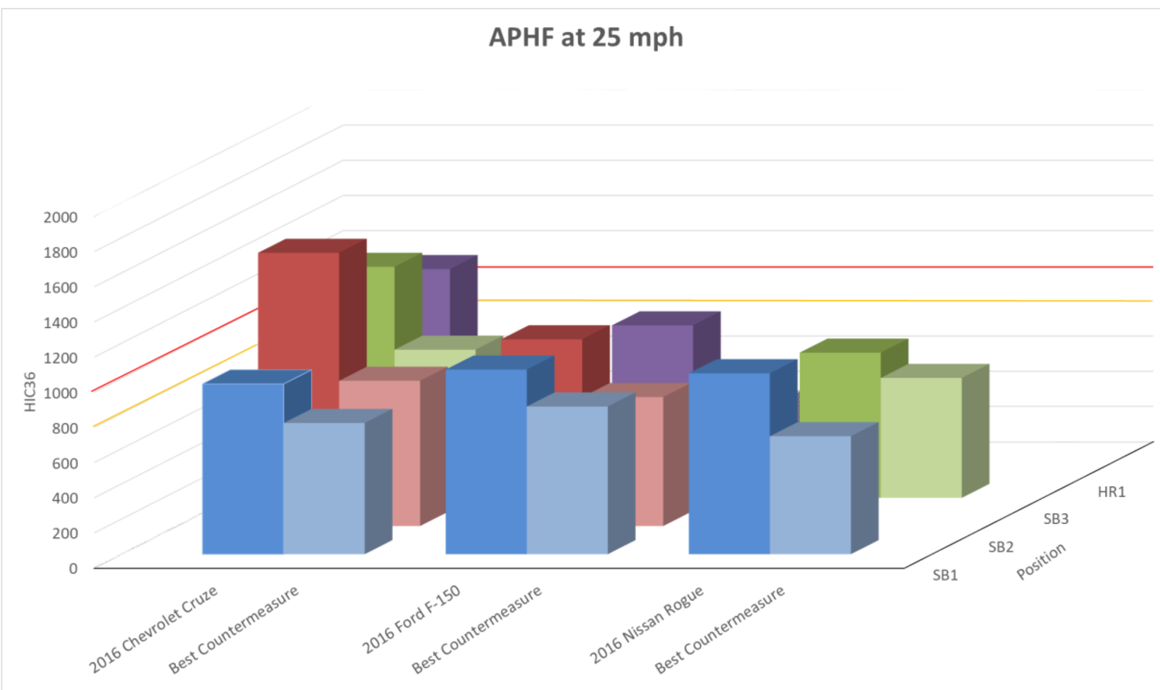


Figure 15. Countermeasure results by impact location and vehicle – APHF at 25 mph

2.4.5 Seat Back Countermeasure Test Discussion

At least one countermeasure solution was found that reduced HIC36 values below 800 for 9 of the 11 impact locations with the 201HF and for 6 of the 9 impact locations with the APHF. There is no apparent trend in the results to determine if one countermeasure performed superior to the other. The APHF typically required more countermeasure solutions to achieve the goal of lowering HIC36 values under 800.

The highest percent reductions of HIC36 values were seen at target SB2. The head restraint proved to be a challenging structure for the 201HF. A reduction in HIC below 800 was achieved only in the Chevrolet Cruze. A review of videos showed the headform chin striking the top of the seat back shortly after contact with the head restraint target. Adding countermeasures to this area did not reduce the force curve in most cases. In addition, the front of the head restraint contacted the water dummy that may contribute to loading in the headform.

2.5 Additional Vehicle Models Test Series (CDB Nos. C01741 to C01825)

Based on results from the previous test series on seat backs and head restraints, it was decided to remove the water dummy from the test setup since the interaction with the fill neck on the top of the water dummy and the head restraint seemed to affect the head restraint tests. Additionally, the water dummy being constantly engaged with the seat back was not representative of a vehicle frontal crash where the front row occupant would move forward toward the dash and be less engaged with the seat when a rear seat occupant's head might contact the seat in front of them. The seat would also undergo inertial force during a frontal crash pulling the seat forward, as well as possible loading from the seat belts for integrated seat designs. Therefore, in this test series, three seat conditions were tested: (1) with no occupant in the front seat, (2) with a Hybrid III 50th percentile male (HIII-50M) anthropomorphic test device (ATD) in the front seat, and (3) with an applied load to the seat prior to and held during impact (and no ATD in the seat).

The first vehicle platform used for seat back testing was a 2016 Mazda CX-5. In this initial test series, impacts were conducted in the conditions with and without a HIII-50M ATD in the seat. The last test with the Mazda CX-5 applied a load to the seat back, but due to deformation observed when loading the seat, only one test was able to be completed.

After the initial seat back tests on the Mazda CX-5, the seat load fixture was modified to minimize pinching on the seat back frame. Additional vehicle platforms were tested both with and without the ATD and using the modified seat load fixture. After a subset of tests was completed with and without the ATD in the seat, it was decided that the condition with the ATD in the seat was not representative of a crash scenario because the front occupant would not be engaged with the front seat back at the time of the impact. Thus, to determine the effect of the load on the seat back during impact, testing continued without an ATD in the front seat, but both with and without the applied load on the seat back.

2.5.1 Test Matrix

A total of six vehicles platforms, shown in Table 3, were tested in the conditions both with and without load applied. And, a subset of three vehicle platforms were tested with a HIII-50M in the seat for comparisons (without load applied); the specific models were from a 2016 Chrysler 300, 2018 Dodge Journey, and 2018 Toyota Sienna. Images of the seat backs tested can be found in Appendix B.

Table 3. Additional vehicle models test vehicles

Test Vehicles
2016 Chrysler 300 (VIN# 2C3CCAAG4GH134994)
2018 Dodge Journey (VIN# 3C4PDCAB8JT182880)
2018 Toyota Sienna (VIN# 5TDKZ3DC3JS902287)
2016 Ford F-250 (VIN# 1FT7W2A64GEA19398)
2016 Toyota Tacoma (VIN# 5TFAX5GN1GX059512)
2015 Chevrolet Tahoe (VIN# 1GNSCAEC9FR116060)

2.5.2 Test Method

The seat load fixture was fabricated to apply a specified load to the seat back during an impact test. The modified seat load fixture (Figure 16) allowed a load to be exerted on the seat back, while reducing the pinching that was observed in the previous fixture design. The fixture loads the seat back without changing the horizontal angles for any of the target locations. The 1.5-inch (38-mm) strap used in the fixture was designed to load the seat without interfering with the impact locations or headform.

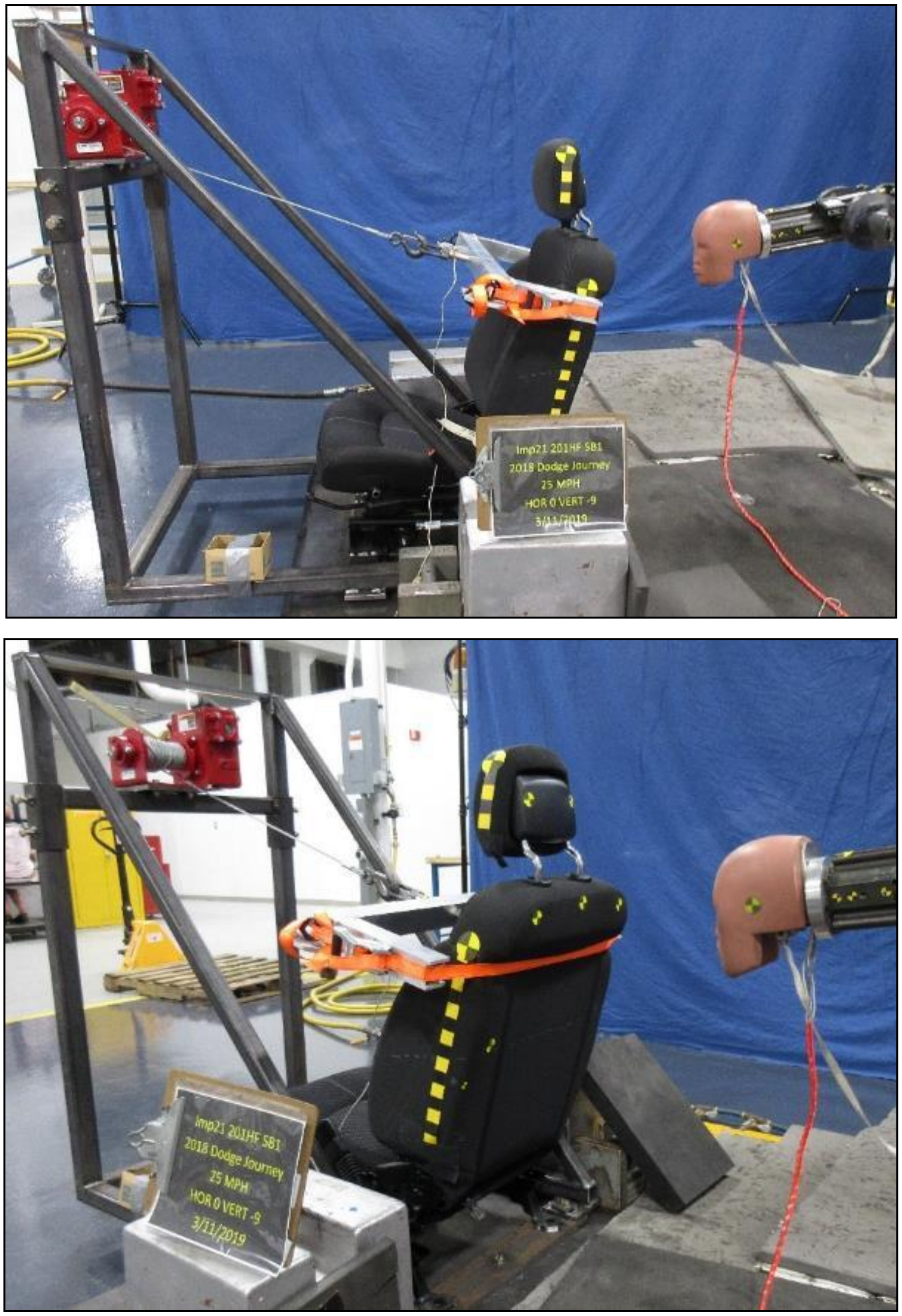


Figure 16. Setup of impacts with forward force exerted on seat backs

The force applied to each seat back was calculated using the average peak acceleration from New Car Assessment Program (NCAP) crash test pulses for each specific vehicle from testing in 2015 through 2017. Each seat was pulled with a respective load depending on the variable mass and shape of the seat back.

Seat backs were removed from each seat assembly, and together with the head restraint, weighed and marked for center of gravity. Using the mass, center of gravity location/distance, and average peak acceleration data (43.9 g) for each seat, the following formulas were used to calculate the load to be applied:

$$M_1 = M_2$$

$$F_1 * d_1 = F_2 * d_2$$

$$F_{1*} = m * a / \cos(\theta)$$

$$F_2 = m * a * d_1 / (\cos(\theta) * d_2)$$

F_1 is the force exerted due to impact acceleration (a), at the distance (d_1) between the center of gravity of the seat back and seat back pivot. M_1 is the moment at the location of center of gravity. F_2 and M_2 are the force and moment, respectively, at the distance (d_2) between the pull fixture and the seat back pivot. The seats were pulled at location d_2, which was determined to have the least interference with seat back targets for each vehicle platform. Due to seat back angle and design variabilities, the angle of the pull force was adjusted from horizontal to a direction perpendicular to the seat back. The seat back angle (θ) from the SAE J826 manikin as measured from vertical was used for calculation purposes. F_{1*} is the force exerted due to impact acceleration at the perpendicular angle. During the initial test series of the seat load fixture, the seat back loading angle was adjusted to prevent slipping of the loading strap during testing, making the pull force recorded an approximation.

One major difference between the loaded and unloaded seat conditions was that adjustments to the vertical approach angles were required. When a forward load was applied, the seat back would rotate forward, changing the seat back angle. In order to comply with the test procedure, approach angles were re-assigned after the seats were loaded in order to make the headform impact vector perpendicular to the impact surface. Another major challenge of these tests was that load-relaxation was observed with the loaded seats. An additional 15 to 20 minutes was required to perform one test with load versus without load. During this extra time, the applied load relaxed an average of 97 lb over the average setup time of 17 minutes. The procedure with the seat load fixture was more intensive, required adjustments to vertical approach angles due to forward deflection after loading, and involved two personnel to run a single test.

2.5.3 Results

Impact tests on the three vehicle seat backs used the 201HF and are listed in this report under CDB Test Nos. C01751 through C01764, C01798 through C01811, and C01812 through C01825, respectively and given in Appendix A, Table A4. At each of the four target locations, two impacts were performed, one with an ATD and one without, for a total of eight FMH impacts per vehicle seat back. All impacts were performed at a target velocity of 25 mph.

Impacts on the three different vehicle models showed higher HIC36 values with the HIII-50M ATD in the front seat, as opposed to tests with no ATD. Figures 17 to 20 illustrate the higher HIC36 values when the ATD was placed in the seat.

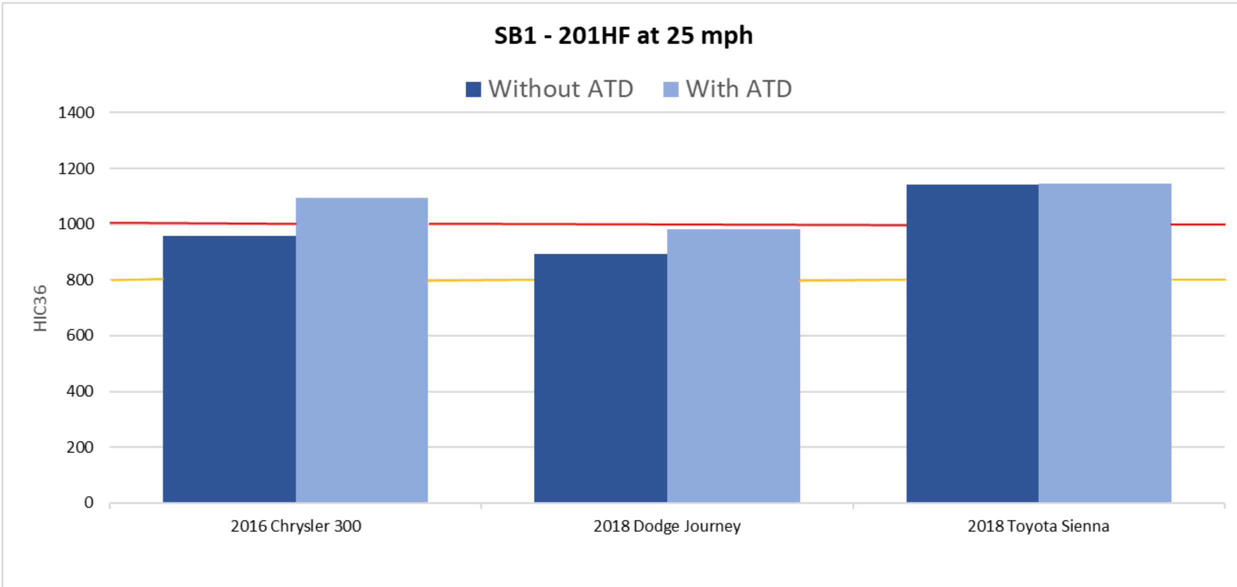


Figure 17. HIC results at SB1 without and with an ATD

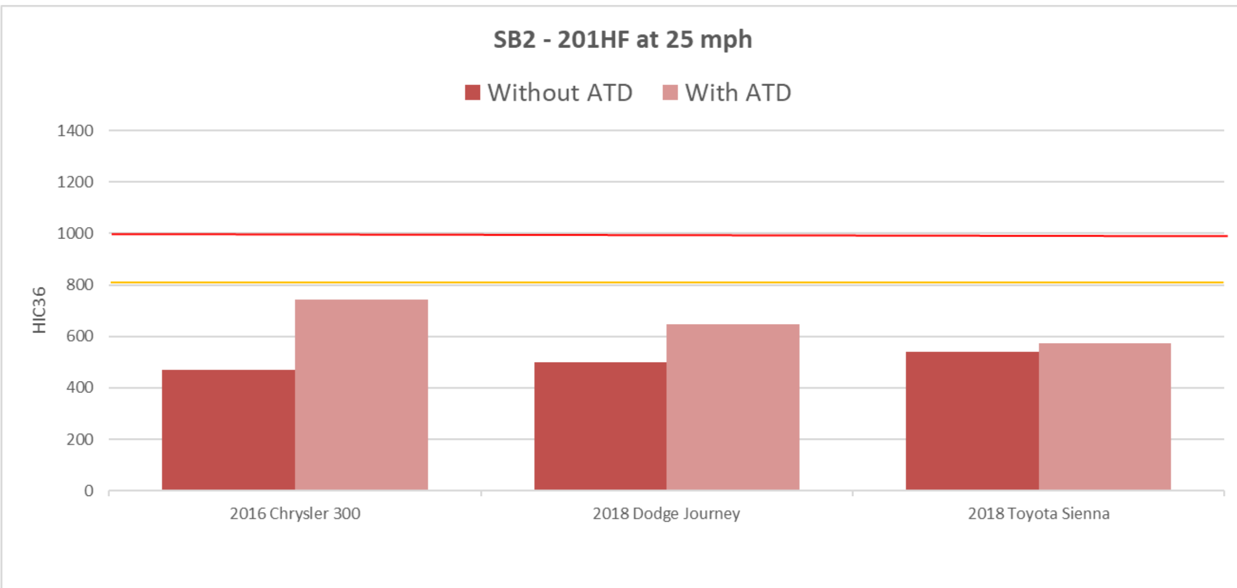


Figure 18. HIC results at SB2 without and with an ATD

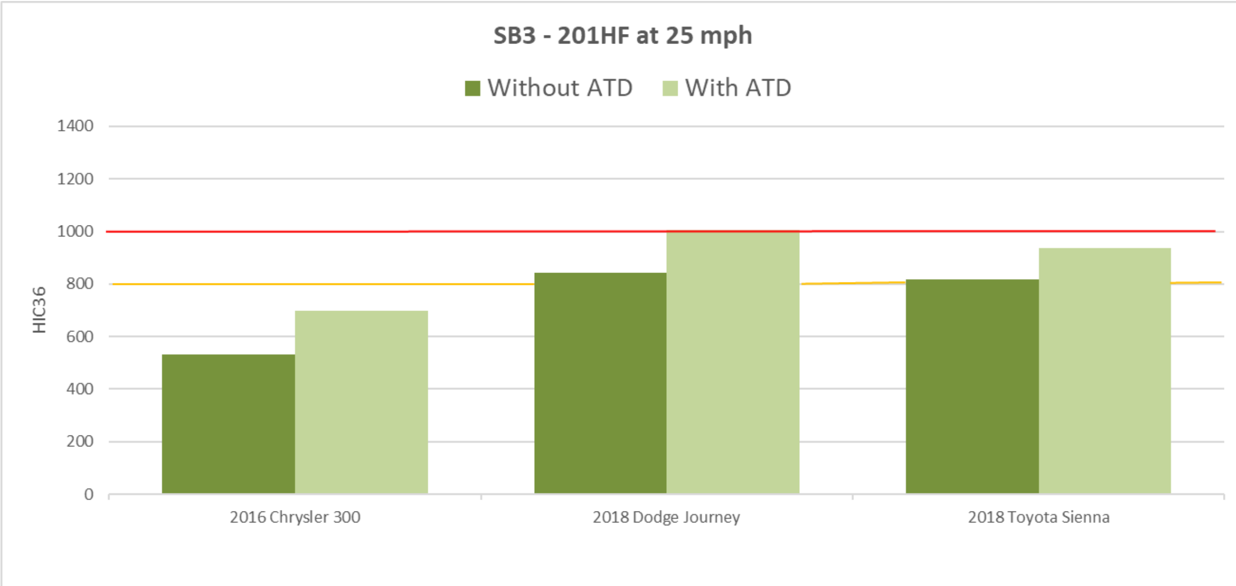


Figure 19. HIC results at SB3 without and with an ATD

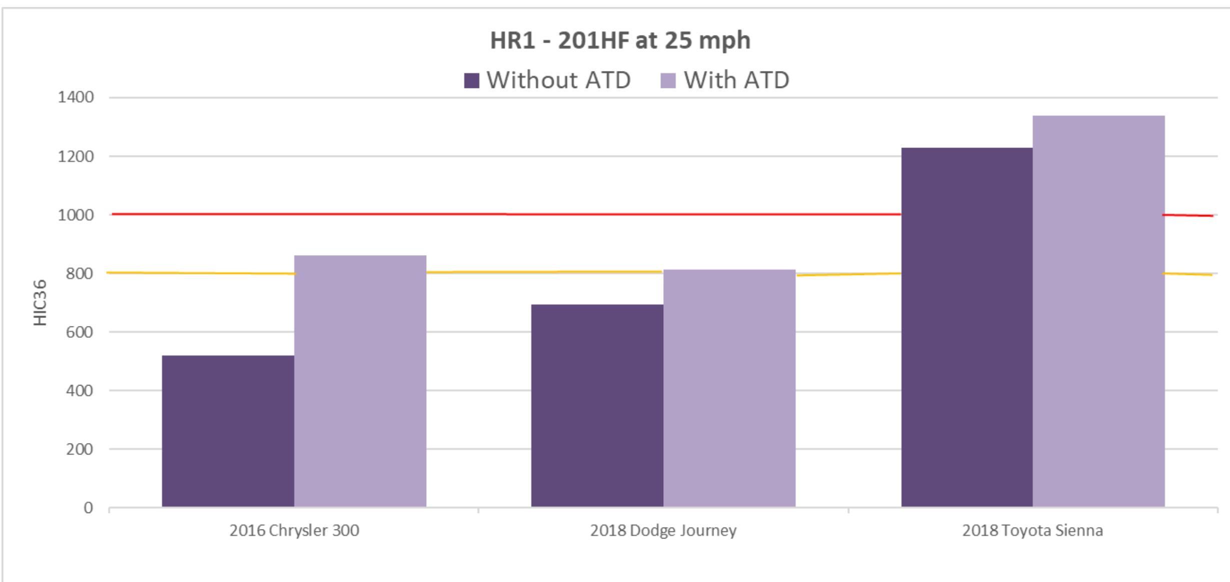


Figure 20. HIC results at HR1 without and with an ATD

The bar charts shown in Figures 21 through 24 illustrate the HIC36 values for the seat back and head restraint impacts for the six vehicle platforms tested to compare the test conditions with and without applied load. The 2018 Toyota Sienna seat back produced higher HIC36 values overall compared to the other vehicles and exceeded the IARV in two of four tests, for both test conditions (seat without load applied and seat with load applied).

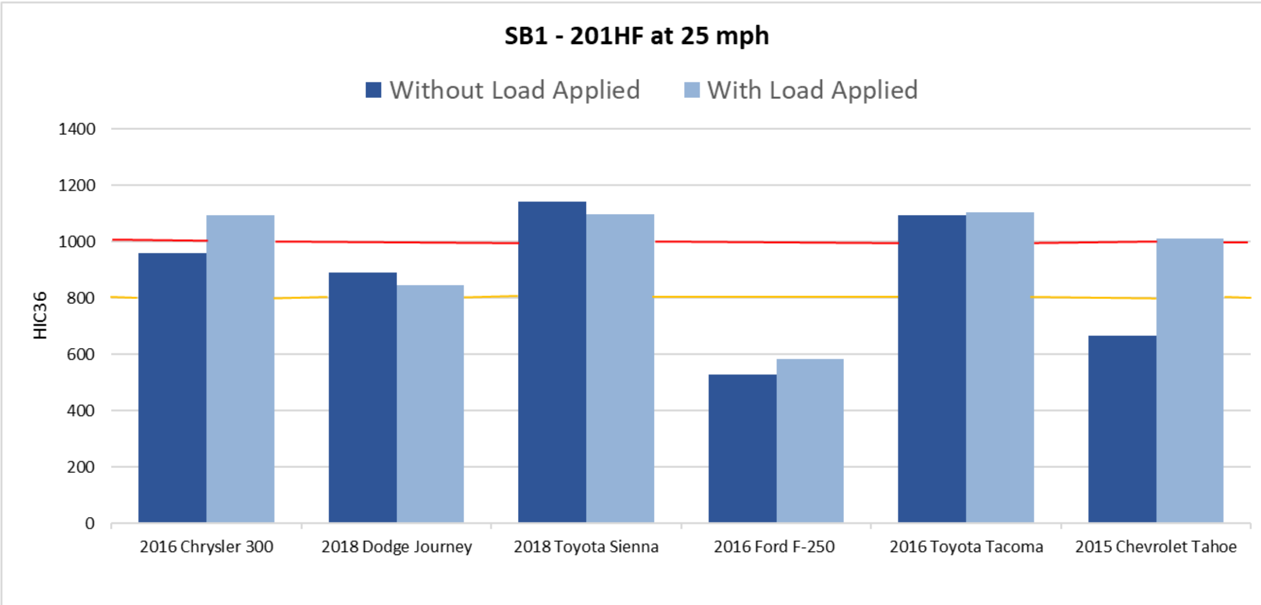


Figure 21. HIC results at SB1 without and with load applied

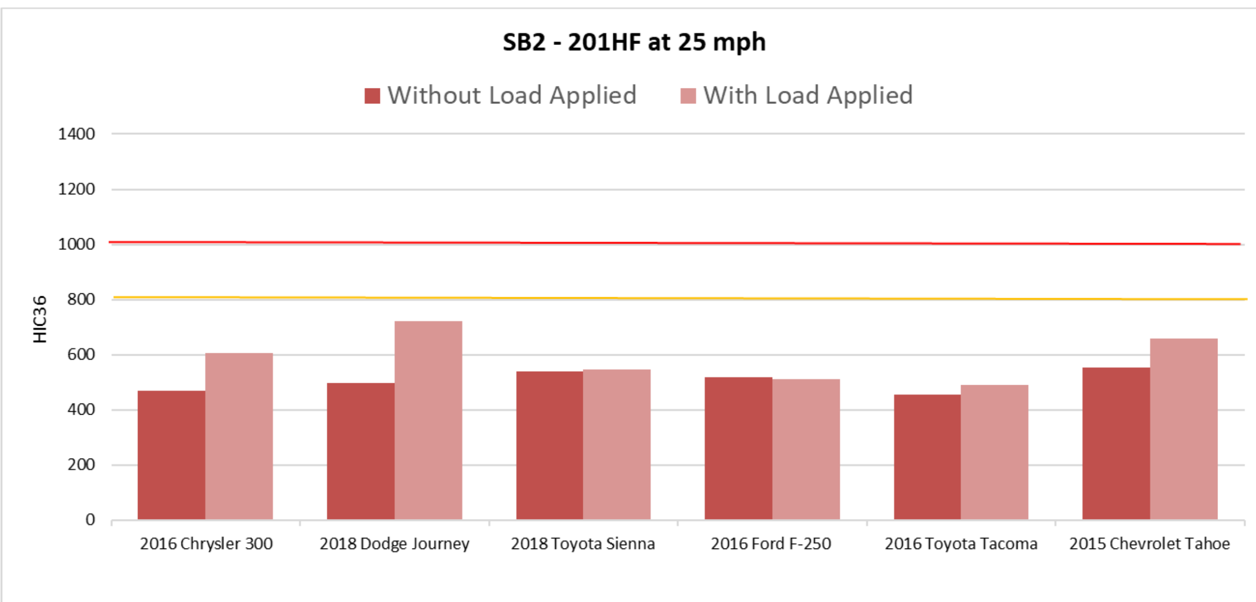


Figure 22. HIC results at SB2 without and with load applied

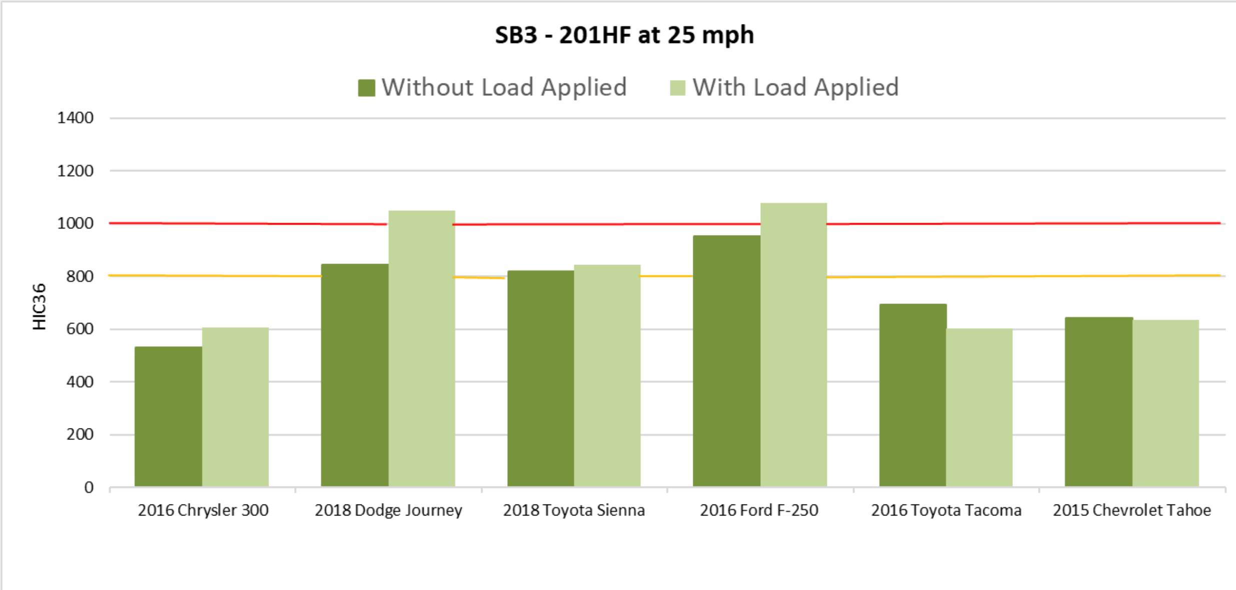


Figure 23. HIC results at SB3 without and with load applied

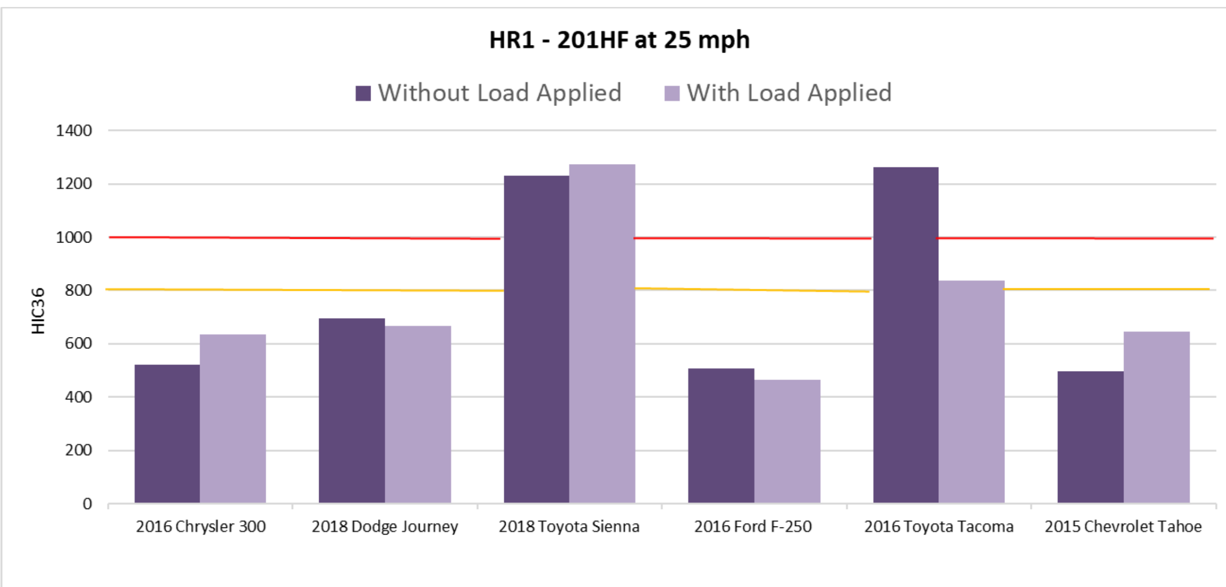


Figure 24. HIC results at HR1 without and with load applied

The HIC36 differences were not consistent when comparing the two conditions. Four of the six vehicles reported higher HIC36 average values for the loaded condition at SB1, compared to three of the six vehicles when struck at HR1.

2.5.4 Discussion

The three vehicle platforms were tested to determine the effect of having a front seat occupant in the seat at impact. Across all vehicle seat models and all target locations, the HIC36 values were higher with an ATD positioned in the seat. The difference in HIC36 values for each target location ranged between 2 and 340, with a mean difference of 142. Although the HIC36 values of impact tests with a HIII-50M ATD in the seat at the time of impact were consistently higher as compared to impacts without an ATD, it was decided that this method does not represent a real crash scenario because the front seat occupant would not be fully engaged with the seat back at the time when a rear seat occupant would impact the seat back.

After initial tests were completed with one impact at each target location, a study was performed to determine if the load and seat back angle changed during the load setup process, referred to as the load-relaxation study.

The perpendicular pull orientation was consistent in loading the seat backs to the fully calculated load, without slipping of the loading strap. Compared to the no load condition, after the initial load was applied, the seat backs pivoted forward an average of 3.8 degrees. Seat back angles did not change a substantial amount while at full load. Seat back loads remained steady at the 30-minute mark after the calculated load was applied. All impacts after the load-relaxation study used loads calculated perpendicular to the seat back, and all impacts in the condition with the applied load were not struck until 30 minutes after loading for consistent methodology.

Because there was not enough data to complete statistical analyses, additional testing was performed to collect more data to compare the two test conditions.

2.6 Effect of Seat Load on Impacts Test Series (CDB Nos. C01910 to C01978; C02012 to C02045)

An additional test series was conducted to assess the repeatability of impacts using the test procedures, both with and without load applied to the seat back. This effect of seat load on impacts (ESLI) test series was performed on three different vehicle platforms using two headforms. The three platforms were selected based on availability, previous test results on the seat backs, and design variations that included seat back material, seat back curvature design, electric versus manual seat adjustment, and single versus dual-sided pivot locking mechanisms. All loads applied to the seat back were perpendicular to the seat back and calculated using the formula in Section 2.5.2. The FMH test procedure with load applied was refined as the repeatability testing was performed, and the final version used can be found in Appendix C.

2.6.1 Test Matrix

A total of three front passenger seat vehicle platforms were tested (Table 4). All vehicles had been used in MDB crash tests. Images of the seat backs tested can be found in Appendix B.

Table 4. ESLI test vehicles

Test Vehicles
2018 Dodge Journey (VIN# 3C4PDCAB8JT182880)
2018 Toyota Sienna (VIN# 5TDKZ3DC3JS902287)
2015 Chevrolet Tahoe (VIN# 1GNSCAEC9FR116060)

For each vehicle, three repeat impacts were performed on each target location with the 201HF, with one set of repeats with load applied to the seat back and one set without, for a total of 23 impacts per vehicle platform. Only two impacts were completed at SB1 without load for each vehicle platform during this series, as one impact of the three repeats was conducted in the previous series (C01803, C01817, C01745). A total of 69 impacts were conducted with the 201HF. All impacts were performed at a target velocity of 25 mph.

After testing with the 201HF, repeatability testing with the APHF was conducted. In this subset, only the set of repeat tests with the load applied to the seat back were completed. A total of 36 impacts were conducted with the APHF at a velocity of 25 mph.

2.6.2 Test Method

Following the steps detailed in Appendix C, a vehicle seat back was struck three times at each target location in both test conditions (with and without a load applied) with the 201HF and tested with the APHF in only the loaded condition. The seat load fixture was used on all impacts conducted with a load applied to the seat back. The seats were monitored for visual damage or deformation and were replaced as necessary. Often, new parts including seat back frames were replaced. Based on the additional time needed during setup, all impacts were performed about 30 minutes after the seat back was loaded. For each impact, seat back and head restraint angles were measured prior to impact. In addition, for tests with load applied, the seat back and head restraint angles were measured just after load application and 25 minutes after the load was applied to monitor how the seat back angle changed during the 30-minute loading window. After each impact, the seat back and seat pan were inspected for damage.

2.6.3 Results

Impacts tests on three vehicle seat backs with and without a load applied, using the 201HF and APHF, are listed in this report under CDB Test Nos. C01910 to C01978 and C02012 to C02045, and given in Appendix A, Table A5. HIC36 values differed between vehicle platforms, headform type used, and impacts with load and without load applied to the seat back. When using the 201HF, impacts with load applied to the seat back tended to result in higher HIC36 values than impacts with no load applied. Additionally, impacts with the load applied had lower percent coefficient of variation (CV) values than the tests without a load applied. All statistics calculated are shown in Appendix A, Table A6. Based on the results of testing with the 201HF, the repeatability of the loaded condition using the APHF was assessed. The bar charts shown in Figures 25 through 28 illustrate the HIC results between the tests with no load applied to the seat and load applied conditions with the 201HF, as well as the load applied condition with the APHF. The shade of color represents the three conditions.

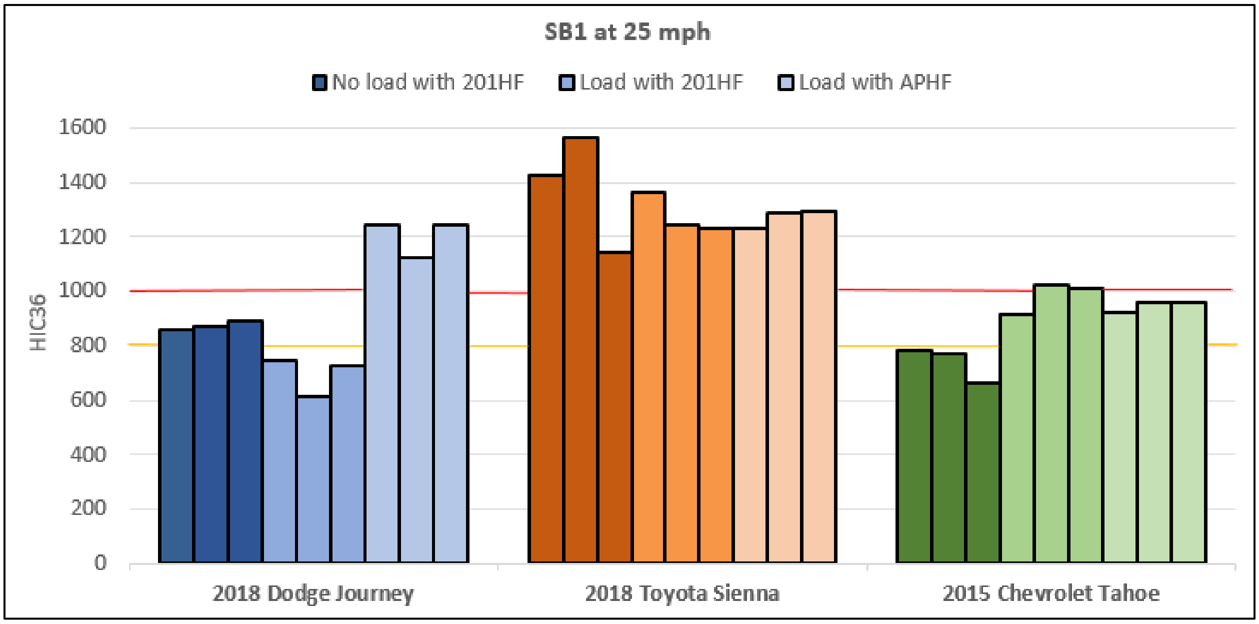


Figure 25. HIC results at SB1 with and without load applied by headform

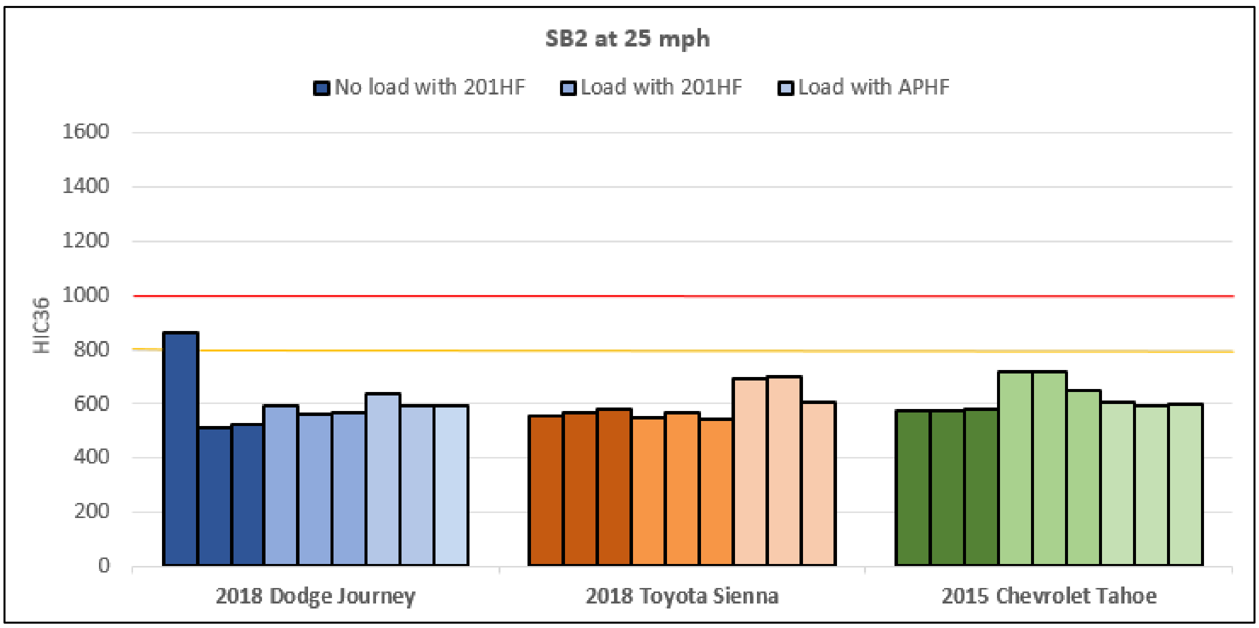


Figure 26. HIC results at SB2 with and without load applied by headform

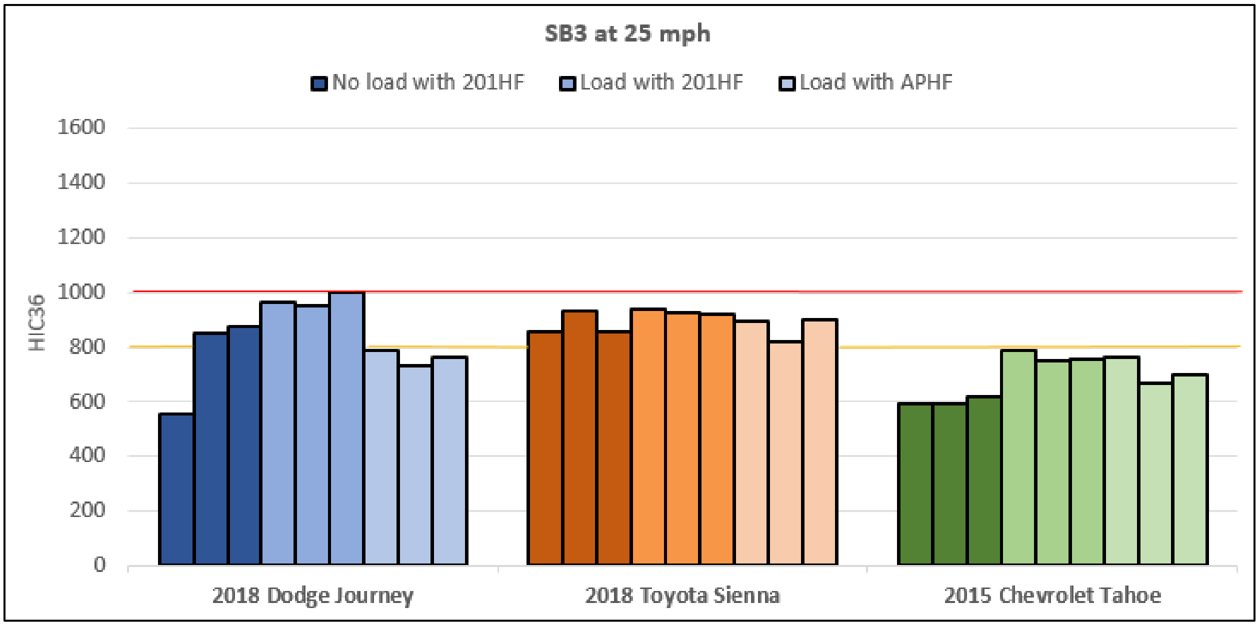


Figure 27. HIC results at SB3 with and without load applied by headform

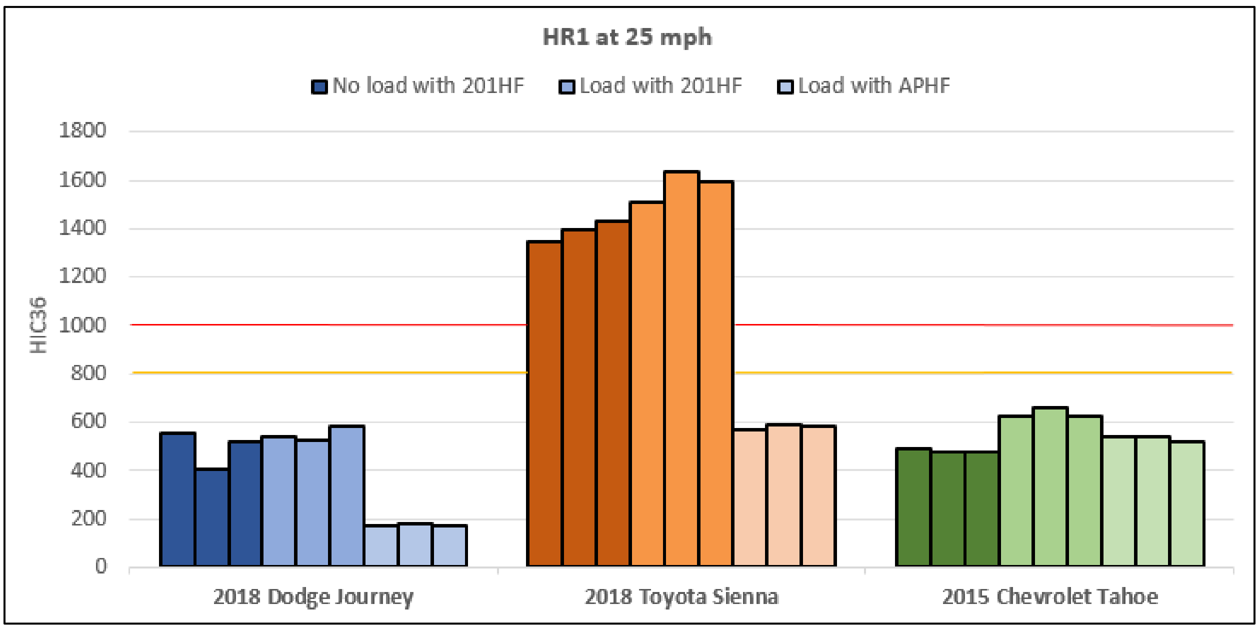


Figure 28. HIC results at HR1 with and without load applied by headform

Overall, higher HIC36 results were observed when the seat back was loaded. Six of the 12 different sets of repeats with load applied reported an average HIC36 result over 80 percent IARV, with two sets exceeding the IARV with the 201HF. Five of the 12 sets of repeat impacts with no load applied and 201HF resulted in an average HIC36 value over the 80 percent IARV value, with two sets exceeding the IARV.

Two-sample unequal variance t-test analyses (t Stat < t Critical, df =2, p>0.05) were completed to determine whether HIC36 values were statistically different, at a significance level of 0.05, when a forward load was applied to the seat back when tested using the 201HF. This analysis was completed on each vehicle for each impact location, and p-values were generated comparing the two conditions. Six p-values were less than 0.05, showing significance between the conditions, while the other six indicated no significance between the seat loading conditions tested with the 201HF. The Chevrolet Tahoe was the only platform that showed significantly higher HIC36 values for all four target locations when the seat backs were loaded compared to impacts with no load applied to the seat back (p-values for the target locations are shown in Table 5). The other two significant results were at for the Toyota Sienna. Overall, higher HIC36 results were observed when the seat back was loaded. Six of the 12 different sets of repeats with load applied reported an average HIC36 result over 80 percent IARV, with two sets exceeding the IARV. Four of the 12 sets of repeat impacts with no load applied resulted in an average HIC36 value over the 80 percent IARV value, with two sets exceeding the IARV.

Table 5. P-values calculated to compare load conditions

	SB1	SB2	SB3	HR1
2018 Dodge Journey	0.59	0.23	0.17	0.35
2018 Toyota Sienna	0.52	<0.01	0.20	0.02
2015 Chevrolet Tahoe	0.01	0.03	<0.01	<0.01

Percent CV was calculated for all sets of repeats with the 201HF and ranged from 0.9 to 34.5 percent for the unloaded condition and from 1.1 to 6.5 percent for the loaded condition; Table 6 summarizes the percent CV results. Percent CV values on repeat tests were lower on average for the loaded seat condition. For the unloaded repeat tests at target locations SB2 and SB3 for the Dodge Journey with the 201HF, one test at each location resulted in a substantially lower HIC36 value. Video comparisons were made and higher seat back deflection values were observed for the two tests (C01918 and C01924), potentially explaining the lower HIC36 values.

Table 6. Percent CV results calculated to compare load conditions

	SB1		SB2		SB3		HR1	
	Load	No Load	Load	No Load	Load	No Load	Load	No Load
2018 Dodge Journey	6.5%	1.7%	3.3%	34.5%	2.7%	23.2%	5.5%	15.7%
2018 Toyota Sienna	5.7%	15.6%	2.3%	2.3%	1.1%	4.9%	4.2%	3.0%
2015 Chevrolet Tahoe	6.0%	8.6%	5.6%	0.9%	2.8%	2.4%	3.0%	1.6%

When comparing the 201HF and the APHF in the loaded condition, trends showed that using the 201HF produced higher HIC results. In 9 of the 12 sets of repeat impacts, the average HIC36 was higher with the 201HF; the exception was for the SB1 and SB2 impact location on the Dodge Journey and the SB2 impact location on the Toyota Sienna. Additionally, 6 of 12 sets of repeat impacts with the 201HF resulted in HIC36 over 80 percent IARV, with 2 of the 6 exceeding the IARV. This compares to the APHF tests that resulted in 4 of 12 sets of repeat impacts with HIC36 over 80 percent IARV and 2 of the 4 exceeding IARV.

Two-sample unequal variance t-test analyses (t Stat < t Critical, df=2, p>0.05) were completed to determine whether the HIC36 results were statistically different, at a significance level of 0.05, between tests using the two headforms. This analysis was completed on each vehicle for each impact location. P-values were generated comparing the two conditions, and six values were less than 0.05. These P-values corresponded to three impact locations on the Dodge Journey seat, one impact location on the Toyota Sienna seat, and two impact locations on the Chevrolet Tahoe seat as shown in Table 7. Of the six sets of significantly different tests, five of the six sets showed significantly higher HIC36 values with the 201HF than the APHF.

Table 7. P-values calculated to compare headforms

	SB1	**SB2**	**SB3**	**HR1**
2018 Dodge Journey	<0.01	0.16	<0.01	<0.01
2018 Toyota Sienna	0.86	0.06	0.16	<0.01
2015 Chevrolet Tahoe	0.40	0.05	0.17	<0.01

Percent CV was calculated for all sets of repeat tests with the APHF in the loaded seat condition, and results ranged from 1.4 to 8.1 percent. This was less than tests with the 201HF, which resulted in percent CV ranging from 1.1 to 6.5 percent. Table 8 summarizes the percent CV results.

Table 8. Percent CV results calculated to compare headforms

	SB1		**SB2**		**SB3**		**HR1**	
	201HF	**APHF**	**201HF**	**APHF**	**201HF**	**APHF**	**201HF**	**APHF**
2018 Dodge Journey	6.5%	5.7%	3.3%	4.0%	2.7%	3.7%	5.5%	2.4%
2018 Toyota Sienna	5.7%	2.5%	2.3%	8.1%	1.1%	5.1%	4.2%	1.6%
2015 Chevrolet Tahoe	6.0%	2.5%	5.6%	1.4%	2.8%	6.7%	3.0%	2.8%

2.6.4 Discussion

One-hundred and five FMH impacts were conducted in this series using three different vehicle platforms. Three repeat tests were performed at each target location both with and without a load applied to the seat back. Both the 201HF and APHF were used to assess repeatability of the test with load applied. During the test series, damage was observed to the seat pans, seat back frames, and head restraint posts. As a result, new parts were used in every test to eliminate variability. Statistically higher HIC36 results were recorded in 6 of 12 sets of repeat impacts when a load was applied to the seat back, as compared to the unloaded condition, while the other 6 sets did not show a significant difference. Additionally, the HIC36 values when a load was applied had consistently lower percent CVs. Therefore, it was decided that the loaded condition would be used in future tests.

When comparing repeatability between headforms, both the 201HF and APHF had repeatable results with similar percent CV results less than 10 percent. Statistically different HIC36 results were recorded at 6 of 12 impact locations; and higher HIC36 results were obtained with the 201HF in 5 of those 6.

3.0 Development of a Lower B-pillar Test Procedure

3.1 Background

To develop a procedure that addresses head injuries from lower B-pillar impacts, FMH testing was conducted at a regulated impact point on the B-pillar (BP4) and a new location lower on the B-pillar toward the rear of the vehicle (P9-R). This new location was at the height of Plane 9, which is the lowest plane defined when establishing the B-pillar coordinate system in the upper interior test procedure of FMVSS No. 201. The plane is at the height of the lowest point on the bottom edge of the front window. Throughout testing, the front window was always lower than any other side windows for the vehicles tested. The impact location on this plane was chosen as it is the closest point to the CG-R location.[2] The underlying structure beneath the trim at the impact location is sheet metal.

The upper interior test procedure of FMVSS No. 201 was followed for establishing the vertical and horizontal approach angles at the BP4 and P9-R target shown in Figure 29. The standard defines the vertical approach angle limits as -10 and 50 degrees for the B-pillar structure. The horizontal limits are defined based on the CG-R and CG-F occupant positions. The horizontal approach angle is the angle between the +X axis (towards the rear of the vehicle) and the impact velocity vector projected onto the X-Y plane and measured in the counter-clockwise direction. The horizontal approach angle for a right-side B-pillar is limited to between 15 and 165 degrees.

Figure 29. Lower B-pillar impact locations

Vertical angles were found by following the upper interior test procedure of FMVSS No. 201 (not constrained to limits for the P9-R location) or were perpendicular for the APHF. Figure 30 shows the difference in vertical angles for the two headforms. The spherical shape of the APHF allowed for perpendicular (normal to the surface) impacts to the targets. The impact velocity

[2] CG-R, CG-F1 and CG-F2 are defined in TP-201U. The points represent the coordinates for head CG of the forward front seat position occupant (CG-F1), the aft front seat position occupant (CG-F2), and rear seat position occupant (CG-R) on both driver and passenger sides of the test vehicle.

used was 15 mph, as it is the test speed specified in the upper interior test procedure of FMVSS No. 201.

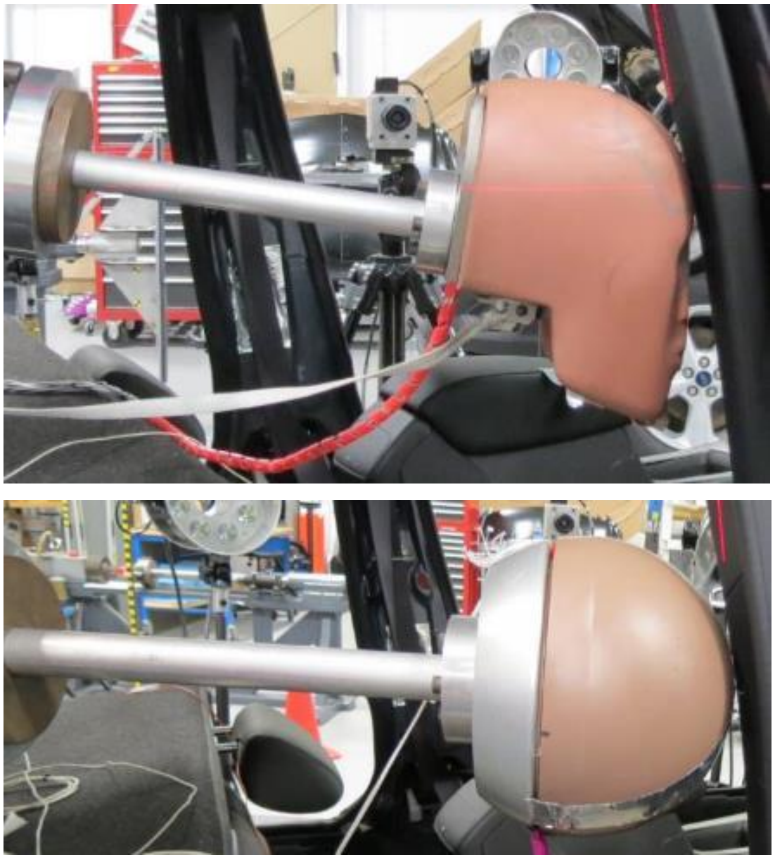


Figure 30. 201HF (top) versus APHF (bottom) vertical approach angles

3.2 Initial Test Series (CDB Nos. C01378 to C01468)

An initial B-pillar test series was conducted on passenger side trim components on a 2016 Honda Fit and 2016 Chevrolet Tahoe at 15 mph (24 kph) and at several horizontal and vertical approach angles. Impact locations were selected by identifying hard points under the trim. Impacts were conducted at the upper interior test procedure of FMVSS No. 201 impact location BP4 for comparison purposes, at the windowsill line (Plane 9) defined in the upper interior test procedure of FMVSS No. 201, and at the trim transition line (TT) to determine if overlap in the trim pieces could cause elevated HIC results. This initial test series showed no evidence of countermeasures lower on the B-pillar than the BP4 location in either vehicles trim design, B-pillar impacts exceeded the HIC36 limit of 1000 in most cases, and the APHF produced higher HIC results at the B-pillar impact locations compared to the 201HF for both vehicles tested. From the initial testing, a test procedure was drafted, and the Plane 9 impact location was chosen for additional testing.

3.3 Fleet Test Series (CDB Nos. C01486 to C01605)

The objective of the fleet test series was to evaluate a fleet of recent model year vehicles at the lower B-pillar impact location. This section details the test method and results of free-motion impacts on lower B-pillars using the 201HF and APHF to evaluate the head injury possibilities for rear seat occupants.

3.3.1 Test Matrix

The test matrix included two impact locations on the B-pillar: BP4 from the standard and the P9-R impact location lower on the B-pillar. Six vehicles were selected to represent the U.S. fleet and are listed in Table 9. Vehicle types included passenger cars, SUV's, and a truck. The vehicles were obtained from NHTSA's inventory of crash tested vehicles with the MDB into the driver side. Passenger side B-pillar and trim were tested in this series.

Table 9. Fleet study test vehicles

Test Vehicles
2016 Chevrolet Cruze (VIN# 1G1BC5SMXG7242432)
2016 Mazda CX-5 (VIN# JM3KE4BY4G0669264)
2017 Toyota Corolla (VIN# 2T1BURHEXHC750301)
2016 Chevrolet Malibu (VIN# 1G11B5SA2GU116636)
2016 Ford F-150 (VIN# 1FTEW1CG7GKD30154)
2016 Nissan Rogue (VIN# KNMAT2MV6GP613626)

The Chevrolet Cruze B-pillar trim consisted of a single piece; there was no energy absorption countermeasures, such as plastic ribbing, at the P9-R location. The Mazda CX-5 B-pillar trim consisted of upper and lower pieces with the trim transition above the windowsill height; there were no energy absorption countermeasures at the P9-R location. The Toyota Corolla B-pillar trim consisted of upper and lower pieces with the trim transition above the windowsill height; there was energy absorption countermeasures, consisting of ribs, designed into the plastic piece at the P9-R location. The Chevrolet Malibu B-pillar trim consisted of a single piece; there was a single rib at the P9-R impact position. The Ford F-150 B-pillar trim consisted of upper and lower pieces with the trim transition above the windowsill height; the B-pillar included a grab handle near the BP4 location, and there were energy absorption countermeasures designed into the plastic piece at the P9-R location. The Nissan Rogue B-pillar trim consisted of upper and lower trim pieces; there was a single rib at the P9-R impact position.

3.3.2 Test Method

The upper interior test procedure of FMVSS No. 201 was followed for testing at BP4 and as closely as possible for the P9-R impact location. BP4 was tested for comparison purposes. Vertical angles were found for the 201HF by following upper interior test procedure of 201 (not constrained to limit for P9-R location) or were perpendicular for APHF. All impacts were centered on the midsagittal plane of both headforms. The impact velocity was 15 mph.

3.3.3 Results

Appendix A, Table A2 lists all the test results. The APHF produced HIC36 values greater than 1000 at the P9-R location in five of six vehicles; the exception was the Chevrolet Cruze as illustrated in Figure 31. The APHF also produced HIC36 values less than 1000 at the BP4 location in five of six vehicles, with the exception being the Ford F-150 as illustrated in Figure 32. The 201HF produced HIC36 values greater than 1000 at the P9-R location in three vehicles and below the 80 percent threshold in the other three vehicles. It also produced HIC36 values at BP4 below the 80 percent threshold in five vehicles, while the HIC36 value at BP4 exceeded 1000 in the Ford F-150.

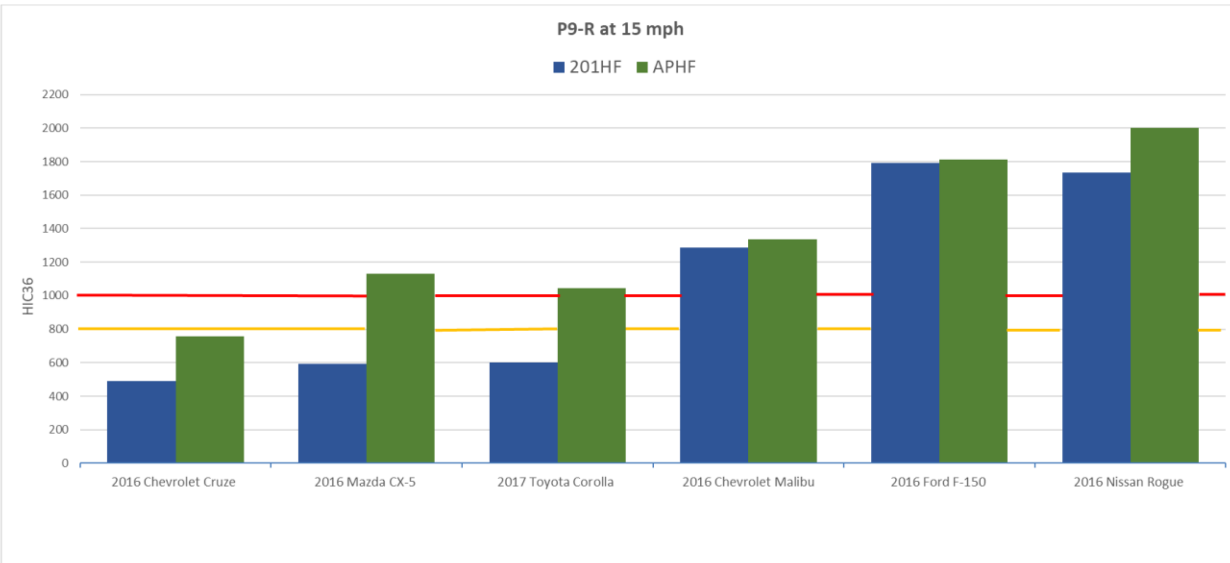


Figure 31. Lower B-pillar P9-R impact location fleet results

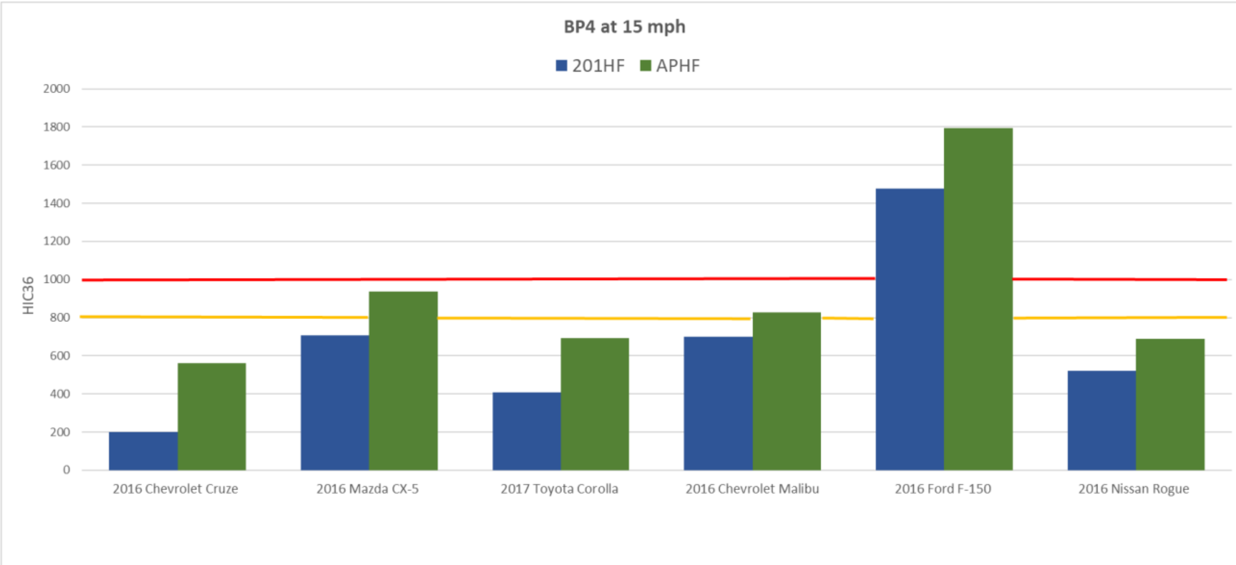


Figure 32. Lower B-pillar BP4 impact location fleet results

The results show higher HIC values for the APHF compared to the 201HF for both impact locations in the six vehicles. The APHF's hemispherical geometry allows for an impact velocity vector perpendicular to the trim surface resulting in a more severe test condition.

3.3.4 Discussion

The design differences between the two headforms lead to different approach angles. The APHF's hemi-spherical design allows for a more direct impact than the 201HF. In order to impact the 201HF within the forehead zone, the headform must be positioned at a more downward angle due to the relatively vertical B-pillar component, resulting in lower HIC values compared to the APHF.

The vehicles tested in this fleet study used plastic trim designed with energy management characteristics at the BP4 location. These integrated trim pieces were designed with a ribbed backing on the underside of the piece to fill the space between the trim and sheet metal that is intended to crush in a way that manages the FMH impact energy. The HIC results at BP4 showed that this concept is effective in producing HIC values that were below 80 percent of the IARV in five of six vehicles. The energy management ribbing was not always included at the P9-R location since it is out of the regulated test area.

3.4 Countermeasure Test Series (CDB Nos. C01606 to C01697)

Next, a study was initiated to investigate countermeasures that absorb enough energy to lower the baseline HIC values found in the fleet test series. The objective of the countermeasure test series was to find a countermeasure that lowers HIC to less than 800 for each impact location.

3.4.1 Test Matrix

Three vehicles were chosen from the fleet study that resulted in the highest HIC values from the baseline testing. The vehicles also encompassed a range of vehicle types: sedan, cross-over, and truck. The vehicles are listed in Table 10. The countermeasure materials used in the B-pillar testing were IMPAXX foam and O-Flex tubing, as described in section 2.4.1.

Table 10. Countermeasure test vehicles

Test Vehicles
2016 Chevrolet Malibu (VIN# 1G11B5SA2GU116636)
2016 Ford F-150 (VIN# 1FTEW1CG7GKD30154)
2016 Nissan Rogue (VIN# KNMAT2MV6GP613626)

3.4.2 Test Method

Countermeasure testing was limited to the P9-R target that was defined in the fleet study test series. P9-R was established on the rear corner of the trim following the upper interior test procedure of FMVSS No. 201 at the height of the horizontal plane. There were minimal energy absorption countermeasures, such as plastic ribbing, present at the P9-R location for these three vehicles. The underlying structure is sheet metal. There was a gap between the trim surface and underlying structure in the Y-axis measuring between 0.9 and 1.4 inches (23 and 36 mm) for the three vehicles.

Horizontal and vertical approach angles established for the 201HF and APHF in the baseline fleet study were used in the countermeasure test series. Figure 33 shows the difference in vertical angles for the two headforms for an IMPAXX countermeasure test. The spherical shape of the APHF allowed for perpendicular impacts to the target. All impacts were centered on the midsagittal plane for both headforms. The impact velocity used was 15 mph, as it is the test speed in the upper interior test procedure of FMVSS No. 201.

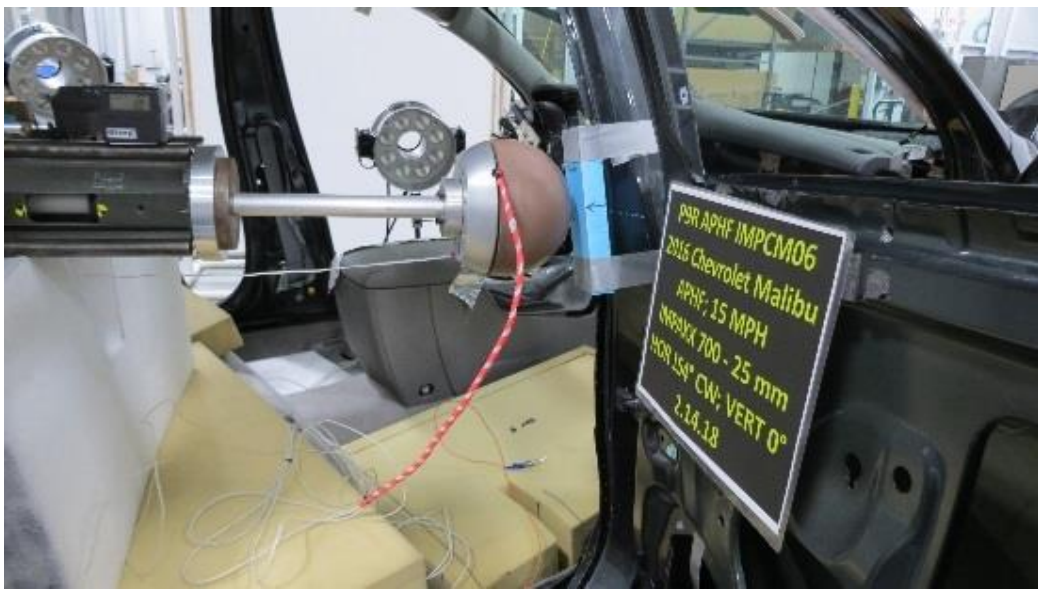


Figure 33. 201HF (top) versus APHF (bottom) vertical approach angles - IMPAXX foam

3.4.3 Results

The results from impacts to P9-R with countermeasure materials implemented are shown in Appendix A and graphically in Figures 34 and 35. The darker shade of color represents the baseline test and the lighter shade of color shows the lowest achieved HIC with countermeasures regardless of countermeasure used. Due to unfamiliarity with the countermeasure response, a trial and error approach was taken with the Chevrolet Malibu, the first vehicle tested in the series. This resulted in a high number of tests on this vehicle. With the gained experience, the process was streamlined for the two other vehicles. Baseline HIC36 values were reduced to less than 800 for both the 201HF and APHF in all three vehicles, and a reduction in HIC36 values below 800 was achieved in 15 of the 26 (58 percent) impacts performed. Of the 11 other impacts, 8 had some reduction in HIC.

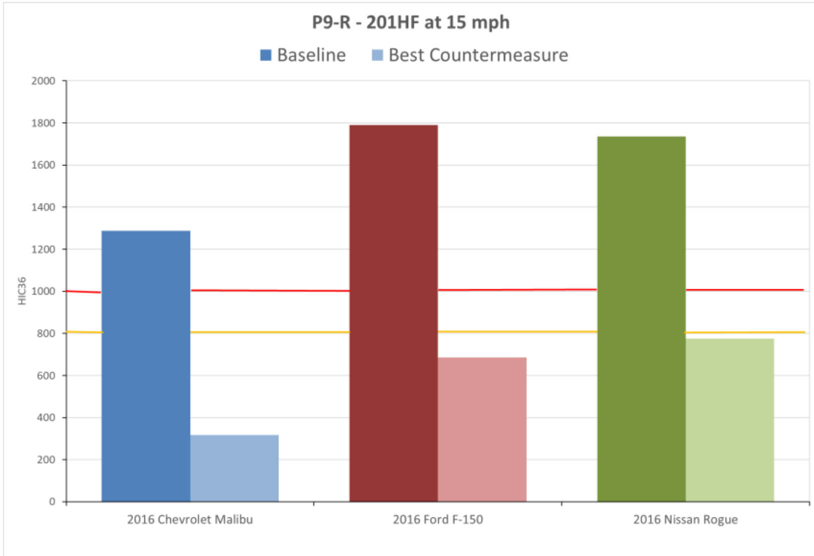


Figure 34. Countermeasure results at P9-R impact location with 201HF

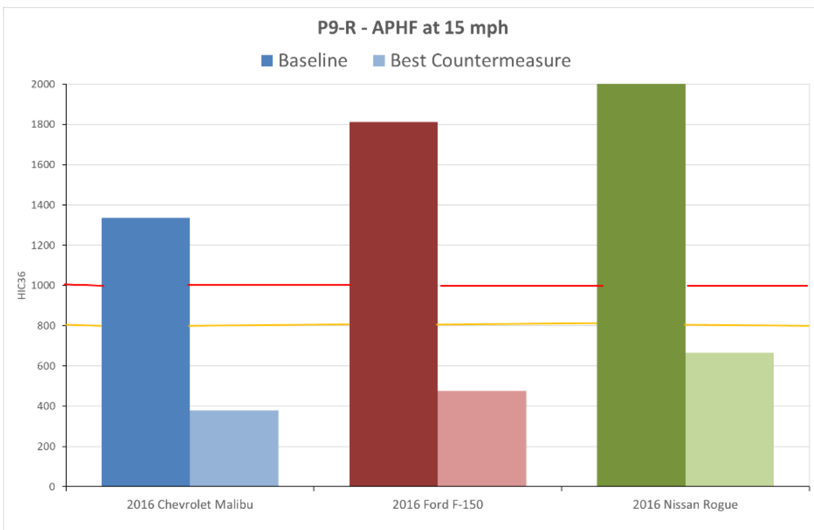


Figure 35. Countermeasure results at P9-R impact location with APHF

3.4.4 Discussion

The goal to reduce baseline HIC36 values below 800 at P9-R was achieved with two countermeasure products designed for energy management in the upper interior environment: O-Flex tubing and IMPAXX foam. The foam bezel from the Jeep Grand Cherokee was not tested on the B-pillar as it was better suited for a seat back environment. It is expected that manufacturers would add additional ribbing into the lower B-pillar trim as opposed to adding foams or other materials behind the trim.

The APHF typically required more countermeasure solutions to achieve the goal of reducing HIC36 values below 800. O-Flex was easiest to implement on the B-pillar substructure due to the various geometries available during the testing and the ability to stack individual pieces. The countermeasure tests were conducted with the countermeasure material secured directly to the underlying structure and covered with a section of the original trim part. Integral design of the countermeasure and trim part could improve the effectiveness in a production B-pillar design.

3.5 Additional Vehicle Models Test Series (CDB Nos. C01741 to C01825)

Testing at the lower B-pillar impact location continued with additional vehicle models (baseline vehicle without countermeasures). In this series of testing, newer MY vehicles were tested, and the test procedure was refined to include a section about avoiding obstructions, such as grab handles, door trim, or upper B-pillar trim.

3.5.1 Test Matrix

Six vehicle models were used for the lower B-pillar testing (Table 11). Each vehicle was struck with both the 201HF and APHF at a target speed of 15 mph. The test matrix consisted of 12 total impacts.

Table 11. Additional vehicle models test vehicles

Test Vehicles
2018 Dodge Journey (VIN# 3C4PDCAB8JT182880)
2018 Toyota Sienna (VIN# 5TDKZ3DC3JS902287)
2016 Chrysler 300 (VIN# 2C3CCAAG4GH134994)
2016 Ford F-250 (VIN# 1FT7W2460GEA19397)
2016 Toyota Tacoma (VIN# 5TFAX5GN1GX059512)
2015 Chevrolet Tahoe (VIN# 1GNSCAEC9FR116060)

3.5.2 Test Method

To conduct the impacts, the B-pillar procedure detailed in Appendix D was followed. For each vehicle, the P9-R impact location was determined with the trim installed. New trim parts were then installed before every test.

The upper interior test procedure of FMVSS No. 201, Section 12.7.1.A.2.v, states that in cases where there is an obstruction between the headform and impact target, the headform may be moved away from the midsagittal plane while remaining within the forehead impact zone. If the obstruction persists after moving the headform, the impact target may be moved to any location within a 0.98-inch (25-mm) radius of the original target center. This methodology was incorporated into the research test procedure that included maintaining the horizontal approach angle defined as a line between the CG-R location and the closest point on the vehicle B-pillar trim. The vertical approach angle was always found by following the upper interior test procedure of FMVSS No. 201 at the intended impact location.

3.5.3 Results

HIC results were tabulated by impact location, headform used, and vehicle model tested. In Appendix A, Table A4, HIC results for all lower B-pillar tests are given. Figure 36 shows HIC36 results for both the 201HF and APHF.

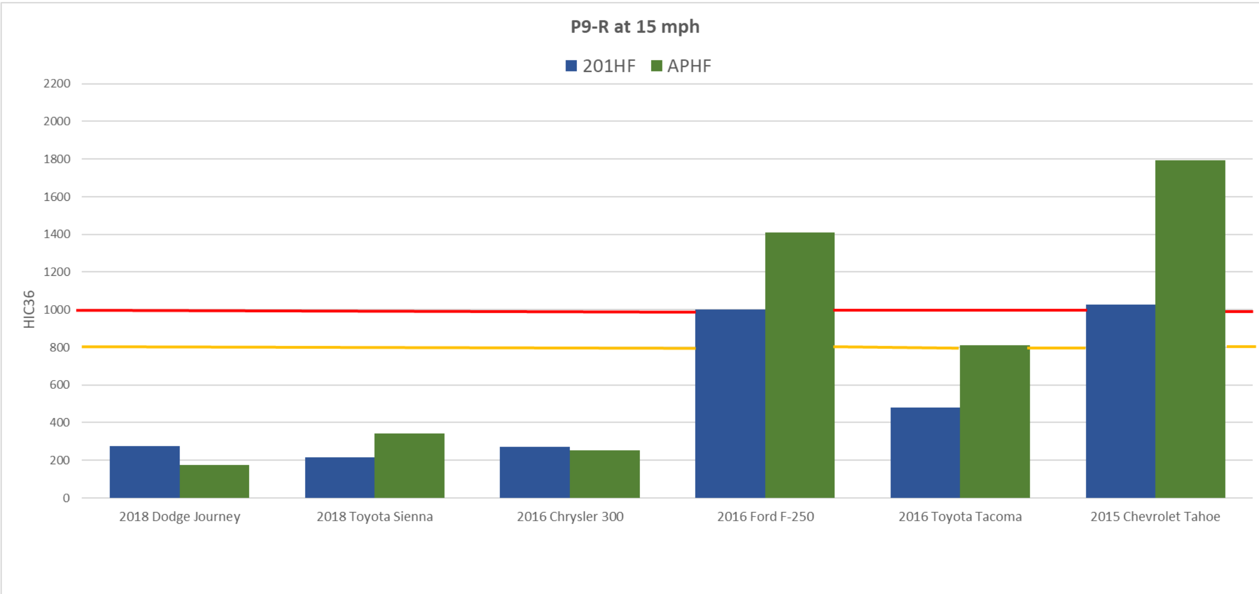


Figure 36. HIC results from lower B-pillar testing

A wide range in HIC results were observed for lower B-pillar tests at the P9-R impact location in this series. HIC36 results ranged from 174 to 1792 for the six vehicles tested. HIC36 results with the APHF were on average 60 percent higher than with 201HF in three vehicles. The trim depth did seem to show correlation to HIC36 values.

The headform alignment also affected the HIC results. Refining the test methodology to avoid obstructions allowed for impacts to more frequently occur off the midsagittal plane of the headform. This produced generally lower HIC responses compared to the previous series of lower B-pillar tests, which struck on the midsagittal plane of the headform.

3.5.4 Discussion

With the updated procedure, the P9-R impact location had to be adjusted for the headform to make first contact with the target for five of the six lower B-pillars tested. As an example, Figure 37 shows the Toyota Sienna adjusted P9-R target in red/white. The original impact location (shown with a black/yellow target) did not allow for the headform to make first contact with the target as it was obscured by the grab handle. Moving the target downward 0.98 inch (25 mm) allowed the headform trajectory to clear the obstruction and to be tested without interference.

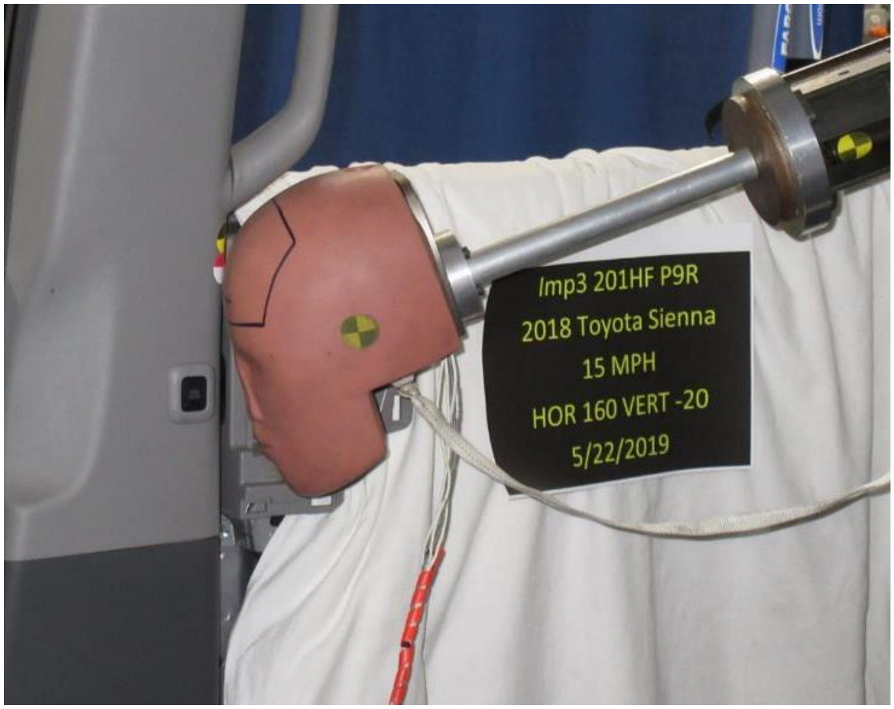


Figure 37. P9-R adjusted (red/white target) to avoid contact with a vehicle obstruction

Throughout this test series as the test procedure was refined to avoid obstructions, it was noted that many components were considered potential obstructions (grab handles, door handles, door trim, upper B-pillar trim) that should not be removed for testing. This was previously not always an option depending on the availability of parts from crashed vehicles. Thus, it was decided that future testing on lower B-pillars will use the updated test procedure found in Appendix D with the rear door closed, adjacent trim installed, and window fully down.

4.0 Summary

To evaluate head injury potential of production vehicles as rear seat occupant heads contact lower B-pillars and seat backs, vehicles were tested using a methodology based on the upper interior test procedure of FMVSS No. 201 with both the 201HF and APHF.

Seat back impact locations were chosen using engineering judgment that targeted various hard spots. Three targets were chosen on the seat back and one on the head restraint for each seat model. Tests series were completed on seat backs to refine the research test procedure, and it was found that there were elevated HIC results from contact to these surfaces and that countermeasures were feasible to implement into the seat back designs. It was also found that a loaded seat back condition, which is more realistic to a crash environment, produced more repeatable HIC36 responses than an unloaded seat back condition and was possible to incorporate into a free-motion impact test setup.

For lower B-pillars, a procedure was developed for a new location lower on the B-pillar toward the rear of the vehicle (P9-R). This new location was at the height of Plane 9 that is the lowest plane defined when establishing the B-pillar coordinate system in the upper interior test procedure of FMVSS No. 201. The plane is at the height of the lowest point on the bottom edge of the front window. The impact location on this plane was chosen as it is the closest point to the CG-R location that represents the rear occupant's head. The underlying structure beneath the trim at the impact location is sheet metal. Tests series were completed on lower B-pillars to refine the research test procedure, and it was found that there were elevated HIC results from contact to this location, that countermeasures were feasible to implement into the B-pillar trim, and that having the door closed and adjacent trim installed, which is more realistic to a crash environment, was possible to incorporate into a free-motion impact test setup.

References

62 FR 16725, § 571.201 Standard No. 201; Occupant protection in interior impact. Section 6, Requirements for upper interior components (Apr. 8, 1997). www.ecfr.gov/current/title-49/subtitle-B/chapter-V/part-571/subpart-B/section-571.201

Louden, A., Wietholter, K., & Duffy, S. J. (2017, January 25-27). *Lower interior impacts to seat backs and B-pillars* [PowerPoint]. 2017 SAE Government/Industry Meeting, Washington, DC. www.nhtsa.gov/sites/nhtsa.gov/files/documents/sae2017alouden.pdf

National Highway Traffic Safety Administration. (2016, January). *Laboratory test procedure for FMVSS No. 201U, occupant protection in interior impact -Upper interior head impact protection (Test Procedure No. TP-201U-02)*. www.nhtsa.gov/sites/nhtsa.gov/-files/documents/tp-201u-02_tag.pdf

Wietholter, K. (2019, April 3-5). *Update on lower interior impacts to seat backs and B-pillars* [PowerPoint]. 2019 SAE Government/Industry Meeting, Washington, DC. www.nhtsa.gov/sites/nhtsa.gov/files/documents/lower_interior_2019_sae_gim_040319_final-tag.pdf

Appendix A. Test Results

All FMH testing in this report used the HIC calculated from the resultant acceleration time histories and HIC36 (36-millisecond limit) as a measure of the potential for injury. A HIC36 value of 1000 is generally considered the threshold for serious injury and is the IARV used in reporting results. HIC36 values exceeding this IARV are shown in red and values above 80 percent are in orange. In addition, the HIC(d) transform was computed for all testing with the 201HF. Similarly, HIC(d) values exceeding the IARV of 1000 are shown in red and values above 80 percent are in orange. Note: a limited number of tests on the 2014 Honda Odyssey were conducted using a child pedestrian headform (CPHF). While these tests are not discussed in this report, they are in the NHTSA Component Database (CDB) and are included here for completeness.

Table A1. Initial test series results (CDB Nos. C01378 to C01468)

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	HIC36	HIC(d)
2011 Jeep Grand Cherokee (VIN 1J4RR4GG7BC555692)									
c01378	53	SB1	201HF	20	19.8	0	0	392	462
c01379	54	SB1	201HF	25	24.9	0	0	779	754
c01380	55	SB1	201HF	25	24.8	0	0	794	765
c01381	56	SB1	201HF	20	19.9	-10	0	382	454
c01382	57	SB1	201HF	25	24.8	-10	0	711	703
c01383	58	SB1	201HF	20	19.9	-10	20 CCW	322	410
c01384	59	SB1	201HF	25	24.9	-10	20 CCW	672	673
c01385	79	SB1	APHF	25	21.3	0	0	798	N/A
c01386	80	SB1	APHF	25	25.0	-15	0	708	N/A
c01387	60	SB2	201HF	20	20.0	-5	0	350	430
c01388	61	SB2	201HF	25	24.9	-5	0	720	710
c01389	62	SB2	201HF	20	19.9	0	0	379	452
c01390	64	SB2	201HF	25	24.9	0	0	782	756

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	HIC36	HIC(d)
c01391	65	SB2	201HF	20	20.0	-10	55 CW	94	237
c01392	66	SB2	201HF	20	19.9	-10	55 CW	184	305
c01393	67	SB2	201HF	25	24.8	-10	55 CW	385	457
c01394	68	SB2	201HF	20	20.0	-10	35 CW	281	379
c01395	69	SB2	201HF	25	24.8	-10	35 CW	565	592
c01396	70	SB2	201HF	20	20.0	-10	35 CW	233	342
c01397	71	SB2	201HF	25	24.9	-10	35 CW	477	526
c01398	81	SB2	APHF	25	25.5	-5	0	672	N/A
c01399	82	SB2	201HF	25	24.8	-10	0	625	638
c01400	83	SB3	201HF	25	24.6	18	0	876	827
c01401	84	SB3	APHF	25	24.6	35	0	910	N/A
c01402	72	HR1	201HF	20	20.0	-10	0	422	485
c01403	73	HR1	201HF	25	25.0	-10	0	728	716
c01404	78	HR1	APHF	25	24.7	-5	30 CCW	493	N/A
c01405	76	HR1	201HF	25	24.8	-25	25 CCW	661	665
c01406	77	HR1	APHF	25	16.5	-5	30 CCW	857	N/A
c01407	74	HR2	201HF	20	20.0	-10	0	458	512
c01408	75	HR2	201HF	25	24.9	-10	0	684	683

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	HIC36	HIC(d)
2014 Honda Odyssey (No VIN available)									
c01409	1	SB1	APHF	15	14.9	0	0	580	N/A
c01410	2	SB1	APHF	20	19.7	0	0	1136	N/A
c01411	15	SB1	CPHF	15	15.0	0	0	740	N/A
c01412	16	SB1	CPHF	20	20.0	0	0	1511	N/A
c01413	17	SB1	CPHF	25	24.8	0	0	2367	N/A
c01414	29	SB1	201HF	20	19.9	0	0	825	789
c01415	30	SB1	201HF	25	24.8	0	0	1285	1136
c01416	31	SB1	201HF	20	20.0	-5	0	719	709
c01417	32	SB1	201HF	25	24.8	-5	0	1077	797
c01418	33	SB1	201HF	20	20.0	-10	0	666	669
c01419	34	SB1	201HF	25	24.9	-10	0	1101	997
c01420	47	SB1	201HF	20	19.9	-5	20 CCW	667	669
c01421	48	SB1	201HF	25	24.7	-5	20 CCW	1007	926
c01422	89	SB1	APHF	25	25.1	0	0	1408	N/A
c01423	90	SB1	201HF	25	25.0	-25	0	785	759
c01424	3	SB2	APHF	15	14.8	0	0	187	N/A
c01425	4	SB2	APHF	20	19.9	0	0	438	N/A
c01426	5	SB2	APHF	25	24.6	0	0	767	N/A
c01427	18	SB2	CPHF	15	15.1	0	0	334	N/A

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	HIC36	HIC(d)
c01428	19	SB2	CPHF	20	20.1	0	0	778	N/A
c01429	20	SB2	CPHF	25	25.0	0	0	1330	N/A
c01430	35	SB2	201HF	20	19.9	0	0	325	441
c01431	36	SB2	201HF	25	24.9	0	0	672	674
c01432	37	SB2	201HF	20	20.0	-5	0	339	422
c01433	38	SB2	201HF	25	24.9	-5	0	721	711
c01434	41	SB2	201HF	20	20.1	-10	55 CW	757	737
c01435	42	SB2	201HF	25	25.0	-10	55 CW	1584	1361
c01436	43	SB2	201HF	20	20.1	-5	35 CW	668	671
c01437	44	SB2	201HF	25	24.9	-5	35 CW	1521	1314
c01438	45	SB2	201HF	20	20.1	-10	35 CW	535	570
c01439	46	SB2	201HF	25	25.0	-10	35 CW	1131	1019
c01440	49	SB2	201HF	20	19.9	-10	20 CCW	253	358
c01441	50	SB2	201HF	25	24.7	-10	20 CCW	492	537
c01442	87	SB2	201HF	25	24.9	-20	35 CW	1171	1050
c01443	88	SB2	APHF	25	25.8	-5	35 CW	1247	N/A
c01444	6	SB3	APHF	15	14.7	0	0	352	N/A
c01445	7	SB3	APHF	20	19.9	0	0	904	N/A
c01446	8	SB3	APHF	25	25.1	0	0	1373	N/A
c01447	21	SB3	CPHF	15	15.1	0	0	478	N/A

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	HIC36	HIC(d)
c01448	22	SB3	CPHF	20	20.1	0	0	1032	N/A
c01449	23	SB3	CPHF	25	25.0	0	0	2111	N/A
c01450	24	SB3	201HF	15	14.9	0	0	369	444
c01451	25	SB3	201HF	20	20.0	0	0	874	825
c01452	26	SB3	201HF	25	24.8	0	0	1606	1378
c01453	27	SB3	201HF	20	19.8	10	0	1055	963
c01454	28	SB3	201HF	25	24.8	10	0	2234	1852
c01455	39	SB3	201HF	20	20.0	2.5	0	719	709
c01456	40	SB3	201HF	20	20.0	7.5	0	948	881
c01457	85	SB3	APHF	25	25.1	25	0	1874	N/A
c01458	86	SB3	201HF	25	24.7	5	0	1550	1336
c01459	9	HR1	APHF	15	14.9	0	0	131	N/A
c01460	10	HR1	APHF	20	19.9	0	0	309	N/A
c01461	11	HR1	APHF	25	25.1	0	0	636	N/A
c01462	12	HR1	CPHF	15	15.0	0	0	149	N/A
c01463	13	HR1	CPHF	20	20.0	0	0	359	N/A
c01464	14	HR1	CPHF	25	24.8	0	0	704	N/A
c01465	51	HR1	201HF	20	19.8	-10	0	704	697
c01466	52	HR1	201HF	25	24.8	-10	0	1604	1376
c01467	91	HR1	201HF	25	24.7	-45	35 CW	996	918

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	HIC36	HIC(d)
c01468	92	HR1	APHF	25	24.7	-25	35 CW	687	N/A

Table A2. Fleet test series results (CDB Nos. C01486 to C01605)

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	HIC36	HIC(d)
2016 Chevrolet Cruze (VIN 1G1BC5SMXG7242432)									
c01486	F1	BP4	201HF	15	14.97	-2	159	200	317
c01487	F2	BP4	APHF	15	15.02	0	159	563	N/A
c01488	F3	P9-R	201HF	15	15.03	-8	157	490	536
c01489	F4	P9-R	APHF	15	15.03	0	157	758	N/A
c01490	F5	SB1	201HF	20	20.11	-3	0	557	586
c01491	F6	SB1	201HF	25	24.88	-3	0	955	887
c01492	F7	SB1	APHF	20	20.15	0	0	559	N/A
c01493	F8	SB1	APHF	25	25.26	0	0	968	N/A
c01494	F9	SB2	201HF	20	20.06	-4	15 CW	740	724
c01495	F10	SB2	201HF	25	24.92	-4	15 CW	1496	1295
c01496	F11	SB2	APHF	20	20.25	0	15 CW	831	N/A
c01497	F12	SB2	APHF	25	25.18	0	15 CW	1554	N/A

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	HIC36	HIC(d)
c01498	F13	SB3	201HF	20	19.77	8	0	720	709
c01499	F14	SB3	201HF	25	24.65	8	0	1318	1161
c01500	F15	SB3	APHF	20	19.69	25	0	717	N/A
c01501	F16	SB3	APHF	25	24.67	25	0	1314	N/A
c01502	F17	HR1	201HF	20	20.27	-35	0	635	645
c01503	F18	HR1	201HF	25	24.83	-35	0	1300	1147
c01504	F19	HR1	APHF	20	20.04	-15	0	568	N/A
c01505	F20	HR1	APHF	25	25.16	-15	0	1141	N/A
2016 Chevrolet Malibu (VIN 1G11B5SAGU116636)									
c01506	F61	BP4	201HF	15	14.78	-3	154	700	694
c01507	F62	BP4	APHF	15	14.74	0	154	828	N/A
c01508	F63	P9-R	201HF	15	14.77	-10	154	1288	1138
c01509	F64	P9-R	APHF	15	14.99	0	154	1336	N/A
c01510	F65	SB1	201HF	20	19.83	-13	0	563	591
c01511	F66	SB1	201HF	25	24.75	-13	0	1091	990
c01512	F67	SB1	APHF	20	19.89	0	0	626	N/A
c01513	F68	SB1	APHF	25	25.12	0	0	1284	N/A
c01514	F69	SB2	201HF	20	19.94	-12	0	531	567
c01515	F70	SB2	201HF	25	24.87	-12	0	1024	939
c01516	F71	SB2	APHF	20	19.96	0	0	584	N/A

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	HIC36	HIC(d)
c01517	F72	SB2	APHF	25	24.99	0	0	1281	N/A
c01518	F73	SB3	201HF	20	19.77	10	0	370	446
c01519	F74	SB3	201HF	25	24.88	10	0	769	747
c01520	F75	SB3	APHF	20	19.83	35	0	487	N/A
c01521	F76	SB3	APHF	25	24.35	35	0	966	N/A
c01522	F77	HR1	201HF	20	19.91	-32	0	606	624
c01523	F78	HR1	201HF	25	24.61	-32	0	1316	1160
c01524	F79	HR1	APHF	20	19.89	-19	0	541	N/A
c01525	F80	HR1	APHF	25	24.85	-19	0	1001	N/A
2016 Ford F-150 (VIN 1FTEW1CG7GKD30154)									
c01526	F81	BP4	201HF	15	14.48	-10	157	1477	1281
c01527	F82	BP4	APHF	15	14.5	0	157	1795	N/A
c01528	F83	P9-R	201HF	15	14.51	-10	157	1791	1518
c01529	F84	P9-R	APHF	15	14.61	0	157	1811	N/A
c01530	F85	SB1	201HF	20	19.93	-15	0	502	545
c01531	F86	SB1	201HF	25	24.73	-15	0	862	817
c01532	F87	SB1	APHF	20	20.07	0	0	608	N/A
c01533	F88	SB1	APHF	25	25.1	0	0	1050	N/A
c01534	F89	SB2	201HF	20	19.94	-15	0	529	566
c01535	F90	SB2	201HF	25	24.83	-15	0	825	789

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	HIC36	HIC(d)
c01536	F91	SB2	APHF	20	19.91	0	0	507	N/A
c01537	F92	SB2	APHF	25	24.77	0	0	1062	N/A
c01538	F93	SB3	201HF	20	19.79	5	0	314	403
c01539	F94	SB3	201HF	25	24.97	5	0	665	668
c01540	F95	SB3	APHF	20	20.09	0	0	428	N/A
c01541	F96	SB3	APHF	25	25.06	0	0	849	N/A
c01542	F97	HR1	201HF	20	19.77	-30	0	914	856
c01543	F98	HR1	201HF	25	24.57	-30	0	1684	1437
c01544	F99	HR1	APHF	20	20.13	0	0	436	N/A
c01545	F100	HR1	APHF	25	24.95	0	0	821	N/A
2016 Mazda CX-5 (VIN JM3KE4BY4G0669264)									
c01546	F21	BP4	201HF	15	14.98	-6	155	708	701
c01547	F22	BP4	APHF	15	15.23	0	155	936	N/A
c01548	F23	P9-R	201HF	15	14.9	-10	155	591	612
c01549	F24	P9-R	APHF	15	15.09	0	155	1132	N/A
c01550	F25	SB1	201HF	20	20.05	-6	0	247	353
c01551	F26	SB1	201HF	25	25.03	-6	0	493	538
c01552	F27	SB1	APHF	20	20.29	0	0	376	N/A
c01553	F28	SB1	APHF	25	25.41	0	0	581	N/A
c01554	F29	SB2	201HF	20	20.07	-10	20 CW	216	329

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	HIC36	HIC(d)
c01555	F30	SB2	201HF	25	25.02	-10	20 CW	455	508
c01556	F31	SB2	APHF	20	20.17	0	20 CW	230	N/A
c01557	F32	SB2	APHF	25	25.41	0	20 CW	421	N/A
c01558	F33	SB3	201HF	20	20.13	-6	0	445	502
c01559	F34	SB3	201HF	25	24.92	-6	0	1074	977
c01560	F35	SB3	APHF	20	20.01	14	0	541	N/A
c01561	F36	SB3	APHF	25	25.03	14	0	1012	N/A
c01562	F37	HR1	201HF	20	20.11	-20	20 CW	443	501
c01563	F38	HR1	201HF	25	24.74	-20	20 CW	833	794
c01564	F39	HR1	APHF	20	20.27	-35	20 CW	218	N/A
c01565	F40	HR1	APHF	25	25.23	-35	20 CW	330	N/A
2016 Nissan Rogue (VIN KNMAT2MV6GP613626)									
c10566	F101	BP4	201HF	15	14.92	-10	158	523	561
c01567	F102	BP4	APHF	15	14.92	0	158	690	N/A
c01568	F103	P9-R	201HF	15	15.02	-10	158	1736	1476
c01569	F104	P9-R	APHF	15	14.77	0	158	2003	N/A
c01570	F105	SB1	201HF	20	19.78	-17	0	551	582
c01571	F106	SB1	201HF	25	24.58	-17	0	956	888
c01572	F107	SB1	APHF	20	19.65	0	0	664	N/A
c01573	F125	SB1	APHF	25	25.05	0	0	1029	N/A

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	HIC36	HIC(d)
c01574	F109	SB2	201HF	20	19.72	-13	0	488	534
c01575	F110	SB2	201HF	25	24.61	-13	0	952	885
c01576	F111	SB2	APHF	20	20	0	0	593	N/A
c01577	F123	SB2	APHF	25	25.24	0	0	680	N/A
c01578	F113	SB3	201HF	20	19.73	6	6 CW	625	638
c01579	F114	SB3	201HF	25	24.76	6	6 CW	1207	1077
c01580	F115	SB3	APHF	20	20.2	15	6 CW	571	N/A
c01581	F124	SB3	APHF	25	24.98	15	6 CW	826	N/A
c01582	F117	HR1	201HF	20	19.51	-40	0	626	639
c01583	F118	HR1	201HF	25	24.31	-40	0	1365	1196
c01584	F121	HR1	APHF	20	19.94	-25	0	655	N/A
c01585	F122	HR1	APHF	25	24.78	-25	0	684	N/A
2017 Toyota Corolla (VIN 2T1BURHEXHC750301)									
c01586	F41	BP4	201HF	15	14.87	-4	145	409	475
c01587	F42	BP4	APHF	15	15.17	0	145	691	N/A
c01588	F43	P9-R	201HF	15	14.95	-10	145	602	621
c01589	F44	P9-R	APHF	15	15.02	0	145	1045	N/A
c01590	F45	SB1	201HF	20	19.97	-10	0	389	460
c01591	F46	SB1	201HF	25	24.93	-10	0	654	660
c01592	F47	SB1	APHF	20	20.14	0	0	583	N/A

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	HIC36	HIC(d)
c01593	F48	SB1	APHF	25	25.15	0	0	940	N/A
c01594	F49	SB2	201HF	20	20.03	-10	13 CW	291	386
c01595	F50	SB2	201HF	25	24.91	-10	13 CW	578	602
c01596	F51	SB2	APHF	20	20.05	0	13 CW	398	N/A
c01597	F52	SB2	APHF	25	25.18	0	13 CW	871	N/A
c01598	F53	SB3	201HF	20	19.7	14	0	355	434
c01599	F54	SB3	201HF	25	24.62	14	0	793	765
c01600	F55	SB3	APHF	20	19.3	35	0	411	N/A
c01601	F56	SB3	APHF	25	24.43	35	0	859	N/A
c01602	F57	HR1	201HF	20	19.86	-45	0	794	764
c01603	F58	HR1	201HF	25	24.77	-45	0	1703	1452
c01604	F59	HR1	APHF	20	20.16	-18	0	428	N/A
c01605	F60	HR1	APHF	25	25.27	-18	0	963	N/A

Table A3. Countermeasure test series results (CDB Nos. 01606 to C01697)

CDB Number	**Impact (Imp) Test Number**	**Impact Position**	**Countermeasure**	**Countermeasure Thickness**	**Headform**	**Target Speed (mph)**	**Actual Speed (mph)**	**Vertical Impactor Approach Angle (deg)**	**Horizontal Impactor Approach Angle (deg)**	**HIC36**	**HIC(d)**
2016 Chevrolet Cruze (VIN 1G1BC5SMXG7242432)											
c01606	31	SB1	Coastal Automotive IMPAXX 700 with foam/cover 25 mm total	25 mm total	201HF	25	24.5	-3	0	795	766
c01607	32	SB1	Coastal Automotive IMPAXX 700 25 mm total	25 mm total	201HF	25	24.6	-3	0	942	877
c01608	33	SB1	Coastal Automotive IMPAXX 700 with foam/cover 25 mm total	25 mm total	APHF	25	25.04	0	0	1038	N/A
c01609	34	SB1	Coastal Automotive IMPAXX 700 with foam/cover 50 mm total	50 mm total	APHF	25	25.11	0	0	851	N/A

CDB Number	Impact (Imp) Test Number	Impact Position	Countermeasure	Countermeasure Thickness	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	HIC36	HIC(d)
c01610	35	SB1	Coastal Automotive IMPAXX 700 with foam/cover 64 mm total	64 mm total	APHF	25	25.1	0	0	867	N/A
c01611	36	SB1	Coastal Automotive IMPAXX 700 50 mm total	50 mm total	APHF	25	25.05	0	0	853	N/A
c01612	37	SB1	Jeep Black Foam 38 mm	38 mm	201HF	25	24.62	-3	0	857	813
c01613	38	SB1	Jeep Black Foam with insert piece 38 mm	38 mm	201HF	25	24.74	-3	0	944	879
c01614	39	SB1	Jeep Black Foam with insert piece 38 mm	38 mm	APHF	25	25.17	0	0	865	N/A

CDB Number	Impact (Imp) Test Number	Impact Position	Countermeasure	Countermeasure Thickness	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	HIC36	HIC(d)
c01615	40	SB1	O-Flex 23x23-2802 square tubing Adjacent to 15x30-2103 + 10x20-1133 over lower tube with IMPAXX 700 insert piece	23 mm x 23 mm. 15 mm x 30 mm 10 mm x 20 mm	201HF	25	24.72	-3	0	934	871
c01616	41	SB1	O-Flex 23x23-2802 + 23x23-2802 square tubing Adjacent to 15x30-2103 + 10x20-1133 over lower tube with IMPAXX 700 insert piece	23 mm x 23 mm 23 mm x 23 mm. 15 mm x 30 mm 10 mm x 20 mm	201HF	25	24.71	-3	0	751	733
c01617	42	SB1	O-Flex 23x23-2802 + (2)15x30-1103 tubing Adjacent to 15x30-2103 + 10x20-1133 over lower tube with IMPAXX 700 insert piece	23 mm x 23 mm 15 mm x 30 mm 15 mm x 30 mm. 15 mm x 30 mm 10 mm x 20 mm	APHF	25	25.09	0	0	746	N/A

CDB Number	Impact (Imp) Test Number	Impact Position	Countermeasure	Countermeasure Thickness	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	HIC36	HIC(d)
c01618	43	SB2	Coastal Automotive IMPAXX 700 50 mm	50 mm total	201HF	25	24.63	-4	15 CW	952	884
c01619	44	SB2	Coastal Automotive IMPAXX 700 50 mm	50 mm total	APHF	25	25.13	0	15 CW	1030	N/A
c01620	45	SB2	Coastal Automotive IMPAXX 700 65 mm	65 mm total	APHF	25	25.08	0	15 CW	893	N/A
c01621	46	SB2	Coastal Automotive IMPAXX 700 65 mm	65 mm total	201HF	25	24.59	-4	15 CW	701	695
c01622	47	SB2	Jeep Bezel Foam 36 mm	36 mm	201HF	25	24.67	-4	15 CW	1061	967
c01623	48	SB2	Jeep Bezel Foam 36mm	36 mm	APHF	25	25.15	0	15 CW	1077	N/A

CDB Number	Impact (Imp) Test Number	Impact Position	Countermeasure	Countermeasure Thickness	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	HIC36	HIC(d)
c01624	80	SB2	O-Flex 23x23-2103 square tubing over 23x23-2103 square tubing	23 mm x 23 mm 23 mm x 23 mm.	201HF	25	24.79	-4	15 CW	1310	1154
c01625	81	SB2	O-Flex 23x23-2103 square tubing over 23x23-2103 square tubing	23 mm x 23 mm 23 mm x 23 mm	201HF	25	24.64	-4	15 CW	1053	961
c01626	82	SB2	O-Flex 28x28-3802 square tubing over 28x28-3802 square tubing	28 mm x 28 mm 28 mm x 28 mm	201HF	25	24.75	-4	15 CW	709	701
c01627	83	SB2	O-Flex 28x28-3802 square tubing over 28x28-3802 square tubing	28 mm x 28 mm 28 mm x 28 mm	APHF	25	25.46	0	15 CW	826	N/A
c01628	51	SB3	Coastal Automotive IMPAXX 700 65 mm total	65 mm total	201HF	25	24.55	8	0	731	718

CDB Number	Impact (Imp) Test Number	Impact Position	Countermeasure	Countermeasure Thickness	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	HIC36	HIC(d)
c01629	52	SB3	Coastal Automotive IMPAXX 700 65 mm total	65 mm total	APHF	25	24.78	25	0	843	N/A
c01630	53	SB3	Jeep Bezel Foam 35 mm	35 mm	201HF	25	24.63	8	0	759	739
c01631	54	SB3	Jeep Bezel Foam 35 mm	35 mm	APHF	25	24.58	25	0	883	N/A
c01632	55	HR1	Coastal Automotive IMPAXX 700 65 mm total	65 mm total	201HF	25	24.5	-35	0	594	615
c01633	56	HR1	Coastal Automotive IMPAXX 700 65 mm total	65 mm total	APHF	25	25.38	-15	0	478	N/A
c01634	57	HR1	Coastal Automotive IMPAXX 700 25 mm total	25 mm total	201HF	25	24.64	-35	0	1062	967
c01635	58	HR1	Coastal Automotive IMPAXX 700 25 mm total	25 mm total	APHF	25	25.67	-15	0	748	N/A

CDB Number	Impact (Imp) Test Number	Impact Position	Countermeasure	Countermeasure Thickness	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	HIC36	HIC(d)
2016 Chevrolet Malibu (VIN 1G11B5SAGU116636)											
c01636	1	P9-R	Coastal Automotive IMPAXX 300 25 mm	33 mm total 25 mm to groove	201HF	15	14.83	-10	154	964	894
c01637	2	P9-R	Coastal Automotive IMPAXX 300 50 mm	50 mm total 42 mm to groove	201HF	15	14.68	-10	154	318	406
c01638	3	P9-R	Coastal Automotive IMPAXX 300 50 mm	50 mm total	APHF	15	14.88	0	154	822	N/A
c01639	4	P9-R	Coastal Automotive IMPAXX 700 25 mm	31 mm total 25 mm to groove	201HF	15	14.96	-10	154	491	537
c01640	5	P9-R	Coastal Automotive IMPAXX 700 25 mm	32 mm total 25 mm to groove	APHF	15	14.97	0	154	1521	N/A
c01641	6	P9-R	Coastal Automotive IMPAXX 700 25 mm	25 mm (no groove)	APHF	15	15.19	0	154	1643	N/A

CDB Number	Impact (Imp) Test Number	Impact Position	Countermeasure	Countermeasure Thickness	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	HIC36	HIC(d)
c01642	8	P9-R	Coastal Automotive IMPAXX 700 50 mm	50 mm total	APHF	15	14.93	0	154	406	N/A
c01643	9	P9-R	O-Flex 23x23-2103 square tubing	23 mm x 23mm	201HF	15	14.94	-10	154	670	672
c01644	11	P9-R	O-Flex 23x23-2103 square tubing with trim installed	23 mm x 23mm	201HF	15	14.85	-10	154	1216	1084
c01645	12	P9-R	O-Flex 23x23-2103 square tubing	23 mm x 23mm	APHF	15	14.87	0	154	1243	N/A
c01646	13	P9-R	O-Flex 10x20-1103 rectangular tubing over 23x23-2103 square tubing	10 mm x 20 mm 23 mm x 23 mm	APHF	15	14.92	0	154	632	N/A

CDB Number	Impact (Imp) Test Number	Impact Position	Countermeasure	Countermeasure Thickness	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	HIC36	HIC(d)
c01647	14	P9-R	O-Flex 10x20-1103 rectangular tubing over 23x23-2103 square tubing with trim plastic piece	10 mm x 20 mm 23 mm x 23 mm	APHF	15	14.92	0	154	661	N/A
c01648	15	P9-R	O-Flex 23x23-2103 square tubing with trim plastic piece	23 mm x 23mm	201HF	15	15.06	-10	154	581	605
c01649	17	P9-R	Coastal Automotive IMPAXX 700 25 mm with trim plastic piece	32 mm total 25 mm to groove	201HF	15	14.9	-10	154	472	523
c01650	18	P9-R	Coastal Automotive IMPAXX 700 50 mm with trim plastic piece	50 mm total	APHF	15	14.89	0	154	380	N/A

CDB Number	Impact (Imp) Test Number	Impact Position	Countermeasure	Countermeasure Thickness	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	HIC36	HIC(d)
c01651	19	P9-R	O-Flex 23x23-2103 square tubing with trim plastic piece	23 mm x 23mm	APHF	15	14.92	0	154	1844	N/A
2016 Ford F-150 (VIN 1FTEW1CG7GKD30154)											
c01652	20	P9-R	Coastal Automotive IMPAXX 700 25 mm with trim plastic piece	31 mm total 25 mm to groove	201HF	15	14.58	-10	157	787	760
c01653	21	P9-R	Coastal Automotive IMPAXX 700 50 mm with trim plastic piece	50 mm total	APHF	15	14.5	0	157	821	N/A
c01654	23	P9-R	Coastal Automotive IMPAXX 700 60 mm with trim plastic piece	60 mm total	APHF	15	14.63	0	157	961	N/A

CDB Number	Impact (Imp) Test Number	Impact Position	Countermeasure	Countermeasure Thickness	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	HIC36	HIC(d)
c01655	24	P9-R	O-Flex 23x23-2802 square tubing with trim plastic piece	23 mm x 23mm	APHF	15	14.7	0	157	1365	N/A
c01656	25	P9-R	O-Flex 23x23-2802 square tubing over 15x30-2103 rectangular tubing with trim plastic piece	23 mm x 23 mm 15 mm x 30 mm	APHF	15	14.67	0	157	475	N/A
c01657	26	P9-R	O-Flex 23x23-2802 square tubing with trim plastic piece	23 mm x 23mm	201HF	15	14.44	-10	157	686	684
c01658	59	SB1	Coastal Automotive IMPAXX 700 50 mm total	50 mm total	201HF	25	24.7	-15	0	702	696
c01659	60	SB1	Coastal Automotive IMPAXX 700 50 mm total	50 mm total	APHF	25	25.47	0	0	890	N/A

CDB Number	Impact (Imp) Test Number	Impact Position	Countermeasure	Countermeasure Thickness	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	HIC36	HIC(d)
c01660	61	SB1	Coastal Automotive IMPAXX 700 65 mm total	65 mm total	APHF	25	25.31	0	0	980	N/A
c01661	62	SB1	Jeep Bezel Foam 35 mm	35 mm	201HF	25	24.77	-15	0	903	848
c01662	63	SB1	Jeep Bezel Foam 35 mm	35 mm	APHF	25	25.23	0	0	1207	N/A
c01663	64	SB1	O-Flex 23x23-2103 square tubing over 23x23-2103 square tubing Adjacent to 25 mm IMPAXX 700	23 mm x 23 mm 23 mm x 23 mm. 25 mm	201HF	25	24.71	-15	0	726	714
c01664	65	SB1	O-Flex 23x23-2103 square tubing over 23x23-2103 square tubing Adjacent to 25 mm IMPAXX 700	23 mm x 23 mm 23 mm x 23 mm. 25 mm	APHF	25	25.38	0	0	840	N/A

CDB Number	Impact (Imp) Test Number	Impact Position	Countermeasure	Countermeasure Thickness	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	HIC36	HIC(d)
c01665	79	SB1	O-Flex 28x28 square tubing over 28x28 square tubing Adjacent to 25 mm IMPAXX 700	28 mm x 28 mm 28 mm x 28 mm. 25 mm	APHF	25	25.4	0	0	854	N/A
c01656	66	SB2	Coastal Automotive IMPAXX 700 50 mm total	50 mm total	201HF	25	24.76	-15	0	649	656
c01667	67	SB2	Coastal Automotive IMPAXX 700 50 mm total	50 mm total	APHF	25	25.66	0	0	734	N/A
c01668	68	SB2	Jeep Bezel Foam 35 mm	35 mm	201HF	25	24.75	-15	0	955	887
c01669	69	SB2	Jeep Bezel Foam 35 mm	35 mm	APHF	25	25.32	0	0	1169	N/A
c01670	70	HR1	Coastal Automotive IMPAXX 700 50 mm total	50 mm total	201HF	25	24.67	-30	0	1841	1555

CDB Number	Impact (Imp) Test Number	Impact Position	Countermeasure	Countermeasure Thickness	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	HIC36	HIC(d)
c01671	71	HR1	Coastal Automotive IMPAXX 700 50 mm total	50 mm total	201HF	25	24.68	-30	0	1811	1533
c01672	72	HR1	Coastal Automotive IMPAXX 700 75 mm total	75 mm total	201HF	25	24.63	-30	0	1073	976
c01673	73	HR1	Coastal Automotive IMPAXX 700 75 mm total Adjacent to 50 mm IMPAXX 700	75 mm total 50 mm	201HF	25	24.63	-30	0	979	905
c01674	74	HR1	Coastal Automotive IMPAXX 700 75 mm total	75 mm total	201HF	25	24.59	0	0	1112	1006
c01675	75	HR1	Coastal Automotive IMPAXX 700 50 mm total	50 mm total	201HF	25	24.71	0	0	1558	1342

CDB Number	Impact (Imp) Test Number	Impact Position	Countermeasure	Countermeasure Thickness	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	HIC36	HIC(d)
c01676	76	HR1	O-Flex 23x23-2103 square tubing over 23x23-2103 square tubing Adjacent to 50 mm IMPAXX 700	23 mm x 23 mm 23 mm x 23 mm. 50 mm	APHF	25	25.35	-30	0	378	N/A
c01677	77	HR1	O-Flex 28x28-2102 square tubing 28x28-2103 square tubing Adjacent to IMPAXX 700 25 mm	28 mm x 28 mm 28 mm x 28 mm. 25 mm	APHF	25	25.26	-30	0	641	N/A
c01678	78	HR1	O-Flex 23x23-2103 square tubing over 23x23-2103 square tubing	23 mm x 23 mm 23 mm x 23 mm	APHF	25	25.53	0	0	370	N/A

CDB Number	Impact (Imp) Test Number	Impact Position	Countermeasure	Countermeasure Thickness	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	HIC36	HIC(d)
2016 Nissan Rogue (VIN KNMAT2MV6GP613626)											
c01679	27	P9-R	Coastal Automotive IMPAXX 700 25 mm with trim plastic piece	31 mm total 25 mm to groove	201HF	15	15.27	-10	158	811	778
c01680	28	P9-R	Coastal Automotive IMPAXX 700 50 mm with trim plastic piece	50 mm total	APHF	15	15.21	0	158	666	N/A
c01681	29	P9-R	O-Flex 23x23-2802 square tubing Adjacent to 15x30-1103 over off-axis metal frame with trim plastic piece	23 mm x 23mm	201HF	15	15.19	-10	158	774	751
c01682	30	P9-R	O-Flex 23x23-2802 square tubing over 15x30-2103 rectangular tubing	23 mm x 23 mm 15 mm x 30 mm	APHF	15	15.22	0	158	786	N/A

CDB Number	Impact (Imp) Test Number	Impact Position	Countermeasure	Countermeasure Thickness	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	HIC36	HIC(d)
			with trim plastic piece								
c01683	84	SB1	Coastal Automotive IMPAXX 700 50 mm total	50 mm total	201HF	25	24.85	-17	0	481	529
c01684	85	SB1	O-Flex 23x23-2103 square tubing over 23x23-2103 square tubing	23 mm x 23 mm 23 mm x 23 mm	201HF	25	24.85	-17	0	434	494
c01685	86	SB1	O-Flex 23x23-2103 square tubing Adjacent to 23x23-2103 square tubing	23 mm x 23 mm. 23 mm x 23 mm	201HF	25	24.88	-17	0	640	649
c01686	87	SB1	Coastal Automotive IMPAXX 700 50 mm total	50 mm total	APHF	25	25.46	0	0	777	N/A

CDB Number	Impact (Imp) Test Number	Impact Position	Countermeasure	Countermeasure Thickness	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	HIC36	HIC(d)
c01687	88	SB1	O-Flex 23x23-2103 square tubing over 23x23-2103 square tubing Adjacent to 28x28-3802 square tubing.	23 mm x 23 mm 23 mm x 23 mm. 28 mm x 28 mm	APHF	25	25.34	0	0	671	N/A
c01688	89	SB2	Coastal Automotive IMPAXX 700 50 mm total	50 mm total	201HF	25	24.78	-13	0	439	497
c01689	90	SB2	O-Flex 23x23-2103 square tubing Adjacent to 23x23-2103 square tubing	23 mm x 23 mm. 23 mm x 23 mm	201HF	25	24.76	-13	0	561	589
c01690	91	SB3	Coastal Automotive IMPAXX 700 50 mm total	50 mm total	201HF	25	24.69	6	6 CW	716	706

CDB Number	Impact (Imp) Test Number	Impact Position	Countermeasure	Countermeasure Thickness	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	HIC36	HIC(d)
c01691	92	SB3	O-Flex 23x23-2103 square tubing over 23x23-2103 square tubing	23 mm x 23 mm 23 mm x 23 mm.	201HF	25	24.71	6	6 CW	718	708
c01692	93	SB3	Coastal Automotive IMPAXX 700 25 mm total	25 mm total	APHF	25	25.33	15	6 CW	808	N/A
c01693	94	SB3	O-Flex 23x23-2103 square tubing over 23x23-2103 square tubing	23 mm x 23 mm 23 mm x 23 mm.	APHF	25	24.86	15	6 CW	682	N/A
c01694	95	HR1	Coastal Automotive IMPAXX 700 50 mm total	50 mm total	201HF	25	24.64	-40	0	1490	1291
c01695	96	HR1	Coastal Automotive IMPAXX 700 65 mm total Adjacent to IMPAXX 700 50 mm	65 mm total 50 mm	201HF	25	24.67	-40	0	1382	1209

CDB Number	Impact (Imp) Test Number	Impact Position	Countermeasure	Countermeasure Thickness	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	HIC36	HIC(d)
c01696	97	HR1	O-Flex 28x28-2102 square tubing over 28x28-2102 square tubing adjacent to O-Flex 23x23-2103 tubing	28 mm x 28 mm 28 mm x 28 mm 23 mm x 23 mm	201HF	25	24.62	-40	0	1491	1291
c01697	98	HR1	O-Flex 23x23-2103 square tubing over 23x23-2103 square tubing over O-Flex 15x30-2103 tubing. Adjacent to 23x23-2103 square tubing	23 mm x 23 mm 23 mm x 23 mm 15 mm x 30mm 23mm x 23mm	201HF	25	24.66	-40	0	1369	1199

Table A4. Additional vehicle models test series results (CDB Nos. C01741 to C01825)

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	Seat ATD	Seat Back Load (lb)	HIC36	HIC(d)
2015 Chevrolet Tahoe (VIN 1GNSCAEC9FR116060)											
c01741	24	HR1	201HF	25	24.79	-35	0	No ATD	0	498	542
c01742	36	HR1	201HF	25	24.78	-32	8 CW	No ATD	944	647	654
c01743	11	P9-R	201HF	15	15.37	-20	156	N/A	N/A	1027	941
c01744	12B	P9-R	APHF	15	14.97	0	156	N/A	N/A	1792	N/A
c01745	21	SB1	201HF	25	25.12	-3	0	No ATD	0	665	668
c01746	33	SB1	201HF	25	25.09	-4	0	No ATD	944	1013	931
c01747	22	SB2	201HF	25	24.89	0	10 CW	No ATD	0	553	583
c01748	34	SB2	201HF	25	25	-1	10 CW	No ATD	944	657	662
c01749	23	SB3	201HF	25	25.05	0	5 CW	No ATD	0	641	650
c01750	35	SB3	201HF	25	24.89	0	5 CW	No ATD	944	636	647
2016 Chrysler 300 (VIN 2C3CCAAG4GH134994)											
c01751	7	HR1	201HF	25	24.56	-34	0	No ATD	0	521	559
c01752	8	HR1	201HF	25	24.76	-34	0	HIII 50M	0	861	816
c01753	12B	HR1	201HF	25	24.74	-40	0	No ATD	760	636	646
c01754	6	P9-R	201HF	15	15.12	-10	155	N/A	N/A	272	372
c01755	5	P9-R	APHF	15	15.27	0	155	N/A	N/A	251	N/A
c01756	1	SB1	201HF	25	24.58	-3	0	No ATD	0	959	890

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	Seat ATD	Seat Back Load (lb)	HIC36	HIC(d)
c01757	2	SB1	201HF	25	24.78	-3	0	HIII 50M	0	1094	992
c01758	9	SB1	201HF	25	24.79	-9	0	No ATD	760	1093	991
c01759	3	SB2	201HF	25	24.73	0	0	No ATD	0	471	522
c01760	4	SB2	201HF	25	24.73	0	0	HIII 50M	0	743	727
c01761	10	SB2	201HF	25	24.72	-6	0	No ATD	760	607	625
c01762	5	SB3	201HF	25	24.74	0	0	No ATD	0	532	568
c01763	6	SB3	201HF	25	24.57	0	0	HIII 50M	0	696	692
c01764	11	SB3	201HF	25	24.77	0	0	No ATD	760	607	624
2016 Ford F-250 (VIN 1FT7W2A64GEA19398)											
c01765	16	HR1	201HF	25	25.07	-23	0	No ATD	0	508	550
c01766	28	HR1	201HF	25	24.96	-19	0	No ATD	944	464	517
c01767	7	P9-R	201HF	15	15.24	-20	156	N/A	N/A	1000	921
c01768	8	P9-R	APHF	15	15.03	0	156	N/A	N/A	1410	N/A
c01769	13	SB1	201HF	25	24.81	0	0	No ATD	0	527	564
c01770	25	SB1	201HF	25	24.93	-5	0	No ATD	944	585	608
c01771	14	SB2	201HF	25	24.85	0	0	No ATD	0	519	558
c01772	26	SB2	201HF	25	25.03	-3	0	No ATD	944	513	553
c01773	15	SB3	201HF	25	25.02	-4	0	No ATD	0	952	885

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	Seat ATD	Seat Back Load (lb)	HIC36	HIC(d)
c01774	27	SB3	201HF	25	25.09	0	0	No ATD	944	1077	979
2016 Mazda CX-5 (VIN JM3KE4BY4G0669264)											
c01775	7	HR1	201HF	25	24.67	-35	20 CCW	No ATD	0	967	896
c01776	5	HR1	201HF	25	24.65	-35	20 CW	HIII 50M	0	1148	1033
c01777	8	HR1	APHF	25	24.87	-20	20 CCW	No ATD	0	257	N/A
c01778	6	HR1	APHF	25	24.92	-20	20 CW	HIII 50M	0	585	N/A
c01779	1	SB1	201HF	25	24.75	-6	0	No ATD	0	470	521
c01780	3	SB1	201HF	25	24.78	-6	0	HIII 50M	0	545	577
c01781	16	SB1	201HF	25	24.8	-12	0	No ATD	370	298	392
c01782	2	SB1	APHF	25	24.99	0	0	No ATD	0	564	N/A
c01783	4	SB1	APHF	25	25.04	0	0	HIII 50M	0	560	N/A
c01784	12	SB3	201HF	25	24.86	-6	0	No ATD	0	923	862
c01785	14	SB3	201HF	25	24.78	-6	0	HIII 50M	0	1107	1001
c01786	13	SB3	APHF	25	24.85	0	0	No ATD	0	772	N/A
c01787	15	SB3	APHF	25	24.91	0	0	HIII 50M	0	826	N/A

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	Seat ATD	Seat Back Load (lb)	HIC36	HIC(d)
2016 Toyota Tacoma (VIN 5TFAX5GN1GX059512)											
c01788	20	HR1	201HF	25	24.81	-33	10 CW	No ATD	0	1262	1119
c01789	32	HR1	201HF	25	24.74	-41	10 CW	No ATD	922	839	799
c01790	10	P9-R	201HF	15	15.35	-20	156	N/A	N/A	480	529
c01791	9	P9-R	APHF	15	15.17	0	156	N/A	N/A	812	779
c01792	17	SB1	201HF	25	25.01	-10	0	No ATD	0	1095	993
c01793	29	SB1	201HF	25	24.98	-15	0	No ATD	922	1106	1001
c01794	18	SB2	201HF	25	25.07	-9	0	No ATD	0	457	511
c01795	30	SB2	201HF	25	24.93	-15	0	No ATD	922	492	537
c01796	19	SB3	201HF	25	25.02	0	16 CW	No ATD	0	692	688
c01797	31	SB3	201HF	25	24.74	-41	10 CW	No ATD	922	603	621
2018 Dodge Journey (VIN 3C4PDCAB8JT182880)											
c01798	19	HR1	201HF	25	24.78	-29	0	No ATD	0	694	690
c01799	20	HR1	201HF	25	24.78	-29	0	HIII 50M	0	814	781
c01800	24	HR1	201HF	25	24.72	-31	0	No ATD	500	668	671
c01801	1	P9-R	201HF	15	15.17	-16	157	N/A	N/A	274	373
c01802	2	P9-R	APHF	15	15.19	0	157	N/A	N/A	174	N/A
c01803	13	SB1	201HF	25	24.88	-7	0	No ATD	0	892	839
c01804	14	SB1	201HF	25	24.8	-7	0	HIII 50M	0	983	908

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	Seat ATD	Seat Back Load (lb)	HIC36	HIC(d)
c01805	21	SB1	201HF	25	24.78	-9	0	No ATD	500	847	805
c01806	15B	SB2	201HF	25	24.66	-2	0	No ATD	0	498	542
c01807	16	SB2	201HF	25	24.72	-2	0	HIII 50M	0	647	655
c01808	22	SB2	201HF	25	24.68	-4	0	No ATD	500	722	711
c01809	17	SB3	201HF	25	24.82	-2	0	No ATD	0	842	802
c01810	18	SB3	201HF	25	24.79	-2	0	HIII 50M	0	1006	925
c01811	23	SB3	201HF	25	24.68	-4	0	No ATD	500	1049	958
2018 Toyota Sienna (VIN 5TDKZ3DC3JS902287)											
c01812	31	HR1	201HF	25	24.7	-40	0	No ATD	0	1230	1094
c01813	32	HR1	201HF	25	24.64	-40	0	HIII 50M	0	1339	1176
c01814	36	HR1	201HF	25	24.75	-43	0	No ATD	525	1273	1127
c01815	3	P9-R	201HF	15	14.55	-20	161	N/A	N/A	216	329
c01816	4B	P9-R	APHF	15	14.61	0	161	N/A	N/A	342	N/A
c01817	25	SB1	201HF	25	24.8	0	0	No ATD	0	1144	1029
c01818	26	SB1	201HF	25	24.79	0	0	HIII 50M	0	1146	1031
c01819	33	SB1	201HF	25	24.72	0	0	No ATD	525	1097	994
c01820	27	SB2	201HF	25	24.77	0	30 CW	No ATD	0	540	574

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	Seat ATD	Seat Back Load (lb)	HIC36	HIC(d)
c01821	28	SB2	201HF	25	24.83	0	30 CW	HIII 50M	0	574	600
c01822	34	SB2	201HF	25	24.8	0	30 CW	No ATD	525	545	577
c01823	29	SB3	201HF	25	24.83	0	0	No ATD	0	817	783
c01824	30	SB3	201HF	25	24.82	0	0	HIII 50M	0	938	874
c01825	35	SB3	201HF	25	24.78	0	0	No ATD	525	842	802

Table A5. Effect of seat load on impacts test series (CDB Nos. C01910 to C01978; C02012 to C02045)

CDB Number	Impact (Imp) Test Number	Impact Position	Head Form	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	Seat Back Load (lb)	HIC36	HIC(d)
2018 Dodge Journey (VIN 3C4PDCAB8JT182880)										
c01910	1B	SB1	201HF	25	24.89	-19	0	562	874	826
c01911	2B	SB1	201HF	25	24.89	-19	0	562	792	764
c01912	3B	SB1	201HF	25	24.93	-19	0	562	899	844
c01913	4B	SB1	201HF	25	24.94	-7	0	0	862	817
c01914	5B	SB1	201HF	25	24.81	-7	0	0	873	825
c01915	16	SB2	201HF	25	25.08	-12	0	562	596	616
c01916	17B	SB2	201HF	25	25	-12	0	562	559	588

CDB Number	Impact (Imp) Test Number	Impact Position	Head Form	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	Seat Back Load (lb)	HIC36	HIC(d)
c01917	18	SB2	201HF	25	24.88	-12	0	562	570	597
c01918	19B	SB2	201HF	25	24.92	-2	0	0	260	362
c01919	20B	SB2	201HF	25	24.94	-2	0	0	509	550
c01920	21	SB2	201HF	25	24.9	-2	0	0	525	563
c01921	28	SB3	201HF	25	25.04	-7	0	562	962	892
c01922	29	SB3	201HF	25	24.94	-7	0	562	954	886
c01923	30	SB3	201HF	25	24.91	-7	0	562	1004	924
c01924	22	SB3	201HF	25	24.9	-2	0	0	557	587
c01925	23	SB3	201HF	25	24.8	-2	0	0	852	809
c01926	24	SB3	201HF	25	28.82	-2	0	0	873	825
c01927	31	HR1	201HF	25	24.64	-34	0	562	537	571
c01928	32	HR1	201HF	25	24.81	-34	0	562	524	562
c01929	33	HR1	201HF	25	24.72	-34	0	562	581	605
c01930	25	HR1	201HF	25	24.81	-29	0	0	552	583
c01931	26	HR1	201HF	25	24.88	-29	0	0	406	473
c01932	27	HR1	201HF	25	24.88	-29	0	0	522	560
c02010	70	SB1	APHF	25	24.93	-7	0	562	1246	NA
c02011	71	SB1	APHF	25	24.88	-7	0	562	1125	NA
c02012	72	SB1	APHF	25	24.92	-7	0	562	1241	NA
c02013	73	SB2	APHF	25	25.01	-5	0	562	634	NA

CDB Number	Impact (Imp) Test Number	Impact Position	Head Form	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	Seat Back Load (lb)	HIC36	HIC(d)
c02014	74	SB2	APHF	25	24.81	-5	0	562	590	NA
c02015	75	SB2	APHF	25	25.02	-5	0	562	595	NA
c02016	76	SB3	APHF	25	24.94	0	0	562	785	NA
c02017	77	SB3	APHF	25	24.98	0	0	562	728	NA
c02018	78	SB3	APHF	25	25.06	0	0	562	762	NA
c02019	79	HR1	APHF	25	24.97	-16	0	562	173	NA
c02020	80	HR1	APHF	25	24.98	-16	0	562	179	NA
c02021	81	HR1	APHF	25	24.94	-16	0	562	170	NA
2018 Toyota Sienna (VIN 5TDKZ3DC3JS902287)										
c01933	6	SB1	201HF	25	25.03	-2	0	582	1364	1196
c01934	7	SB1	201HF	25	24.92	-2	0	582	1243	1104
c01935	8	SB1	201HF	25	24.95	-2	0	582	1231	1095
c01936	9	SB1	201HF	25	25.07	0	0	0	1426	1242
c01937	10	SB1	201HF	25	24.88	0	0	0	1565	1347
c01938	43	SB2	201HF	25	24.66	0	30 CW	582	550	582
c01939	44	SB2	201HF	25	24.98	0	30 CW	582	569	596
c01940	45	SB2	201HF	25	24.78	0	30 CW	582	544	577
c01941	34	SB2	201HF	25	24.94	0	30 CW	0	557	587
c01942	35	SB2	201HF	25	24.81	0	30 CW	0	568	595
c01943	36	SB2	201HF	25	24.9	0	30 CW	0	583	606

CDB Number	Impact (Imp) Test Number	Impact Position	Head Form	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	Seat Back Load (lb)	HIC36	HIC(d)
c01944	46	SB3	201HF	25	24.87	0	0	582	940	875
c01945	47	SB3	201HF	25	24.85	0	0	582	926	865
c01946	48	SB3	201HF	25	24.81	0	0	582	920	861
c01947	37	SB3	201HF	25	24.94	0	0	0	860	816
c01948	38	SB3	201HF	25	24.95	0	0	0	932	870
c01949	39	SB3	201HF	25	24.95	0	0	0	856	812
c01950	49	HR1	201HF	25	24.58	-48	0	582	1508	1304
c01951	50	HR1	201HF	25	24.74	-48	0	582	1637	1401
c01952	51	HR1	201HF	25	24.88	-48	0	582	1591	1367
c01953	40	HR1	201HF	25	24.72	-40	0	0	1347	1183
c01954	41	HR1	201HF	25	24.71	-40	0	0	1395	1219
c01955	42	HR1	201HF	25	24.75	-40	0	0	1431	1246
c02022	82	SB1	APHF	25	24.98	0	0	582	1234	NA
c02023	83	SB1	APHF	25	24.98	0	0	582	1285	NA
c02024	84	SB1	APHF	25	25.01	0	0	582	1292	NA
c02025	85	SB2	APHF	25	24.83	0	30CW	582	694	NA
c02026	86	SB2	APHF	25	24.93	0	30CW	582	697	NA
c02027	87	SB2	APHF	25	25	0	30CW	582	603	NA
c02028	88	SB3	APHF	25	24.93	0	0	582	895	NA
c02029	89	SB3	APHF	25	24.97	0	0	582	821	NA

CDB Number	Impact (Imp) Test Number	Impact Position	Head Form	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	Seat Back Load (lb)	HIC36	HIC(d)
c02030	90	SB3	APHF	25	25.01	0	0	582	903	NA
c02031	91	HR1	APHF	25	24.78	-26	0	582	571	NA
c02032	92	HR1	APHF	25	24.77	-26	0	582	589	NA
c02033	93	HR1	APHF	25	24.77	-26	0	582	582	NA
2015 Chevrolet Tahoe (VIN 1GNSCAEC9FR116060)										
c01956	11	SB1	201HF	25	25.08	-8	0	687	916	858
c01957	12	SB1	201HF	25	24.81	-8	0	687	1023	938
c01958	13	SB1	201HF	25	24.8	-8	0	687	1012	930
c01959	14	SB1	201HF	25	24.93	-3	0	0	781	755
c01960	15	SB1	201HF	25	24.88	-3	0	0	770	748
c01961	61	SB2	201HF	25	24.99	-5	10 CW	687	720	710
c01962	62	SB2	201HF	25	24.85	-5	10 CW	687	717	707
c01963	63	SB2	201HF	25	24.9	-5	10 CW	687	651	658
c01964	52	SB2	201HF	25	24.94	0	10 CW	0	572	598
c01965	53	SB2	201HF	25	24.92	0	10 CW	0	575	600
c01966	54	SB2	201HF	25	24.85	0	10 CW	0	582	605
c01967	64	SB3	201HF	25	24.91	0	5 CW	687	790	763
c01968	65	SB3	201HF	25	24.86	0	5 CW	687	749	731
c01969	66	SB3	201HF	25	24.87	0	5 CW	687	759	739
c01970	55	SB3	201HF	25	24.89	0	5 CW	0	595	615

CDB Number	Impact (Imp) Test Number	Impact Position	Head Form	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	Seat Back Load (lb)	HIC36	HIC(d)
c01971	56	SB3	201HF	25	24.82	0	5 CW	0	596	616
c01972	57	SB3	201HF	25	24.86	0	5 CW	0	620	634
c01973	67	HR1	201HF	25	24.72	-42	0	687	623	636
c01974	68	HR1	201HF	25	24.78	-42	0	687	658	663
c01975	69	HR1	201HF	25	24.83	-42	0	687	628	640
c01976	58	HR1	201HF	25	24.87	-35	0	0	488	535
c01977	59	HR1	201HF	25	24.85	-35	0	0	473	523
c01978	60	HR1	201HF	25	24.95	-35	0	0	478	527
c02034	94	SB1	APHF	25	24.86	-4	0	687	920	NA
c02035	95	SB1	APHF	25	24.94	-4	0	687	960	NA
c02036	96	SB1	APHF	25	24.93	-4	0	687	962	NA
c02037	97	SB2	APHF	25	24.94	-4	10 CW	687	607	NA
c02038	98	SB2	APHF	25	24.93	-4	10 CW	687	591	NA
c02039	99	SB2	APHF	25	25.09	-4	10 CW	687	602	NA
c02040	100	SB3	APHF	25	24.92	0	5 CW	687	762	NA
c02041	101	SB3	APHF	25	24.93	0	5 CW	687	668	NA
c02042	102	SB3	APHF	25	24.99	0	5 CW	687	700	NA
c02043	103	HR1	APHF	25	24.94	-20	0	687	543	NA
c02044	104	HR1	APHF	25	24.77	-20	0	687	544	NA
c02045	105	HR1	APHF	25	24.81	-20	0	687	517	NA

Table A6. Statistics on effect of seat load on impacts test series (CDB Nos. C01910 to C01978; C02012 to C02045)

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	Seat Back Load (lb)	HIC36	HIC(d)
2018 Dodge Journey (VIN 3C4PDCAB8JT182880)										
c01910	1B	SB1	201HF	25	24.89	-19	0	562	874	826
c01911	2B	SB1	201HF	25	24.89	-19	0	562	792	764
c01912	3B	SB1	201HF	25	24.93	-19	0	562	899	844
								Avg.	855	811
								SD	55.97	42.0
								%CV	6.5%	5.2%
c02010	70	SB1	APHF	25	24.93	-7	0	562	1246	NA
c02011	71	SB1	APHF	25	24.88	-7	0	562	1125	NA
c02012	72	SB1	APHF	25	24.92	-7	0	562	1241	NA
								Avg.	1204	NA
								SD	68.5	NA
								%CV	5.7%	NA
								P-value	<0.01	

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	Seat Back Load (lb)	HIC36	HIC(d)
c01915	16	SB2	201HF	25	25.08	-12	0	562	596	616
c01916	17B	SB2	201HF	25	25	-12	0	562	559	588
c01917	18	SB2	201HF	25	24.88	-12	0	562	570	597
								Avg.	575	600
								SD	19.0	14.3
								%CV	3.3%	2.4%
c02013	73	SB2	APHF	25	25.01	-5	0	562	634	NA
c02014	74	SB2	APHF	25	24.81	-5	0	562	590	NA
c02015	75	SB2	APHF	25	25.02	-5	0	562	595	NA
								Avg.	606	NA
								SD	24.1	NA
								%CV	4.0%	NA
								P-value	0.16	
c01921	28	SB3	201HF	25	25.04	-7	0	562	962	892
c01922	29	SB3	201HF	25	24.94	-7	0	562	954	886
c01923	30	SB3	201HF	25	24.91	-7	0	562	1004	924

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	Seat Back Load (lb)	HIC36	HIC(d)
								Avg.	973	901
								SD	26.9	20.4
								%CV	2.8%	2.3%
c02016	76	SB3	APHF	25	24.94	0	0	562	785	NA
c02017	77	SB3	APHF	25	24.98	0	0	562	728	NA
c02018	78	SB3	APHF	25	25.06	0	0	562	762	NA
								Avg.	758	NA
								SD	28.7	NA
								%CV	3.8%	NA
								P-value	<0.01	
c01927	31	HR1	201HF	25	24.64	-34	0	562	537	571
c01928	32	HR1	201HF	25	24.81	-34	0	562	524	562
c01929	33	HR1	201HF	25	24.72	-34	0	562	581	605
								Avg.	547	579
								SD	29.9	22.7
								%CV	5.5%	3.9%

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	Seat Back Load (lb)	HIC36	HIC(d)
c02019	79	HR1	APHF	25	24.97	-16	0	562	173	NA
c02020	80	HR1	APHF	25	24.98	-16	0	562	179	NA
c02021	81	HR1	APHF	25	24.94	-16	0	562	170	NA
								Avg.	174	NA
								SD	4.6	NA
								%CV	2.6%	NA
								P-value	<0.01	

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	Seat Back Load (lb)	HIC36	HIC(d)
2018 Toyota Sienna (VIN 5TDKZ3DC3JS902287)										
c01933	6	SB1	201HF	25	25.03	-2	0	582	1364	1196
c01934	7	SB1	201HF	25	24.92	-2	0	582	1243	1104
c01935	8	SB1	201HF	25	24.95	-2	0	582	1231	1095
								Avg.	1279	1132
								SD	73.57	55.9
								%CV	5.8%	4.9%
c02022	82	SB1	APHF	25	24.98	0	0	582	1234	NA
c02023	83	SB1	APHF	25	24.98	0	0	582	1285	NA
c02024	84	SB1	APHF	25	25.01	0	0	582	1292	NA
								Avg.	1270	NA
								SD	31.7	NA
								%CV	2.5%	NA
								P-value	0.86	
c01938	43	SB2	201HF	25	24.66	0	30 CW	582	550	582
c01939	44	SB2	201HF	25	24.98	0	30 CW	582	569	596

c01940	45	SB2	201HF	25	24.78	0	30 CW	582	544	577
								Avg.	554	585
								SD	13.1	9.8
								%CV	2.4%	1.7%
c02025	85	SB2	APHF	25	24.83	0	30CW	582	694	NA
c02026	86	SB2	APHF	25	24.93	0	30CW	582	697	NA
c02027	87	SB2	APHF	25	25	0	30CW	582	603	NA
								Avg.	665	NA
								SD	53.4	NA
								%CV	8.0%	NA
								P-value	0.06	
c01944	46	SB3	201HF	25	24.87	0	0	582	940	875
c01945	47	SB3	201HF	25	24.85	0	0	582	926	865
c01946	48	SB3	201HF	25	24.81	0	0	582	920	861
								Avg.	929	867
								SD	10.3	7.2
								%CV	1.1%	0.8%
c02028	88	SB3	APHF	25	24.93	0	0	582	895	NA
c02029	89	SB3	APHF	25	24.97	0	0	582	821	NA

c02030	90	SB3	APHF	25	25.01	0	0	582	903	NA
								Avg.	873	NA
								SD	45.2	NA
								%CV	5.2%	NA
								P-value	0.16	
c01950	49	HR1	201HF	25	24.58	-48	0	582	1508	1304
c01951	50	HR1	201HF	25	24.74	-48	0	582	1637	1401
c01952	51	HR1	201HF	25	24.88	-48	0	582	1591	1367
								Avg.	1579	1357
								SD	65.4	49.2
								%CV	4.1%	3.6%
c02031	91	HR1	APHF	25	24.78	-26	0	582	571	NA
c02032	92	HR1	APHF	25	24.77	-26	0	582	589	NA
c02033	93	HR1	APHF	25	24.77	-26	0	582	582	NA
								Avg.	581	NA
								SD	9.1	NA
								%CV	1.6%	NA
								P-value	<0.01	

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	Seat Back Load (lb)	HIC36	HIC(d)
2015 Chevrolet Tahoe (VIN 1GNSCAEC9FR116060)										
c01956	11	SB1	201HF	25	25.08	-8	0	687	916	858
c01957	12	SB1	201HF	25	24.81	-8	0	687	1023	938
c01958	13	SB1	201HF	25	24.8	-8	0	687	1012	930
								Avg.	984	909
								SD	58.86	44.1
								%CV	6.0%	4.8%
c02034	94	SB1	APHF	25	24.86	-4	0	687	920	NA
c02035	95	SB1	APHF	25	24.94	-4	0	687	960	NA
c02036	96	SB1	APHF	25	24.93	-4	0	687	962	NA
								Avg.	947	NA
								SD	23.7	NA
								%CV	2.5%	NA
								P-value	0.40	
c01961	61	SB2	201HF	25	24.99	-5	10 CW	687	720	710
c01962	62	SB2	201HF	25	24.85	-5	10 CW	687	717	707

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	Seat Back Load (lb)	HIC36	HIC(d)
c01963	63	SB2	201HF	25	24.9	-5	10 CW	687	651	658
								Avg.	696	692
								SD	39.0	29.2
								%CV	5.6%	4.2%
c02037	97	SB2	APHF	25	24.94	-4	10 CW	687	607	NA
c02038	98	SB2	APHF	25	24.93	-4	10 CW	687	591	NA
c02039	99	SB2	APHF	25	25.09	-4	10 CW	687	602	NA
								Avg.	600	NA
								SD	8.2	NA
								%CV	1.4%	NA
								P-value	0.05	
c01967	64	SB3	201HF	25	24.91	0	5 CW	687	790	763
c01968	65	SB3	201HF	25	24.86	0	5 CW	687	749	731
c01969	66	SB3	201HF	25	24.87	0	5 CW	687	759	739

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	Seat Back Load (lb)	HIC36	HIC(d)
								Avg.	766	744
								SD	21.4	16.7
								%CV	2.8%	2.2%
c02040	100	SB3	APHF	25	24.92	0	5 CW	687	762	NA
c02041	101	SB3	APHF	25	24.93	0	5 CW	687	668	NA
c02042	102	SB3	APHF	25	24.99	0	5 CW	687	700	NA
								Avg.	710	NA
								SD	47.8	NA
								%CV	6.7%	NA
								P-value	0.17	
c01973	67	HR1	201HF	25	24.72	-42	0	687	623	636
c01974	68	HR1	201HF	25	24.78	-42	0	687	658	663
c01975	69	HR1	201HF	25	24.83	-42	0	687	628	640
								Avg.	636	646
								SD	18.9	14.6
								%CV	3.0%	2.3%

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	Seat Back Load (lb)	HIC36	HIC(d)
c02043	103	HR1	APHF	25	24.94	-20	0	687	543	NA
c02044	104	HR1	APHF	25	24.77	-20	0	687	544	NA
c02045	105	HR1	APHF	25	24.81	-20	0	687	517	NA
								Avg.	535	NA
								SD	15.3	NA
								%CV	2.9%	NA
								P-value	<0.01	

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	Seat Back Load (lb)	HIC36	HIC(d)
2018 Dodge Journey (VIN 3C4PDCAB8JT182880)										
c01913	4B	SB1	201HF	25	24.94	-7	0	0	862	817
c01914	5B	SB1	201HF	25	24.81	-7	0	0	873	825
c01803	13	SB1	201HF	25	24.88	-7	0	0	892	839
								Avg.	876	827

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	Seat Back Load (lb)	HIC36	HIC(d)
								SD	15.18	11.1
								%CV	1.7%	1.3%
c01910	1B	SB1	201HF	25	24.89	-19	0	562	874	826
c01911	2B	SB1	201HF	25	24.89	-19	0	562	792	764
c01912	3B	SB1	201HF	25	24.93	-19	0	562	899	844
								Avg.	855	811
								SD	56.0	42.0
								%CV	6.5%	5.2%
								P-value	0.59	
c01918	19B	SB2	201HF	25	24.92	-2	0	0	260	362
c01919	20B	SB2	201HF	25	24.94	-2	0	0	509	550
c01920	21	SB2	201HF	25	24.9	-2	0	0	525	563
								Avg.	431	492
								SD	148.6	112.5
								%CV	34.5%	22.9%
c01915	16	SB2	201HF	25	25.08	-12	0	562	596	616

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	Seat Back Load (lb)	HIC36	HIC(d)
c01916	17B	SB2	201HF	25	25	-12	0	562	559	588
c01917	18	SB2	201HF	25	24.88	-12	0	562	570	597
								Avg.	575	600
								SD	19.0	14.3
								%CV	3.3%	2.4%
								P-value	0.23	
c01924	22	SB3	201HF	25	24.9	-2	0	0	557	587
c01925	23	SB3	201HF	25	24.8	-2	0	0	852	809
c01926	24	SB3	201HF	25	28.82	-2	0	0	873	825
								Avg.	761	740
								SD	176.7	133.0
								%CV	23.2%	18.0%
c01921	28	SB3	201HF	25	25.04	-7	0	562	962	892
c01922	29	SB3	201HF	25	24.94	-7	0	562	954	886
c01923	30	SB3	201HF	25	24.91	-7	0	562	1004	924
								Avg.	973	901

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	Seat Back Load (lb)	HIC36	HIC(d)
								SD	26.9	20.4
								%CV	2.8%	2.3%
								P-value	0.17	
c01930	25	HR1	201HF	25	24.81	-29	0	0	552	583
c01931	26	HR1	201HF	25	24.88	-29	0	0	406	473
c01932	27	HR1	201HF	25	24.88	-29	0	0	522	560
								Avg.	493	539
								SD	77.1	58.0
								%CV	15.6%	10.8%
c01927	31	HR1	201HF	25	24.64	-34	0	562	537	571
c01928	32	HR1	201HF	25	24.81	-34	0	562	524	562
c01929	33	HR1	201HF	25	24.72	-34	0	562	581	605
								Avg.	547	579
								SD	29.9	22.7
								%CV	5.5%	3.9%
								P-value	0.35	

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	Seat Back Load (lb)	HIC36	HIC(d)
2018 Toyota Sienna (VIN 5TDKZ3DC3JS902287)										
c01936	9	SB1	201HF	25	25.07	0	0	0	1426	1242
c01937	10	SB1	201HF	25	24.88	0	0	0	1565	1347
c01817	25	SB1	201HF	25	24.8	0	0	0	1144	1029
								Avg.	1378	1206
								SD	214.51	162.0
								%CV	15.6%	13.4%
c01933	6	SB1	201HF	25	25.03	-2	0	582	1364	1196
c01934	7	SB1	201HF	25	24.92	-2	0	582	1243	1104
c01935	8	SB1	201HF	25	24.95	-2	0	582	1231	1095
								Avg.	1279	1132
								SD	73.6	55.9
								%CV	5.8%	4.9%
								P-value	0.52	

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	Seat Back Load (lb)	HIC36	HIC(d)
c01941	34	SB2	201HF	25	24.94	0	30 CW	0	557	587
c01942	35	SB2	201HF	25	24.81	0	30 CW	0	568	595
c01943	36	SB2	201HF	25	24.9	0	30 CW	0	583	606
								Avg.	569	596
								SD	13.1	9.5
								%CV	2.3%	1.6%
c01938	43	SB2	201HF	25	24.66	0	30 CW	582	550	582
c01939	44	SB2	201HF	25	24.98	0	30 CW	582	569	596
c01940	45	SB2	201HF	25	24.78	0	30 CW	582	544	577
								Avg.	554	585
								SD	13.1	9.8
								%CV	2.4%	1.7%
								P-value	<0.01	
c01947	37	SB3	201HF	25	24.94	0	0	0	860	816
c01948	38	SB3	201HF	25	24.95	0	0	0	932	870
c01949	39	SB3	201HF	25	24.95	0	0	0	856	812

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	Seat Back Load (lb)	HIC36	HIC(d)
								Avg.	883	833
								SD	42.8	32.4
								%CV	4.8%	3.9%
c01944	46	SB3	201HF	25	24.87	0	0	582	940	875
c01945	47	SB3	201HF	25	24.85	0	0	582	926	865
c01946	48	SB3	201HF	25	24.81	0	0	582	920	861
								Avg.	929	867
								SD	10.3	7.2
								%CV	1.1%	0.8%
								P-value	0.20	
c01953	40	HR1	201HF	25	24.72	-40	0	0	1347	1183
c01954	41	HR1	201HF	25	24.71	-40	0	0	1395	1219
c01955	42	HR1	201HF	25	24.75	-40	0	0	1431	1246
								Avg.	1391	1216
								SD	42.1	31.6
								%CV	3.0%	2.6%

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	Seat Back Load (lb)	HIC36	HIC(d)
c01950	49	HR1	201HF	25	24.58	-48	0	582	1508	1304
c01951	50	HR1	201HF	25	24.74	-48	0	582	1637	1401
c01952	51	HR1	201HF	25	24.88	-48	0	582	1591	1367
								Avg.	1579	1357
								SD	65.4	49.2
								%CV	4.1%	3.6%
								P-value	0.02	

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	Seat Back Load (lb)	HIC36	HIC(d)
2015 Chevrolet Tahoe (VIN 1GNSCAEC9FR116060)										
c01959	14	SB1	201HF	25	24.93	-3	0	0	781	755
c01960	15	SB1	201HF	25	24.88	-3	0	0	770	748
c01745	21	SB1	201HF	25	25.12	-3	0	0	665	668
								Avg.	739	724

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	Seat Back Load (lb)	HIC36	HIC(d)
								SD	64.03	48.3
								%CV	8.7%	6.7%
c01956	11	SB1	201HF	25	25.08	-8	0	687	916	858
c01957	12	SB1	201HF	25	24.81	-8	0	687	1023	938
c01958	13	SB1	201HF	25	24.8	-8	0	687	1012	930
								Avg.	984	909
								SD	58.9	44.1
								%CV	6.0%	4.8%
								P-value	0.01	
c01964	52	SB2	201HF	25	24.94	0	10 CW	0	572	598
c01965	53	SB2	201HF	25	24.92	0	10 CW	0	575	600
c01966	54	SB2	201HF	25	24.85	0	10 CW	0	582	605
								Avg.	576	601
								SD	5.1	3.6
								%CV	0.9%	0.6%
c01961	61	SB2	201HF	25	24.99	-5	10 CW	687	720	710

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	Seat Back Load (lb)	HIC36	HIC(d)
c01962	62	SB2	201HF	25	24.85	-5	10 CW	687	717	707
c01963	63	SB2	201HF	25	24.9	-5	10 CW	687	651	658
								Avg.	696	692
								SD	39.0	29.2
								%CV	5.6%	4.2%
								P-value	0.03	
c01970	55	SB3	201HF	25	24.89	0	5 CW	0	595	615
c01971	56	SB3	201HF	25	24.82	0	5 CW	0	596	616
c01972	57	SB3	201HF	25	24.86	0	5 CW	0	620	634
								Avg.	604	622
								SD	14.2	10.7
								%CV	2.3%	1.7%
c01967	64	SB3	201HF	25	24.91	0	5 CW	687	790	763
c01968	65	SB3	201HF	25	24.86	0	5 CW	687	749	731
c01969	66	SB3	201HF	25	24.87	0	5 CW	687	759	739
								Avg.	766	744

CDB Number	Impact (Imp) Test Number	Impact Position	Headform	Target Speed (mph)	Actual Speed (mph)	Vertical Impactor Approach Angle (deg)	Horizontal Impactor Approach Angle (deg)	Seat Back Load (lb)	HIC36	HIC(d)
								SD	21.4	16.7
								%CV	2.8%	2.2%
								P-value	<0.01	
c01976	58	HR1	201HF	25	24.87	-35	0	0	488	535
c01977	59	HR1	201HF	25	24.85	-35	0	0	473	523
c01978	60	HR1	201HF	25	24.95	-35	0	0	478	527
								Avg.	480	528
								SD	7.6	6.1
								%CV	1.6%	1.2%
c01973	67	HR1	201HF	25	24.72	-42	0	687	623	636
c01974	68	HR1	201HF	25	24.78	-42	0	687	658	663
c01975	69	HR1	201HF	25	24.83	-42	0	687	628	640
								Avg.	636	646
								SD	18.9	14.6
								%CV	3.0%	2.3%
								P-value	<0.01	

Appendix B. Seat Back Designs

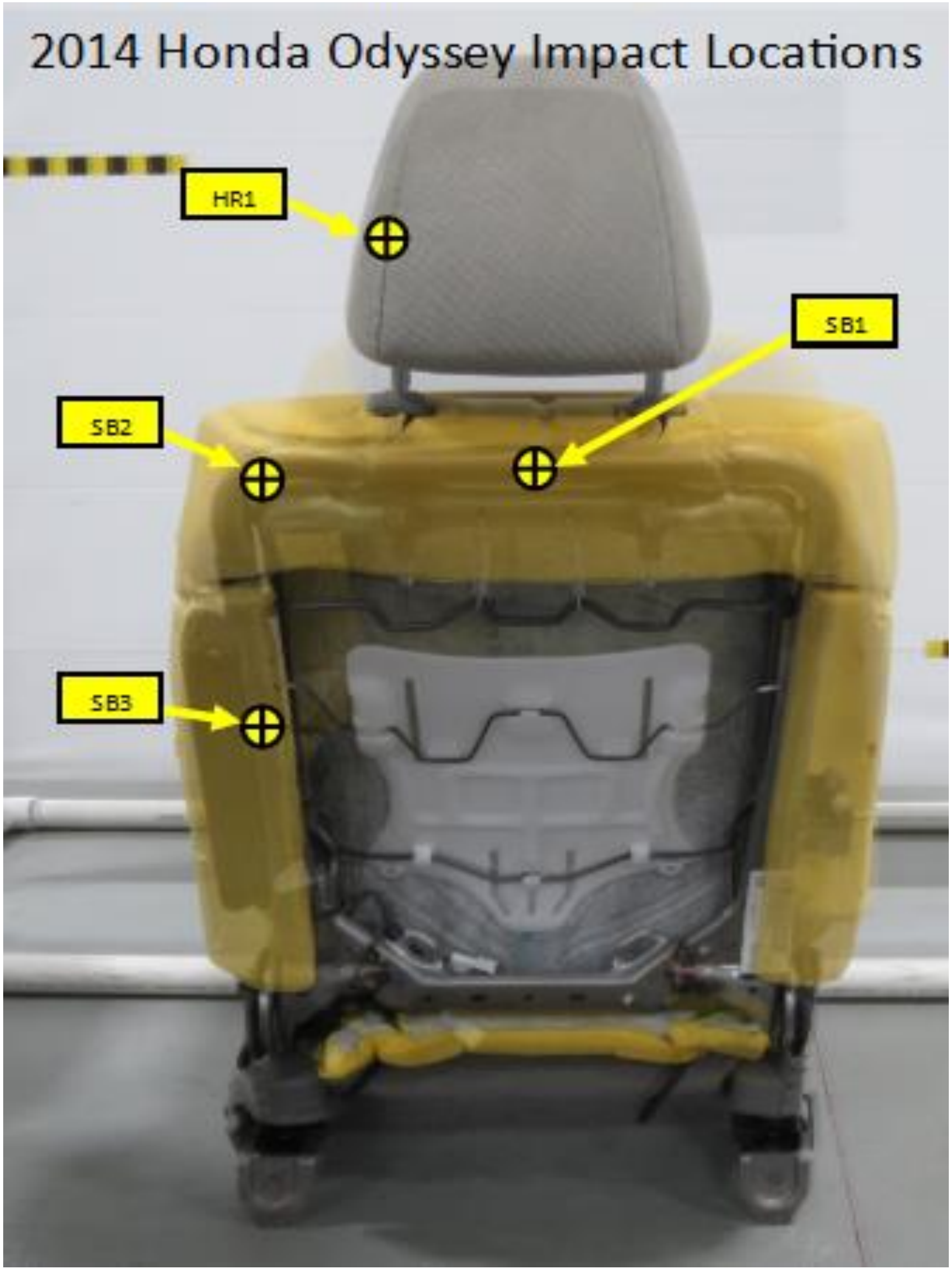


Figure B1. 2014 Honda Odyssey

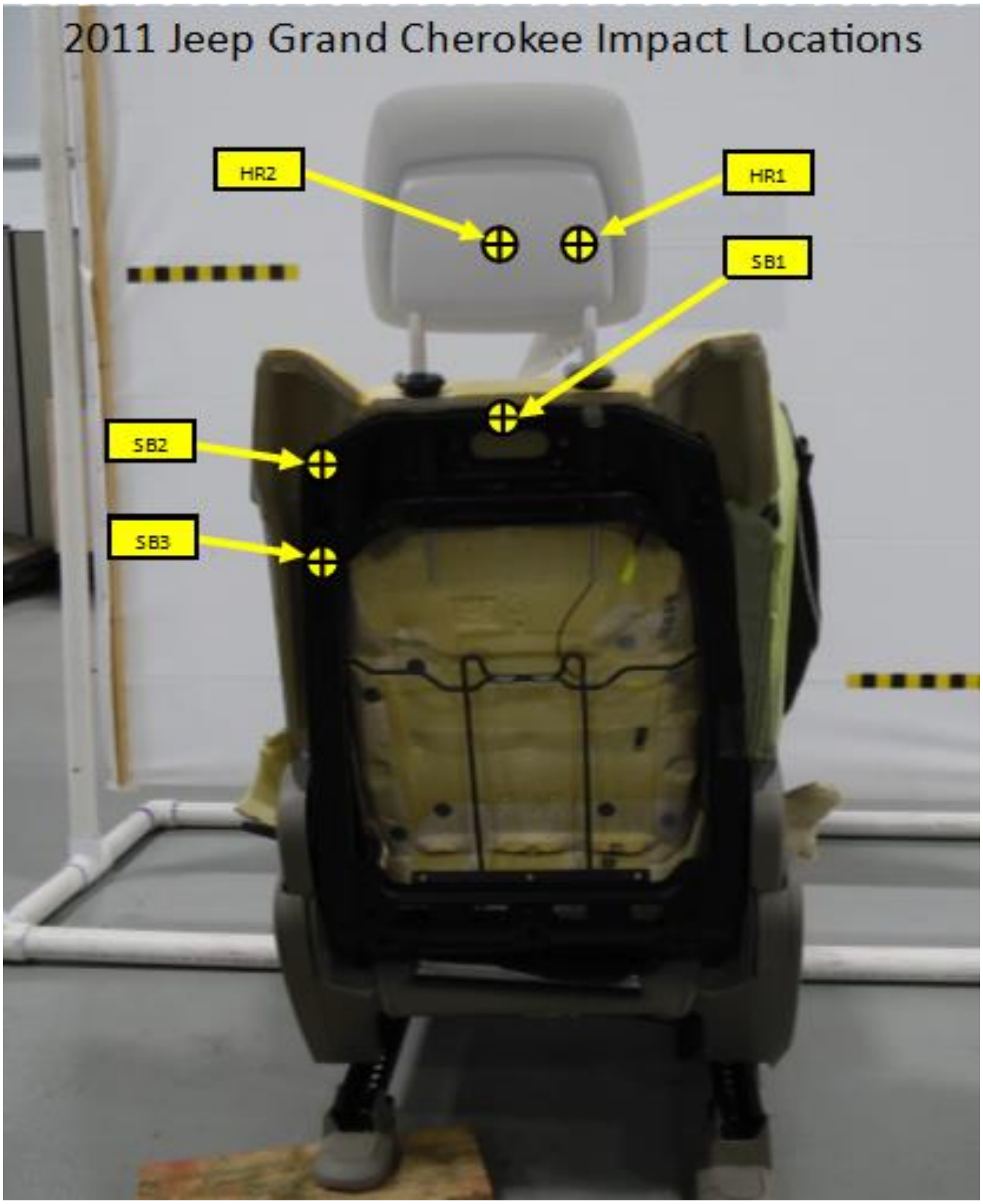


Figure B2. 2011 Jeep Grand Cherokee

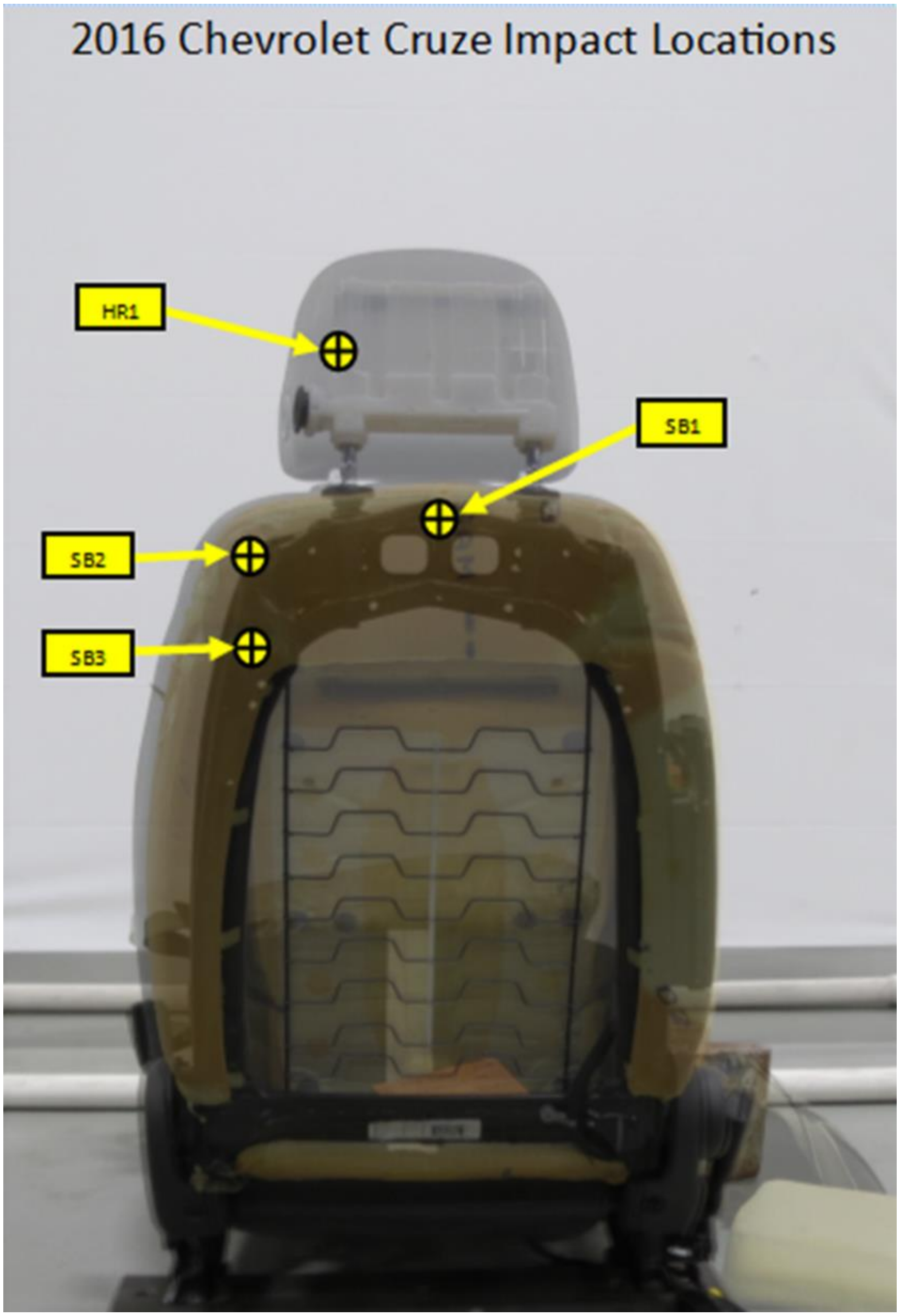


Figure B3. 2016 Chevrolet Cruze

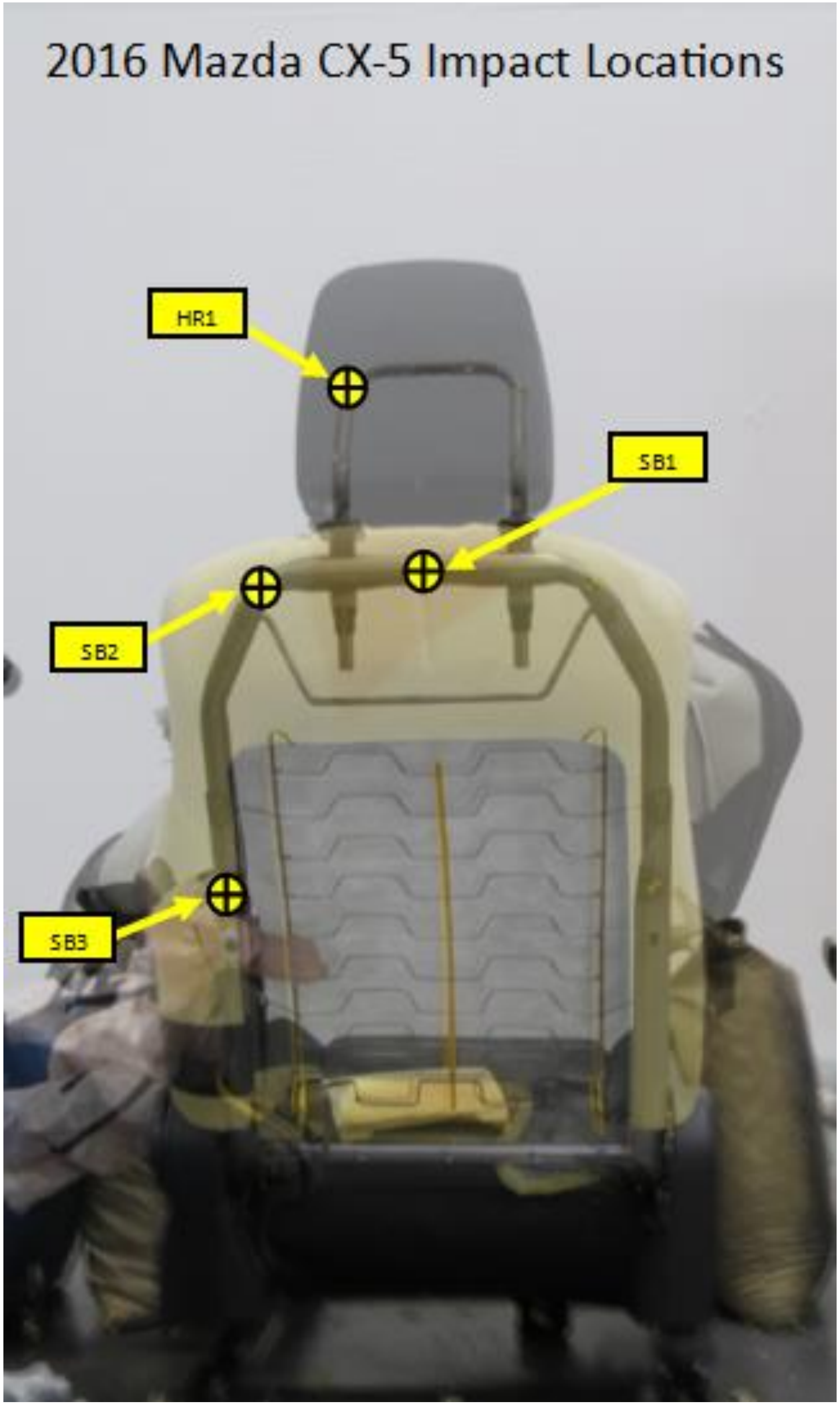


Figure B4. 2016 Mazda CX-5

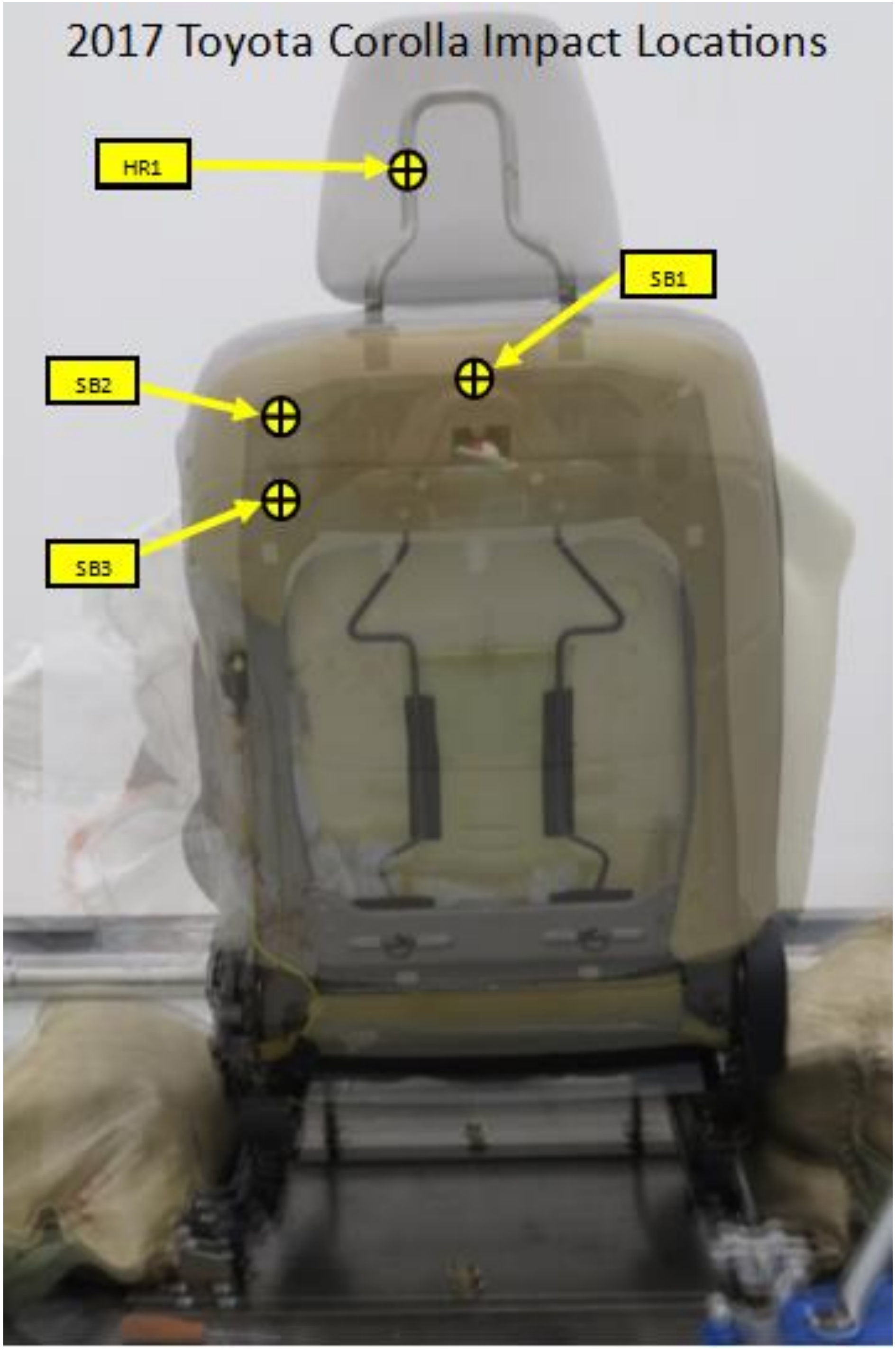


Figure B5. 2017 Toyota Corolla

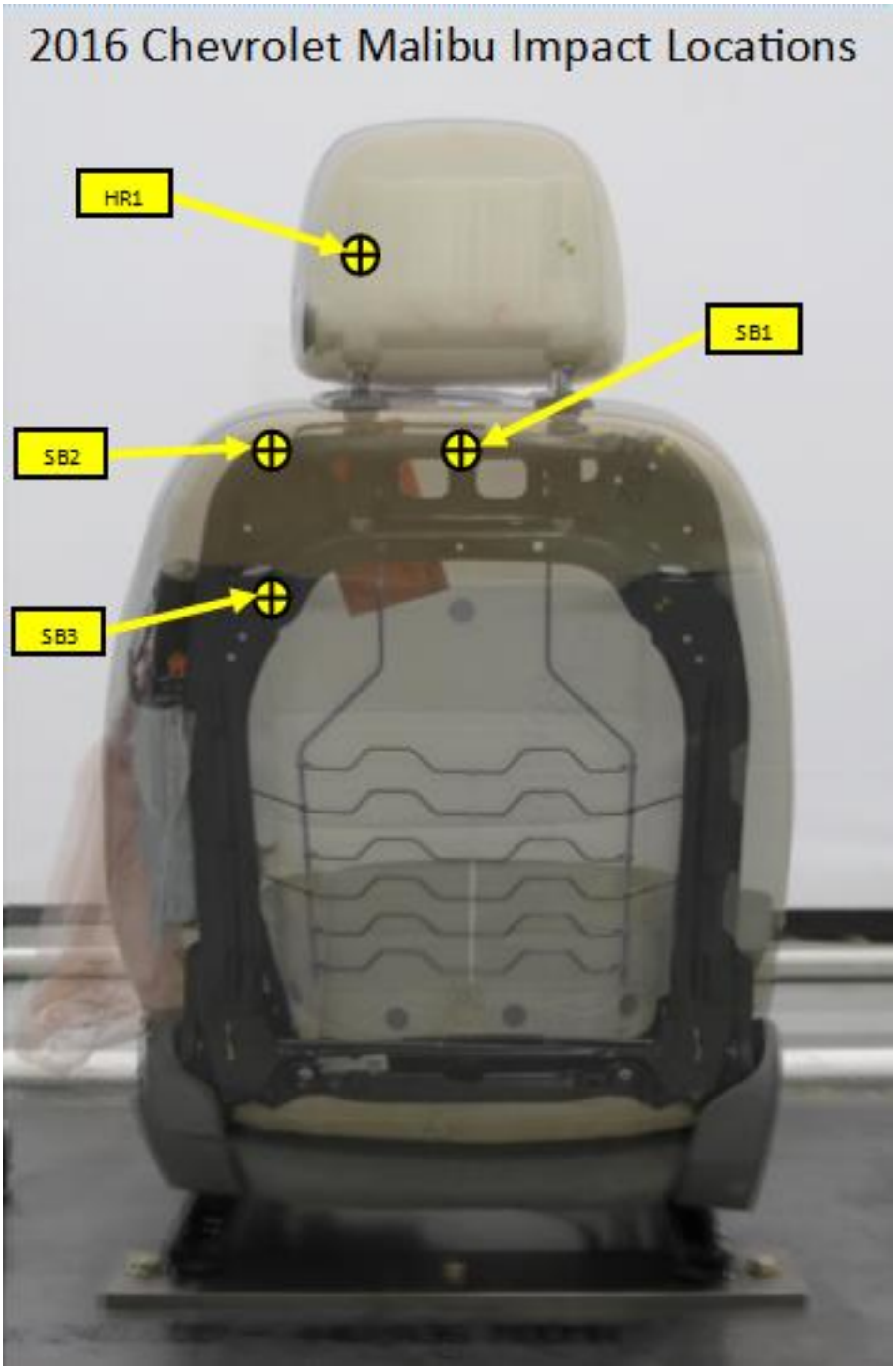


Figure B6. 2016 Chevrolet Malibu

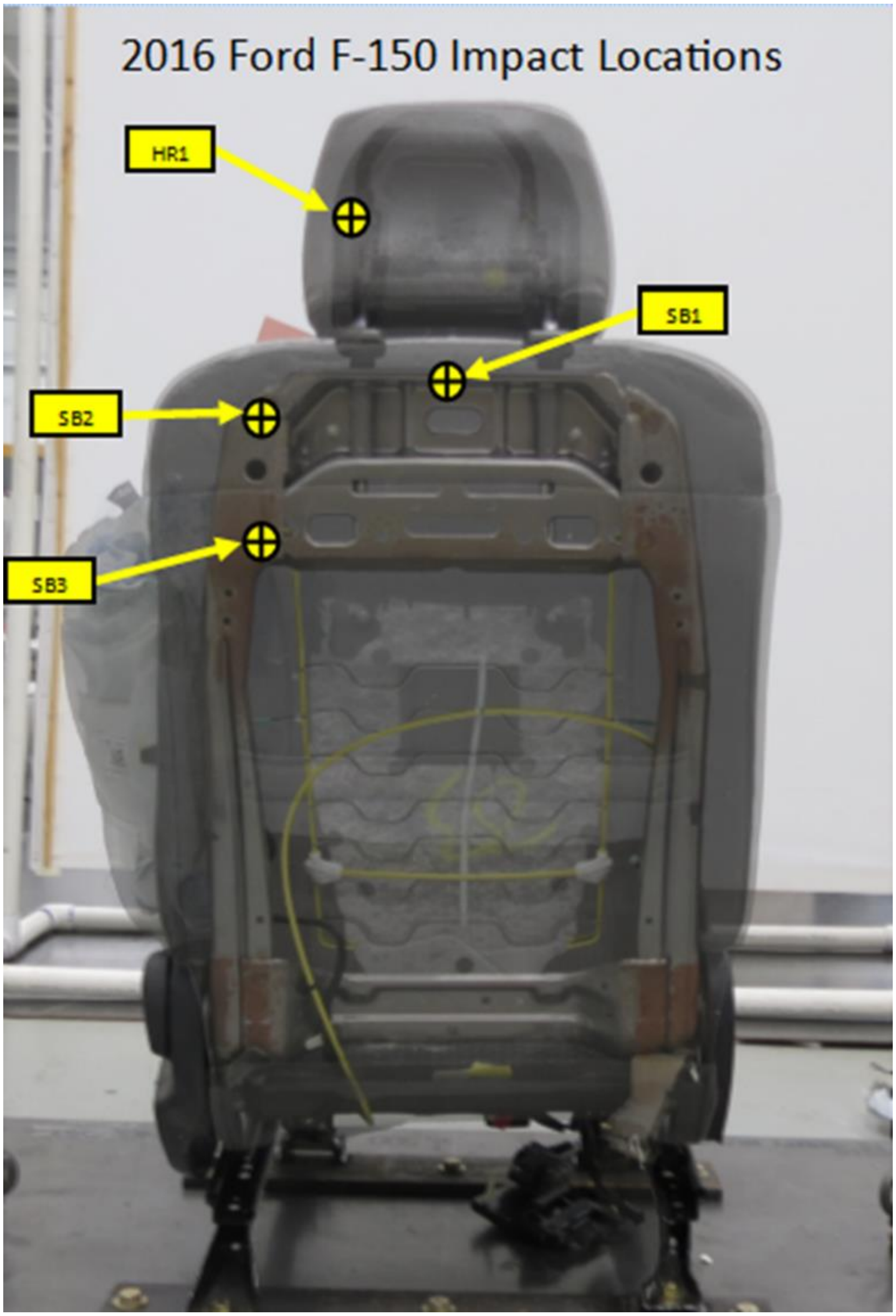


Figure B7. 2016 Ford F-150

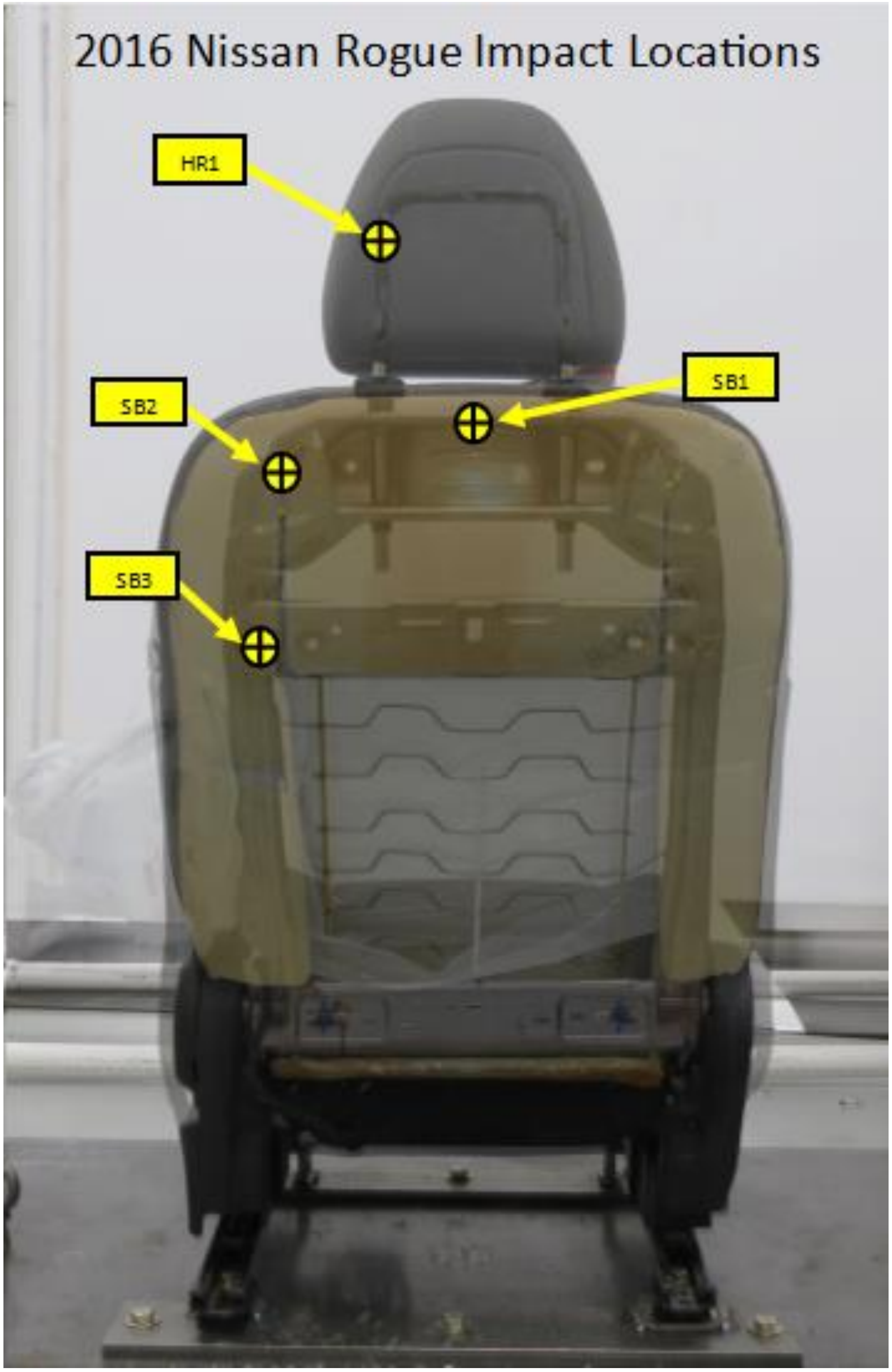


Figure B8. 2016 Nissan Rogue

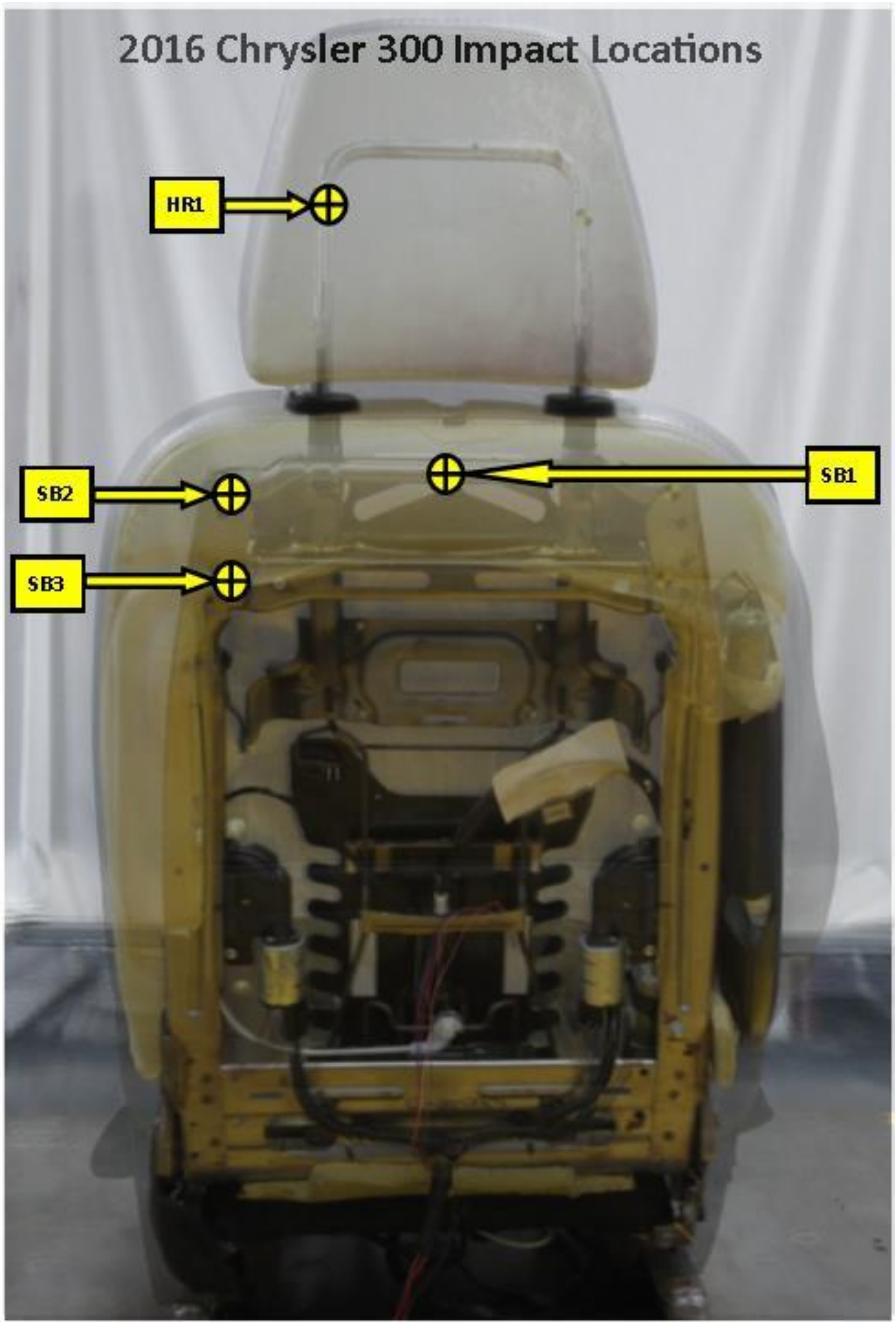


Figure B9. 2016 Chrysler 300

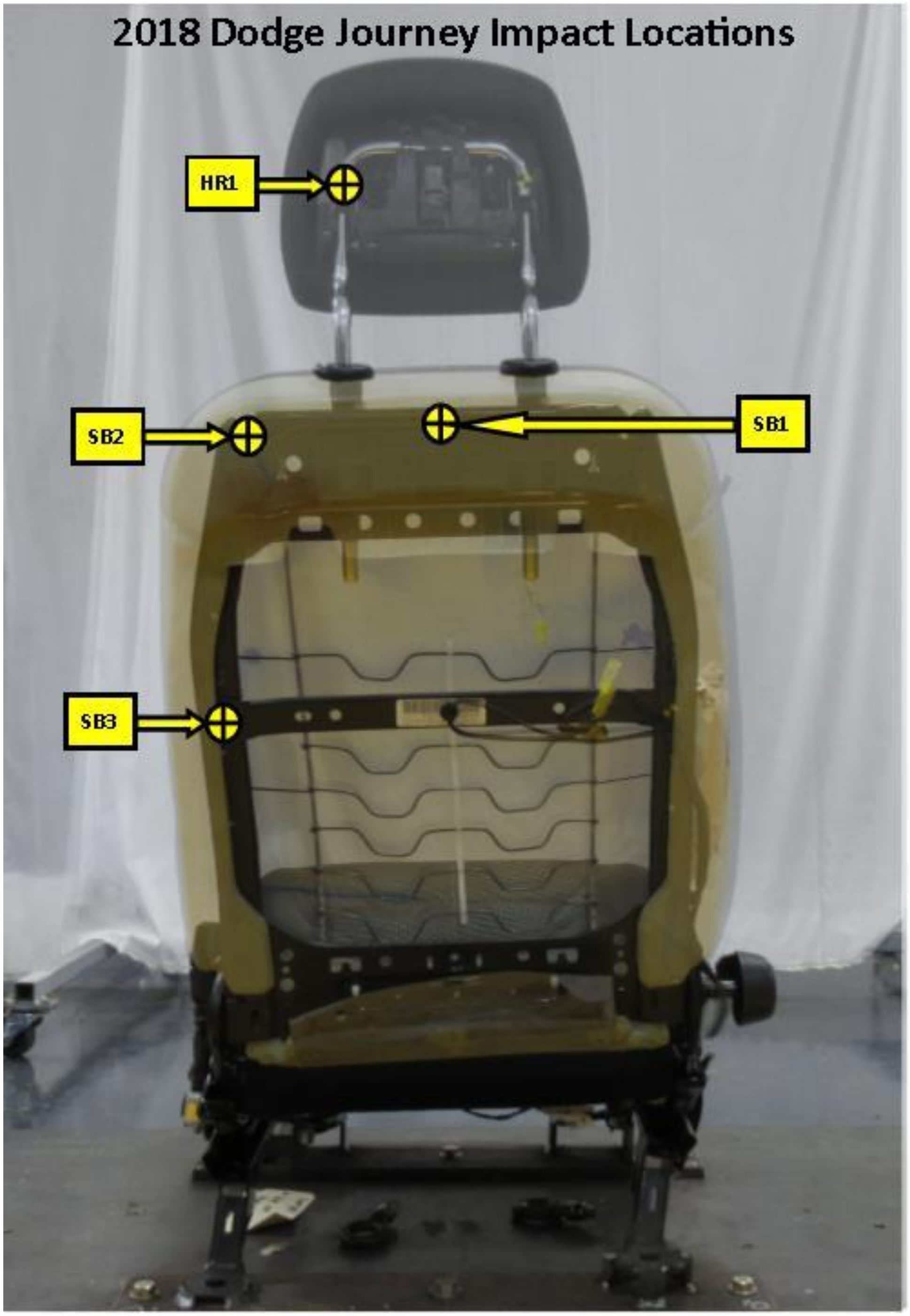


Figure B10. 2018 Dodge Journey

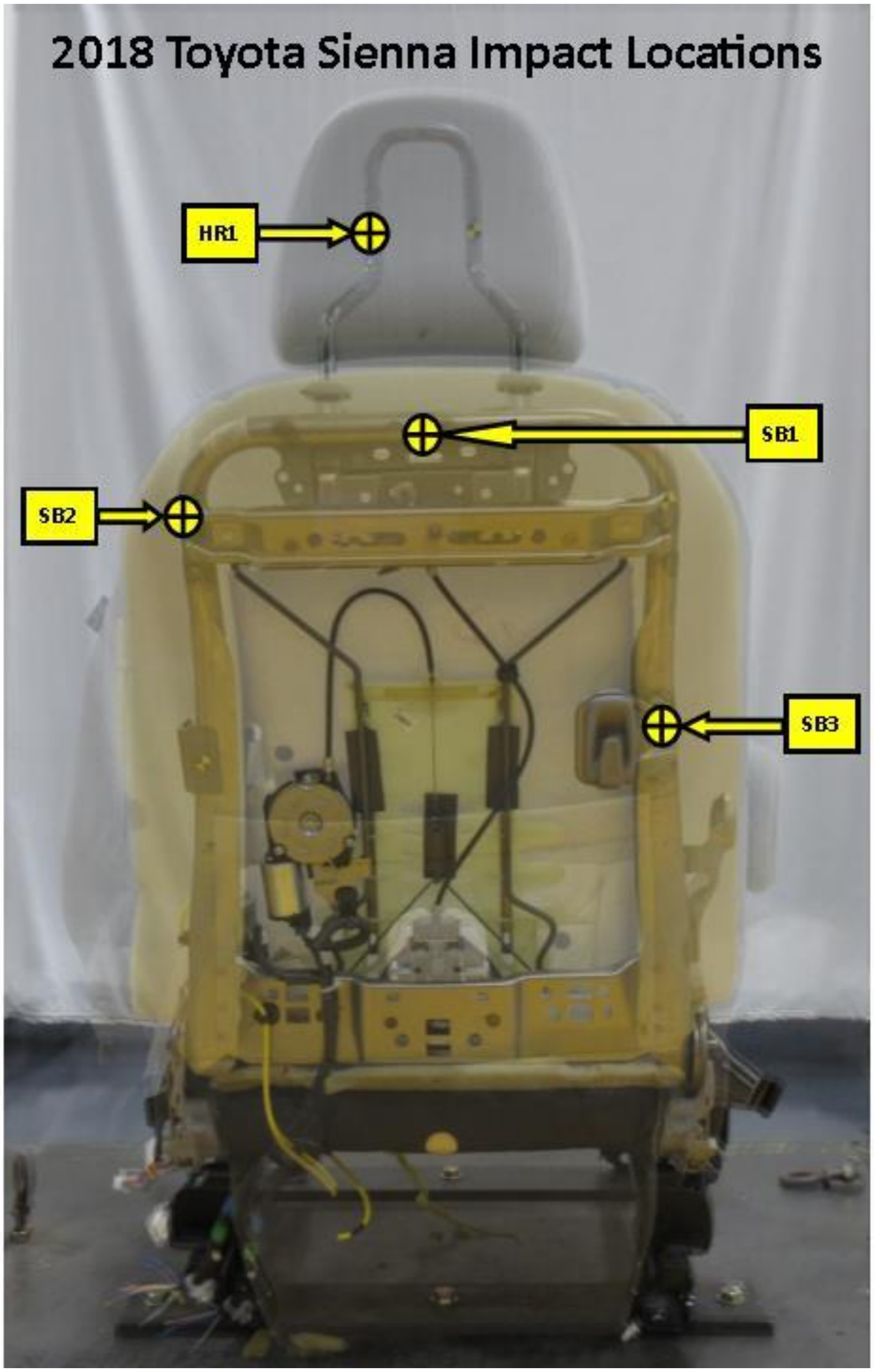


Figure B11. 2018 Toyota Sienna

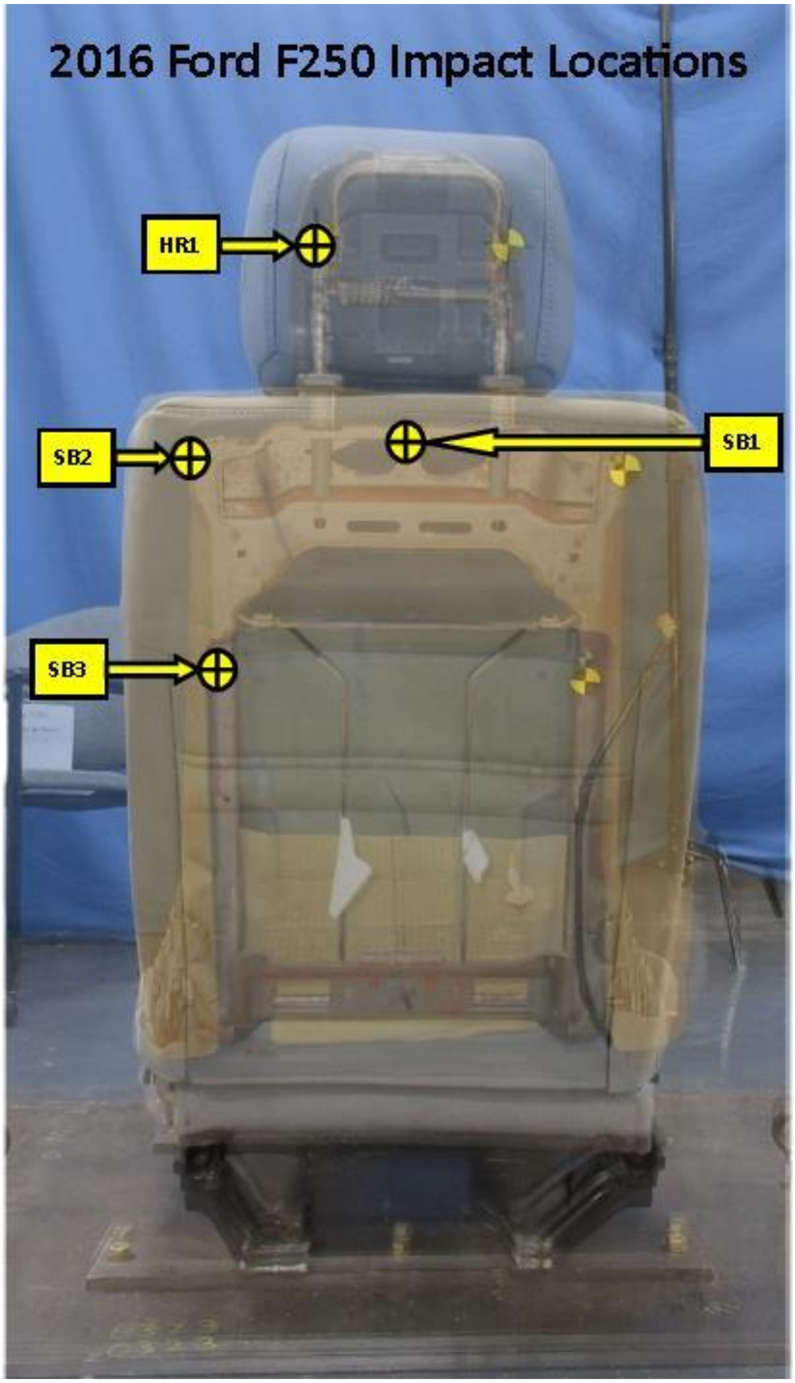


Figure B12. 2016 Ford F-250

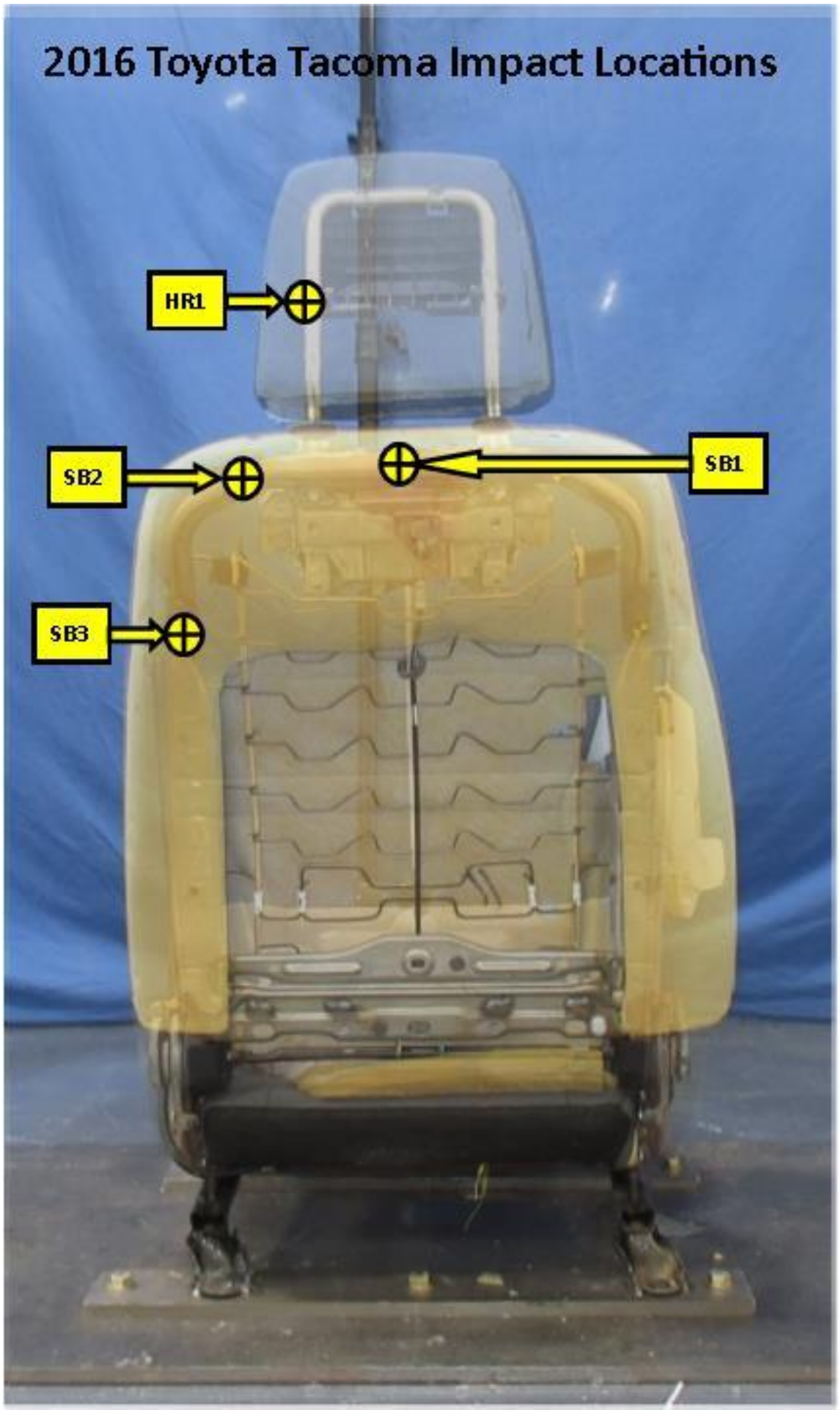


Figure B13. 2016 Toyota Tacoma

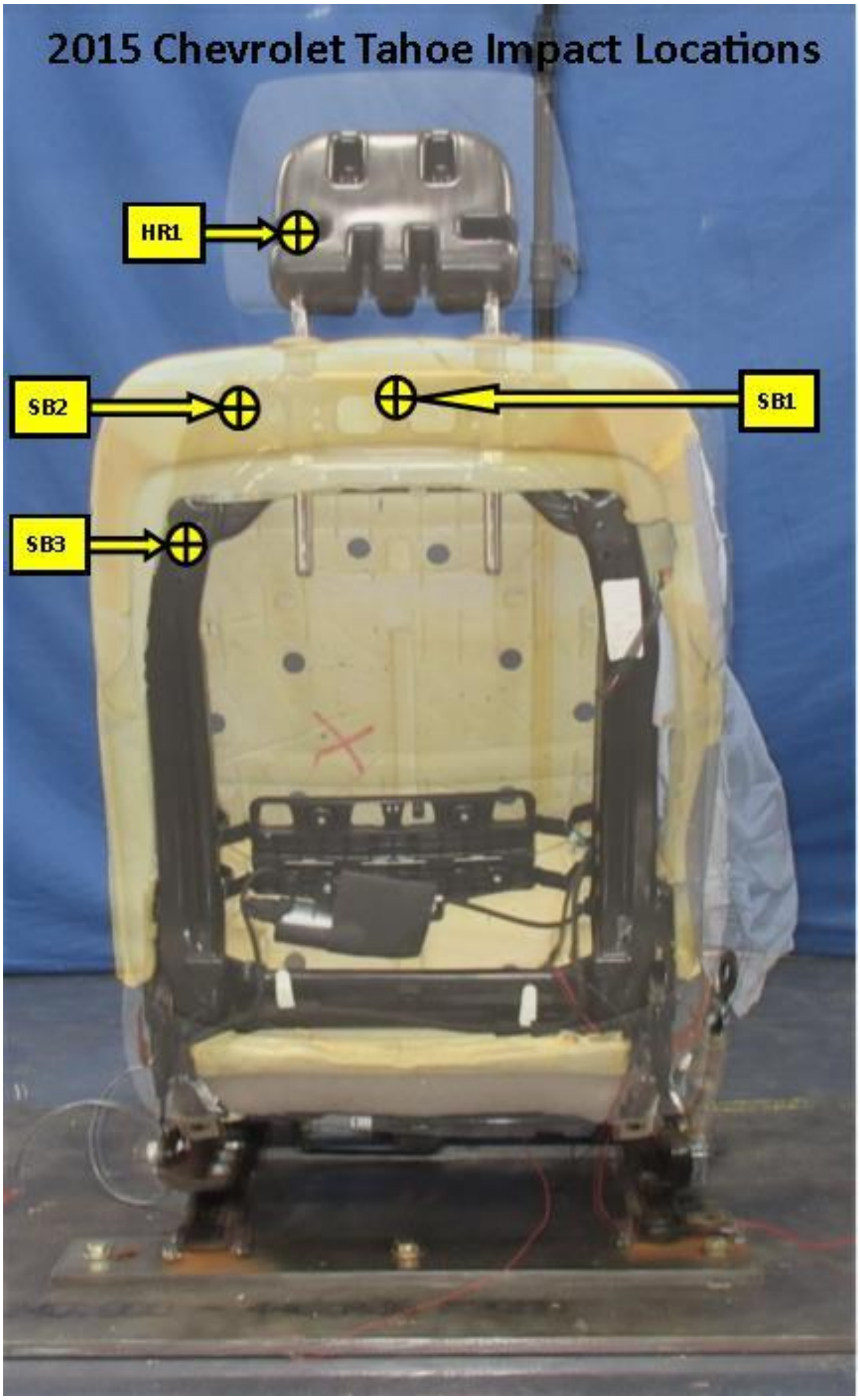


Figure B14. 2015 Chevrolet Tahoe

Appendix C. Procedure for Seat Back and Head Restraint Testing with Applied Load

Define Impact Locations

1. To determine the target locations, begin with the seat pan in the lowest position, mid-track, and mid-angle. The head restraint should be in lowest locking detent.
2. The seat back should be set to 25 degrees (or the closest angle allowed by the detents) using the SAE-J826 manikin. Remove the manikin and measure the seat back angle using an inclinometer and level. The level should be in contact with as much of the seat back cushion as possible without resting on the seat pan (Figure C1). Measure the head restraint post angles (left and right) using an inclinometer (Figure C2). Record the values.

Figure C1. Seat back angle measurement

Figure C2. Head restraint post angle measurement

3. Once the seat has been set to 25 degrees and all angles recorded, use a portable CMM to measure the following:
   - Floor plane
   - Centerline of the seat
   - Left and right seat back pivot points
   - Outside edge of the left and right head restraint post
   - Highest point of the assembled head restraint with the head restraint in the lowest locking position
   - Lowest point of the assembled head restraint with the head restraint in the lowest locking position
4. Create a SAE-J211 right-handed coordinate system using the floor plane as the XY plane, the centerline of the seat as the X-axis, and either the left or right seat back pivot as the origin.
5. Use a CMM to collect the assembled seat (foam) profile.
6. Disassemble the seat back and head restraint by removing the seat cover and cushion to access to the framework. Use a portable CMM to collect frame profiles.
7. Verify seat back frame is adjusted to the angles recorded in Step 2 using the head restraint post measurements.
8. With the CMM aligned to the seat using the left and right seat back pivots and the left and right head restraint posts measured in Step 3, use the CMM to define and measure the impact locations (Figure C3). The left and right targets should be symmetrical.
   - SB1: Mid-seat back frame
   - SB2L: Corner of seat back frame over weld/hard spot on left side
   - SB2R: Corner of seat back frame over weld/hard spot on right side
   - SB3L: Lower on seat back frame near weld/hard spot on left side
   - SB3R: Lower on seat back frame near weld/hard spot on right side
   - HR1L: On restraint post, halfway up assembled head restraint on left side
   - HR1R: On restraint post, halfway up assembled head restraint on right side

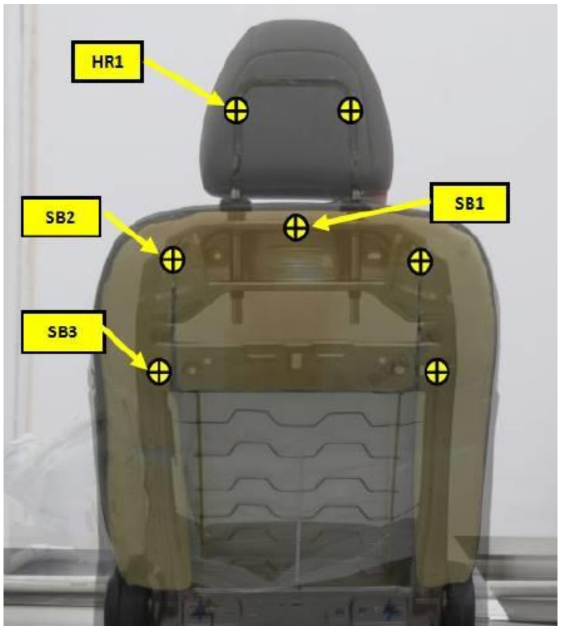


Figure C3. Impact locations

9. Reassemble the seat back and head restraints with new cushions and covers; a new head restraint may be required.
10. Before reinstalling the seat back:
    - Record the mass of the seat back including the head restraint.
    - Balance the seat back on a bar in order to locate the center of gravity (CG) of the fully assembled seat back with the head restraint in the lowest locking detent.
    - Mark the CG location on the side of the seat.
11. Once seat back has been fully assembled, reinstall the seat back onto the seat pan. The seat back should be positioned to the same angles found in Step 2 using the 2-foot level on the seat back and the inclinometer on the head restraint posts.
12. Re-align the portable CMM to the seat using the left and right seat back pivot and the left and right head restraint posts originally measured in Step 3.
13. Verify the selected seat back pivot is 0,0,0 and use the CMM to place the impact locations onto the seat assembly; to do this only the Y and Z axis measurement should be matched for each of the impact locations.
14. If several seat backs are being used, repeat Steps 9 thru 11 to mark up and layout additional seat backs.

Seat Setup

15. Perform speed shots as necessary.
16. Mount the seat to the steel mounting plate. If the test is not the first impact on a platform's seat pan, then verify the seat pan width stays within a 0.4-inch (10-mm) tolerance. Verify the seat pan is in the lowest position, at mid-track, and at mid-angle. The head restraint should be in full down position at the time of impact.

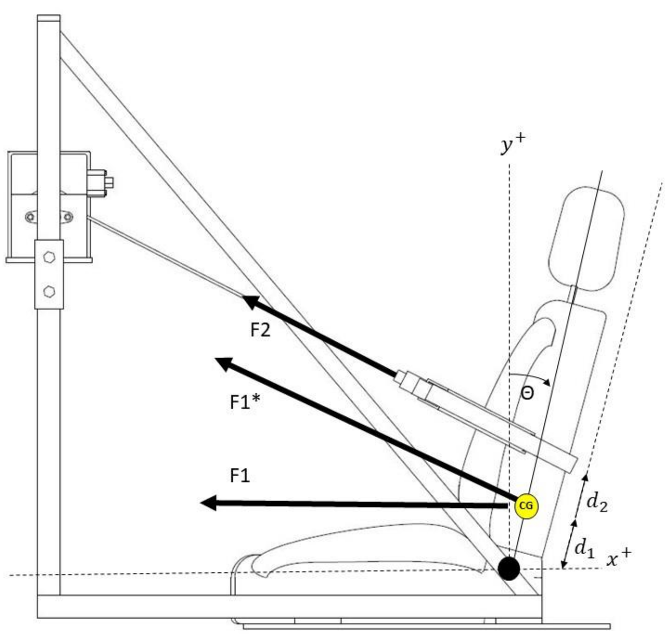
17. Place the steel mounting plate on the floating floor and align the front edge and secure it by adding weights. Typically, two 500-pound (227-kg) weights and three 50-pound (22.5-kg) weights are used. Add sandbags on the opposite end of the floating table until there is an equal distribution of weights, such that the floating table glides with minimal vibration and noise.
18. The seat back should be prepared with new parts with the seat back mounting bolts torqued to the vehicle manufacturer's specified values. The seat back should be set to the angles recorded in Step 2.
19. Verify the target locations SB1, SB2, SB3, and HR1 are measured and marked on the seat back. Record seat back mass, seat back CG, and how impact locations were defined.
20. Unbolt the outer seat bolts from the steel mounting plate.
21. Clear the immediate vicinity of the seat to make room for the seat load fixture (Figure C4).

Figure C4. Seat load fixture

22. Mount the seat load fixture, through the seat mounting brackets, to the steel mounting plate. Note that the load fixture uses the same mounting holes as the seat mounting brackets; longer bolts will be required when mounting the load fixture.
23. Determine a location for the loading strap that does not interfere with seat back impact locations and mark its location (Figure C5). Measure the distance between the forward tension attachment strap and the seat back pivot (d_2).

Figure C5. Forward tension attachment strap

24. Calculate pull force required for the current test, using the SAE-J826 manikin torso angle (θ), measured from vertical from Step 2.



Variables:

a = 43.9 g = 430.5 m/s^2 = Average NCAP crash test pulse from 2015-2017

m (lb) = Combined mass of seat back and head restraint

d_1 (in) = Distance from seat back pivot to center of mass axis

d_2 (in) = Distance from seat back pivot to pull axis

θ = Seat back angle from the SAE-J826 manikin as measured (from vertical)

$F_1 = m*a$

$F_{1*} = F_1/\cos(\theta)$

$M_1 = F_{1*} * d_1$

$M_2 = F_2 * d_2$

Solve for F_2:

$M_1 = M_2$

$F_1 * d_1 = F_2 * d_2$

$F_{1*} = m * a / \cos(\theta)$

$F_2 = m * a * d_1 / (\cos(\theta) * d_2)$

25. Align the winch such that the tension cable pulls in a direction as close to perpendicular to the seat back as possible at the location identified for the pulling attachment strap (d_2). Hold the forward tension attachment and strap in place and add enough tension to straighten the steel cable. Record the angle of the cable.

Impact Approach Angles and Headform Alignment

26. Prepare data system in real-time view mode.

The next set of steps may require two personnel (one person at the seat and one person at the winch to tighten strap for the load to be applied):

27. Display the digital output from the force gauge. One person should hold the forward tension attachment strap at the loading height (Step 23) and instruct the second person to operate the winch until the indicator reaches the force calculated in Step 24.
28. Record the angle of the seat back using a 2-foot level and head restraint post angles.

If using the 201HF, go to Step 29 then skip to Step 31. If using the APHF, go directly to Step 30. If testing for repeatability, determine approach angles for the first test and then skip to Step 39 for repeat tests.

29. Follow the 201U test procedure to determine the vertical approach angle for the seat while monitoring the load and seat back angle with a 2-foot level (Laboratory Test Procedure for FMVSS 201, 12.7.1B). Keeping the forehead impact zone in contact with the target, the headform is rotated downward until the lip, chin, or nose region of the FMH contacts another part of the seat back or head restraint. Record this angle then rotate the headform downward by 10° to determine the maximum vertical angle. Repeat three times for consistency. Record the maximum angle.

30. Line up the APHF to the back of the seat back per target to achieve the most perpendicular angle from the APHF forehead to the seat back target while monitoring the load and seat back angle with a 2-foot level. Repeat three times for consistency. Record the angle.
31. To determine the horizontal approach angle, use a digital protractor with one edge on the flat part of the seat back or head restraint and the other edge along the curved surface where the impact target is placed (Figure C6). The headform should impact the target in a perpendicular direction. Record the angle.

Figure C6. Measuring horizontal approach angle

32. Measure and document the height of the impact location using a horizontal laser level and tape measure.
33. Adjust the impactor angle and height for the current test position to values determined in Steps 29 through 32.
34. Position the floating floor so that the headform (placed on the extender) is in line with the impact target, using the vertical and horizontal approach angle determined.
35. Measure the horizontal approach angle using a digital protractor. Use a marked line on the floor that is parallel to the Y-axis (Figure C7). Alternatively, if a CMM is available, measure the horizontal approach angle by recording two collinear points on the impactor and two more points on the seat centerline.
36. Remove the headform and extender, then release the load.

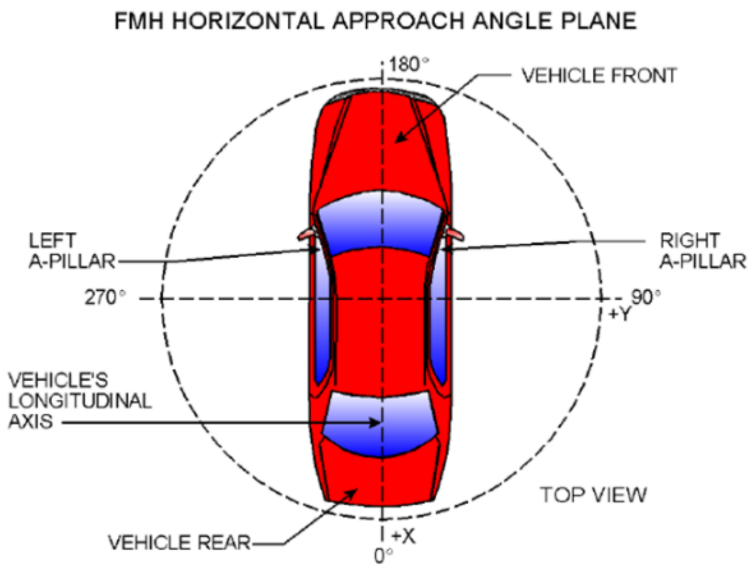


Figure C7. Horizontal approach angle definitions.

Impact Testing and Setup

37. Set up a high-speed camera perpendicular to the impact location. The video should capture the full event (head leaving impactor through seat movement after impact).
38. Turn on the FMH data acquisition console.
39. Prepare data system in data collection mode, keeping the Test ID and Description consistent with the assigned format:

    Sample Test ID: ESLI_IMP_1 201HF SB1

    Sample Test Description: 2018 DODGE JOURNEY / 201HF / SB1 / HOR 0 DEG / VERT 0 DEG / 25 MPH / 11.19.19

40. Load the seat, making sure to use the calculated pull force from Step 24. Once the channels are set up and the system is in live mode, the seat should be loaded to the force found in Step 24. Record load shown on the display screen. Record seat back angle using the level and the head restraint post angles with the inclinometer.

Start a timer after loading the seat as instructed in Step 40. Steps 41-51 should be aimed to be completed 30 minutes after the full load is applied. If the setup is ready before 30 minutes, wait a minimum of 30 minutes before striking the seat. If the FMH impact test should occur after the 30 minutes, record the time past 30 minutes and conduct the test.

Measure the seat back angle to confirm that the recorded value matches the value measured in the determination of approach angles to the loaded seat for the initial pull (Steps 29 to 31) within a tolerance of 2.5 degrees. If the change in seat back angle exceeds the angle tolerance, stop the test and resolve.

41. The seat and floating floor may need to be adjusted to the final impact position. With the headform and extender on the end of the impactor, position the floating floor such that the headform is aligned with the impact location, with a gap of no more than 0.5 inch (13 mm) between the headform and the target and within 0.5 degree of the determined approach angles.
42. Add a signboard (Figure C8) such that it is within the frame of the video view. The signboard should include test number, vehicle make and model, speed, horizontal and vertical approach angles, and date.

Figure C8. Example signboard

43. Take pre-test photos.
44. Place contact tape vertically over the headform and over the impact target.
45. Place a targeting sticker with the sticky side out at the contact point on the head using a target and Vaseline (Figure C9).

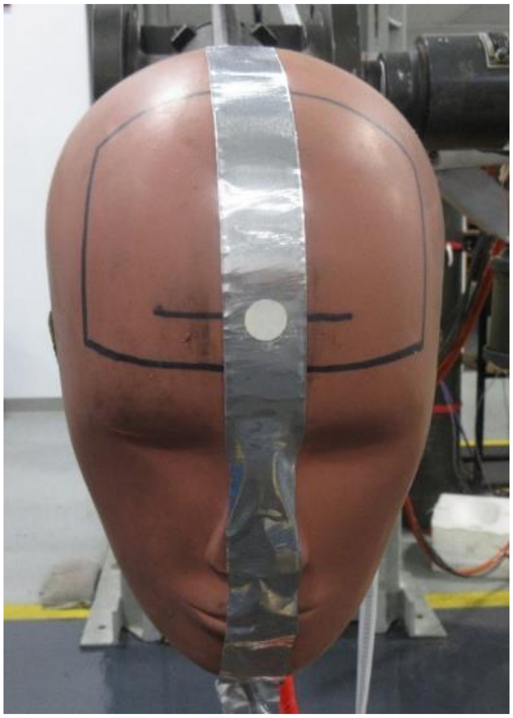


Figure C9. Targeting sticker placed on the headform

46. Write and verify all impact notes.
47. Arm data system and verify high-speed cameras are waiting for trigger.

Near the 25-minute mark, measure the seat back angle to confirm that the recorded value matches the value measured in the determination of approach angles to the loaded seat (Steps 29 to 31) within 2.5 degrees. If the change in seat back angle is greater than 2.5 degrees, stop the test and resolve.

48. Turn on lights and verify video camera view (Figure C10).

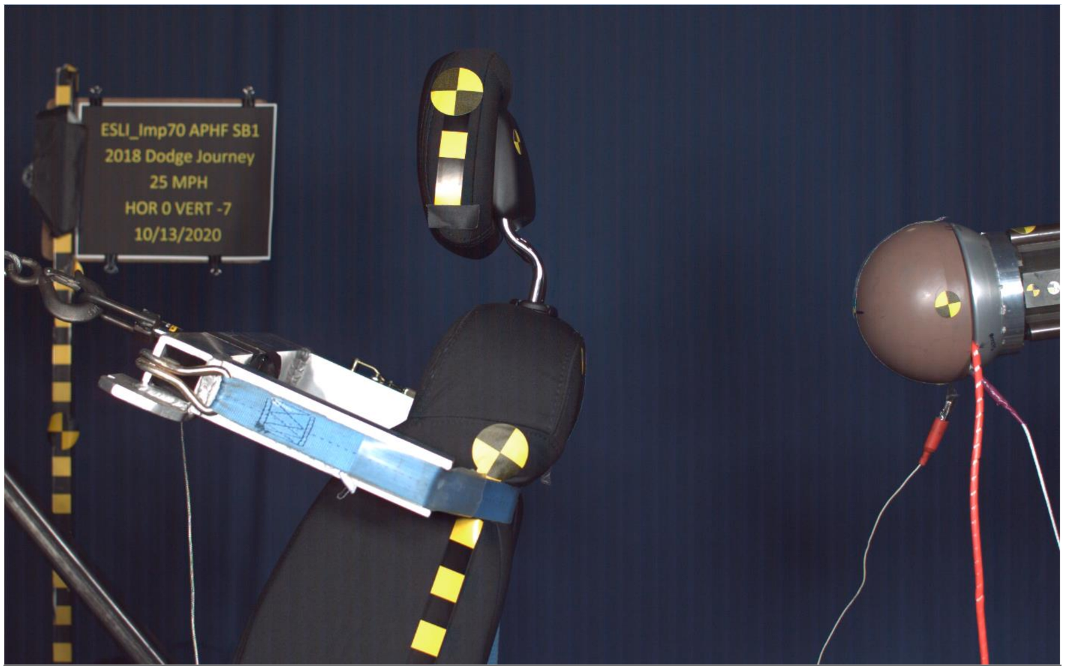


Figure C10. Camera view for loaded seat impact

49. Conduct the test, matching impactor air pressure to the pre-determined value for the required impact velocity.
50. Collect actual time and actual force at test time.
51. Collect the seat back angle and head restraint angles with the seat back load still active.
52. Take post-test photos with the seat back load still active.
53. Fully release the load that was applied to the seat back.
54. Collect post-test notes and record post-test seat back angles and left and right head restraint post angles.
55. Take post-test photos with the seat back load released.
56. Download data and videos.
57. Deconstruct seat and check for damage. Report all damage and take pictures.

Appendix D. Procedure for Lower B-pillar Testing

Vehicle Setup

1. Remove front driver and passenger seats and any other parts that are not needed for B-pillar testing. Ensure the door trim, lower and upper B-pillar trim, and second row seat are installed.
2. Verify all tire pressures are at the manufacturer's specified pressure for the specific vehicle.
3. Place a minimum of three reference points on the vehicle in order to relocate the CMM during testing (Figure D1).

Figure D1. Example of reference point locations

4. Measure and record the door sill angle with an inclinometer at the center of the passenger and driver door sills.
5. Position the vehicle on jack stands on the floating floor and match previously the measured door sill angle.
6. Determine the center of gravity of the head of the rear occupant (CG-R) point.

   6.1 Position the SAE-J826 manikin in the right rear passenger seat of the vehicle.

   6.2 Record the outboard and inboard H-point locations of the SAE-J826 manikin and create the seating reference point (SRP) midway between the outboard and inboard H-points.

6.3. Create the center of gravity of the head for manikin in the rear outboard designated seating position (CG-R). This point is located 6.3 inches (160 mm) rearward and 26 inches (660 mm) upward from the SRP.

Define Impact Location

7. Determine the Plane 9 – Rear Edge (P9-R) impact location.

7.1. Create a Plane 9 line that is at the Z-height of the lowest point of daylight opening forward of the B-pillar with the door closed (Figure D2).

7.2. Mark the Plane 9 line on the B-pillar trim (Figure D2).

7.3. Using the CMM, find the shortest distance from the CG-R point to the Plane 9 line on the B-pillar, and mark a crosshair at that location.

7.4. Record the P9-R location from the crosshair. Place a target at the point and label it P9-R (Figure D3).

Figure D2. Determine P9-R impact location

Figure D3. P9-R impact location on B-pillar trim

Impact Approach Angles and Headform Alignment

8. Ensure the vehicle doors are closed and adjacent trim installed before determining approach angles.
9. The horizontal approach angle used for research is defined using the CG-R point, the P9-R impact location, and the centerline of the vehicle. The horizontal approach angle is the angle between the +X axis (towards the rear of the vehicle) and the impact velocity vector projected onto the X-Y plane and measured in the counter-clockwise direction.

9.1. Using the CMM, create an approach line using the CG-R and the P9-R points.

9.2. The horizontal approach angle is measured from the X-axis centerline of the vehicle and the approach line. Record the XY-angle measurement from the CMM.

9.2.1. If the forehead of the FMH cannot stay in contact with the impact location due to an obstruction, move the headform away from the midsagittal centerline within the forehead impact zone, while maintaining the horizontal approach angle. If this allows the obstruction to be cleared, report the distance from the midsagittal centerline of headform to the impact location.

9.2.2. If the obstruction persists, relocate P9-R to any location within a 1-inch (25-mm) radius of the original target center as shown in Figure D4. Move the target location the minimum amount necessary to avoid the obstruction, while maintaining the horizontal approach angle. For research purposes, try to stay on Plane 9 if possible, or lower than Plane 9 if further adjustments are required.

9.2.3. Continue to increase the radius in increments of 1 inch (25 mm) until the impact location can achieve first contact with the FMH forehead impact zone at the approach angles determined.

Figure D4. P9-R adjusted (red/white target) to avoid headform contact with an obstruction

9.3. Record the final impact location.

9.4. Verify the horizontal approach angle determined is within the range as specified in the FMVSS No. 201 test procedure: 15 degrees to 165 degrees for right side B-pillar testing (Figure D5).

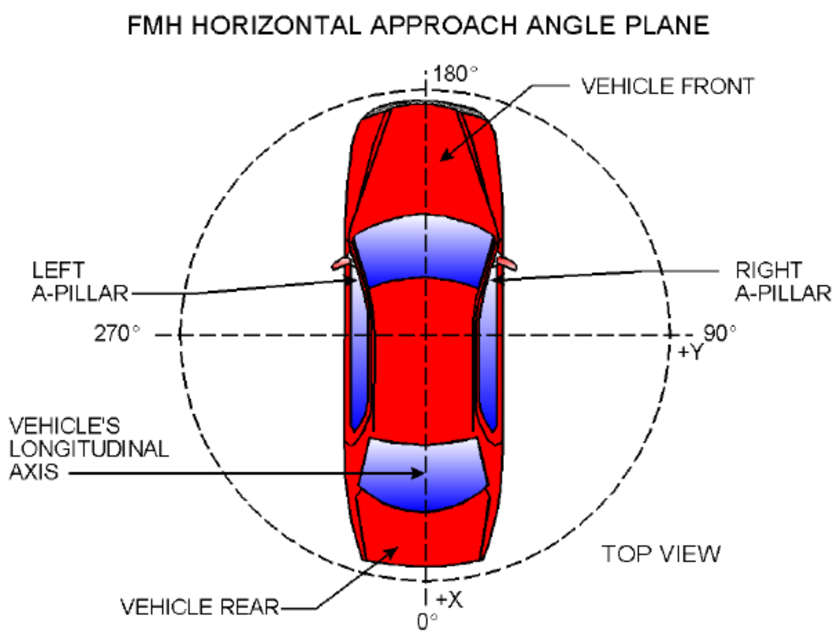


Figure D5. Horizontal approach angle definitions

10. Determine the vertical approach angles.

    10.1. When testing with the adult pedestrian headform (APHF), the vertical approach is defined as the vector perpendicular to the impact location.

    10.2. When testing with the 201HF, the vertical approach angle is determined by using the following FMVSS No. 201 test procedure (TP-201U-02) and positioning the forehead impact zone in contact with the P9-R target at the prescribed horizontal approach angle.

        10.2.1 Keeping the forehead impact zone in contact with the target, rotate the FMH upward (chin forward) until the lip, chin or other part of the FMH contacts a component of the vehicle and record the angle.

        10.2.2 Keeping the forehead impact zone in contact with the target, rotate the FMH downward by 10 degrees from the angle found in Step 10.2.1 and record the vertical approach angle.

            10.2.2.1 If the forehead of the FMH cannot stay in contact with the impact location, move the headform away from the midsagittal centerline within the forehead impact zone. If this allows the obstruction to be cleared, report the distance from the midsagittal centerline of headform to the anticipated impact location.

            10.2.2.2 If the obstruction persists, relocate P9-R to any location within a 1 inch (25 mm) radius of the original target center as shown in Figure C5. For research purposes, try to stay on Plane 9 if possible, or lower than Plane 9 if further adjustments are required.

            10.2.2.3 Continue to increase the radius in increments of 1 inch (25 mm) until the impact location can achieve first contact with the FMH forehead impact zone at the approach angles determined.

    10.3. Record the final adjusted impact location.

11. Remove the B-pillar trim and repeat Step 7 to mark P9-R on the B-pillar frame. Document with pictures (Figure D6).

Figure D6. P9-R marked on B-pillar frame

12. Install new trim parts onto the B-pillar frame.
13. Using the CMM, place a target at the P9-R impact location on the new trim piece. If the P9-R location was adjusted to avoid obstructions, place both targets (P9-R and P9-R Adjusted) on the new B-pillar trim and label according.
14. Remove rear vehicle components (i.e. rear seat, bumper, etc.) to create space for the impactor.
15. Ensure the front and rear windows are fully open.

Impact Approach Angle and Headform Alignment

16. Perform speed shots for each headform using the determined horizontal and vertical angles (Steps 9 and 10) before testing. Record the pressure and speed results.
17. Determine how the impactor is going to be positioned inside the vehicle. The impactor may need to come through the rear or the side of the vehicle depending on the type and size of the vehicle.
18. Loosen the vertical height adjustment bolts on the impactor so that the impactor can be adjusted while moving the vehicle into position.
19. Once the impactor is inside the vehicle and roughly at the horizontal approach angle, the vertical angle can be fine-tuned.
20. Adjust the vertical angle by loosening the bolts and adjusting the impactor arm to the vertical angle found in Step 10.
21. Install the extender and the headform being tested onto the end of the impactor.
22. Position the floating floor so that the headform placed on the extender is in line with the P9-R impact location, using the vertical and horizontal approach angles found in Steps 9 and 10 (Figure D7).

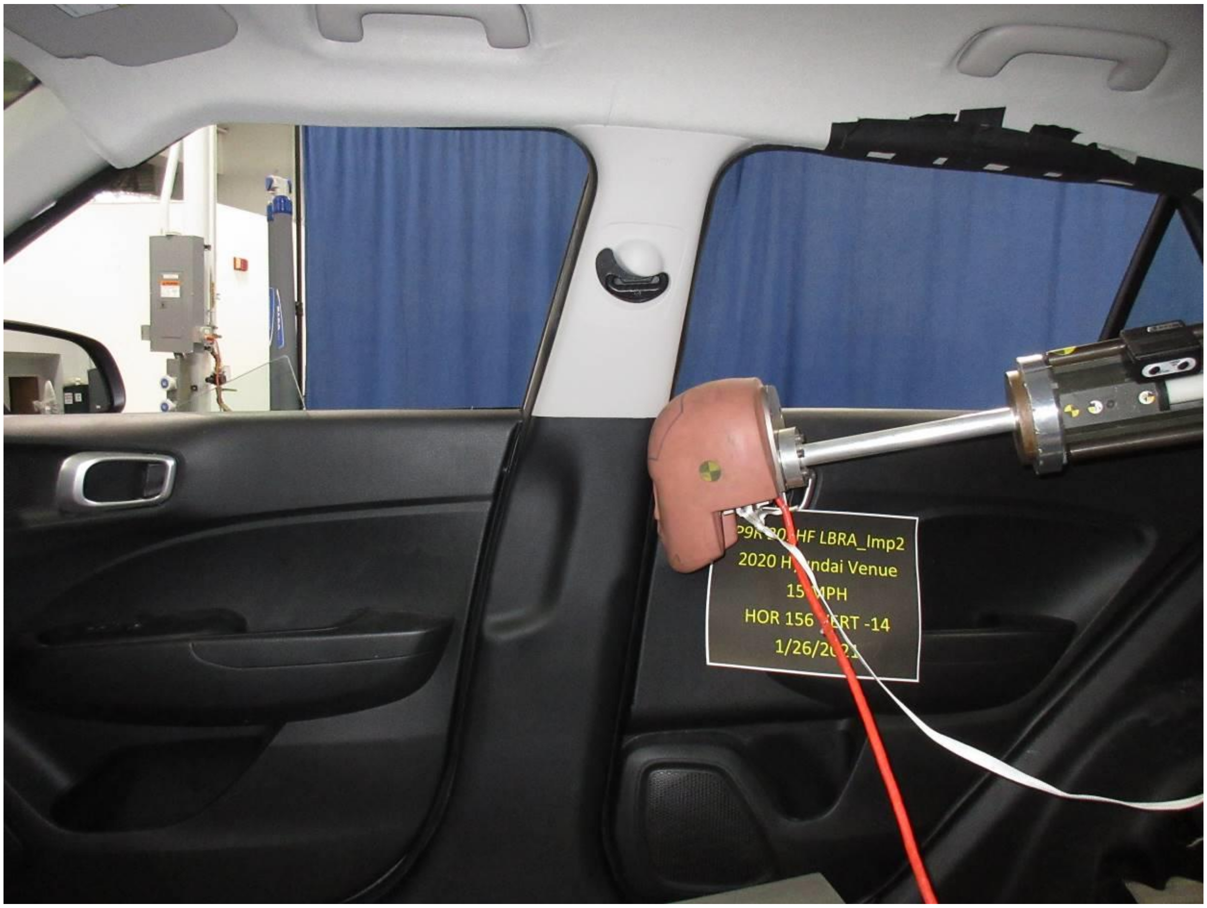


Figure D7. Position impactor to match the vertical and horizontal angles for impact

23. Use a horizontal laser level set at the P9-R (or P9-R adjusted) target location in order to set the height of the impactor.
24. A second laser level may be placed at the rear of the impactor arm pointed vertically down the extender at the back of the headform.
25. If the impactor arm cannot be positioned at the correct approach angle for testing due to inference from other vehicle components (i.e. bumpers, taillights, etc.), it may be necessary to remove parts until the obstructions are cleared. Before removing or cutting any parts, confirm that the parts being removed will not affect the structural integrity of the B-pillar. Document what was removed in order to achieve the correct approach angle.
26. Verify that all impactor adjustment bolts have been tightened.
27. Using the reference points created in Step 3, align the CMM to the vehicle to measure the horizontal and vertical approach angles of the impactor. Measure two points (center rear and center forward) of the impactor arm. Create an approach line and measure the angle between the approach line and the X-axis centerline of the vehicle.
28. Finalize the alignment of the headform to the impact location, with a gap of no more than 0.5 inch (13 mm) between the headform and the target and within 0.5 degree of the determined approach angles.

Impact Testing and Setup

29. Add a signboard (Figure D8) such that it is within the frame of the video view. The signboard should include test number, vehicle make and model, speed, horizontal and vertical angle, and date.

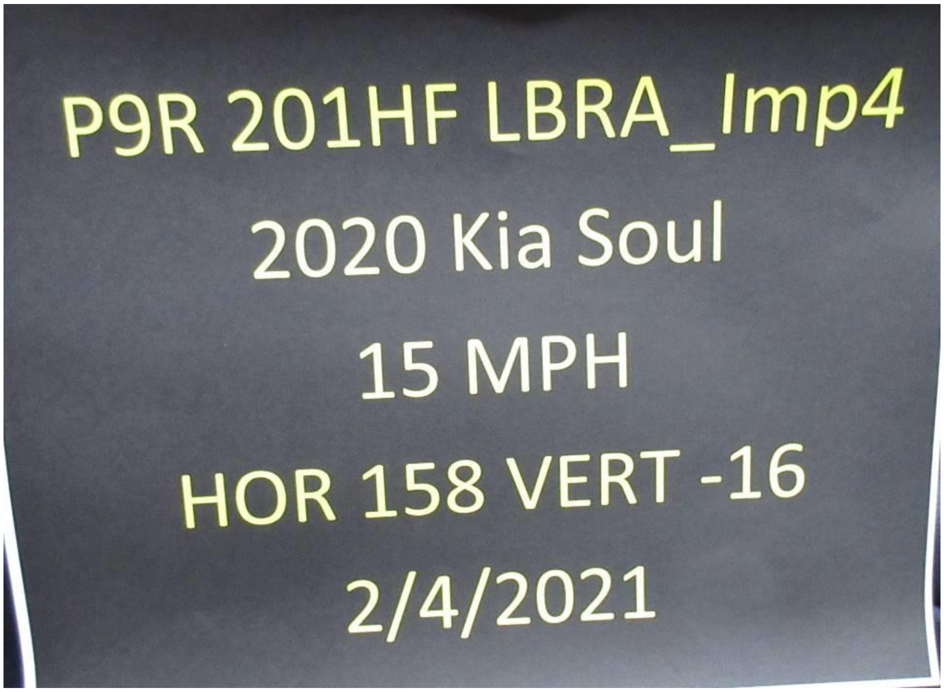


Figure D8. Example signboard

30. Take pre-test photos.
31. Place contact tape vertically over the headform and over the impact point (Figure D9).
32. Place a targeting sticker with the sticky side out at the contact point on the head using a target and Vaseline (Figure D9).

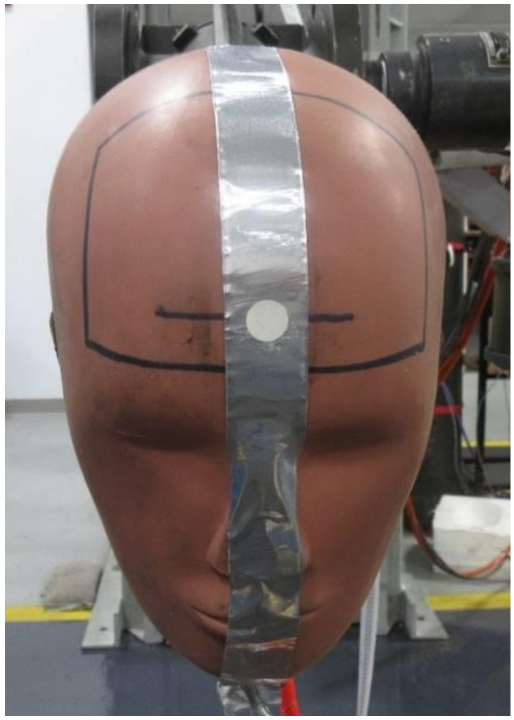


Figure D9. Targeting sticker placed on the headform

33. Write and verify all impact notes.
34. Turn on FMH console.
35. Prepare data system in data collection mode, keeping the Test ID and Description consistent with the assigned format:

    Sample Test ID: IMP-2 APHF P9-R

    Sample Test Description: 2018 DODGE JOURNEY / APHF / P9-R / HOR157 DEG / VERT 0 DEG/ 15 MPH / 5.15.19

36. Arm data system and verify high-speed cameras are waiting for trigger.
37. Turn on lights and verify video camera view (Figure D10).

Figure D10. Camera view for lower B-pillar impact

38. Conduct the test, matching impactor air pressure to the pre-determined value for the required impact velocity.
39. Collect post-test notes, including any damage to the front or back of the trim pieces.
40. Take post-test photos including of the B-pillar damage and frame.
41. Download data and videos.

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