

**NCAP-KAR-DR-21-07
NEW CAR ASSESSMENT PROGRAM (NCAP)
DYNAMIC ROLLOVER RESISTANCE TEST**

TOYOTA MOTORS MANUFACTURING, INDIANA, INC.

2021 TOYOTA SIENNA AWD 5-DOOR MINIVAN

**PREPARED BY:
APPLUS IDIADA KARCO ENGINEERING, LLC.
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ADELANTO, CA 92301**



MARCH 26, 2021

FINAL REPORT

**PREPARED FOR:
U.S. DEPARTMENT OF TRANSPORTATION
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION
NEW CAR ASSESSMENT PROGRAM
MAIL CODE: NRM-110
1200 NEW JERSEY AVE, SE
WASHINGTON, D.C. 20590**

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15. Supplementary Notes			
16. Abstract An NCAP Dynamic Rollover Maneuver (Fishhook) Test was conducted on a 2021 Toyota Sienna AWD 5-Door Minivan by Applus+ IDIADA KARCO Engineering, LLC. on March 19, 2021. The vehicle did not experience two-wheel lift. The vehicle's steering angle at 0.3 g lateral acceleration at 50 mph was 29.5 degrees.			
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SECTION I INTRODUCTION

The National Highway Traffic Safety Administration (NHTSA) has engaged Applus+ IDIADA KARCO Engineering, LLC to conduct dynamic rollover testing and gather data from that testing as part of NHTSA's New Car Assessment Program (NCAP).

The purpose of the testing reported herein was to determine if a 2021 Toyota Sienna AWD 5-Door Minivan would experience tip-up, defined as simultaneous two-wheel lift of two inches or more at an entry speed of 50 mph or less in the Dynamic Rollover Test Procedure developed by NHTSA. This procedure may be found at www.regulations.gov, docket item NHTSA-2006-26555-0136.

The testing reported herein was accomplished under contract 693JJ920D000011.

SECTION II

VEHICLE PREPARATION

A. TEST VEHICLE

The test vehicle was new or in as-new condition, meaning the vehicle had been driven no more than 500 miles prior to the start of dynamic rollover testing. It was acquired through a commercial rental/leasing company. Details of the test vehicle are given in Table 1.

B. TIRES

All tires used were new, and of the same make, model, size, and DOT specification of those installed on the vehicle when purchased new. Tire inflation pressures were in accordance with the recommendations indicated on each vehicle's identification placard. To further reduce the possibility of tire debanding, the tires were mounted to the rims without the use of tire mounting lubricant. Tire specifications are listed in Table 2.

C. VEHICLE LOADING

The multi-passenger load, described in the Fishhook Procedure, was used for all tests. The load and positioning of the load in the vehicle are listed in Table 3.

In addition to water dummies, the loading included instrumentation, a steering machine, and outriggers. Test vehicle bumper assemblies were removed for outrigger installation. The reduction in vehicle weight due to the removal of the bumpers was offset by the additional weight of the outriggers and their mounting system. The outrigger system typically outweighs the bumper assemblies.

Table 1. Test Vehicle Data

General Data					
Model year, make, model	2021 Toyota Sienna				
VIN	5TDJSKFC5MS01xxxx				
Body style	Minivan				
Number of doors	5				
Trim level	XSE				
Seating positions	Front:	2 nd row	3 rd row	4 th row	5 th row
	2	2	3		
Electronic stability control	Yes				
4-Wheel ABS (Yes/No)	Yes				
Power steering (Yes/No)	Yes				
Major optional equipment	-				
Odometer at start of testing	100 miles				
Drivetrain					
Engine cylinder arrangement	Inline 4				
Engine displacement	2.5 L				
Transmission type	CVT				
Drive arrangement	AWD				
Chassis					
Track width	F: 71.1 in (1805 mm), R: 71.1 in (1805 mm)				
Wheelbase	120.9 in (3070 mm)				
Curb weight	4776 lb (2166.5 kg)				
Certification Data from Vehicle's Label					
Vehicle manufactured by	Toyota Motors Manufacturing, Indiana, Inc.				
Date of manufacture	2/21				
GVWR	6170 lb (2800 kg)				
GAWR Front	3505 lb (1590 kg)				
GAWR Rear	3505 lb (1590 kg)				

Table 2. Tire Information

Tire Manufacturer	Falken
Tire Model	ZIEX ZE001A
Tire Size	Front: 235/65R17 Rear: 235/65R17
Load rating	Front: 103 Rear: 103
Speed rating	Front: T Rear: T
Treadwear grade	Front: 380 Rear: 380
Traction grade	Front: B Rear: B
Temperature grade	Front: B Rear: B
Location of "Recommended Tire Pressure" label	Driver's door jamb
Recommended cold tire pressure	Front: 35 psi, (240 kPa) Rear: 35 psi, (240 kPa)
DOT code (8 last digits)	Front: 3MZR 4320 Rear: 3MZR 4320

Table 3. Vehicle Loading

Water dummy and other loading	Multi-Passenger Configuration 2 water dummies in second row, 1 in third row
Water dummy weight	525.1 lb (238.2 kg)
Fuel level	Full
Weight as Tested	
Left front	1489 lb (675.5 kg)
Right front	1456 lb (660.5 kg)
Left rear	1476 lb (669.5 kg)
Right rear	1461 lb (662.5 kg)
Total weight	5882 lb (2668.0 kg)

D. STEERING CONTROLLER

Precise steering control is accomplished using a steering machine designed and constructed by ABD. It can provide up to 45 ft-lb torque and at rates over 1000 deg/sec. The integrated angle encoder has an unlimited range with a resolution of 0.25 degrees and an accuracy of ± 0.25 degrees. The steering motor is controlled by RC8 software from ABD, which also acts as the data acquisition system.

E. REAL-TIME CONTROLLER AND DATA ACQUISITION

Data acquisition is achieved using a MOSES Meas X, which also serves as the real-time system for the steering controller. Data from the OXTS, including Longitudinal, Lateral, and Vertical Acceleration, Roll, Yaw, and Pitch Rate, Forward and Lateral Velocity, Roll and Pitch Angle, are sent over Ethernet to the MOSES MeasX. The Oxford IMUs are calibrated per the manufacturer's recommended schedule (Table 5).

Two video cameras were used to record the Fishhook runs. They were positioned nominally as shown in Figure 1. The recorded video was reviewed after the Fishhook runs to check for any two-wheel lift. If any two-wheel lift was observed, four infrared distance measuring sensors for measurement of wheel lift (two sensors at each wheel) were then mounted for use in subsequent confirmation Fishhook tests.

F. EQUIPMENT WEIGHT

Table 4 lists the equipment and associated weights outlined in the NHTSA Laboratory Test Procedure for Dynamic Rollover and the equipment at Applus+ IDIADA KARCO Engineering, LLC used for this specific test program.

Table 4. Weight of In-Cab Test Equipment

Equipment	Location	Equipment Weight (lb)	
		NHTSA*	IDIADA
Data Acquisition System	Front passenger seat	58	35
GPS Inertial unit	At the chassis in a flat and rigid surface		7
Steering Machine	Handwheel	31	51
Steering Machine Electronics Box	Passenger row foot well behind the front passenger seat. If vehicle does not have a rear passenger row foot well, the Electronics Box should be placed in the front passenger seat footwell.	39	39
	Total	128	132

* Table A.1 from US DOT NHTSA - Laboratory Test Procedure for Dynamic Rollover - The Fishhook Maneuver Test Procedure - New Car Assessment Program (NCAP) - March 2013

G. SENSORS

A list of the sensors is given in Table 5.

H. OTHER VEHICLE PREPARATION

In addition to installation and preparation discussed above, the test vehicle was prepared as follows:

- Front and rear bumpers were removed.
- Outrigger mounts were installed in the bumper locations and titanium outriggers were fastened to these mounts.
- Airbags were removed or otherwise disabled.

Photographs of the vehicle tested are given in Appendix A.

Table 5. Sensor Specifications

Type	Measured Variable	Sensor	Range	Resolution	Accuracy	Specifics	Serial Number	Calibration	Unit
<i>Multi-Axis Inertial Sensing System</i>	Longitudinal speed	GPS inertial unit	-	0.01 %/s 0.01 m/s ²	±0.1	OXTS (RT)	1611	By: IDIADA Date: 6/16/2020 Due: 6/16/2022	km/h
	Lateral speed		-		±0.1				km/h
<i>Distance Measuring System</i>	Longitudinal acc.		±100		±0.1				m/s ²
	Lateral acc.		±100		±0.05				°
<i>Radar Speed Sensor</i>	Roll angle		±100		±0.05				°
	Pitch angle		±100		±0.1				°/s
	Yaw angle		±100		±0.1				°/s
<i>Data Flag (Roll Rate Flag)</i>	Roll rate		±100		±0.1				°/s
	Pitch rate		±100		±0.1				°/s
	Yaw rate		±100		±0.1				°/s
<i>Angle Encoder¹</i>	Steering angle	Steering wheel robot	>1000	0.25 deg	±0.20	ABD	769/17	By: IDIADA Date: 8/01/2019 Due: 8/01/2021	°
<i>Data Flag (Handwheel Command Flag)</i>	Steering torque		60		±0.25				Nm
<i>Infrared Distance Measuring System</i>	Tire wheel lift	Height sensors	300-700	0.01 mm	±0.8	OPTImess	OMS 4140-3098 OMS 4140-4506 OMS 4140-4508 OMS 4140-4509	By: IDIADA Date: 7/7/2020 Due: 7/7/2021	mm
<i>Load Cell</i>	Brake Pedal Force	Load Cell	±600	-	±0.5	Novatech	48305	By: IDIADA Date: 3/27/2020 Due: 3/27/2021	N
<i>Acquisition system</i>	-	Acquisition system	200	-	-	IDIADA Moses MEAS X	180749	By: IDIADA Date: 05/21/2020 Due: 05/21/2022	-

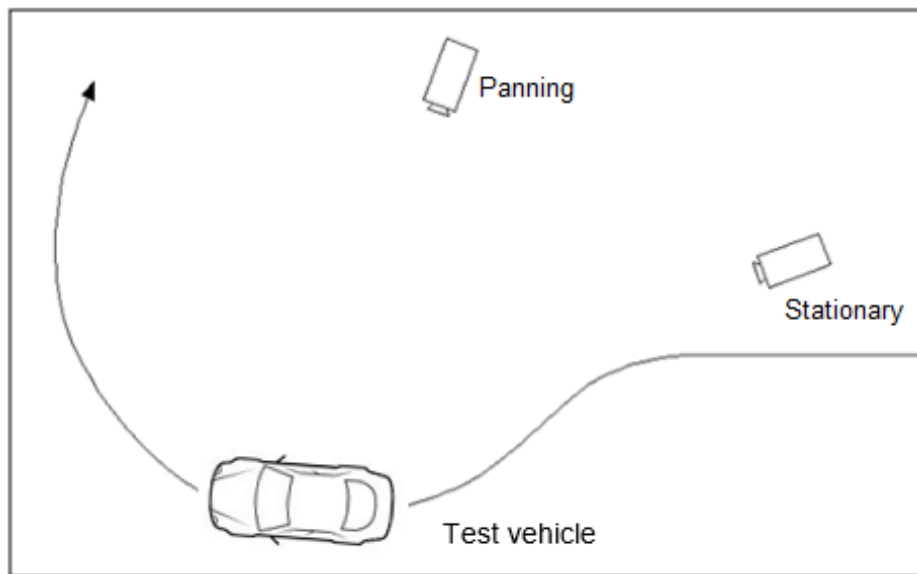


Figure 1. Nominal Position of Video Cameras for Fishhook Tests

SECTION III TEST PROCEDURES

A. TEST PROCEDURE OVERVIEW

This test was conducted in accordance with NHTSA's NCAP Rollover Resistance Test Procedure (Fishhook) as described in the Federal Register (68 FR 59250). Detailed descriptions of the test procedure, pass/fail criteria, and data acquisition specifications may be found at docket NHTSA-2001-9663.

There are two major components of the test procedure, the Slowly Increasing Steer (SIS) pre-test and the Fishhook test.

The Slowly Increasing Steer (SIS) maneuver was used to characterize the steady state lateral dynamics of each vehicle, and is based on the "Constant Speed, Variable Steer" test defined in SAE J266. The maneuver is used to determine the handwheel angle that produces a lateral acceleration of 0.3 g at 50 mph. This handwheel angle is then used to determine the magnitude of steering to be used for the NHTSA Fishhook maneuver.

SIS tests were performed at a constant speed of 50 mph. Handwheel angle was input at a rate of 13.5 deg/sec, from 0 to an angle that provided at least 0.55 g. Three tests were conducted in each direction, and the data for the six runs were averaged to obtain the handwheel angle that produced 0.3 g at 50 mph.

The Fishhook test is a programmed steering maneuver that is implemented via the steering controller. The vehicle was initially steered in one direction and then the steering was reversed. The timing, magnitude and rate of the steering were prescribed by the Fishhook Procedure.

To begin the maneuver, the vehicle was driven in a straight line at a speed slightly greater than the desired entrance speed. The driver then released the throttle. When the vehicle was at the target speed, the steering controller automatically initiated the steering maneuver. Following completion of the steering reversal, the handwheel position was maintained for 3 seconds, and then returned to zero angle in 2 seconds.

The tests were conducted in both left-right and right-left directions. The “Default” test series used a handwheel angle equal to 6.5 times the handwheel angle that produced 0.3 g at 50 mph in the SIS tests, and initial vehicle speeds beginning at 35 mph and concluding up to 50 mph (if no two-wheel lift occurs). Supplemental tests were also done, as specified in the Fishhook Procedure.

A. TEST CONDITIONS

1. Test Surface

The tests were conducted on the Vehicle Dynamics Area (VDA) at HONDA Proving Center facility, located in Cantil, California, on 3/19/2021. The VDA has a smooth, flat (slope less than 0.5% throughout) asphaltic concrete surface. Its dimensions are as shown in Figure 2. The test was accomplished using an ASTM E1136 tire with an inflation pressure of 35 (± 0.5) psi at a test speed of 40 (± 0.5) mph. The net slip angle of the test tire for each test run was 7.5 deg. The surface friction measurement results are shown in Table 6.

Table 6. Lateral Surface Friction

Date of surface friction measurements	3/19/2021
Average lateral friction coefficient	0.93
Peak braking coefficient	0.92

2. Fishhook Handwheel Angles

The 0.3 g handwheel angle obtained from the SIS tests and the handwheel angles used in the Fishhook tests are shown in Table 7.

Table 7. Handwheel Angles

0.3 g handwheel angle (from SIS tests at 50 mph)	29.5°
5.5 scalar handwheel angle for Fishhook Test	162.3°
6.5 scalar handwheel angle for Fishhook Test	191.8°

3. Weather Conditions

The weather conditions, recorded at the end of testing, are shown in Table 8.

Table 8. Weather Conditions

Ambient temperature	72.2 °F (22.3 °C)
Wind Speed	14.2 mph (6.3 m/s)
Wind Direction	WNW

SECTION IV

RESULTS

There is Appendix A with the photographic documentation. The test run log is given in Appendix B. A summary of the Slowly Increasing Steer Test is given in Appendix C. Appendix D contains time history plots for the 50 mph runs and any runs which resulted in two-wheel lift. For the 2021 Toyota Sienna AWD 5-Door Minivan, there was no two-wheel lift at any test condition.

**APPENDIX A
PHOTOGRAPHS**

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TOYOTA
Let's Go Places

DESC.: **SIENNA XLE AWD 7 PASSENGER**
VIN: **5TDJSKFC5MS01**
YR/MDL: 2021/5407A
CLR: **SUNSET BRONZE MICA/EA10** (04U3/10)
FINAL ASSEMBLY POINT: **PRINCETON, INDIANA, U.S.A.**

GOVERNMENT 5-STAR SAFETY RATINGS

This vehicle has not been rated by the government for overall vehicle score, frontal crash, side crash or rollover risk.

Star ratings range from 1 to 5 stars (★★★★★) with 5 being the highest.
Source: National Highway Traffic Safety Administration (NHTSA)
www.safercar.gov or 1-888-327-4236

STANDARD EQUIPMENT

- MECHANICAL & PERFORMANCE**
- 2.5L 4-Cylinder Engine
 - 24S Combined Net Horsepower
 - Electronic Continuous Var. Tran. (ECVT)
 - 17-in Alloy Wheels
 - Electronic On-Demand All-Wheel Drive
- SAFETY & CONVENIENCE**
- Toyota Safety Sense 2.0: Pre-Collision Sys w/ Pedestrian Detection, Full-Speed Range Dynamic Radar Cruise Control, Lane Departure Alert w/ Steering Assist, Lane Tracing Assist, Automatic High Beams, Road Sign Assist
 - STAR Safety System
 - LATCH-Lower Anchor & Tether for Children
 - Blind Spot Monitor w/ RCTA
 - 5-Door Smart Key w/ Push Button Start
 - Safety & Remote Connect w/ 1-Year Trial
- EXTERIOR**
- LED Headlights with Auto on/off feature
 - Hands-Free Dual Power Sliding SideDoors
 - Power Liftgate
 - Frt & Rear Parking Assist w/ Auto Brake
 - Power Tilt / Slide Moonroof
- INTERIOR**
- Audio Plus - 9-in Touchscreen, 8 Spkrs, HandsFree Bluetooth Phone/Music, USB Media Port, 6 USB Charge Ports, SiriusXM w/ 3-Month All Access Trial, Android Auto & Apple CarPlay Compatible
 - Four Zone Auto Climate Control
 - SofTex-Trimmed Seats, Heated & Power Front Seats, 2nd-Row Captain's Chairs w/ Super Long-Slide Feature, 60/40 One-Motion-Stow w/Split & Stow 3rd Row Seat
 - Rear Seat Reminder
 - For Full Product Details, Please Visit Toyota.com/Sienna
 - ***Full Tank of Gas***

MANUFACTURER'S SUGGESTED RETAIL PRICE \$41,750.00

OPTIONAL EQUIPMENT		
FE	50 State Emissions	75.00
ST	Temporary Spare Tire	2,000.00
XL	XLE Plus Package: Includes Wireless Smartphone Charging, Black Roof Rails, Premium Audio - 9-in Touchscreen, Dynamic Navigation with 3-Year Trial, 12 JBL Speakers Including Subwoofer & Amplifier, Connected Services - Safety Connect with 1-Year Trial, Service Connect with 10-Year Trial, Remote Connect with 1-Year Trial, Wi-Fi Connect with Up To 2 GB within 3-Month Trial, and Destination Assist with 1-Year Trial. See Toyota.com/Connected-Services For Details	
2T	All Weather Floor Liners	220.00
3T	Cross Bars	200.00

EPA DOT Fuel Economy and Environment

Gasoline Vehicle

Fuel Economy

35 MPG
combined city/hwy

35 city
36 highway

2.9 gallons per 100 miles

You save \$1,750
in fuel costs over 5 years compared to the average new vehicle.

Minivans range from 23 to 48 MPG. The best vehicle rates 141 MPG.

Annual fuel cost \$1,150

Fuel Economy & Greenhouse Gas Rating (tailpipe only) **7**

Smog Rating (tailpipe only) **7**

This vehicle emits 253 grams CO2 per mile. The best emits 0 grams per mile (tailpipe only). Producing and distributing fuel also create emissions. Learn more at fuelconomy.gov.

fuelconomy.gov
Calculate personalized estimates and compare vehicles

Actual results will vary for many reasons, including driving conditions and how you drive and maintain your vehicle. The average new vehicle gets 27 MPG and costs \$7,500 to fuel over 5 years. Cost estimates are based on 15,000 miles per year at 32.19 per gallon. MPG is miles per gasoline gallon equivalent. Vehicle emissions are a significant cause of climate change and smog.

Smartphone QR Code

DELIVERY PROCESSING AND HANDLING FEE 1,175.00

TOTAL \$45,420.00

The New Vehicle Limited Warranty provides 3-year/36,000 mile basic coverage, 5-year/60,000 mile powertrain coverage, plus 3-year/unlimited mile corrosion perforation coverage. See Warranty and Maintenance Guide for details. An extended service contract may be available for the vehicle.

Ask dealer for details.
Manufacturer's suggested retail price includes manufacturer's recommended pre-delivery service. Gasoline, license and title fees, applicable federal, state and local taxes and dealer and distributor installed options and accessories are not included in the manufacturer's suggested retail price.

ToyotaCare, which covers normal factory scheduled maintenance for two years or 25,000 miles, whichever occurs first, is included as part of the sales price of the vehicle for qualifying buyers. See participating dealer for eligibility and coverage details.

Delivered by Truck to 04222
TOYOTA CARLSBAD
5424 PASEO DEL NORTE
CARLSBAD CA92008



Figure A1. Monroney Label



Figure A2. Right Front View, Test Vehicle As-Delivered



Figure A3. Left Rear View, Test Vehicle As-Delivered



Figure A4. Left Front View, Test Vehicle in Test Condition



Figure A5. Right Rear View, Test Vehicle in Test Condition

MFD. BY: TOYOTA MOTOR MANUFACTURING, INDIANA, INC.

02/21

GVWR: 2800KG (6170LB)

GAWR: FRT. 1590KG (3505LB) WITH P235/65R17 TIRES,
17X7J RIMS.

RR. 1590KG (3505LB) WITH P235/65R17 TIRES,
17X7J RIMS.

THIS VEHICLE CONFORMS TO ALL APPLICABLE FEDERAL MOTOR
VEHICLE SAFETY AND THEFT PREVENTION STANDARDS IN EFFECT ON
THE DATE OF MANUFACTURE SHOWN ABOVE.

5TDJSKFC5MS01

MPV



C/TR: 4U3/EA10

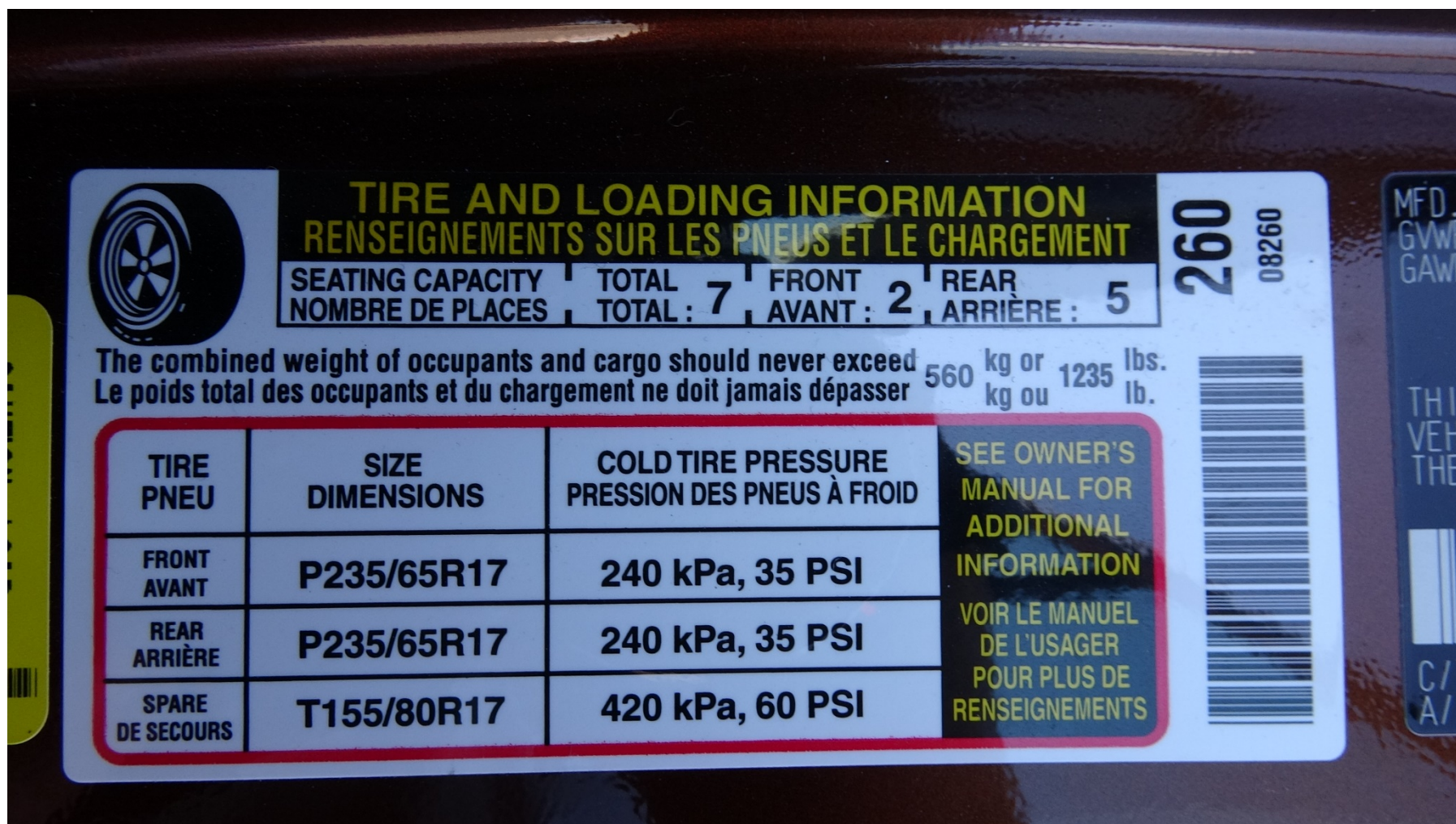
AXLH45L-PNXXHA

A/TM: /P810

MADE IN U.S.A. 862

A

Figure A6. Vehicle's Certification Label



TIRE AND LOADING INFORMATION
RENSEIGNEMENTS SUR LES PNEUS ET LE CHARGEMENT

SEATING CAPACITY | TOTAL : 7 | FRONT | REAR
 NOMBRE DE PLACES | TOTAL : 7 | AVANT : 2 | ARRIÈRE : 5

The combined weight of occupants and cargo should never exceed 560 kg or 1235 lbs.
 Le poids total des occupants et du chargement ne doit jamais dépasser 560 kg ou 1235 lb.

TIRE PNEU	SIZE DIMENSIONS	COLD TIRE PRESSURE PRESSION DES PNEUS À FROID	SEE OWNER'S MANUAL FOR ADDITIONAL INFORMATION VOIR LE MANUEL DE L'USAGER POUR PLUS DE RENSEIGNEMENTS
FRONT AVANT	P235/65R17	240 kPa, 35 PSI	
REAR ARRIÈRE	P235/65R17	240 kPa, 35 PSI	
SPARE DE SECOURS	T155/80R17	420 kPa, 60 PSI	

260
08260



MFD.
GWR
GAWR

THIS
VEH
THE

C/T
A/T

Figure A7. Vehicle's Tire Information Placard



Figure A8. Instrumentation in Test Vehicle



Figure A9. Steering Controller and Computer



Figure A10. Ballast Condition

APPENDIX B
TEST RUN LOG

Run Number	Test Type	Speed (mph)	Handwheel Angle (deg)	Dir. of First Steer	2 Wheel Lift	Notes
1	Tire Warm-Up	35	30.0	Left	N/A	Resulted in ay = 0.18g
2	"	"	58.1	"	"	Resulted in ay = 0.31g
3	"	"	"	"	"	
4	"	"	"	"	"	
5	2x SWA last cycle	"	116.2	"	"	2x SWA last cycle
6	Static	0	0	N/A	N/A	
7	Steady State	50	0	N/A	N/A	
8	Slowly Increasing Steer	50	30.0	Left	N/A	
9	"	"	40.4	Left	"	HW angle at 0.3 g = -27.6
10	"	"	"	Left	"	HW angle at 0.3 g = -27.1
11	"	"	"	Left	"	HW angle at 0.3 g = -28.6
12	"	"	"	Right	"	HW angle at 0.3 g = 30.5
13	"	"	"	Right	"	HW angle at 0.3 g = 31.8
14	"	"	"	Right	"	HW angle at 0.3 g = 31.5
						Average = 29.5
15	Fishhook 6.5 Scalar	35	191.8	Left	No	
16	"	40	"	"	"	
17	"	45	"	"	"	
18	"	47.5	"	"	"	
19	"	50	"	"	"	
20	Fishhook 6.5 Scalar	35	191.8	Right	No	
21	"	40	"	"	"	
22	"	45	"	"	"	

Run Number	Test Type	Speed (mph)	Handwheel Angle (deg)	Dir. of First Steer	2 Wheel Lift	Notes
23	"	47.5	"	"	"	
24	"	50	"	"	"	
25	Fishhook 5.5 Scalar	45	162.3	Left	No	
26	"	47.5	"	"	"	
27	"	50	"	"	"	
28	Fishhook 5.5 Scalar	45	162.3	Right	No	
29	"	47.5	"	"	"	
30	"	50	"	"	"	

APPENDIX C
SLOWLY INCREASING STEER TEST WORKSHEET

2021 Toyota Sienna AWD 5-Door Minivan, Multi-Passenger Configuration,
 Test Date: 3/19/2021



Slowly Increasing Steer



Vehicle: 2021 Toyota Sienna AWD
 Test Date: 3/19/2021
 Analysis Date: 3/19/2021
 Analysed by: EL
 Executed by: OG
 Configuration: ESC on

Weight Condition: Test condition
 Test Track: Dynamic Platform
 Test Speed: 50 mph

Run	Dir of Steer	Start speed [mph]	End speed [mph]	Speed red [%]	Index of ay	HW angle [deg] at 0.3g	ay [g] 0.3g index	6.5x HW angle [deg]	Ramp time [sec] at 6.5x	5.5x HW angle [deg]	Ramp time [sec] at 5.5x	R2	Zero Begin index	Zero End index
sis001	L	49.9	0.4	99.1	618	-27.6	-0.300	-179.2	-0.2489	-151.6	-0.2106	0.9946	0	140
sis002	L	50.3	0.3	99.3	610	-27.1	-0.300	-176.4	-0.2450	-149.3	-0.2073	0.9984	0	139
sis003	L	50.5	1.8	96.4	631	-28.6	-0.300	-185.8	-0.2581	-157.2	-0.2184	0.9979	0	149
sis004	R	49.8	0.1	99.8	661	30.5	0.300	197.9	0.2749	167.5	0.2326	0.9967	0	178
sis005	R	49.6	0.4	99.3	692	31.8	0.300	206.7	0.2871	174.9	0.2429	0.9962	0	193
sis006	R	50.0	0.2	99.6	686	31.5	0.300	204.5	0.2840	173.0	0.2403	0.9927	0	194

Mean: 29.5

Steering Controller Input values

Scalar 6.5 values:

Initial HW angle: 191.8 deg

Reversal HW angle: -191.8 deg

Scalar 5.5 values:

Initial HW angle: 162.3 deg

Reversal HW angle: -162.3 deg

APPENDIX D
TIME HISTORY PLOTS

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FILENAME: FH005

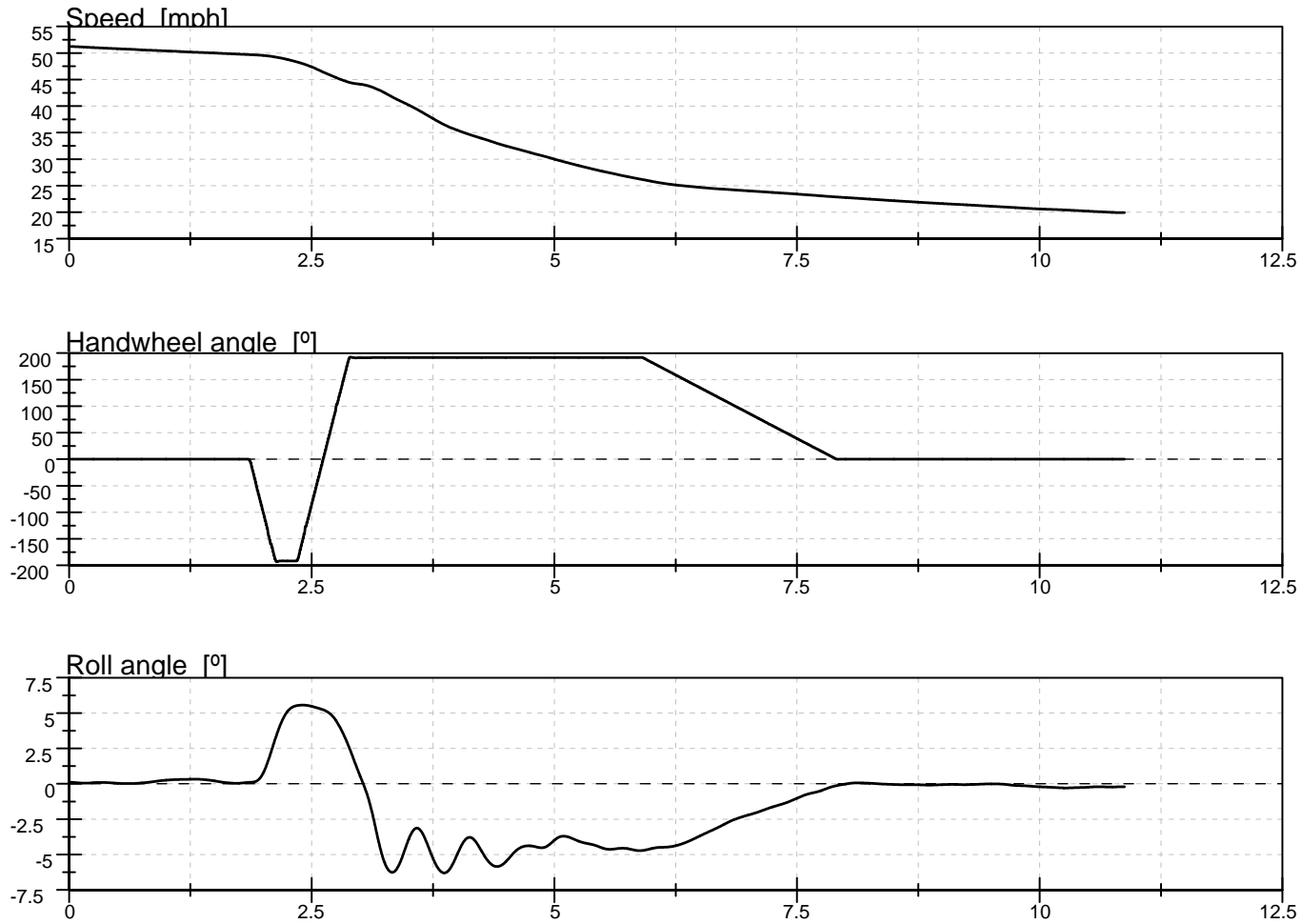


Figure D1. Vehicle Speed, Handwheel Angle, and Roll Angle Time History Plots for Default Test Series, L-R, 50 mph

FILENAME: FH005

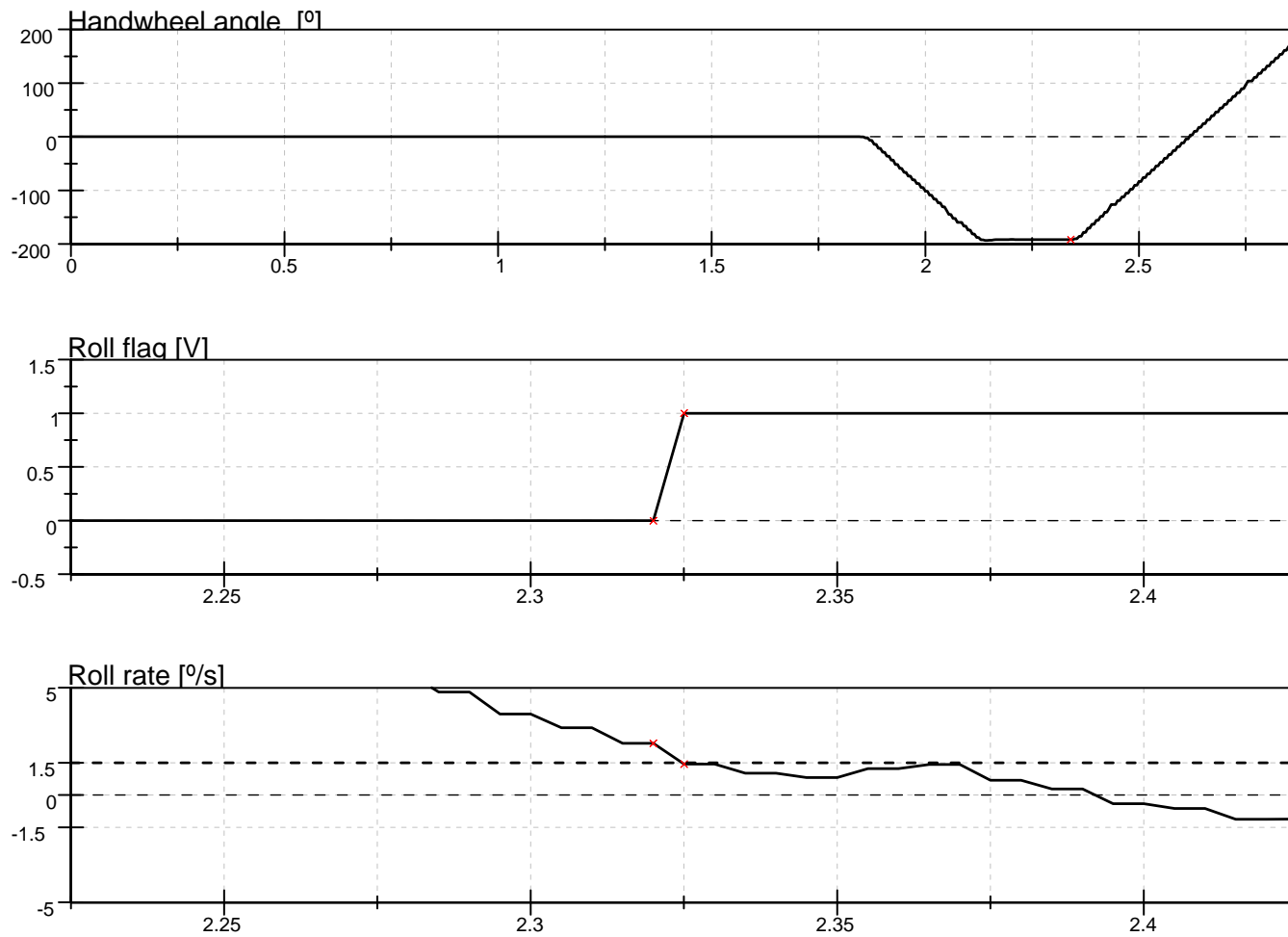


Figure D2. Steering Machine Operation Time History Plots for Default Test Series, L-R, 50 mph

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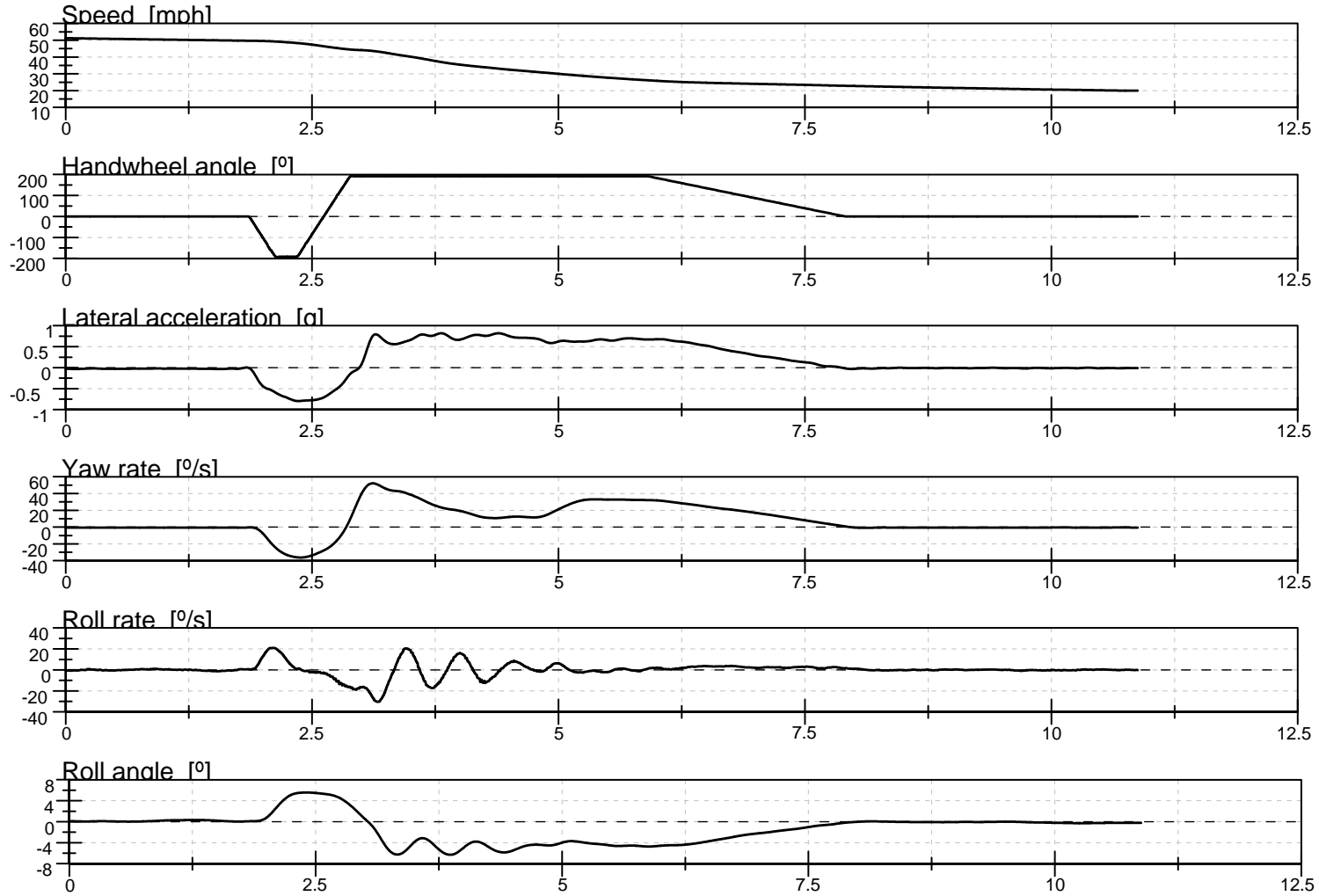


Figure D3. Yaw Rate, Roll Rate, and Lateral Acceleration Time History Plots For Default Test Series, L-R, 50 mph

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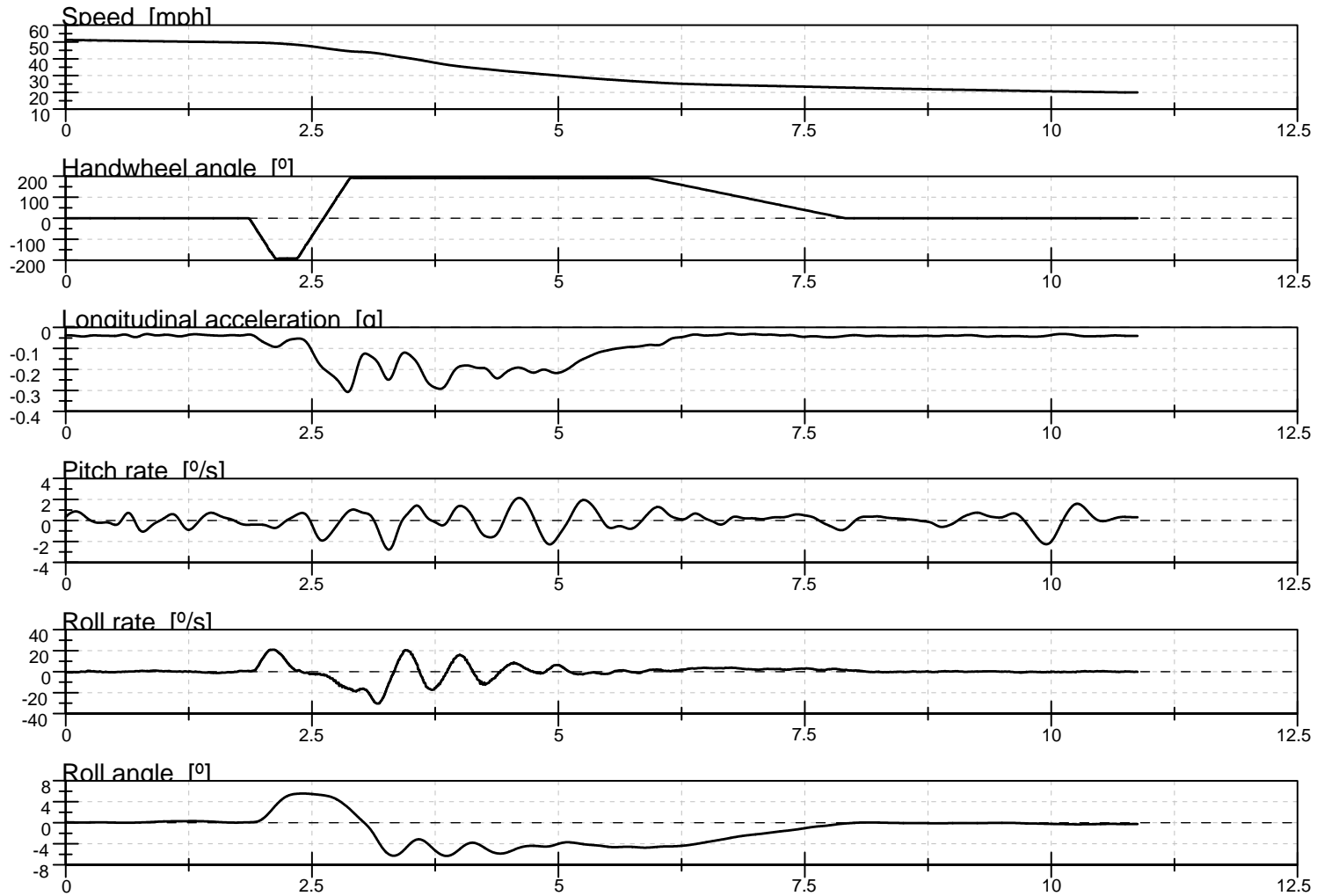


Figure D4. Pitch Rate and Longitudinal Acceleration Time History Plots for Default Test Series, L-R, 50 mph

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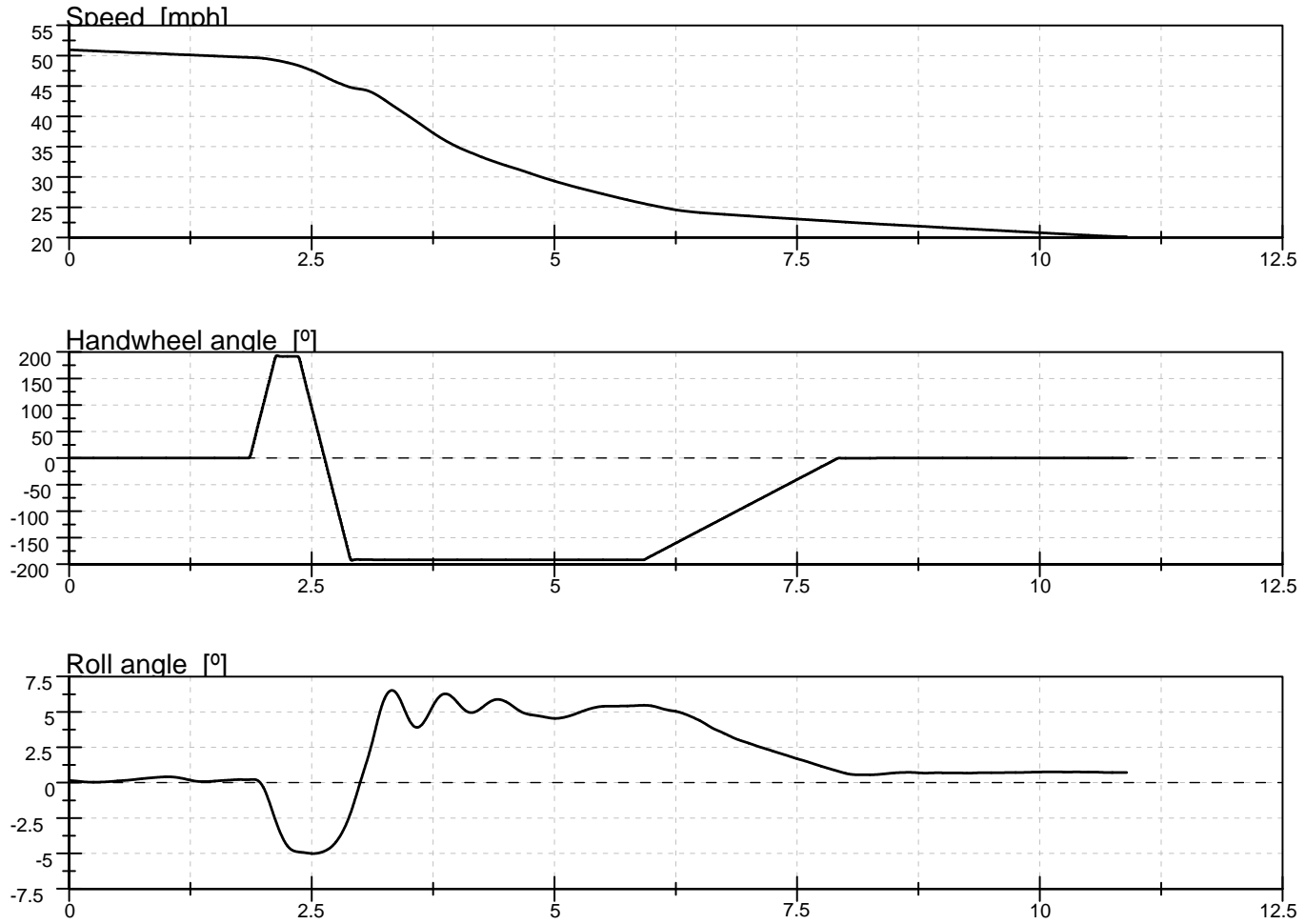


Figure D5. Vehicle Speed, Handwheel Angle, and Roll Angle Time History Plots for Default Test Series, R-L, 50 mph

FILENAME: FH010

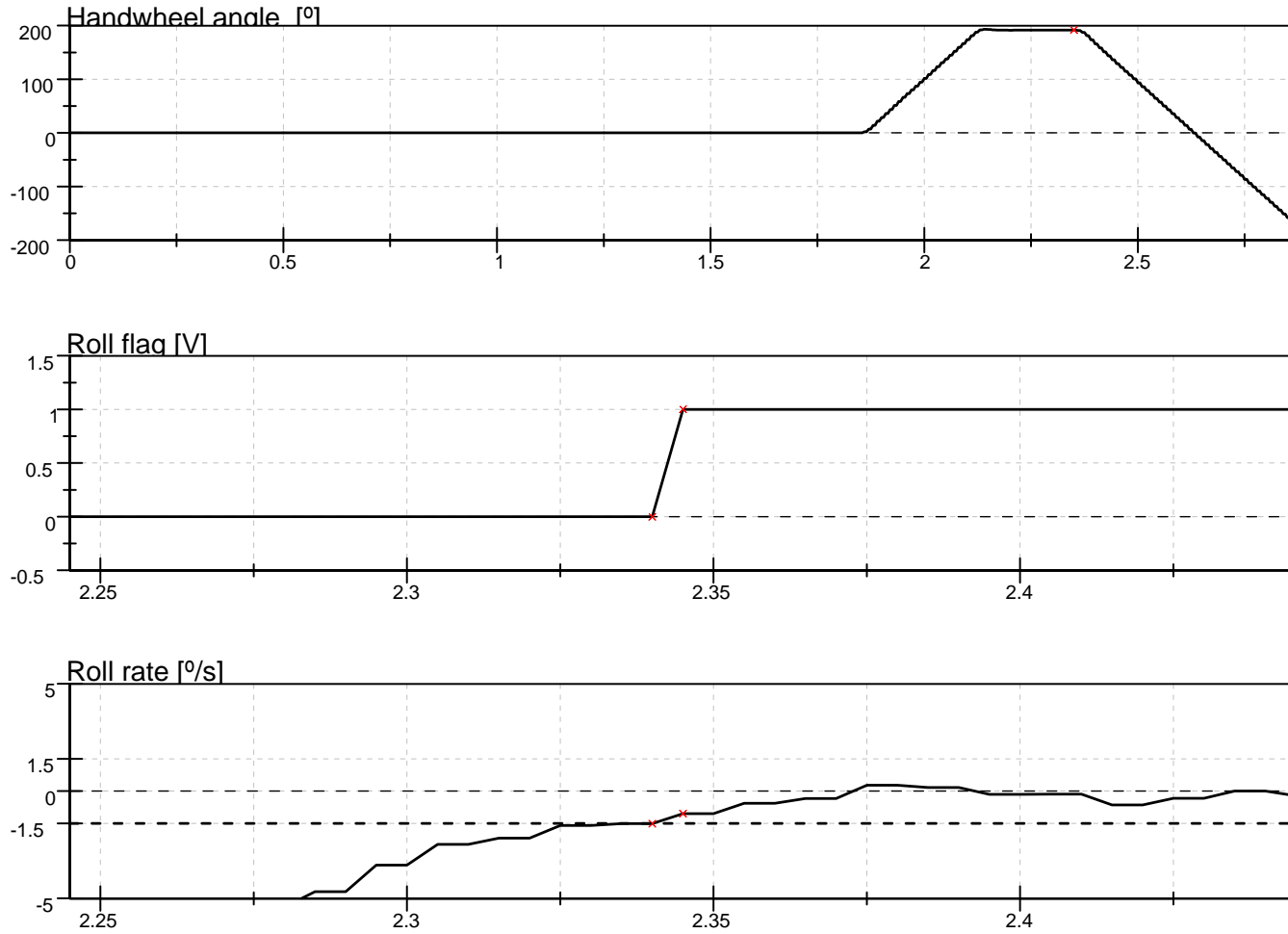


Figure D6. Steering Machine Operation Time History Plots for Default Test Series, R-L, 50 mph

FILENAME: FH010

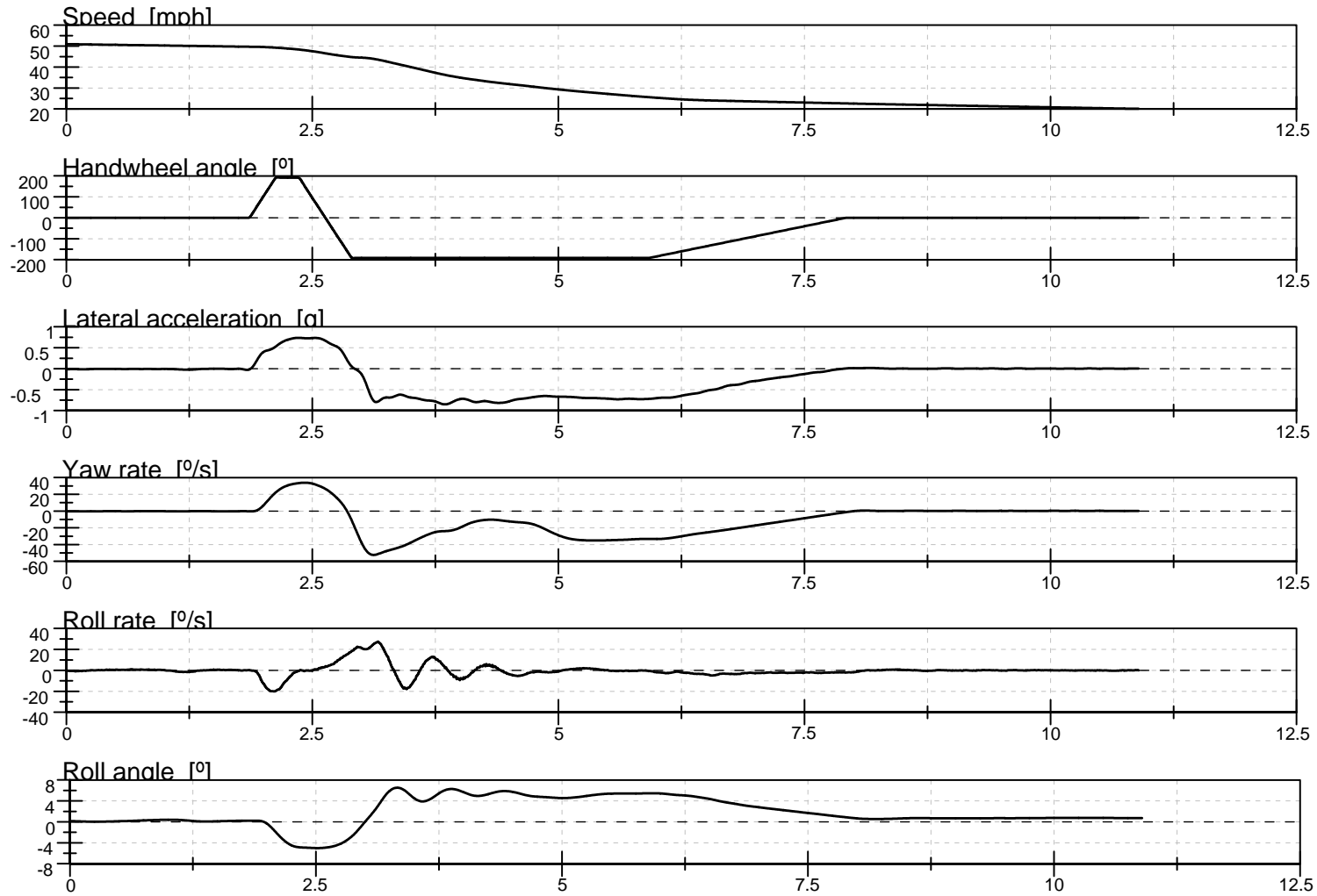


Figure D7. Yaw Rate, Roll Rate, and Lateral Acceleration Time History Plots for Default Test Series, R-L, 50 mph

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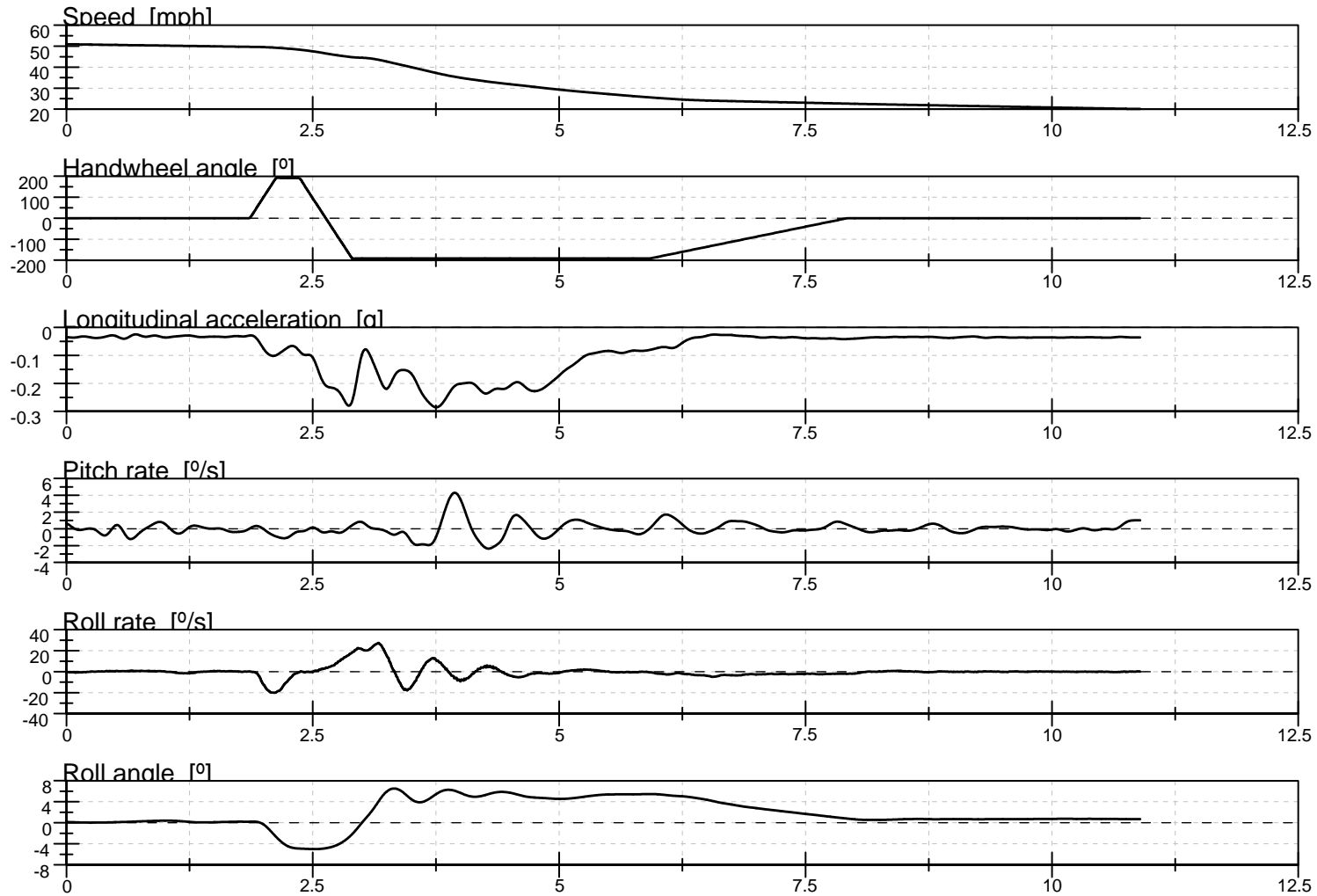


Figure D8. Pitch Rate and Longitudinal Acceleration Time History Plots or Default Test Series, R-L, 50 mph

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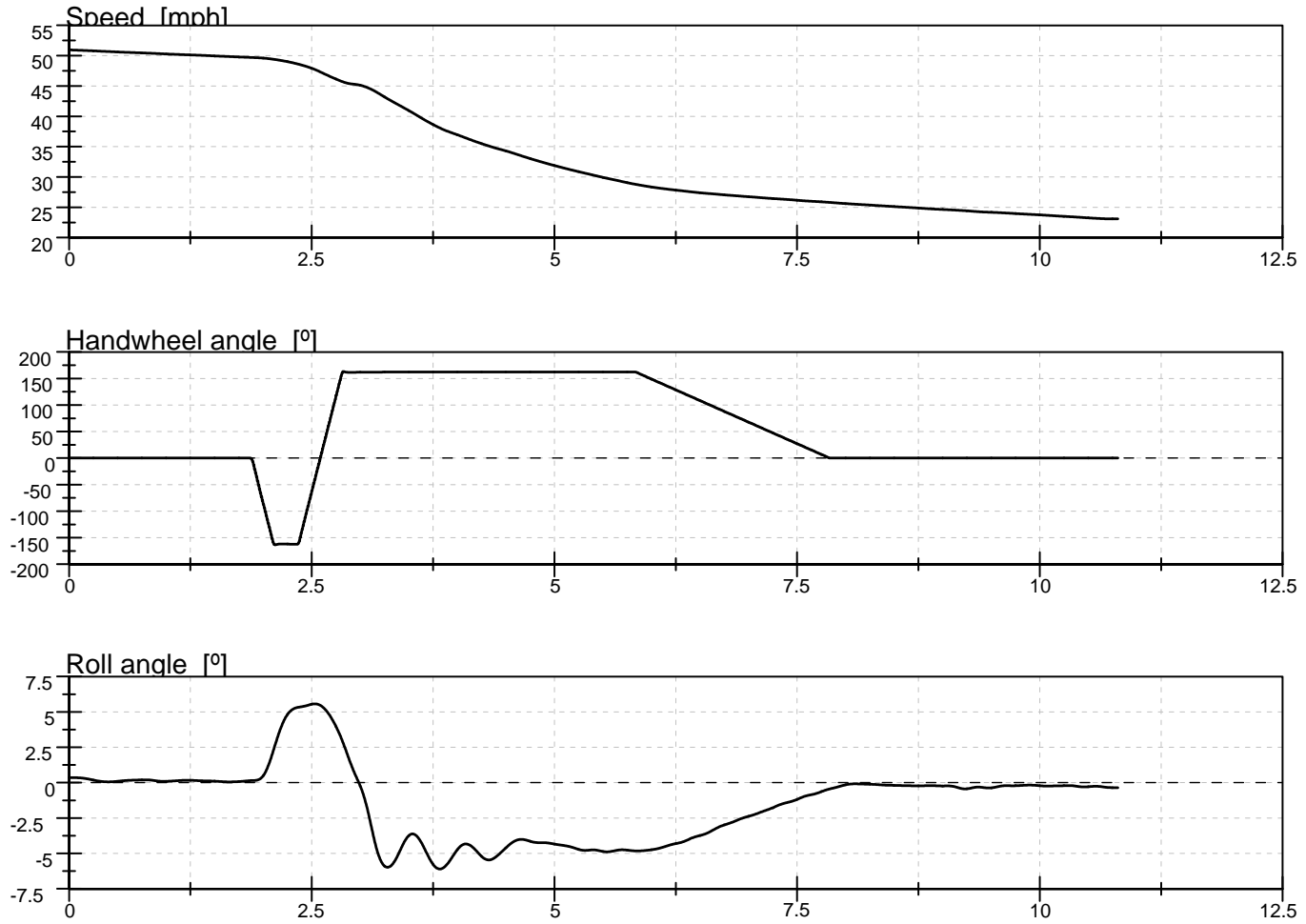


Figure D9. Vehicle Speed, Handwheel Angle, and Roll Angle Time History Plots for Supplemental 2 Test Series, L-R, 50 mph

FILENAME: FH013

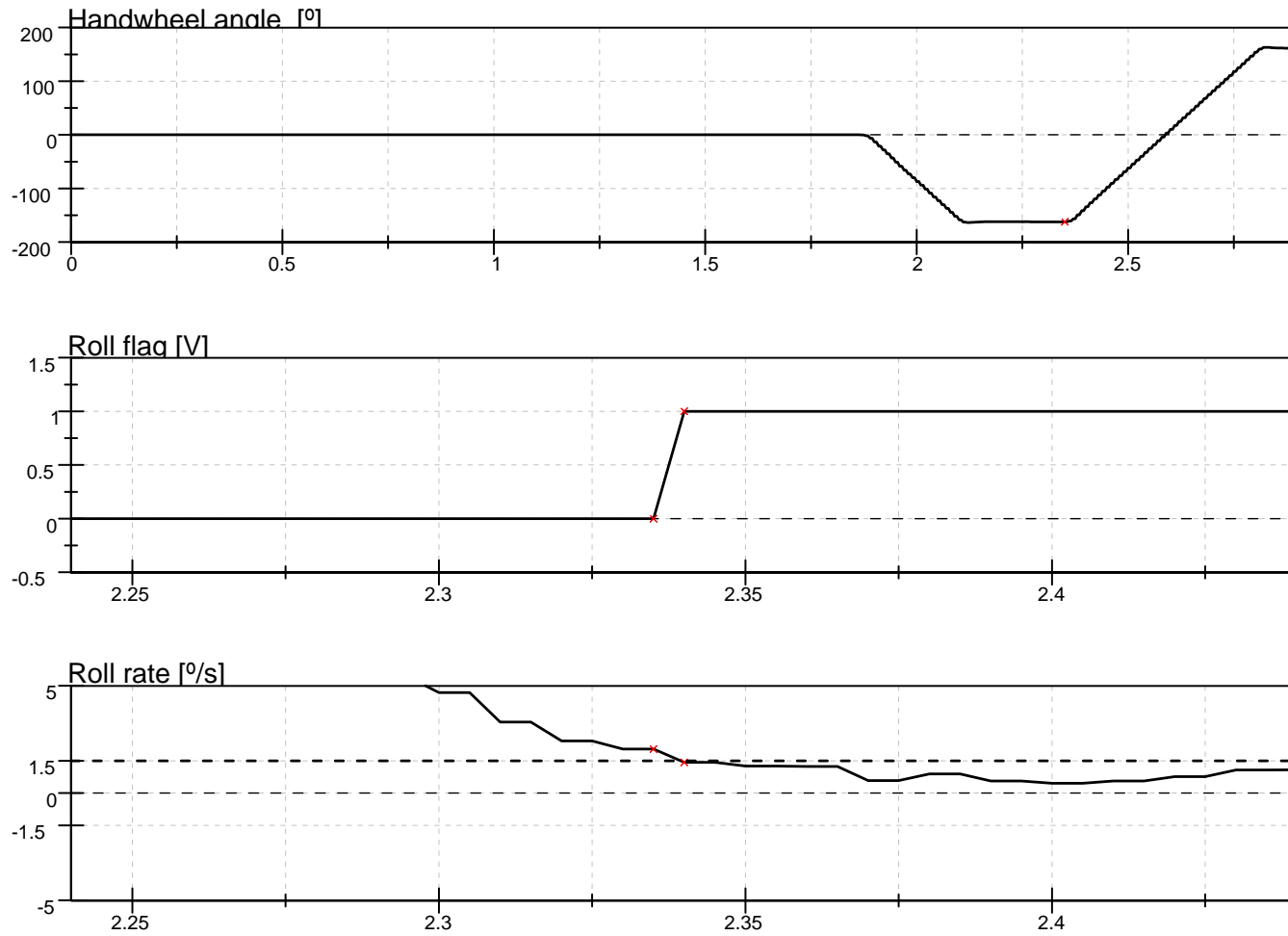


Figure D10. Steering Machine Operation Time History Plots for Supplemental 2 Test Series, L-R, 50 mph

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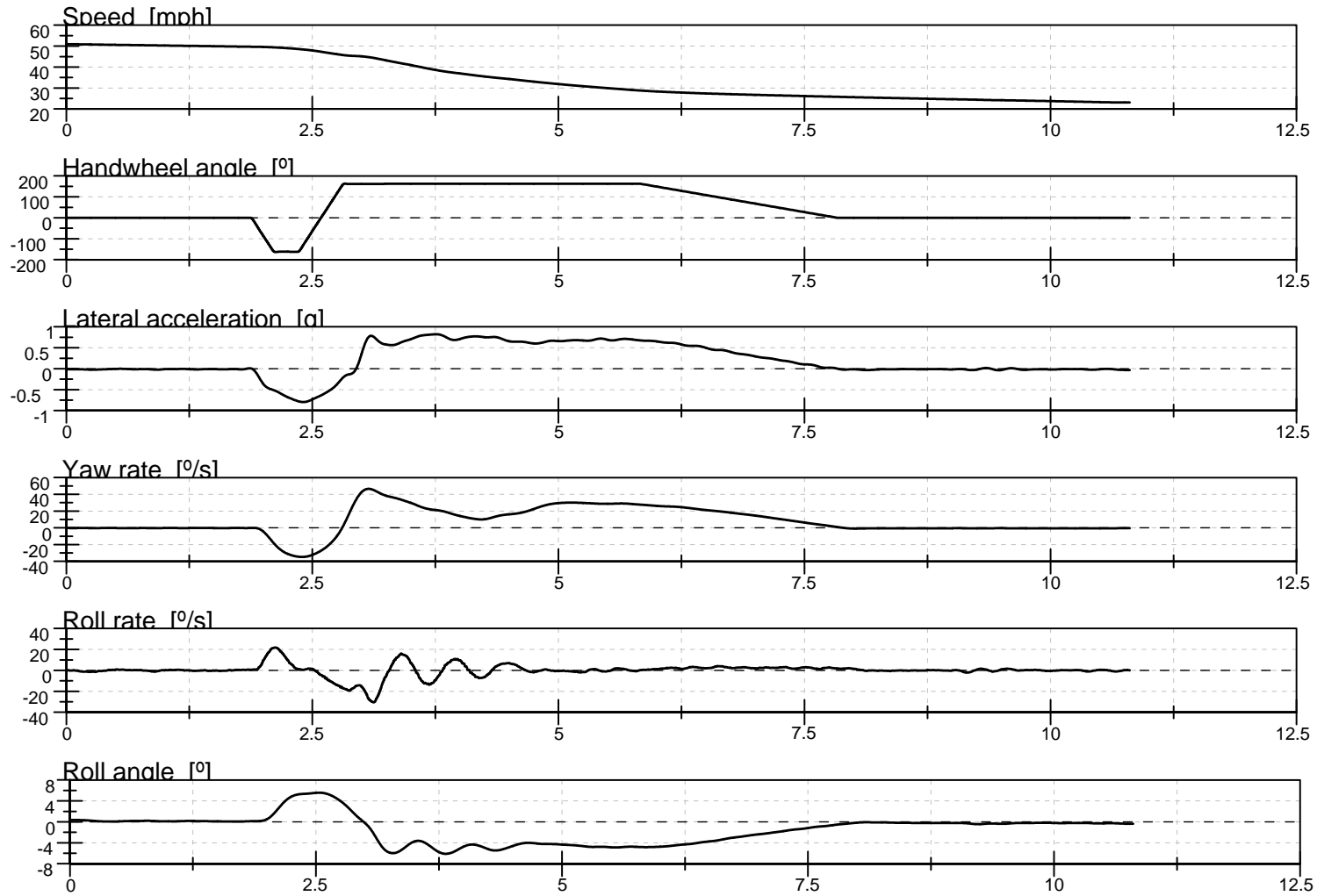


Figure D11. Yaw Rate, Roll Rate, and Lateral Acceleration Time History Plots for Supplemental 2 Test Series, L-R, 50 mph

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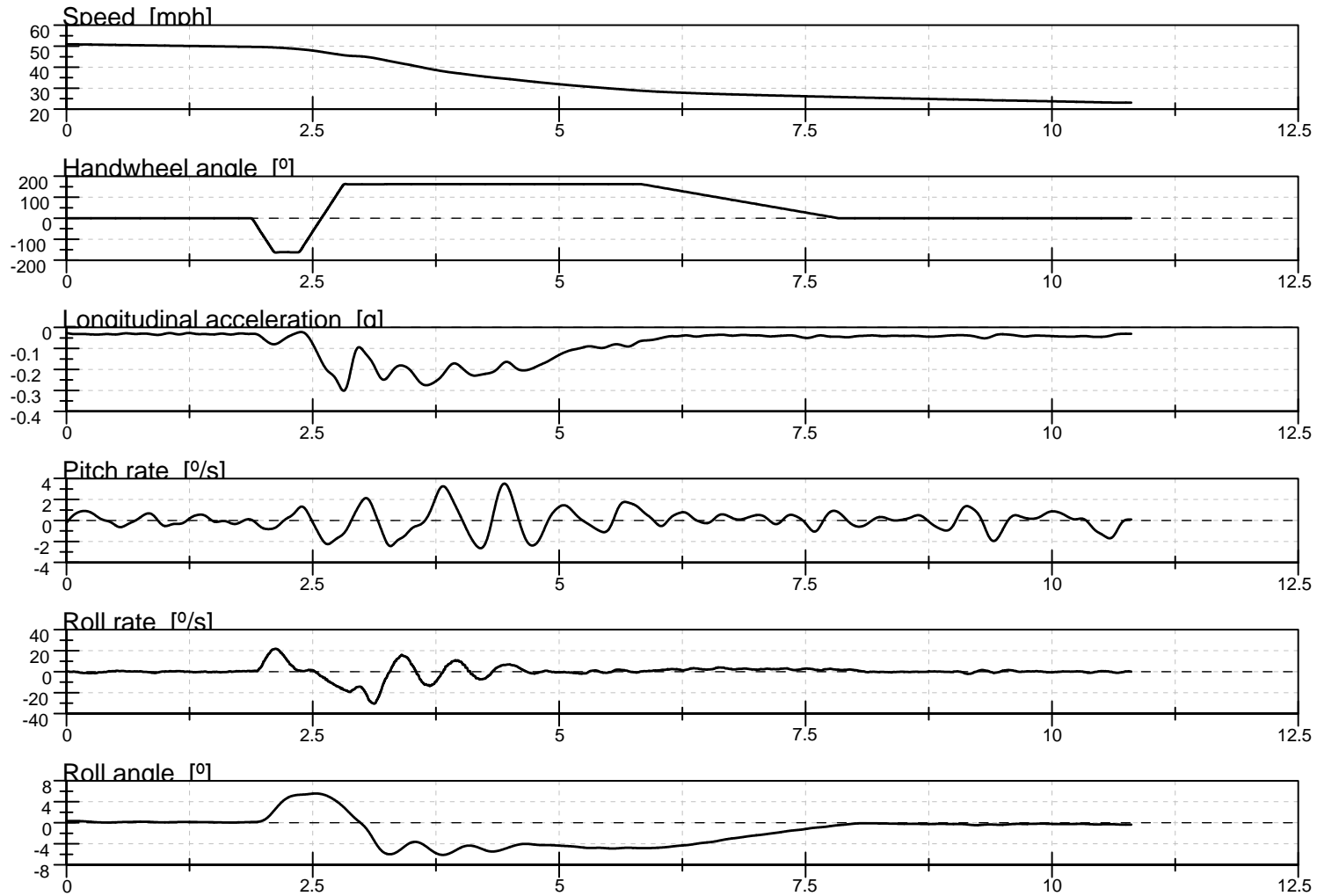


Figure D12. Pitch Rate and Longitudinal Acceleration Time History Plots for Supplemental 2 Test Series, L-R, 50 mph

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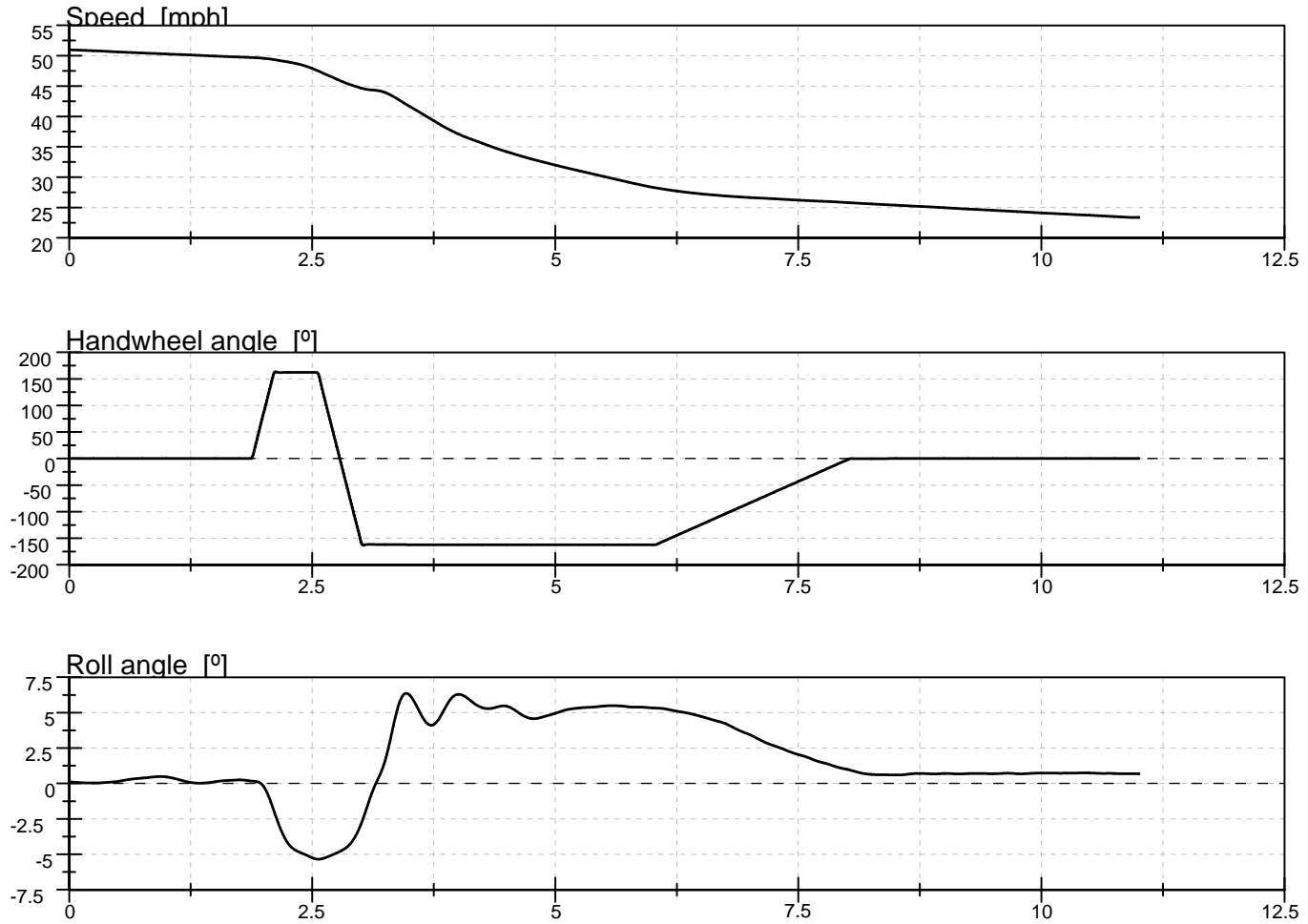


Figure D13. Vehicle Speed, Handwheel Angle, and Roll Angle Time History Plots for Supplemental 2 Test Series, R-L, 50 mph

FILENAME: FH016

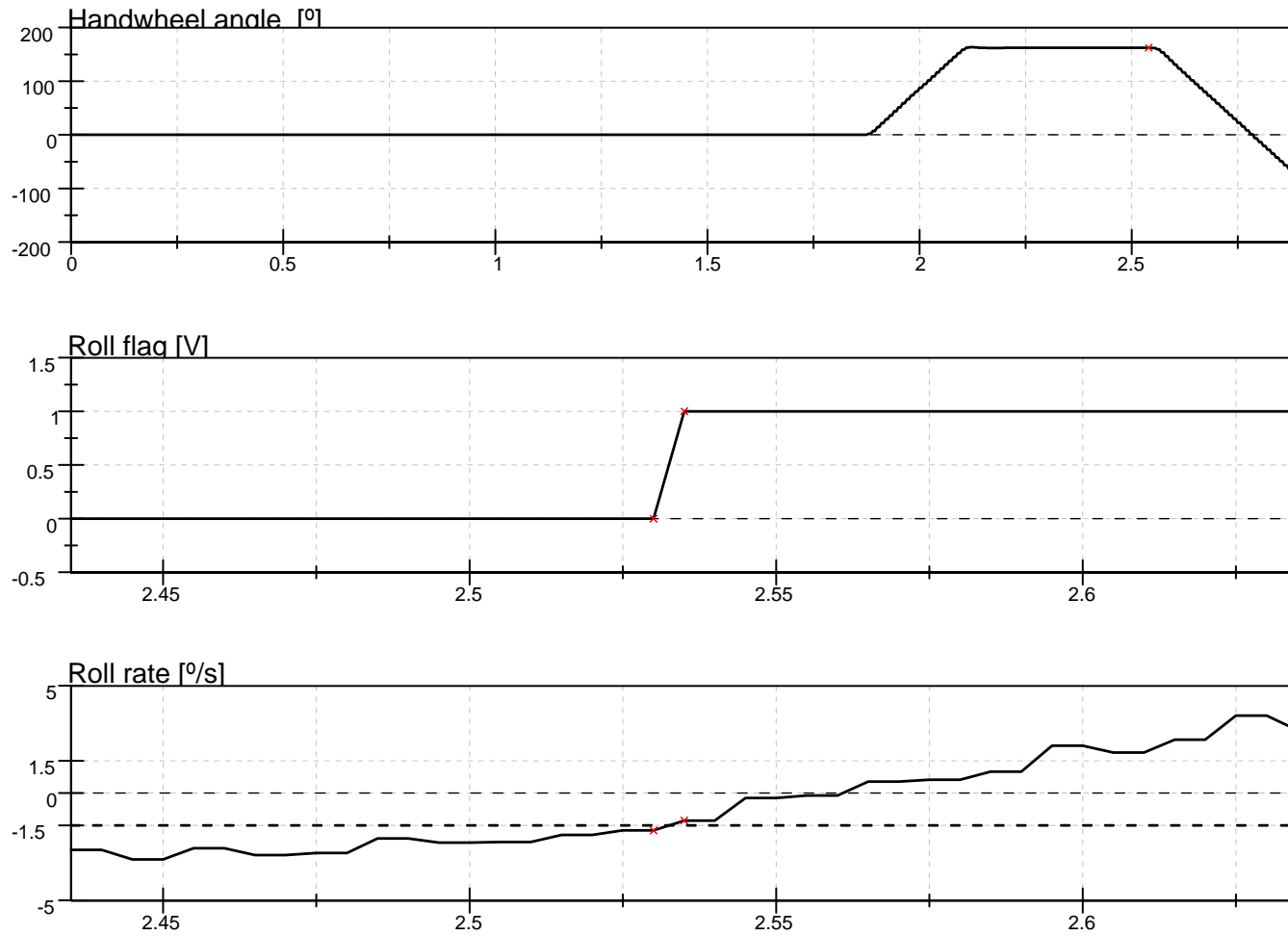


Figure D14. Steering Machine Operation Time History Plots for Supplemental 2 Test Series, R-L, 50 mph

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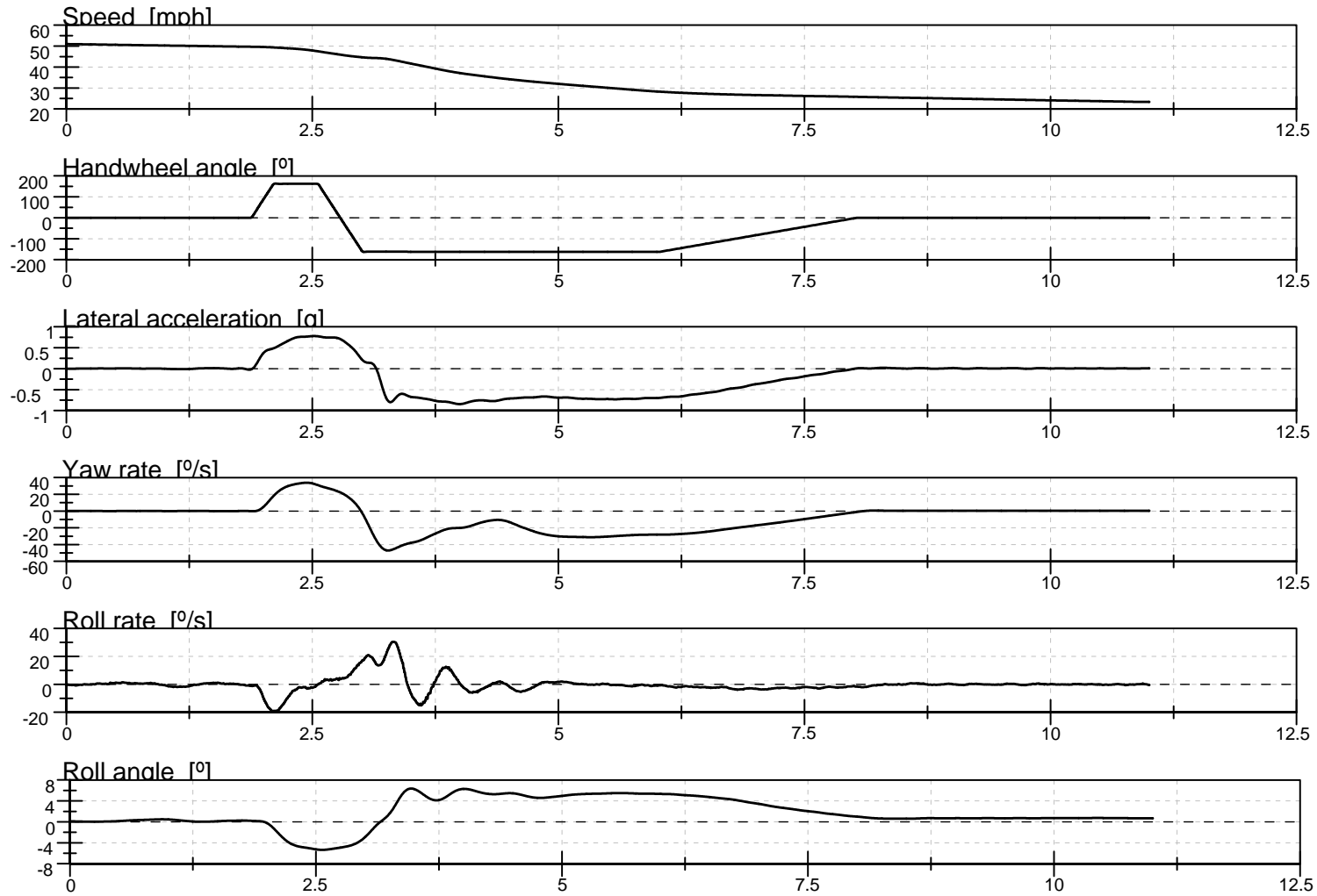


Figure D15. Yaw Rate, Roll Rate, and Lateral Acceleration Time History Plots for Supplemental 2 Test Series, R-L, 50 mph

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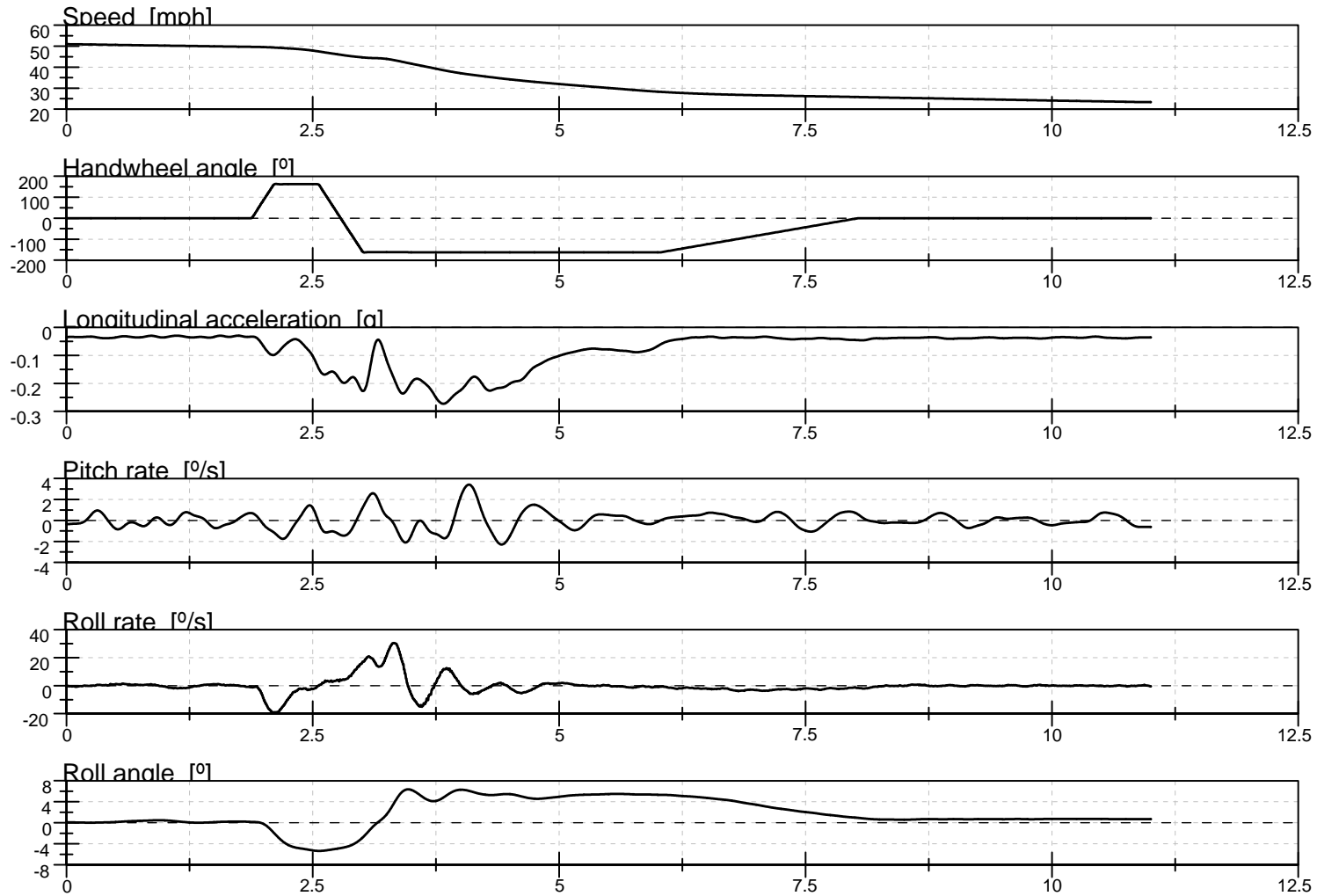


Figure D16. Pitch Rate and Longitudinal Acceleration Time History Plots for Supplemental 2 Test Series, R-L, 50 mph