

2023 SAE Government-Industry Meeting, January 17-19, 2023, Washington, DC



# NHTSA

**NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION**

## Status of NHTSA's Glazing Research

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- NHTSA’s Evaluation of Glazing Performance Testing Research Program is examining FMVSS No. 205 “Glazing Materials” which uses impact test methods from ANSI/SAE Z26.1-1996.
- NHTSA is interested in learning about and collecting performance data from selected tests in ANSI Z26.1-1996 and corresponding tests from UN ECE R43.
- Selected tests include:
  - Impact, ANSI Test 6 (Ball Drop, 3.05m [10ft]), ECE test – 2m [6.6 ft]
  - Impact, ANSI Test 8 (Shot Bag, 8 ft), ECE test - none
  - Impact, ANSI Test 9 (Dart Drop, 9.14m [30ft]), ECE test - none
  - Impact, ANSI Test 12 (Ball Drop, 9.14m [30ft]), ECE test – 9m [29.5 ft]
  - Fracture, ANSI Test 7, ECE test – different methods

# Background - Standards Comparison

ANSI Z26.1-1996		ECE R43		Impact Object	Glass Type	Difference (ANSI vs ECE)
Section	Drop Height	Section	Drop Height			
5.6. Impact, Test 6 (Ball Drop, 3.05m [10ft])	10 ft (3.05 m)	Annex 5 Uniformly toughened glass panes, Section 3 – Mechanical strength test, 227 g ball test [2m]	6.6 ft (2 m)	224-230g (0.5lb±0.1oz) smooth, steel sphere	Tempered 12" x 12" flat specimens	Height difference: ANSI is 3.05m (10ft) and ECE is 2m (6.6ft)
5.8. Impact, Test 8 (Shot Bag)	8 ft (2.44 m)	N/A	N/A	4.99 kg (11lb) shot bag	Tempered 12" x 12" flat specimens	No shot bag test in ECE R43
5.9. Impact, Test 9 (Dart Drop, 9.14m [30ft])	30 ft (9.14 m)	N/A	N/A	196-201g (7±0.5oz) steel dart	Laminated 12" x 12" flat specimens	No dart test in ECE R43
5.12 Impact, Test 12 (Ball Drop, 9.14m [30ft])	30 ft (9.14 m)	Annex 7 Laminated-glass panes, Section 3 – Mechanical strength test 227 g ball test [9m]	29.5 ft (9 m)	224-230g (0.5lb±0.1oz) smooth, steel sphere	Laminated 12" x 12" flat specimens	Height difference: ANSI is 9.14m (30ft) and ECE is 9.0 m (29.5ft)
5.7. Fracture, Test 7	N/A	Annex 5 Uniformly toughened glass panes, Section 2 – Fragmentation test	N/A	Centerpunch	Tempered Production	ANSI is weight of largest piece, location is mid-point of longest edge ECE is based on count in 5x5cm square, location is geometric center

# Background - Objective

- Objectives of the research are:
  1. Evaluate various testing situations from ANSI Z26.1 including situations for comparison with ECE R43
    - Compare the standard shot bag to a shot bag with stiffer sidewalls
    - Examine altered fracture test for tempered glazing with one impact point vs two (ANSI vs ECE)
    - Compare results from laminated glazing impacted by 227 gram ball drop (30 ft) and 198 gram dart (30 ft)
  2. Evaluate differences in ANSI 12" x 12" flat pieces and matching production parts
  3. Evaluate and compare results from different impact heights
  4. Learn about potential changes to tempered glass strength due to ceramic painted area (CPA)
- Latest status update was presented at 2021 SAE Government-Industry Meeting<sup>1</sup>



Sample glass with 50mm painted band (top) and unpainted sample glass (bottom)

<sup>1</sup>Pruitt, C. & Prasad, A., "Status of NHTSA's Glazing Evaluation Tests", SAE Government Industry Meeting, Feb 2021

# Test Items

- 227 gram ball (~38mm diameter)
- 5 kg shot bags
  - ANSI Z26.1-1996 specified bag
  - Modified bag (stiffened sidewalls)
- 198 gram dart (modified for use with gun barrel)
- Centerpunch – used for fracture testing



227 gram Ball



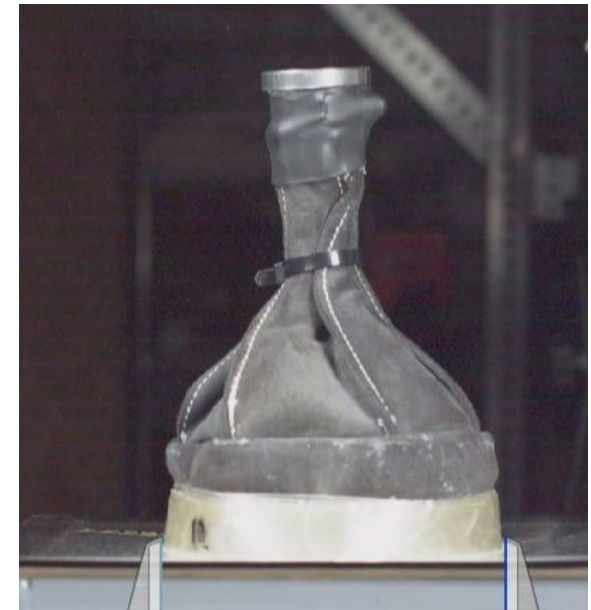
ANSI Shot Bag



Centerpunch



Dart (modified on right)



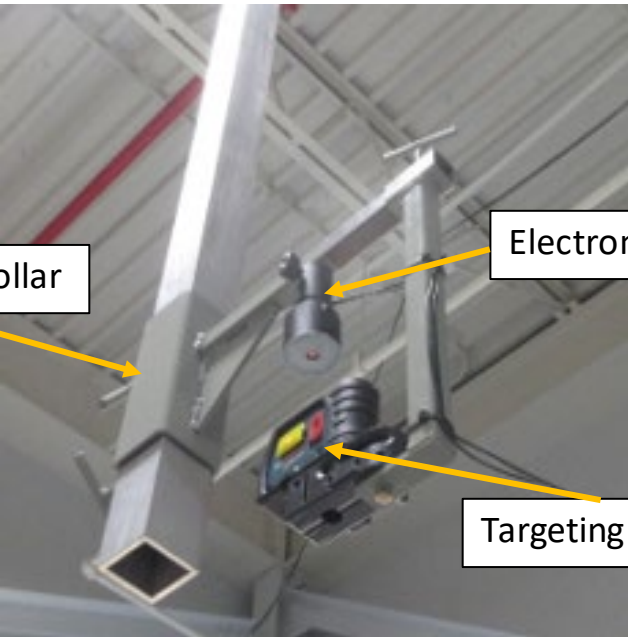
Modified Shot Bag

# Test Equipment Overview

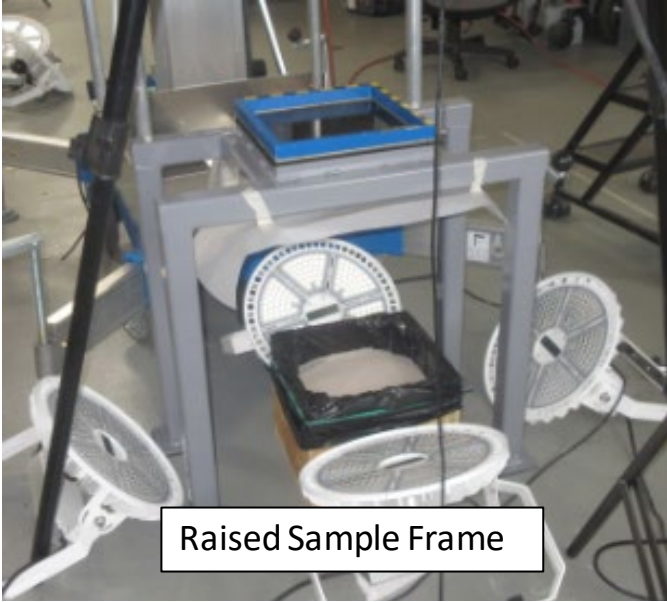
- Drop Tower
  - Electromagnet drop mechanism
  - Laser for targeting
  - Adjustable to different heights
    - 1ft to 14ft for ball
    - 1ft to 13ft for shot bag
- Support frames
  - Raised sample frame
  - Production frames fabricated for each glass type

Adjustment Collar

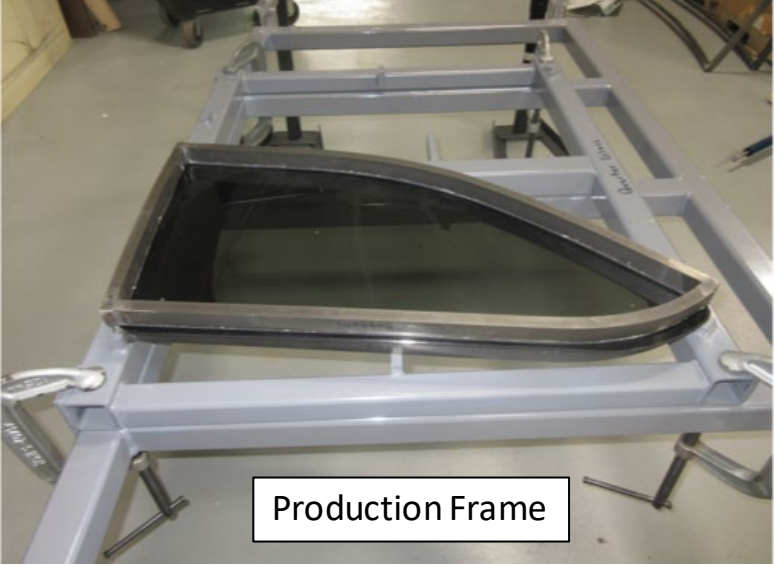
Electromagnet



Targeting Laser



Raised Sample Frame

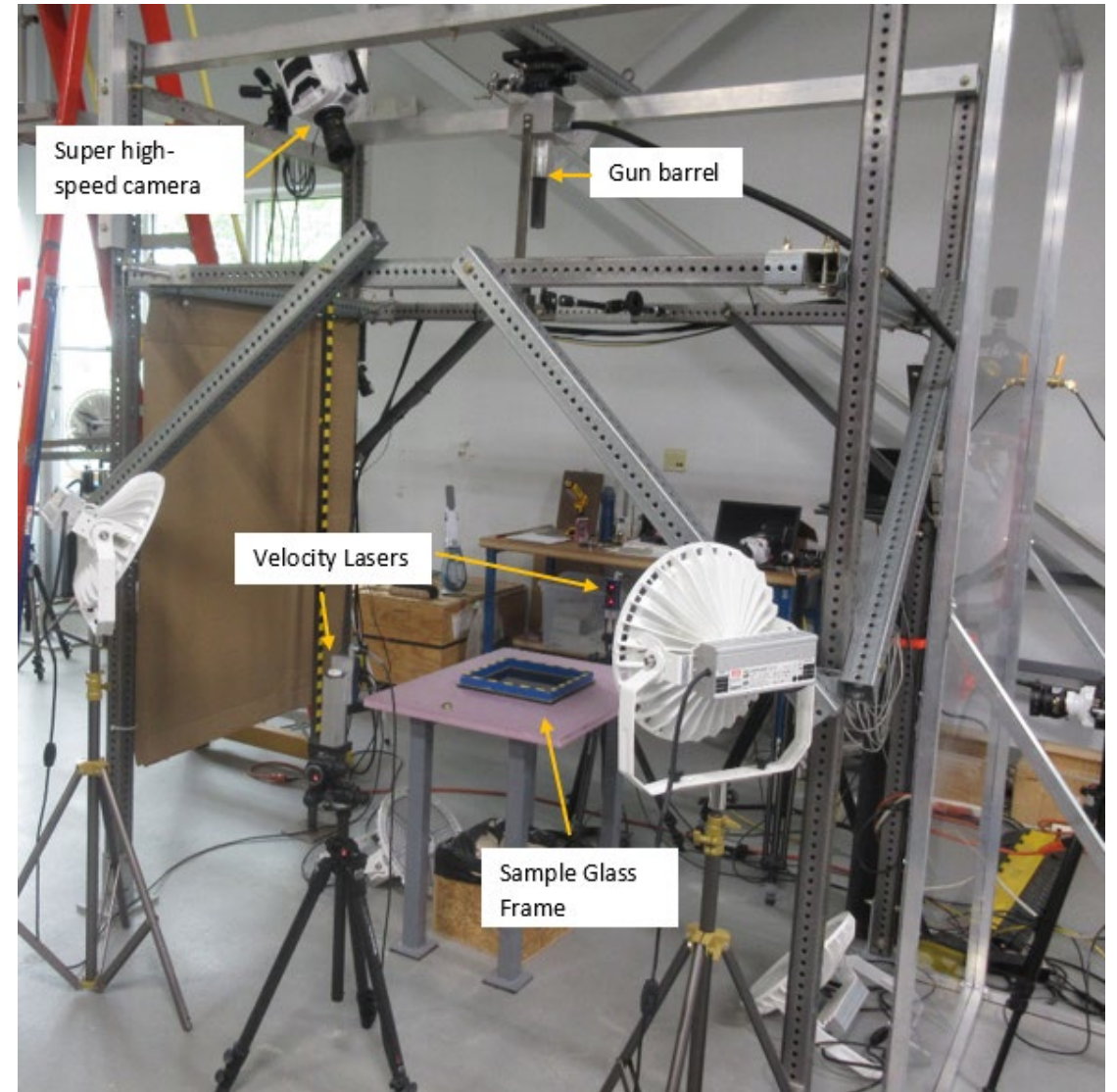


Production Frame

# Pneumatic Gun Setup

*Used for 30ft and break height testing*

- Separate barrels for ball and dart
- Velocity lasers
  - IES 2206 Velocity Measuring Laser Light Trap
- Glass holding frame
  - Sample and production frames
    - Presented in 2021 GIM
- Cameras
  - Overhead view
    - Super high speed (up to 200k fps) – Phantom V2512
  - Side and laser views
    - Phantom MIRO R-321S (1000 fps)



# Summary of All Planned Tests

Glazing	Description	Test Type		Height	# of Locations	Qty of Tests	Glazing	Description	Test Type		Height	# of Locations	Qty of Tests		
Rear Quarter (RQ)	Tempered Galaxsee 3.5mm	ball	sample	painted & unpainted	10ft	4	26	Sunroof (SR)	Tempered Galaxsee 4.0mm	ball	sample	painted & unpainted	10ft	4	26
					6.6ft	4	26						6.6ft	4	26
					10ft +	4	36						10ft +	4	36
			production	painted & unpainted	10ft	4	26				production	painted & unpainted	10ft	4	26
					6.6ft	4	26						6.6ft	4	26
					10ft +	4	26						10ft +	4	26
		shot bag (ANSI)	sample	painted & unpainted	8ft	3	12			shot bag (ANSI)	sample	painted & unpainted	8ft	3	12
					9ft+	3	24						9ft+	3	24
		production	painted & unpainted	8ft +	6	33	production			painted & unpainted	8ft +	6	33		
				8ft	3	12					8ft	3	12		
		shot bag (modified)	sample	painted & unpainted	9ft +	3	24			shot bag (modified)	sample	painted & unpainted	9ft +	3	24
					8ft +	6	33						8ft +	6	33
fracture	production	painted & unpainted	ANSI	mid pt of edge	14	fracture	production	painted & unpainted	ANSI	mid pt of edge	14				
			ECE	center	14				ECE	center	14				
Windshield (WS)	Laminated 2.1/acoustic PVB/2.1 EZ-Kool	dart	sample	painted & unpainted	30ft	3	26	Backlight (BL)	Tempered EZ-Kool 3.5mm	ball	sample	painted & unpainted	10ft	4	26
					31ft+	2	36						6.6ft	4	26
			production	painted & unpainted	30ft	3	26				production	painted & unpainted	10ft	4	26
					31ft+	2	36						6.6ft	4	26
		ball	sample	painted & unpainted	30ft	3	26			shot bag (ANSI)	sample	painted & unpainted	8ft	3	12
					31ft+	2	36						9ft+	3	24
			production	painted & unpainted	30ft	3	26			production	painted & unpainted	8ft +	6	33	
					31ft+	2	36					8ft	3	12	
			sample cold (-20°C)	unpainted	27.9ft	3	13			shot bag (modified)	sample	painted & unpainted	9ft +	3	24
					30ft+	2	18						production	painted & unpainted	8ft +
		sample hot (+40°C)	unpainted	29.5ft	3	13	fracture			production	painted & unpainted	ANSI			mid pt of edge
				30ft+	2	18						ECE	center	14	

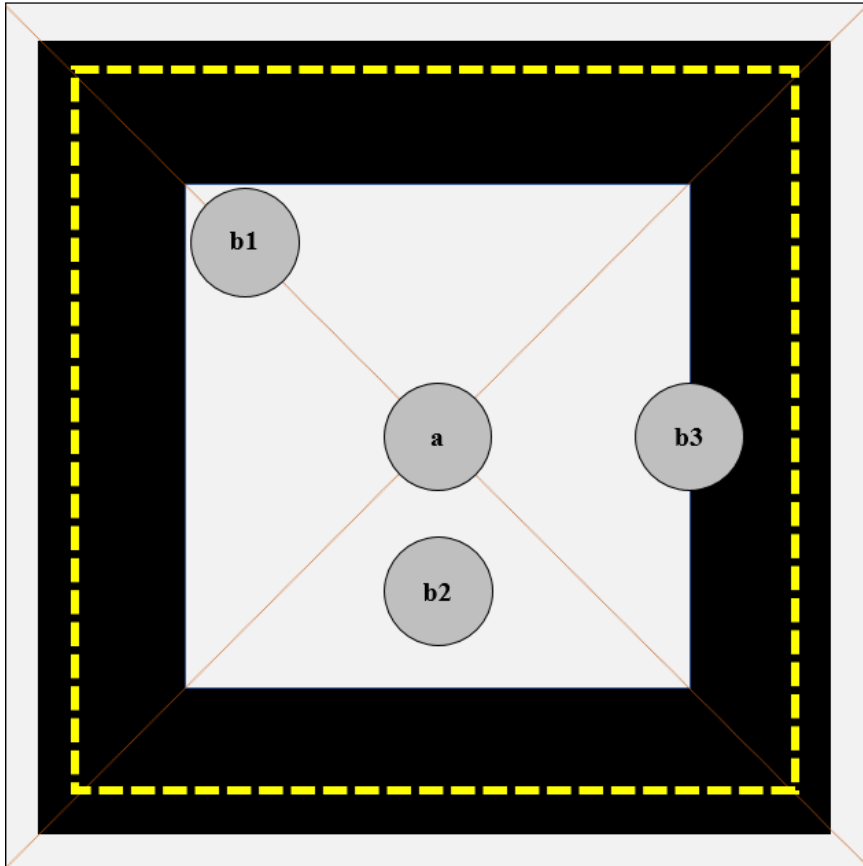
“+” means greater than ANSI drop height (break height testing)

Total number of tests: 1306



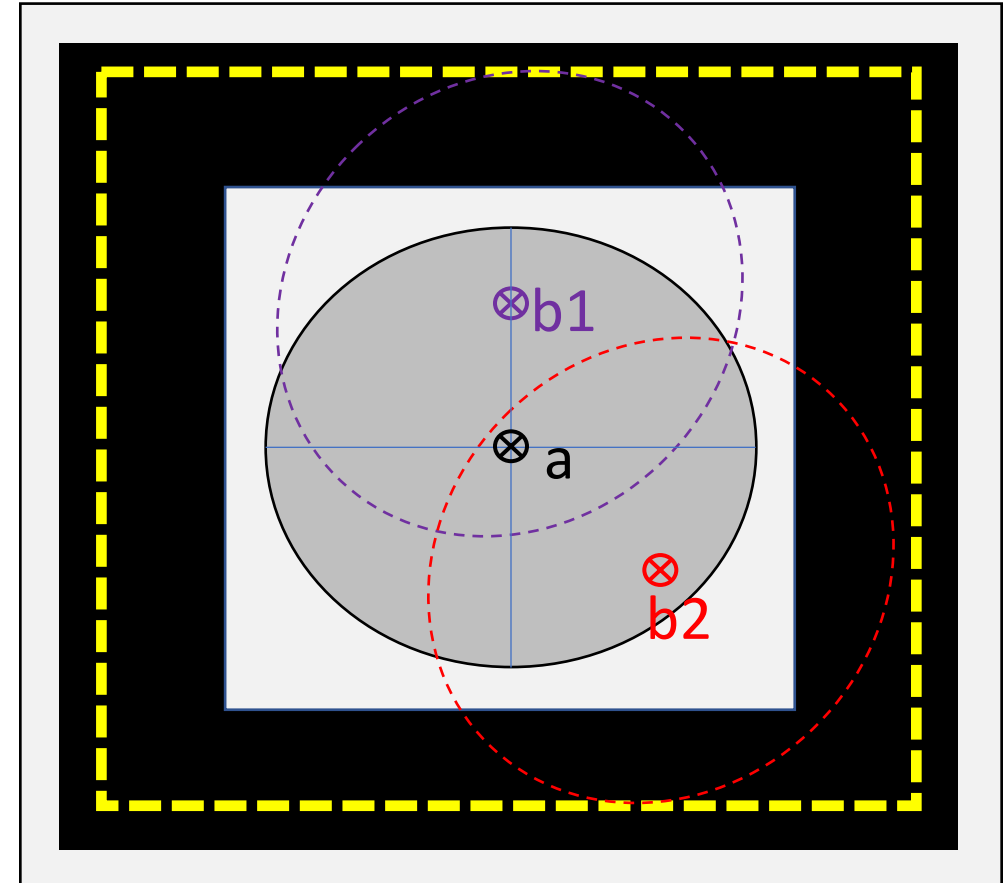
# Impact Locations – 12" Sample

Rear Quarter – Ball/Dart  
Exterior Surface



- a: ANSI Z26.1 impact point
- b1: sphere's shadow tangent to both paint edges at a clear glass corner
- b2: sphere shadow one sphere radius from CPA edge, midpoint glass width
- b3: sphere impact point on CPA to clear class transition edge, midpoint glass

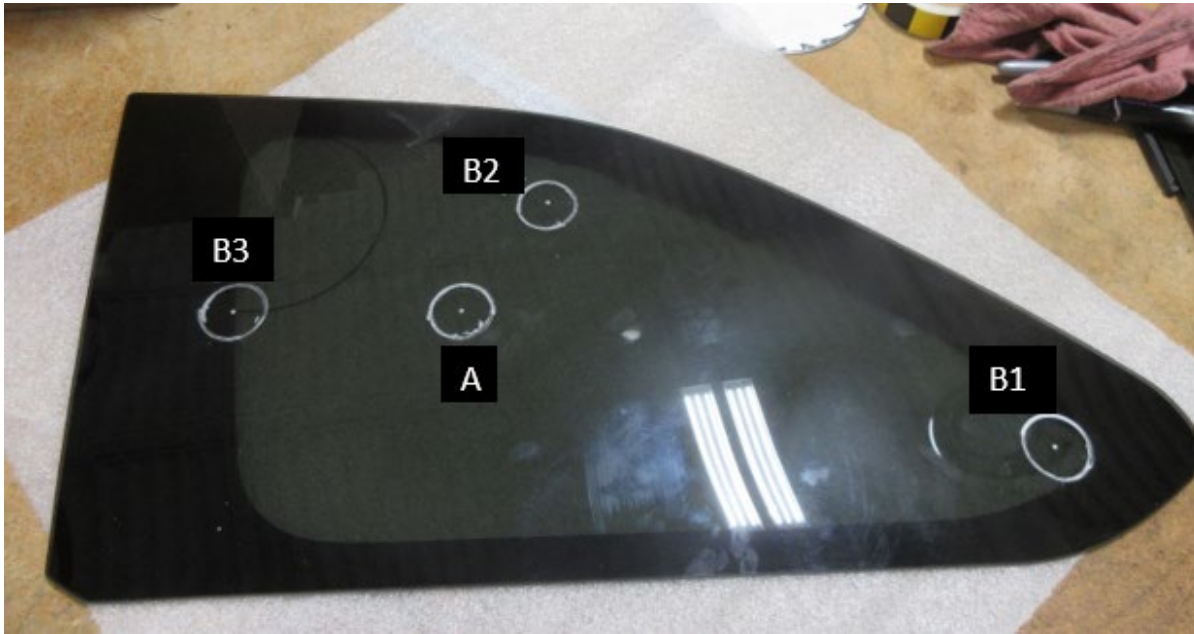
Rear Quarter – Shot Bag  
Interior Surface



- a: ANSI Z26.1 impact point
- b1: bag's outer diameter tangent to mid-point of fixture inner support edge
- b2: bag's outer diameter tangent to two of fixture inner support edges

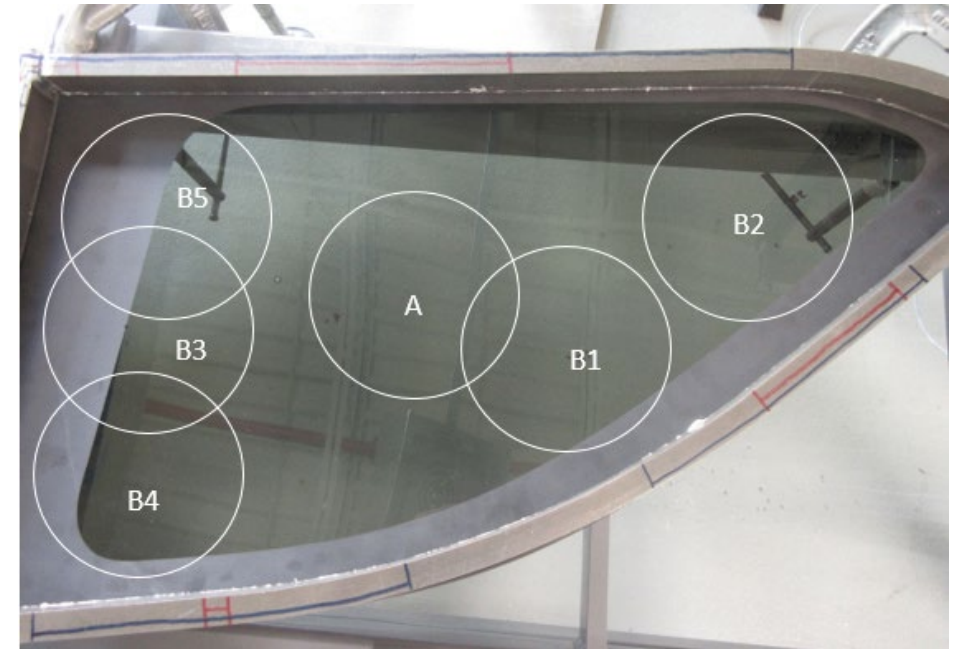
# Impact Locations – Rear Quarter Production

Rear Quarter - Ball  
Exterior Surface



- A: uniformly tempered portion
- B1: corner of panel, strength transition zone of CPA to uniformly tempered, sphere shadow on CPA edge(s)
- B2: sphere radius from CPA edge, mid-width of panel.
- B3: impact point on CPA edge, mid-width of panel

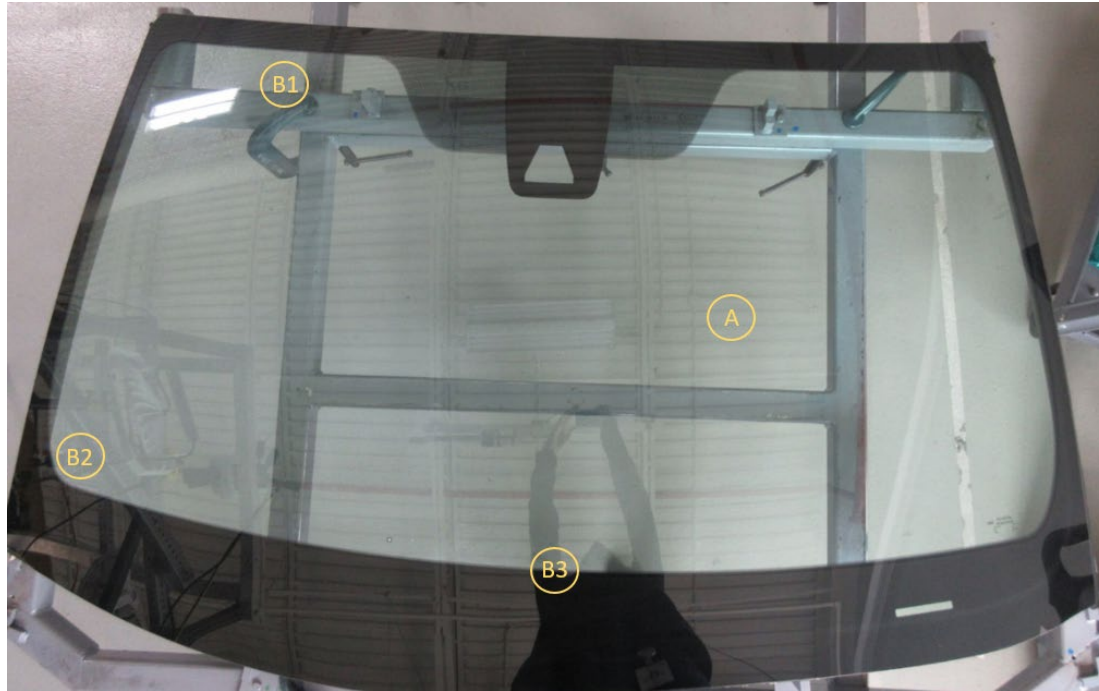
Rear Quarter – Shot Bag  
Interior Surface



- A: center of fully tempered portion
- B1: edge near CPA to tempered transition zone
- B2: corner of panel, bag diameter to frame edge
- B3: edge of CPA, mid-width of panel
- B4: corner of panel, bag diameter to frame edge
- B5: corner of panel, bag diameter to frame edge

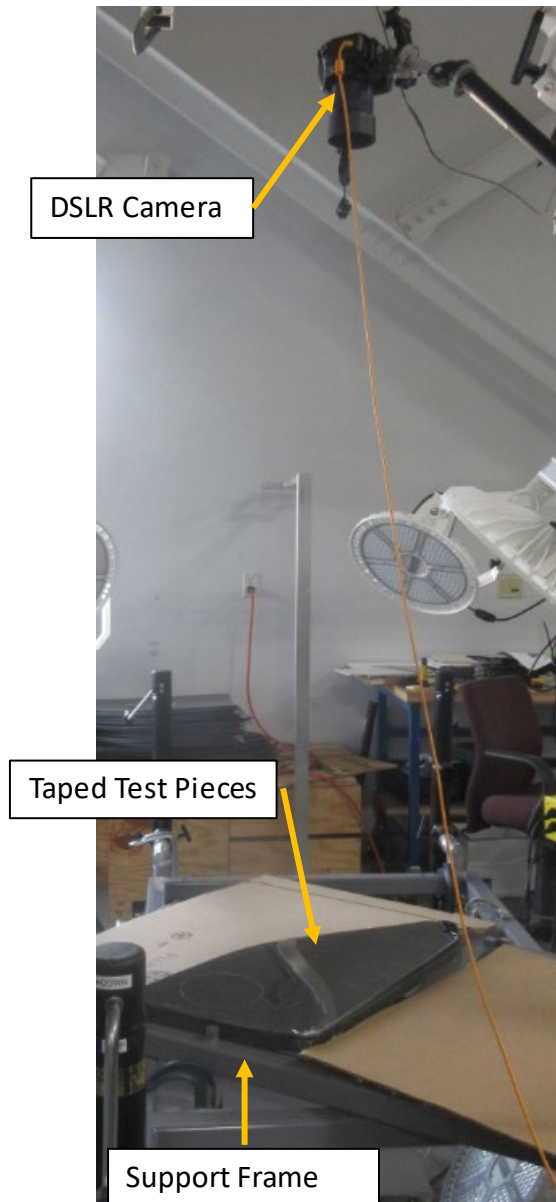
# Impact Locations – Windshield Production

## Windshield – Ball/Dart Exterior Surface



- A: uniform laminated area,  $\frac{1}{3}$  windshield bottom edge width, middle of unpainted area
- B1: sphere radius from CPA edge,  $\frac{1}{4}$  of windshield top edge width
- B2: corner of CPA edge, sphere tangent to CPA
- B3: center of panel ( $\frac{1}{2}$  bottom edge width) on CPA edge

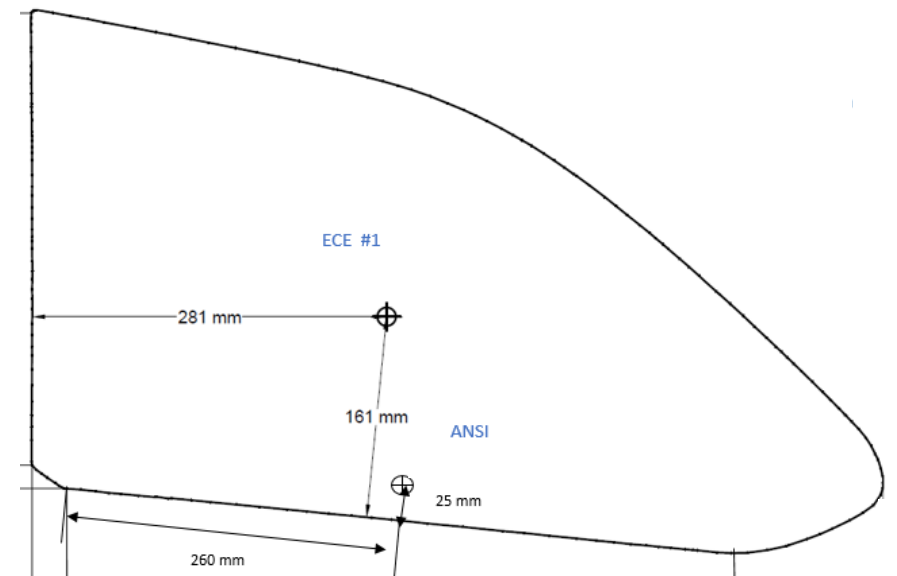
# Rear Quarter Fracture Test Setup



- Glass test piece placed concave down on identical support piece and taped with tape overlap of 20 mm along exclusion zone line around edges
- Placed on support frame for test
- Broken using spring loaded centerpunch
  - Centerpunch tip replaced after every 6 tests
- Two punch locations tested
  - ECE R43 point #1 – geometric center
  - FMVSS 205/ANSI – mid-point of longest edge
- Images taken with perpendicular DSLR camera at 10 seconds, 1 minute, 2 minutes, 3 minutes after punch



Centerpunch



Example of locations on RQ glass

# Fracture Test Criteria

- Test Criteria

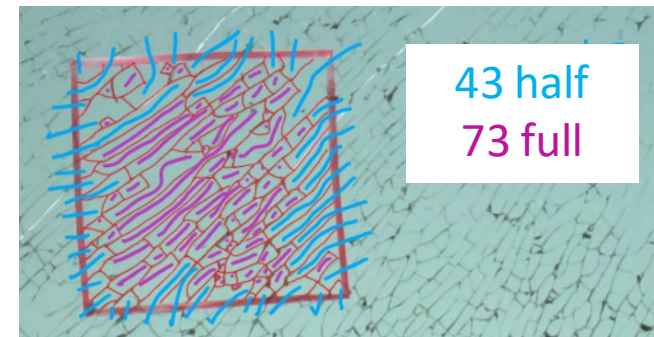
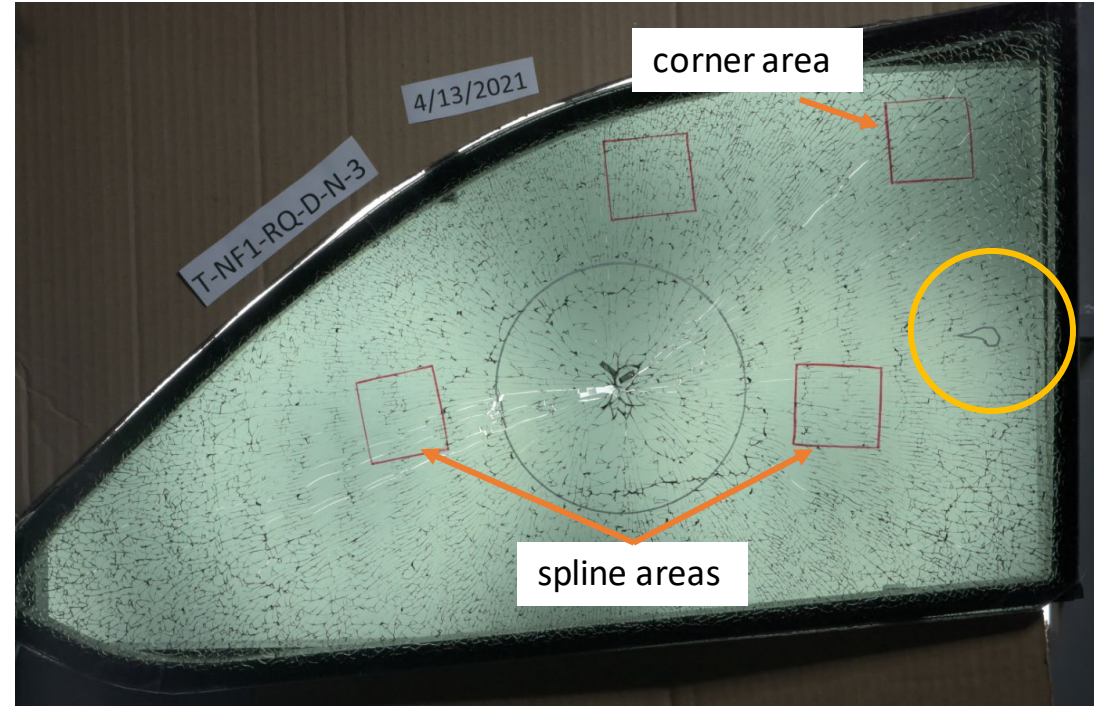
- Each punch location was evaluated using both the ANSI Z26.1 weight criteria and the ECE R43 count criteria.
- Both painted and unpainted production glass pieces were evaluated

- Weight description

- ANSI Z26.1: (Weight) Largest piece selected and weighed within 3 minutes of test. No individual fragment, free from cracks shall weigh greater than 4.25g.
  - Glass pieces identified between 10 seconds and 3 minutes and outlined for weighing (yellow circle in right image)
  - After 3 minutes identified piece was removed and weighed

- Counting description

- ECE R43: (Count) Any 5 x 5 cm square on the glass shall not have less than 40 fragments
  - 5x5 cm squares fabricated and placed on glass before test (red squares in right image)
  - Counted squares in both spline and corner areas, as well as at each time interval
  - Pieces extending across an edge of square = 1/2 , others = 1
  - Had same technician counting for all tests

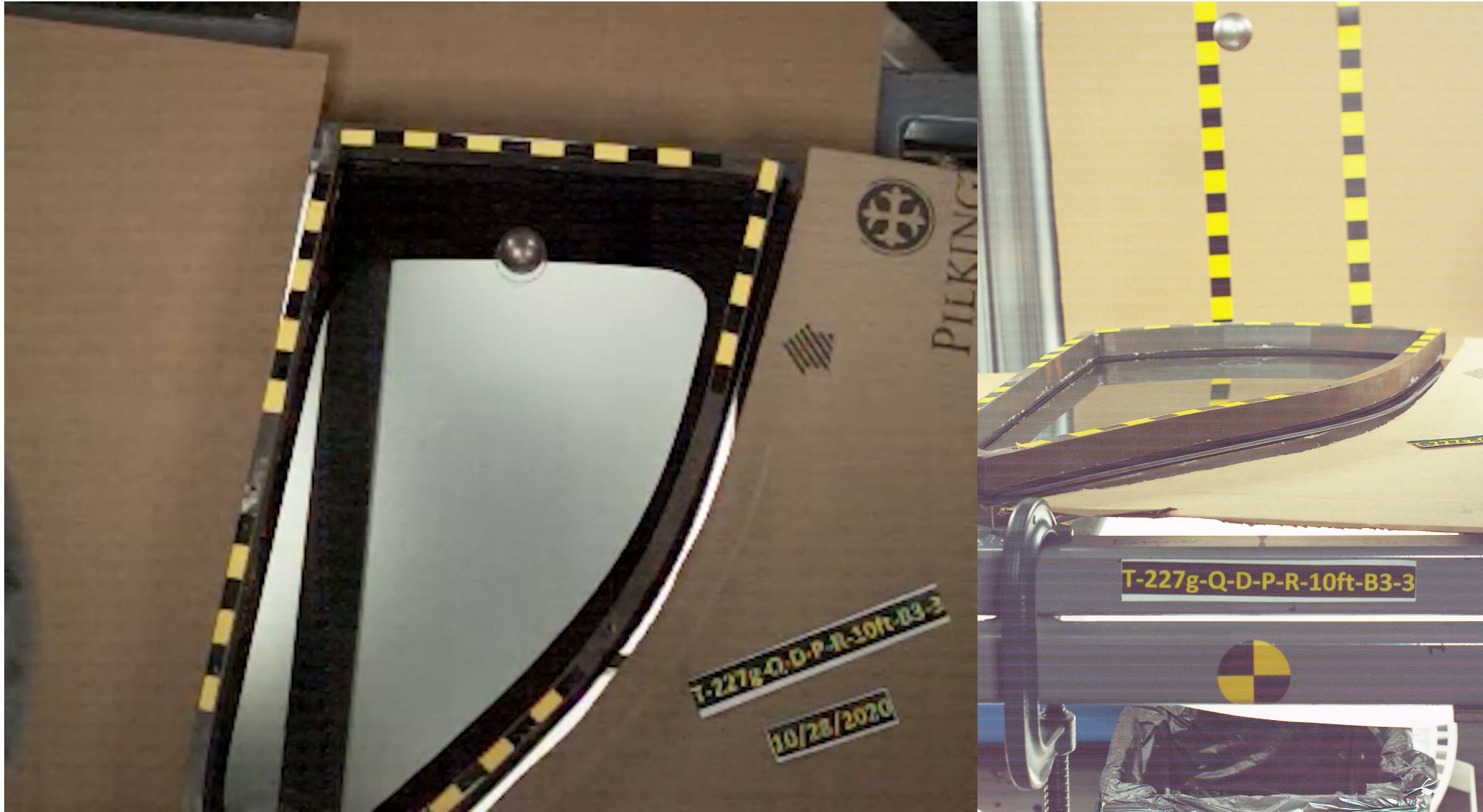


# Preliminary Results



*Rear Quarter (Tempered) and Windshield (Laminated)*

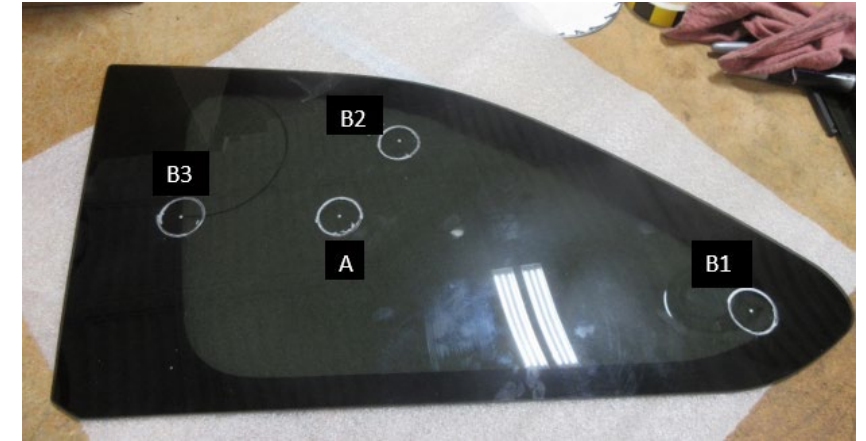
# Video – Ball – Production Rear Quarter – Tempered Glass



Edge location – ball – production – 10ft

# Preliminary Results – Ball – Tempered Glass

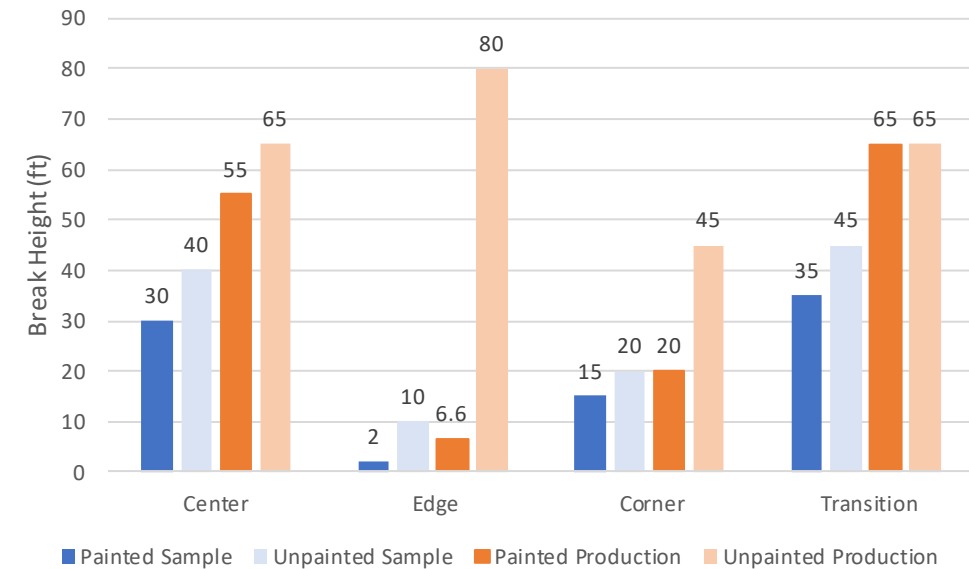
Glazing	Description	* + means break height evaluation		Painted	Unpainted	Painted	Unpainted	Painted	Unpainted	Painted	Unpainted			
				Test Type		Height	center		corner		transition		edge	
Rear Quarter	Tempered Galaxsee 3.5mm	ball	sample	10ft	Y	Y	Y	Y	Y	Y	N	Y		
				6.6ft	[Greyed out]								N	[Greyed out]
				10ft +	30	40	15	20	35	45	2	10		
		production	10ft	Y	Y	Y	Y	Y	Y	Y	N	Y		
			6.6ft	[Greyed out]								N	[Greyed out]	
			10ft +	55	65	20	45	65	65	6.6	80			



Current requirement is no breaks at 10ft center

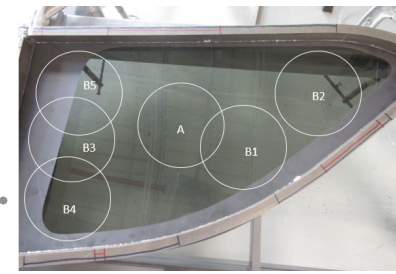
- Center location (current ANSI regulation)
  - All tests meet current requirements
  - Unpainted glass is stronger than painted and production stronger than sample
- Edge location
  - Unpainted production glass was much stronger

Rear Quarter Tempered Break Height





# Preliminary Results – Shot Bag



Glazing	Description	* + means break height evaluation		Painted	Unpainted	Painted	Unpainted	Painted	Unpainted	Painted	Unpainted	Painted	Unpainted	Painted	Unpainted	
		Test Type	Height	center		Corner (b2)		transition		edge		corner 2		corner 3		
Rear Quarter	Tempered Galaxsee 3.5mm	shot bag (ANSI)	sample	8ft	Y	Y	Y	Y	Y	Y						
			sample	9ft+	*	*	*	*	*	*						
		production	8ft	Y	Y	Y	Y	N	Y	Y	Y					
		shot bag (modified)	sample	8ft	Y	Y	Y	Y	N	Y						
			sample	9ft+	*	*	11	13								
		production	8ft	Y	Y	N	Y	N	Y	Y	Y	Y	Y	Y	Y	Y

Current requirement is no breaks at 8ft drop center

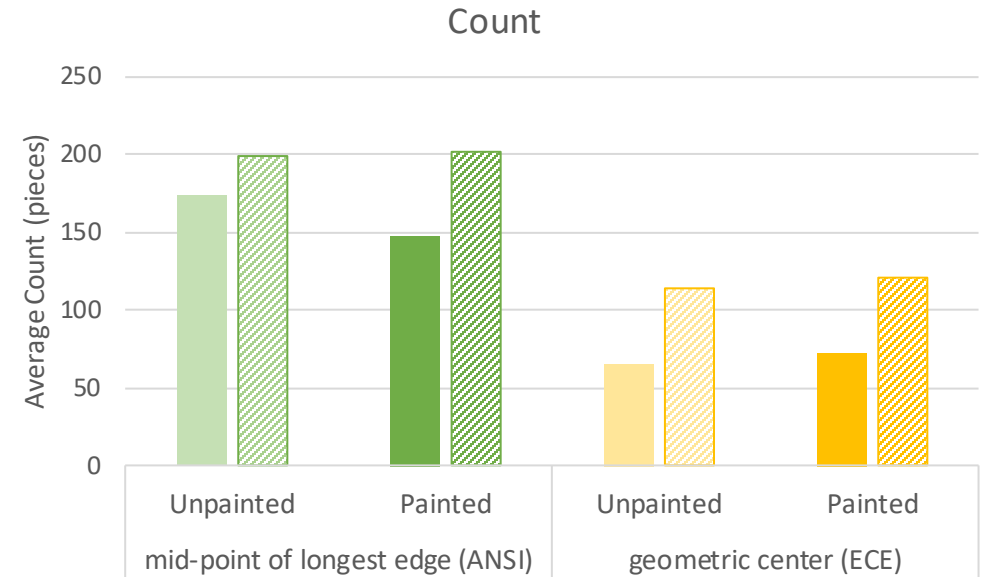
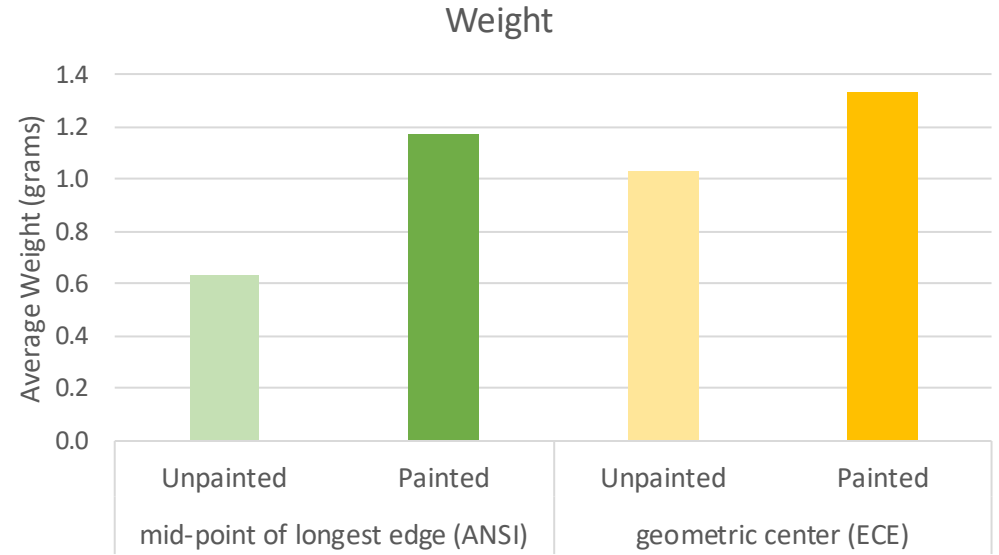
\* - met criteria at max height of tower (13ft)

- Center location
  - Similar performance between painted & unpainted, sample & production, and ANSI & modified shot bags
- Transition location
  - Painted glass weaker than unpainted for sample & production with modified bag
- Modified bag produced larger quantity of breaks than ANSI bag

# Preliminary Results - Fracture

Rear Quarter	Tempered Galaxsee 3.5mm	Description			< 4.25 gram		> 40 pieces		> 40 pieces	
					Avg. Weight		Avg. Count - Spline		Avg. Count - Corner	
					painted	unpainted	painted	unpainted	painted	unpainted
fracture	production	ANSI	1.2	0.6	148	173	202	199		
		ECE	1.3	1.0	73	66	121	115		

- Weight of largest piece
  - Painted produced larger pieces than unpainted
  - Similar size pieces between ANSI and ECE locations
- Number of pieces in 5cm x 5cm area
  - ECE impact location resulted in larger pieces
  - For both impact locations, spline areas were the worst case with larger pieces in those areas



# Video – Dart - Production Windshield – Laminated Glass

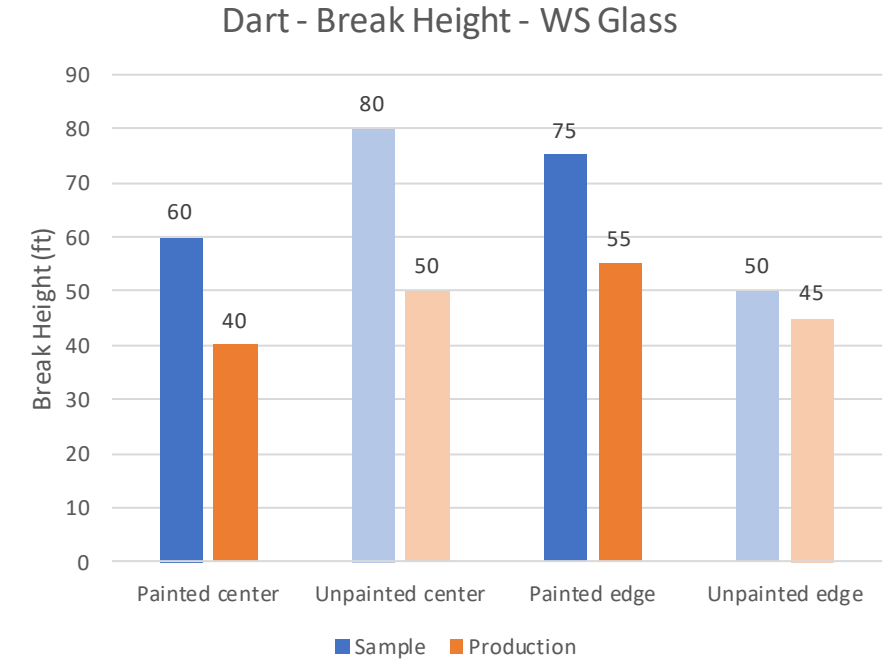


Center location – dart – production – 30ft

# Preliminary Results – Dart – Laminated Glass

Glazing	Description	* + means break height evaluation		Painted	Unpainted	Painted	Unpainted	Painted	Unpainted	Painted	Unpainted
		Test Type	Height	center		corner		transition		edge	
Windshield	Laminated 2.1/acoustic PVB/2.1 EZ-Kool	dart	sample	30ft	Y	Y	Y	Y	Y	Y	Y
			31ft+	60	80					75	50
		production	30ft	Y	Y	Y	Y	Y	Y	Y	Y
			31ft+	40	50					50	45

Needs to meet criteria at 30ft drop

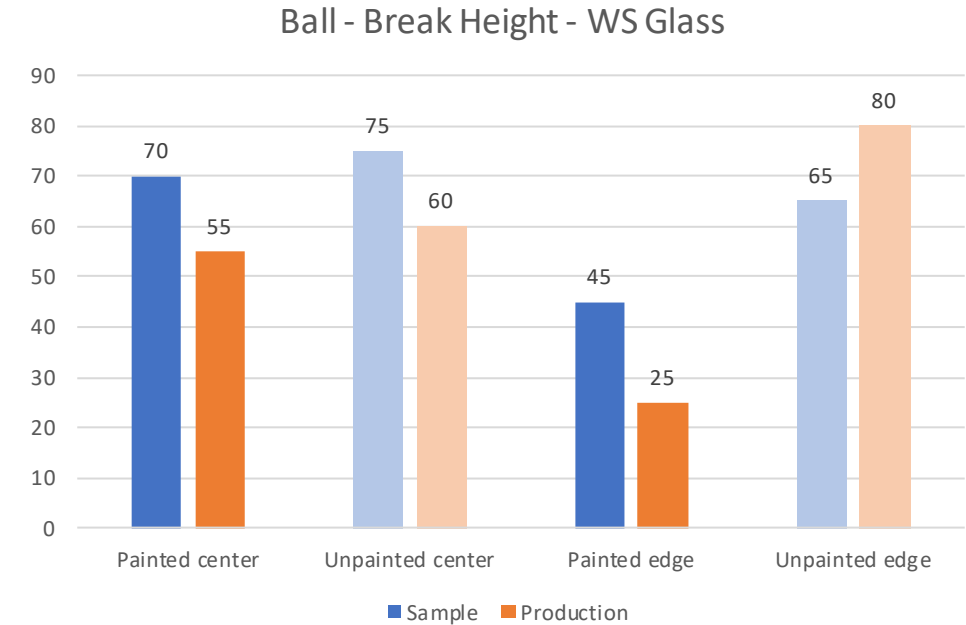


- Sample & production and painted & unpainted met current requirements (30ft drop height) at center
- Sample glass withstood higher impacts than production

# Preliminary Results – Ball – Laminated Glass

Glazing	Description	* + means break height evaluation		Painted	Unpainted	Painted	Unpainted	Painted	Unpainted	Painted	Unpainted
				center		corner		transition		edge	
		Test Type	Height								
Windshield	Laminated 2.1/acoustic PVB/2.1 EZ-Kool	ball	sample	30ft	Y	Y	Y	Y	Y	Y	Y
			31ft+	70	75					45	65
		production	30ft	Y	Y	Y	Y	Y	Y	Y	Y
			31ft+	55	60					25	80

Needs to meet criteria at 30ft drop



- Sample & production and painted & unpainted met current requirements (30ft drop height) at center
- Sample glass withstood higher impacts than production, except for unpainted edge

# Takeaways & Next Steps

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- Takeaways

- Tempered glass
  - Paint weakens glass
  - Sample & production met current requirements, however at greater heights the production glass was stronger than sample
- Shot bag
  - Modified bag produced more quantity of breaks than current ANSI bag
- Fracture
  - ECE impact location resulted in larger pieces than ANSI location with counting method but had similar size pieces when comparing with weight method
- Laminated glass
  - Sample & production met current requirements, however at greater heights the sample glass was stronger than production

- Next Steps

- Ongoing analysis and documentation of completed testing
- Ongoing testing to complete matrix with tempered sunroof and backlight glass
  - Testing expected completion by Fall/Winter 2023

# Thank you

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## *Contact information:*

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