Status of NHTSA's Ejection Mitigation Research

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NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

Background

- Annual average (2002-2012) fatalities (~233) and serious injuries (~200)
- Tests done on production vehicles with laminated sunroof panels
  - 2009 Ford Flex (fixed)
  - 2014 Ford Cmax (fixed)
  - 2013 Subaru Forester (movable)
- Tested at center and corners of daylight openings
- Impactor was contained (no tear-through of plastic layer)
- For fixed panels - ram excursions < 100 mm
- For movable panel ram excursion
  - ~ 100 mm at center and rear corner
  - >> 100 mm at forward corner (rail mount failure)
- Paper at 25th Conference on Enhanced Safety of Vehicles (ESV), Detroit, 2017
- **Next step: Evaluate countermeasures**
  - **F-150 completed December 2017**

Why F-150?

- Production panes use laminated glass (glass-PVB-glass 2.1-0.76-2.1 mm)
- Has fixed and movable panels
- Supplier (Webasto) agreed to provide countermeasures
  - Thicker PVB (2.1 - 1.52 - 2.1 mm; annealed glass – PVB - annealed glass)
  - Protec II film (inner surface; 5.0 mm tempered glass)
- The moving panel mount was one of the stronger designs (per Webasto)
- Testing completed December 2017

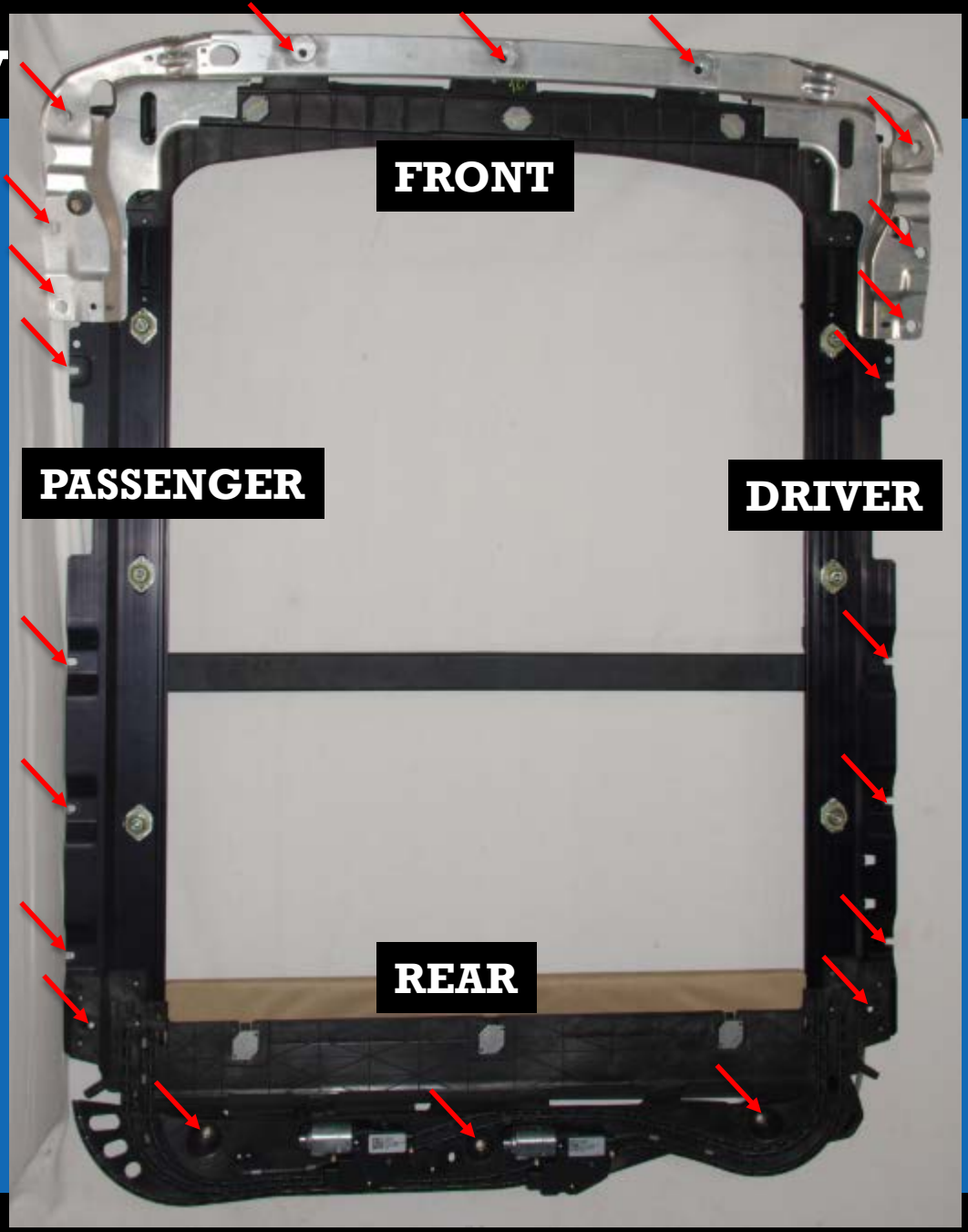
Sunroof Module Assembly

Front and rear panels attached to sunroof module

Sunroof module attached to vehicle roof from the inside- using 22 bolts

Front (movable) panel

Rear (fixed) panel



Sunroof module

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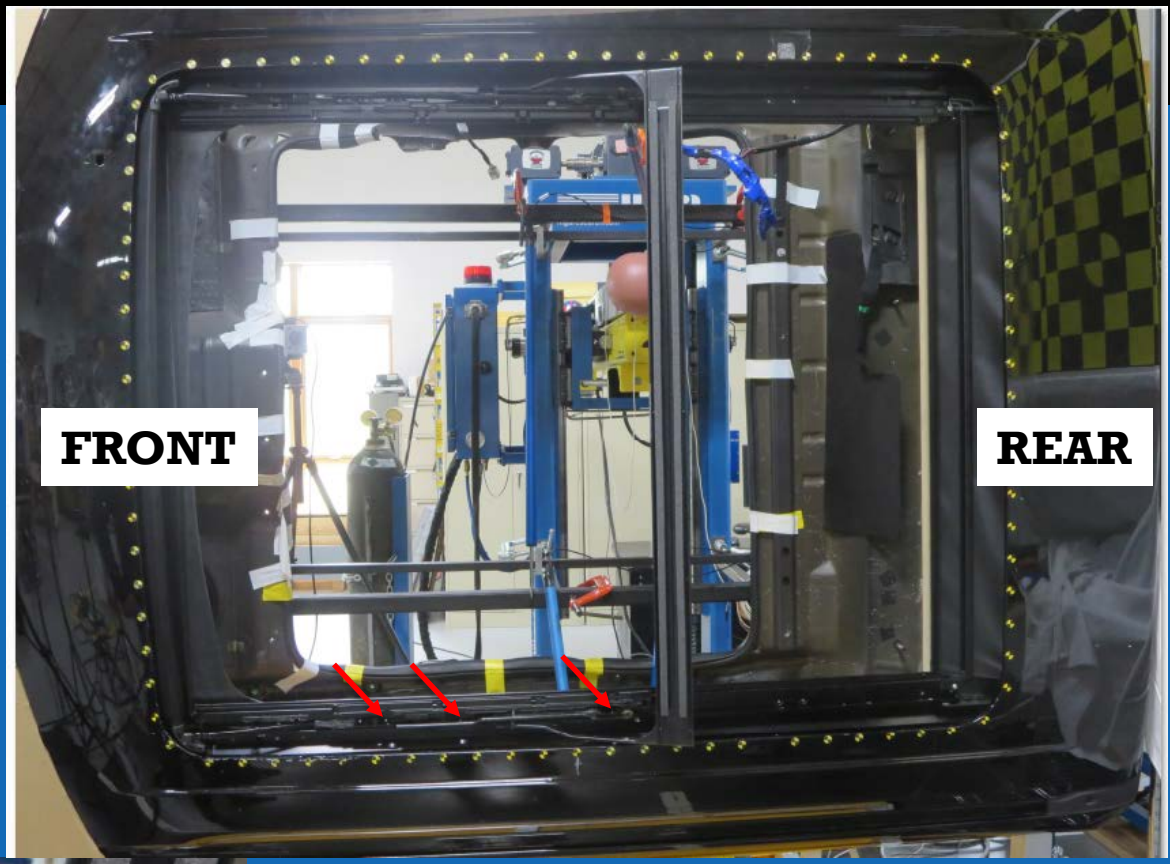
Front (movable) panel



Panel attached (6 screws)from the outside to rails that moves in a C channel

Rail attached to the C channel with metal and plastic inserts

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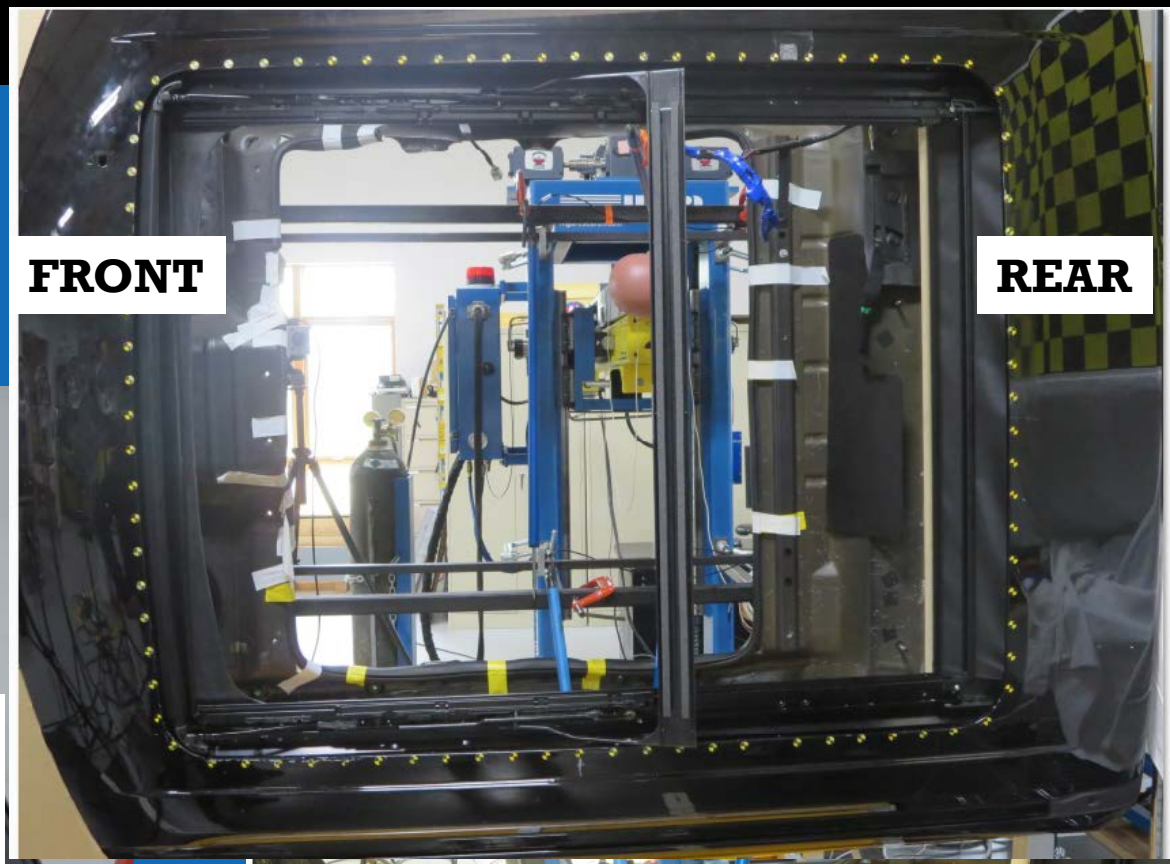
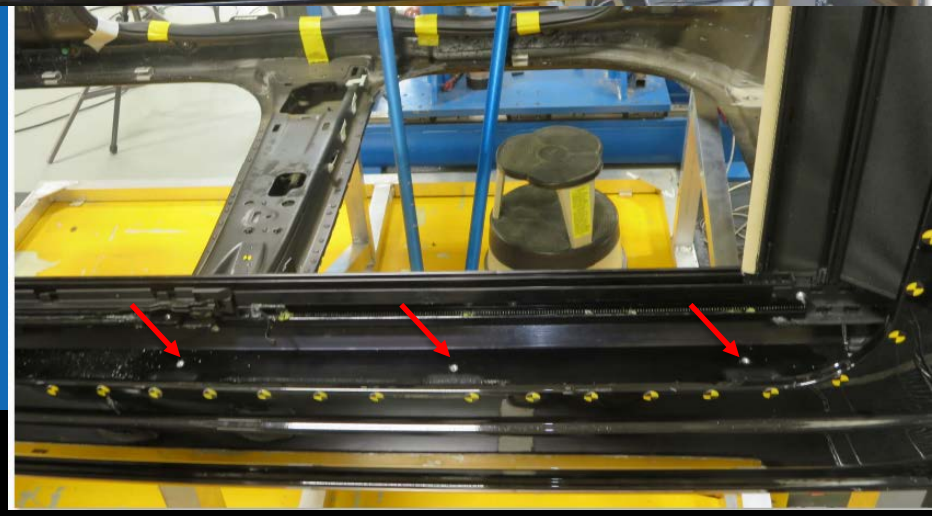
Rear (fixed) Panel





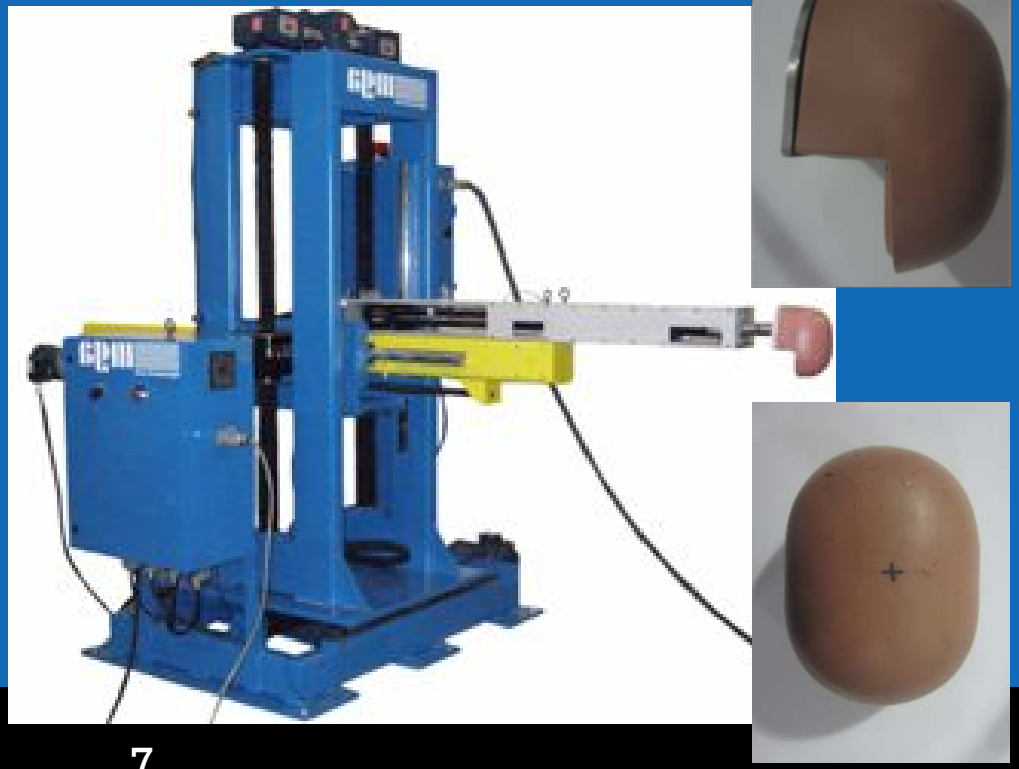
Panel attached (6 screws) from the outside

Test Setup (Impactor, Instrumentation)

Guided Impactor

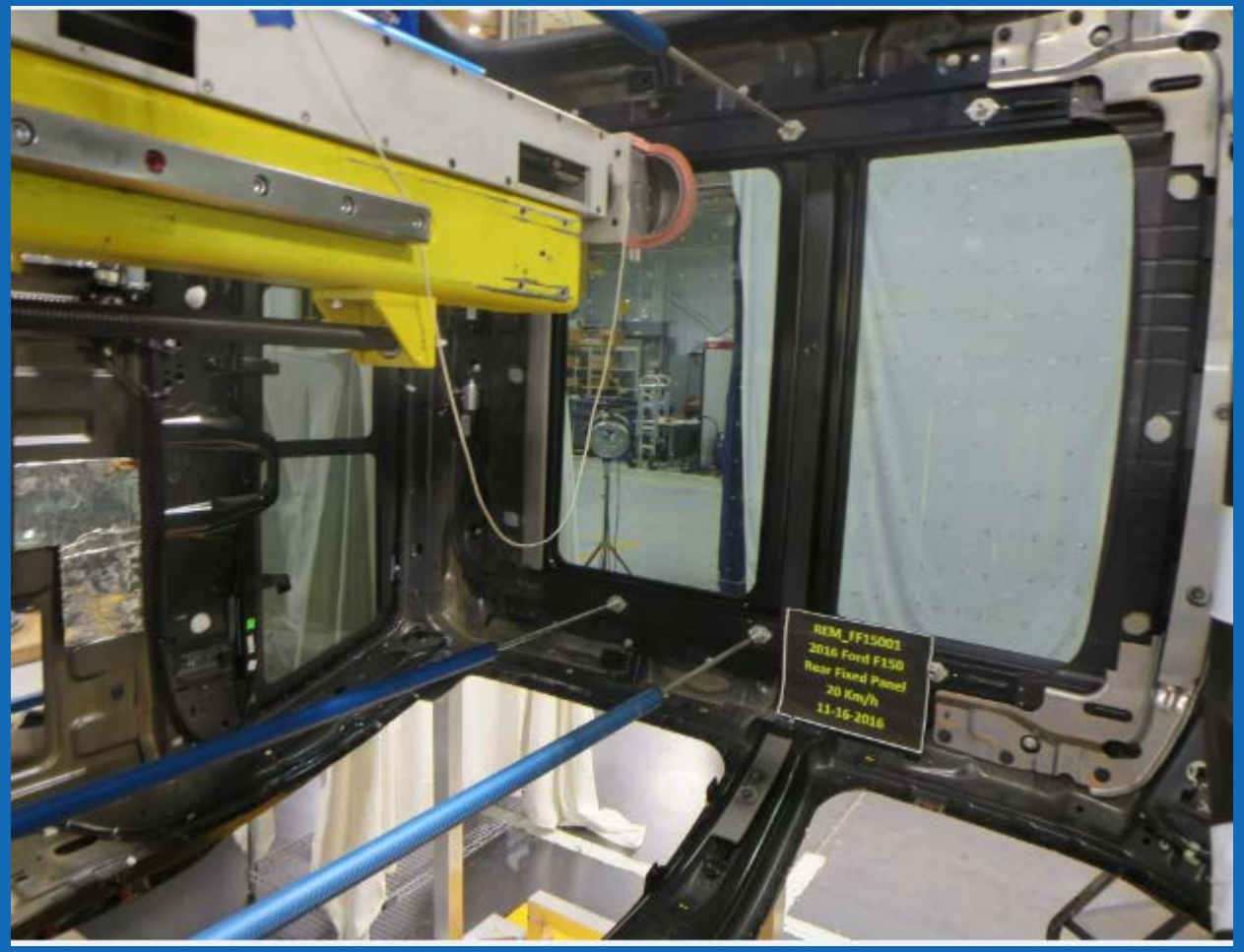
- Featureless Headform(176.8 x 226.1 mm)
- 40 lbs. (18 kg)
- Displacement from Linear Pot (LVDT)
- Impact Velocity – 14/16*/20* kph

***Used in FMVSS No. 226**



Mounted sideways
Glass pre-broken on both sides (except ProTEC II)
75 mm offset pattern per FMVSS No. 226

Instrumentation



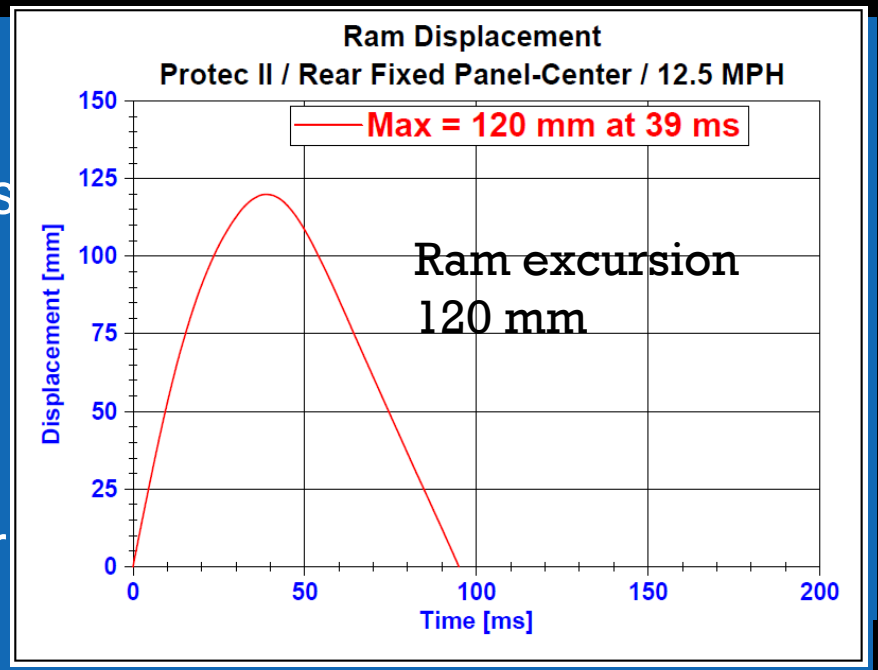
Linear potentiometer measures ram displacement
4 linear potentiometer on the sunroof frame (detect permanent deformation)

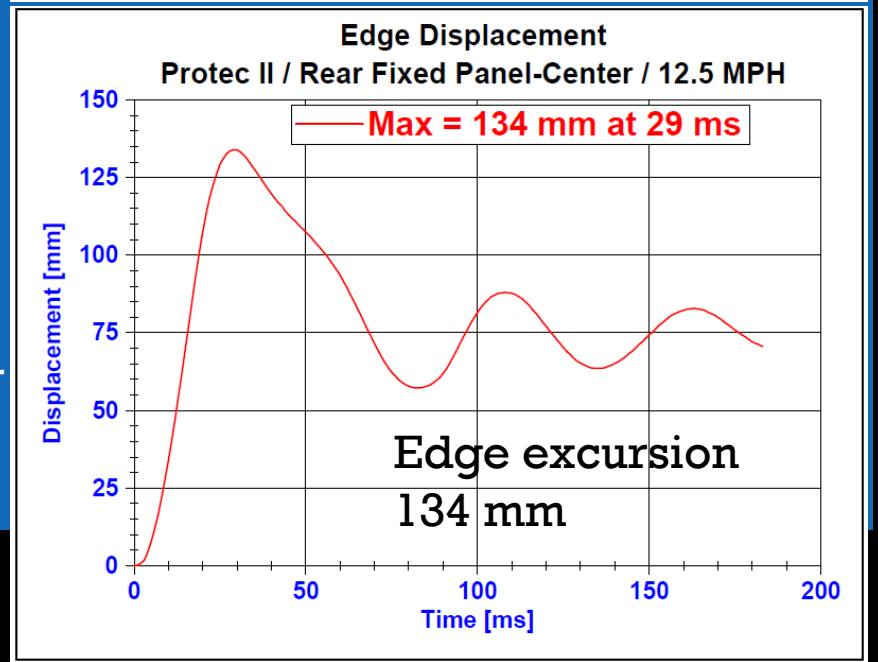
Targets at unsupported edges to measure dynamic excursion using photogrammetry (TEMA)

Example of Video and Data

- ProTEC II panel
  - Single tempered glass
  - Plastic layer inside
- Center of panel
- 20 kph
- Ram excursion (LVDT)
  - Used in test procedur
- Edge excursion (TEMA)
  - For research

Note: Edge excursions were higher than ram excursions for ProTEC panels





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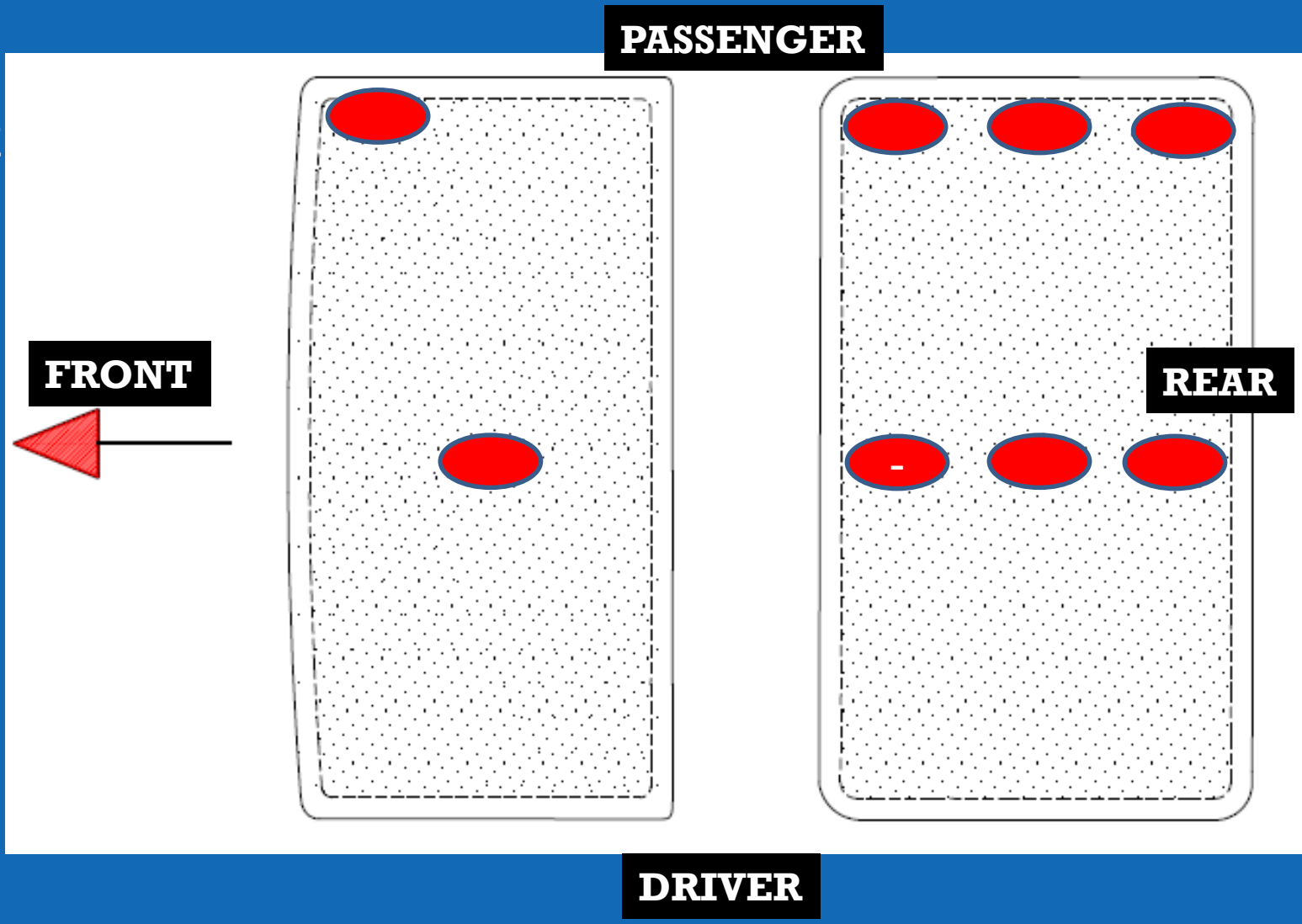
Initial Assessment Impact locations

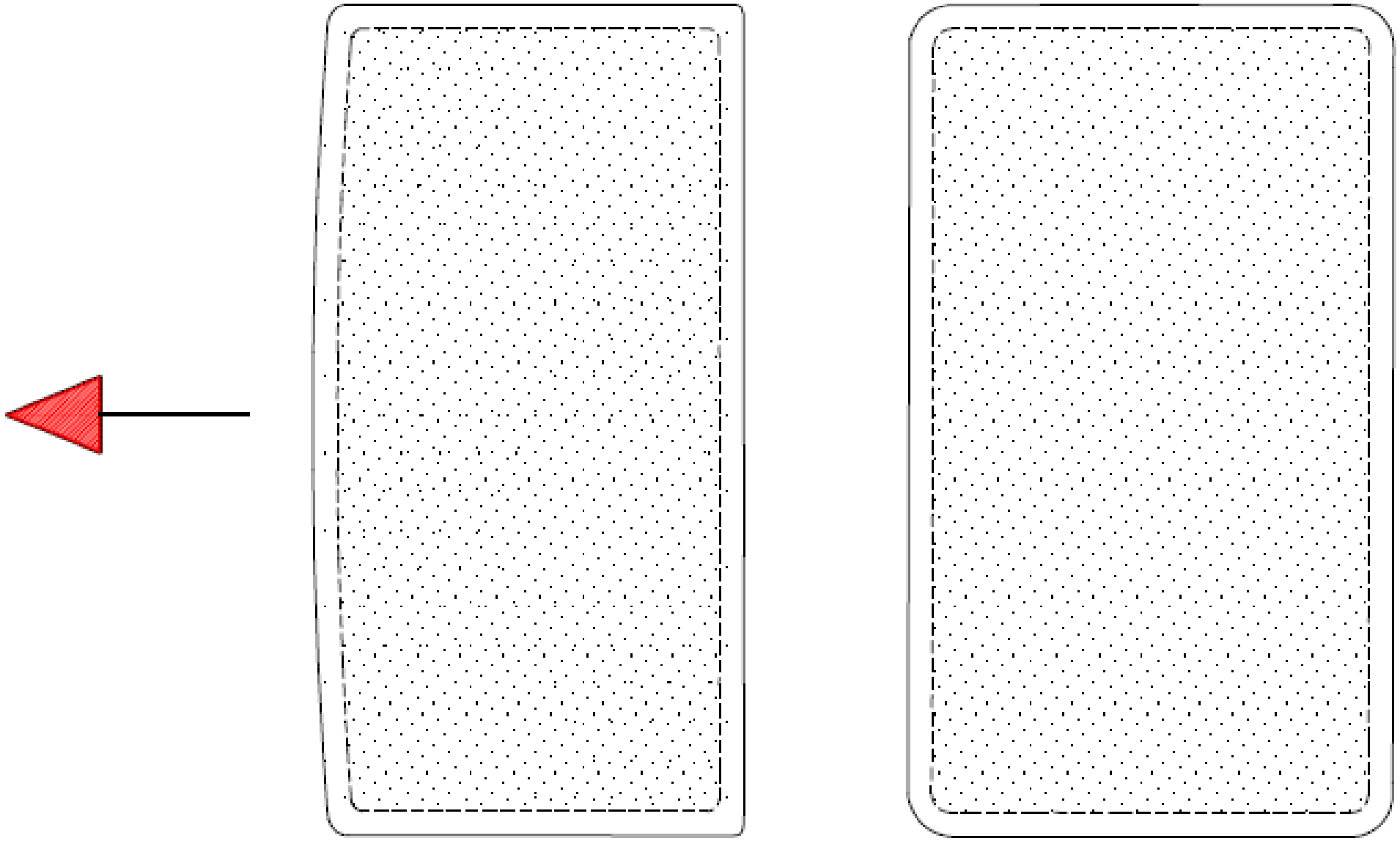
- Based on engineering judgment
  - Loading on glass
  - Loading on panel attachment
- Assumes
  - Left-right sides are identical
  - Front-rear are NOT identical



Ram Excursions (Production Glass - Baseline)

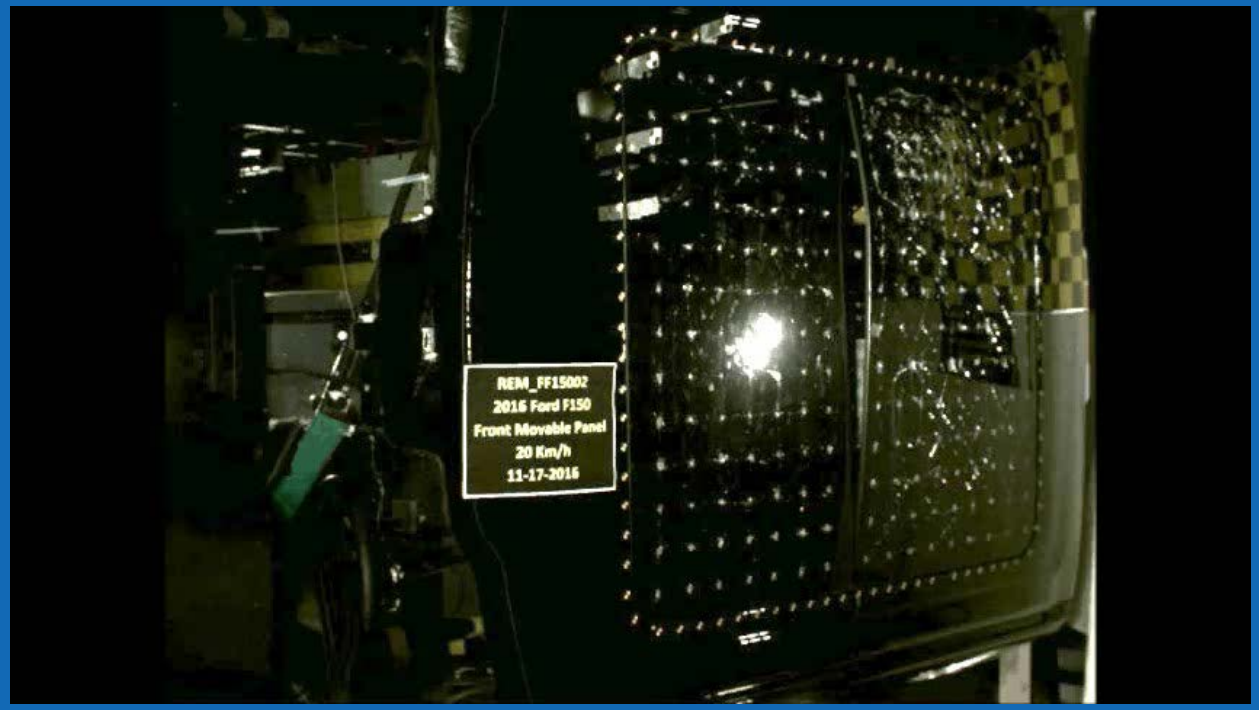
At 14 kph
At 16 kph
At 20 kph

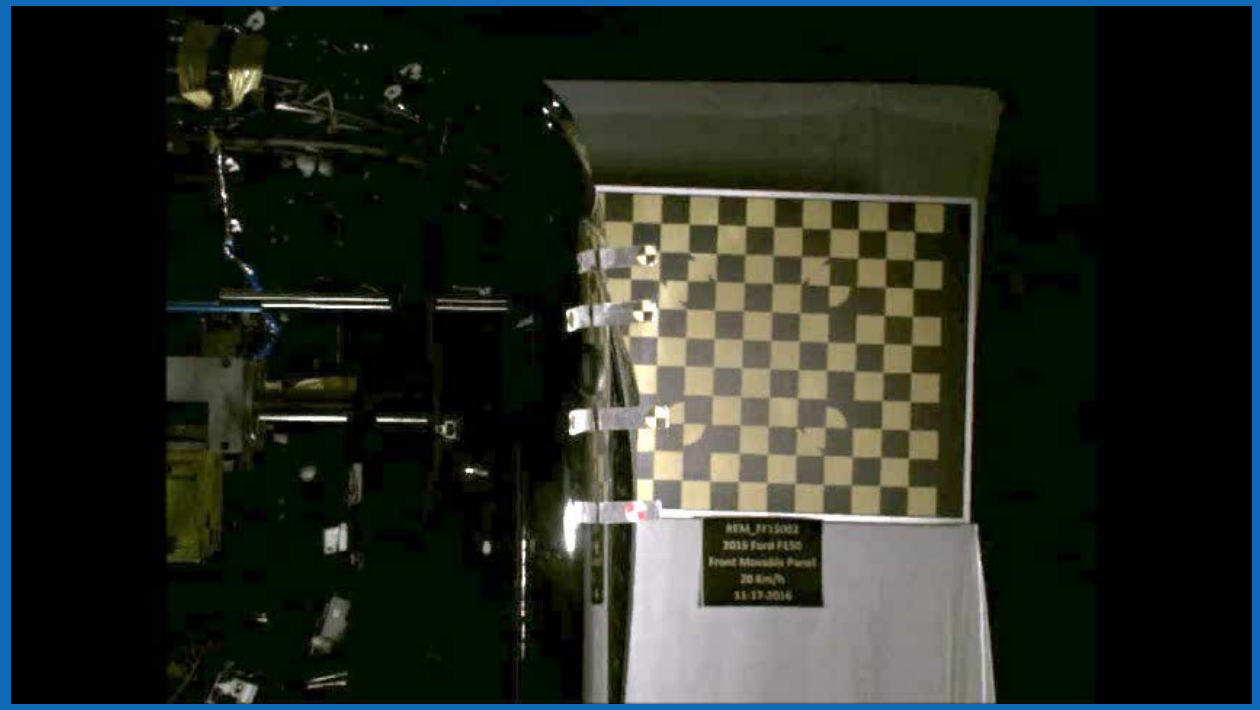
* Rail mount failure



<u>Observations</u>: Front mova
Center: PVB stretch + trar
Corner: Rail failure => lar

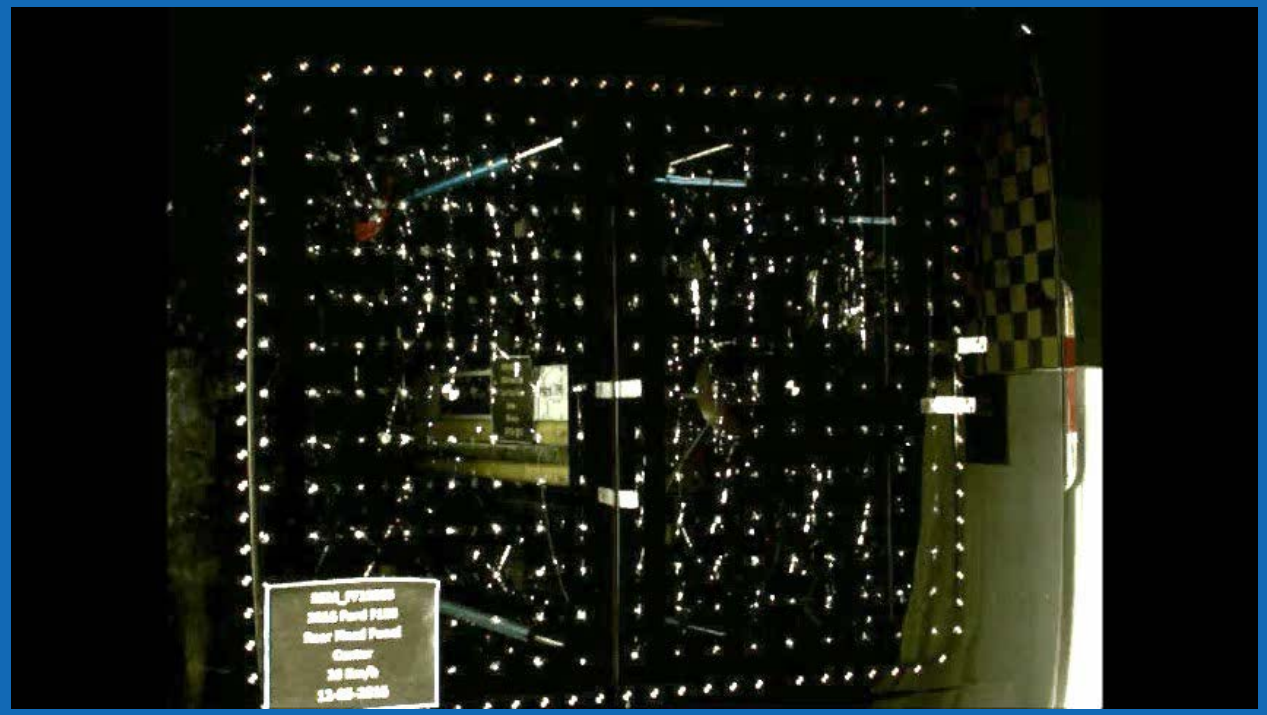
Video of Front Panel Corner





Glazing:	Baseline (production)
Location:	Front Panel Front Corner
Speed:	20 kph (12.4 mph)
Excursion:	178 mm (at the ram)

Video of Rear Panel Center

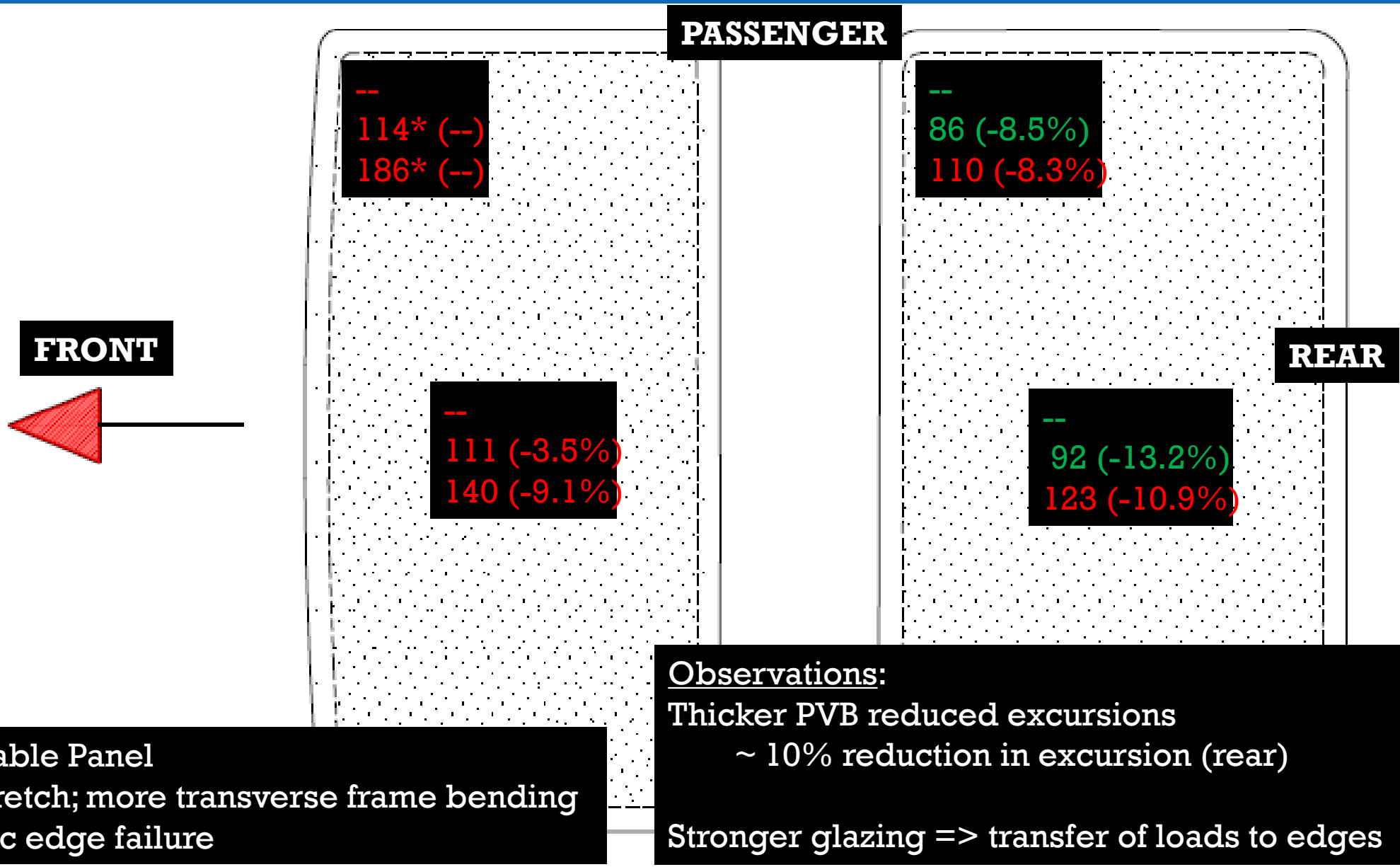


Glazing: Baseline (production)
Location: Rear Fixed Panel Center
Speed: 20 kph (12.4 mph)
Excursion: 138 mm (at the ram); 101 mm (at the edge)

Ram Excursions (Double Thickness PVB Panel)

At 14 kph
At 16 kph
At 20 kph
(% change from baseline)

* Rail mount failure



Observations: Front Movable Panel
Center - Less PVB stretch; more transverse frame bending
Corner – catastrophic edge failure

Observations:
Thicker PVB reduced excursions
~ 10% reduction in excursion (rear)

Stronger glazing => transfer of loads to edges

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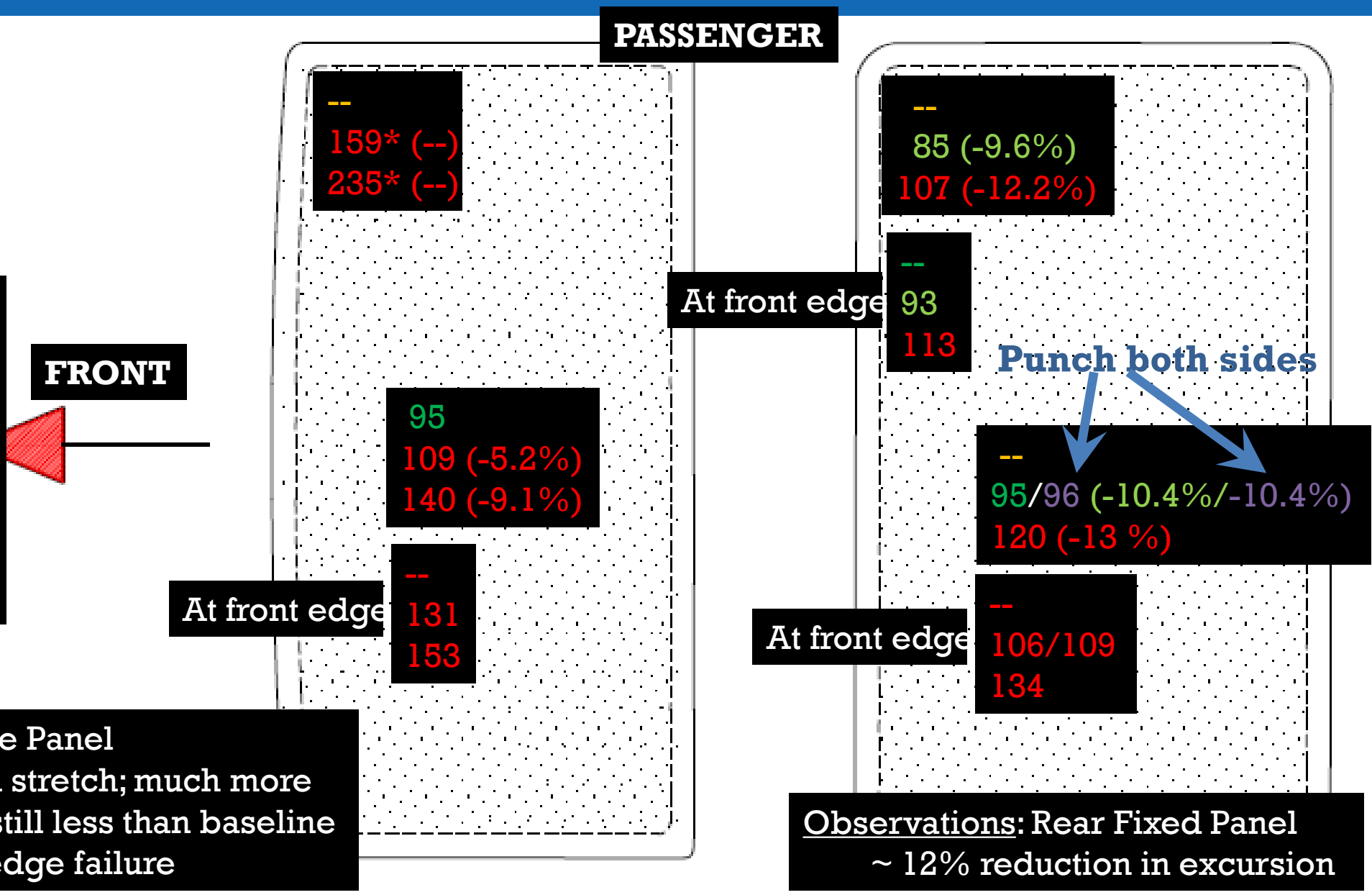
Ram Excursions (ProTEC II Panel (Inside))

At 14 kph
At 16 kph
At 20 kph
(% change from baseline)

* Rail mount failure

- Glass punched on the outside (one exception)
- Punching the Protec II layer => no difference
- Protec II film stretches less => transfers more loads to the edges

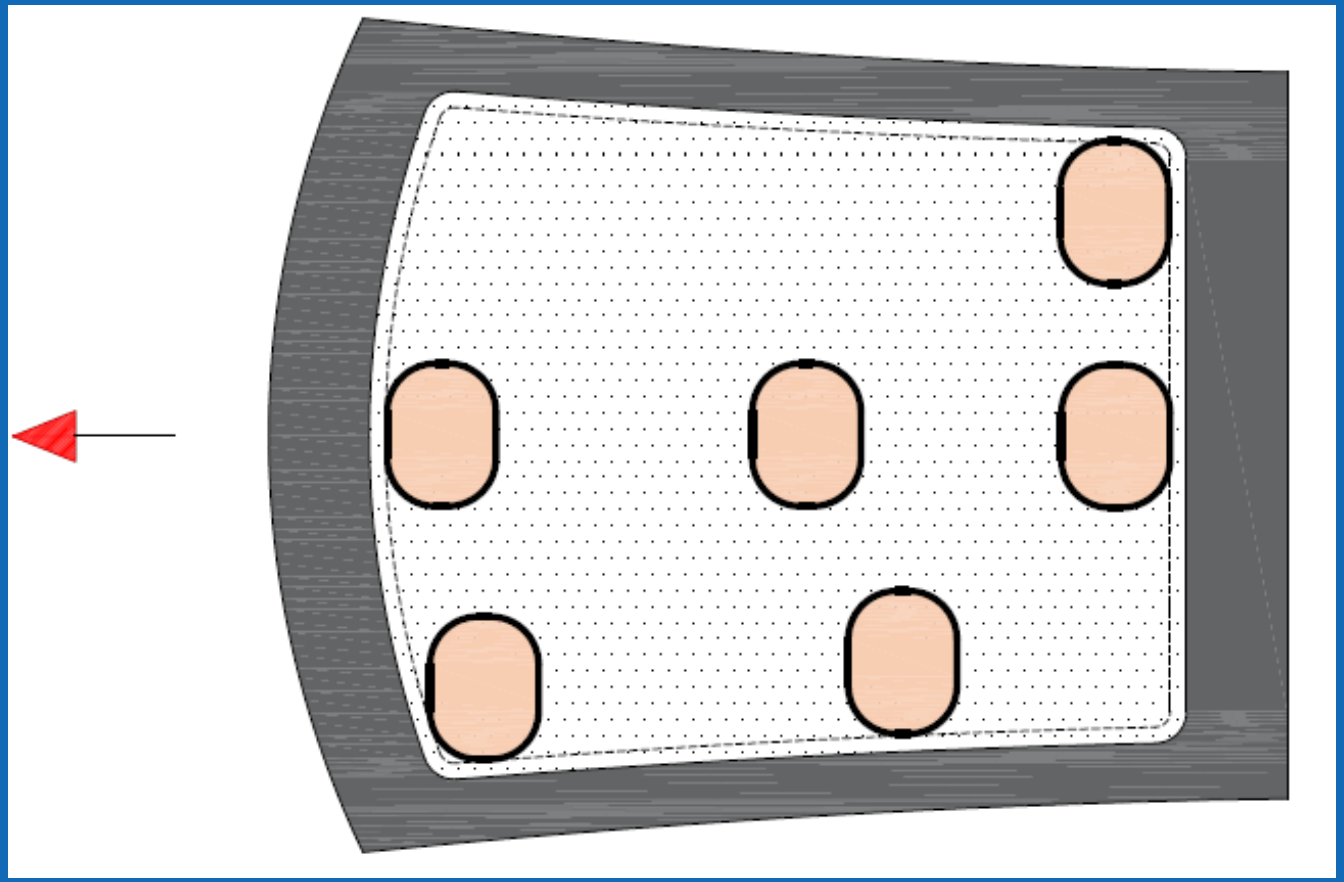


Observations: Front Movable Panel
Center – much less film stretch; much more transverse frame bending; still less than baseline
Corner – catastrophic edge failure

Observations: Rear Fixed Panel
~ 12% reduction in excursion

Revised Test Procedure

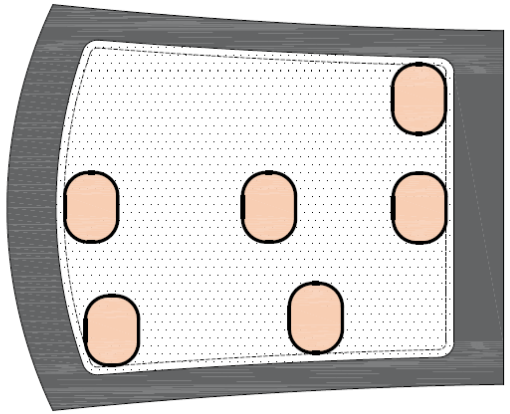
- Based on results and engineering judgement
- Headform rotated
- Additional speed (14/16/20 kph)
- Assumes
  - Left-right side are identical
  - Front-back are NOT identical
- Test each panel at
  - Front corner
  - Rear corner
  - Center
  - Mid-point of front transverse edge
  - Mid-point of rear transverse edge
  - At 2/3 of longitudinal edge



Ram Excursions (Production Glass - Baseline)

At 14 kph
At 16 kph
At 20 kph

* Rail mount failure



FRONT

PASSENGER

86
103
191*

--
95
114

Thicker PVB

REAR

107/111/104
127
--

106/97
123
--

108
125
--

109/106/100
119
--

102/87
112/112/111/108/111
--

91
103
--

93/98/95/94/106/107*
145
--

91
101
--

92/82
101
--

88
95
124

DRIVER

Observations:
Front movable panel:
Center - PVB stretch + transverse frame bending
Corner – Rail failure => large excursions

Rear fixed panel: No edge failure

Forward transverse edge is thinner and weaker
Test showed good repeatability
Thicker PVB reduced excursion by ~9 mm

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Observations

- Movable panels present more challenges to contain than fixed panels
  - Ford Flex; CMax; Subaru Forester (with movable panel) [2017 ESV]
  - True for F-150 including countermeasures
  - Moving panel - Failure at the inserts (into the rails)
  - Fixed panels can have higher excursions at unsupported transverse edges (F-150 fixed rear panel has front and rear unsupported edges)
- Thicker plastic PVB interlayer (laminated) and PET film (Protec II) :
  - Did not tear
  - Reduced stretch (and ram excursions)
  - Transferred more forces to the edges
    - Greater challenge for movable panels
  - Can produce larger opening at an edge (not ram)
- Headform orientation can affect ram excursions
- Results may change for different sunroof designs

Future work

- 2012 Toyota Prius v (trim Five) Technology Package option
  - Polycarbonate sunroof panel –1 fixed panel with 2 daylight openings
- Additional sunroof designs (opening to the outside; curtains)

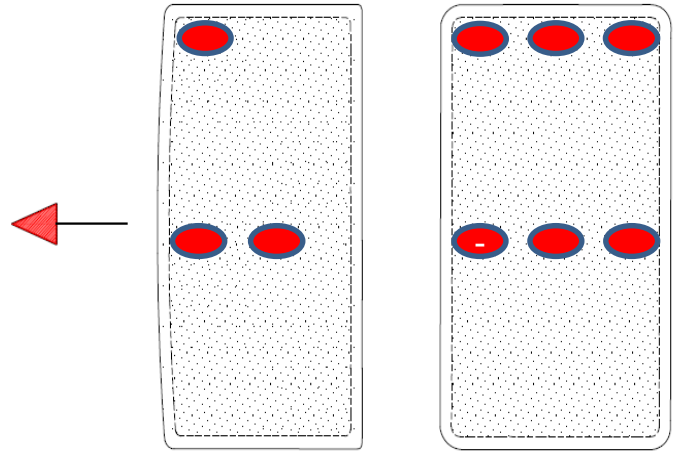
2013 Prius v

Table of Excursions

	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*
14 Km/h	97 mm*	86 mm	*107 mm**	*147 mm*	104 mm*	*No Data*	87 mm*	78 mm	*82 mm**	*74*	100 mm*	95 mm
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*
14 Km/h	95 mm*	93 mm	---	---	---	---	---	---	---	---	---	---
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

* New Headform Orientation

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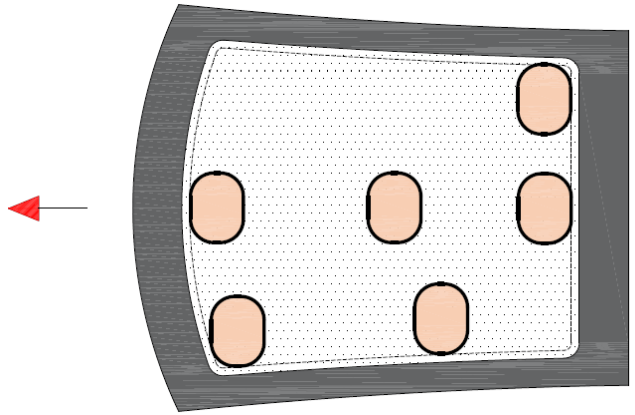
Table of Excursions

	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	94	50	95	37	103	58
20 Km/h	---	---	---	---	---	---	124	56	115	58	---	---

Rail mechanism failure

Edge excursion greatear than ram excursion



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