EVALUATING WINDOW RETENTION OF MOTORCOACH SIDE WINDOWS

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Aloke K. Prasad, NHTSA
J. Stephen Duffy, TRC, Inc.

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Outline of Presentation

- Background
- Safety Problem
- Dynamic Test Procedure Development
- NHTSA Research Summary

  Bus frame testing

  - Latch impacts
    - Establish unlatching threshold conditions
    - Latch countermeasure development
  - Center impacts
    - Pre-broken glazing impacts
      - Development of glass breaking procedure
      - Thicker PVB Interlayer

Background

- 2003 Transport Canada (T.C.) and NHTSA focused on improving glazing and window retention on motorcoaches to prevent ejection.
  - Develop dynamic test procedure for evaluating advanced glazing materials and bonding
  - Research conducted by Martec Ltd.

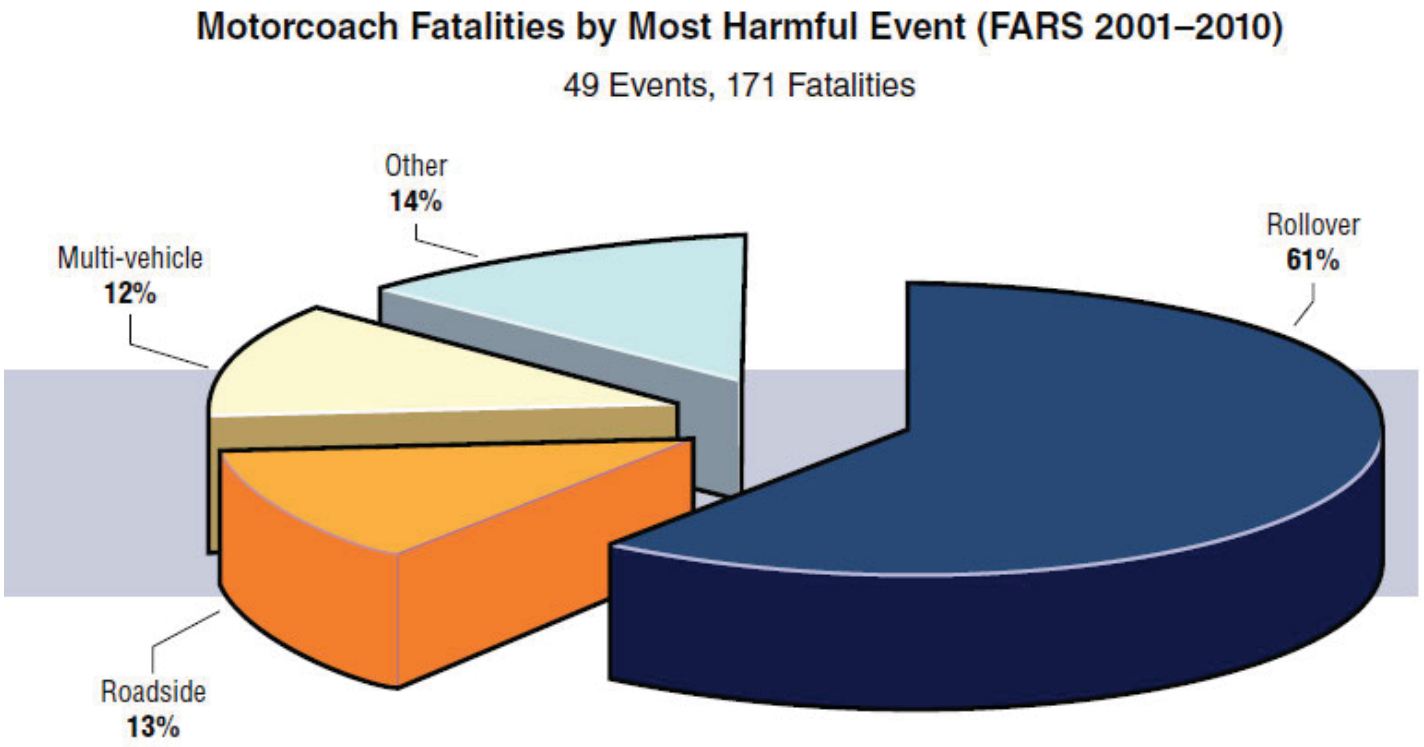
- 2007 NHTSA Approach to Motorcoach Safety
  - Reduce risk of passenger ejection
  - Improve rollover structural integrity
  - Enhance emergency evacuation
  - Upgrade fire safety
  - http://www.nhtsa.gov/DOT/NHTSA/Vehicle Safety/Articles/Associated Files/481217.pdf

- 2009 DOT Motorcoach Safety Action Plan
  - Require installation of seat belts on motorcoaches
  - Improve structural integrity
  - Follow up with test procedure and more stringent window retention performance requirements
  - http://www.nhtsa.gov/DOT/NHTSA/reports/HS811177.pdf
  - http://www.fmcsa.dot.gov/safety-security/pcs/Motorcoach-Safety-Action-Plan.aspx (updated 2012)

- 2012 MAP-21
  - Issue regulations for improved occupant protection with anti-ejection safety countermeasures (by July 2014)
  - Consider requiring advanced glazing standards for motorcoach portals

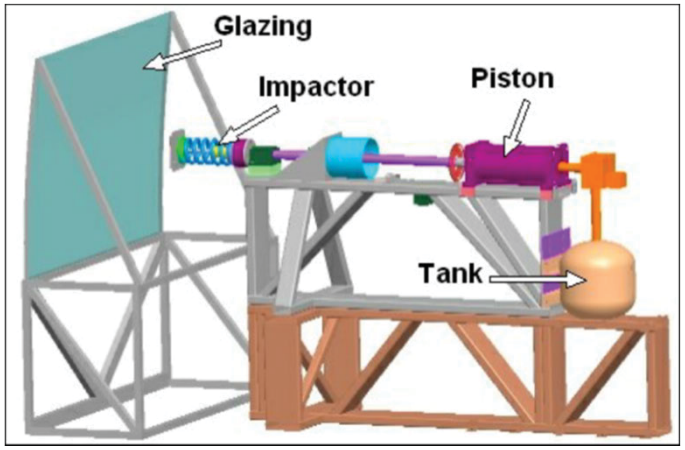
Safety Problem

- 17 Motorcoach Occupant Fatalities per year (2001 – 2011)
  - Higher average number fatalities than earlier decade
- Rollovers cause 61 percent of motorcoach occupant fatalities
  - 70 percent of these fatalities are partial or full ejections through side windows



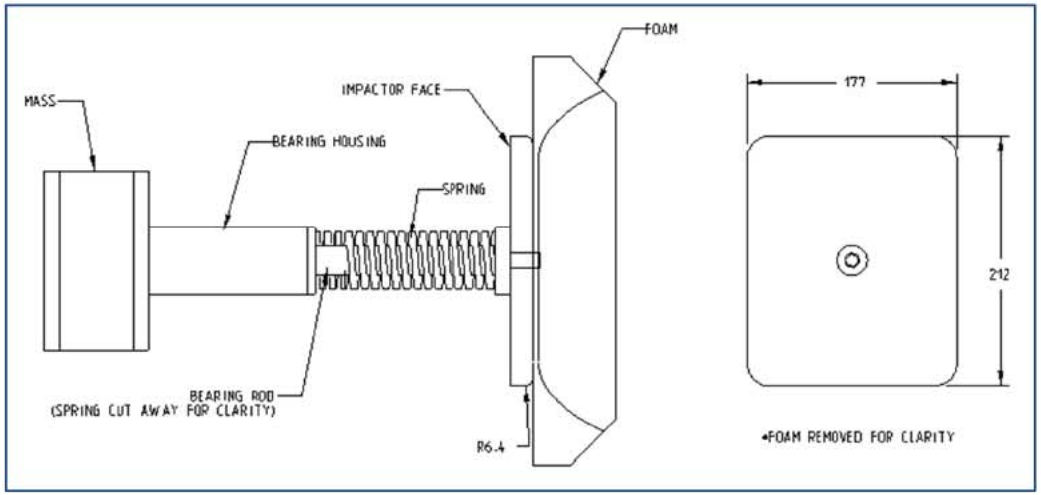
Dynamic Test Procedure

- FE modeling and testing was used to determine impact test conditions representing the loading of a 50th percentile male occupant falling from the far-side of the bus on window glazing during a motorcoach rollover event.
  - Largest load on glazing due to torso impact
- End result → Dynamic impact test rig
  - 26 kg impactor mass
  - 21.6 km/h (13.4 mph) velocity
  - Martec study conditions



Dynamic Test Procedure (con't)

- Linear – Constrained to Uniaxial Motion at Specified Speed
- Represents Mass and Stiffness of SID Dummy Torso
- Mass of Impactor: 26 Kg (Effective Mass Measurements from Computer Modeling)
- Spring Used to Replicate Compression of Thorax (from Computer Modeling)
- Shoulder Foam Part from SID Affixed to Impactor Face
- Impactor Face Geometry Estimated as Contact Area Between Shoulder and Glazing
- Piezoelectric Force Transducer
- Linear Potentiometer records impactor displacement



Test Matrix

- Motorcoach Frame Testing
  - MCI-E/J, Van Hool, Prevost

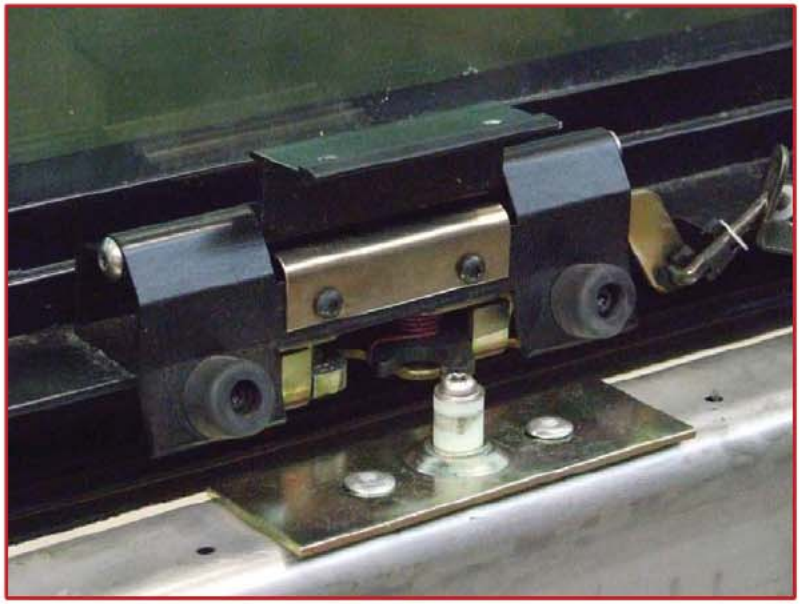
Double-glazed laminated(interior)/tempered
Single-glazed laminated

Double-glazed tempered/tempered

  - Center and near latch impacts
  - Center impacts with pre-broken glazing

MCI E/J Series

- Single Glazed - Laminated Glass
- Double Glazed-Tempered Outside/Laminated Inside
- Latching Mechanism Similar to Passenger Vehicle

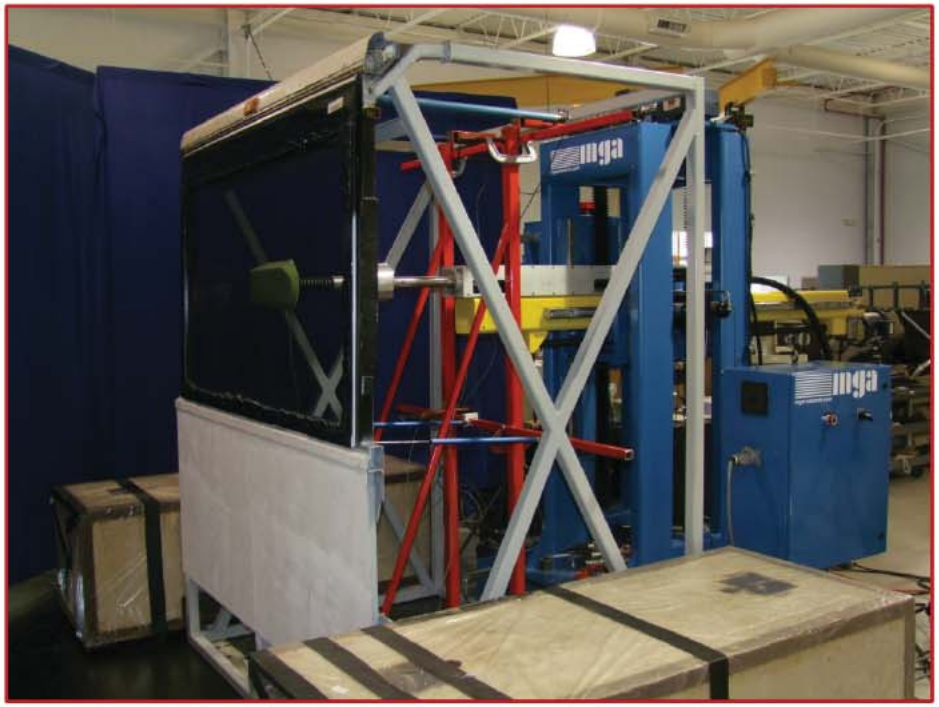


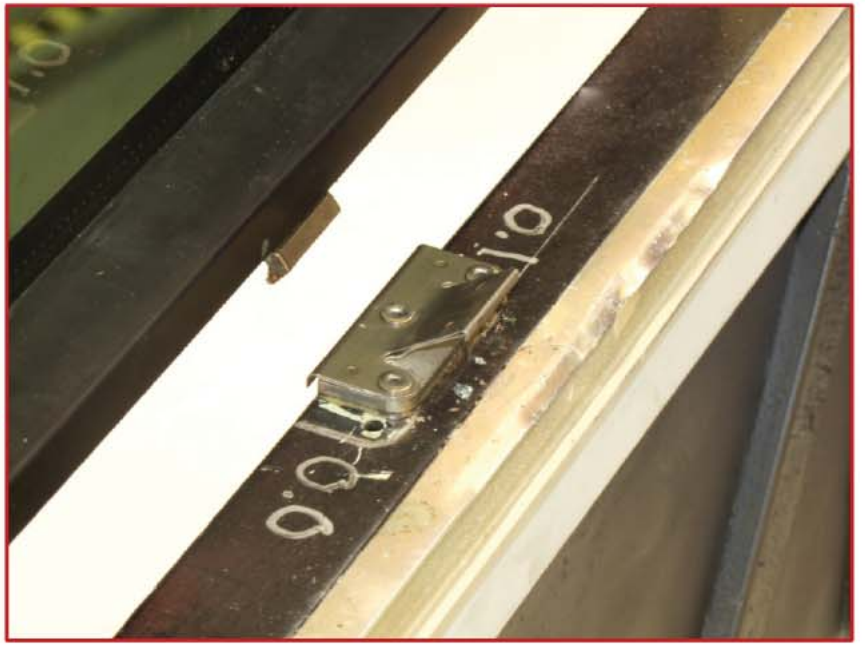
MCI-E/J Near Latch Impact

- **Glazing Type: Single Glazed - Laminated**
- **Impact Speed: 21.6 km/h**
- **Peak Excursion Beyond Window Plane: 337 mm**

Van Hool C2045

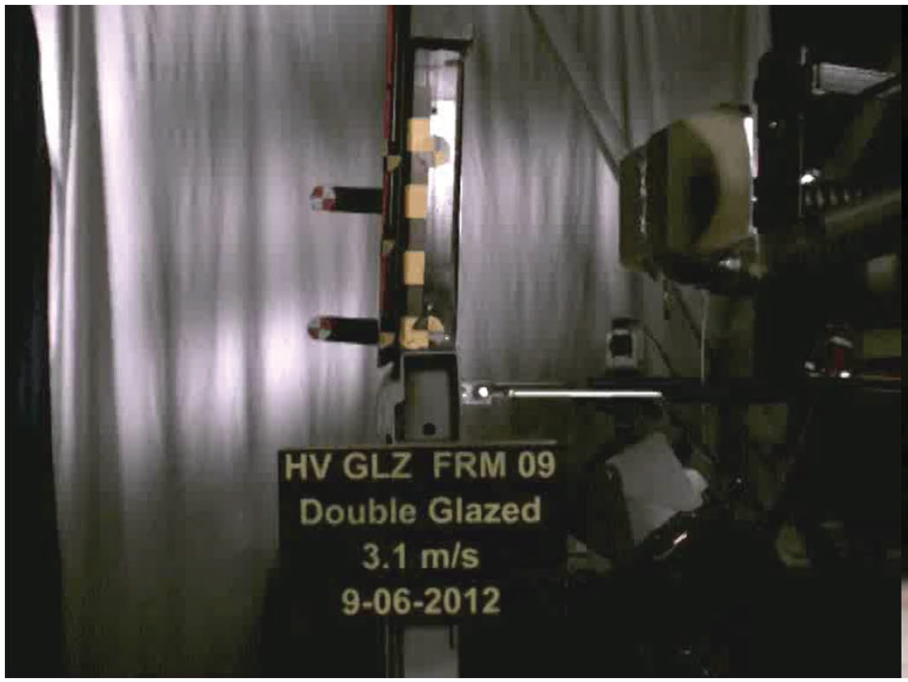
- Double Glazed – Tempered/Tempered Glass
- Sliding Latch Mechanism





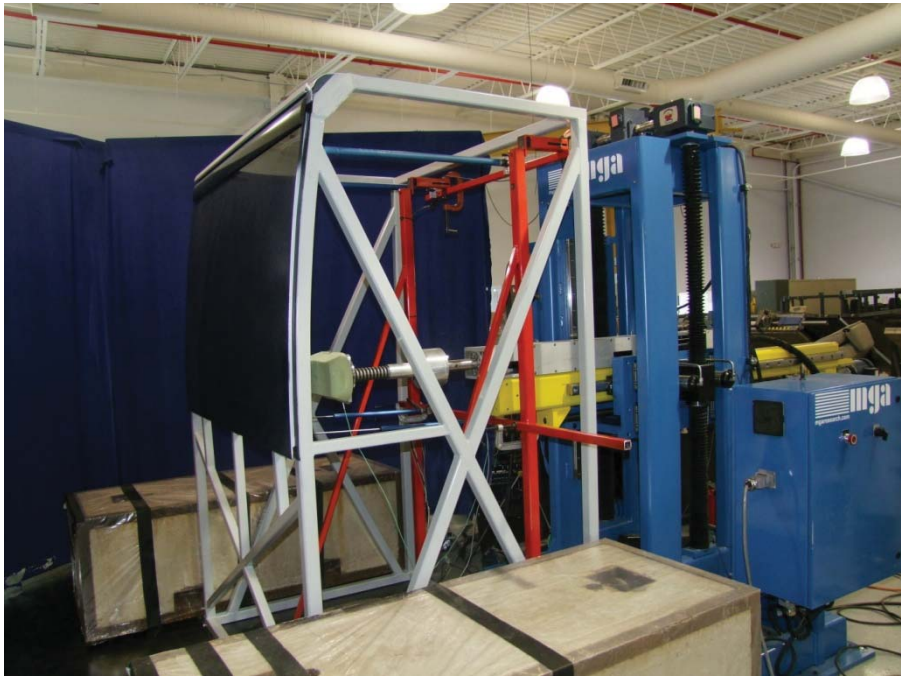
Van Hool Near Latch Impact

- **Glazing Type: Double Glazed - Tempered Outside/Tempered Inside**
- **Impact Speed: 11.0 km/h (TC speed is 21.6 kph)**
- **Peak Excursion Beyond Window Plane: 88 mm**



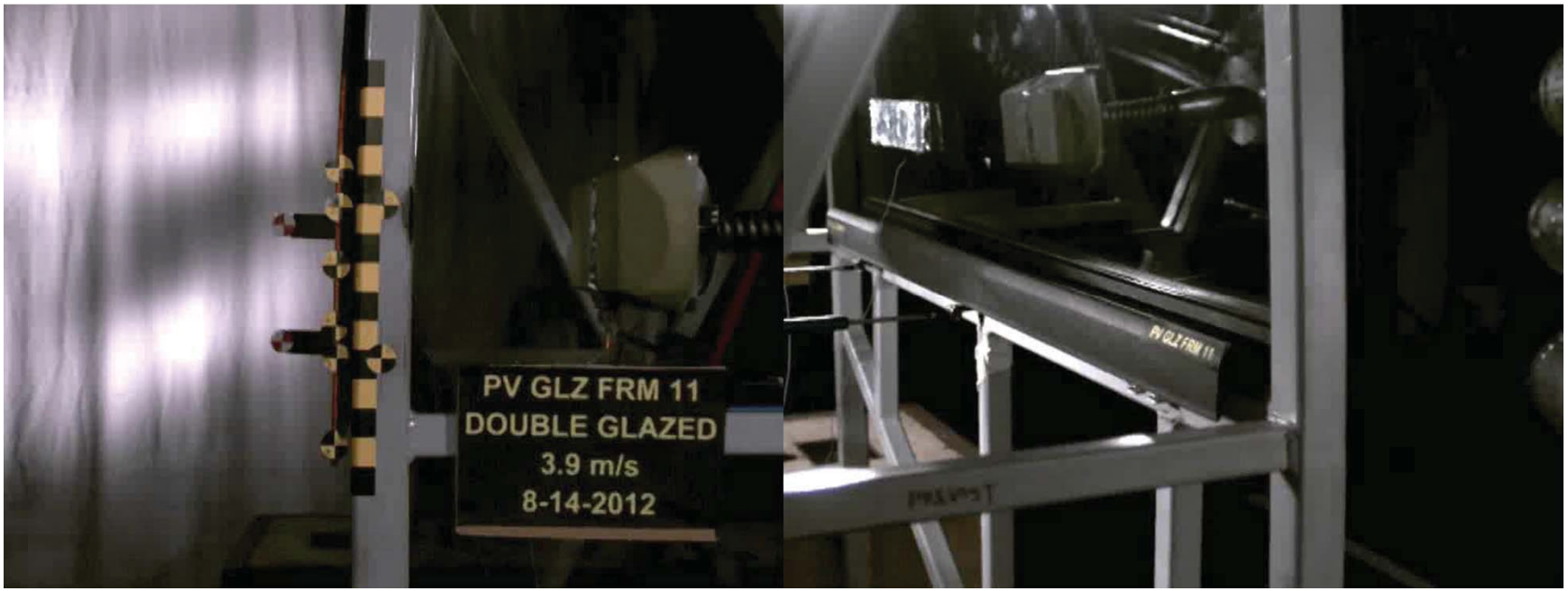
Prevost H3-45

- Double Glazed – Tempered/Tempered
- Latch Bar Latching Mechanism

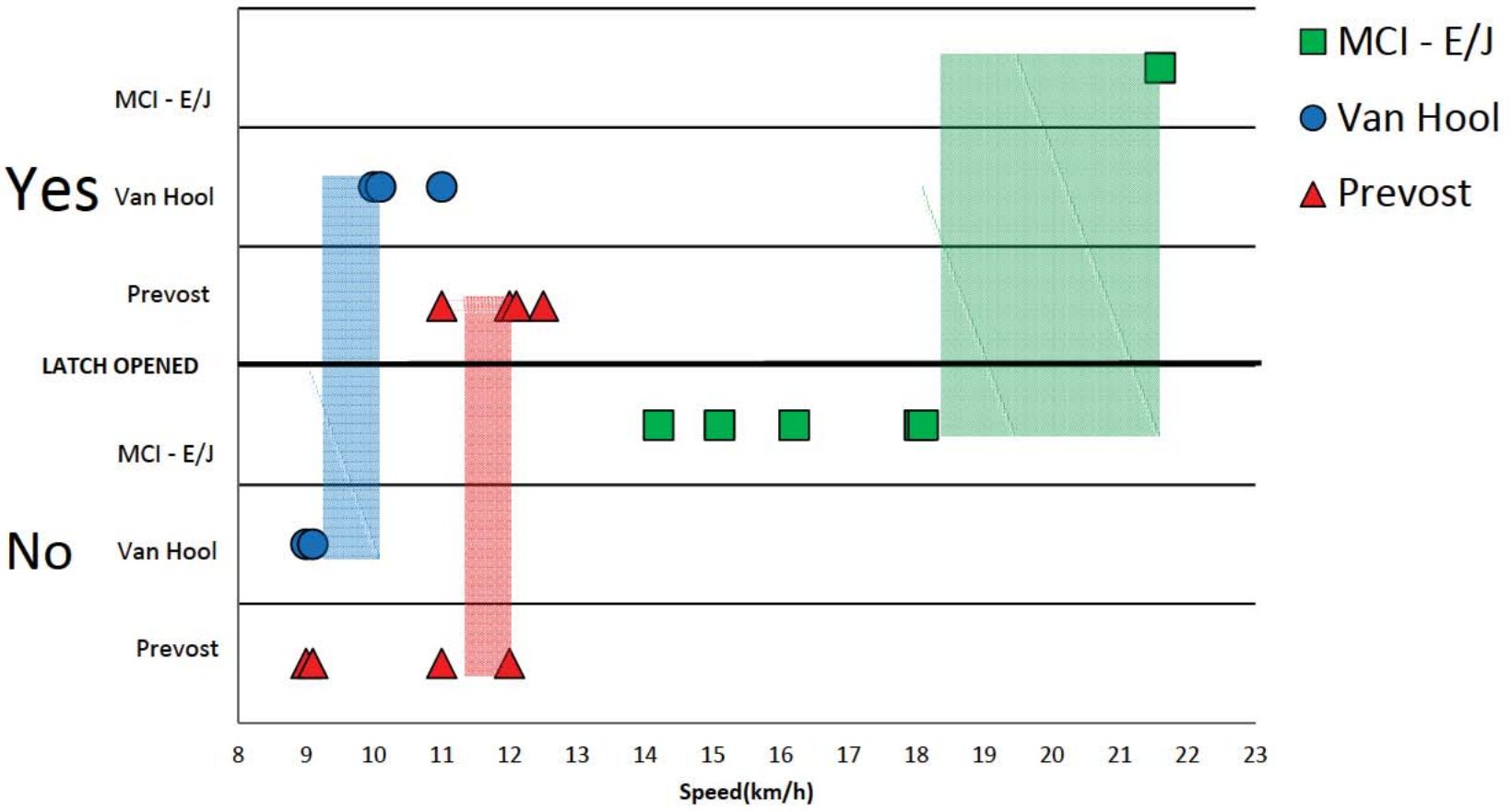


Prevost Near Latch Impact

- **Glazing Type: Double Glazed - Tempered Outside/Tempered Inside**
- **Impact Speed: 12.5 km/h (TC speed is 21.6 kph)**
- **Peak Excursion Beyond Window Plane: 225 mm**



Unlatching Threshold Velocity



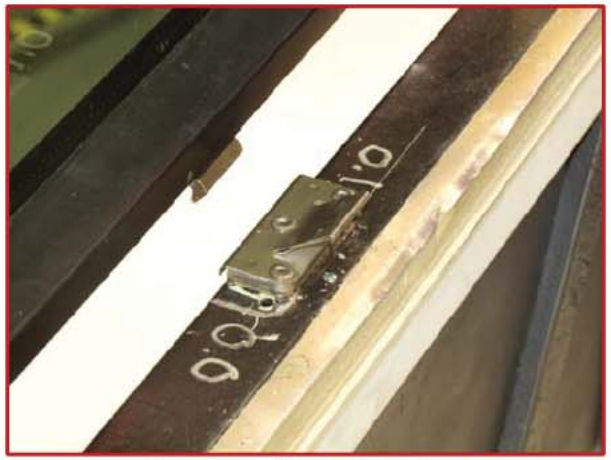
Threshold Test Results

- Windows from all three manufacturers exhibited latch openings.
  - Van Hool exhibited latch opening in the 9 – 10 km/h range.
  - Prevost exhibited latch opening in the 11 – 12 km/h range.
  - MCI E/J-series exhibited latch opening in the 18 – 21 km/h range.

Frame Impacts - Countermeasure

MCI E/J countermeasure

Prevost countermeasure

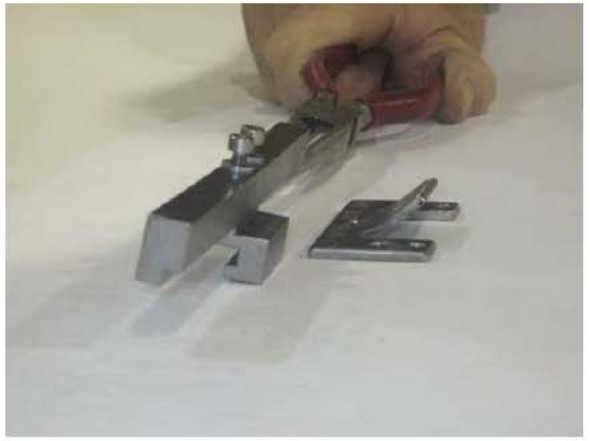

Van Hool production

Near latch impact with countermeasure latches:

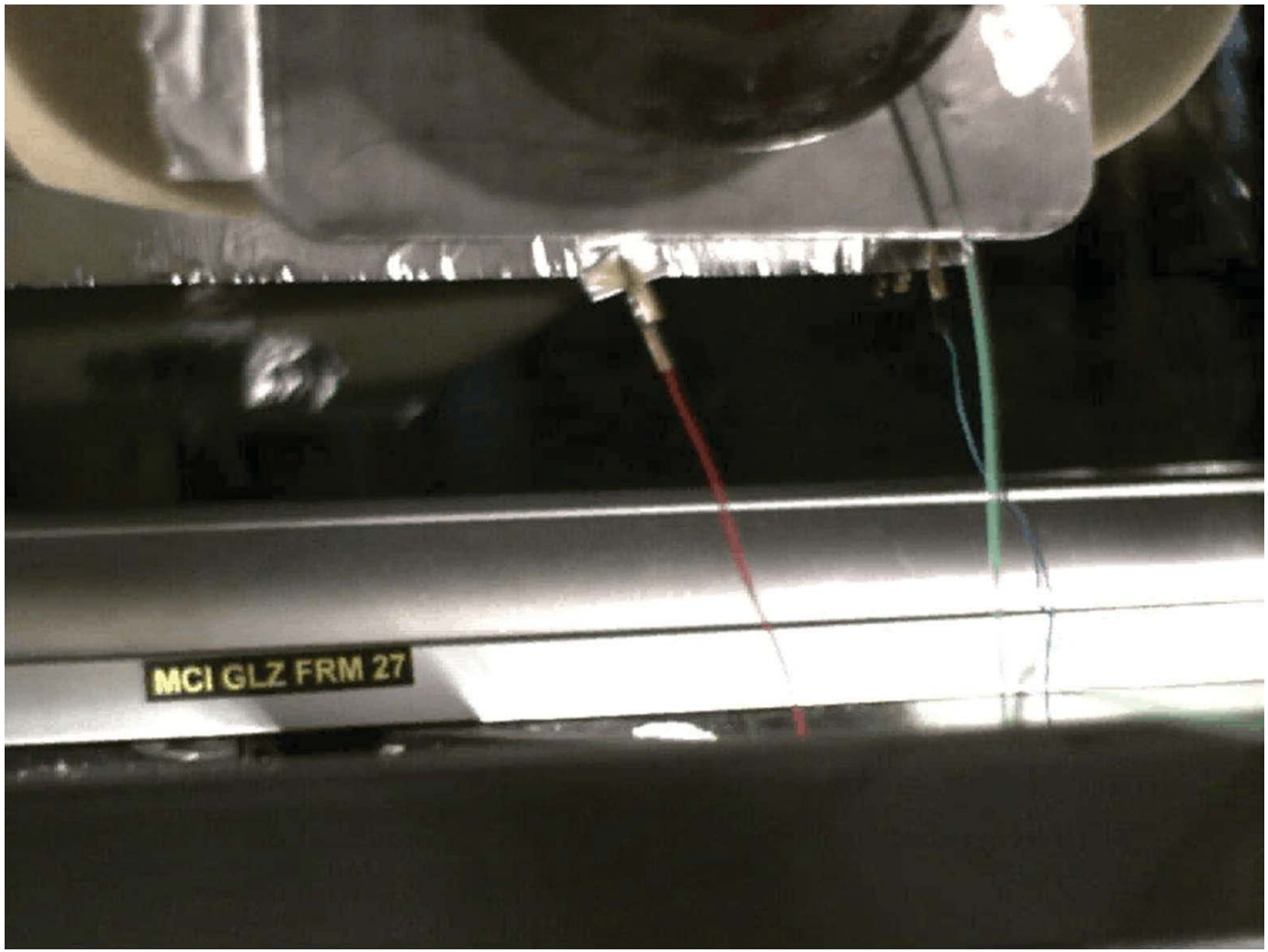
- MCI: latch & glass intact, simple countermeasure
- Prevost: latch failed, glass intact
- Van Hool: latch failed, glass intact

Center impacts with countermeasure latches:

- MCI: latch intact, laminated pane broke
- Prevost: latch intact, glass panes intact
- Van Hool: latch intact, both panes shatter


Van Hool countermeasure

MCI Countermeasure Latch

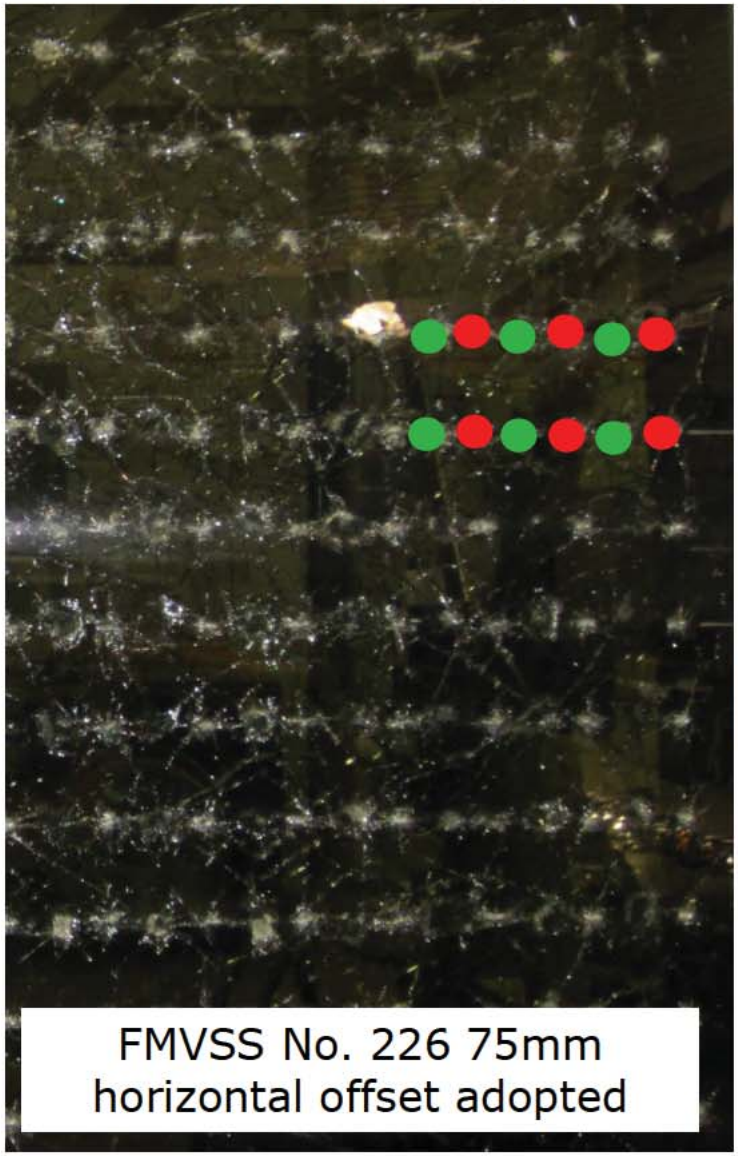


Glass Breakage Procedure

- Addresses glazing strength in case window is pre-broken prior to occupant loading in rollover incident
- Applies to laminated glass panes (only MCI currently uses laminated glass)
- Impact Testing on MCI Laminated Glass
  - Center of Daylight Opening at Martec Study Conditions (21.6 kph, 26 kg.)
  - Countermeasure Latches Used (latches need to stay shut)
  - One unbroken glass test to establish lower bound
  - Three fully pummeled glass (both panes) to establish upper bound
  - Two 50 mm grid; two 75 mm grid pattern (grid on inner glass ply was offset from outer glass grid pattern to avoid punching through plastic
    - 75 mm pattern results in 52% less effort
  - Electric Staple gun used (automatic center punch tool used in Ejec Mit not practical on large windows)
    - Allows for one person operation
- Results follow expected trend that more glass breakage results in more peak excursion

Pre-Broken Glazing

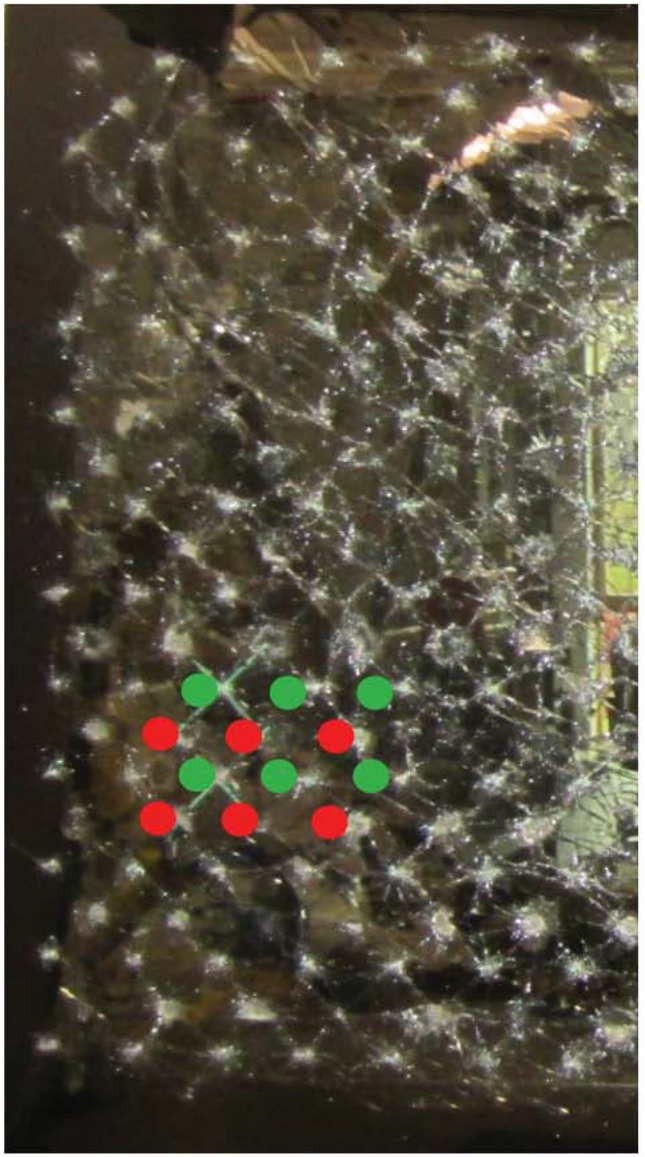
Horizontally Staggered



INTERIOR

EXTERIOR

Diagonally Staggered



Center Impacts – Pre-Broken

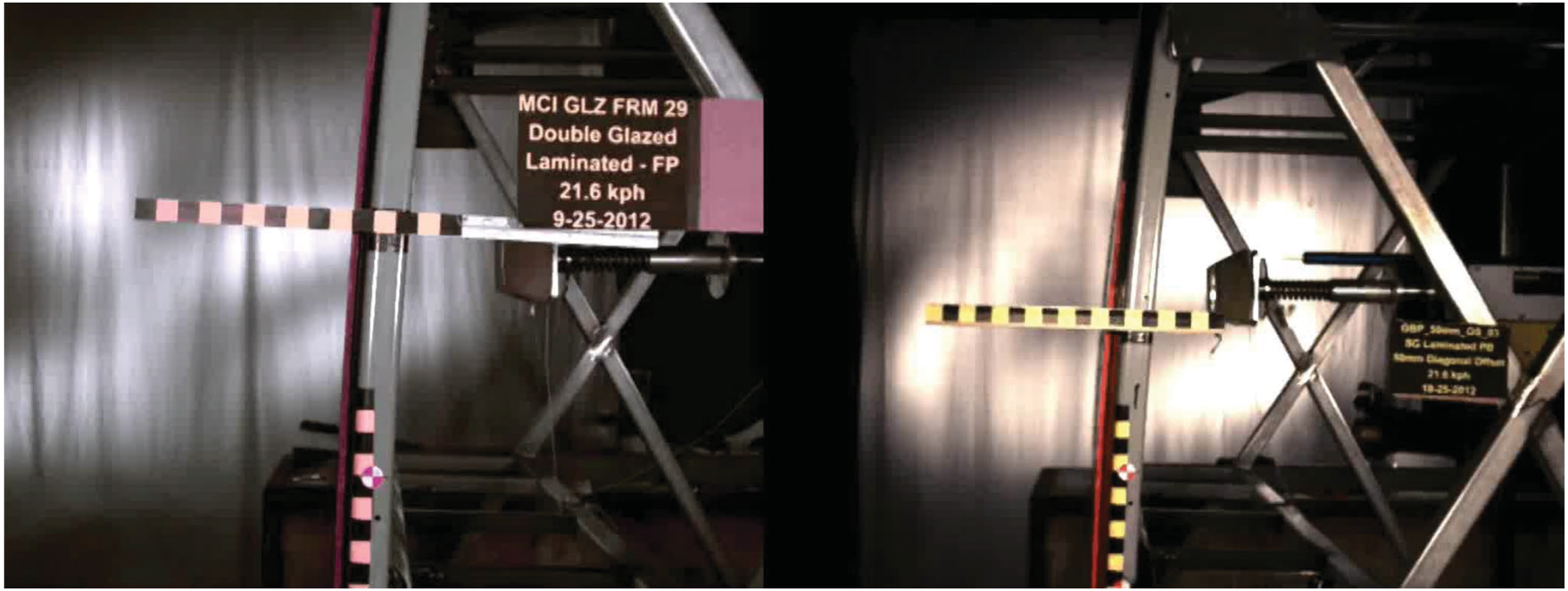
- Glazing Type: MCI - Laminated Glass Pre-Broken
- Impact Speed: 21.6 km/h
- Excursion from linear potentiometer on impactor face plate

Fully Pummeled

224 mm Excursion

50 mm Diagonal Staggered Grid Pattern

199 mm Excursion



Center Impacts – Pre-Broken (Cont.)

- Glazing Type: MCI - Laminated Glass Pre-Broken
- Impact Speed: 21.6 km/h
- Excursion from linear potentiometer on impactor face plate

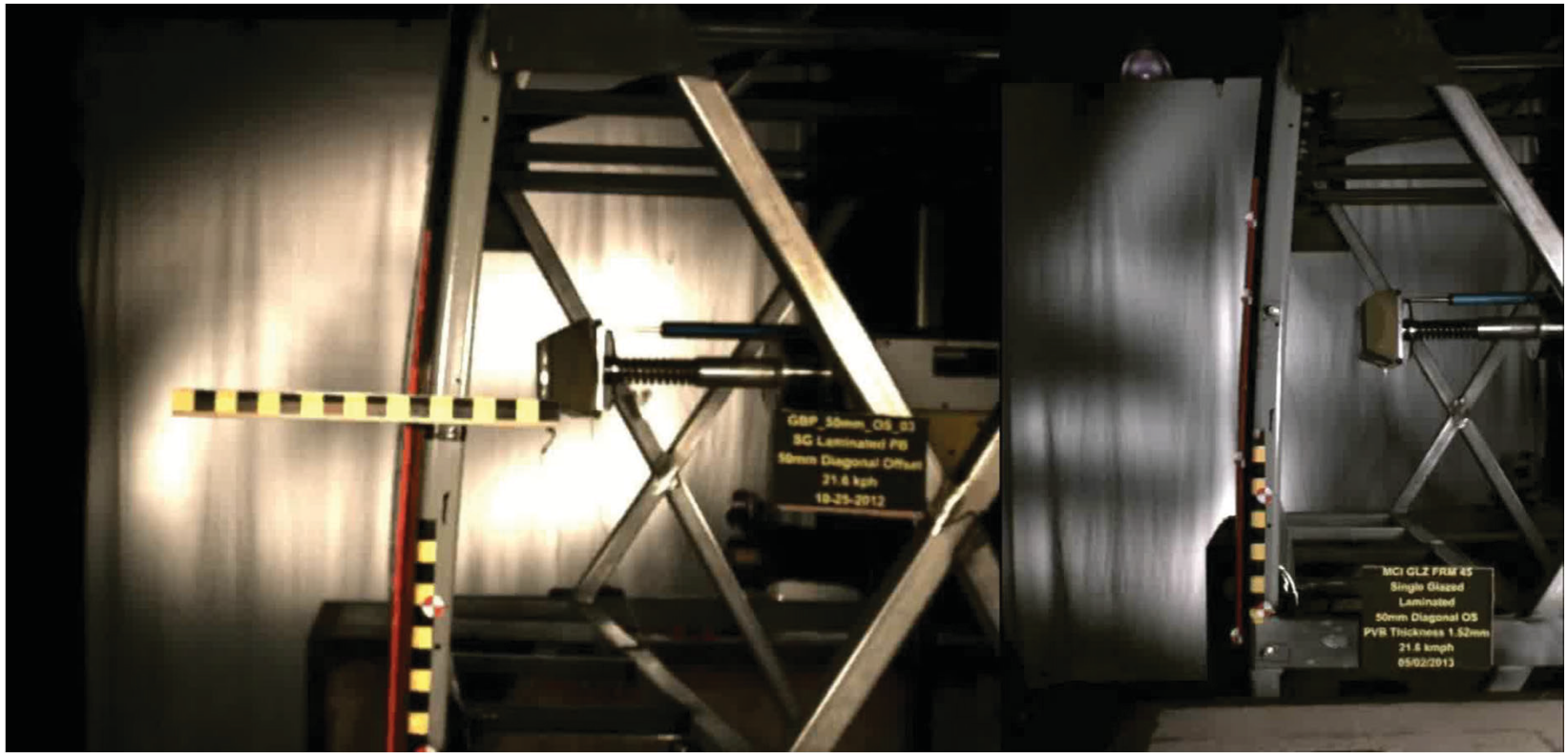
50 mm Diagonally Staggered Grid Pattern

199 mm Excursion

50 mm Diagonally Staggered Grid Pattern

Thicker PVB Interlayer

166 mm Excursion



Glass Breaking Test Results

- Center of daylight opening impacts (Martec study conditions) into fully pummeled production glazings resulted in an average maximum excursion of 214 mm.
  - The 50 mm diagonally offset breakage pattern produced an average maximum excursion of 184 mm (86 percent of fully pummeled).
  - The 75 mm diagonally offset breakage pattern produced an average maximum excursion of 175 mm (82 percent of fully pummeled).
  - The 75 mm horizontally offset breakage pattern produced an average maximum excursion of 151 mm (71 percent of fully pummeled).
- There was little difference in maximum excursions between the 50 and 75 mm diagonally offset pattern methods.
- Use of an electric staple gun (without the staples) to pre-break the glass panes was practical, allowed for single person operation, and did not produce tears in the PVB layer.
- Thicker PVB interlayer produced maximum excursions that were 13 percent less than similar impacts into the pre-broken production glazings.

Reference

- NHTSA Technical Report
  - Motorcoach Side Glazing Retention Research, DOT HS 811 862, November 2013
  - http://www.nhtsa.gov/DOT/NHTSA/NVS/Vehicle Research & Test Center (VRTC)/cw/811862.pdf
- Martec Study Report
  - “Motorcoach Glazing Retention Test Development for Occupant Impact During a Rollover.” Docket No. NHTSA-2002-11876, August 2006

The End