NCAP-KAR-DR-21-02

NEW CAR ASSESSMENT PROGRAM (NCAP)
DYNAMIC ROLLOVER RESISTANCE TEST

KIA MOTORS MANUFACTURING GEORGIA, INC.

2021 KIA SORENTO FWD 5-DOOR SUV

PREPARED BY:

APPLUS IDIADA KARCO ENGINEERING, LLC.

9270 HOLLY ROAD

ADELANTO, CA 92301

FEBRUARY 12, 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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Date: February 12, 2021

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NCAP-KAR-DR-21-02		

4. Title and Subtitle	5. Report Date
Final Report of New Car Assessment Program Dynamic Rollover Resistance Maneuver (Fishhook) Test of a 2021 Kia Sorento FWD 5-Door SUV	February 12, 2021
	6. Performing Organization Code KAR
7. Authors Mr. Bernat Ferrer, Program Manager, Applus+ IDIADA KARCO Engineering Mr. Eduard Lucas, Project Engineer, Applus+ IDIADA KARCO Engineering	**8. Performing Organization Report No.** TR-P40015-01-NC
9. Performing Organization Name and Address Applus IDIADA KARCO Engineering, LLC. 9270 Holly Rd. Adelanto, CA 92301	**10. Work Unit No.** **11. Contract or Grant No.** 693JJ920D000011
12. Sponsoring Agency Name and Address U. S. Department of Transportation National Highway Traffic Safety Administration New Car Assessment Program 1200 New Jersey Ave., SE Washington, D.C. 20590	**13. Type of Report and Period Covered** Final Test Report, February 5 - 12, 2021 **14. Sponsoring Agency Code** NRM-110

15. Supplementary Notes

16. Abstract

An NCAP Dynamic Rollover Maneuver (Fishhook) Test was conducted on a 2021 Kia Sorento FWD 5-Door SUV by Applus+ IDIADA KARCO Engineering, LLC. on February 5, 2021. The vehicle did not experience two-wheel lift. The vehicle's steering angle at 0.3 g lateral acceleration at 50 mph was 27.7 degrees

17. Key Words	18. Distribution Statement
New Car Assessment Program (NCAP) NCAP Rollover Resistance Ratings Fishhook Test	Copies of this report are available from: National Highway Traffic Safety Admin. Technical Reference Division 1200 New Jersey Ave., SE Washington, DC 20590

19. Security Classification of this report	20. Security Classification of this page	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED	53	

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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 Kia Sorento FWD 5-Door SUV 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 debeading, 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 Kia Sorento				
VIN	5XYRL4LC5MG02xxxx				
Body style	SUV				
Number of doors	5				
Trim level	S				
Seating positions	Front:	2nd row	3rd row	4th row	5th row
	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	9 miles				
Drivetrain					
Engine cylinder arrangement	Inline 4				
Engine displacement	2.5 L				
Transmission type	Automatic				
Drive arrangement	FWD				
Chassis					
Track width	F: 68.5 in (1740 mm), R: 68.8 in (1747 mm)				
Wheelbase	111.0 in (2820 mm)				
Curb weight	3778 lb (1713.5 kg)				
Certification Data from Vehicle's Label					
Vehicle manufactured by	Kia Motors Manufacturing Georgia, Inc.				
Date of manufacture	DEC/16/20				
GVWR	5357 lb (2430 kg)				
GAWR Front	2866 lb (1300 kg)				
GAWR Rear	2976 lb (1350 kg)				

Table 2. Tire Information

Tire Manufacturer	Continental
Tire Model	Cross Contact
Tire Size	Front: 235/60R18 Rear: 235/60R18
Load rating	Front: 103 Rear: 103
Speed rating	Front: H Rear: H
Treadwear grade	Front: 480 Rear: 480
Traction grade	Front: A Rear: A
Temperature grade	Front: A Rear: A
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 first digits)	Front: 1HW 03HCF Rear: 1HW 03HCF

Table 3. Vehicle Loading

Water dummy and other loading	Multi-Passenger Configuration 1 dummy in second row, 2 dummies in third row
Water dummy weight	525.1 lb (238.2 kg)
Fuel level	Full
Weight as Tested	
Left front	1262 lb (572.5 kg)
Right front	1206 lb (547.0 kg)
Left rear	1230 lb (558.0 kg)
Right rear	1203 lb (545.5 kg)
Total weight	4901 lb (2223.0 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
Multi-Axis Inertial Sensing System *Distance Measuring System* *Radar Speed Sensor* *Data Flag (Roll Rate Flag)*	Longitudinal speed Lateral speed Longitudinal acc. Lateral acc. Roll angle Pitch angle Yaw angle Roll rate Pitch rate Yaw rate	GPS inertial unit	- - ±100 ±100 ±100 ±100 ±100 ±100 ±100 ±100	0.01 º/s 0.01 m/s2	±0.1 ±0.1 ±0.1 ±0.1 ±0.05 ±0.05 ±0.1 ±0.1 ±0.1 ±0.1	OXTS (RT)	1611	By: IDIADA Date: 6/16/2020 Due: 6/16/2022	km/h km/h m/s² m/s² º º º º/s º/s º/s
Angle Encoder[1] *Data Flag (Handwheel Command Flag)*	Steering angle Steering torque	Steering wheel robot	>1000 60	0.25 deg	±0.20 ±0.25	ABD	769/17	By: IDIADA Date: 8/01/2019 Due: 8/01/2021	º Nm
Infrared Distance Measuring System	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
Load Cell	Brake Pedal Force	Load Cell	±600	-	±0.5	Novatech	48305	By: IDIADA Date: 3/27/2020 Due: 3/27/2021	N
Acquisition system	-	Acquisition system	200	-	-	IDIADA Moses MEAS X	180749	By: IDIADA Date: 05/21/2020 Due: 05/21/2022	-

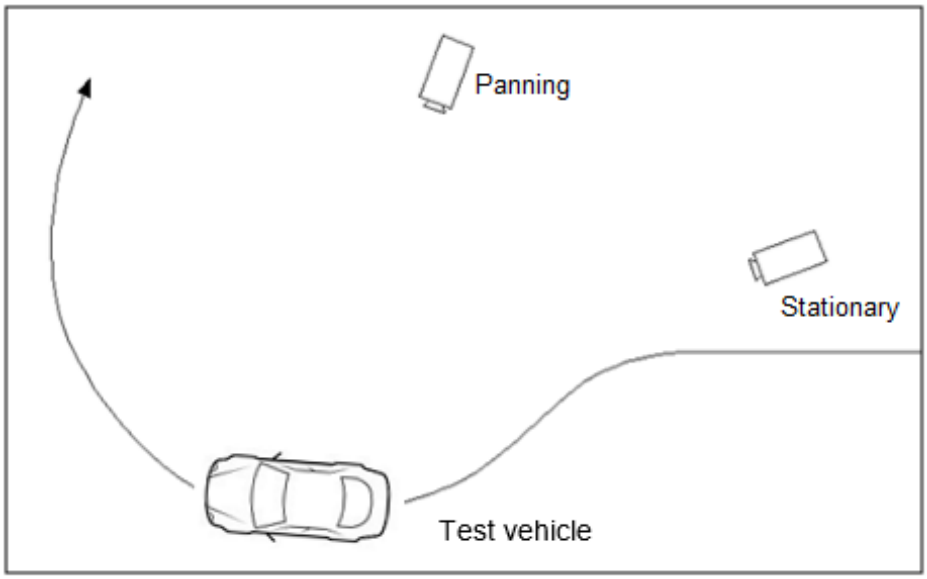


Figure 1. Nominal Position of Video Cameras for Fishhook Tests

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 2/5/2021. 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	2/5/2021
Average lateral friction coefficient	0.92
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)	27.7º
5.5 scalar handwheel angle for Fishhook Test	180.1º
6.5 scalar handwheel angle for Fishhook Test	152.4º

3. Weather Conditions

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

Table 8. Weather Conditions

Ambient temperature	58.8 ºF (14.9 ºC)
Wind Speed	1.2 mph (0.5 m/s)
Wind Direction	NNE

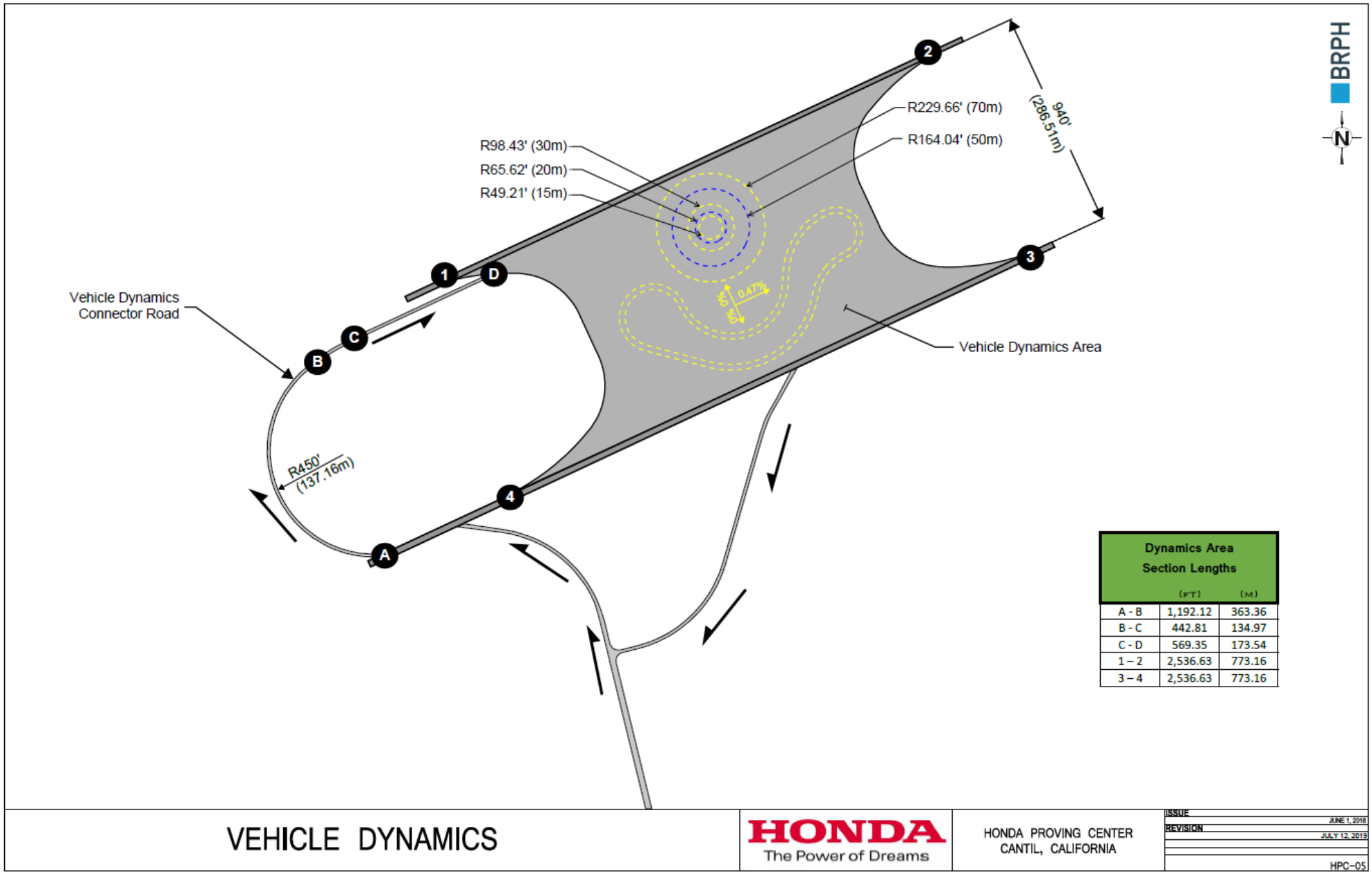


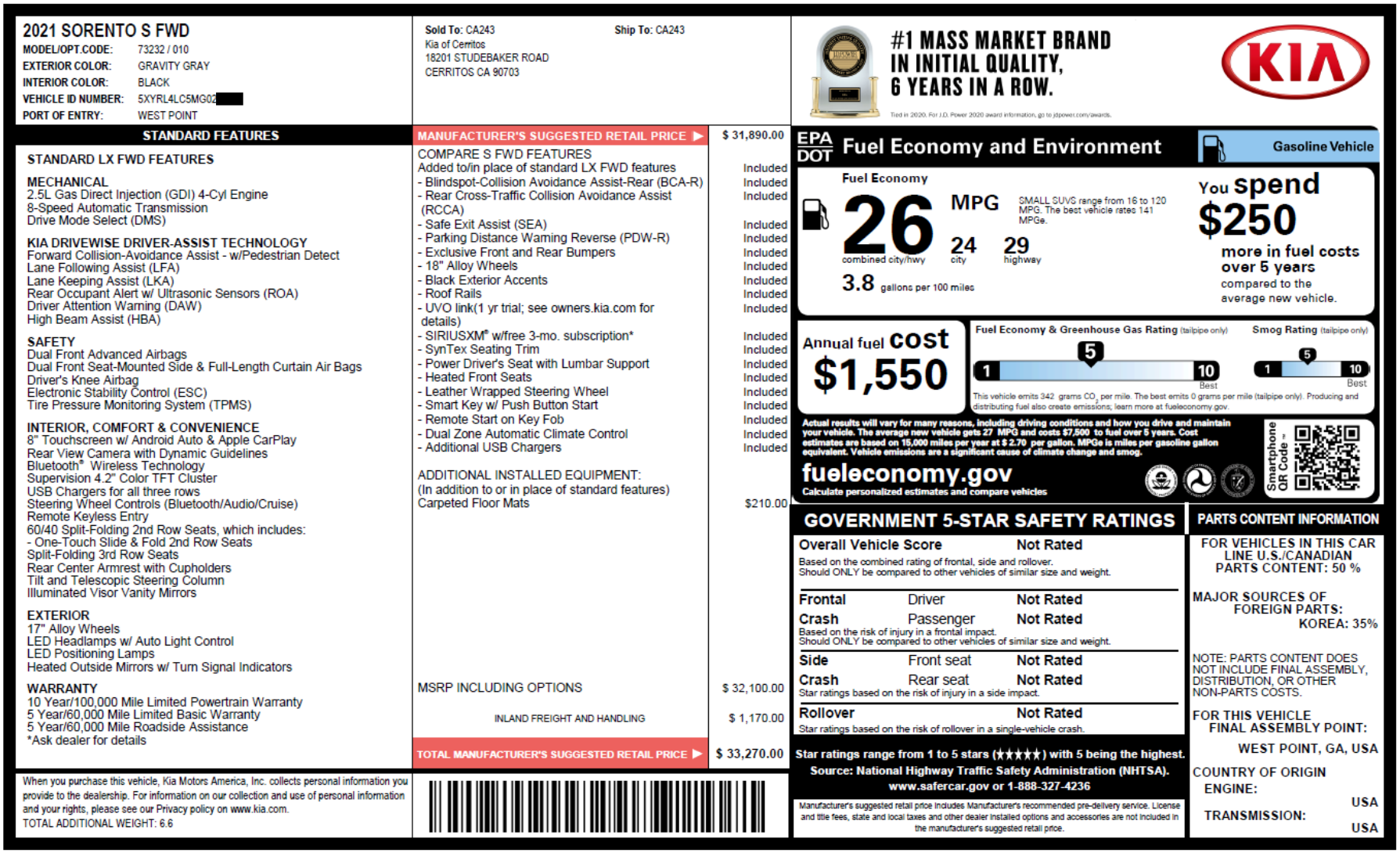
Figure 2. Vehicle Dynamics Area at Honda Proving Center

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 Kia Sorento FWD 5-Door SUV, there was no two-wheel lift at any test condition.

APPENDIX A
PHOTOGRAPHS

LIST OF FIGURES



2021 SORENTO S FWD

MODEL/OPT.CODE: 73232 / 010
EXTERIOR COLOR: GRAVITY GRAY
INTERIOR COLOR: BLACK
VEHICLE ID NUMBER: 5XYRL4LC5MG02[redacted]
PORT OF ENTRY: WEST POINT

Sold To: CA243
Kia of Cerritos
18201 STUDEBAKER ROAD
CERRITOS CA 90703

Ship To: CA243

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Tied in 2020. For J.D. Power 2020 award information, go to jdpower.com/awards.

KIA

STANDARD FEATURES

STANDARD LX FWD FEATURES

MECHANICAL
2.5L Gas Direct Injection (GDI) 4-Cyl Engine
8-Speed Automatic Transmission
Drive Mode Select (DMS)

KIA DRIVEWISE DRIVER-ASSIST TECHNOLOGY
Forward Collision-Avoidance Assist - w/Pedestrian Detect
Lane Following Assist (LFA)
Lane Keeping Assist (LKA)
Rear Occupant Alert w/ Ultrasonic Sensors (ROA)
Driver Attention Warning (DAW)
High Beam Assist (HBA)

SAFETY
Dual Front Advanced Airbags
Dual Front Seat-Mounted Side & Full-Length Curtain Air Bags
Driver's Knee Airbag
Electronic Stability Control (ESC)
Tire Pressure Monitoring System (TPMS)

INTERIOR, COMFORT & CONVENIENCE
8" Touchscreen w/ Android Auto & Apple CarPlay
Rear View Camera with Dynamic Guidelines
Bluetooth® Wireless Technology
Supervision 4.2" Color TFT Cluster
USB Chargers for all three rows
Steering Wheel Controls (Bluetooth/Audio/Cruise)
Remote Keyless Entry
60/40 Split-Folding 2nd Row Seats, which includes:
- One-Touch Slide & Fold 2nd Row Seats
Split-Folding 3rd Row Seats
Rear Center Armrest with Cupholders
Tilt and Telescopic Steering Column
Illuminated Visor Vanity Mirrors

EXTERIOR
17" Alloy Wheels
LED Headlamps w/ Auto Light Control
LED Positioning Lamps
Heated Outside Mirrors w/ Turn Signal Indicators

WARRANTY
10 Year/100,000 Mile Limited Powertrain Warranty
5 Year/60,000 Mile Limited Basic Warranty
5 Year/60,000 Mile Roadside Assistance
*Ask dealer for details

MANUFACTURER'S SUGGESTED RETAIL PRICE ▶	$ 31,890.00
COMPARE S FWD FEATURES	
Added to/in place of standard LX FWD features	Included
- Blindspot-Collision Avoidance Assist-Rear (BCA-R)	Included
- Rear Cross-Traffic Collision Avoidance Assist (RCCA)	Included
- Safe Exit Assist (SEA)	Included
- Parking Distance Warning Reverse (PDW-R)	Included
- Exclusive Front and Rear Bumpers	Included
- 18" Alloy Wheels	Included
- Black Exterior Accents	Included
- Roof Rails	Included
- UVO link(1 yr trial; see owners.kia.com for details)	Included
- SIRIUSXM® w/free 3-mo. subscription*	Included
- SynTex Seating Trim	Included
- Power Driver's Seat with Lumbar Support	Included
- Heated Front Seats	Included
- Leather Wrapped Steering Wheel	Included
- Smart Key w/ Push Button Start	Included
- Remote Start on Key Fob	Included
- Dual Zone Automatic Climate Control	Included
- Additional USB Chargers	Included
ADDITIONAL INSTALLED EQUIPMENT: (In addition to or in place of standard features)	
Carpeted Floor Mats	$210.00
MSRP INCLUDING OPTIONS	$ 32,100.00
INLAND FREIGHT AND HANDLING	$ 1,170.00
TOTAL MANUFACTURER'S SUGGESTED RETAIL PRICE ▶	$ 33,270.00

When you purchase this vehicle, Kia Motors America, Inc. collects personal information you provide to the dealership. For information on our collection and use of personal information and your rights, please see our Privacy policy on www.kia.com.
TOTAL ADDITIONAL WEIGHT: 6.6

EPA DOT Fuel Economy and Environment — Gasoline Vehicle

Fuel Economy
26 MPG combined city/hwy
24 city
29 highway
3.8 gallons per 100 miles

SMALL SUVS range from 16 to 120 MPG. The best vehicle rates 141 MPGe.

You **spend $250** more in fuel costs over 5 years compared to the average new vehicle.

Annual fuel cost $1,550

Fuel Economy & Greenhouse Gas Rating (tailpipe only): 5 (1 – 10, Best)
Smog Rating (tailpipe only): 5 (1 – 10, Best)

This vehicle emits 342 grams CO_2 per mile. The best emits 0 grams per mile (tailpipe only). Producing and distributing fuel also create emissions; learn more at fueleconomy.gov.

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 $ 2.70 per gallon. MPGe is miles per gasoline gallon equivalent. Vehicle emissions are a significant cause of climate change and smog.

fueleconomy.gov
Calculate personalized estimates and compare vehicles

Smartphone QR Code

GOVERNMENT 5-STAR SAFETY RATINGS

Overall Vehicle Score		**Not Rated**
Based on the combined rating of frontal, side and rollover. Should ONLY be compared to other vehicles of similar size and weight.		
Frontal Crash	Driver	**Not Rated**
	Passenger	**Not Rated**
Based on the risk of injury in a frontal impact. Should ONLY be compared to other vehicles of similar size and weight.		
Side Crash	Front seat	**Not Rated**
	Rear seat	**Not Rated**
Star ratings based on the risk of injury in a side impact.		
Rollover		**Not Rated**
Star ratings based on the risk of rollover in a single-vehicle crash.		

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

Manufacturer's suggested retail price includes Manufacturer's recommended pre-delivery service. License and title fees, state and local taxes and other dealer installed options and accessories are not included in the manufacturer's suggested retail price.

PARTS CONTENT INFORMATION

FOR VEHICLES IN THIS CAR LINE U.S./CANADIAN PARTS CONTENT: 50 %

MAJOR SOURCES OF FOREIGN PARTS:
KOREA: 35%

NOTE: PARTS CONTENT DOES NOT INCLUDE FINAL ASSEMBLY, DISTRIBUTION, OR OTHER NON-PARTS COSTS.

FOR THIS VEHICLE FINAL ASSEMBLY POINT:
WEST POINT, GA, USA

COUNTRY OF ORIGIN
ENGINE: USA
TRANSMISSION: USA

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

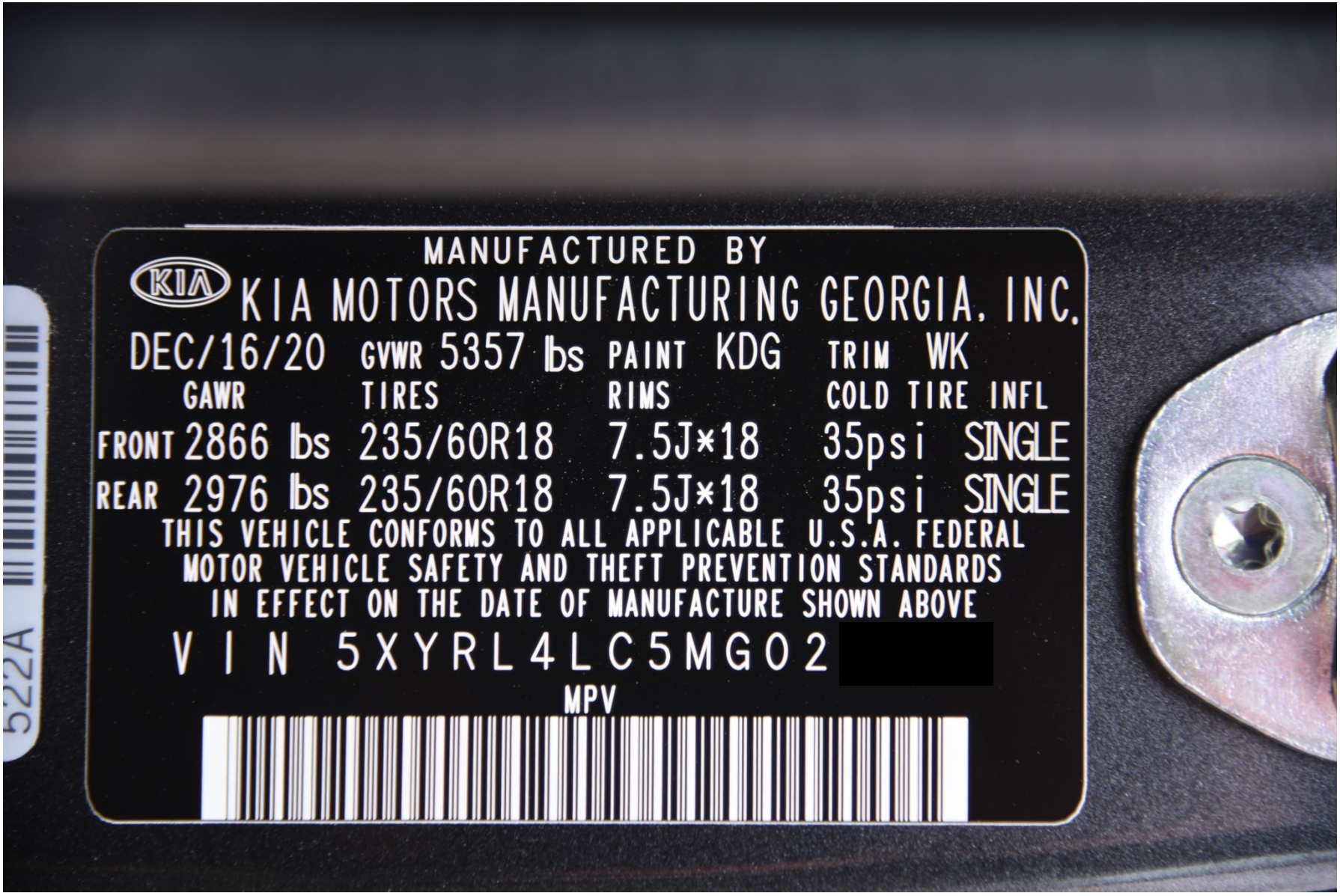

Figure A6. Vehicle's Certification Label

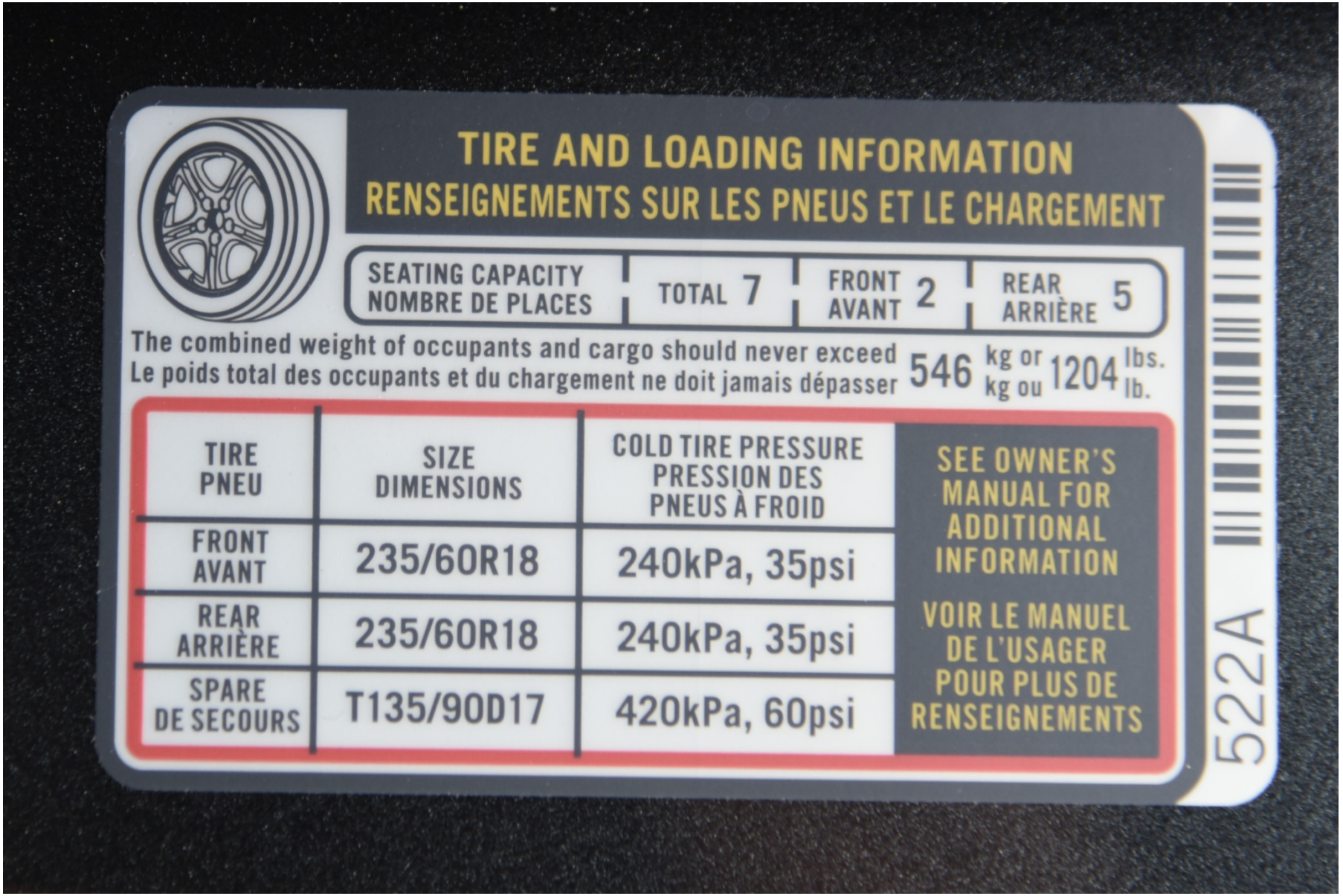

Figure A7. Vehicle's Tire Information Placard

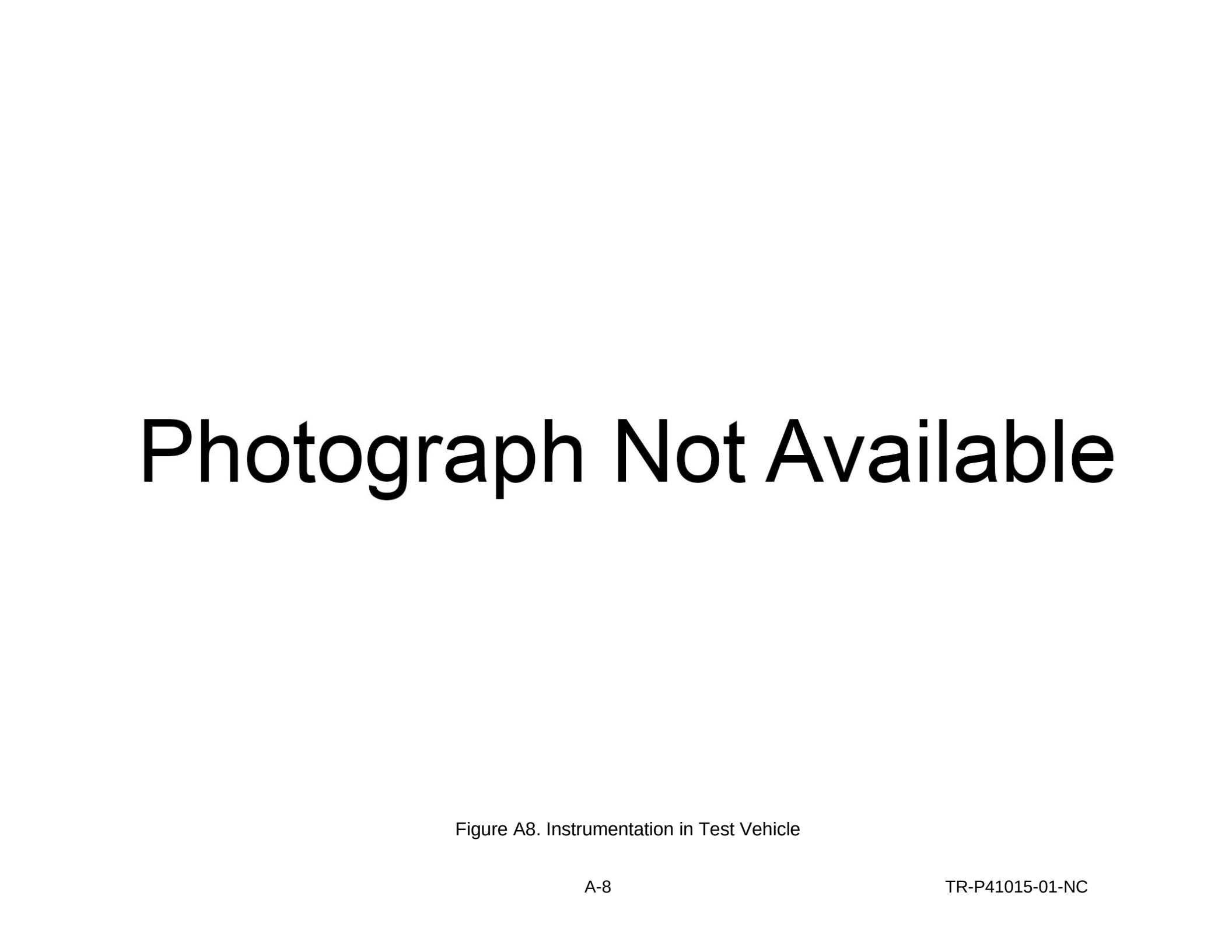

Figure A8. Instrumentation in Test Vehicle

Figure A9. Steering Controller and Computer

Figure A10. Ballast Condition

APPENDIX B

TEST RUN LOG

Vehicle: **2021 KIA SORENTO FWD 5-DOOR SUV** Driver: **Omar Gonzalez** Date: **2/5/2021**

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 = 0.19g
2	"	"	56.3	"	"	Resulted in ay = 0.33g
3	"	"	"	"	"	
4	"	"	"	"	"	
5	2x SWA last cycle	"	112.6	"	"	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	"	"	38.9	Left	"	HW angle at 0.3 g = -27.0
10	"	"	"	Left	"	HW angle at 0.3 g = -27.4
11	"	"	"	Left	"	HW angle at 0.3 g = -27.9
12	"	"	"	Right	"	HW angle at 0.3 g = 27.4
13	"	"	"	Right	"	HW angle at 0.3 g = 28.4
14	"	"	"	Right	"	HW angle at 0.3 g = 28.2
						Average = **27.7**
15	**Fishhook 6.5 Scalar**	35	180.1	Left	No	
16	"	40	"	"	"	
17	"	45	"	"	"	
18	"	47.5	"	"	"	
19	"	50	"	"	"	
20	**Fishhook 6.5 Scalar**	35	180.1	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	152.4	Left	No	
26	"	47.5	"	"	"	
27	"	50	"	"	"	
28	**Fishhook 5.5 Scalar**	45	152.4	Right	No	
29	"	47.5	"	"	"	
30	"	50	"	"	"	

APPENDIX C
SLOWLY INCREASING STEER TEST WORKSHEET

Applus IDIADA

Slowly Increasing Steer

Analyzed with dynasoft

Vehicle: 2021 Kia Sorento
Test Date: 2/5/2021
Analysis Date: 2/5/2021
Analysed by: EL
Executed by: OG
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
sis_001	L	50.7	0.3	99.5	1005	-27.0	-0.300	-175.7	-0.2440	-148.6	-0.2065	0.9972	362	562
sis_002	L	49.8	0.2	99.6	1013	-27.4	-0.300	-178.2	-0.2475	-150.8	-0.2094	0.9975	362	562
sis_003	L	49.7	-0.2	100.4	1015	-27.9	-0.300	-181.2	-0.2517	-153.3	-0.2130	0.9968	364	564
sis_004	R	50.5	0.5	99.1	1011	27.4	0.300	178.4	0.2478	151.0	0.2097	0.9976	367	567
sis_005	R	49.7	0.1	99.8	1021	28.4	0.300	184.7	0.2565	156.3	0.2170	0.9966	376	576
sis_006	R	49.8	-0.2	100.5	1027	28.2	0.300	183.0	0.2542	154.9	0.2151	0.9981	370	570

Mean: 27.7

Steering Controller Input values

Scalar 6.5 values:

Initial HW angle: 180.1 deg

Reversal HW angle: -180.1 deg

Scalar 5.5 values:

Initial HW angle: 152.4 deg

Reversal HW angle: -152.4 deg

APPENDIX D
TIME HISTORY PLOTS

LIST OF FIGURES

FILENAME: FH005

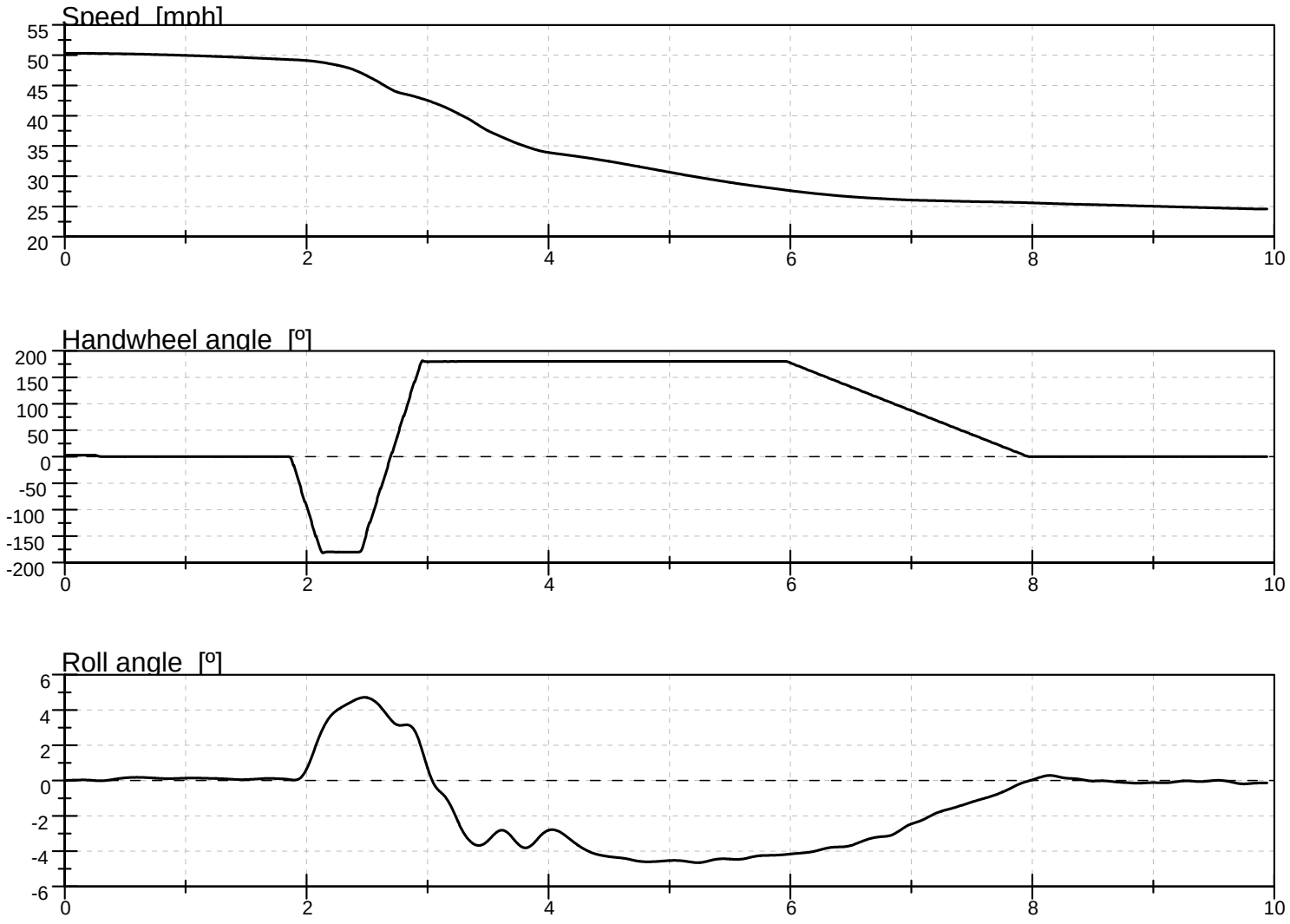

Figure D1. Vehicle Speed, Handwheel Angle, and Roll Angle Time History Plots for Default Test Series, L-R, 50 mph

FILENAME: FH005

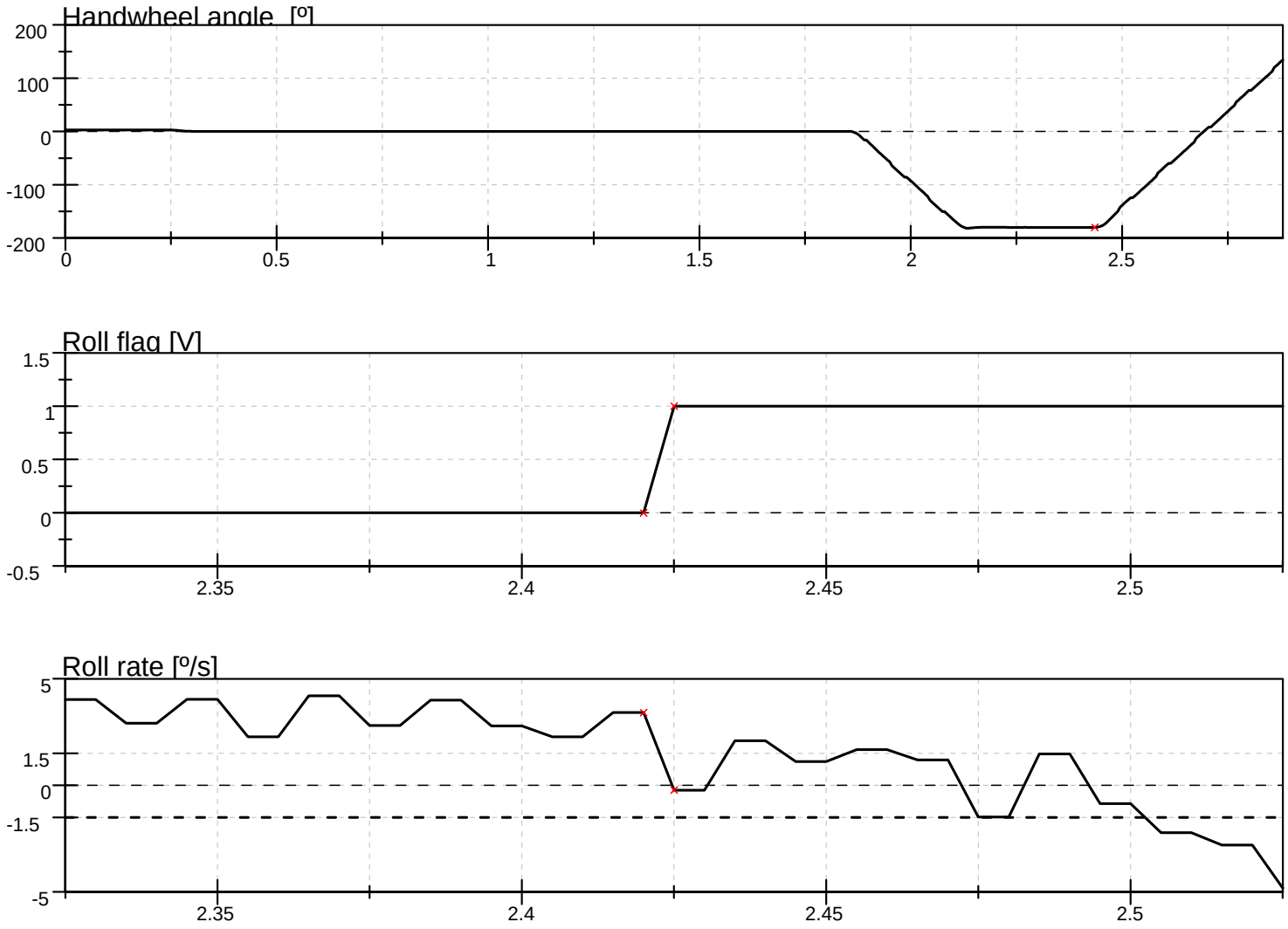

Figure D2. Steering Machine Operation Time History Plots for Default Test Series, L-R, 50 mph

FILENAME: FH005

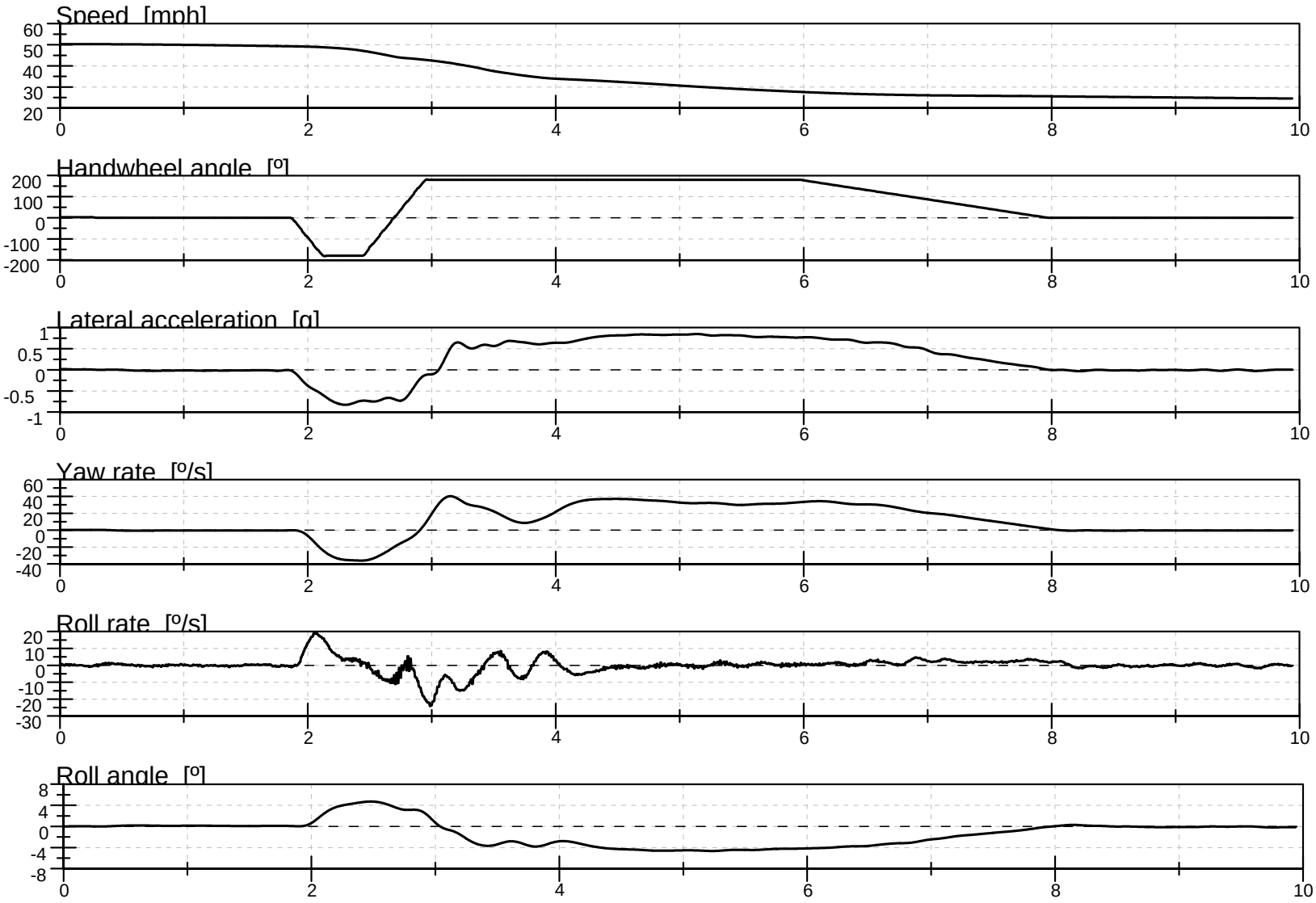

Figure D3. Yaw Rate, Roll Rate, and Lateral Acceleration Time History Plots For Default Test Series, L-R, 50 mph

FILENAME: FH005

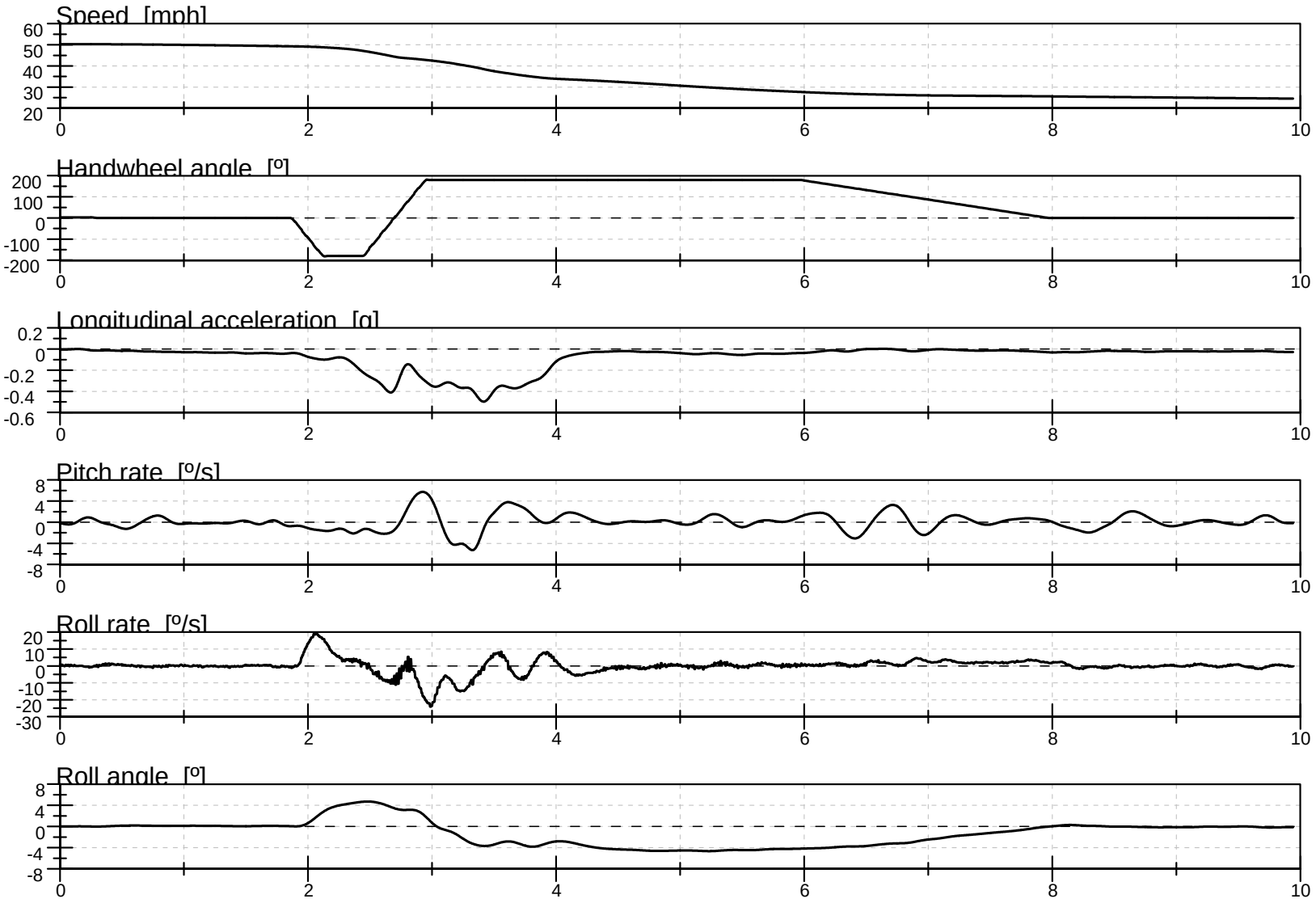

Figure D4. Pitch Rate and Longitudinal Acceleration Time History Plots for Default Test Series, L-R, 50 mph

FILENAME: FH010

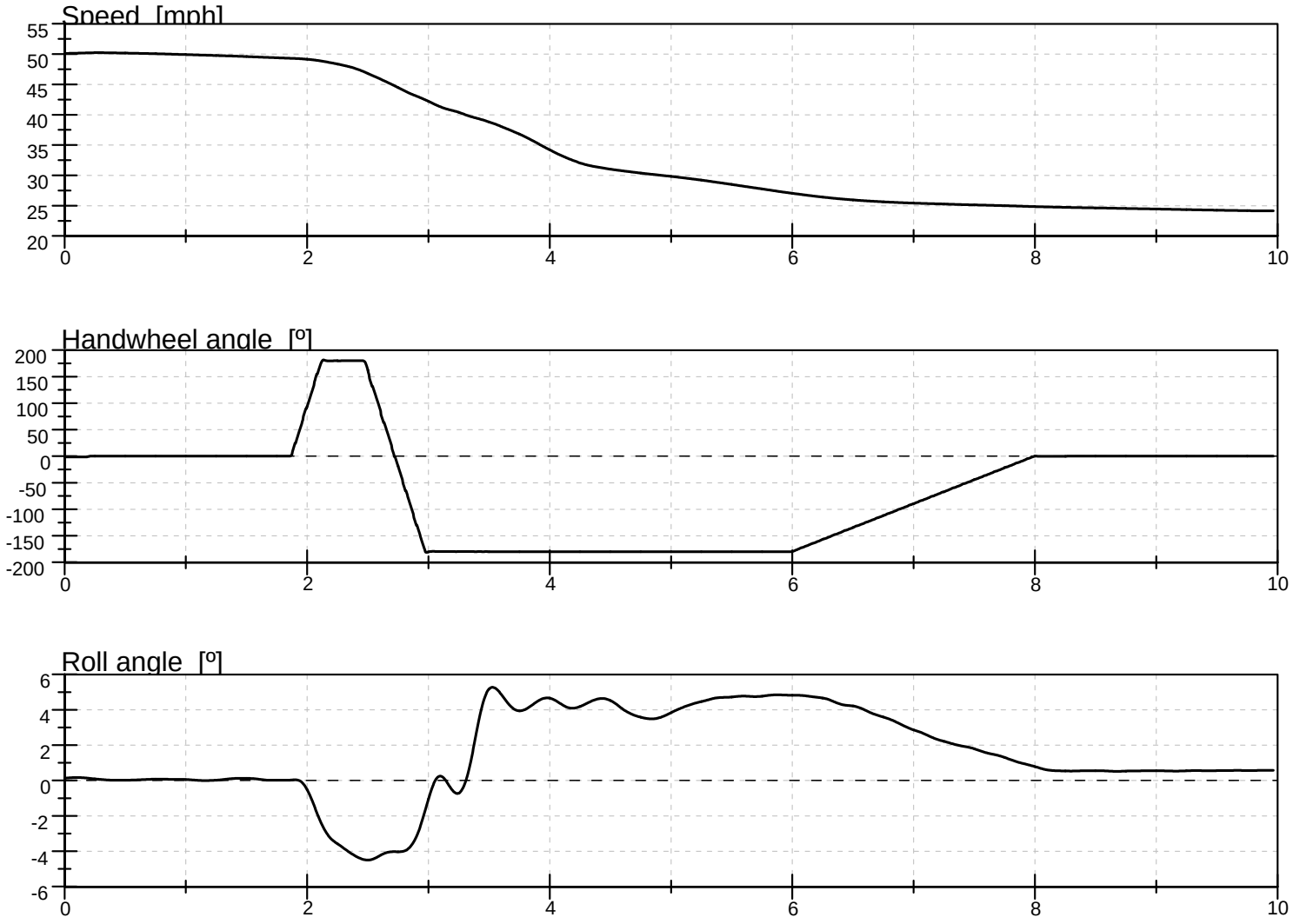

Figure D5. Vehicle Speed, Handwheel Angle, and Roll Angle Time History Plots for Default Test Series, R-L, 50 mph

FILENAME: FH010

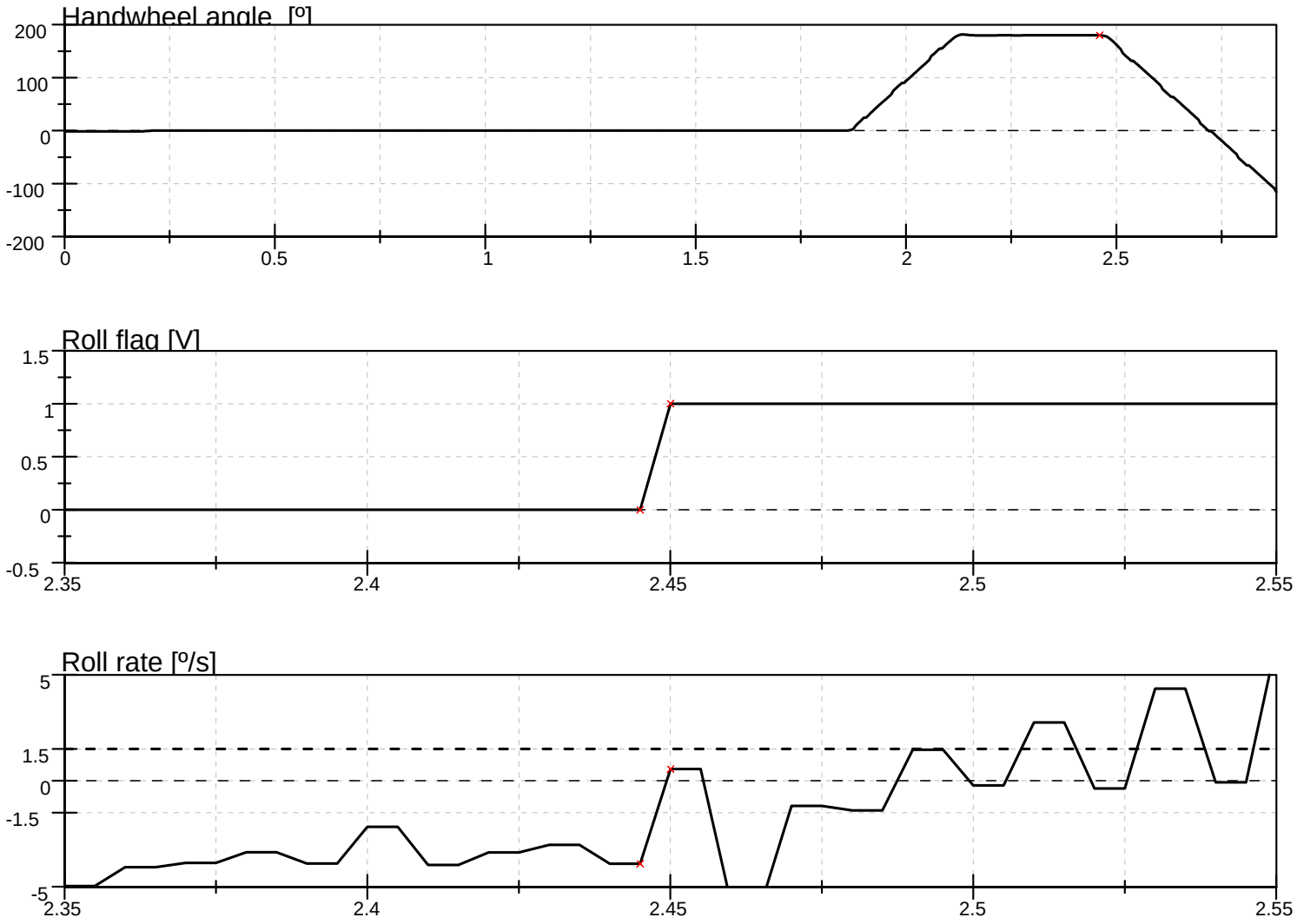

Figure D6. Steering Machine Operation Time History Plots for Default Test Series, R-L, 50 mph

FILENAME: FH010

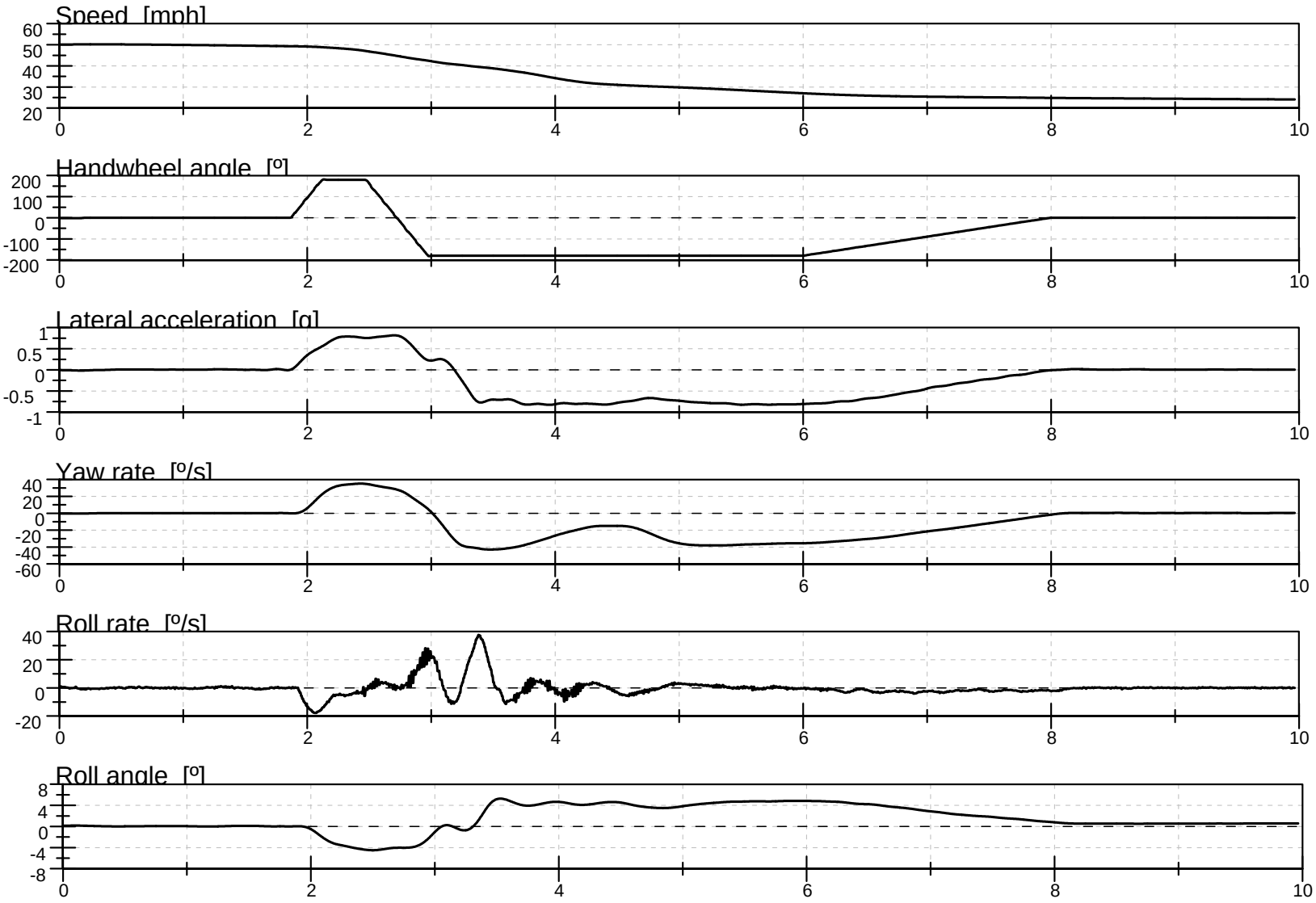

Figure D7. Yaw Rate, Roll Rate, and Lateral Acceleration Time History Plots for Default Test Series, R-L, 50 mph

FILENAME: FH010

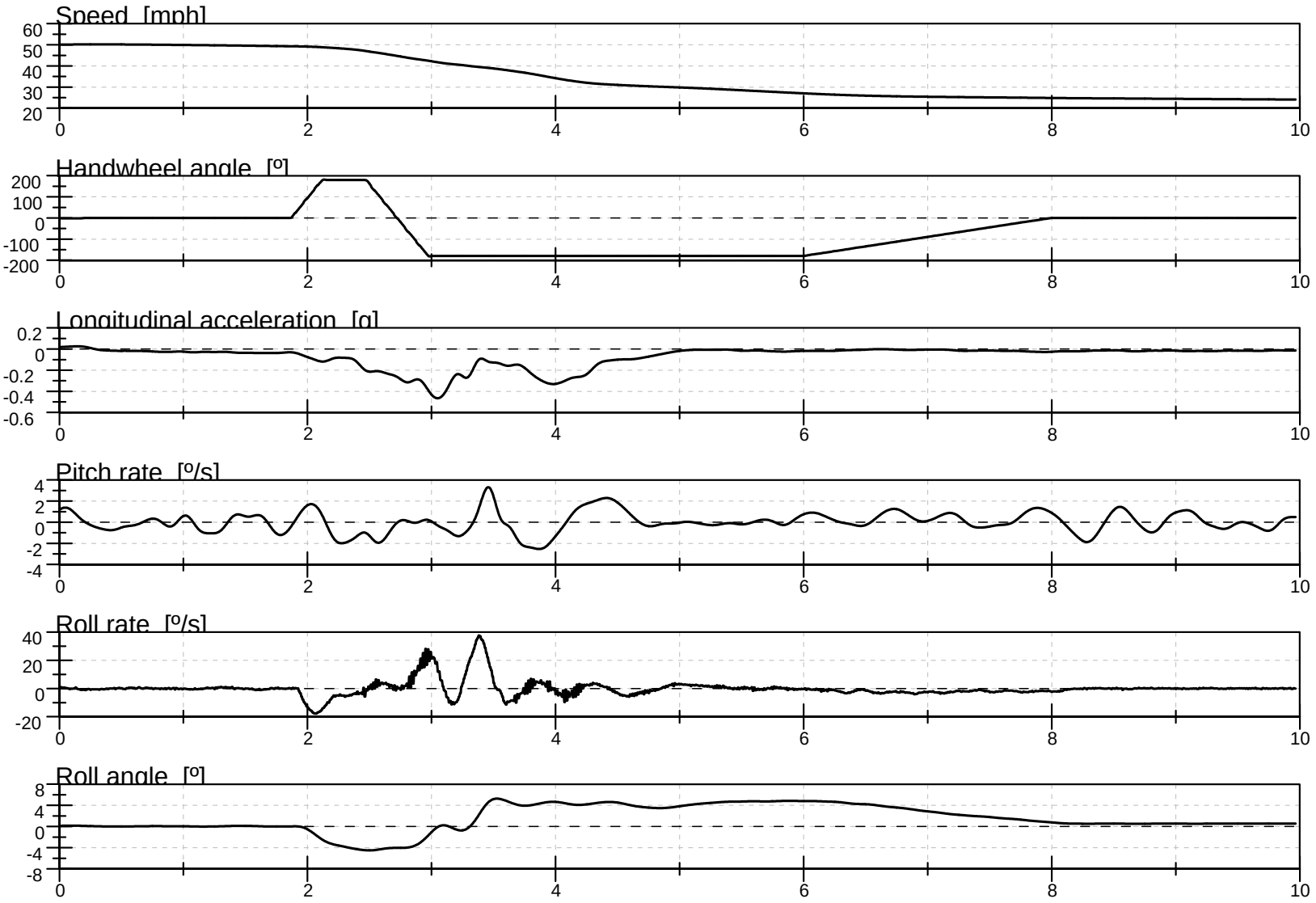

Figure D8. Pitch Rate and Longitudinal Acceleration Time History Plots or Default Test Series, R-L, 50 mph

FILENAME: FH013

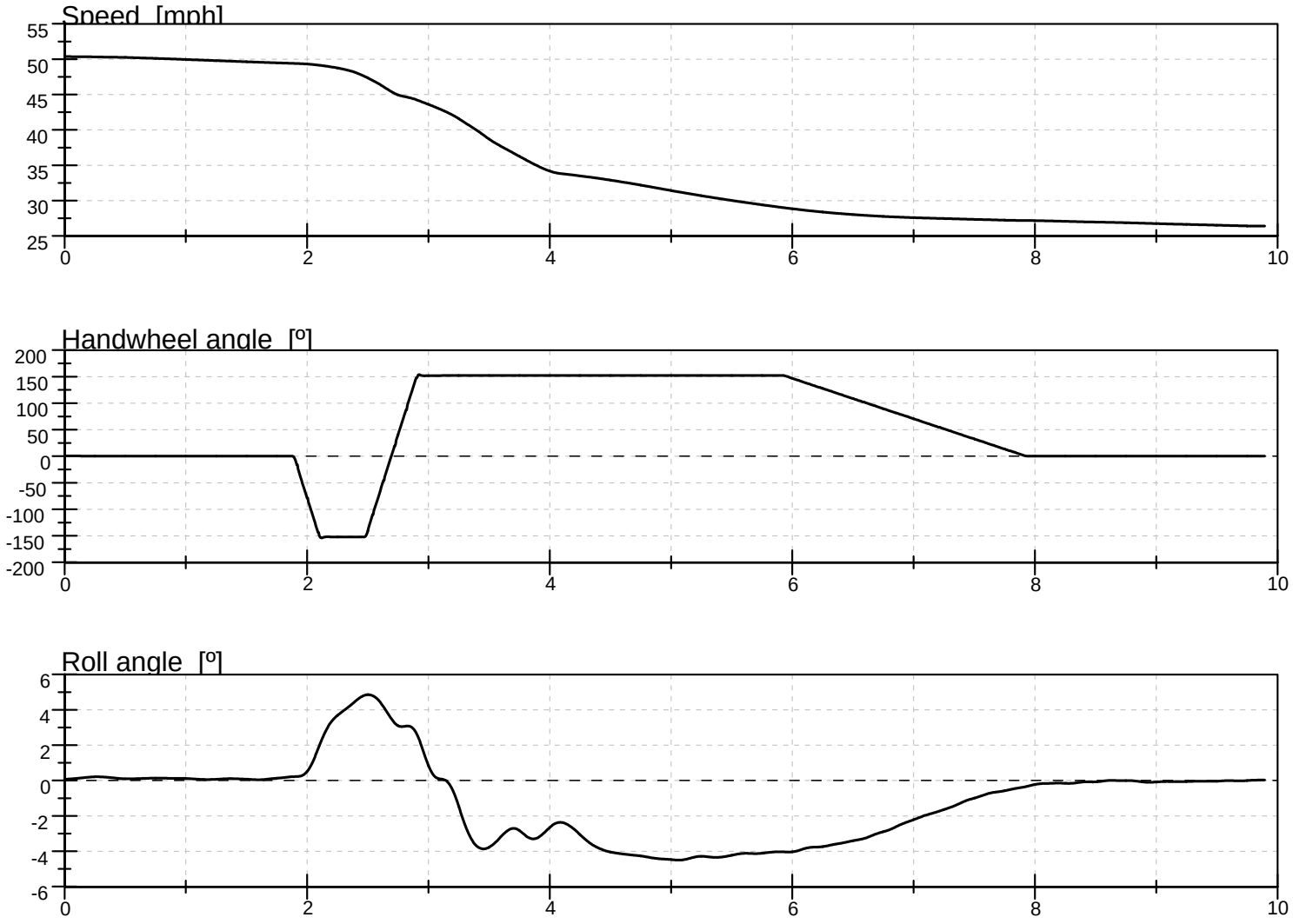

Figure D9. Vehicle Speed, Handwheel Angle, and Roll Angle Time History Plots for Supplemental 2 Test Series, L-R, 50 mph

FILENAME: FH013

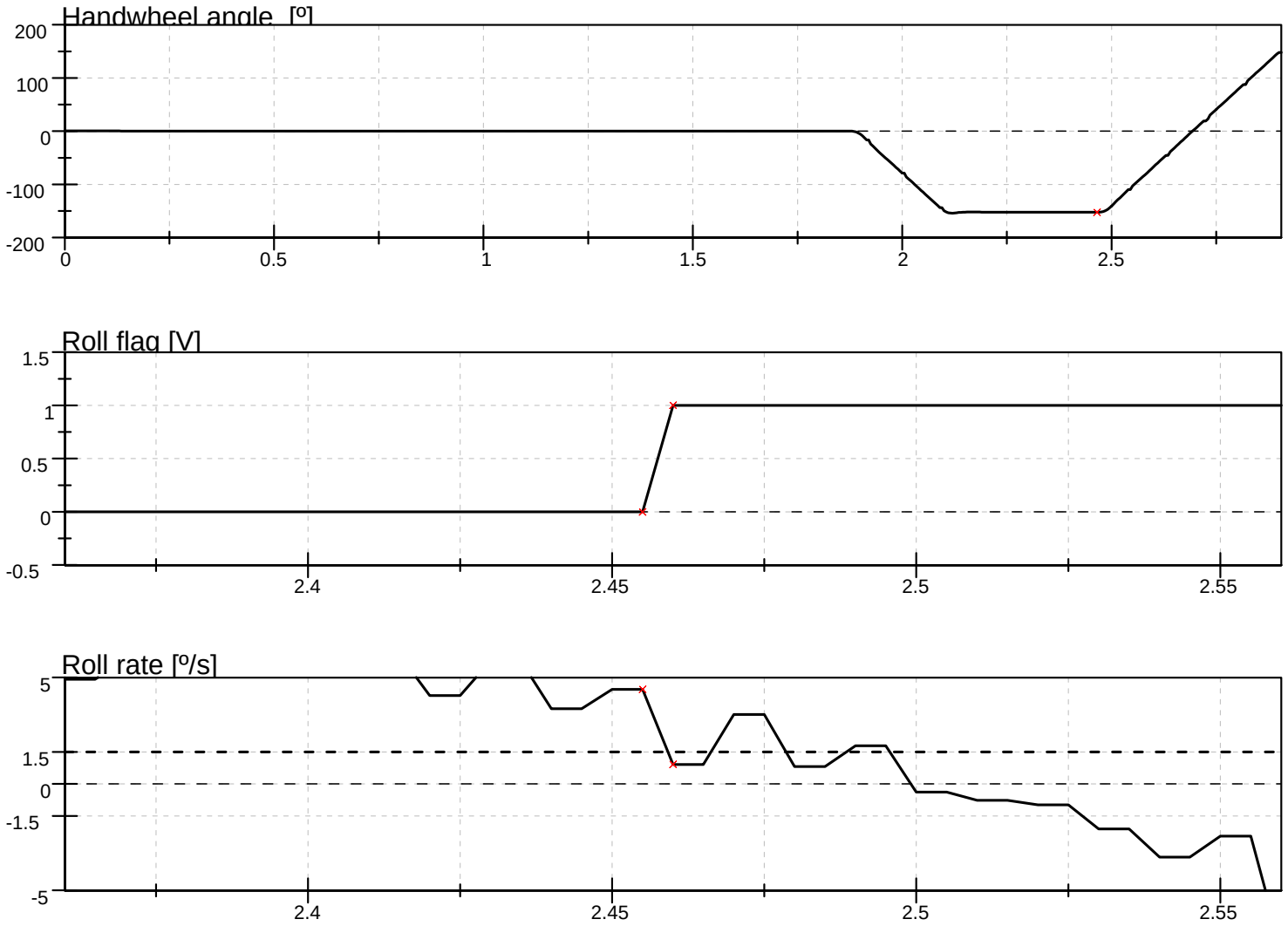

Figure D10. Steering Machine Operation Time History Plots for Supplemental 2 Test Series, L-R, 50 mph

FILENAME: FH013

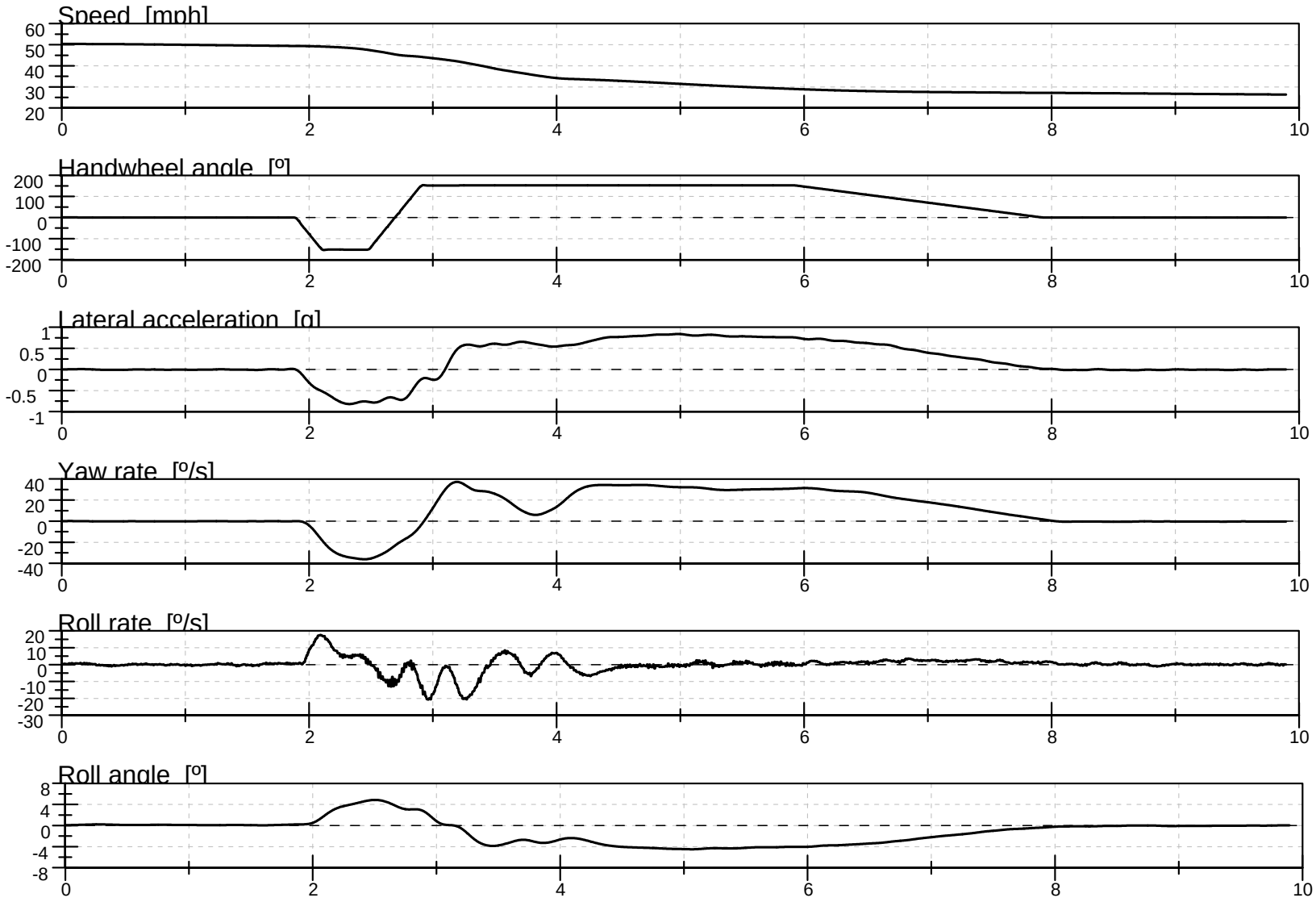

Figure D11. Yaw Rate, Roll Rate, and Lateral Acceleration Time History Plots for Supplemental 2 Test Series, L-R, 50 mph

FILENAME: FH013

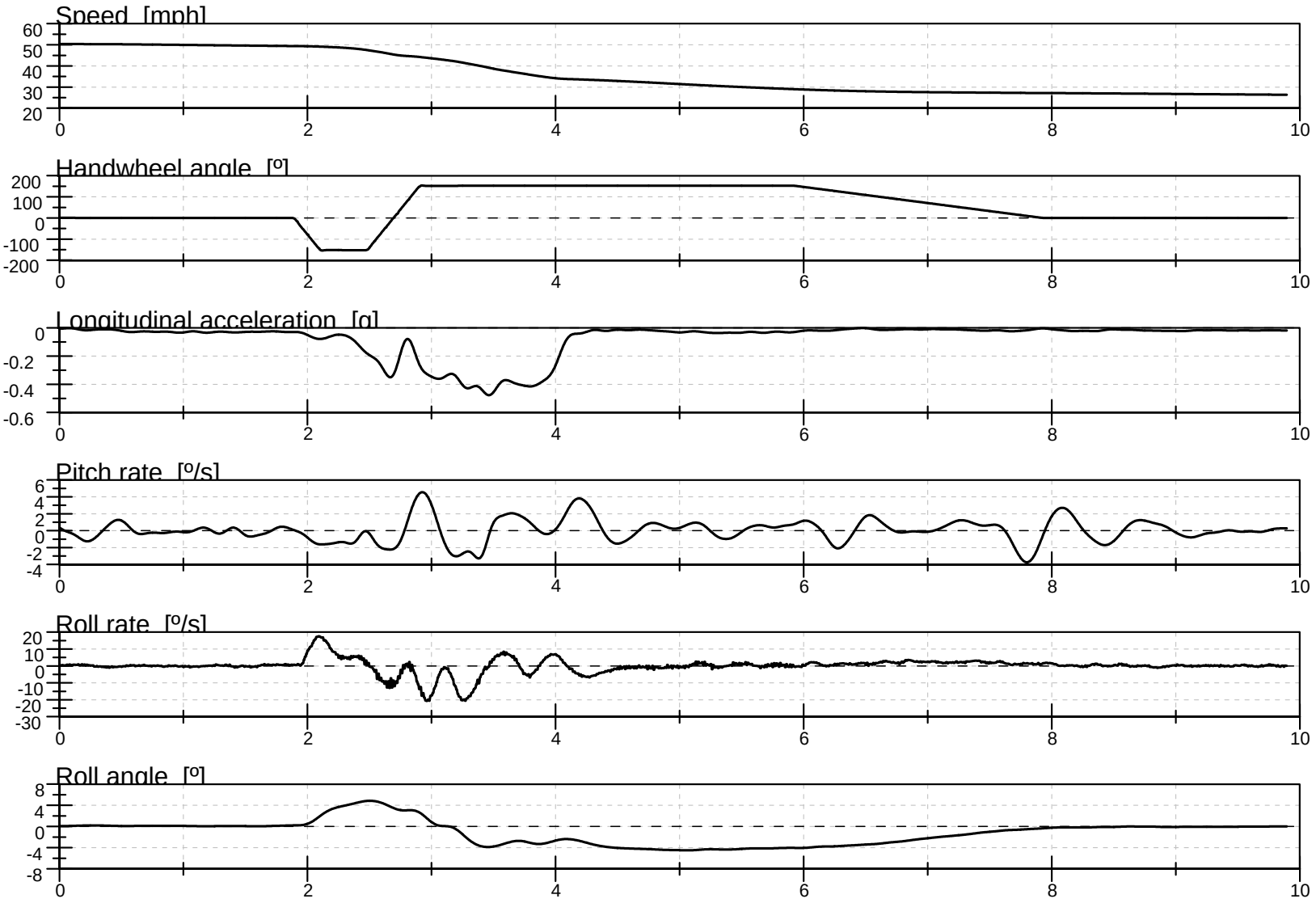

Figure D12. Pitch Rate and Longitudinal Acceleration Time History Plots for Supplemental 2 Test Series, L-R, 50 mph

FILENAME: FH016

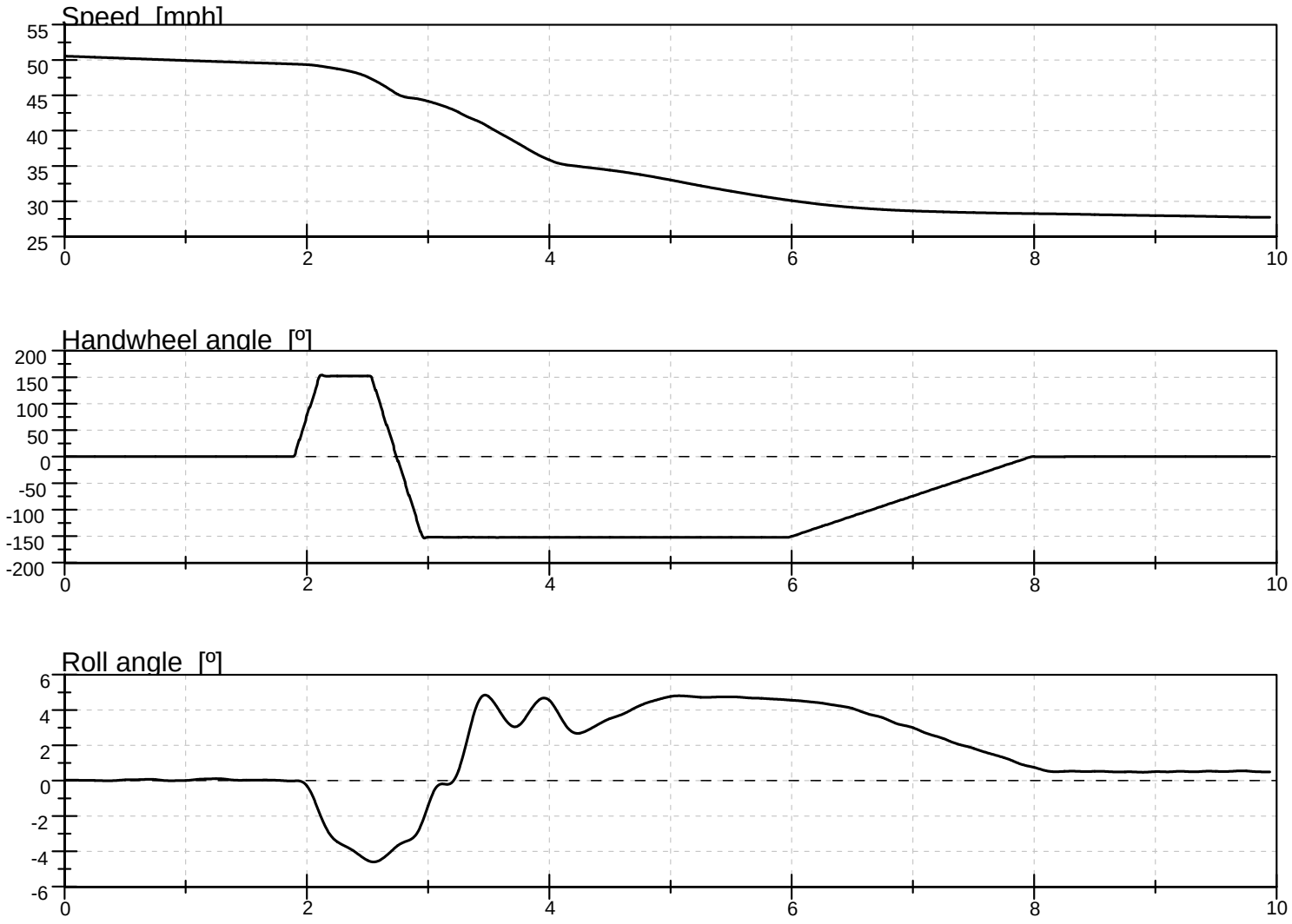

Figure D13. Vehicle Speed, Handwheel Angle, and Roll Angle Time History Plots for Supplemental 2 Test Series, R-L, 50 mph

FILENAME: FH016

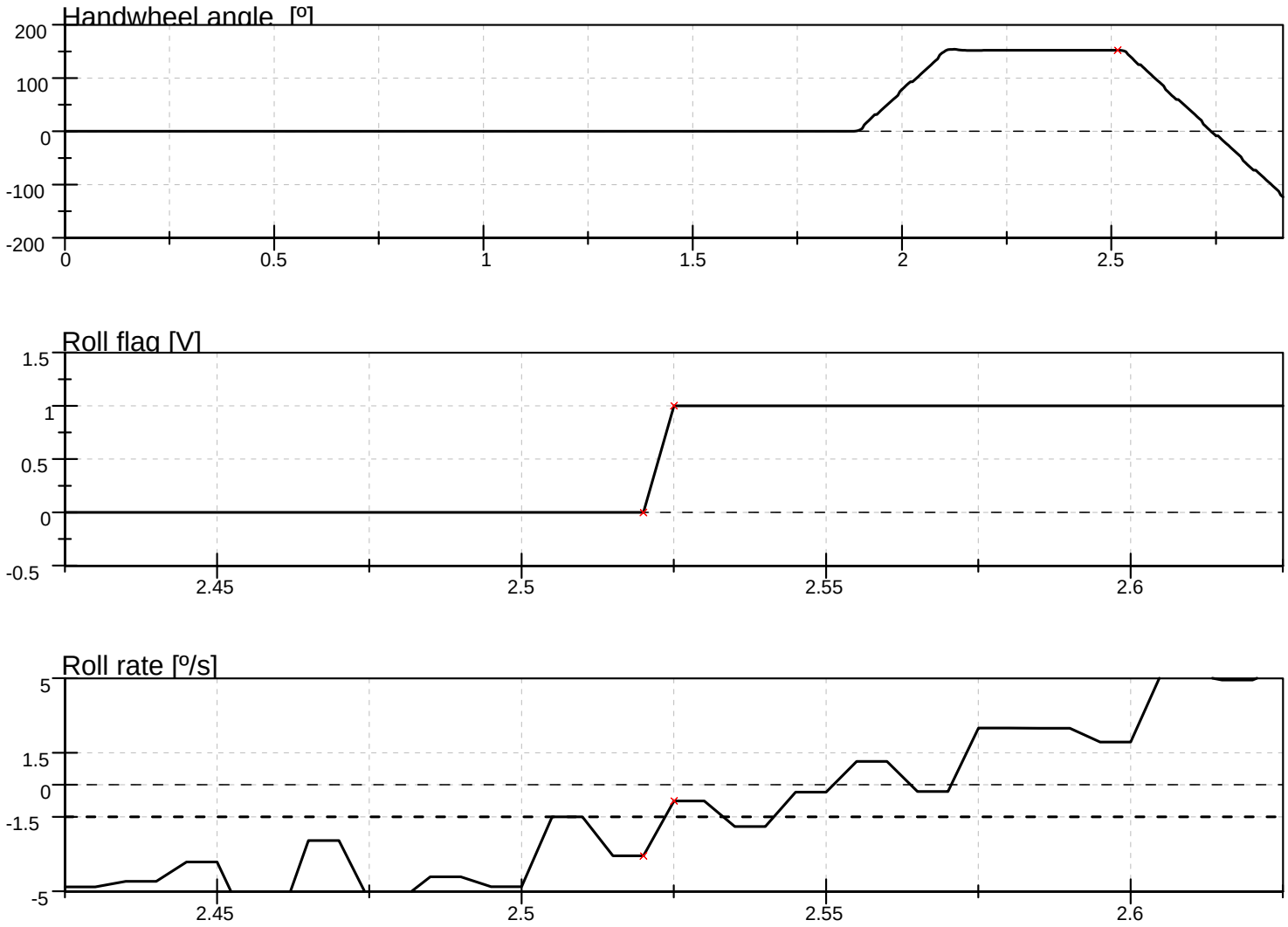

Figure D14. Steering Machine Operation Time History Plots for Supplemental 2 Test Series, R-L, 50 mph

FILENAME: FH016

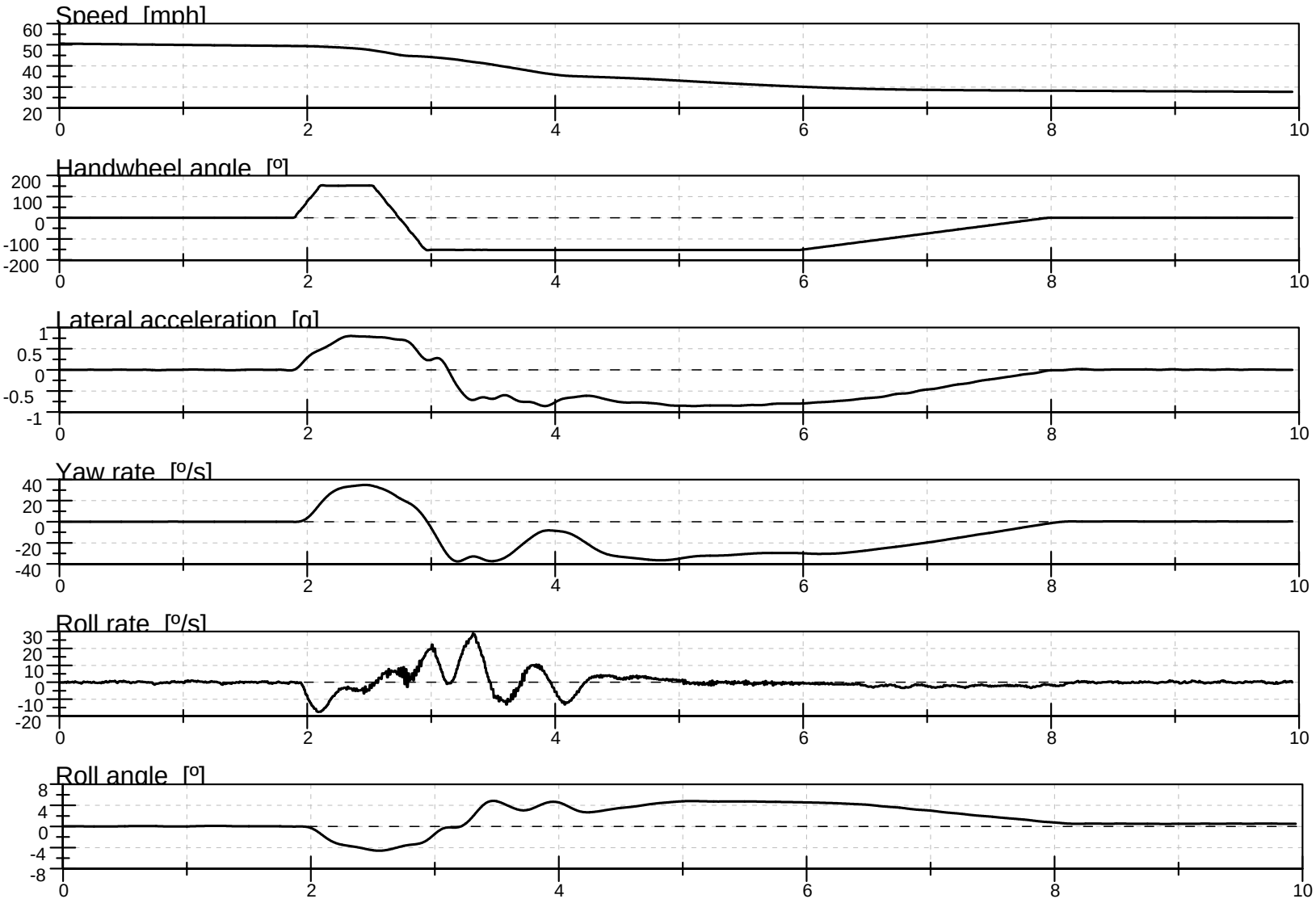

Figure D15. Yaw Rate, Roll Rate, and Lateral Acceleration Time History Plots for Supplemental 2 Test Series, R-L, 50 mph

FILENAME: FH016

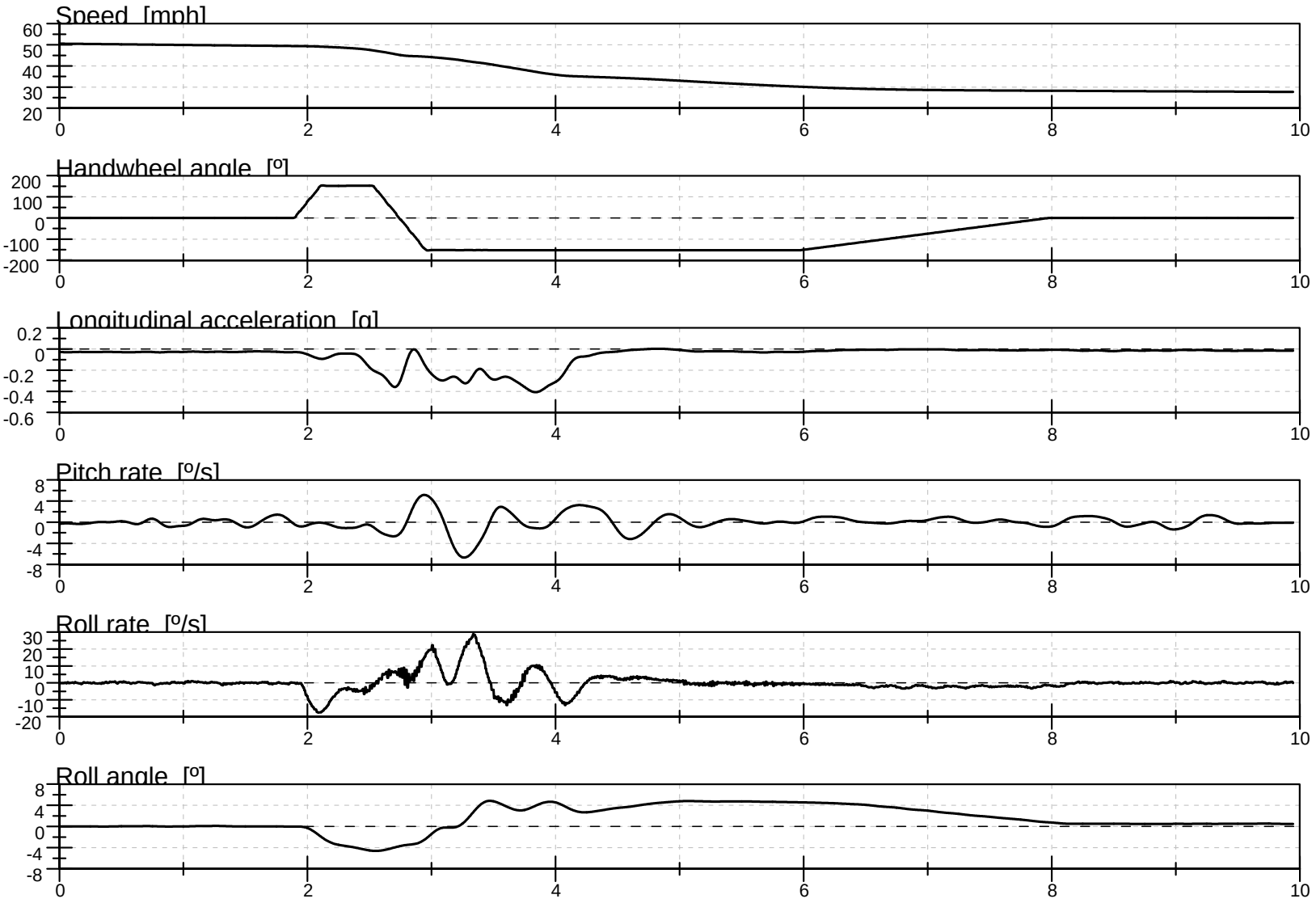

Figure D16. Pitch Rate and Longitudinal Acceleration Time History Plots for Supplemental 2 Test Series, R-L, 50 mph