



NHTSA

NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

Evaluation of THOR-05F in a Full Vehicle Crash Series

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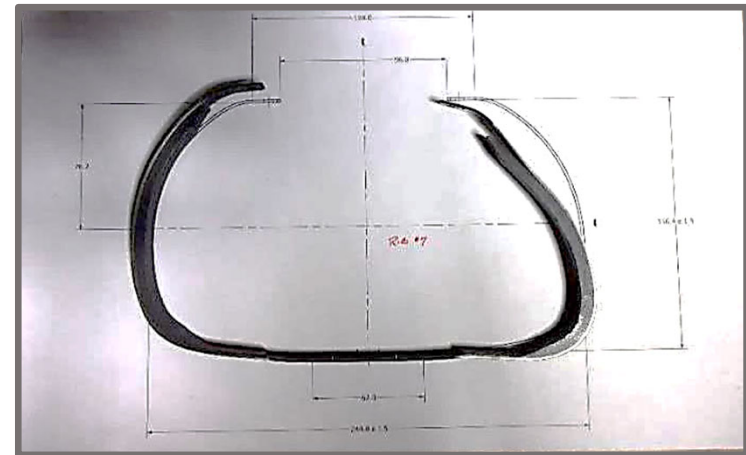
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- NHTSA developed the THOR-05F ATD to better evaluate injury risk of small female adult occupants
 - Alternative to Hybrid-III in frontal crash tests
 - Improved biofidelity and measurement capability
 - More thoroughly evaluate & improve advanced restraint systems



Durability Background

- Sled test series in 2019-2020
 - Rear seat occupant
 - Pulse: 35mph ΔV , 40g (similar to NCAP)
 - No load limiter or pretensioner
 - Key results:
 - Severe rib deformation
 - IR-TRACC failures



Durability Background

Contact authors for videos:

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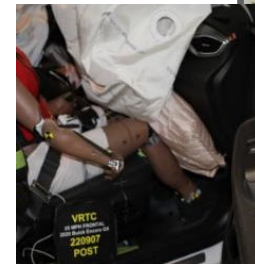
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- Do similar durability problems exist when THOR-05F is in the front seat of a vehicle?
 - 3 belted tests at 35mph and 3 unbelted tests at 25mph
- NHTSA performed a series of full vehicle crash tests with the following objectives:
 1. Evaluate THOR-05F thorax durability when tested with advanced restraints and air bags.
 2. Investigate THOR-05F lower extremity responses and durability during foot interaction with pedal and floor pan.
 3. Refine the draft seating procedure to be used for THOR-05F.

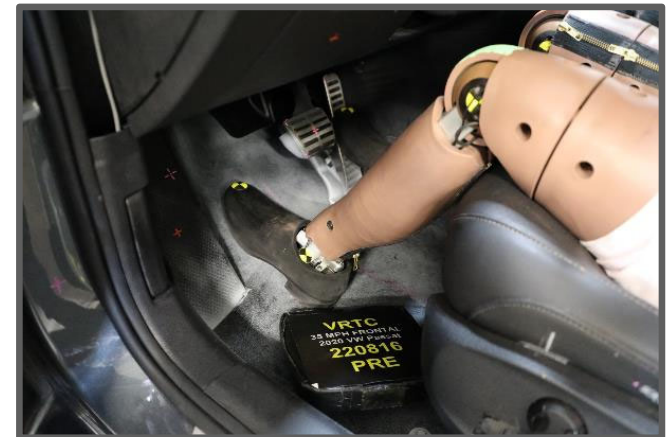
Vehicle Selection

- 2019 Nissan Rogue
 - Elevated neck & thorax loading on H3-5 in previous tests
 - FE model refinement (vehicle and THOR-05F)
- 2020 Volkswagen Passat
 - Elevated thorax & lower leg loading on H3-5 in previous tests
 - Hinged accelerator pedal
- 2020 Buick Encore
 - Elevated head & thorax loading on H3-5 in previous tests
 - Knee air bags



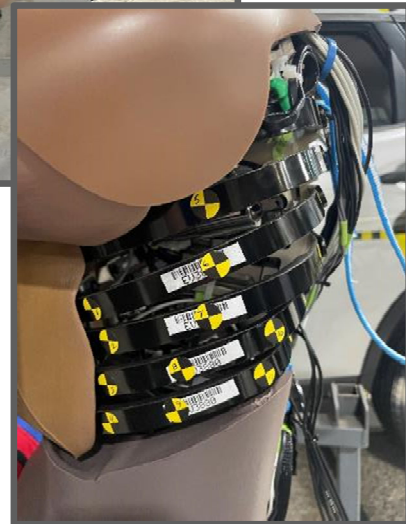
ATD Details

- THOR-05F
 - Driver & front passenger seats
 - Each instrumented with 113 channels
 - Fully qualified (preliminary corridors) prior to crashes, mid-series, and post-series
 - Damage inspection performed after each crash
 - Part repair/replacement and requalification tests were performed as needed
- Seating procedure - preliminary
 - Lumbar spine adjustment set to “erect” for front seat
 - Adjust the ATD to obtain pelvis at $20^\circ \pm 2.5^\circ$
 - Seat back adjusted to position head at $0^\circ \pm 1.0^\circ$
 - Move seat forward until contact with dash or full forward
 - Knees and feet equally spaced
 - Driver right foot on accelerator



Rib Evaluation Method

- Needed a method to evaluate rib performance between crashes.
 - Avoid full tear-down inspection!
- Evaluation procedure:
 - Each ATD was seated on a chair & tilt sensors were recorded.
 - XYZ coordinates of 60 points were measured on ribs 1-7 pre & post-crash with the ATD in the same position.
 - Distances between the points were calculated (n=77).
 - Changes between pre-test and post-test distances were monitored.
 - Large change → inspect further for rib deformation

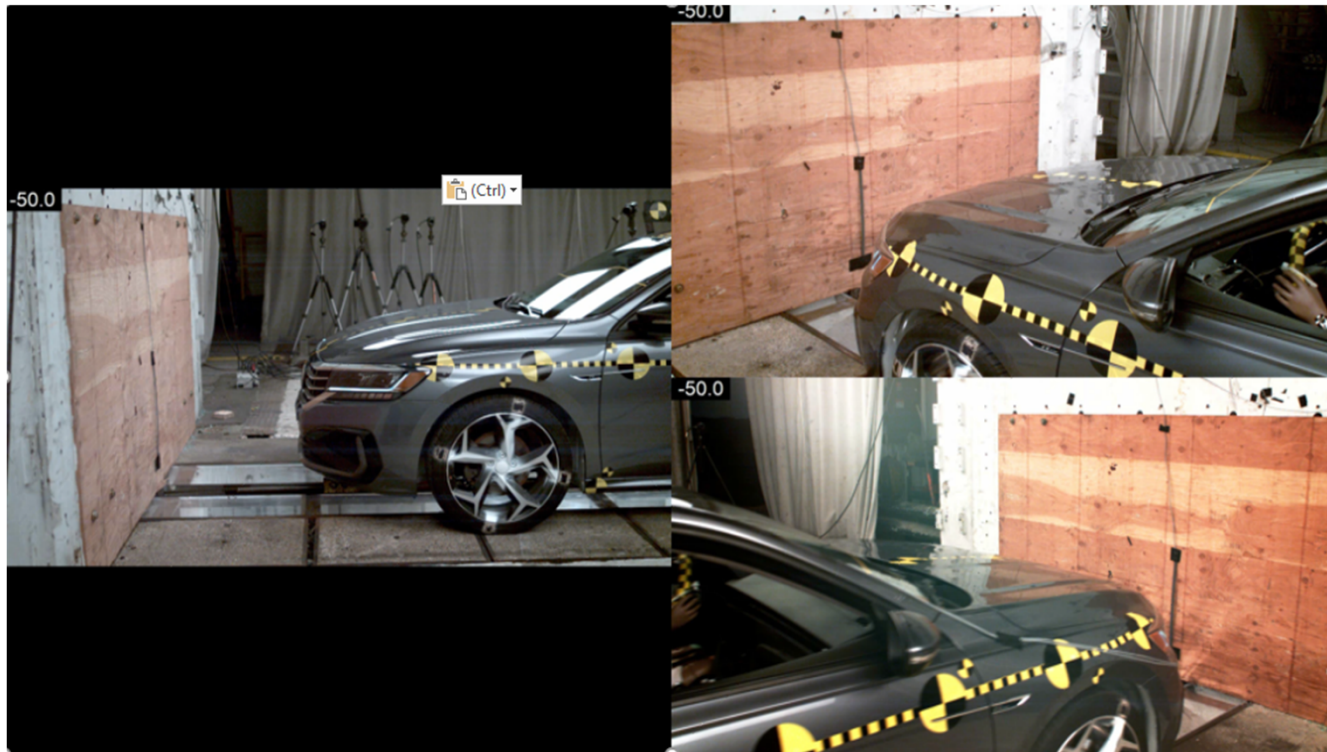


Results: Belted 35mph Video

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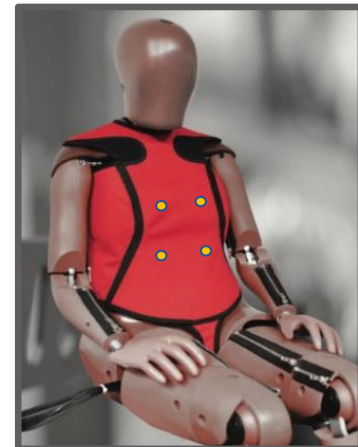
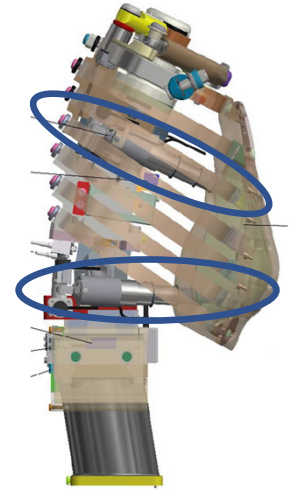
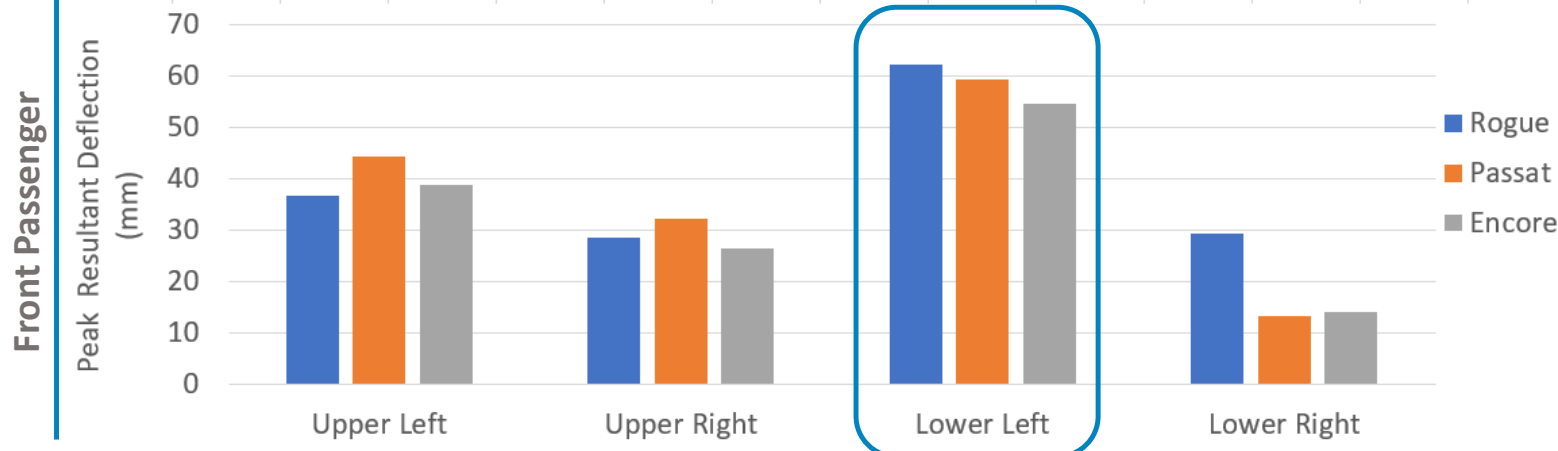
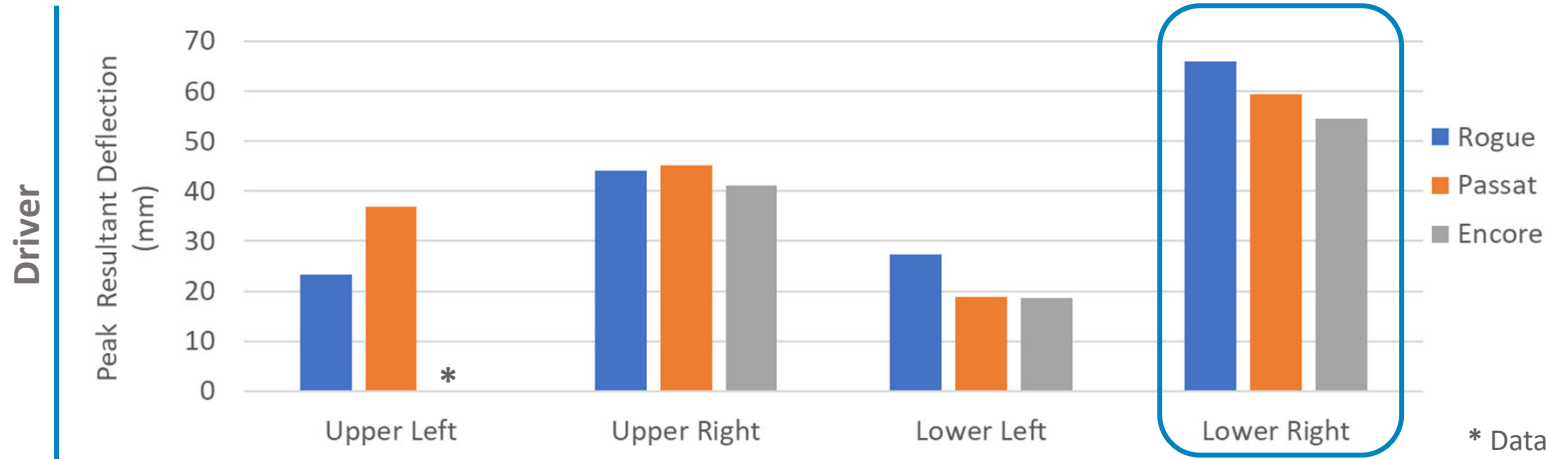
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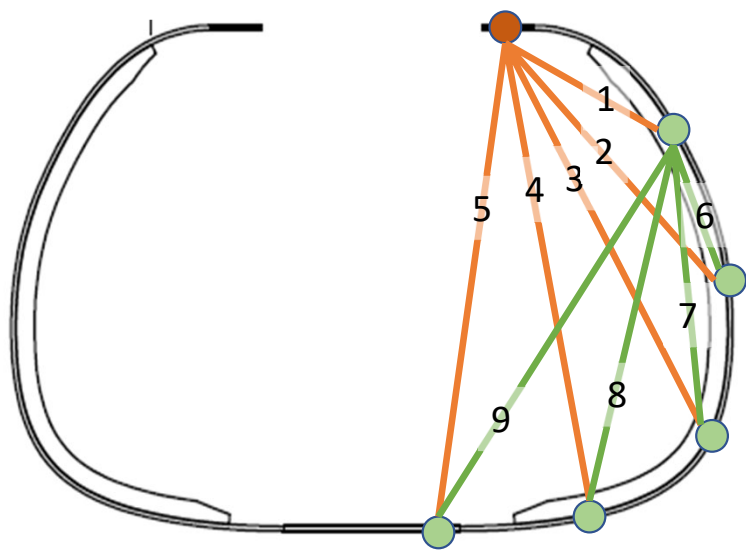
Belted 35mph Crashes: Thorax Data

- 4 IR-TRACCs measured chest compression



Belted 35mph Crashes: Rib Data

- Rib deformation noted only after the 35mph belted Rogue crash
- Ribs 6 & 7 of the driver only
- Anterior rib attachment was pushed posteriorly by 8-10mm
- Ribs 6 & 7 were replaced & the lower thorax was requalified



Distance	Pre-Test (mm)	Post-Test (mm)	Difference (mm)
1	89.9	81.4	8.5
2	127.4	118.1	9.3
3	177.0	168.9	8.1
4	179.1	169.7	9.5
5	191.1	181.1	10.0
6	41.0	40.7	0.4
7	91.5	92.1	-0.7
8	123.6	123.2	0.4
9	155.6	154.1	1.5

Results: Unbelted 25mph Video

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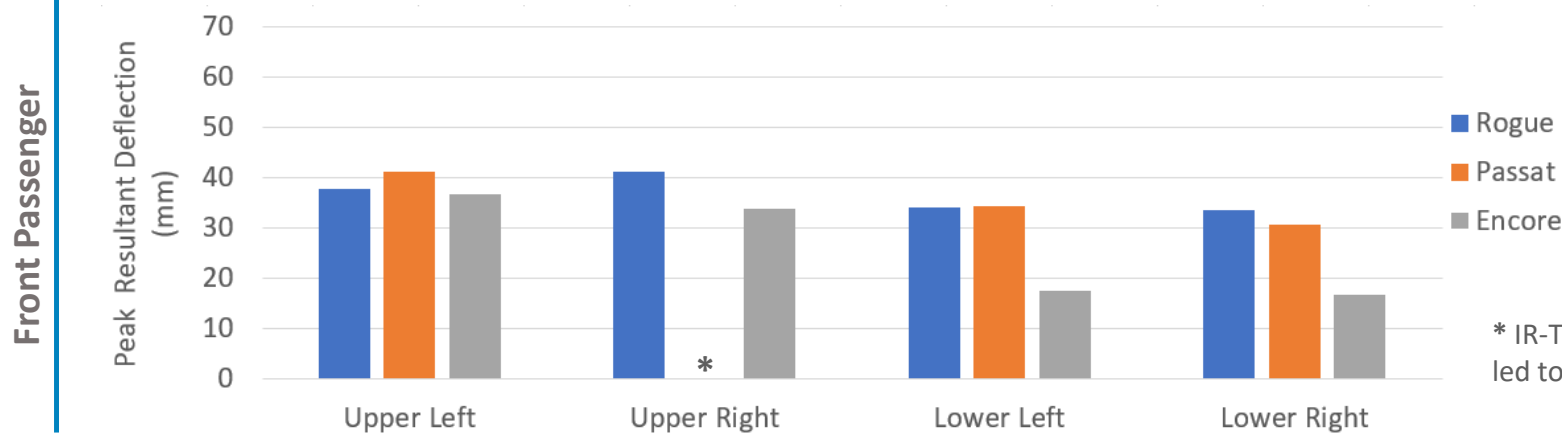
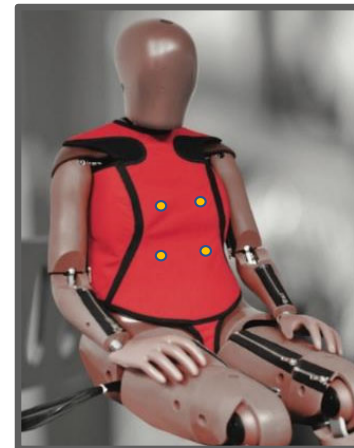
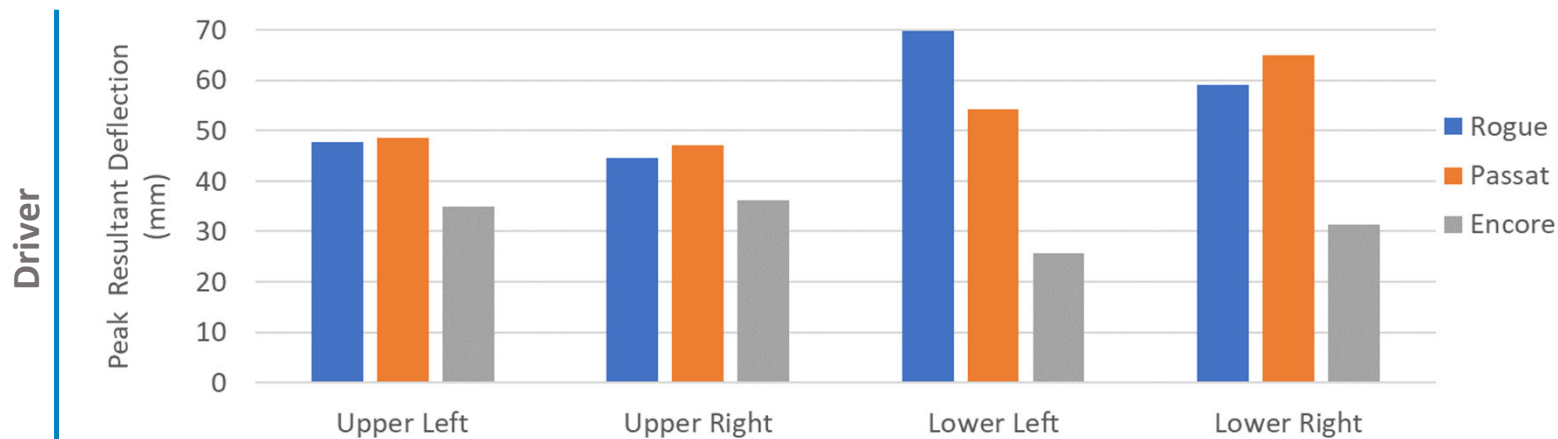
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Unbelted 25mph Crashes: Thorax Data

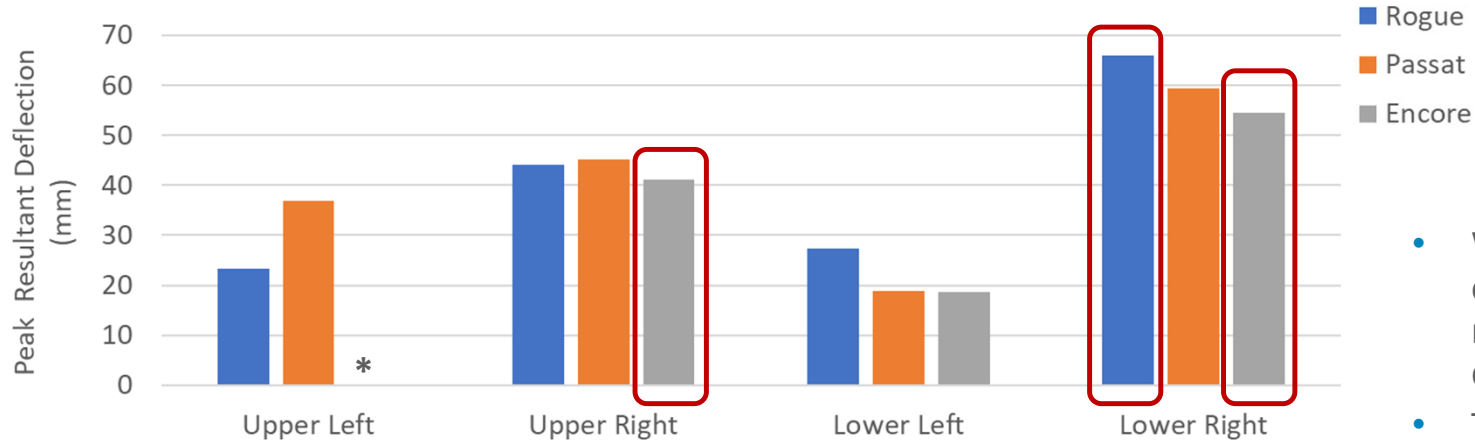
- 4 IR-TRACCs measured chest compression



* IR-TRACC had a manufacturing defect that led to data anomalies.

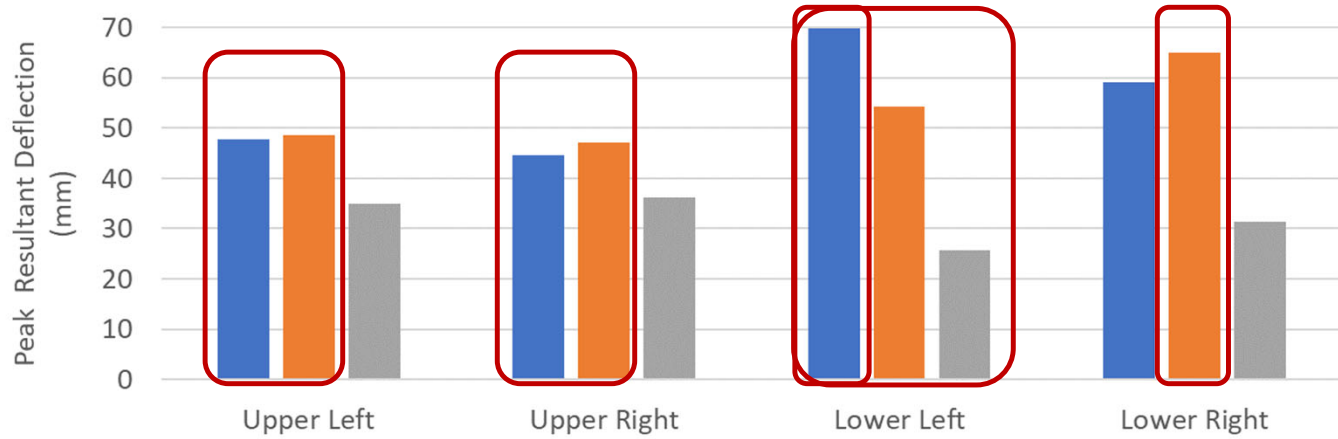
Belted/Unbelted Comparison

35mph Belted Driver



- While rib deformation was observed during a belted test, max deflection occurred on the driver during an unbelted test.
- The unbelted driver generally experiences more deflection at each IR-TRACC despite the lower speed.
 - 8/11 matched pair comparisons
 - 8mm on average

25mph Unbelted Driver

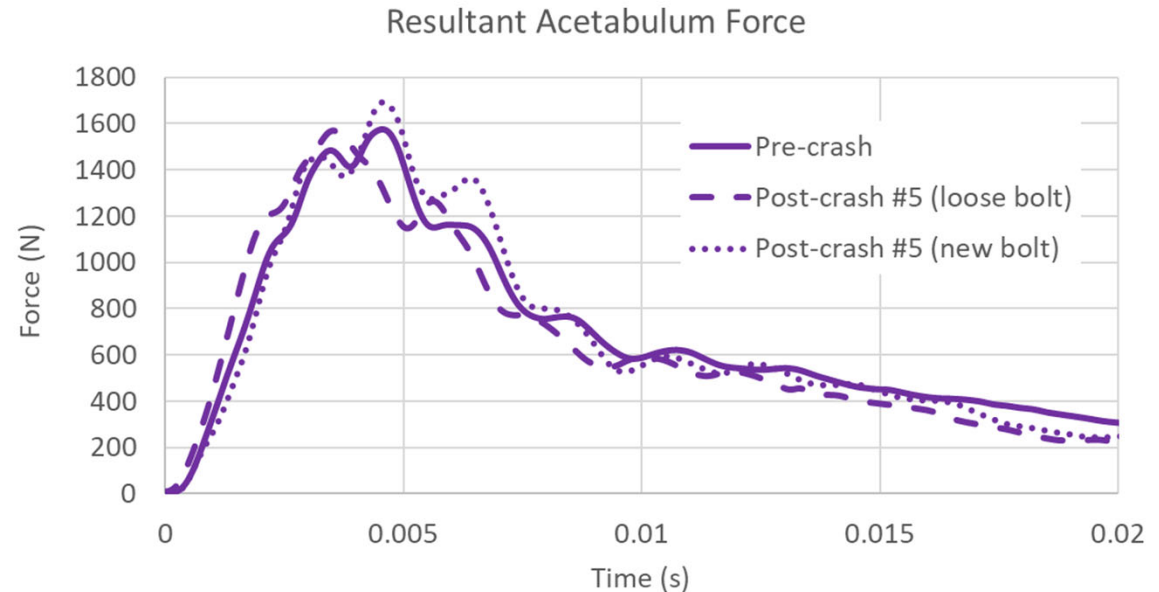


Thorax Results Summary

- Minor deformation to ribs 6 & 7 in a single belted test (35mph).
- IR-TRACC deflection:
 - 35mph Belted – Max at lower IR-TRACC closest to the seat belt buckle.
 - Range: 55-66mm depending on occupant position & vehicle.
 - 25mph Unbelted – Frequently greater than 35mph belted deflection.
 - Location of max deflection on the ATD varied.
 - Driver max deflection > passenger, likely due to steering column.
 - Range: 36-70mm depending on occupant position & vehicle.
- While high IR-TRACC deflections are a red flag for rib deformation, other variables (load distribution & rate) likely contribute.

Leg Results

- No part or instrumentation failures in the THOR-05F legs.
- After 5 crashes, the bolt between the acetabulum load cell and femur loosened slightly.
- No effect on left upper leg qualification performance!
 - Knee impact on a seated ATD with a 7.26 kg probe at 3.3 m/s.
- Replaced the bolt & requalified.



Results: Occupant Kinematics

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35mph Belted



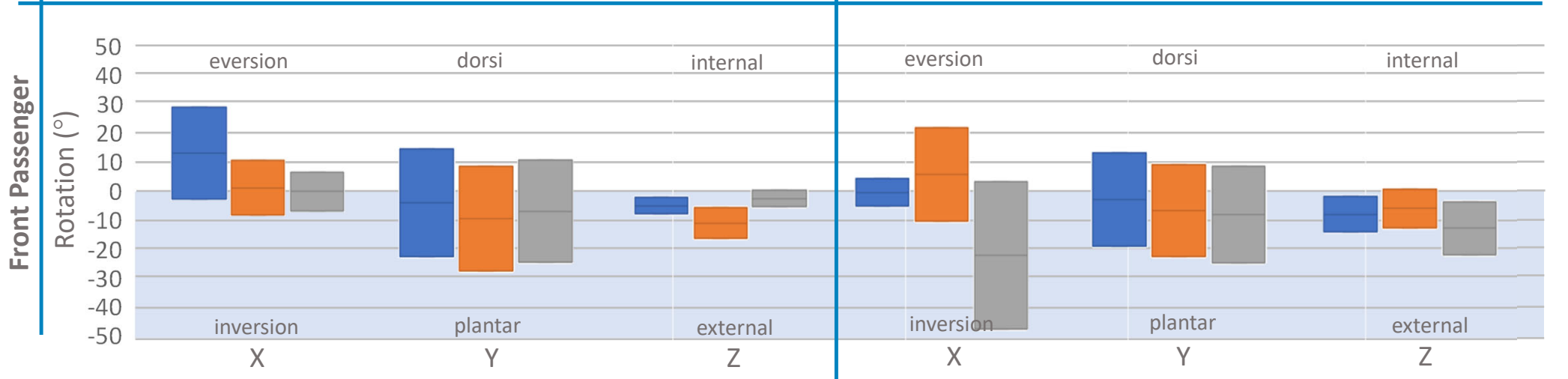
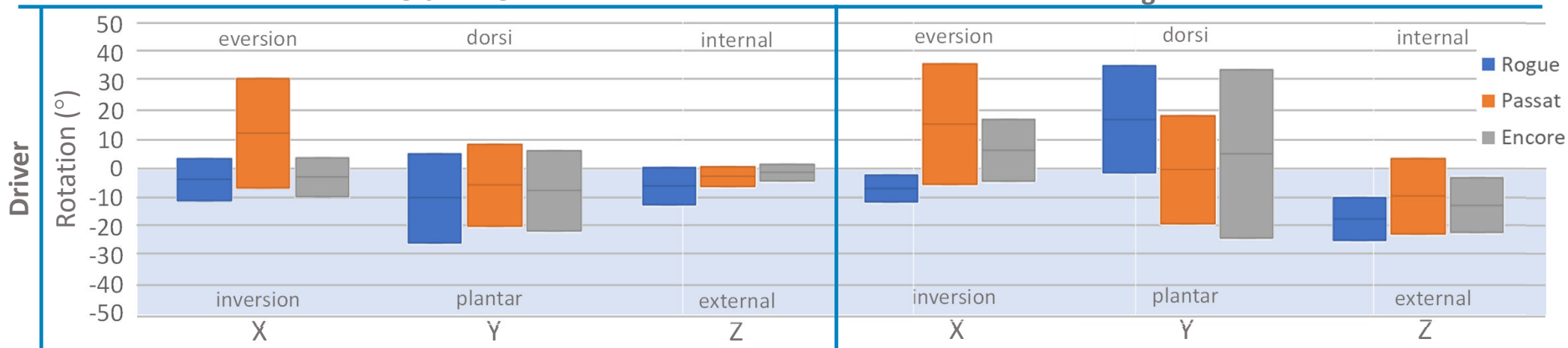
25mph Unbelted



Belted 35mph Crashes: Ankle Data

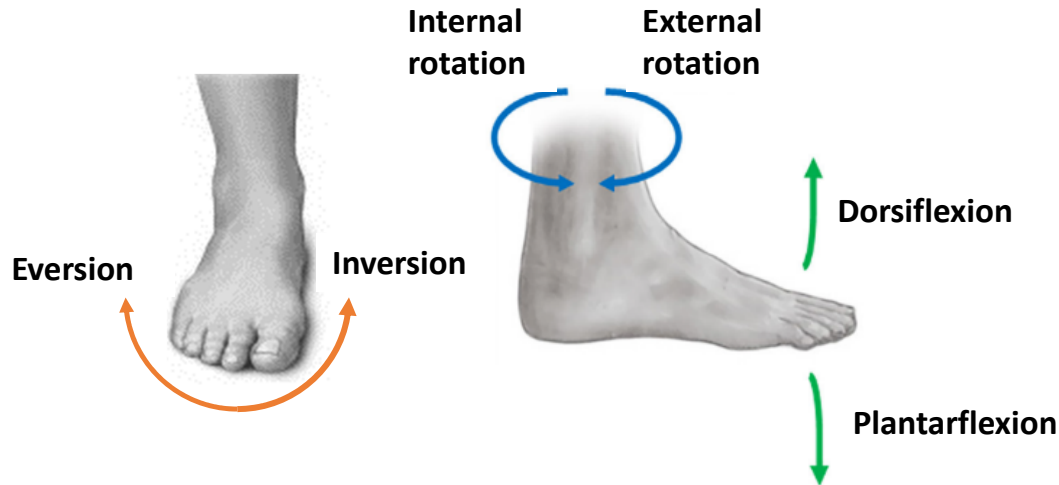
Left Ankle

Right Ankle



Lower Leg Results Summary

- Ankle displacement: 6 tests, 2 THOR-05Fs each with 2 ankles that have 3DOF.
 - Highly dynamic & variable response.
 - Crash series exercised the ankle joint through a large range of motion.
 - In general:
 - Ranges of rotation about each axis were similar for the belted & unbelted tests.
 - More rotation about X & Y axes than the Z axis.
 - Data that can't be collected on a Hybrid III-5th.

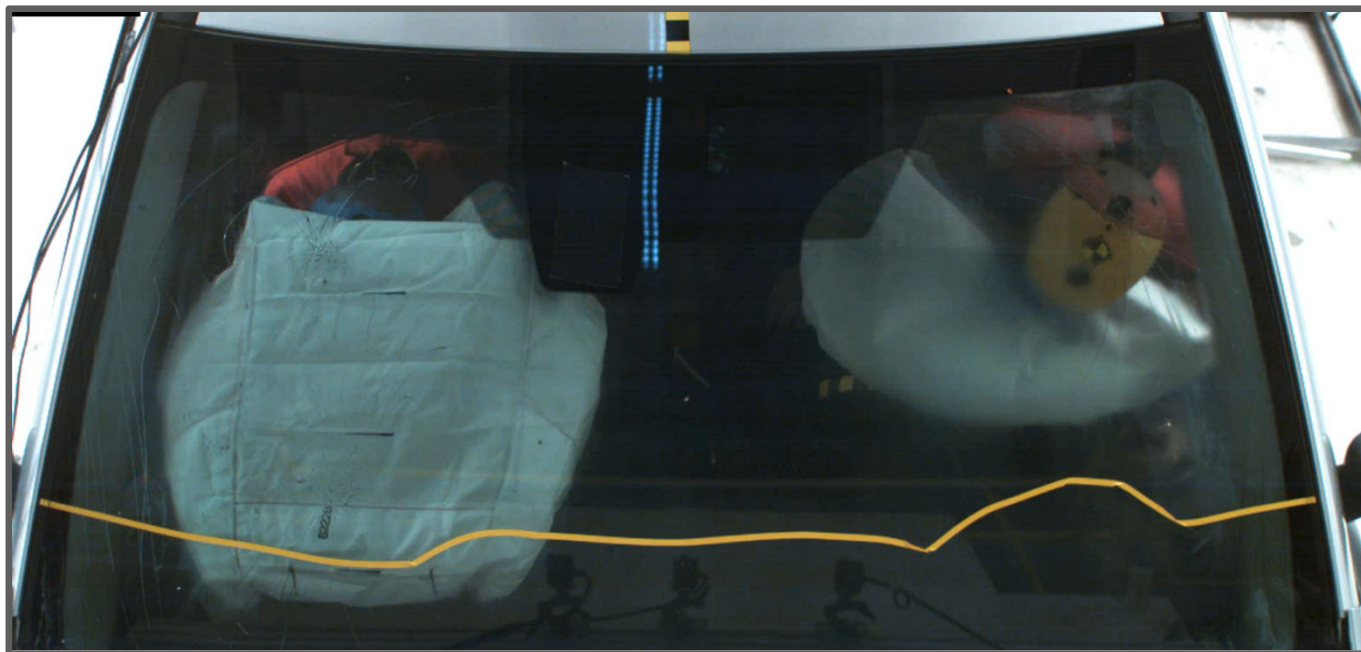


Across all 6 tests:

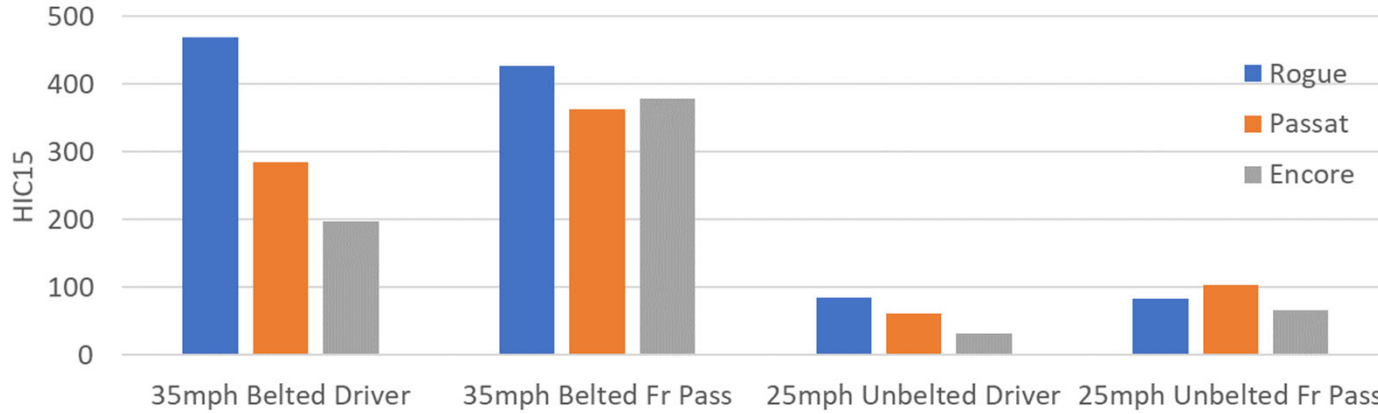
Measurement		Belted (35mph)		Unbelted (25mph)	
		Peak Rotation (°)	Range (°)	Peak Rotation (°)	Range (°)
X-Axis	Inversion	48.6	85.1	49.8	89.1
	Eversion	36.5		39.3	
Y-Axis	Plantarflex	28.2	64.6	35.2	69.1
	Dorsiflex	36.4		33.9	
Z-Axis	Internal	10.2	35.4	10.7	34.3
	External	25.2		23.6	

Results: Head Injury Criteria

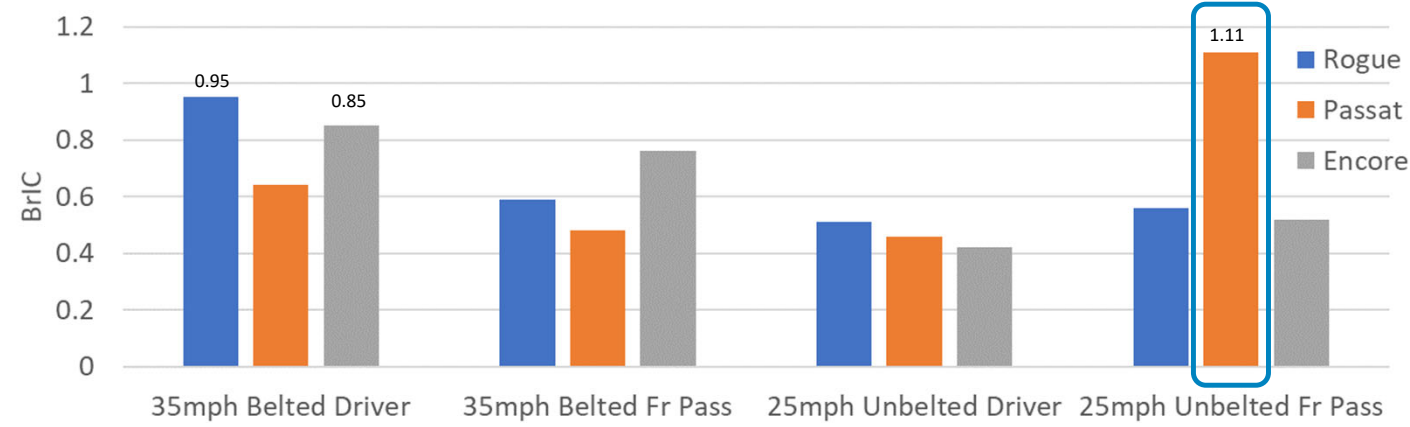
- We are currently developing injury criteria specific to small females based on PMHS testing.
 - Neck, thorax, abdomen, & lower leg are under development.
- Head injury criteria for 5th percentile female does exist.
 - HIC15 & BrIC



Results: Head Injury Criteria



- Lower HIC15 for unbelted test is likely due to lower speed.
- All max HIC15 < 700



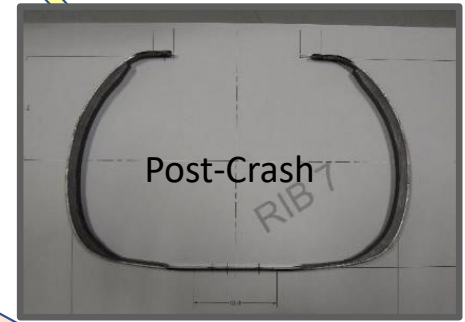
- Max BrIC (1.1) occurred during an unbelted test despite the lower speed.
- Nissan Rogue belted driver resulted in BrIC of 0.95

- THOR-05F draft seating procedure was followed throughout the test series.
 - Target position: Pelvis at $20^{\circ} \pm 2.5^{\circ}$ and Head at $0^{\circ} \pm 1.0^{\circ}$.
 - Lumbar spine was erect & seat full forward or until contact with the dash.
- Results:
 - ATD could obtain these parameters without any major concerns

- Objective 1: Evaluate THOR-05F thorax durability when tested with advanced restraints and air bags.
 - Minor deformation of ribs 6 & 7 during the belted Rogue test.
- Objective 2: Investigate THOR-05F lower extremity responses and durability during foot interaction with pedal and floor pan.
 - No issues observed.
 - Loading was complex and variable across 6 crashes.
- Objective 3: Refine the draft seating procedure to be used for THOR-05F.
 - Procedures had clear language - minor edits

Discussion: Thorax Durability

	Test	Vehicle	ATD seat	ATD posture	Max Chest Deflection		Rib Deformation	
					mm	IR TRACC location		
Front Seat	Full Vehicle Crashes	Belted	Rogue	DR	Erect	66.0	Lower Right	< 10mm
				Pass	Erect	62.3	Lower Left	No
			Passat	DR	Erect	59.4	Lower Right	No
				Pass	Erect	59.3	Lower Left	No
			Encore	DR	Erect	54.5	Lower Right	No
				Pass	Erect	54.5	Lower Left	No
		Unbelted	Passat	DR	Erect	65.0	Lower Right	No
				Pass	Erect	41.2	Upper Left	No
			Rogue	DR	Erect	70.0	Lower Left	No
				Pass	Erect	41.2	Upper Right	No
			Encore	DR	Erect	36.1	Upper Right	No
				Pass	Erect	36.7	Upper Left	No
Rear Seat	Sled Tests	Belted	Mazda Buck	Rear Left	Erect	75.3	Lower right	Severe
			Mazda Buck	Rear Left	Slouch	61.6	Lower right	



- Rear seat sled test is the most severe loading condition measured thus far.
- NHTSA currently has a contract to redesign the THOR-05F thorax to address durability concerns.

- Assess the new thorax design when parts are available (early 2023).
 - Biofidelity
 - Qualification-style durability (increased energy)
 - Rear seat sled testing
- R&R testing if new thorax design is acceptable.
 - VRTC and outside labs
- Documentation including updated drawing package, PADI, qualification manual, injury criteria report, & seating procedures will be drafted.
- Additional crash and sled tests

Questions?

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