

Insurance Institute for Highway Safety Large Truck Underride Research

2009 Chevrolet Malibu Front-into-Trailer Side Underride Guard

64.3 km/h; Malibu perpendicular into trailer center
CF17005

2015 Vanguard

Vehicle identification number:	5V8VC5320FM508751
Body style:	53 ft. dry van semi-trailer
Empty weight:	6,384 kg
Test weight:	16,584 kg

2009 Chevrolet Malibu

Vehicle identification number:	1G1ZJ57B59F127855
Body style:	Midsize 4-door sedan
Engine/transmission:	Transverse 2.4-liter 4-cylinder, 6-speed automatic, front-wheel drive

Vehicle specifications (provided by manufacturer)

Wheelbase:	285 cm
Overall length:	487 cm
Overall width:	179 cm
Curb weight:	1,549 kg

Vehicle specifications (measured)

Test weight:	1,668 kg (56% front, 44% rear)
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Nominal test parameters

64.4 km/h, Malibu perpendicular into Vanguard's side/center

Dummy seating protocol

IIHS Guidelines for Using the UMTRI ATD Positioning Procedure for ATD and Seat Positioning (Version V) (IIHS, 2004)

Crash test date

August 29, 2017

Figure 1
Video frame capture – Trailer and 2009 Chevrolet Malibu



Figure 2
Postcrash – Trailer and 2009 Chevrolet Malibu



Summary

On August 29, 2017, the Insurance Institute for Highway Safety (IIHS) conducted a crash test with a 2015 Vanguard 53-foot dry van semi-trailer equipped with a side underride prevention structure and a 2009 Chevrolet Malibu. The Malibu was traveling at 64.3 km/h when it's front struck the longitudinal center of the trailer at a perpendicular angle. The trailer was stationary and connected to a Kenworth W900 tractor. An instrumented Hybrid III 50th percentile male dummy was positioned in the driver seat of the Malibu with the lap/shoulder belt fastened.

The underride guard is comprised of two side assemblies, each with seven rectangular steel vertical members welded at their lower edge to a 500-cm-long rectangular tube. Each of the vertical members are attached to the trailer's lateral I-beam floor supports with a single fastener. The left-and-right side assemblies are connected together at each vertical member with two rectangular steel tubes that form an X. Each of the cross braces are fastened to the top and bottom of a vertical member, and also where they cross (Figure 3). The struck side had a fiberglass skirt installed along the length of the structure. The skirt on the nonstruck side was not installed.

Reported under separate cover are companion side underride tests conducted on March 30-31, 2017; one with and one without an underride structure attached to the trailer, both tests were conducted at 56.3 km/h (CF17002 and CF17003, respectively).

Figure 3
Underride guard – Nonstruck side, without side skirt



Test conditions

The pretest setup followed the *Crashworthiness Evaluation Offset Barrier Crash Test Protocol (Version XVIII)* (IIHS, 2017), with several deviations to account for the different test configuration, including:

- The Malibu struck the side of a 53-foot semi-trailer with an underride guard installed (Figure 3).
- The Malibu was aligned perpendicular to, and at the longitudinal centerline of, the left side of the trailer's overall length (Figure 5).
- Three onboard cameras with their respective power supplies and control units were installed on the Malibu.

The trailer was connected to a Kenworth W900 tractor. The trailer was loaded with six concrete blocks over the rear axles, totaling approximately 10,200 kg. The sliding rear axles were placed in their middle position, with a 190 cm clearance between the rear of the trailer and the rearmost surface of the rear tires. The ground clearance of the side underride guard was 50 cm to the bottom of the longitudinal rectangular tube. Prior to the test, the trailer's brakes were pressurized to 40 psi to simulate being stopped in traffic.

The Malibu's driver seat back, steering column adjustments, and Hybrid III dummy seating parameters were set according to the *Guidelines for Using the UMTRI ATD Positioning Procedure for ATD and Seat Positioning (Version V)* (IIHS, 2004). After final positioning of the dummy, measurements from various parts of the dummy to a number of vehicle interior points were made. These measurements and the seat back, shoulder belt upper anchorage, and steering column adjustments are described in the Appendix, Dummy Clearance Measurements.

The vehicle speed recorded just before impact was 64.3 km/h.

Figure 4
Top view of test configuration

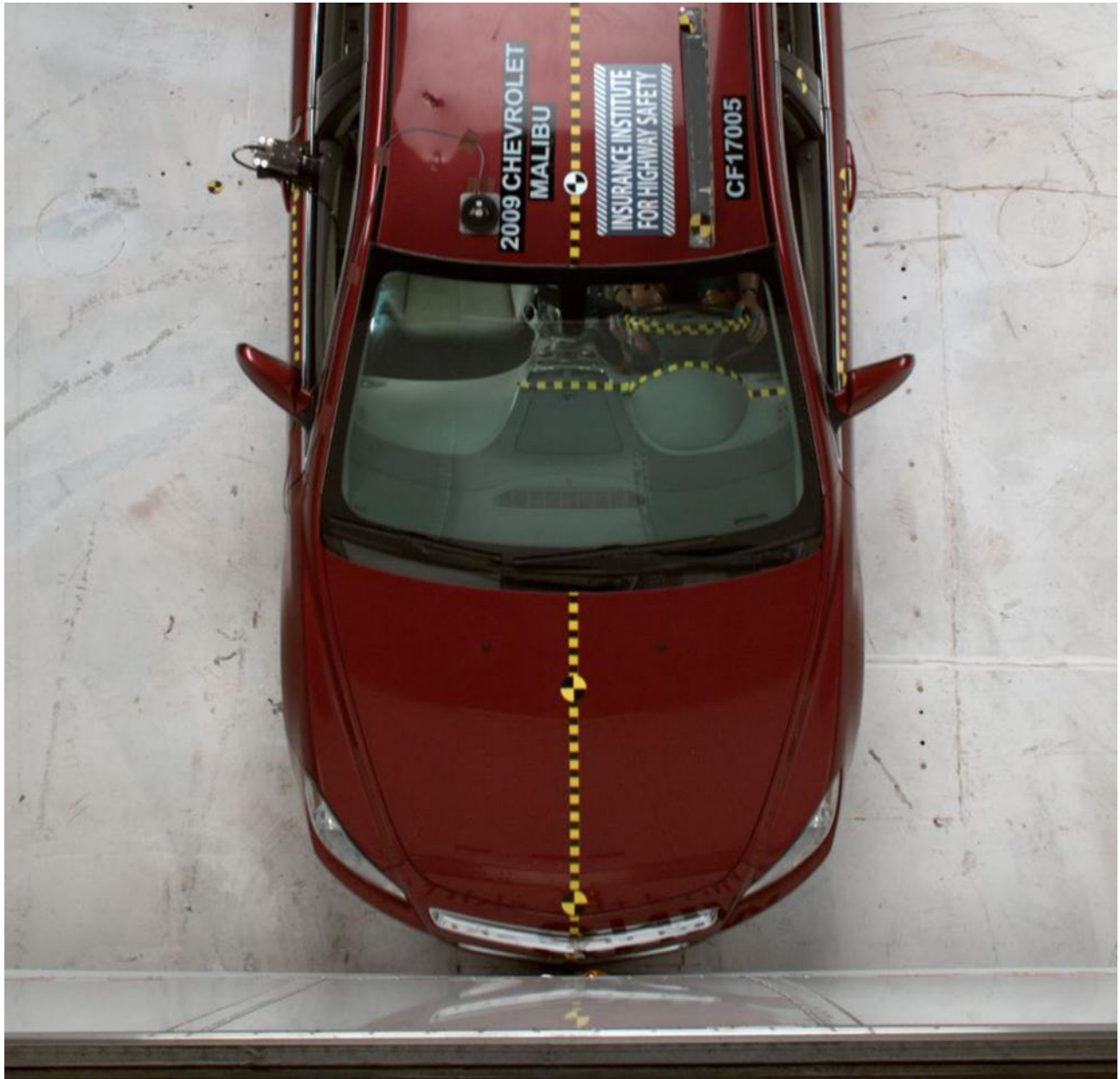
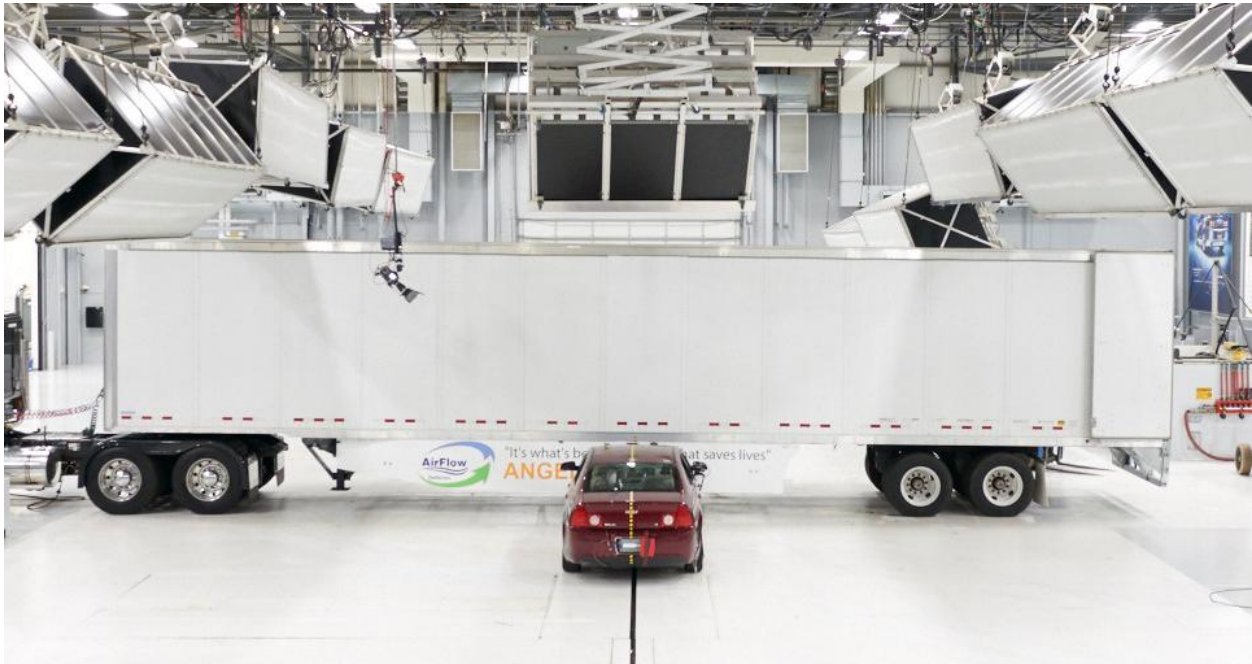


Figure 5
Rear, wide view of test configuration



Underride guard performance and vehicle interaction

Pre-crash static measurements indicated the side underride guard had a ground clearance of 50.0 cm and a height of 60.5 cm. The Malibu's bumper bar had a ground clearance of 40.3 cm and a height of 12.4 cm. This resulted in a vertical overlap of 2.7 cm between the lowermost portion of the underride guard and the Malibu's bumper bar.

During the crash, the vertical members on the struck side of the underride guard bent inward, and the crossbeam supports nearest the impact point buckled. The nonstruck side sill of the Vanguard was pushed outward as it was loaded by the crossbeams of the underride guard. Two of the lower attachment flanges on the nonstruck side of the guard broke free from the lower longitudinal. The rest of the structure remained intact and the Malibu rebounded with no underride.

During the crash, the dummy's head loaded the fully-inflated frontal airbag. During rebound, the rear of the head contacted the driver head restraint.

Analysis of the high-speed film indicated the maximum forward excursion of the Malibu's center of gravity relative to the trailer was approximately 148 cm at 146 ms.

Figures 6-8 show post-crash views of the trailer and side underride guard.

Figure 9 shows pre-crash and post-crash side views of the Malibu.

Figure 10 shows the postcrash position of the test dummy in the Malibu.

Table 1 describes the dummy kinematics.

Measures of occupant compartment intrusion are shown in Table 2.

Tables 3-6 contain summaries of the peak dummy injury measures.

Figure 6

Postcrash – Underride guard damage, struck side of trailer chassis



Figure 7
Postcrash – Underride guard damage, without skirt



Figure 8
Postcrash – Underride guard damage, nonstruck side of trailer chassis



Figure 9
2009 Chevrolet Malibu – Precrash and postcrash side views



Figure 10
2009 Chevrolet Malibu — Driver dummy, postcrash



Table 1 Restraint system performance and dummy kinematics — 2009 Chevrolet Malibu

Event	Time (ms)
Activation of seat belt crash tensioner	16
Deployment of driver frontal airbag	30
Frontal airbag fully inflated	52
Face begins loading frontal airbag	80
Maximum forward excursion of Malibu	146
Rear of head contacts driver head restraint	280

Table 2 Residual Measurements of Intrusion Relative to Driver Seat — 2009 Chevrolet Malibu

Selected Locations*	Longitudinal	Lateral	Vertical	Resultant
Steering column	0	1	-1	2
Left lower instrument panel	-1	0	0	1
Right lower instrument panel	-1	0	0	1
Brake pedal	-6	0	1	6
Left toepan	-1	0	1	1
Center toepan	-2	0	0	2
Right toepan	-3	-1	1	3
Footrest	-1	0	1	1
Average displacement of the four seat attachment bolts relative to reference system	0	0	0	--
Door aperture closure at beltline	0	--	--	--

* All measurements taken on driver side. From the driver's position, positive is rearward, right, and up. All measures in centimeters.

Table 3 Head Injury Measurements — 2009 Chevrolet Malibu

Measure	Published Tolerance Threshold	Result	Time (ms)
Vector resultant acceleration (g), during frontal airbag loading	80	50	122
Vector resultant acceleration — 3 ms clip (g), during frontal airbag loading	80	49	120-123
Head Injury Criterion (HIC)	1000	297	108-144
Head Injury Criterion — 15 ms interval (HIC-15)	700	211	115-130

Table 4 Neck Injury Measurements — 2009 Chevrolet Malibu

Measure	Published Tolerance Threshold	Result	Time (ms)
A-P shear force (kN)	±3.1	-0.7	127
Axial compression force (kN)	4.0	0.1	343
Axial tension force (kN)	3.3	1.1	130
N _{ij} Tension-Extension	1.00	0.15	75
N _{ij} Tension-Flexion	1.00	0.30	133
N _{ij} Compression-Extension	1.00	0.08	337
N _{ij} Compression-Flexion	1.00	0.01	19
Flexion bending moment (Nm)		47	134
Extension bending moment (Nm)		9	334

Table 5 Chest Injury Measurements — 2009 Chevrolet Malibu

Measure	Published Tolerance Threshold	Result	Time (ms)
Vector resultant spine acceleration — 3 ms clip (g)	60	31	111-114
Rib compression (mm)	-50	-41	136
Viscous criteria (m/s)	1.0	0.2	72
Sternum deflection rate (m/s)	-8.2	-1.4	23

Table 6 Leg and Foot Injury Measurements — 2009 Chevrolet Malibu

Measure	Published Tolerance Threshold	Left	Time (ms)	Right	Time (ms)
Tibia-femur displacement (mm)	-15	-6	78	-2	112
Upper Tibia					
L-M moment (Nm)	±225	-27	146	33	103
A-P moment (Nm)	±225	105	76	94	111
Vector resultant moment (Nm)	225	106	76	94	111
Index	1.00	0.48	76	0.47	111
Lower Tibia					
L-M moment (Nm)	±225 *	59	98	-19	108
A-P moment (Nm)	±225 *	56	76	104	110
Vector resultant moment (Nm)	225 *	62	96	105	110
Axial force (kN)	-8.0 *	-2.5	94	-2.0	110
Index	1.00	0.34	96	0.52	110
Foot					
A-P acceleration (g)	±150	-64	71	-82	73
I-S acceleration (g)	±150	-30	90	-39	68
Vector resultant acceleration (g)	150	65	71	86	73

* These published thresholds are for fractures of the tibia. Ankle and foot injuries have been associated with bending moments as low as 50-100 Nm, and heel fractures have been associated with axial forces as low as -6.0 kN

References

Insurance Institute for Highway Safety. 2004. Crashworthiness evaluation offset barrier crash test protocol (version XIII). Arlington, VA.

Insurance Institute for Highway Safety. 2004. Guidelines for using the UMTRI ATD positioning procedure for ATD and seat positioning (version V). Arlington, VA.

Attachment 1 Dummy Clearance Measurements

Test Number: CF17005
Vehicle: 2009 Chevrolet Malibu
Seat Type: Adjustable bucket seat (manual fore/aft, electric height, and manual seat back angle)
Upper Belt Anchorage: Set to topmost of 4 positions
Steering Column Adjustment: Tilt adjustment set to midpoint position and telescopic set to midpoint of range
Foot Pedal Adjustment: Fixed

Location	Code	Measure	Location	Code	Measure
Head to header	HH	373	Striker to CG, horizontal	CGH	-44
Nose to rim	NR	440	Striker to CG, lateral	CGL	339
Chest to dash	CD	736	Striker to CG, vertical	CGV	503
Rim to abdomen	RA	249	Striker to knee**	SK	568
Knee to dash, left	KDL	259	Striker to knee angle**	SKA	-6.1°
Knee to dash, right	KDR	250	Striker to H-point, horizontal	SHH	-169
Steering wheel to chest, horizontal	SCH	363	Striker to H-point, vertical	SHV	-139
Steering wheel to chest, reference	SCR	425	Ankle to ankle	AA	336
Hub to chest, minimum	HCM	276	Knee to knee	KK	330
Pelvic angle	PA	27.1°	Arm to door	AD	135
Seat back angle*	SA	7.3°	H-point to door	HD	150
Torso recline angle (H-point to Head CG)	TRA	11.1°	Head to A-pillar	HA	498
Neck bracket angle	NBA	0.0°	Head to roof	HR	153
Neck angle, seated	NAS	5.3°	Head to side window	HS	286

