2020 SAE Government Industry Meeting

NHTSA

NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

Status of NHTSA's Roof Ejection Mitigation Research

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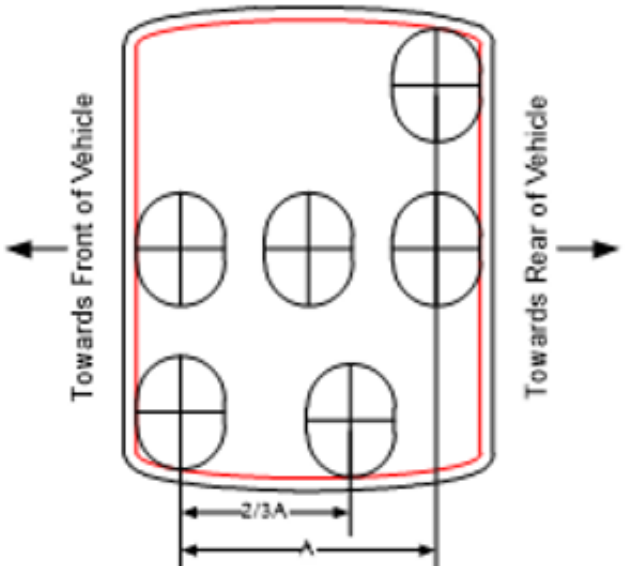
Background

- FMVSS No. 226 Final Rule (Jan 2011) preamble says, “NHTSA is interested in learning more about roof ejections and would like to explore this area further…”
- Annual average 87 fatalities (FARS 2004-2017, coded as roof ejection path, excluding unknown path)
  - “Occupant Injuries Related to Rollover Crashes and Ejections from Recent Crash Data” Jingshu Wu et. al. 26th ESV, 2019
- Tests on production vehicles with laminated sunroof panels at 16, 20 km/h
  - 2009 Ford Flex (fixed); 2014 Ford CMax (fixed); 2013 Subaru Forester (movable)
    - 2016 SAE Government Industry Meeting
    - Paper at 25th Conference on Enhanced Safety of Vehicles (ESV), Detroit, 2017
- Tests on production and countermeasure* sunroof panels at 14, 16, 20 km/h
  - 2016 Ford F-150* (laminated - inner slider); 2010 Toyota Prius (fixed polycarbonate); 2019 Aisin (laminated - outer slider)
    - Paper at 26th Conference on Enhanced Safety of Vehicles (ESV), Eindhoven, Netherlands, 2019

Test Setup



- FMVSS No. 226 Impactor
- Featureless headform (40 lbs. [18kg])
- Displacement, speed from Linear Pot (LVDT)
- Accelerometer on the ram

- Impact locations and speeds
  - Speeds (14/16/20 km/h)
  - 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

Linear Variable Differential Transformer (LVDT)

Lincoln MKZ

- Large panoramic design
- Outer slider type (opens to outside)
- ProTec 2® (PET) film
- Attached to rails at front and back
- Production and countermeasure panels

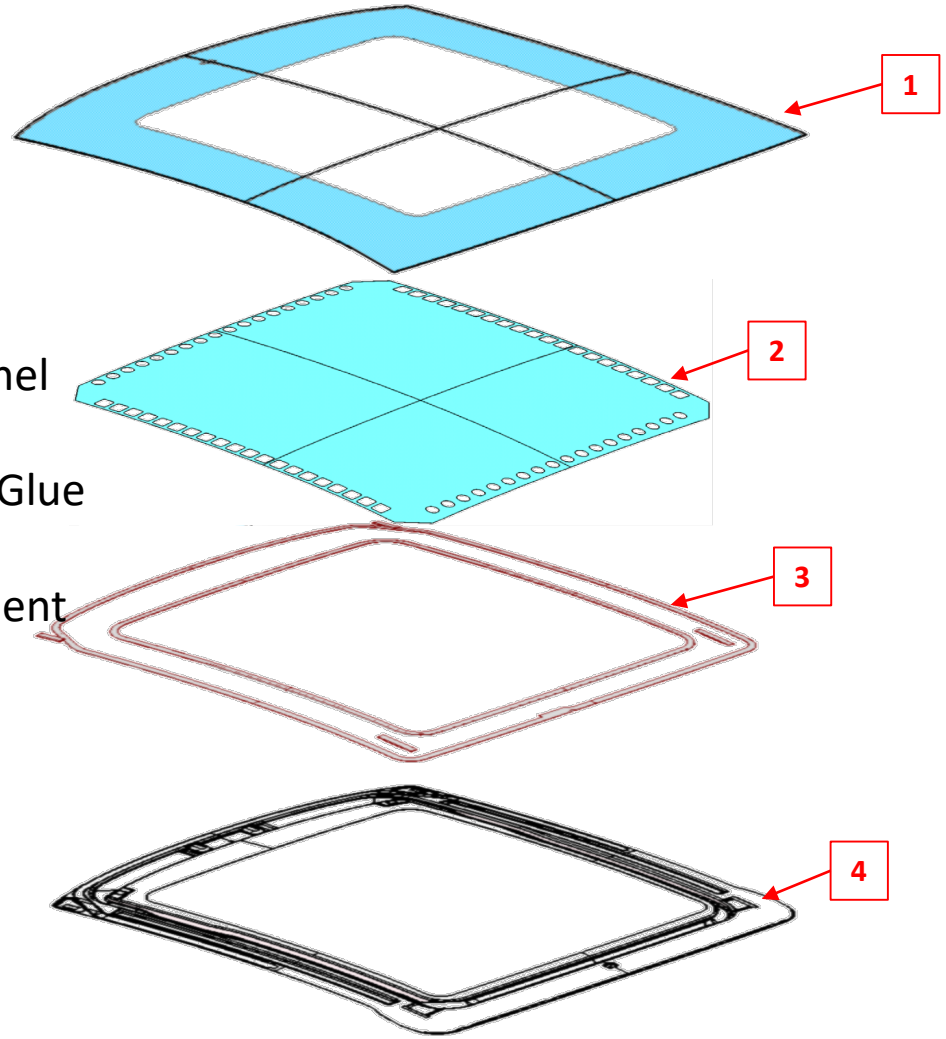
PET = polyethylene terephthalate

Lincoln MKZ – Module Description

- Glass panel bonded to ProTec 2® film and glued to steel assembly
  - Protec 2® film (0.2mm PET film) – bonded to inner side of tempered glass
  - Film does not go all the way to edge of glass just to outside of frit line
- Production film has holes along edges (2) – reinforcement glued to both glass and film
- Countermeasure film does not have holes – reinforcement glued directly to film

Moving Glass Panel Assembly:

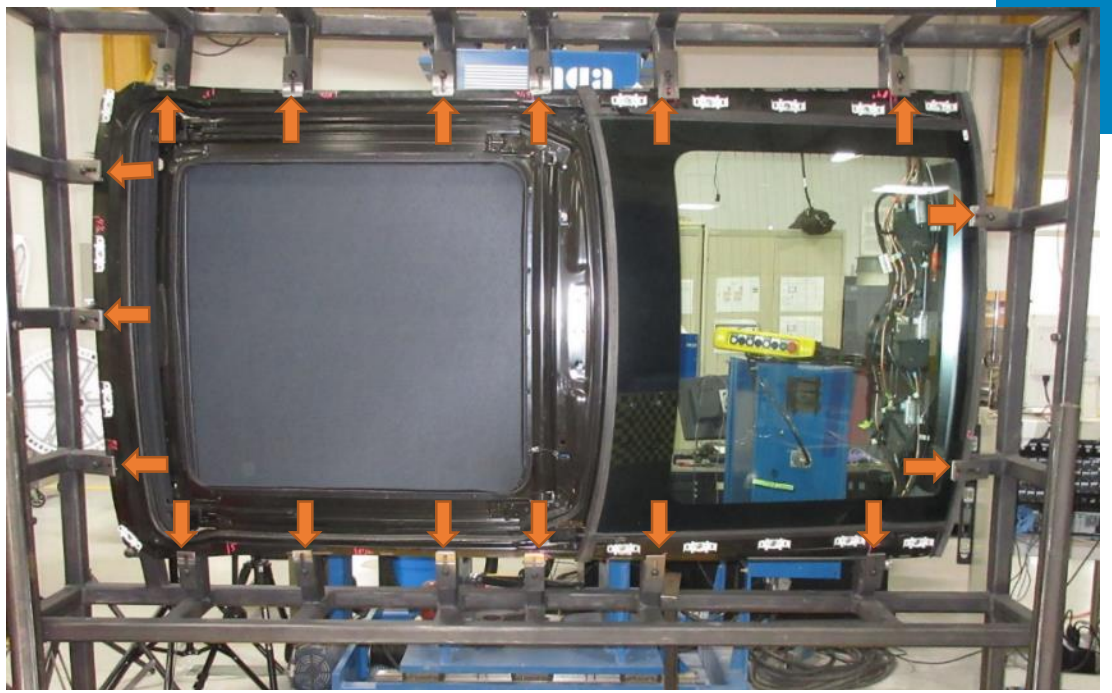
1. Moving Glass Panel
2. ProTec2 Film
3. Inner and Outer Glue Beads
4. Steel Reinforcement Assembly



frit = a black enamel band that is baked into the edges of the windshield for better adhesive bond and protect bond from UV

Test Setup

- Custom made frame – module attached to frame using 17 sliding brackets (shown with arrows)



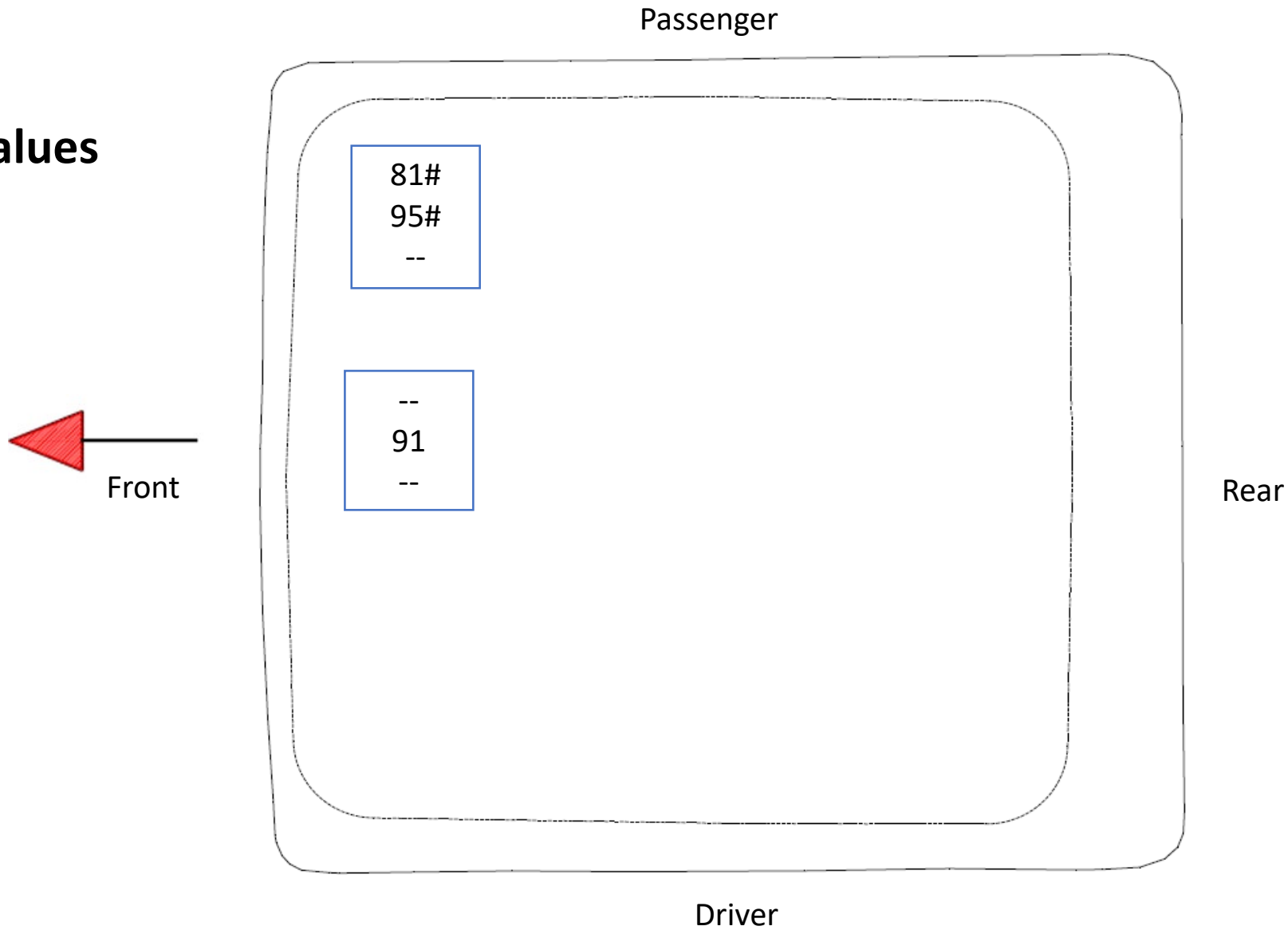
- Glass pre-broken on one side (outside)
  - Punched once in corner– glass fractured all the way across
- Brackets with targets for photographic analysis attached at inner glue line (near frit line) – measure edge excursions

Lincoln MKZ (Webasto) Production ProTec 2®

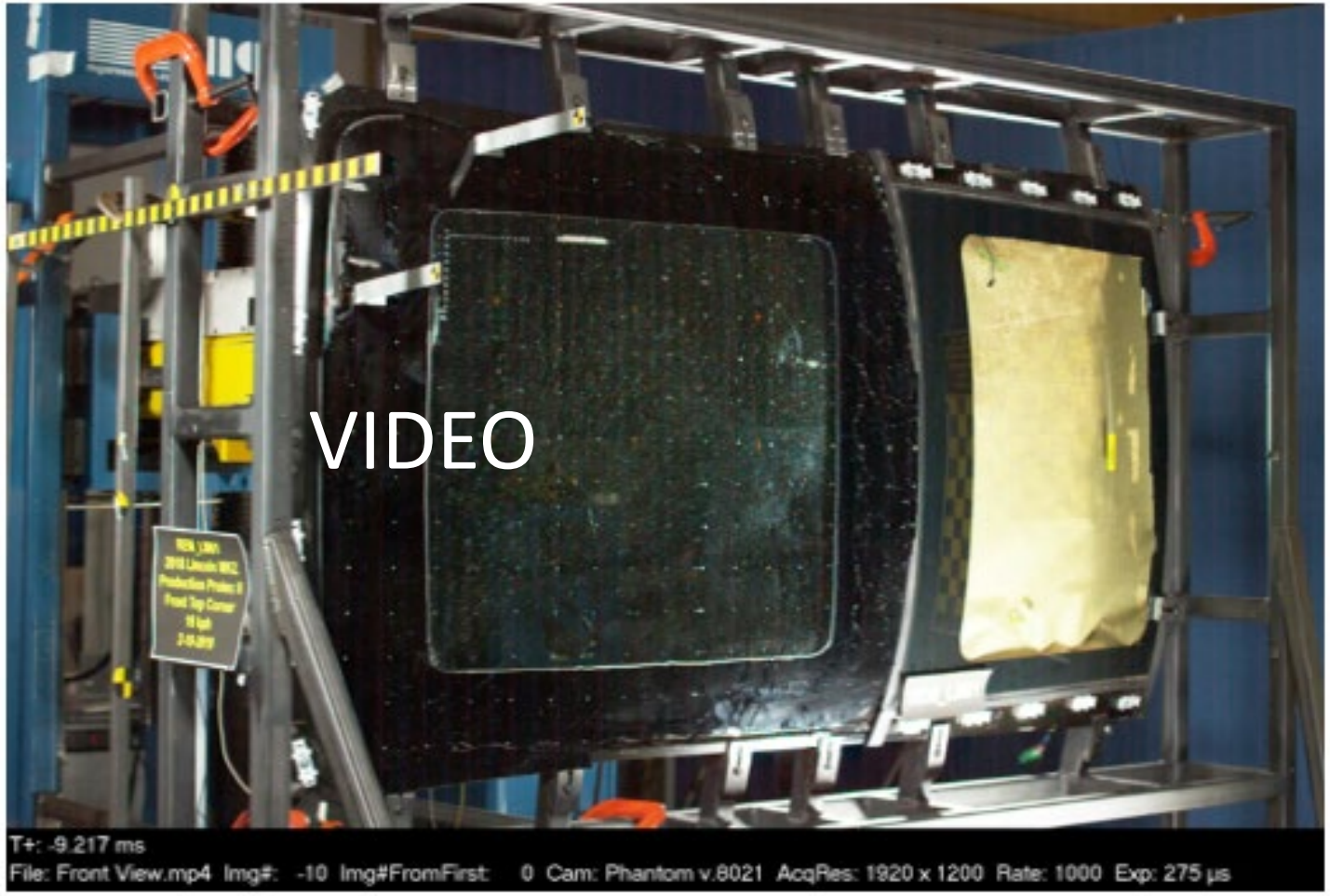
Results/Ram Excursion Values

At 14 km/h
At 16 km/h
At 20 km/h

Plastic film tear



Plastic Film Tear



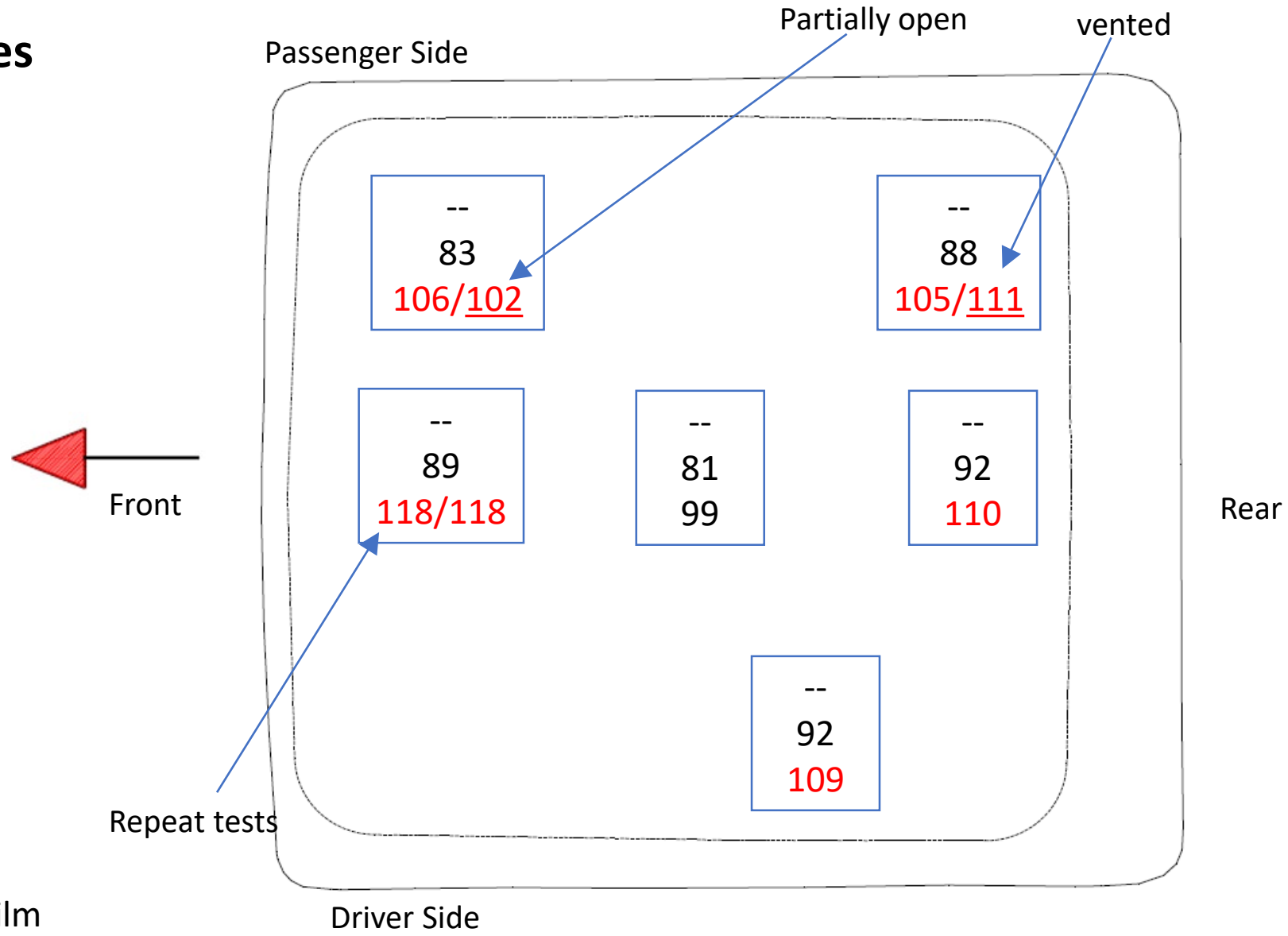
Production panel- Front corner – 16 km/h

Lincoln MKZ (Webasto) Countermeasure ProTec 2®

Results/Ram Excursion Values

At 14 km/h
At 16 km/h
At 20 km/h

- No rips or tears in PET layer
- No gross failures at mounting or attachment brackets
- Some bending of steel reinforcement of glass

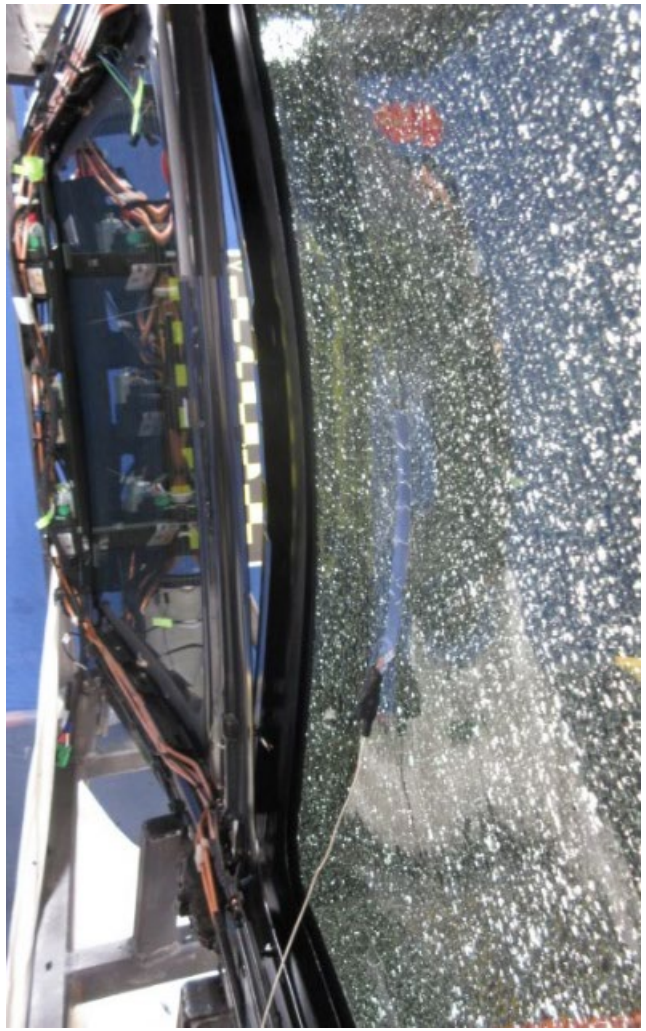


Only difference between production and countermeasure panels are holes in PET film

Results – Countermeasure

Some bending of steel frame

- 4 inch ball did not pass through



Rear edge – mid @ 20 km/h

Bottom edge 2/3 A @ 20km/h

Front edge mid @ 20 km/h

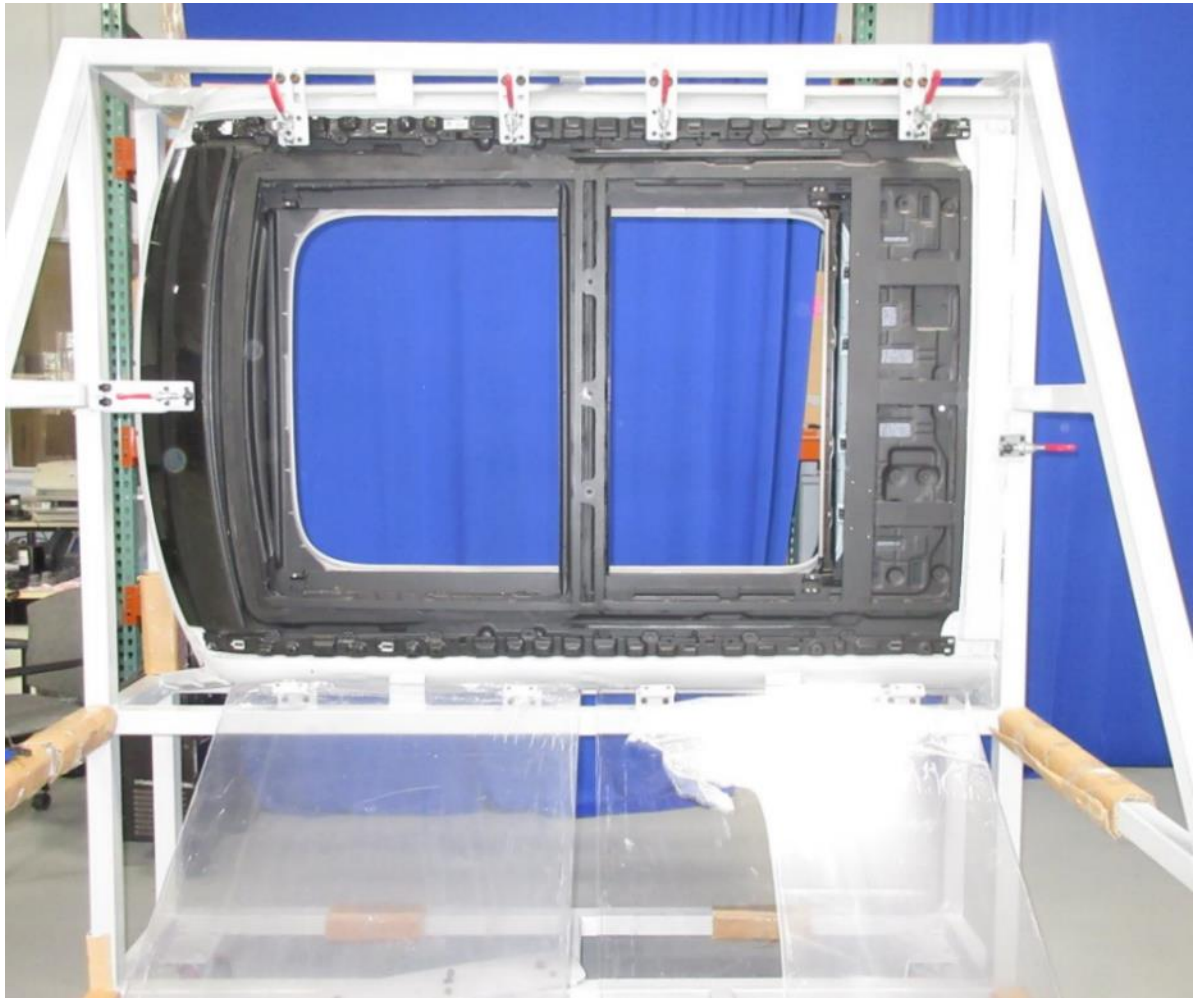
Test Observations – MKZ Countermeasure

- Excursion values below 100 mm at 16 km/h and just slightly above at 20 km/h
- No rips or tears in PET layer
- No gross failures at mounting or attachment brackets
- Bending of steel reinforcement of glass
  - Most severe when impacted at mid points of transverse and 2/3 of lateral edges at 20 km/h
  - 4 inch ball did not pass through

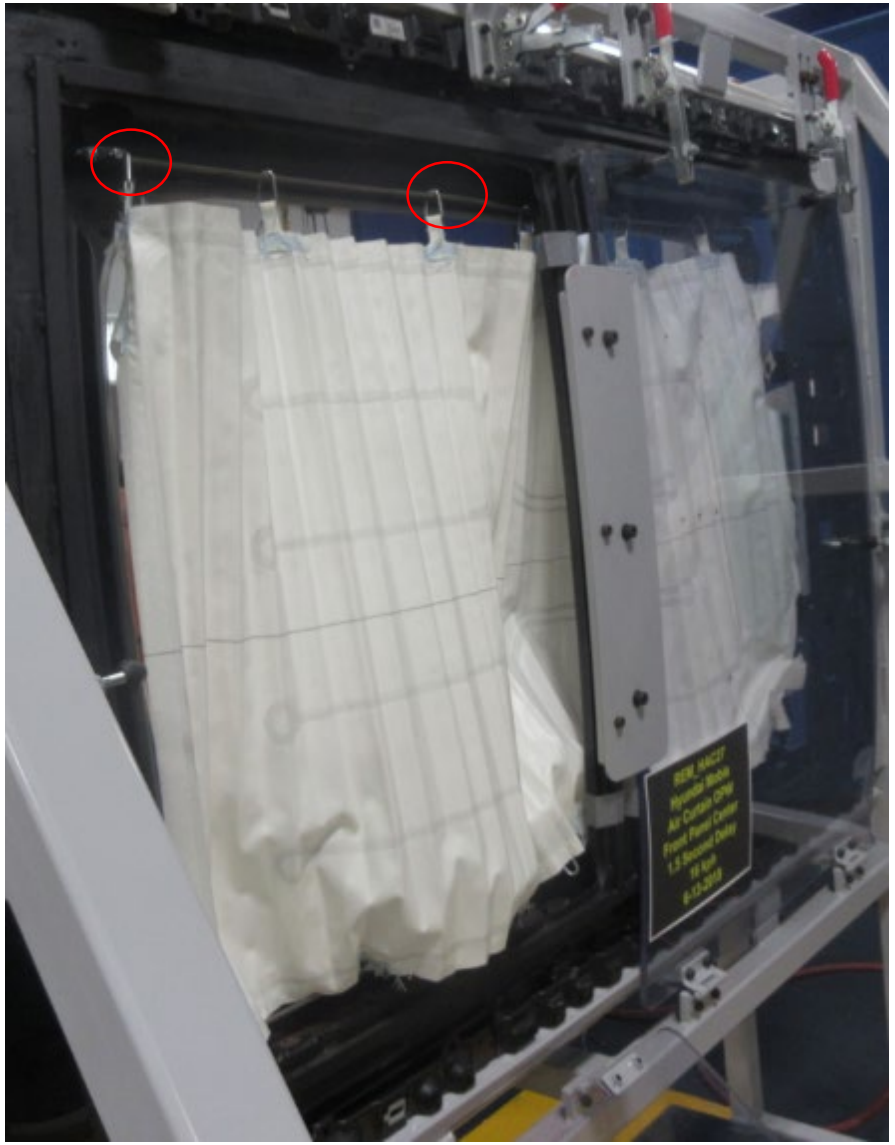
Hyundai-Mobis Roof Air Curtain System

Curtain Air Bag Module

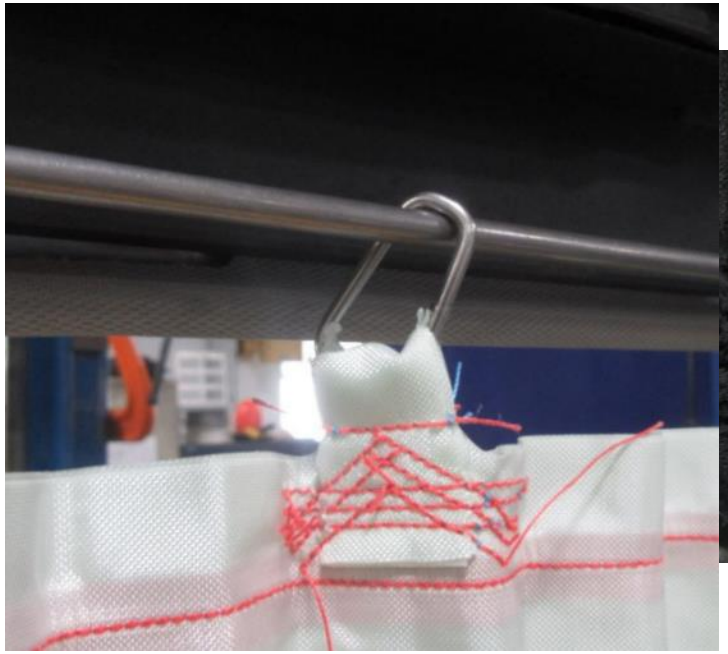
- Headliner (interior) and roof frame (exterior)
- Polycarbonate “glass” → aid in target alignment, zero plane
- Fabricated for testing purposes – not from production or prototype vehicle
- Guide rods and air bag to be installed for each test

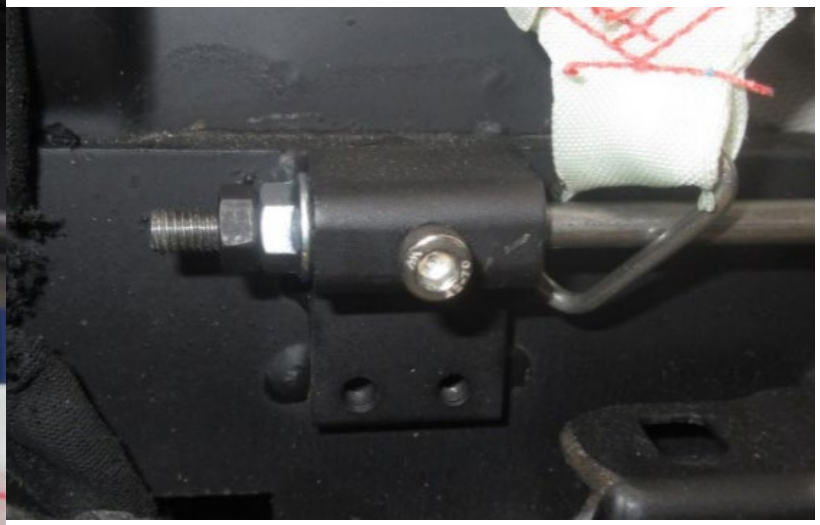


Curtain Air Bag Module Assembly



- Guide rods mounted along lateral edges
  - 2 nuts per end
  - Bolt to prevent turning
- Guide rings on both sides hold bag to module along guide rods





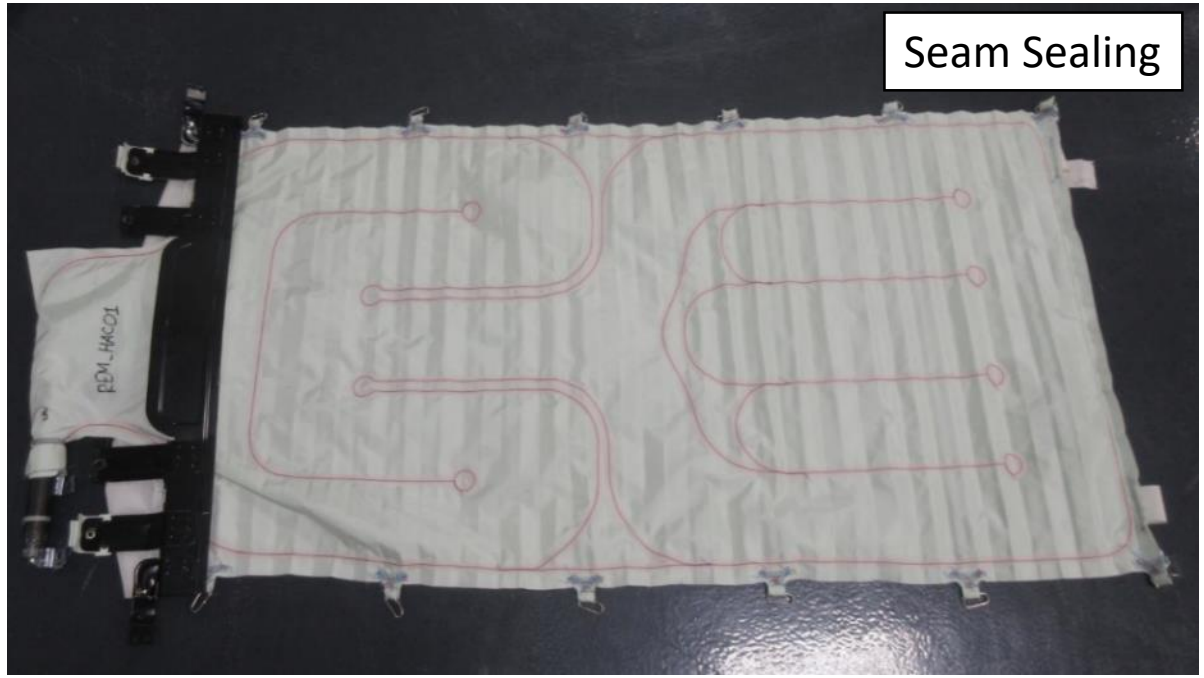
Curtain Air Bag Module Assembly

- Air bag mounted on rear of module at six locations, four on interior, two on exterior
- Inflator secured at two locations

Curtain Air Bag Types

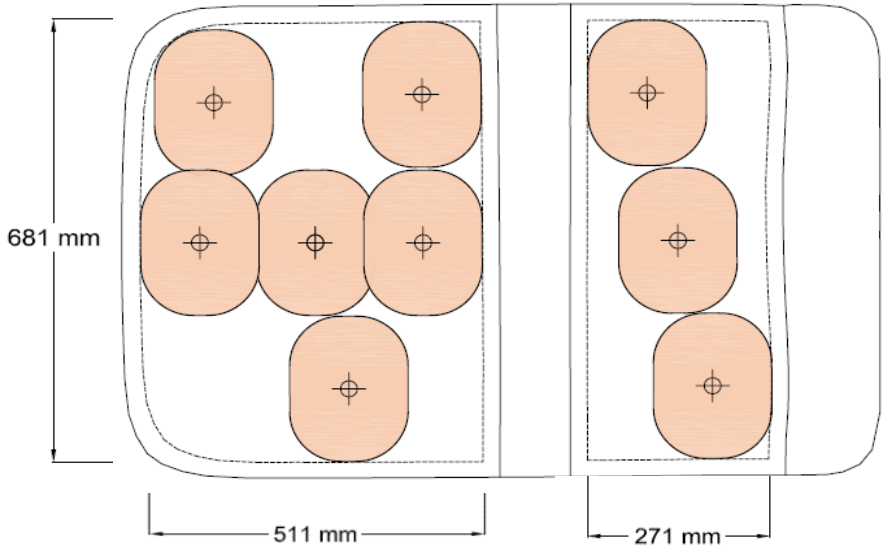
- Curtain types
  - One Panel Woven (OPW)
    - 30 bags
  - Seam Sealing (SS)
    - 15 bags
  - Same inflator and chamber layout

- Differences between the two:
  - Material
  - Fabric in OPW sealed by plastic film material, woven together at seam



Test Setup

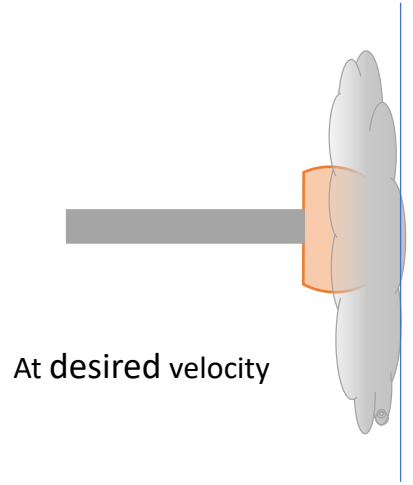
- Open bag across daylight opening
  - Assumed successful deployment
  - Full automatic deployment found to not be reliable – 2 trials
  - 6 Impact Locations
  - Front Corner, Front Edge – Mid, Center, 2/3 Lateral Edge, Rear Edge – Mid, Rear Corner
- 3 speeds
  - 14 km/h, 16 km/h, 20 km/h
- Plexiglass positioning
  - Front panel impacts – front plexiglass down, rear up – “moveable panel”
  - Rear panel impacts – front and rear plexiglass down
  - Plexiglass is zero plane for excursion measurements

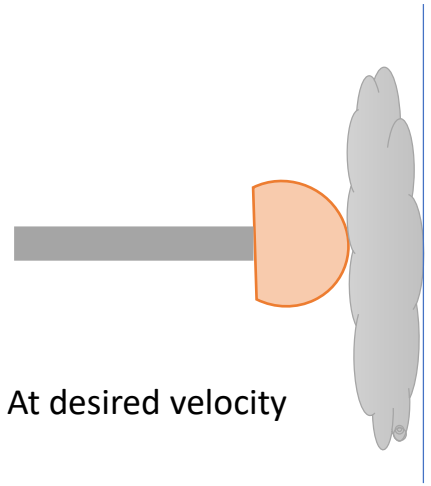


Some rear panel targets eliminated per FMVSS No. 226 procedure

Propulsion Methods

- Method 1
  - Tested front panel center, front corner, front edge-mid (8 tests)
  - Headform positioned so desired velocity achieved at plexiglass location
  - Zero plane at plexiglass
    - Caused questionable speed readouts
- Method 2
  - Re-tested front edge-mid and all remaining impacts (37 tests)
  - Headform positioned so desired velocity achieved just before impact with bag
    - Zero plane at plexiglass
- 6 second delay between inflation and impact
  - Additional tests done at 1.5, 3 and 8 second delays





At 1 inch after free flight

Hyundai-Mobis Curtain - Results

Results/Excursion Values

6 second delay

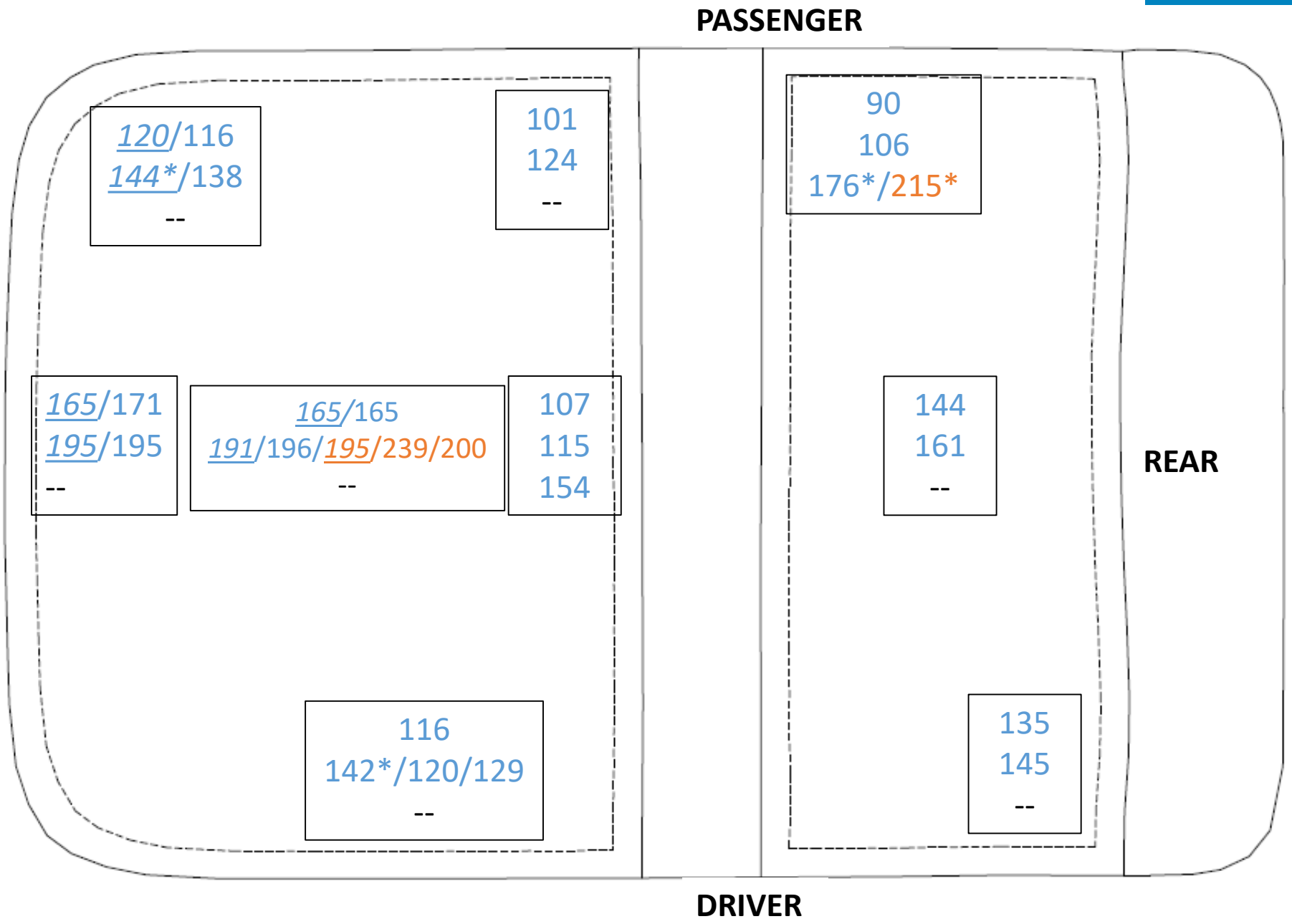
At 14 km/h
At 16 km/h
At 20 km/h

* Bag ripped at stitching

Underline = Method 1

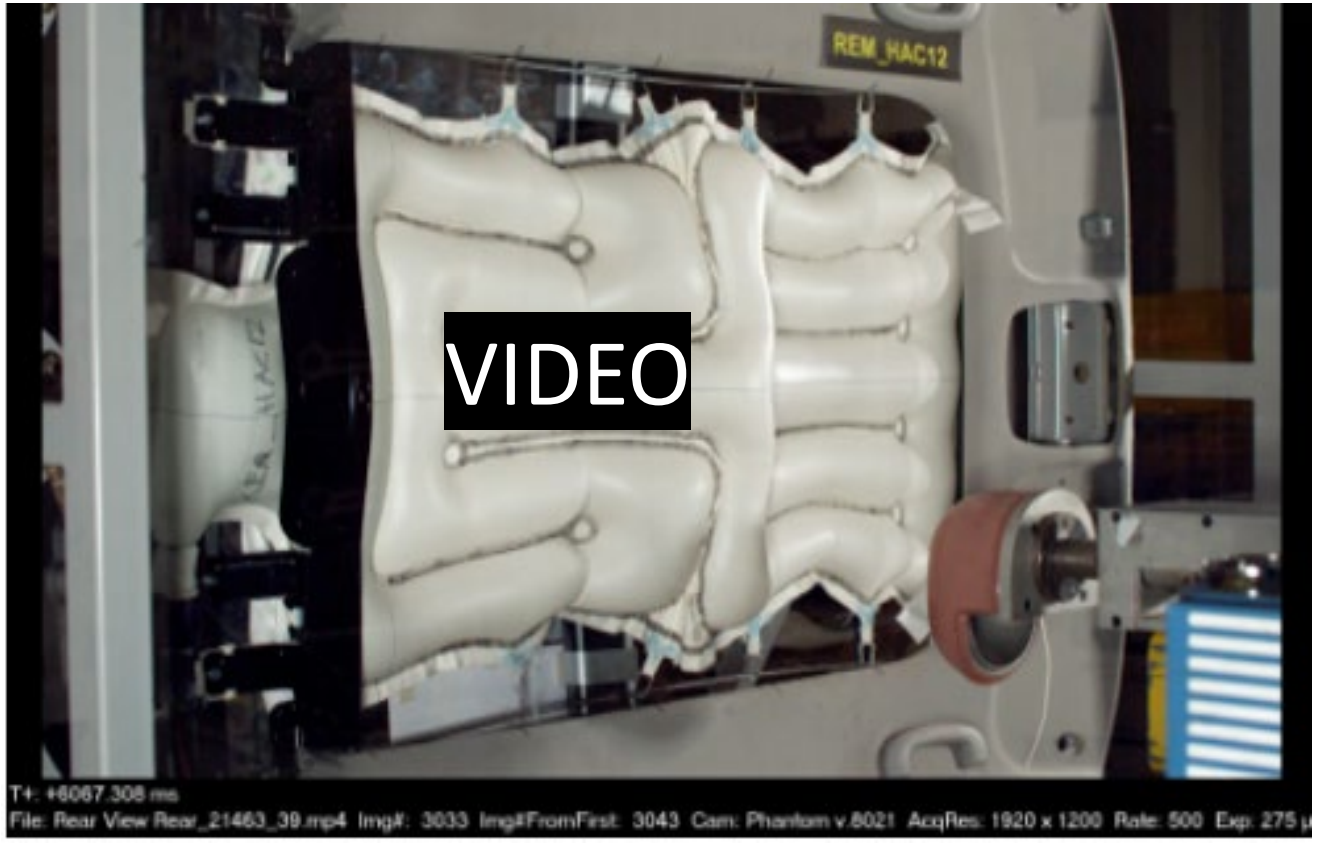
Seam Sealing Bag

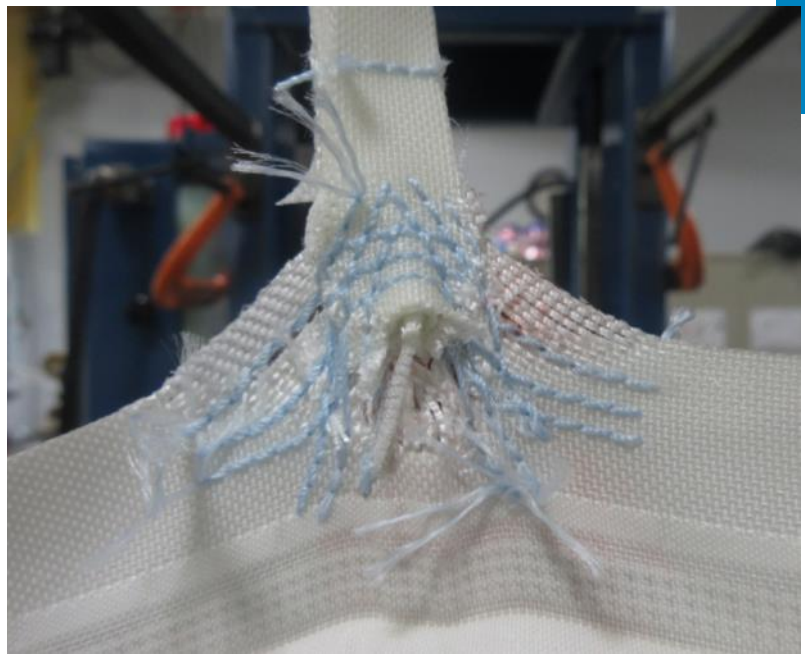
- Bag more likely to rip or tear when hit at guide ring attachment
- Excursions less in corners and on lateral edges where more supported by guide rings and rods
- Excursions less closer to center support area

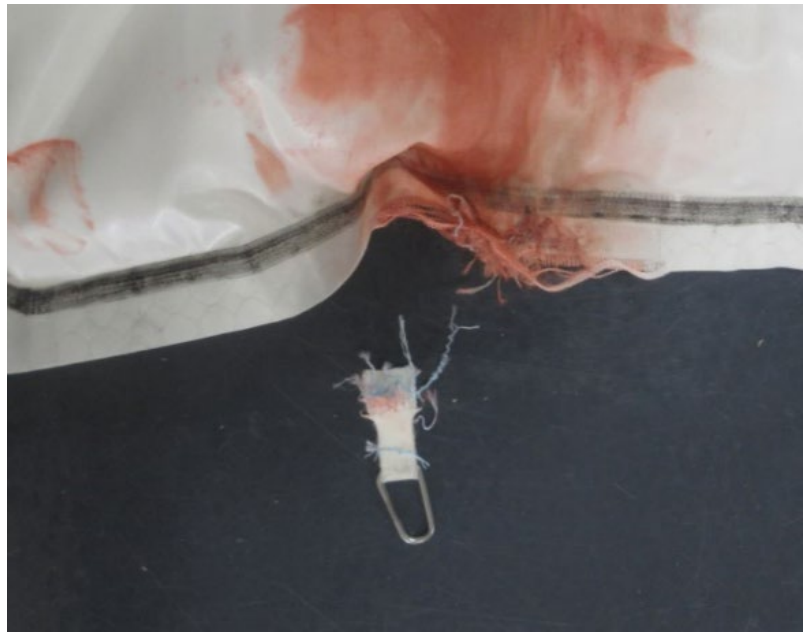


Failure Modes

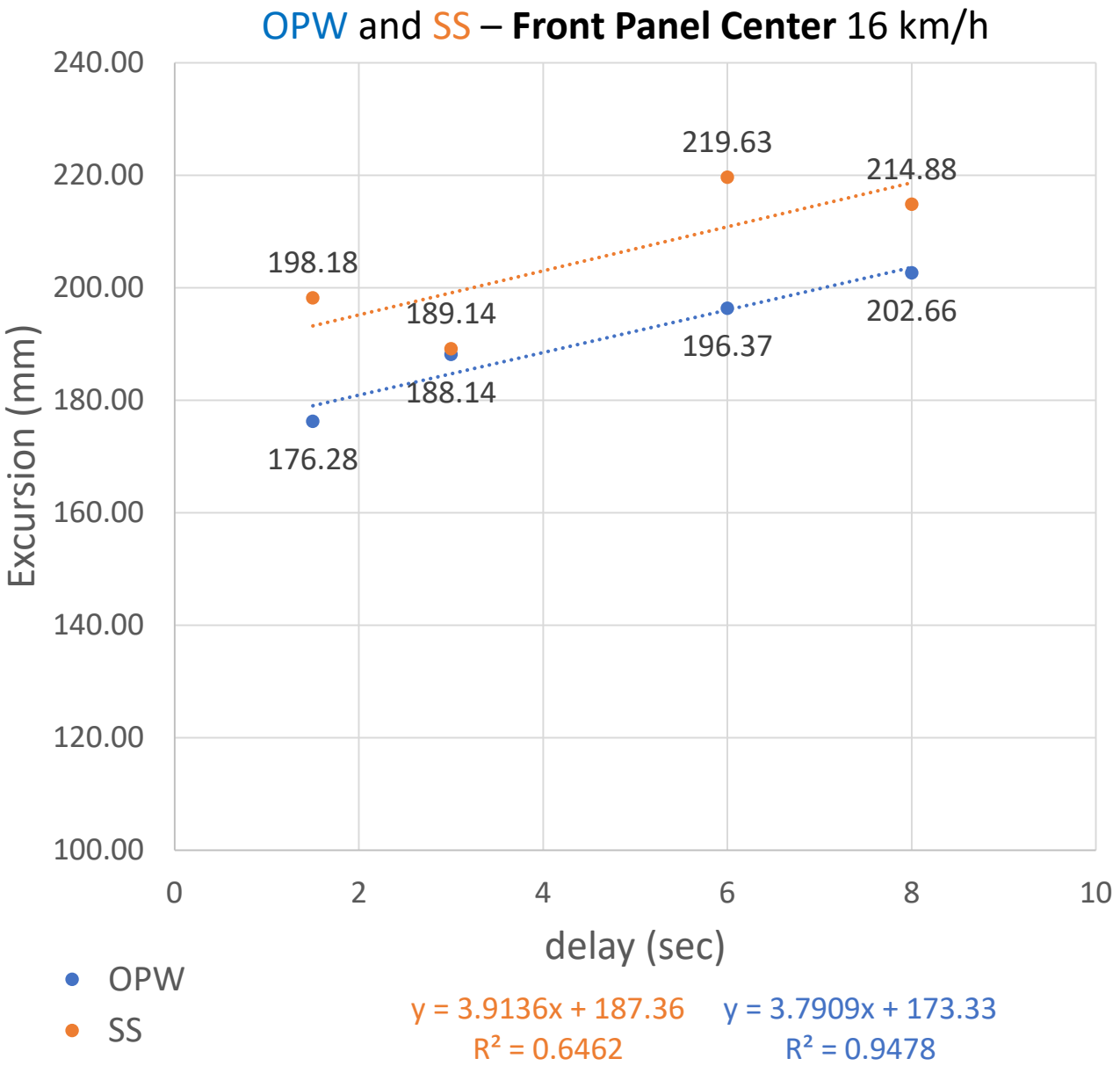
- Ripping at stitching of guide ring
  - When headform impacted near stitching
  - Full and partial ripping
  - Headform still contained

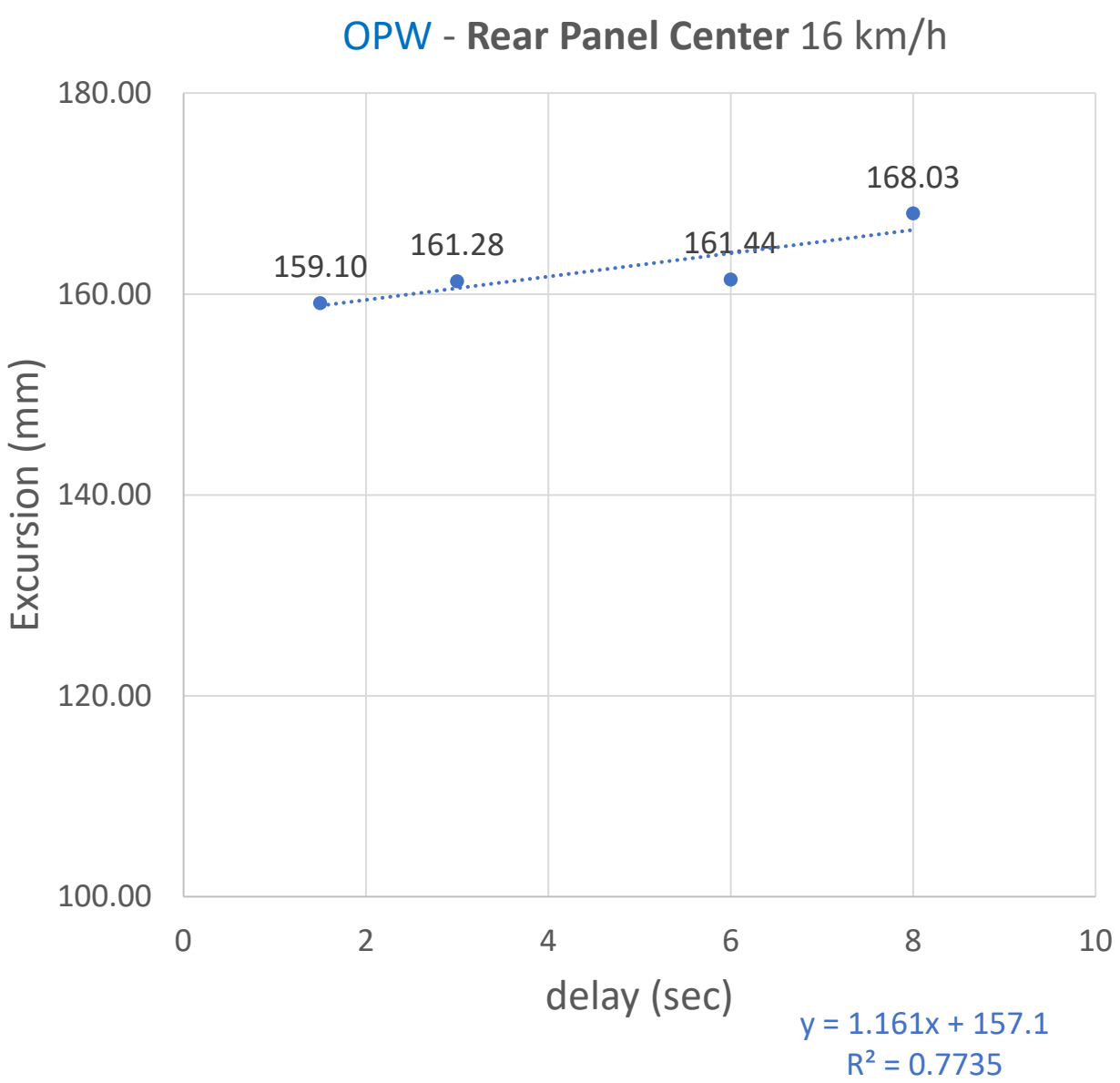






Timing Delay Effect on Excursion



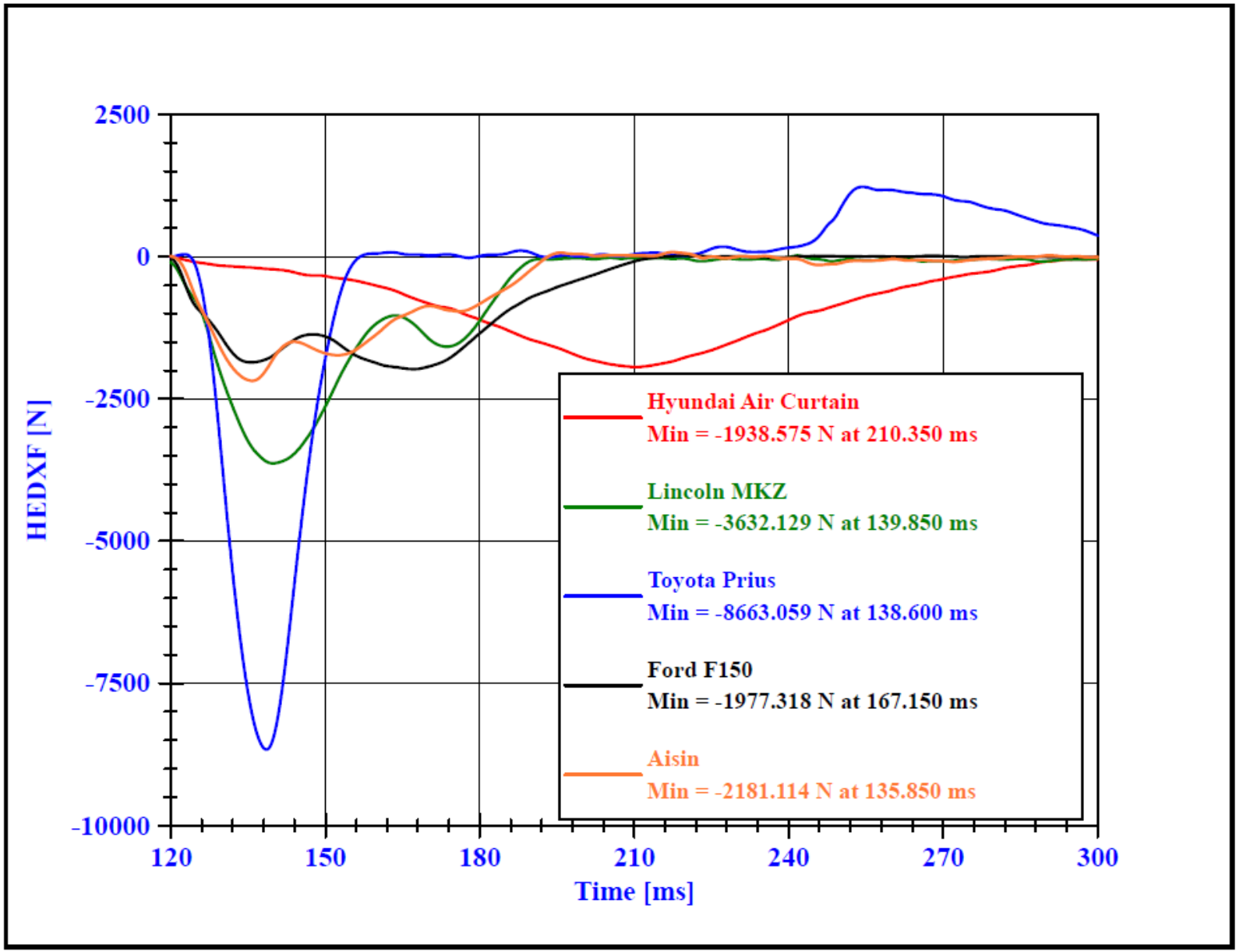


Test Observations – Hyundai-Mobis Curtain

- Bag more likely to rip or tear when hit at guide ring attachment
- Excursions less in corners and on lateral edges where more supported by guide rings and rods
- Excursions less closer to center support area
- Delay Timing Effect on Excursion
  - Longer delay = greater excursion
  - Greater effect of delay differences on front panel than rear
  - Greater scatter with OPW than Seam Sealing

Force Comparison

- Front panel – Center – 16 km/h
  - Red – Hyundai Air Curtain
  - Green – Lincoln MKZ
  - Blue – Toyota Prius *
  - Black – Ford F150 *
  - Orange – Aisin *
- Using accelerometer mounted to the ram



* 26th Conference on Enhanced Safety of Vehicles (ESV), Eindhoven, Netherlands, 2019

Overall Observations

- Movable panels with good attachment designs can perform well (excursion <100mm)
  - MKZ had metal rails, pins and cam
- Air curtains feasible for preventing ejection but still in development stages
- Roof air curtain produced similar headform forces and energy as good performing laminate movable sunroofs, higher excursions
  - More testing needed on other air curtain setups
- All components in load path need to be designed for occupant containment
  - Rail, rail inserts, bonding to glass, glass/plastic strength
- Smaller excursions may lead to higher head and neck forces (Prius)
  - Perhaps no worse than metal roof (no testing of metal roof was conducted)
  - May be better than getting ejected!

Thank You for Your Attention

Data can be found at: Component Test Database (COMDB)
https://www-nrd.nhtsa.dot.gov/database/VSR/com/QueryTest.aspx
Test Numbers: c01826 through c01888