STATUS OF NHTSA'S EJECTION MITIGATION RESEARCH

Aloke Prasad
National Highway Traffic Safety Administration
United States of America

Corinn Pruitt
Transportation Research Center Inc.
United States of America

Paper Number 19-0036

ABSTRACT

The objective of this paper is to present an update on the research conducted by the National Highway Traffic Safety Administration (NHTSA) to assess the performance of roof glazing in production vehicles and certain countermeasure designs in preventing occupant ejections.

Federal Motor Vehicle Safety Standard (FMVSS) No. 226 "Ejection mitigation" set requirements for ejection mitigation systems to reduce the likelihood of complete and partial ejections of vehicle occupants through side windows during rollovers or side impact events.

In the preamble of the final rule establishing the standard (Jan 2011), the agency stated "NHTSA is interested in learning more about roof ejections and would like to explore this area further..." It also stated that while sun/moon roof ejection could be potentially cost effective to mitigate, the agency was not in a position to extend coverage to roof glazing in the final rule because the agency wanted to research a viable performance test procedure.

The assessment of ejection protection offered by sunroofs was made using a guided impactor (18 kg) directed toward roof glazing (pre-broken) from inside the vehicle, based on the procedures developed in the FMVSS No. 226 regulation[2], with test speeds of 14, 16, and 20 kilometers per hour.

Tests were conducted on production and countermeasure sunroof designs for the 2016 Ford F-150, production sunroofs for 2012 Toyota Prius, and production sunroofs provided by the Aisin Technical Center of America.

For sunroofs with both a fixed and a moving panel (F-150, Aisin), the movable panels presented more challenges to contain the headform than fixed panels. For the moving panels, the sunroof attachment structure separated at the inserts (into the rails). Fixed panels had higher excursions at unsupported transverse edges or edges without any metal encapsulation frames. The F-150 fixed rear panel had front and rear transverse unsupported edges, while the Aisin had longitudinal edges without metal frames. Laminated glazing panes with thicker polyvinyl butyral (PVB) inner layer in and polyethylene terephthalate (PET) film with tempered panes used as countermeasures for the F-150 sunroof reduced glazing stretch (and ram excursions). However, this transferred more forces to the edges and presented a greater challenge for movable panel containment at rail attachments.

The fixed polycarbonate panel used in the Prius had low ram excursions but high ram decelerations.

Meeting some excursion limit will require designs that have strong attachments to the vehicle roof or rails. Deformation of the glazing and encapsulation frame should be limited when impacted at the center of the panel. Any tear/rip of the plastic layer would add to the excursion of the ram.

The number of vehicle designs tested was limited by the availability of laminated glazing used in production or countermeasure designs.

This paper details performance of selected production and countermeasure sunroof designs in limiting headform excursions. Some of the fixed sunroof designs had excursions of less than 100 millimeters. The movable sunroof designs tested will require additional countermeasures to perform at this level.

INTRODUCTION

The National Highway Traffic Safety Administration (NHTSA) is continuing its exploration of roof ejection mitigation which commenced following NHTSA's issuance of FMVSS No. 226. FMVSS No. 226 sets requirements for ejection mitigation systems to reduce the likelihood of complete and partial ejections of vehicle occupants through side windows during rollovers or side impact events.

The final rule (Jan 2011) preamble said, "NHTSA is interested in learning more about roof ejections and would like to explore this area further...".[1] It also stated that while sun/moon roof ejection could be potentially cost effective to mitigate, the agency was not in a position to extend coverage to roof glazing in the final rule because the agency wanted to research a viable performance test procedure.

This paper addresses testing on production and prototype countermeasure sunroof designs to evaluate performance in preventing occupant ejections. In addition, a modified test setup with updated headform orientation and test speeds was evaluated. Additional production sunroof and countermeasure tests were completed with the new test setup.

TEST PROCEDURE AND EQUIPMENT

This study involved impacting three different production sunroofs and potential countermeasures aimed at improving occupant protection. Sunroofs and countermeasures were selected to represent a variety of constructions currently available in the market. The test method (equipment, initial selection of speeds) was adapted from the procedure used for FMVSS No. 226 and involved impacting the sunroofs with a featureless headform at different velocities.[2] The performance of each sunroof was evaluated by analyzing ram excursion, edge excursion using photogrammetry, observations of failures, and high-speed video.

Vehicle and Buck Descriptions

2016 Ford F-150 Construction The 2016 Ford F-150 (gross vehicle weight rating of 2767 kg to 3198 kg) was selected as it had large panels and was one of the widest sunroofs available at the time (Figure 1). It had a tilt slide sunroof with the front moveable panel sliding underneath the rear fixed panel. The sunroof module was bolted to the roof at twenty locations indicated by red arrows in Figure 2. The sunroof module consisted of a fixed panel and a movable panel (Figure 3). Both panels were assembled to the sunroof module using screws along the left and right sides, leaving the transverse sides unsupported (Figure 4). The production panels were made of laminated glass (2.1 – 0.76 – 2.1 mm; annealed glass – PVB – annealed glass) and were used as a baseline condition for the vehicle. Two countermeasure sunroof designs were tested. The first countermeasure increased the thickness of the PVB interlayer (2.1 – 1.52 – 2.1 mm; annealed glass – PVB – annealed glass). The second countermeasure investigated the performance of a polyethylene terephthalate (PET) protective film (Protec® II) applied to tempered glass (Protec® II film on inner surface; 5.0 mm tempered glass). The two countermeasure glass panels were attached to the sunroof assembly in the same manner as the production panels.

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[1] 76 FR 3262, January 19, 2011

[2] 49 C.F.R. § 571.226, S5. Test Procedures

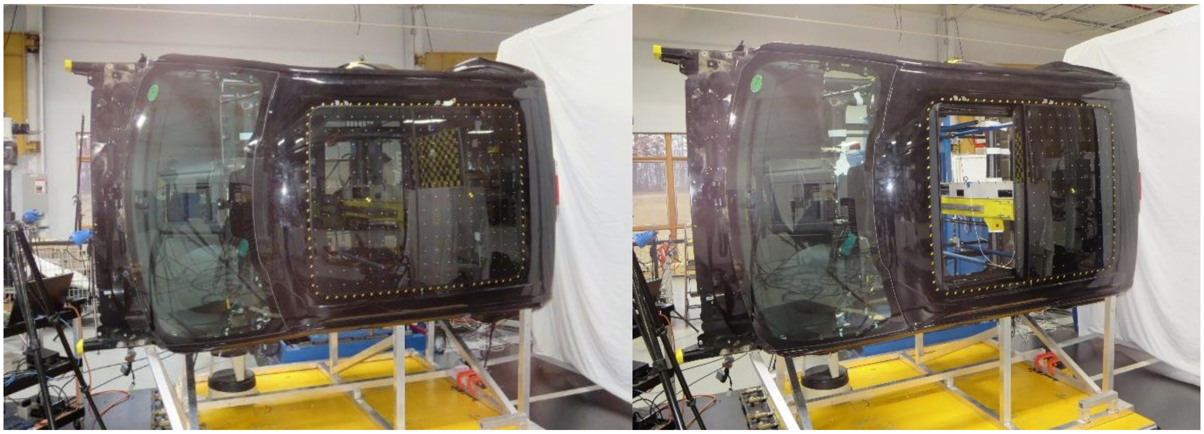

Figure 1. View of F-150 sunroof panel in both closed (left) and open (right) positions from outside. The F-150 had one of the largest sunroofs available at the time.

Figure 2. Red arrows indicate where sunroof module was bolted to the roof of the vehicle.

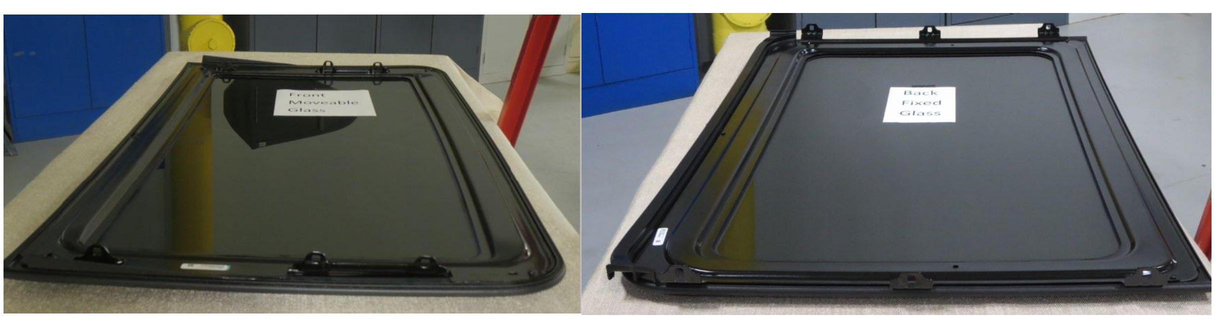

Figure 3. F-150 sunroof panels – left: front moveable panel, right: rear fixed panel.

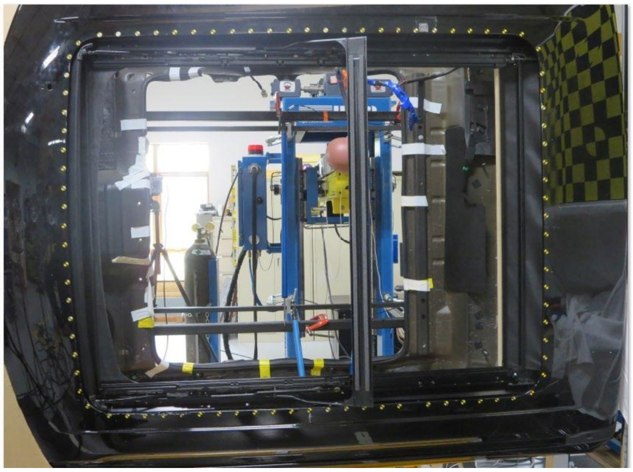

Figure 4. Front and rear panels assembled to module using screws along longitudinal edges.

<u>2012 Toyota Prius V</u> The 2012 Toyota Prius V had a large polycarbonate sunroof composed of one fixed panel with two daylight openings (Figure 5). The overall size of the panel was approximately one meter wide by one meter long. The test area of the daylight openings was approximately 0.29 meter^2. The panel was glued with polyurethane to the roof of the vehicle (Figure 6).

Figure 5. Toyota Prius V large polycarbonate sunroof with two daylight openings.

Figure 6. Sunroof panel glued to roof of vehicle with polyurethane.

Aisin Sunroofs Aisin Technical Center of America (Aisin) provided panoramic moveable sunroofs to be used for testing. The glazing composition of these sunroofs were 2.0-millimeter annealed glass (outside) – 0.76-millimeter PVB – 1.8-millimeter glass (inside). They were outer slider type sunroofs where the moveable front panel slides outside of the fixed rear panel (Figure 7). The sunroof module was attached to a custom-made test fixture at the same locations that it would be attached to the vehicle roof (Figure 8). The panels were attached to the sunroof module along the left and right longitudinal sides using a combination of plastic brackets and glue, while the transverse sides were unsupported (Figure 9).

Figure 7. Aisin outer slider sunroof – front slides outside of rear panel.

Figure 8. Sunroof module attached to custom-made frame at same locations as vehicle roof.

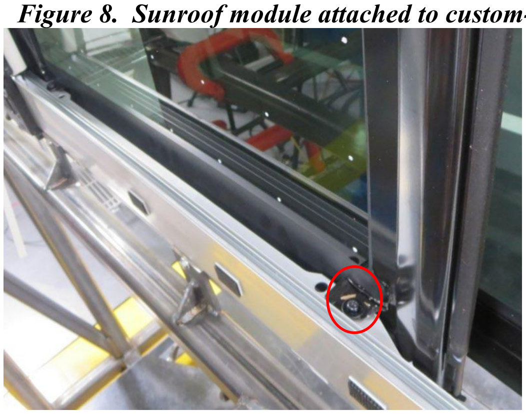

Figure 9. Panels attached to module using plastic brackets and glue along longitudinal edges.

Test Set-Up Description

The F-150 and Prius had the floor and other non-integral components removed, then were turned 90 degrees and mounted sideways to a rigid frame to allow the impactor to be aimed at the roof structure. The Aisin sunroof module was attached to a frame of the same geometry and attachment locations as the vehicle roof. To simulate damage experienced in a rollover crash, glass was pre-broken on both sides in a 75-millimeter offset pattern following the FMVSS No. 226 procedure,[3] except for the Protec® II film which was only punched on one (glass) side. The method used a 75-millimeter offset pattern, with a 75-millimeter by 75-millimeter pattern on the outside surface and the same pattern offset by 37.5 millimeters on the inside surface. Glass was broken using a spring loaded centerpunch. Prior to testing, the daylight opening was established, and an offset line 25 millimeters inside of the daylight opening was marked on the glass.

The ejection impactor used in this project meets FMVSS No. 226 specifications. It was a guided impactor that used a featureless headform (176.8 x 226.1 mm) attached to a shaft (Figure 10). The impactor had a mass of 18 kilograms. Impact velocities used in this project were 14, 16, and 20 kilometers per hour. Both 16 and 20 kilometers per hour are standard speeds used in FMVSS No. 226.

Figure 10. Ejection guided impactor with 18 kg featureless headform.

Measurements were recorded with a variety of transducers, which are summarized in Table 1.

Table 1.
Summary of Transducers Used.

Measurement	**Transducer Details**
Ram Velocity	LVDT (differentiated)
Ram Excursion	LVDT
Dynamic edge excursion	High speed video with targets (analyzed with photogrammetry)

Photographs were taken to document the test setup and post-test observations. High-speed video was used to capture the impact during each test.

Initial Baseline and Countermeasure Tests for the Ford F-150

The 2016 Ford F-150 production sunroof and countermeasures were initially evaluated using the test setup from previous rounds of testing (center and corner impact locations) with additional locations added. Additional locations were selected based on engineering judgement to greater evaluate loading on the glass and loading on panel attachments. These locations were believed more likely to have poor performance. To select these locations, it was assumed that the left and right sides of the panels were identical but the front and rear sides were not. Test locations used are shown in Figure 11. The headform was aligned so that its longitudinal axis was parallel to the vehicle's longitudinal axis. Test speeds were 16 and 20 kilometers per hour. The sunroof panels were replaced after each impact. The entire sunroof module was replaced after each panel was tested once.

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[3] FMVSS No. 226, S5.4.1, Window glazing pre-breaking procedure

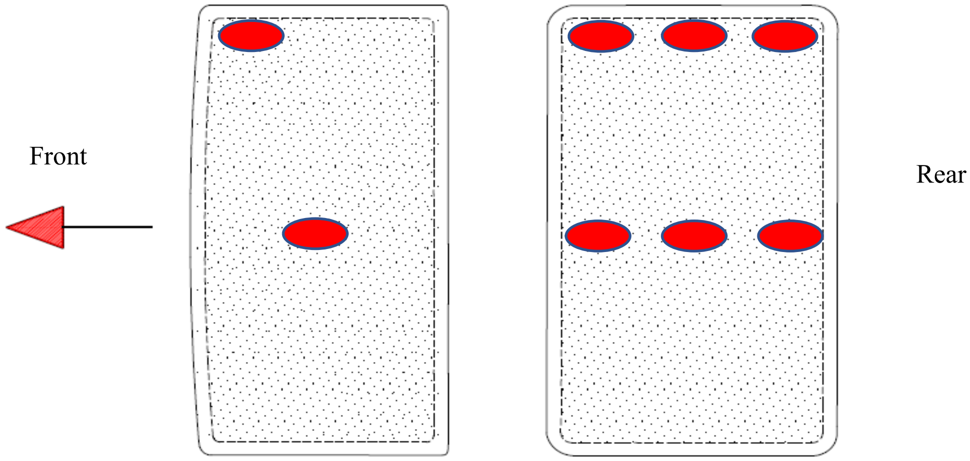

Figure 11. Initial test locations and headform orientation (F-150).

Countermeasures tested were the thicker PVB interlayer and the Protec® II glazing. Countermeasures were only tested at the center and front corner locations. Production glass was tested at the additional locations shown above. The test was setup following the procedure outlined in the section above for each of the tests. The only exception was test 74 where the Protec® II glazing was punched on both sides.

Initial Countermeasure Results

Countermeasures were compared to production glass and results are shown in the figures below. The top and bottom values represent ram excursion at 16 and 20 kilometers per hour respectively, at each location. Any asterisk (*) represents a rail mount failure (separation of the moving panel frame from the rail) at that speed and location. Excursion values exceeding 100 millimeters are shown in red color.[4] For the countermeasure tests, the percent change from the baseline production glass is also shown in parenthesis for instances without detachment at the rails. Full results (ram and edge excursions) can be found in Appendix A (Table A.1).

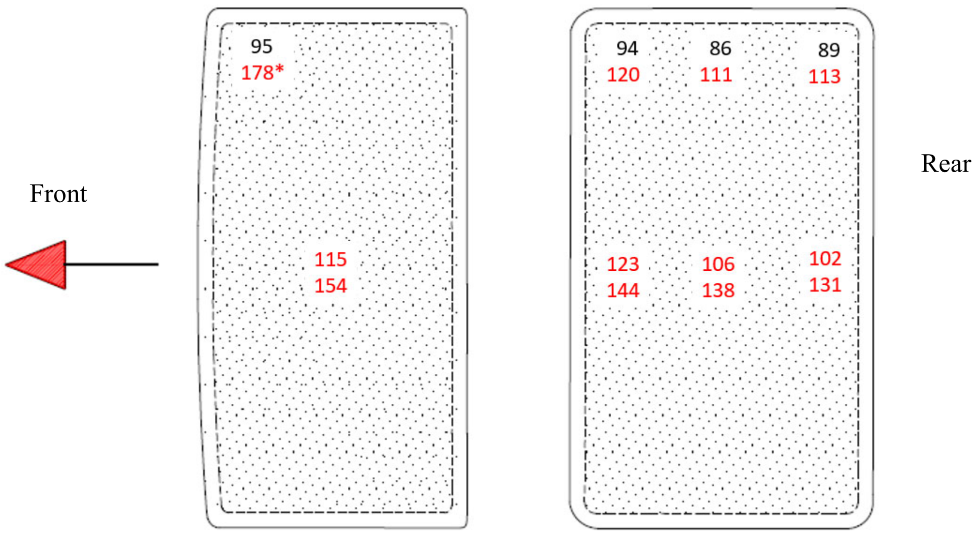

Figure 12. Production Glass (baseline) Results.

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[4] FMVSS No. 226, S4.2.1 limits the headform displacement to 100 millimeters after impact with the glazing pane surface.

For production glass, on the front movable panel, hits at the center had PVB stretch and transverse frame bending. At the corner of the front panel there was rail failure using the higher impact speed and therefore a large ram excursion. On the rear fixed panel, there was no edge failure for any location. At 16 kilometers per hour, ram excursions were below or just over 100 millimeters, except for at the forward transverse edge which is thinner and weaker and therefore had a higher excursion.

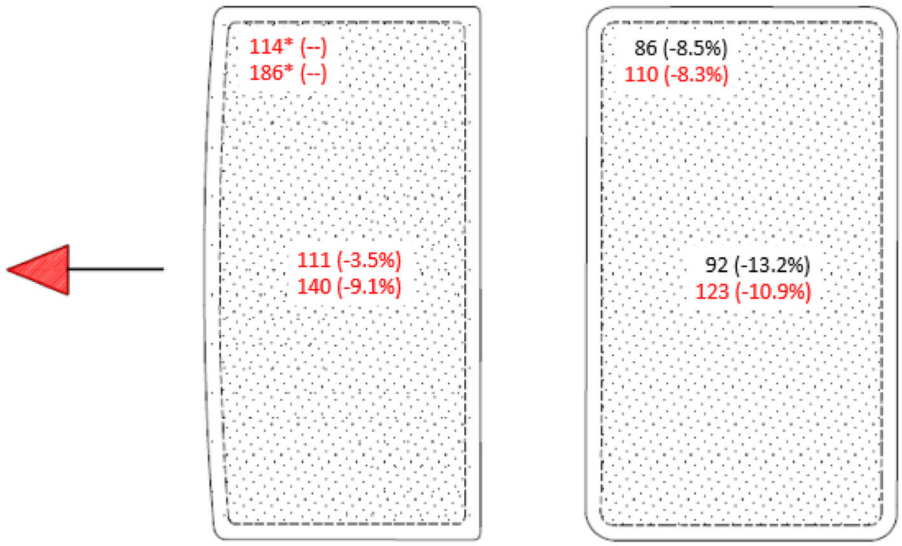


Figure 13. Thicker PVB Results.

For the thicker PVB panels, on the front movable panel, hits at the center showed less stretch but more transverse frame bending than the baseline panels. At the corners, catastrophic edge failure (complete detachment of the panel frame from the rail) was seen. On the rear panel, the thicker PVB reduced excursions by approximately 10 percent.

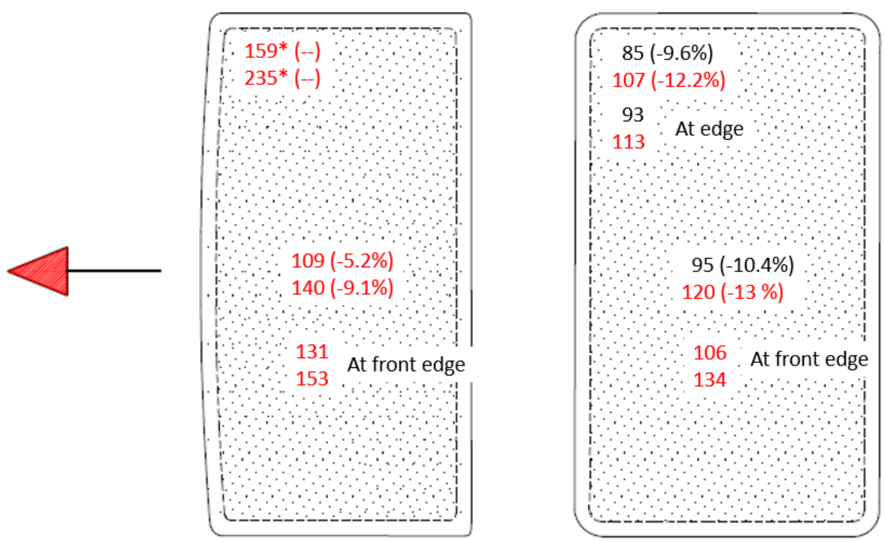


Figure 14. Protec® II Results.

For the Protec® II panels, hits on the front movable panel, at the center, had less film stretch but much more transverse frame bending than the baseline panels. At the corner, there was catastrophic edge failure at both speeds. On the fixed rear panel, there was approximately a 12 percent reduction in excursions. Like the thicker PVB, the reduced film stretching of the Protec® II led to increased loads on the edges.

Movable panels presented more challenges for containing the headform than fixed panels, for both the production panels and countermeasure panels. The thicker PVB and Protec® II panels did not tear and had reduced stretch, however this lead to more forces being transferred to the edges. Overall, baseline production panels showed feasibility at 16 kilometers per hour. Countermeasures showed they can improve the feasibility of meeting a 100-millimeter excursion limit; however, results can change for different panel designs.

Modified Test Conditions

Based on results from initial F-150 testing, impact locations and speeds were modified for future evaluations. The new test setup was based on the wording of FMVSS No. 226, as adapted for ejections through roof portals. Test locations included the corners, center, midpoint of transverse edges, and two-thirds of the longitudinal edge as shown in the figure below. Head orientation was changed so that the longitudinal axis of the headform was perpendicular to the longitudinal axis of the vehicle (Figure 15).

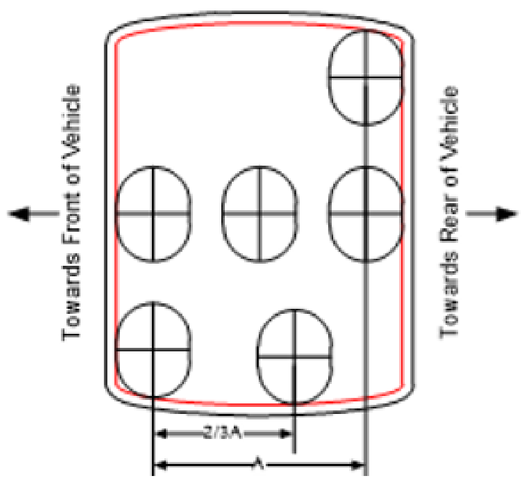


Figure 15. New Test Setup.

A test speed of 14 kilometers per hour was added. Each location was first hit at 16 kilometers per hour. If the ram excursion was greater than 100 millimeters, that location was then impacted at 14 kilometers. If the ram excursion was less than 100 millimeters at 16 kilometers per hour, then it was impacted at 20 kilometers per hour.

The test was setup following the procedure described in the section titled "Test Set-Up Description."

Photographs were taken to document the test setup and post-test observations. High-speed video was used to capture the impact during each test. This video was also used for photogrammetry analysis to determine edge excursion.

EJECTION TEST RESULTS

Ford F-150 Results

The top, middle, and bottom values in Figure 16 represent the ram excursions (in millimeters) at speeds of 14, 16, and 20 kilometers per hour, respectively. An asterisk (*) indicates a rail mount failure. Green represents ram excursion values less than 100 millimeters and red represents excursion values greater than 100 millimeters. Six tests with thicker PVB (3 front panel and 3 rear panel) and one test with Protec® II were done. Tests with thicker PVB are shown in yellow and the test with Protec® II is shown in purple. Full results (ram and edge excursions) can be found in Appendix A (Table A.2).

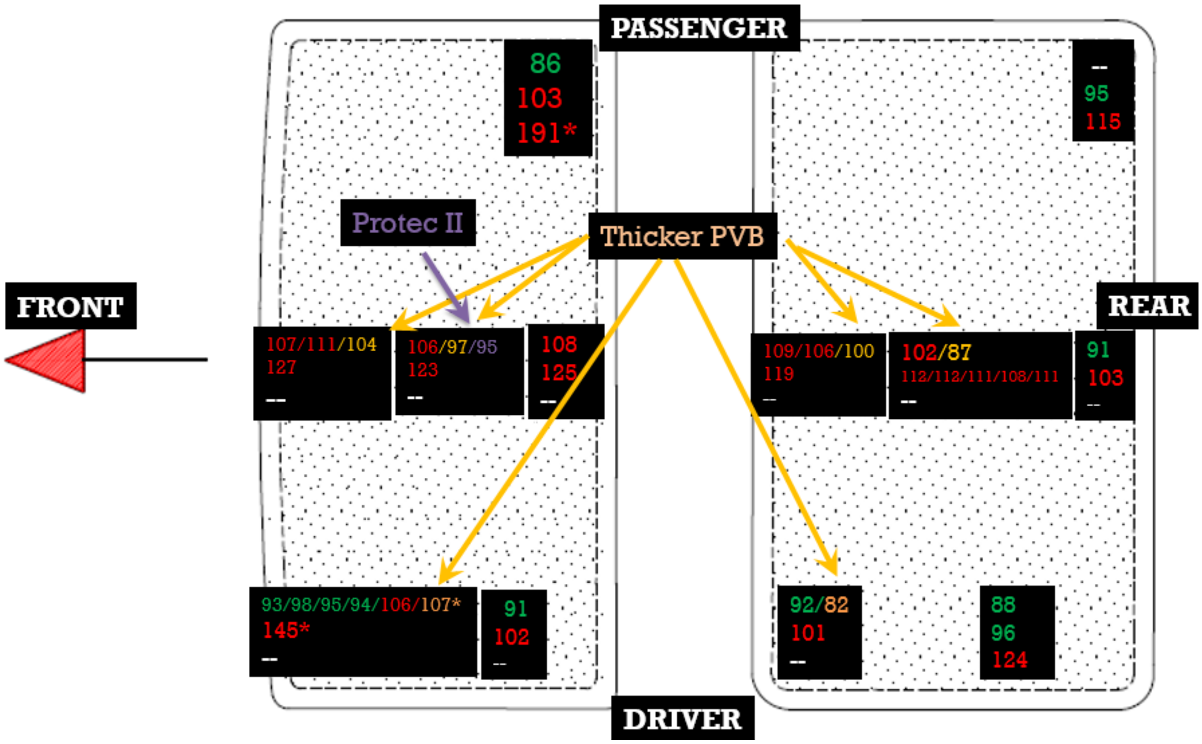


Figure 16. Ford F-150 Results.

As seen in previous testing, the movable panels presented more challenges in containing the headform than fixed panels. Failure at the inserts into the rails occurred on the moving panel. The fixed panel had higher excursions at the unsupported edges (front and rear edges of rear panel).

The plastic layer of the countermeasures (thicker PVB and Protec® II) did not tear in any test. Both countermeasures reduced plastic layer stretch and ram excursions compared to baseline. However, since more forces were transferred to the edges, larger openings were sometimes produced at the edges (i.e. edge excursions, highlighted in yellow in Tables A.1 and A.2).

Toyota Prius V Results

The polycarbonate panel on the Toyota Prius V was replaced after the first nine tests by a professional glass installer using the original glue sourced from Japan. There was no separation at the panel-roof glue interface during the entire test series for the Prius V roof. Ram excursions (in millimeters) can be seen in Figure 17 below. The top, middle, and bottom values represent excursions at speeds of 14, 16, and 20 kilometers per hour, respectively. Three tests were conducted on the rear panel at the two-thirds longitudinal edge locations and at 20 kilometers per hour, to assess the effect of repeated impacts. All three tests produced a ram excursion of 50 millimeters. The test with the * cracked the front windshield of the test vehicle. The windshield was replaced after this test. The test with ** caused the nearby roof structure to deform, however, this was a small static deformation of the structure. The roof structure was pushed back into its pre-impact shape and reinforcement was added. Full results (ram and edge excursions) can be found in Appendix A (Table A.3).

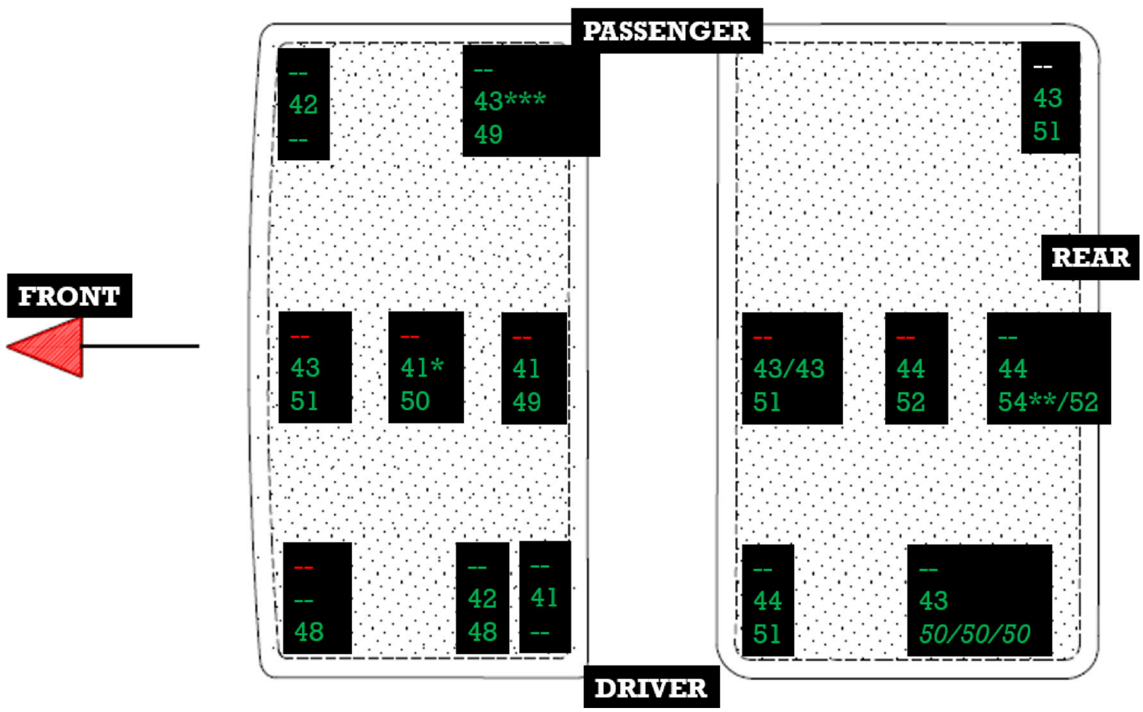


Figure 17. Toyota Prius V Results.

All Prius impacts had less than 100 millimeters excursions, generally around 50 millimeters. No separation at the glue interface was seen. Additionally, no failure of the polycarbonate or glue interface was seen even for multiple impacts at 20 kilometers per hour at the same location. Overall there were low ram displacements, however, due to less flexion of the sunroof panel there were high head deceleration values and therefore high forces on the headform. For example, when comparing an impact in the center of the Ford F-150 fixed panel at 16 kilometers per hour to an impact in the center of the Toyota Prius panel at 16 kilometers per hour, the forces on the headform were 2282 and 8663 Newtons, respectively. This is shown in Figure 18 below, with the F-150 in red and the Prius in blue.

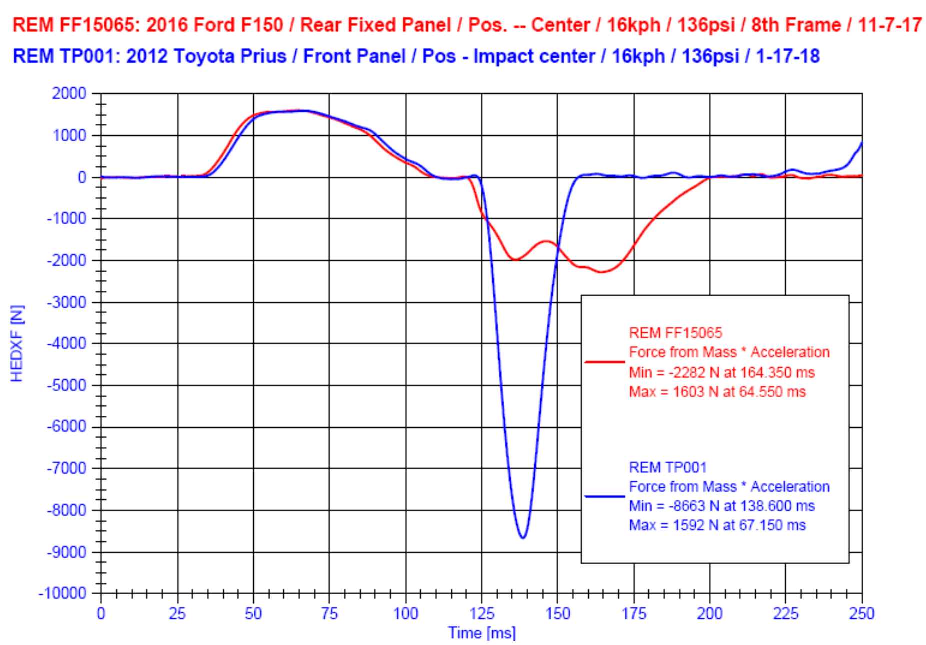


Figure 18. Comparison of forces on headform of F-150 (red) and Prius (blue).

Aisin Sunroof Results

Ram excursions (in millimeters) are shown in Figure 19 below. The top, middle, and bottom values represent excursions at speeds of 14, 16, and 20 kilometers per hour, respectively. An asterisk (*) means a rail insert failure occurred, double asterisks (**) mean an attachment bracket failure, triple asterisks (***) mean attachment glue-to-glass adhesion failure, and a # means a PVB failure, usually a rip in the PVB. Green values indicate excursions less than 100 millimeters and red indicate excursions greater than 100 millimeters. The four yellow values represent tests on the front movable panel where the panel was partially open so that the pin was in the metal rail. The panel was positioned so that for each of these four tests, the front edge of the window trim was 265 millimeters from a target on the front supporting frame. Full results (ram and edge excursions) can be found in Appendix A (Table A.4).

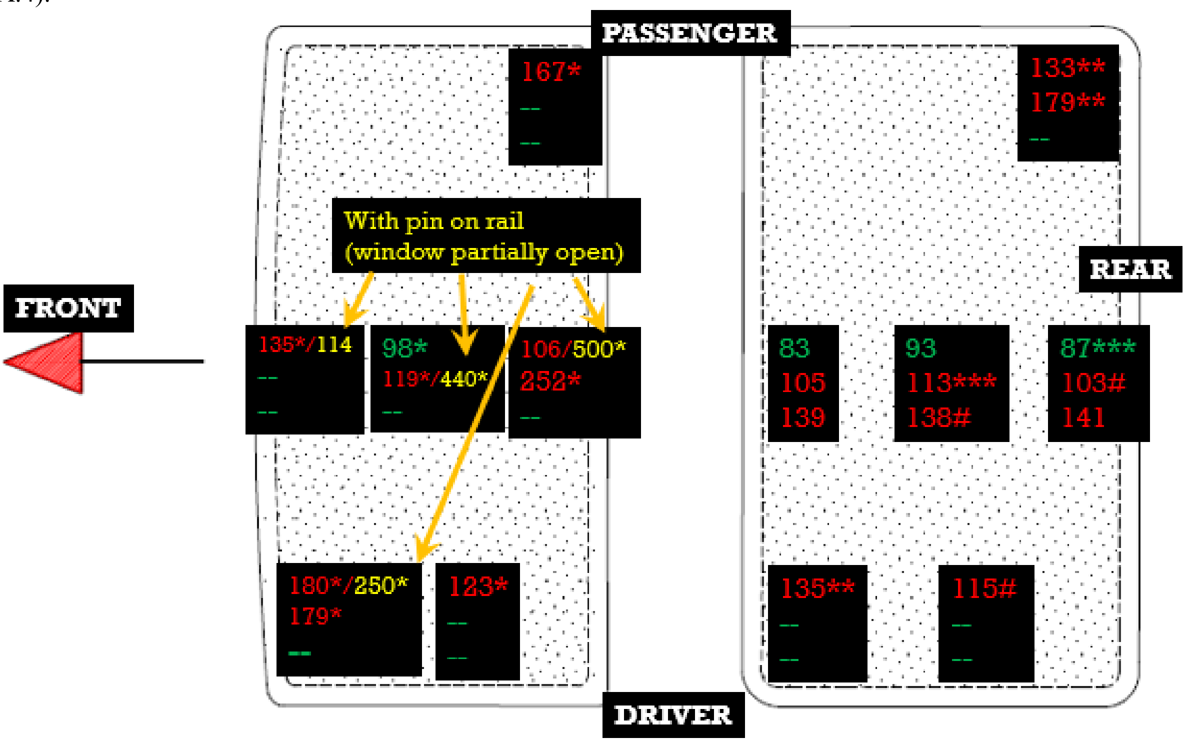
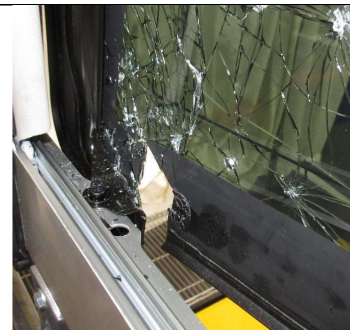
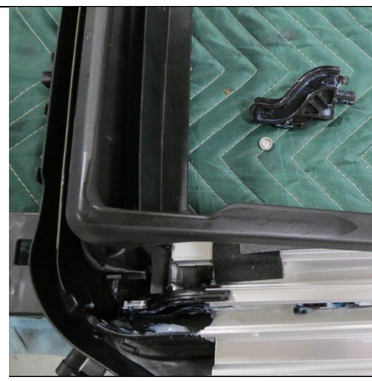


Figure 19. Aisin Sunroof Results.

The Aisin sunroof had many failure modes. Some examples of these failure modes are shown in Table 2 below.

Table 2.
Failure modes of Aisin sunroof.

		
Rear panel - attachment bracket	Rear panel bracket – glue attachment	Rear panel – PVB tear at attachment
		
Glass PVB tear	Front panel corner pin -rail insert	Front panel corner pin and rear attachment

The headform did not push through the PVB layer for any of the tests. In some tests, where the frame inserts didn't fail, the PVB layers had tears in it. On the front movable, panel brittle fracture of the plastic cam, which is used to raise the front edge when sliding the panel to open, occurred in some tests. In tests where the panel was moved to a partially open configuration there were also rail insert failures. The rail inserts had weakness at all locations impacted on the front panel. The rear fixed panel had weakness at the attachment brackets. Failures occurred at the bracket to glass glue adhesion as well as at the bracket attachment bolt. Bending of the encapsulation frame was also observed for many tests.

CONCLUSIONS

This paper details performance of selected production and countermeasure sunroof designs in limiting headform excursions. Additionally, it describes a new test setup that was developed for roof ejection tests adapted from the wording of FMVSS No. 226. Test locations include the corners, center, midpoint of transverse edges, and two-thirds of the longitudinal edge. Head orientation was changed so that the longitudinal axis of the headform was perpendicular to the longitudinal axis of the vehicle. These locations tested attachment, frame, and glazing performance. On movable panels, failure of rail inserts happened when impacted near the rail attachments, and unsupported transverse edges bent when the panel was hit at the center or near the transverse edges. Stronger glazing transferred more load to the attachments.

Some of the fixed sunroof designs had excursions of less than 100 millimeters. The movable sunroof designs tested will require additional countermeasures to perform at this level. The research findings suggest that meeting some excursion limit similar to the 100-millimeter requirement of FMVSS No. 226 will require designs that have limited deformation of the glazing and encapsulation frame when impacted at the center of the panel, strong attachments, with no separation at the attachments. Tears or rips in the plastic layer may lead to additional impactor excursion. Impacts in close proximity to attachments frequently caused failure at the attachments. PVB elasticity also affects the excursions, particularly for center impacts. Any glued plastic sun roofs with low excursions, such as that of the Prius, can cause higher forces on the impactor than those produced from impacts to glass sunroofs. No comparison was made to forces produced from impacts with roofs that do not have a sunroof. The relationship between this loading and potential occupant injury was not assessed.

APPENDIX A: RESULTS TABLES

Table A1: 2016 Ford F-150 - Initial Tests

Production

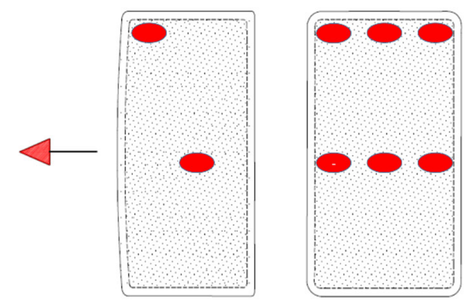
	Front Movable Panel						Rear Fixed Panel											
	Center		Forward Edge - Corner		Forward Edge - Mid		Center		Forward Edge - Corner		Forward Edge - Mid		Top Edge - Mid		Rear Edge - Mid		Rear Edge - Top Corner	
	Ram	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*
16 Km/h	115 mm	86 mm	95 mm	75 mm	---	---	106 mm	80 mm	94 mm	70 mm	123 mm	89 mm	86 mm	56 mm	102 mm	64 mm	89 mm	43 mm
20 Km/h	154 mm	106 mm	178 mm	233 mm	---	---	138 mm	101 mm	120 mm	84 mm	144 mm	132 mm	111 mm	67 mm	131 mm	71 mm	113 mm	56 mm

Double PVB

	Front Movable Panel						Rear Fixed Panel					
	Center		Forward Edge - Corner		Forward Edge - Mid		Center		Forward Edge - Corner		Forward Edge - Mid	
	Ram	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*
16 Km/h	111 mm (-3.5%)	95 mm	114 mm (--%)	174 mm	---	---	92 mm (-13.2%)	94 mm	86 mm (-8.5%)	54 mm	---	---
20 Km/h	140 mm (-9.1%)	137 mm	186 mm (--%)	241 mm	---	---	123 mm (-10.9%)	113 mm	110 mm (-8.3%)	98 mm	---	---

Protec II

	Front Movable Panel						Rear Fixed Panel					
	Center		Forward Edge - Corner		Forward Edge - Mid		Center		Forward Edge - Corner		Center (punch both sides)	
	Ram	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*
16 Km/h	109 mm (-5.2%)	131 mm	159 mm (--%)	235 mm	---	---	95 mm (-10.4%)	106 mm	85 mm (-9.6%)	93 mm	96 mm	109 mm
20 Km/h	140 mm (-9.1%)	153 mm	235 mm (--%)	363 mm	---	---	120 mm (-13%)	134 mm	107 mm (-12.2%)	113 mm	---	---



Rail mechanism failure

Edge excursion greatear than ram excursion

Table A2: 2016 Ford F-150 – New Test Setup

	Production											
	Front Movable Panel											
	Forward Edge - Corner		**Forward Edge - Mid**		**Center**		**Side Edge - 2/3 A**		**Rear Edge - Corner**		**Rear Edge - Mid**	
	Ram	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*
14 Km/h	93/98/95/94/106	ND/120/114/104/127	*111/107*	*96/99*	*106*	*63*	*91*	*No video*	*86*	---	*108*	*91*
16 Km/h	145	194	127	121	123	81	102	*66*	103	76	125	106
20 Km/h	---	---	---	---	---	---	---	---	*191*	208	---	---

	Production											
	Rear Fixed Panel											
	Forward Edge - Corner		**Forward Edge - Mid**		**Center**		**Side Edge - 2/3 A**		**Rear Edge - Corner**		**Rear Edge - Mid**	
	Ram	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*
14 Km/h	*92*	*67*	*109/106*	*87/87*	*102*	*69.3*	88	*42*	---	---	*91*	*47*
16 Km/h	101	120	119	99	112/112/111/108/111	78/84/84/90/86	96	50	95	37	103	58
20 Km/h	---	---	---	---	---	---	124	56	115	58	---	---

	Double PVB											
	Front Movable Panel						Rear Fixed Panel					
	Forward Edge - Corner		Forward Edge - Mid		Center		Forward Edge - Corner		Forward Edge - Mid		Center	
	Ram	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*
14 Km/h	*107 mm*	*147 mm*	104 mm	*No Data*	97 mm	86 mm	*82 mm*	*74*	100 mm	95 mm	87 mm	78 mm

	Protec II											
	Front Movable Panel						Rear Fixed Panel					
	Forward Edge - Corner		Forward Edge - Mid		Center		Forward Edge - Corner		Center (punch both sides)		Center	
	Ram	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*
14 Km/h	---	---	---	---	95 mm	93 mm	---	---	---	---	---	---

Rail mechanism failure (orange)
Edge excursion greatear than ram excursion (yellow)

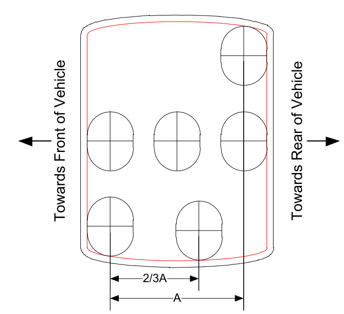


Table A3: 2012 Toyota Prius V

	Production											
	Front fixed Panel											
	Forward Edge - Corner		Forward Edge - Mid		Center		Side Edge - 2/3 A		Rear Edge - Corner		Rear Edge - Mid	
	Ram	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*
14 Km/h												
16 Km/h	42	34	43	37	41	23	42	16	41/43	15/9	41	22
20 Km/h	48	10	51	21	50	10	48	7	49	10	49	9

	Production											
	Rear Fixed Panel											
	Forward Edge - Corner		Forward Edge - Mid		Center		Side Edge - 2/3 A		Rear Edge - Corner		Rear Edge - Mid	
	Ram	Edge	Ram	Edge	Ram	Edge	Ram	Edge	Ram	Edge	Ram	Edge
14 Km/h												
16 Km/h	44	26	43/43	32/7	44	7	43	6	43	8	44	9
20 Km/h	51	7	51	9	52	9	50/50/50	ND	51	10	54/52	69/19

Edge excursion greatear than ram excursion

Tests on original sunroof

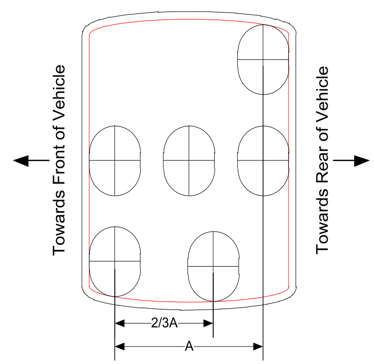


Table A4: Aisin Sunroof

	Production											
	Front moving Panel											
	Forward Edge - Corner		Forward Edge - Mid		Center		Side Edge - 2/3 A		Rear Edge - Corner		Rear Edge - Mid	
	Ram	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*
14 Km/h	180/250*	197/500*	135/114*	143/272*	98	84	123	103	167	155	106/500*	96/500*
16 Km/h	179	212			119/440*	189/586*					252	315
20 Km/h												

	Production											
	Rear Fixed Panel											
	Forward Edge - Corner		Forward Edge - Mid		Center		Side Edge - 2/3 A		Rear Edge - Corner		Rear Edge - Mid	
	Ram	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*	*Ram*	*Edge*
14 Km/h	135	107	83	39	93	45	115	108	133	93	87	ND
16 Km/h			105	82	113	93			179	197	103	38
20 Km/h			139	105	138	109					141	85

Rail mechanism failure (Front Panel)
Attachment failure (Rear Panel)
PVB failure (Rear Panel)
Edge excursion greatear than ram excursion
* Pin on aluminum rail