126-DRI-11-005
SAFETY COMPLIANCE TESTING FOR FMVSS 126
Electronic Stability Control Systems

Kia Motors Corporation
2011 Kia Optima
NHTSA No. CB0516

DYNAMIC RESEARCH, INC.
355 Van Ness Avenue, STE 200
Torrance, California 90501

10 November, 2011

Final Report

Prepared Under Contract No.: DTNH22-08-D-00098

U. S. DEPARTMENT OF TRANSPORTATION
National Highway Traffic Safety Administration
Enforcement
Office of Vehicle Safety Compliance
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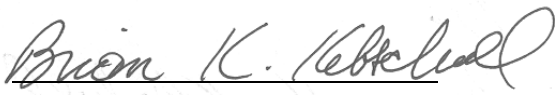
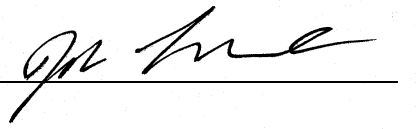
Prepared By: 

Approved By: 

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16. Abstract A test was conducted on a 2011 Kia Optima , NHTSA No. CB0516, in accordance with the specifications of the Office of Vehicle Safety Compliance Test Procedure No. TP-126-02 for the determination of FMVSS 126 compliance. Test failures identified were as follows: None			
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1.0 PURPOSE OF COMPLIANCE TEST

The purpose of this test is to determine if the test vehicle, a 2011 Kia Optima, meets the minimum equipment and performance requirements stated in Federal Motor Vehicle Safety Standard (FMVSS) 126, "Electronic Stability Control Systems."

2.0 TEST PROCEDURE AND DISCUSSION OF RESULTS

Testing of the 2011 Kia Optima was conducted at Dynamic Research, Inc (DRI) in accordance with NHTSA TP-126-02, dated November 19, 2008.

The vehicle was inspected to ensure it was equipped with an ESC system that:

- Augments vehicle directional stability by applying and adjusting brake torques individually at each wheel to induce a correcting yaw moment to a vehicle;
- Is computer controlled with the computer using a closed-loop algorithm to limit vehicle oversteer and to limit vehicle understeer;
- Has a means to determine the vehicle's yaw rate and to estimate its side slip or side slip derivative with respect to time;
- Has a means to monitor driver steering inputs;
- Has an algorithm to determine the need, and a means to modify engine torque, as necessary, to assist the driver in maintaining control of the vehicle; and
- Is operational over the full speed range of the vehicle (except at vehicle speeds less than 20 km/h (12.4 mph), when being driven in reverse, or during system initialization).

The vehicle was subjected to a 0.7 Hz Sine with Dwell steering maneuver to ensure that it would meet the stability and responsiveness requirements of the standard as follows:

- At 1.0 second after completion of a required Sine with Dwell steering input, the yaw rate of the vehicle must not exceed 35 percent of the first peak value of yaw rate recorded after the steering wheel angle changes sign (between first and second peaks during the same test run).

2.0 TEST PROCEDURE AND DISCUSSION OF RESULTS (CONTINUED)

- At 1.75 seconds after completion of a required Sine with Dwell steering input, the yaw rate of the vehicle must not exceed 20 percent of the first peak value of yaw rate recorded after the steering wheel angle changes sign (between first and second peaks during the same test run).

- For steering inputs of scalar 5 and greater, the lateral displacement of the vehicle center of gravity with respect to its initial straight path must be at least 1.83 m (6 feet) (for vehicles with a GVWR of 3,500 kg (7,716 lb) or less) when computed 1.07 seconds after the Beginning of Steer (BOS) at the specified steering wheel angles.

System malfunction simulations were executed to verify vehicle could identify and indicate a malfunction.

The vehicle's ESC System appears to meet the performance and equipment requirements as required by FMVSS 126. The test results are summarized on the following summary sheet.

2.0 TEST PROCEDURE AND DISCUSSION OF RESULTS (CONTD)

Data Summary Sheet (Page 1 of 2)

Vehicle: *2011 Kia Optima*

NHTSA No. *CB0516* VIN: *KNAGM4A7XB5173985*

Vehicle Type: *Passenger Car* Manufacture Date: *7/11*

Laboratory: *Dynamic Research, Inc.*

REQUIREMENTS:	**PASS/FAIL**
ESC Equipment and Operational Characteristics (Data Sheet 2)	
The vehicle is to be equipped with an ESC system that meets the equipment and operational characteristics requirements. (S126, S5.1, S5.6)	***PASS***
ESC Malfunction Telltale (Data Sheet 3)	
Vehicle is equipped with a telltale that indicates one or more ESC system malfunctions. (S126, S5.3)	***PASS***
"ESC Off" and other System Controls and Telltale (Data Sheet 3,4)	
Vehicle is equipped with an ESC off telltale indicating the vehicle has been put into a mode that renders the ESC system unable to satisfy the performance requirements of the standard, if such a mode exists. (S5.5.1)	***PASS***
If provided, off control and other system controls as well as the ESC off telltale meets the operational requirements (S126, S5.4, S5.4.1,S5.4.2, S5.5.4, and S5.5.9)	***PASS***

2.0 TEST PROCEDURE AND DISCUSSION OF RESULTS (CONTD)

Data Summary Sheet (Page 2 of 2)

REQUIREMENTS:	PASS/FAIL
Vehicle Lateral Stability (Data Sheet 8)	
Yaw Rate Ratio at 1 second after COS is less than 35% of peak value. (S126, S5.2.1)	***PASS***
Yaw Rate Ratio at 1.75 seconds after COS is less than 20% of peak value. (S126, S5.2.2)	***PASS***
Vehicle Responsiveness (Data Sheet 8)	
Lateral displacement at 1.07 seconds after BOS is at least 1.83 m (6 feet) for vehicles with a GVWR of 3,500 kg (7,716 lb) or less, and 1.52 m (5 feet) for vehicles with a GVWR greater than 3,500 Kg (7,716 lb). (S126, S5.2.3)	***PASS***
ESC Malfunction Warning (Data Sheet 9)	
Warning is provided to driver after malfunction occurrence. (S126. S5.3)	***PASS***
Malfunction telltale stayed illuminated as long as malfunction existed and must extinguish after malfunction was corrected. (S126, S5.3.7)	***PASS***

3.0 TEST DATA

Data Sheet 1 (Page 1 of 2)

TEST VEHICLE INSPECTION AND TEST PREPARATION

Vehicle: *2011 Kia Optima*

NHTSA No. *CB0516* Data Sheet Completion Date: *8/23/2011*

VIN *KNAGM4A7XB5173985* Manufacture Date: *7/11*

GVWR (kg): *1950* Front GAWR (kg): *1100* Rear GAWR (kg): *960*

Seating Positions Front: *2* Mid: Rear: *3*

Odometer reading at time of inspection: *7 miles (11.2 km)*

DESIGNATED TIRE SIZE(S) FROM VEHICLE LABELING:

Front axle: *P205/65R16* Rear axle: *P205/65R16*

INSTALLED TIRE SIZE(S) ON VEHICLE (from tire sidewall)

	Front Axle	Rear Axle
Tire Manufacturer:	*Nexen*	*Nexen*
Tire Model:	*Classe Premere CP671*	*Classe Premere CP671*
Tire Size:	*P205/65R16*	*P205/65R16*

TIN Left Front: *8EHE FMAR 2611* Right Front: *8EHE FAFL 2611*

Left Rear: *8EHE FMBR 2611* Right Rear: *8EHE FMER 2611*

Are installed tire sizes same as labeled tire sizes? *Yes*

If no, contact COTR for further guidance

DRIVE CONFIGURATION(S):(mark all that apply)

[X] Two Wheel Drive (2WD) [X] Front Wheel Drive [ ] Rear Wheel Drive

[ ] All Wheel Drive (AWD)

[ ] Four Wheel Drive Automatic - differential no locked full time (4WD Automatic)

[ ] Four Wheel Drive (High Gear Locked Differential 4WD HGLD)

[ ] Four Wheel Drive Low Gear (4WD Low)

[ ] Other (Describe)

3.0 TEST DATA (CONTD)

Data Sheet 1 (Page 2 of 2)
TEST VEHICLE INSPECTION AND TEST PREPARATION

DRIVE CONFIGURATIONS AND MODES: (ex. default, performance, off)

(For each of the vehicle's drive configurations identify available operating modes)

Drive Configuration: *FWD*
Mode: *Default - ESC on*
Drive Configuration: *FWD*
Mode: *ESC off*
Drive Configuration:
Mode:

VEHICLE STABILITY SYSTEMS (Check applicable technologies):

List other systems:

[X] ESC	[X] Traction Control	[ ] Roll Stability Control
[ ] Active Suspension	[ ] Electronic Throttle Control	[ ] Active Steering
[X] ABS	[X] Other *Hill Start Assist Control (HAC)*	

Hill-Start Assist Control (HAC)

REMARKS:

RECORDED BY: *J Lenkeit* DATE RECORDED: *8/23/2011*
APPROVED BY: *P Broen* DATE APPROVED: *8/30/2011*

3.0 TEST DATA (CONTD)

Data Sheet 2 (Page 1 of 2)
ESC SYSTEM HARDWARE AND OPERATIONAL CHARACTERISTICS

Vehicle: *2011 Kia Optima*

NHTSA No *CB0516* Data Sheet Completion Date: *9/22/2011*

ESC SYSTEM IDENTIFICATION

Manufacturer/Model *MANDO, MGH 60 ESC*

ESC SYSTEM HARDWARE (Check applicable hardware)

[X] Electronic Control Unit	[X] Hydraulic Control Unit
[X] Wheel Speed Sensors	[X] Steering Angle Sensor
[X] Yaw Rate Sensor	[X] Lateral Acceleration Sensor

List other Components: _____

ESC OPERATIONAL CHARACTERISTICS

System is capable of generating brake torque at each wheel — [X] Yes (Pass) [ ] No (Fail)

Brief explanation: *The brake slip controller controls the absolute slip of each wheel. If the major control loop requests a change in the nominal brake slip, then the change is added to the nominal slip to result in values of the brake slip. The outputs of the brake slip controller are the nominal wheel torques, which are then transformed to the required pressure values in the wheel brake cylinders with due consideration of the engine management for engine drag reduction. These nominal pressure values are then converted to adequate actuation commands for the hydraulic unit.*

System is capable of determining yaw rate — [X] Yes (Pass) [ ] No (Fail)

Brief explanation: *The actual value of the yaw rate is supplied by the yaw rate sensor.*

3.0 TEST DATA (CONTD)

Data Sheet 2 (Page 2 of 3)
ESC SYSTEM HARDWARE AND OPERATIONAL CHARACTERISTICS

ESC OPERATIONAL CHARACTERISTICS (continued)

System is capable of monitoring driver steering input — **X** Yes (Pass) / ___ No (Fail)

Brief explanation: *The actual value of driver steering input is supplied by steering sensor.*

System is capable of estimating side slip or side slip derivative — **X** Yes (Pass) / ___ No (Fail)

Brief explanation: *ESC ECU collects information from steering angle sensor, wheel speed sensor and yaw rate sensor, and they are used to determine estimated side slip or the side slip derivative.*

System is capable of modifying engine torque during ESC activation. — **X** Yes (Pass) / ___ No (Fail)

Method used to modify torque: *As an optional feature, in the case that the wheel brake slip can not sufficiently be reduced by pressure increase, the engine torque can be reduced using ignition or spark timing and fuel delivery.*

System is capable of activation at speeds of 20 km/h (12.4 mph) and higher — **X** Yes (Pass) / ___ No (Fail)

Speed system becomes active: *15 km/h*

System is capable of activation during the following driving phases: — **X** Yes (Pass) / ___ No (Fail)

- acceleration
- braking
- coasting
- during activation of ABS or traction control

Driving phases during which ESC is capable of activation:
ESC system can activate all driving phases (acceleration, deceleration, coasting, during activation of the ABS or Traction Control), but ESC control is disabled during backwards driving, low speed driving.

3.0 TEST DATA (CONTD)

Data Sheet 2 (Page 3 of 3)
ESC SYSTEM HARDWARE AND OPERATIONAL CHARACTERISTICS

ESC OPERATIONAL CHARACTERISTICS (continued)

Vehicle manufacturer submitted documentation explaining how the ESC mitigates understeer	**X**	Yes (Pass)
	___	No (Fail)

DATA INDICATES COMPLIANCE: **X** Yes (Pass)

REMARKS:

RECORDED BY:	*J Lenkeit*	DATE RECORDED:	*9/22/2011*
APPROVED BY:	*P Broen*	DATE APPROVED:	*9/22/2011*

3.0 TEST DATA (CONTD)

Data Sheet 3 (Page 1 of 2)
ESC MALFUNCTION AND OFF TELLTALES

Vehicle: *2011 Kia Optima*

NHTSA No. *CB0516* Data Sheet completion date: *8/30/2011*

ESC Malfunction Telltale

Vehicle is equipped with malfunction telltale? *Yes*

Telltale Location: *Left side of instrument cluster, near center of tachometer*

Telltale Color: *Yellow*

Telltale symbol or abbreviation used

or **ESC**

[X] Vehicle uses this symbol

[ ] Vehicle uses this abbreviation

[ ] Neither symbol or abbreviation is used

If different than identified above, make note of any message, symbol or abbreviation used.

Is telltale part of a common space? *No*

Is telltale also used to indicate activation of the ESC system? *Yes*

If yes explain telltale operation during ESC activation:

When a slippery or low traction condition is encountered, the ESC will operate and the ESC indicator will blink to indicate the ESC is operating.

3.0 TEST DATA (CONTD)

Data Sheet 3 (Page 2 of 2)
ESC MALFUNCTION AND OFF TELLTALES

"ESC OFF" Telltale (if provided)

Vehicle is equipped with "ESC OFF" telltale? *Yes*

Is "ESC Off" telltale combined with "ESC Malfunction" telltale utilizing a two part telltale? *No*

Telltale Location: *Left side of instrument cluster, near center of tachometer*

Telltale Color: *Yellow*

Telltale symbol or abbreviation used

or **ESC OFF**

- [X] Vehicle uses this symbol
- [ ] Vehicle uses this abbreviation
- [ ] Neither symbol or abbreviation is used

If different than identified above, make note of any message, symbol or abbreviation used.

Is telltale part of a common space? *No*

DATA INDICATES COMPLIANCE ***Yes***

(Vehicle is compliant if equipped with a malfunction telltale)

Remarks:

RECORDED BY: *J Lenkeit* DATE RECORDED: *8/30/2011*

APPROVED BY: *P Broen* DATE APPROVED: *8/30/2011*

3.0 TEST DATA (CONTD)

Data Sheet 4 (Page 1 of 3)
ESC AND ANCILLARY SYSTEM CONTROLS

Vehicle: *2011 Kia Optima*

NHTSA No. *CB0516* Data Sheet completion date: *8/30/2011*

"ESC OFF" Controls Identification and Operational Check:

Is the vehicle equipped with a control or controls whose purpose is to deactivate the ESC system or place the ESC system in a mode or modes that may no longer satisfy the performance requirements of the standard? **X** Yes ____ No

Type of control or controls provided? (mark all that apply)

- [X] Dedicated "ESC Off" Control
- [ ] Multi-functional control with an "ESC Off" mode
- [ ] Other (describe)

Identify each control location, labeling and selectable modes.

First Control:	Location	*Left knee bolster*
	Labeling	*Sliding car symbol with the text "OFF" underneath*
	Modes	
Second Control:	Location	
	Labeling	
	Modes	

Identify standard or default drive configuration *FWD*

Verify standard or default drive configuration **X** Yes ____ No

Does the "ESC Off" telltale illuminate upon activation of the dedicated ESC off control or selection of the "ESC Off" mode on the multi-function control?

____ NA **X** Yes ____ No (Fail)

Does the "ESC Off" telltale extinguish when the ignition is cycled from "on" ("Run") to "Lock" or "Off" and then back again to the "On" ("Run") position?

____ NA **X** Yes ____ No (Fail)

If no, describe how the "Off" control functions

3.0 TEST DATA (CONTD)

Data Sheet 4 (Page 2 of 3)
ESC AND ANCILLARY SYSTEM CONTROLS

If a multi-function control is provided, cycle through each mode setting on the control and record which modes illuminate the "ESC Off" telltale. Also, for those modes that illuminate the ESC Off" telltale identify if the telltale extinguishes upon cycling the ignition system.

Control Mode	"ESC Off" telltale illuminates upon activation of control? (Yes/No)	"ESC Off" telltale extinguishes upon cycling ignition? (Yes/No)
NA		

For each mode that illuminates the "ESC Off" telltale, did the telltale extinguish when the ignition was cycled from "On" ("Run") to "Lock" or "Off" and then back again to the "On" ("Run") position?

_X_ NA ___ Yes ___ No

Other System Controls that have an ancillary effect on ESC Operation:

Is the vehicle equipped with any ancillary controls that upon activation may deactivate the ESC system or place the ESC system in a mode or modes that may no longer satisfy the performance requirements of the standard? ___ Yes _X_ No

Ancillary Control: System *NA*
Control Description
Labeling

Ancillary Control: System
Control Description
Labeling

Ancillary Control: System
Control Description
Labeling

3.0 TEST DATA (CONTD)

Data Sheet 4 (Page 3 of 3)
ESC AND ANCILLARY SYSTEM CONTROLS

Activate each ancillary control listed above and record whether the control illuminates the "ESC Off" telltale. Also, record warnings or messages provided regarding the ESC system.

Ancillary Control	Control Activates "ESC Off" Telltale? (Yes/No)	Warnings or Messages Provided
NA		

For those controls that illuminate the "ESC Off" telltale above identify if the "ESC Off" telltale extinguishes upon cycling the ignition system.

Ancillary Control	"ESC Off" telltale extinguishes upon cycling ignition? (Yes/No)
NA	

For each ancillary control that illuminates the "ESC Off" telltale, did the telltale extinguish when the ignition is cycled from "On" ("Run") to "Lock" or "Off" and then back again to the "On" ("Run") position? If activating the control places the vehicle into a low-range four-wheel drive configuration designed for low-speed, off–road driving, the ESC system may remain turned off after the ignition has been cycled off and then back on and therefore the "ESC Off" telltale may not extinguish.

___ Yes ___ No (Fail) X NA

DATA INDICATES COMPLIANCE: PASS

Remarks:

RECORDED BY: *J Lenkeit* DATE RECORDED: *8/30/2011*
APPROVED BY: *P Broen* DATE APPROVED: *8/30/2011*

3.0 TEST DATA (CONTD)

Data Sheet 5 (Page 1 of 3)
TEST TRACK AND VEHICLE DATA

Vehicle: *2011 Kia Optima*

NHTSA No. *CB0516* Data Sheet completion date: *9/7/2011*

Test Track Requirements: Test surface slope (0-1%): *0.5%*

Peak Friction Coefficient (at least 0.9) *0.931*

Test track data meets requirements: *Yes* If no, explain:

Full Fluid Levels: Fuel *Yes* Other Fluids *Yes* (specify)

Coolant *Yes* *Oil, Washer Fluid, Brake Fluid*

Tire Pressures:

Required; Front Axle *225* kPa Rear Axle *225* kPa

Actual; LF *225* kPa RF *225* kPa

LR *225* kPa RR *225* kPa

Vehicle Dimensions: Front Track Width *160.0* cm Wheelbase *280.4* cm

Rear Track Width *159.8* cm

Vehicle Weight Ratings: GAWR Front *1100* kg GAWR Rear *960* kg

Unloaded Vehicle Weight (UVW):

Front Axle *885.0* kg Left Front *474.5* kg Right Front *410.5* kg

Rear Axle *603.3* kg Left Rear *281.2* kg Right Rear *322.1* kg

Total UVW *1488.3* kg

Baseline Weight and Outrigger Selection (only for MPVs, Trucks, Buses)

Calculated baseline weight (UVW + 73kg) *1561.3* kg

Outrigger size required ("Standard" or "Heavy") *None*

Standard - Baseline weight under 2772 kg (6000 lb)
Heavy - Baseline weight equal to or greater than 2772 kg (6000 lb)

3.0 TEST DATA (CONTD)

Data Sheet 5 (Page 2 of 3)
TEST TRACK AND VEHICLE DATA

UVW with Outriggers: (only for MPVs, Trucks, Buses)

Front axle *NA* kg Left front *NA* kg Right front *NA* kg

Rear axle *NA* kg Left rear *NA* kg Right rear *NA* kg

Total UVW with outriggers *NA* kg

Loaded Vehicle Weight w/Driver and Instrumentation (no Ballast)

Front axle *971.6* kg Left front *531.6* kg Right front *440.0* kg

Rear axle *680.8* kg Left rear *323.4* kg Right rear *357.4* kg

Vehicle Weight *1652.4* kg

Ballast Required =	[Total UVW with Outriggers (if applicable)]		+ *168*	kg	- [Loaded Weight w/Driver and Instrumentation)]	
=	*1488.3*	kg	+ *168*	kg	- 1652.4	kg

= *3.9* kg

Total Loaded Vehicle Weight w/Driver and Instrumentation and Ballast

Front axle *973.0* kg Left front *532.1* kg Right front *440.9* kg

Rear axle *683.5* kg Left rear *324.3* kg Right rear *359.2* kg

Total UVW *1656.5* kg

3.0 TEST DATA (CONTD)

Data Sheet 5 (Page 3 of 3)
TEST TRACK AND VEHICLE DATA

Center of Gravity and Inertial Sensing System Location at Loaded Vehicle Condition:

x-distance (longitudinal)	Point of reference is the front axle centerline. (Positive from front axle toward rear of vehicle.)
y-distance (lateral)	Point of reference is the vehicle centerline. (Positive from the center toward the right.)
z-distance (vertical)	Point of reference is the ground plane. (Positive from the ground up.)

Locations:

	Center of Gravity				Inertial Sensing System			
x-distance	*45.5*	in	*115.7*	cm	*70.4*	in	*178.9*	cm
y-distance	*-1.1*	in	*-2.7*	cm	*0.2*	in	*0.6*	cm
z-distance	*21.9*	in	*55.6*	cm	*13.8*	in	*35.0*	cm
Roof Height					*57.578*	in	*146.2*	cm
Distance between ultrasonic sensors					*84.0*	in	*213.4*	cm

Remarks:

RECORDED BY: *B Kebschull* DATE RECORDED: *9/7/2011*
APPROVED BY: *J Lenkeit* DATE APPROVED: *9/12/2011*

3.0 TEST DATA (CONTD)

Data Sheet 6 (Page 1 of 3)
BRAKE AND TIRE CONDITIONING

Vehicle: *2011 Kia Optima*

NHTSA No. *CB0516*

Measured tire pressure: LF *234* kPa RF *232* kPa

LR *234* kPa RR *234* kPa

Wind Speed *1.3* m/s (10 m/sec (22 mph) max for passenger cars; 5m/sec (11 mph) max for MPVs and trucks)

Ambient Temperature (7°C (45°F) - 40°C (104°F)) *28* °C

Brake Conditioning Time: *9:28:00 AM* Date: *9/7/2011*

56 km/h (35 mph) Brake Stops

Number of stops executed (10 required) *10* Stops

Observed deceleration range (0.5g target) *0.45 - 0.55* g

72 km/h (45 mph) Brake Stops

Number of stops executed (3 required) *3* Stops

Number of stops ABS activated (3 required) *3* Stops

Observed deceleration range *0.85 - 0.95* g

72 km/h (45 mph) Brake Cool Down Period

Duration of cool down period (5 minutes min.) *5* Minutes

3.0 TEST DATA (CONTD)

Data Sheet 6 (Page 2 of 3)
BRAKE AND TIRE CONDITIONING

Tire Conditioning series No. 1 Time: *9:42:00 AM* Date: *9/7/2011*

Measured cold tire pressure LF *253* kPa RF *254* kPa

LR *242* kPa RR *245* kPa

Wind Speed *0* m/s (10 m/sec (22 mph) max for passenger cars; 5m/sec (11 mph) max for MPVs and trucks)

Ambient Temperature (7°C (45°F) - 40°C (104°F)) *30*°C

30 meter (100 ft) Diameter Circle Maneuver				
Test Run	Steering Direction	Target Lateral Acceleration (g)	Observed Lateral Acceleration (g)	Observed Vehicle Speed (km/h)
1-3	Clockwise	0.5 – 0.6	*0.5 - 0.6*	*31.2 - 32.8*
4-6	Counterclockwise	0.5 – 0.6	*0.5 - 0.6*	*31.2 - 32.8*

5-1 Hz Cycle Sinusoidal Steering Maneuver to Determine Steering Wheel Angle for 0.5-0.6 g Lateral Acceleration					
Test Run	Data File	Vehicle Speed km/h(mph)	Steering Wheel Angle (degrees)	Target Peak Lateral Acceleration (g)	Observed Peak Lateral Acceleration (g)
1	2	56 ± 2 (35 ± 1)	*60*	0.5 - 0.6	*0.36*
2	3	56 ± 2 (35 ± 1)	*90*	0.5 - 0.6	*0.51*
3		56 ± 2 (35 ± 1)		0.5 - 0.6	
4		56 ± 2 (35 ± 1)		0.5 - 0.6	

Steering wheel angle that corresponds to a peak 0.5-0.6 g lateral acceleration: *90* degrees

10-1 Hz Cycle Sinusoidal Steering Maneuver					
Test Run	Data File	Vehicle Speed km/h (mph)	Steering Wheel Angle (degrees)	Target Peak Lateral Acceleration (g)	Observed Peak Lateral Acceleration (g)
1-3	*4-6*	56 ± 2 (35 ± 1)	*90* (cycles 1-10)	0.5 - 0.6	*0.51*
4	*7*	56 ± 2 (35 ± 1)	*90* (cycles 1-9)	0.5 - 0.6	*0.51*
			180 (cycle10)*	NA	*0.78*

* The steering wheel angle used for cycle 10 should be twice the angle used for cycles 1-9

3.0 TEST DATA (CONTD)

Data Sheet 6 (Page 3 of 3)
BRAKE AND TIRE CONDITIONING

Tire Conditioning series No. 2 Time: *10:56:00 AM* Date: *9/7/2011*

Measured cold tire pressure LF *256* kPa RF *257* kPa

LR *246* kPa RR *251* kPa

Wind Speed *2.5* m/s (10 m/sec (22 mph) max for passenger cars; 5m/sec (11 mph) max for MPVs and trucks)

Ambient Temperature (7°C (45°F) - 40°C (104°F)) *31* °C

30 meter (100 ft) Diameter Circle Maneuver				
Test Run	Steering Direction	Target Lateral Acceleration (g)	Observed Lateral Acceleration (g)	Observed Vehicle Speed (km/h)
1-3	Clockwise	0.5 - 0.6	*0.5 - 0.6*	*31.2 - 32.8*
4-6	Counterclockwise	0.5 - 0.6	*0.5 - 0.6*	*31.2 - 32.8*

Steering wheel angle that corresponds to a peak 0.5-0.6 g lateral acceleration:

90 **degrees**

10-1 Hz Cycle Sinusoidal Steering Maneuver					
Test Run	Data File	Vehicle Speed km/h (mph)	Steering Wheel Angle (degrees)	Target Peak Lateral Acceleration (g)	Observed Peak Lateral Acceleration (g)
1-3	*18-20*	56 ± 2 (35 ± 1)	*90* (cycles 1-10)	0.5 - 0.6	*0.51*
4	*21*	56 ± 2 (35 ± 1)	*90* (cycles 1-9)	0.5 - 0.6	*0.51*
			180 (cycle 10)*	NA	*0.78*

* The steering wheel angle used for cycle 10 should be twice the angle used for cycles 1-9

Remarks:

RECORDED BY: *B Kebschull* DATE RECORDED: *9/7/2011*

APPROVED BY: *P Broen* DATE APPROVED: *9/22/2011*

3.0 TEST DATA (CONTD)

Data Sheet 7 (Page 1 of 2)
SLOWLY INCREASING STEER (SIS) MANEUVER

Vehicle: *2011 Kia Optima*

NHTSA No. *CB0516*

Measured tire pressure: LF *256* kPa RF *257* kPa

LR *246* kPa RR *248* kPa

Wind Speed *2* m/s

(10 m/sec (22 mph) max for passenger cars; 5 m/sec (11 mph) max for MPVs and trucks)

Ambient Temperature (7°C (45°F) - 40°C (104°F)) *31* °C

Selected drive configuration *FWD*

Selected Mode: *Default*

Preliminary Left Steer Maneuver:

Lateral Acceleration measured at 30 degrees steering wheel angle

$a_{y,30degrees}$ = *0.36* g

Assuming a linear relationship the following ratio should be used to calculate the steering wheel angle at 0.55g:

$$\frac{30\,\text{degrees}}{a_{\text{y,30 degrees}}} = \frac{\delta_{SIS}}{0.55\,\text{g}}$$

δ_{sis} = *45.8* degrees (@.55g)

δ_{sis} = *50* degrees (rounded)

Steering Wheel Angle at Corrected 0.3g Lateral Acceleration:

Maneuver	Initial Steer Direction	Time Clock (5 min max between runs)	Steering Wheel Angle to nearest 0.1° (degrees)	Data Run	Good/NG
1	Left	*10:21*	*-28.5*	*11*	*Good*
2	Left	*10:25*	*-28.3*	*12*	*Good*
3	Left	*10:28*	*-28.3*	*13*	*Good*
4	Left				
5	Left				
1	Right	*10:31*		*14*	*NG*
2	Right	*10:33*	*28.3*	*15*	*Good*
3	Right	*10:38*	*28.4*	*16*	*Good*
4	Right	*10:41*	*28.4*	*17*	*Good*
5	Right				

3.0 TEST DATA (CONTD)

Data Sheet 7 (Page 2 of 2)
SLOWLY INCREASING STEER (SIS) MANEUVER

Average Overall Steering Wheel Angle:

$$\delta_{0.3\ g,\ overall} = (\left| \delta_{0.3\ g,\ left\ (1)} \right| + \left| \delta_{0.3\ g,\ left\ (2)} \right| + \left| \delta_{0.3\ g,\ left\ (3)} \right| + \delta_{0.3\ g,\ right\ (1)} + \delta_{0.3\ g,\ right\ (2)} + \delta_{0.3\ g,\ right\ (3)}) / 6$$

$\delta_{0.3\ g,\ overall}$ = *28.3* degrees

[to nearest 0.1 degree]

Remarks:

RECORDED BY: *B Kebschull* DATE RECORDED: *9/7/2011*
APPROVED BY: *J Lenkeit* DATE APPROVED: *9/15/2011*

3.0 TEST DATA (CONTD)

Data Sheet 8 (Page 1 of 3)
VEHICLE LATERAL STABILITY AND RESPONSIVENESS

Vehicle: *2011 Kia Optima*

NHTSA No. *CB0516* Data sheet completion date: *9/7/2011*

Tire conditioning completed	[X] Yes	[ ] No
ESC system is enabled	[X] Yes	[ ] No
On track calibration checks have been completed	[X] Yes	[ ] No
On track static data file for each sensor obtained	[X] Yes	[ ] No

Selected Drive Configuration: *FWD*

Selected Mode: *Default - ESC on*

Overall steering wheel angle ($\delta_{0.3\ g,\ overall}$) *28.3* degrees

Lateral Stability Test Series No. 1 – Counterclockwise Initial Steer Direction

Maneuver #	Clock Time (1.5 – 5.0 min max between runs)	Commanded Steering Wheel Angle[1]		Yaw Rates (degrees/sec)			YRR at 1.0 sec after COS [< 35%]		YRR at 1.75 sec after COS [< 20%]	
		Scalar (* $\delta_{0.3\ g}$)	Angle (degrees)	$\dot{\psi}_{Peak}$	$\dot{\psi}_{1.0sec}$	$\dot{\psi}_{1.75sec}$	%	Pass/Fail	%	Pass/Fail
24	11:20	1.5	42	13.09	-0.32	-0.24	-2.44	*PASS*	-1.85	*PASS*
25	11:25	2.0	57	17.56	-0.27	-0.28	-1.52	*PASS*	-1.62	*PASS*
27	11:31	2.5	71	21.43	-0.11	-0.07	-0.51	*PASS*	-0.31	*PASS*
28	11:35	3.0	85	25.29	-0.49	-0.41	-1.93	*PASS*	-1.60	*PASS*
29	11:37	3.5	99	26.71	-0.16	-0.06	-0.59	*PASS*	-0.23	*PASS*
30	11:41	4.0	113	28.55	-0.40	-0.22	-1.40	*PASS*	-0.77	*PASS*
31	11:44	4.5	127	31.10	-0.07	-0.14	-0.24	*PASS*	-0.45	*PASS*
32	11:48	5.0	142	35.00	-0.11	0.01	-0.31	*PASS*	0.02	*PASS*
33	11:52	5.5	156	38.65	-0.32	-0.38	-0.83	*PASS*	-0.99	*PASS*
35	11:58	6.0	170	41.00	-0.09	-0.24	-0.23	*PASS*	-0.59	*PASS*
36	12:02	6.5	184	43.53	-0.10	-0.02	-0.24	*PASS*	-0.04	*PASS*
37	12:05	7.0	198	42.89	-0.02	0.01	-0.05	*PASS*	0.03	*PASS*
38	12:08	7.5	212	43.71	-0.11	-0.23	-0.25	*PASS*	-0.52	*PASS*
39	12:11	8.0	226	45.74	0.26	0.21	0.58	*PASS*	0.46	*PASS*
40	12:14	8.5	241	46.04	0.03	-0.10	0.05	*PASS*	-0.22	*PASS*
41	12:16	9.0	255	47.70	0.16	0.24	0.34	*PASS*	0.50	*PASS*
43	12:22	9.5	269	46.70	0.13	0.08	0.29	*PASS*	0.18	*PASS*
44	12:25	-	270	46.81	-0.22	-0.29	-0.46	*PASS*	-0.63	*PASS*

1. Maneuver execution should continue until a steering wheel angle magnitude factor of 6.5*$\delta_{0.3\ g,\ overall}$ or 270 degrees is utilized, whichever is greater provided the calculated magnitude of 6.5*$\delta_{0.3\ g,\ overall}$ is less than or equal to 300 degrees. If 6.5*$\delta_{0.3\ g,\ overall}$ is less than 270 degrees maneuver execution should continue by increasing the steering wheel angle magnitude by multiples of 0.5*$\delta_{0.3\ g,\ overall}$ without exceeding the 270 degree steering wheel angle.
2. Runs 26, 34, 42 NG

3.0 TEST DATA (CONTD)

DATA SHEET 8 (2 of 3)
VEHICLE LATERAL STABILITY AND RESPONSIVENESS

LATERAL STABILITY TEST SERIES NO. 2 – Clockwise Initial Steer Direction

Maneuver #	Clock Time (1.5 – 5.0 min max between runs)	Commanded Steering Wheel Angle[1]		Yaw Rates (degrees/sec)			YRR at 1.0 sec after COS [< 35%]		YRR at 1.75 sec after COS [< 20%]	
		Scalar (* $\delta_{0.3\,g}$)	Angle (degrees)	$\dot{\psi}_{Peak}$	$\dot{\psi}_{1.0sec}$	$\dot{\psi}_{1.75sec}$	%	Pass/Fail	%	Pass/Fail
45	12:28	1.5	42	-13.46	0.35	0.25	-2.60	*PASS*	-1.87	*PASS*
46	12:31	2.0	57	-18.39	0.19	0.21	-1.03	*PASS*	-1.13	*PASS*
47	12:33	2.5	71	-22.41	0.29	0.37	-1.28	*PASS*	-1.63	*PASS*
48	12:36	3.0	85	-23.89	0.34	0.27	-1.44	*PASS*	-1.12	*PASS*
49	12:39	3.5	99	-27.96	0.28	0.31	-1.01	*PASS*	-1.11	*PASS*
50	12:42	4.0	113	-30.63	0.30	0.23	-0.98	*PASS*	-0.75	*PASS*
51	12:45	4.5	127	-33.39	0.44	0.40	-1.31	*PASS*	-1.21	*PASS*
52	12:48	5.0	142	-36.73	0.26	0.15	-0.70	*PASS*	-0.41	*PASS*
53	12:51	5.5	156	-40.25	0.13	0.19	-0.33	*PASS*	-0.47	*PASS*
54	12:54	6.0	170	-42.51	0.39	0.36	-0.92	*PASS*	-0.84	*PASS*
55	12:57	6.5	184	-44.27	0.34	0.22	-0.76	*PASS*	-0.50	*PASS*
56	12:59	7.0	198	-46.19	0.33	0.29	-0.70	*PASS*	-0.62	*PASS*
57	13:02	7.5	212	-47.54	0.27	0.31	-0.57	*PASS*	-0.64	*PASS*
58	13:06	8.0	226	-48.06	0.11	0.06	-0.23	*PASS*	-0.13	*PASS*
59	13:08	8.5	241	-48.51	0.33	0.37	-0.68	*PASS*	-0.76	*PASS*
60	13:11	9.0	255	-49.41	0.39	0.33	-0.78	*PASS*	-0.68	*PASS*
61	13:14	9.5	269	-48.35	-0.04	-0.09	0.09	*PASS*	0.18	*PASS*
62		-	270	-51.14	0.11	0.23	-0.22	*PASS*	-0.45	*PASS*

1. Maneuver execution should continue until a steering wheel angle magnitude factor of 6.5*$\delta_{0.3\,g,\,overall}$ or 270 degrees is utilized, whichever is greater provided the calculated 6.5*$\delta_{0.3\,g,\,overall}$ is less than or equal to 300 degrees. If 6.5*$\delta_{0.3\,g,\,overall}$ is less than 270 degrees maneuver execution should continue by increasing the steering wheel angle magnitude by multiples of 0.5*$\delta_{0.3\,g,\,overall}$ without exceeding the 270 degree steering wheel angle.

During execution of the Sine with Dwell maneuvers were any of the following events observed?

Rim-to-pavement contact	☐ Yes	☒ No
Tire debeading	☐ Yes	☒ No
Loss of pavement contact of vehicle tires	☐ Yes	☒ No
Did the test driver experience any vehicle loss of control or spinout?	☐ Yes	☒ No

If "Yes" explain the event and consult with the COTR.

3.0 TEST DATA (CONTD)

DATA SHEET 8 (3 of 3)
VEHICLE LATERAL STABILITY AND RESPONSIVENESS

Responsiveness – Lateral Displacement

Maneuver #	Initial Steer Direction	Commanded Steering Wheel Angle (5.0*$\delta_{0.3\ g,\ overall}$ or greater)		Calculated Lateral Displacement[1]	
		Scalar *$\delta_{0.3\ g}$	Angle (degrees)	Distance (m)	Pass/Fail
32	Counter Clockwise	5.0	142	-2.89	*PASS*
33	Counter Clockwise	5.5	156	-3.01	*PASS*
35	Counter Clockwise	6.0	170	-3.10	*PASS*
36	Counter Clockwise	6.5	184	-3.12	*PASS*
37	Counter Clockwise	7.0	198	-3.02	*PASS*
38	Counter Clockwise	7.5	212	-3.05	*PASS*
39	Counter Clockwise	8.0	226	-3.03	*PASS*
40	Counter Clockwise	8.5	241	-3.05	*PASS*
41	Counter Clockwise	9.0	255	-3.02	*PASS*
43	Counter Clockwise	9.5	269	-3.01	*PASS*
44	Counter Clockwise	-	270	-3.06	*PASS*
52	Clockwise	5.0	142	2.82	*PASS*
53	Clockwise	5.5	156	2.87	*PASS*
54	Clockwise	6.0	170	2.91	*PASS*
55	Clockwise	6.5	184	2.93	*PASS*
56	Clockwise	7.0	198	2.99	*PASS*
57	Clockwise	7.5	212	3.01	*PASS*
58	Clockwise	8.0	226	2.98	*PASS*
59	Clockwise	8.5	241	2.92	*PASS*
60	Clockwise	9.0	255	2.98	*PASS*
61	Clockwise	9.5	269	2.82	*PASS*
62	Clockwise	-	270	2.92	*PASS*

1. Lateral displacement should be $\geq$ 1.83 m (6 ft) for vehicle with a GVWR of 3,500 kg (7,716 lb) or less; and $\geq$ 1.52 m (5 ft) for vehicles with GVWR greater than 3,500 kg (7,716 lb).

DATA INDICATES COMPLIANCE: ☑ PASS ☐ FAIL

Remarks: *Runs 26, 34, 42 of Lateral Stability Test Series No.1 were no good (NG)*

RECORDED BY: *B Kebschull* DATE RECORDED: *9/7/2011*

APPROVED BY: *J Lenkeit* DATE APPROVED: *9/15/2011*

3.0 TEST DATA (CONTD)

Data Sheet 9 (Page 1 of 2)
MALFUNCTION WARNING TESTS

Vehicle: *2011 Kia Optima*

NHTSA No. *CB0516* Data Sheet Completion Date: *9/22/2011*

TEST 1

MALFUNCTION SIMULATION: Describe method of malfunction simulation

Disconnected left front wheel speed sensor

MALFUNCTION TELLTALE ILLUMINATION:

Telltale illuminates and remains illuminated after ignition locking system is activated and if necessary the vehicle is driven at least 2 minutes.

X Yes ___ No

Time for telltale to illuminate after ignition system is activated and vehicle speed of 48 ± 8 km/h (30 ± 5 mph) is reached.

0 Seconds (must be within 2 minutes) [X] Pass [ ] Fail

ESC SYSTEM RESTORATION

Telltale extinguishes after ignition locking system is activated and if necessary the vehicle is driven at least 2 minutes.

X Yes ___ No

Time for telltale to extinguish after ignition system is activated and vehicle speed of 48 ± 8 km/h (30 ± 5 mph) is reached.

0 Seconds (must be within 2 minutes) [X] Pass [ ] Fail

TEST 1 DATA INDICATES COMPLIANCE: *PASS*

Remarks: *With sensor disconnected telltale illuminated immediately upon switching ignition on, no driving was required. When sensor was reconnected the telltale extinguished after the normal bulb check, no driving was required. No other telltales or indicators were activated.*

RECORDED BY: *P Broen* DATE RECORDED: *9/22/2011*

APPROVED BY: *J Lenkeit* DATE APPROVED *9/22/2011*

3.0 TEST DATA (CONTD)

Data Sheet 9 (Page 2 of 2)
MALFUNCTION WARNING TESTS

Vehicle: *2011 Kia Optima*

NHTSA No. *CB0516* Data Sheet Completion Date: *9/22/2011*

TEST 2

MALFUNCTION SIMULATION: Describe method of malfunction simulation

Disconnected brake pedal stop switch.

MALFUNCTION TELLTALE ILLUMINATION:

Telltale illuminates and remains illuminated after ignition locking system is activated and if necessary the vehicle is driven at least 2 minutes.

X Yes ___ No

Time for telltale to illuminate after ignition system is activated and vehicle speed of 48 ± 8 km/h (30 ± 5 mph) is reached.

_____ Seconds (must be within 2 minutes) [X] Pass [ ] Fail

ESC SYSTEM RESTORATION

Telltale extinguishes after ignition locking system is activated and if necessary the vehicle is driven at least 2 minutes.

X Yes ___ No

Time for telltale to extinguish after ignition system is activated and vehicle speed of 48 ± 8 km/h (30 ± 5 mph) is reached.

0 Seconds (must be within 2 minutes) [X] Pass [ ] Fail

TEST 2 DATA INDICATES COMPLIANCE: PASS

Remarks: *With the switch disconnected when the engine was started, the telltale extinguished as if there was no malfunction. The telltale illuminated when brake pedal was depressed for 3 seconds. When the switch was reconnected, the telltale stayed illuminated when engine was started, but extinguished after the brake pedal was depressed for 4 seconds. No other telltales or indicators were activated.*

RECORDED BY: *P Broen* DATE RECORDED: *9/22/2011*

APPROVED BY: *J Lenkeit* DATE APPROVED *9/22/2011*

4.0 TEST EQUIPMENT LIST AND CALIBRATION INFORMATION (1 OF 2)

TABLE 1. TEST INSTRUMENTATION

Type	Output	Range	Resolution	Accuracy	Specifics	Serial Number	Calibration
Tire Pressure Gauge	Vehicle Tire Pressure	0-100 psi 0-690 kPa	1 psi 6.89 kPa	0.5 psi 3.45 kPa	Ashcroft D1005PS	1039350	By: DRI Date:2/22/11 Due: 2/22/12
Platform Scales	Vehicle Total, Wheel, and Axle Load	8000 lb 35.6 kN	0.5 lb 2.2 N	±1.0% of applied load	Intercomp Model SWII	24032361	By: DRI Date: 2/23/11 Due: 2/23/12
Automated Steering Machine with Steering Angle Encoder	Handwheel Angle	±800 deg	0.25 deg	±0.25 deg	Heitz Automotive Testing Model: Sprint 3	60304	By: DRI Date: 3/30/11 Due: 3/30/12
Multi-Axis Inertial Sensing System	Longitudinal, Lateral, and Vertical Acceleration Roll, Yaw, and Pitch Rate	Accelerometers: ±2 g Angular Rate Sensors: ±100 deg/s	Accelerometers: ≤10 ug Angular Rate Sensors: ≤0.004 deg/s	Accelerometers: ≤0.05% of full range Angular Rate Sensors: 0.05% of full range	BEI Technologies Model: MotionPAK MP-1	0767	By: Systron Donner Date: 3/8/11 Due: 3/8/12
Radar Speed Sensor and Dashboard Display	Vehicle Speed	0-125 mph 0-200 km/h	0.009 mph .014 km/h	±0.25% of full scale	A-DAT Corp. Radar Model: DRS-6 Display Model: RD-2	1400.604	By: DRI Date: 5/3/11 Due: 5/3/12
Ultrasonic Distance Measuring System	Left and Right Side Vehicle Height	5-24 inches 127-610 mm	0.01 inches .254 mm	±0.25% of maximum distance	Massa Products Corporation Model: M-5000/220	DOT-NHTSA D2646	By: DRI Date: 2/22/11 Due: 2/21/12
						DOT-NHTSA D3272	By: DRI Date: 2/22/11 Due: 2/22/12

4.0 TEST EQUIPMENT LIST AND CALIBRATION INFORMATION (2 OF 2)

TABLE 1. TEST INSTRUMENTATION (CONTD)

Type	Output	Range	Resolution	Accuracy	Specifics	Serial Number	Calibration
Data Acquisition System [Includes amplification, anti-aliasing, and analog to digital conversion.]	Record Time; Velocity; Distance; Lateral, Longitudinal, and Vertical Accelerations; Roll, Yaw, and Pitch Rates; Steering Wheel Angle.	Sufficient to meet or exceed individual sensors	200 Hz	Sufficient to meet or exceed individual sensors	SoMat eDaq ECPU processor	MSHLB.03-2476	By: DRI Date: 3/29/11 Due: 3/29/12
					SoMat High level Board EHLS	MSHLS.03-3182	By: DRI Date: 3/29/11 Due: 3/29/12
Load Cell	Vehicle Brake Pedal Force	0-300 lb 0-1.33 kN	1 lb 4.44 N	±0.05% of full scale	Lebow 3663-300	767	Operationally verified by DRI prior to test
Coordinate Measurement Machine	Inertial Sensing System Coordinates	0-8 ft 0-2.4 m	±.0020 in. ±.051 mm	±.0020 in. ±.051 mm (Single point articulation accuracy)	Faro Arm Fusion	UO8-05-08-06636	By; DRI Date: 11/7/10 Due: 11/7/11
Outriggers	No output. Safety Item.	NA	NA	NA	DRI manufactured Aluminum meeting the weight and MOI specifications of Docket 2007-27662-11	NA	NA

5.0 PHOTOGRAPHS (1 of 14)

Figure 5.1. Front View of Test Vehicle

5.0 PHOTOGRAPHS (2 of 14)

Figure 5.2. Rear View of Test Vehicle

5.0 PHOTOGRAPHS (3 of 14)

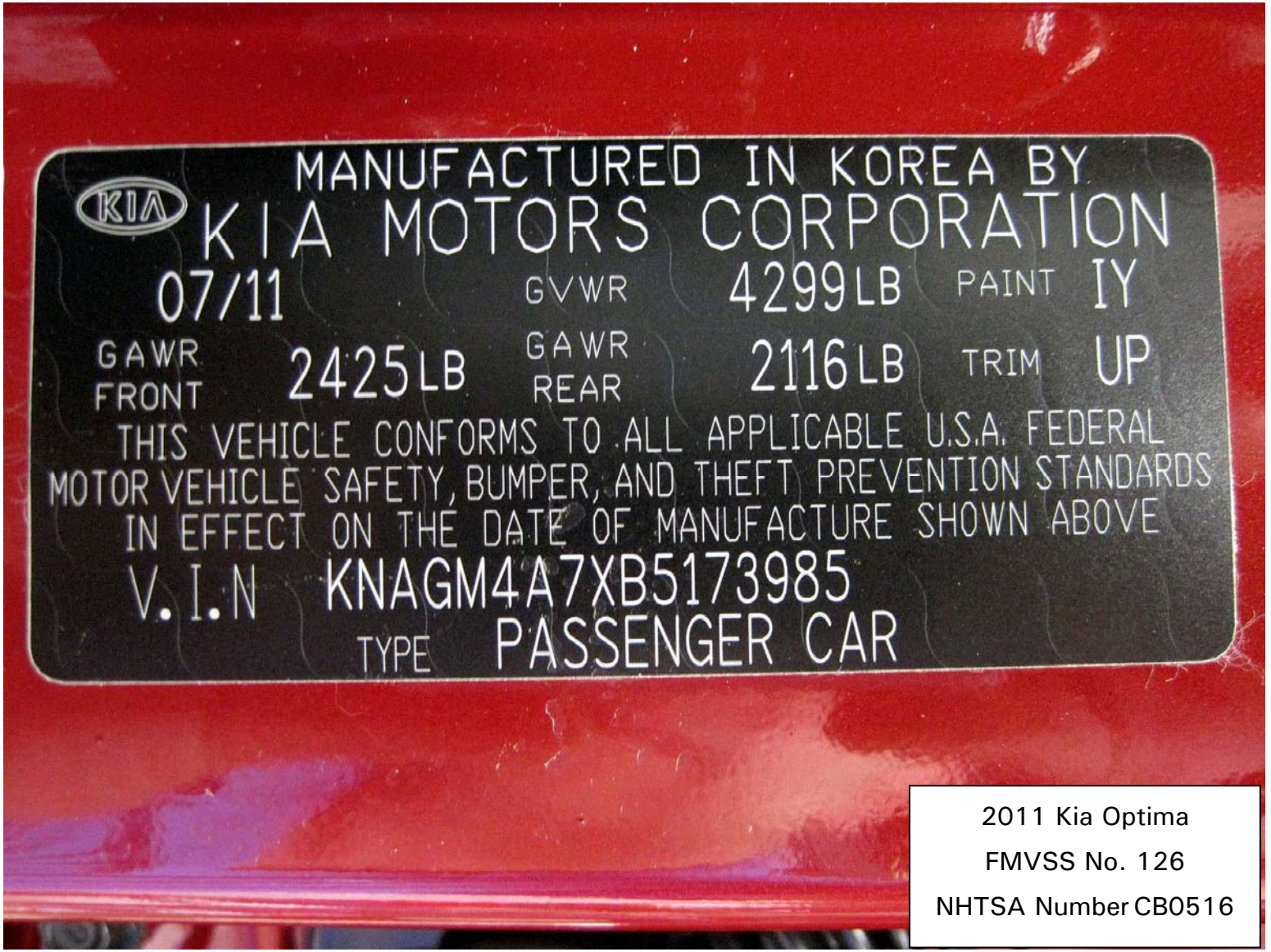

Figure 5.3. Vehicle Certification Label

5.0 PHOTOGRAPHS (4 of 14)

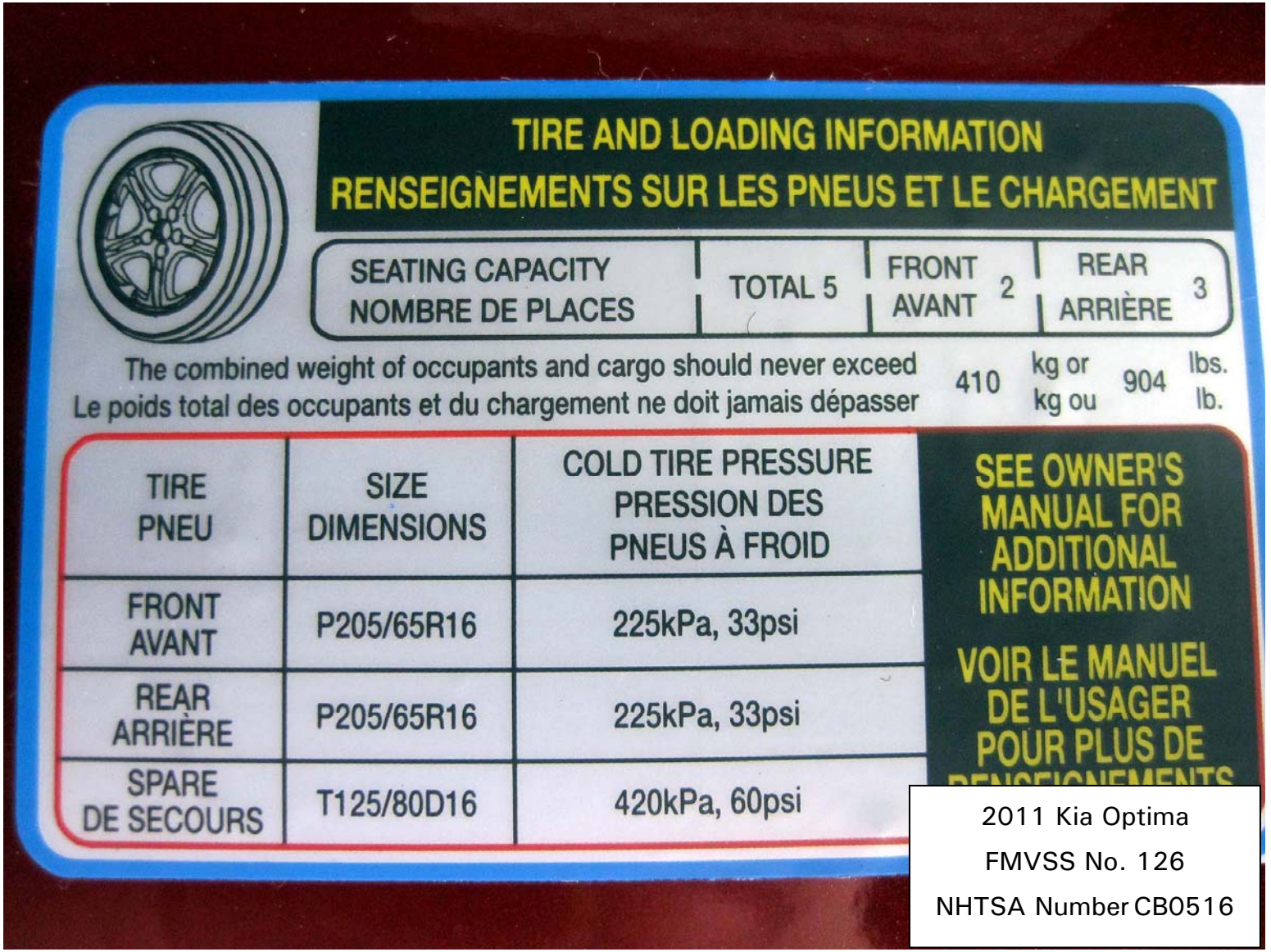

Figure 5.4. Vehicle Placard

5.0 PHOTOGRAPHS (5 of 14)

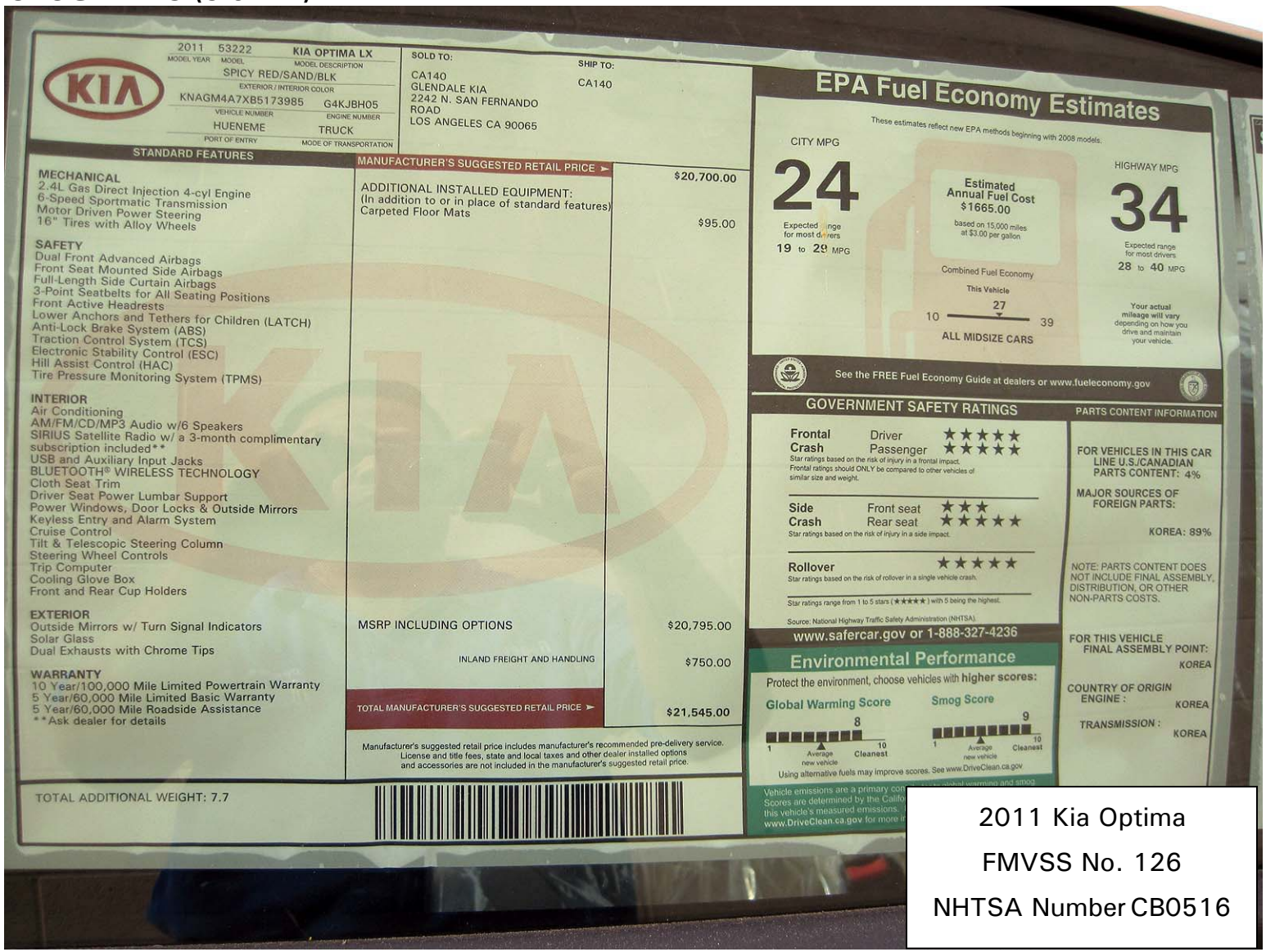

Figure 5.5. Window Sticker (Monroney Label)

5.0 PHOTOGRAPHS (6 of 14)

Figure 5.6. Front View of Vehicle as Tested

5.0 PHOTOGRAPHS (7 of 14)

Figure 5.7. Rear View of Vehicle as Tested

5.0 PHOTOGRAPHS (8 of 14)

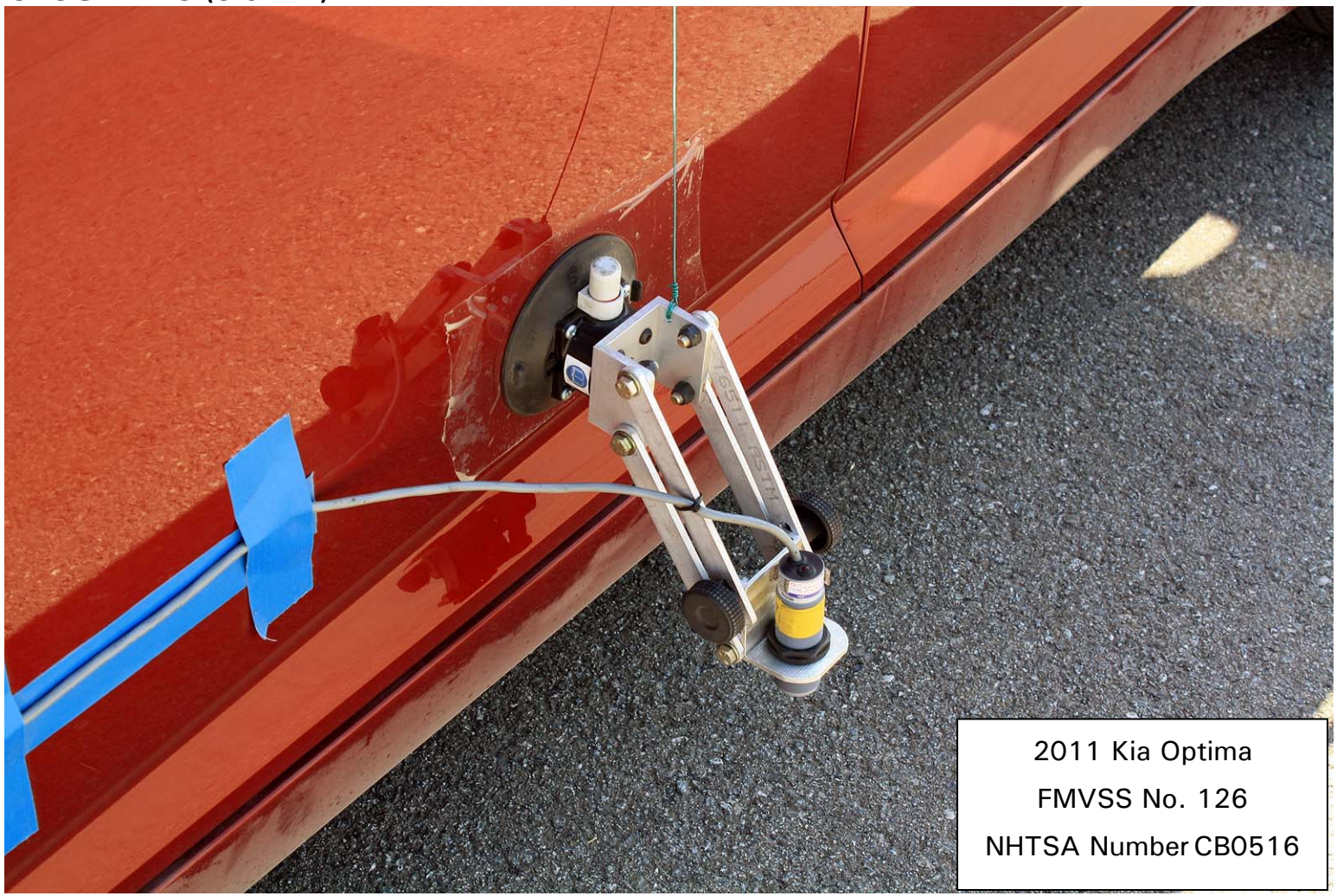

Figure 5.8. Ultrasonic Height Sensor Mounted on Side of Vehicle for Determining Body Roll Angle

5.0 PHOTOGRAPHS (9 of 14)

Figure 5.9. Rear Mounted Speed Sensor

5.0 PHOTOGRAPHS (10 of 14)

Figure 5.10. Steering Controller and Data Acquisition Computer

5.0 PHOTOGRAPHS (11 of 14)

Figure 5.11. Inertial Measurement Unit Mounted in Vehicle

5.0 PHOTOGRAPHS (12 of 14)

Figure 5.12. Brake Pedal Load Cell

5.0 PHOTOGRAPHS (13 of 14)

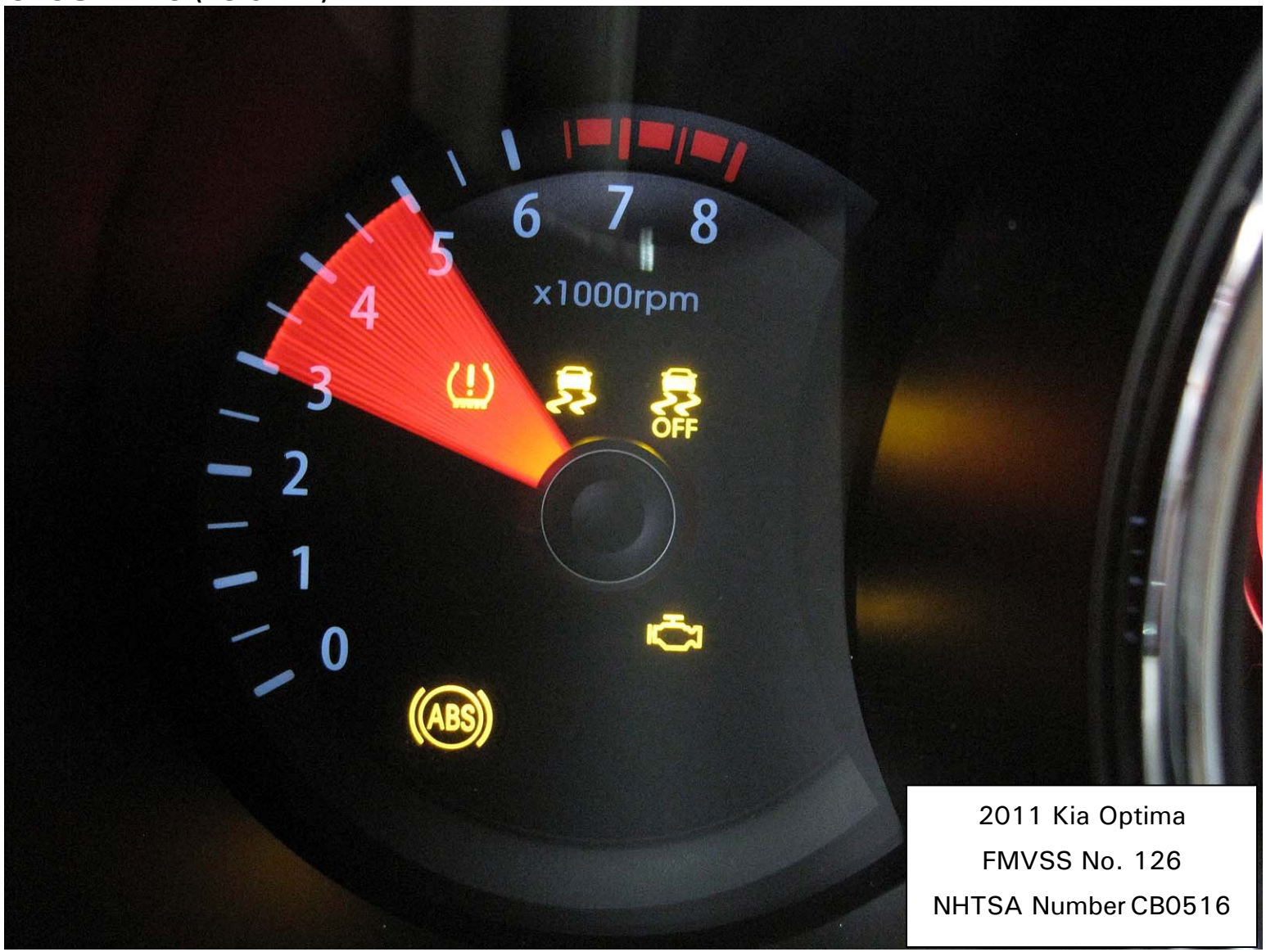

Figure 5.13. Telltales for ESC Activation and Malfunction, ESC Off

5.0 PHOTOGRAPHS (14 of 14)

Figure 5.14. ESC Off Control Switch

6.0 DATA PLOTS (1 of 4)

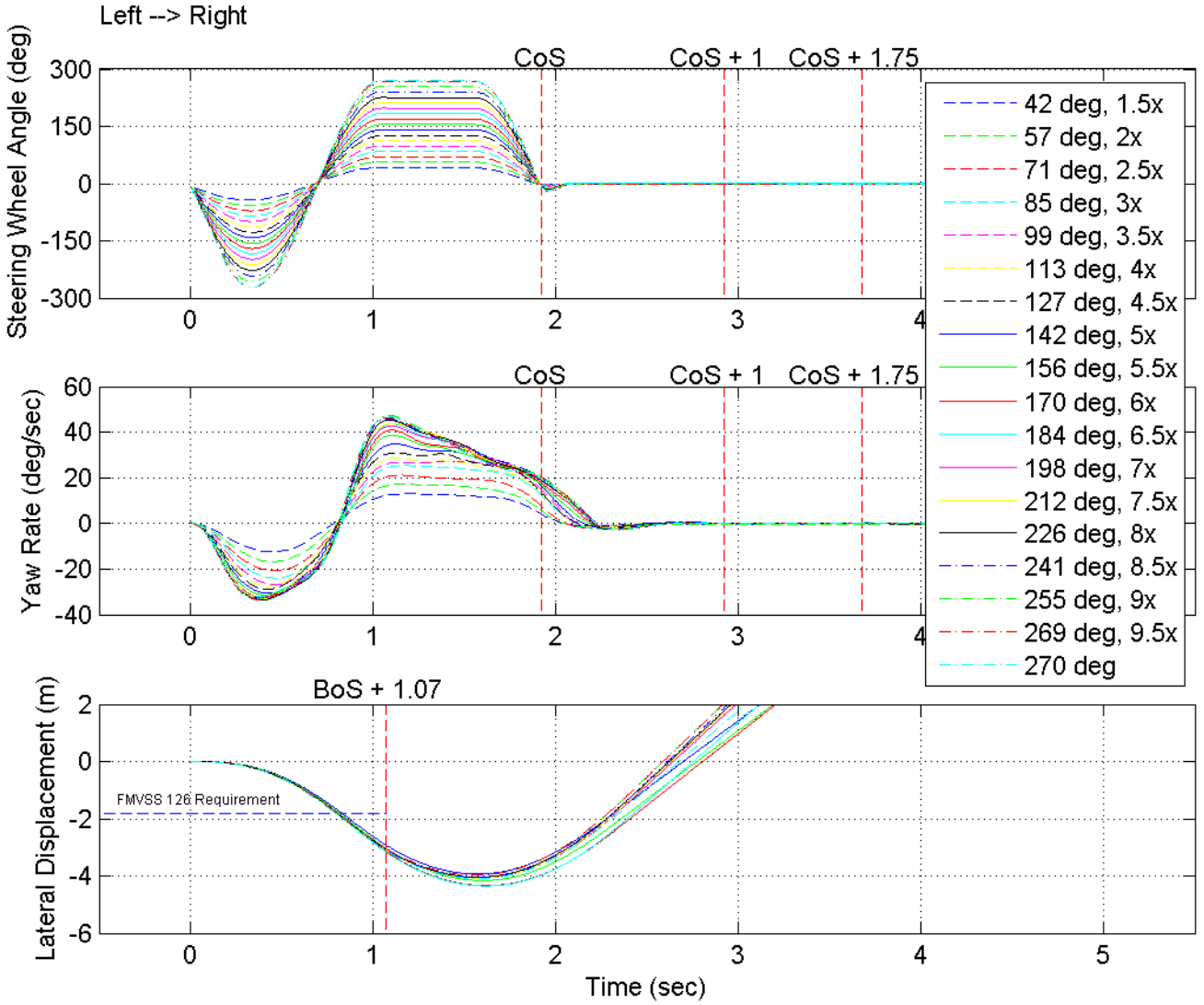

Figure 6.1. Steering Wheel Angle, Yaw Rate and Lateral Displacement for L-R Series

6.0 DATA PLOTS (2 of 4)

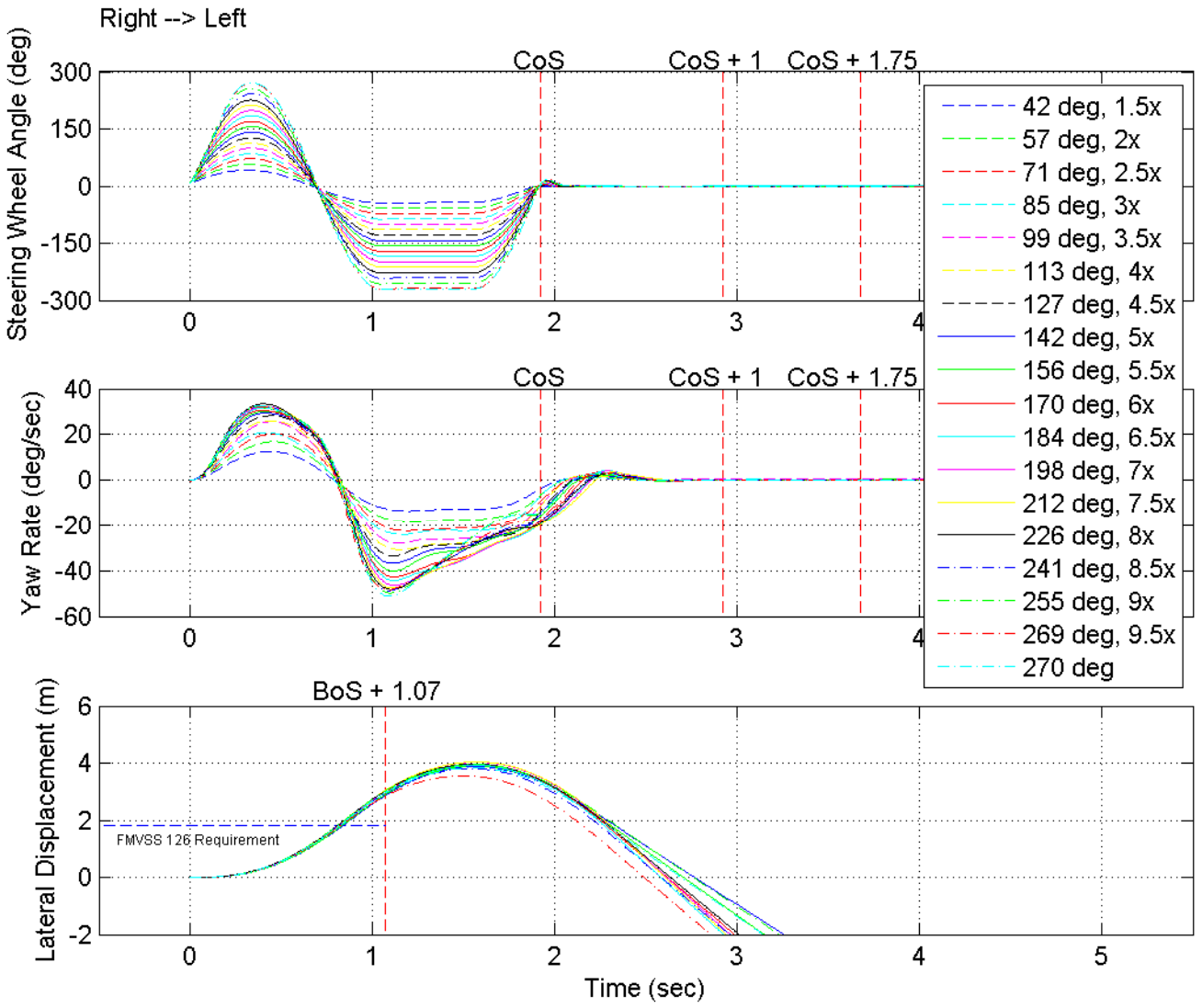

Figure 6.2. Steering Wheel Angle, Yaw Rate and Lateral Displacement for R-L Series

6.0 DATA PLOTS (3 of 4)

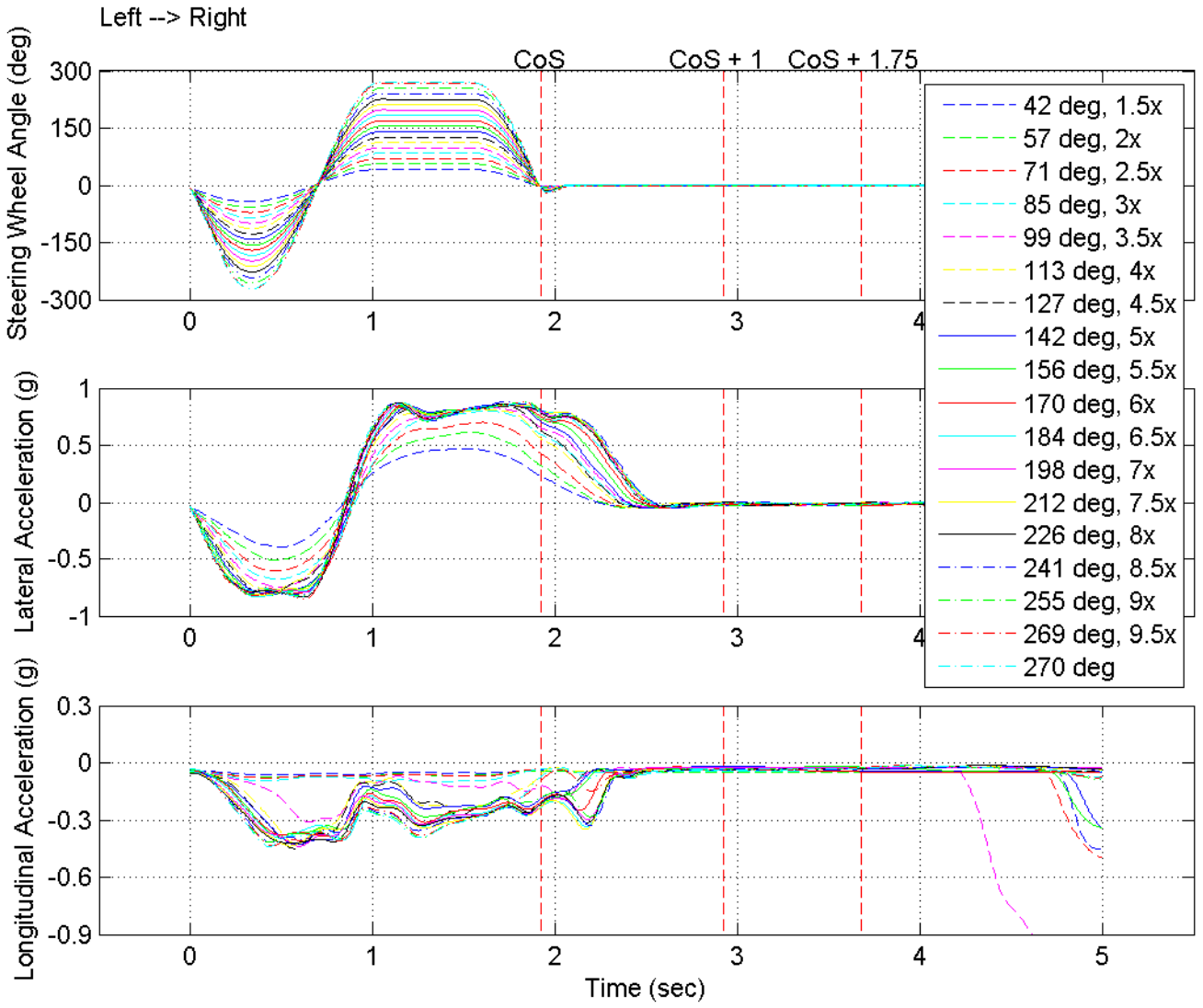

Figure 6.3. Steering Wheel Angle, Lateral Acceleration and Longitudinal Acceleration for L-R Series

6.0 DATA PLOTS (4 of 4)

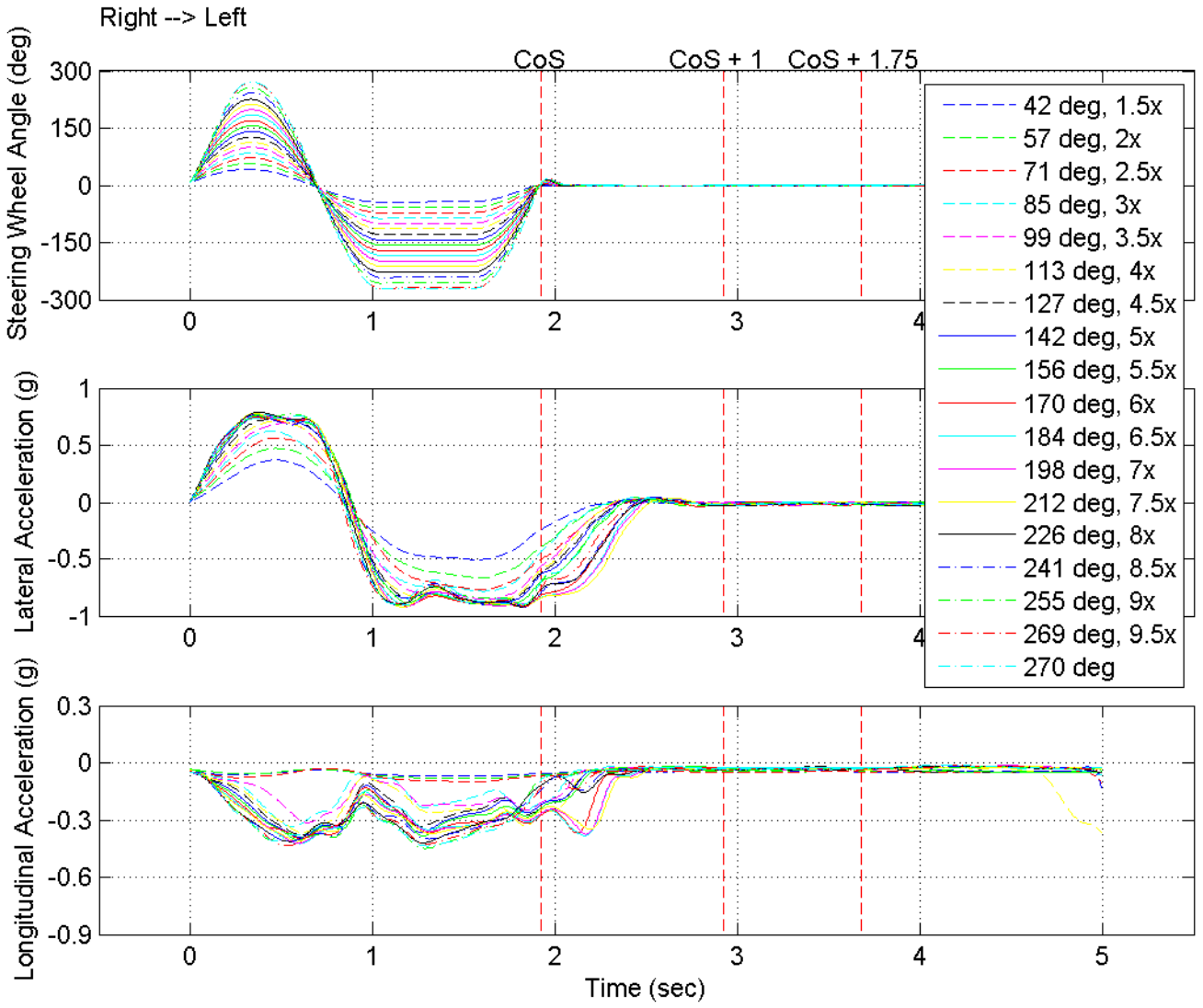

Figure 6.4. Steering Wheel Angle, Lateral Acceleration and Longitudinal Acceleration for R-L Series

7.0 OTHER DOCUMENTATION

7.1 OWNER'S MANUAL PAGES
7.2 VEHICLE ARRIVAL CONDITION REPORT
7.3 VEHICLE COMPLETION CONDITION REPORT
7.4 SINE WITH DWELL TEST RESULTS
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Malfunction indicator lamp (MIL) (check engine light)

This indicator is part of the Engine Control System which monitors various emission control system components. If this indicator illuminates while driving, it indicates that a potential malfunction has been detected somewhere in the emission control system.

This indicator will also illuminates when the ignition switch is turned to the ON position, and will go off in a few seconds after the engine is started. If it illuminates while driving, or does not illuminate when the ignition switch is turned to the ON position, take your vehicle to the nearest authorized KIA dealer and have the system checked.

Generally, your vehicle will continue to be drivable, but have the system checked by an authorized KIA dealer promptly.

⚠ CAUTION

- ***Prolonged driving with the Emission Control System Malfunction Indicator Light illuminated may cause damage to the emission control systems which could effect drivability and/or fuel economy.***
- ***If the Emission Control System Malfunction Indicator Light illuminates, potential catalytic converter damage. This could result in loss of engine power. Have the Engine Control System inspected as soon as possible by an authorized KIA dealer.***

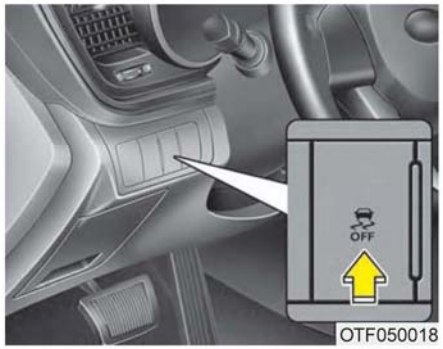
ESC indicator (Electronic Stability Control)

The ESC indicator will illuminate when the ignition switch is turned ON, but should go off after approximately 3 seconds. When the ESC is on, it monitors the driving conditions. Under normal driving conditions, the ESC indicator will remain off. When a slippery or low traction condition is encountered, the ESC will operate, and the ESC indicator will blink to indicate the ESC is operating.

ESC OFF indicator

The ESC OFF indicator will illuminate when the ignition switch is turned ON, but should go off after approximately 3 seconds. To switch to ESC OFF mode, press the ESC OFF button. The ESC OFF indicator will illuminate indicating the ESC is deactivated. If this indicator stays on when ESC OFF is not selected, the ESC may have malfunctioned. Take your vehicle to an authorized KIA dealer and have the system checked.

7.1 OWNER'S MANUAL PAGES



Electronic stability control (ESC)

The Electronic Stability control (ESC) system is designed to stabilize the vehicle during cornering maneuvers. ESC checks where you are steering and where the vehicle is actually going. ESC applies the brakes on individual wheels and intervenes with the engine management system to stabilize the vehicle.

⚠ WARNING

Never drive too fast according to the road conditions or too quickly when cornering. Electronic stability control (ESC) will not prevent accidents. Excessive speed in turns, abrupt maneuvers and hydroplaning on wet surfaces can still result in serious accidents. Only a safe and attentive driver can prevent accidents by avoiding maneuvers that cause the vehicle to lose traction. Even with ESC installed, always follow all the normal precautions for driving - including driving at safe speeds for the conditions.

The Electronic Stability Control (ESC) system is an electronic system designed to help the driver maintain vehicle control under adverse conditions. It is not a substitute for safe driving practices. Factors including speed, road conditions and driver steering input can all affect whether ESC will be effective in preventing a loss of control. It is still your responsibility to drive and corner at reasonable speeds and to leave a sufficient margin of safety.

When you apply your brakes under conditions which may lock the wheels, you may hear a "tik-tik" sound from the brakes, or feel a corresponding sensation in the brake pedal. This is normal and it means your ESC is active.

✻ NOTICE

A click sound may be heard in the engine compartment when the vehicle begins to move after the engine is started. These conditions are normal and indicate that the Electronic Stability Control System is functioning properly.

7.1 OWNER'S MANUAL PAGES

ESC operation

ESC ON condition

- When the ignition is turned ON, ESC and ESC OFF indicator lights illuminate for approximately 3 seconds, then ESC is turned on.
- Press the ESC OFF button for at least half a second after turning the ignition ON to turn ESC off. (ESC OFF indicator will illuminate). To turn the ESC on, press the ESC OFF button (ESC OFF indicator light will go off).
- When starting the engine, you may hear a slight ticking sound. This is the ESC performing an automatic system self-check and does not indicate a problem.

When operating

When the ESC is in operation, ESC indicator light blinks.

- When the Electronic Stability Control is operating properly, you can feel a slight pulsation in the vehicle. This is only the effect of brake control and indicates nothing unusual.
- When moving out of the mud or slippery road, pressing the accelerator pedal may not cause the engine rpm (revolutions per minute) to increase.

ESC operation off

ESC OFF state

- To cancel ESC operation, press the ESC OFF button (ESC OFF indicator light illuminates).
- If the ignition switch is turned to LOCK position when ESC is off, ESC remains off. Upon restarting the engine, the ESC will automatically turn on again.

■ ESC indicator light (blinks)

■ ESC OFF indicator light (comes on)

Indicator light

When the ignition switch is turned ON, the indicator light illuminates, then goes off if ESC system is operating normally.

The ESC indicator light blinks whenever ESC is operating.

ESC OFF indicator light comes on when either the ESC is turned off with the button, or ESC fails to operate when turned on.

⚠ CAUTION

Driving with varying tire or wheel sizes may cause the ESC system to malfunction. When replacing tires, make sure they are the same size as your original tires.

⚠ WARNING

The Electronic Stability Control system is only a driving aid; use precautions for safe driving by slowing down on curved, snowy, or icy roads. Drive slowly and don't attempt to accelerate whenever the ESC indicator light is blinking, or when the road surface is slippery.

ESC OFF usage

When driving

- It's a good idea to keep the ESC turned on for daily driving whenever possible.
- To turn ESC off while driving, press the ESC OFF button while driving on a flat road surface.

Never press the ESC OFF button while ESC is operating (ESC indicator light blinks).

If ESC is turned off while ESC is operating, the vehicle may slip out of control.

✻ NOTICE

- **When operating the vehicle on a dynamometer, ensure that the ESC is turned off (ESC OFF light illuminated). If the ESC is left on, it may prevent the vehicle speed from increasing, and result in false diagnosis.**
- **Turning the ESC off does not affect the ABS or brake system operation.**

7.1 OWNER'S MANUAL PAGES

⚠ WARNING

Never press the ESC OFF button while ESC is operating.

If the ESC is turned off while ESC is operating, the vehicle may go out of control.

To turn ESC off while driving, press the ESC OFF button while driving on a flat road surface.

Hill-start assist control (HAC) (if equipped)

Hill start Assist Control is a comfort function. The main intend is to prevent the vehicle from rolling backwards while driving off uphill on an inclined surface. HAC holds the braking pressure builtup by driver during stopping procedure for 2 seconds after releasing brake pedal.

During the pressure-hold period, the driver has enough time to press the accelerator pedal to drive off.

The braking pressure is reduced as soon as the system detects the driver's intention to drive off.

⚠ WARNING

The HAC is usually activated only for 2 seconds. The driver should be careful from the rolling backward causing the accident with behind objects or human, when the driver may feel the unintended rolling backward while driving off on hill due to insufficient brake hold pressure built-up by driver during stopping procedure.

✻ NOTICE

- **The HAC does not operate when the transaxle shift lever is in the P (Park) or N (Neutral) position.**
- **The HAC activates even though the ESP is off but it does not activate when the ESP has malfunctioned.**

Vehicle stability management (VSM) (if equipped)

This system provides further enhancements to vehicle stability and steering responses when a vehicle is driving on a slippery road or a vehicle detected changes in coefficient of friction between right wheels and left wheels when braking.

VSM operation

When the VSM is in operation, ESC indicator light ( ) blinks.

When the vehicle stability management is operating properly, you can feel a slight pulsation in the vehicle. This is only the effect of brake control and indicates nothing unusual.

The VSM does not operate when:

- Driving on bank road such as gradient or incline
- Driving rearward
- ESC OFF indicator light ( ) remains on the instrument cluster
- ESC indicator light remains on the instrument cluster

VSM operation off

If you press the ESC OFF button to turn off the ESC, the VSM will also cancel and the ESC OFF indicator light ( ) illuminates.

To turn on the VSM, press the button again. The ESC OFF indicator light goes out.

Malfunction indicator

The VSM can be deactivated even if you don't cancel the VSM operation by pressing the ESC OFF button. It indicates that a malfunction has been detected somewhere in the Electric Power Steering system or VSM system. If the ESC indicator light ( ) or ESC warning light remains on, take your vehicle to an authorized KIA dealer and have the system checked.

✻ NOTICE

- **The VSM is designed to function above approximately 15 km/h (9 mph) on curves.**
- **The VSM is designed to function above approximately 30 km/h (18 mph) when a vehicle is braking on a split-mu road. The split-mu road is made of surfaces which have different friction forces.**

⚠ WARNING

- **The Vehicle Stability Management system is not a substitute for safe driving practices but a supplementary function only. It is the responsibility of the driver to always check the speed and the distance to the vehicle ahead. Always hold the steering wheel firmly while driving.**
- **Your vehicle is designed to activate according to the driver's intention, even with installed VSM. Always follow all the normal precautions for driving at safe speeds for the conditions – including driving inclement weather and on a slippery road.**
- **Driving with varying tire or wheel sizes may cause the VSM system to malfunction. When replacing tires, make sure they are the same size as your original tires.**

(Continued)

- **Using tires and wheel other than the recommended sizes could cause unusual handling characteristics and poor vehicle control, resulting in a serious accident.**
- **Wheels that do not meet KIA's specifications may fit poorly and result in damage to the vehicle or unusual handling and poor vehicle control.**
- **The ABS works by comparing the speed of the wheels. Tire size can affect wheel speed. When replacing tires, all 4 tires must use the same size originally supplied with the vehicle. Using tires of a different size can cause the ABS (Anti-lock Brake System) and ESC (Electronic Stability Control) (if equipped) to work irregularly.**

Compact spare tire replacement

A compact spare tire has a shorter tread life than a regular size tire. Replace it when you can see the tread wear indicator bars on the tire. The replacement compact spare tire should be the same size and design tire as the one provided with your new vehicle and should be mounted on the same compact spare tire wheel. The compact spare tire is not designed to be mounted on a regular size wheel, and the compact spare tire wheel is not designed for mounting a regular size tire.

Wheel replacement

When replacing the metal wheels for any reason, make sure the new wheels are equivalent to the original factory units in diameter, rim width and offset.

⚠ WARNING

A wheel that is not the correct size may adversely affect wheel and bearing life, braking and stopping abilities, handling characteristics, ground clearance, body-to-tire clearance, snow chain clearance, speedometer and odometer calibration, headlight aim and bumper height.

7.2 VEHICLE ARRIVAL CONDITION REPORT

CONTRACT NO.: *DTNH22-08-D-00098*
DATE: *8/23/11*

From: *Automotive Allies*

To: *Dynamic Research, Inc*

Purpose ☒ Initial Receipt
☐ Received via Transfer
☐ Present Vehicle Condition

Vehicle VIN: *KNAGM4A7XB5173985* NHTSA NO.: *CB0516*
Model Year: *2011* Odometer Reading: *7* Miles
Make *Kia* Body Style: *Passenger Car*
Model: *Optima* Body Color: *Red*
Manufacture Date: *7/11* Dealer: *Automotive Allies*
GVWR (kg/lb) *1950/4299* Price: *Leased*

☒ All options listed on the "Window Sticker" are present on the test vehicle

☒ Tires and wheel rims are new and the same as listed

☒ There are no dents or other interior or exterior flaws

☒ The vehicle has been properly prepared and is in running condition

☒ The glove box contains an owner's manual, warranty document, consumer information, and extra set of keys

☒ Proper fuel filler cap is supplied on the test vehicle

☒ Place vehicle in storage area

☒ Inspect the vehicle's interior and exterior, including all windows, seats, doors, etc., to confirm that each system is complete and functional per the manufacturer's specifications. Any damage, misadjustment, or other unusual condition that could influence the test program or test results shall be recorded. Report any abnormal condition to the NHTSA COTR before beginning any test.

NOTES:

RECORDED BY: *J Lenkeit* DATE RECORDED: *8/22/2011*

APPROVED BY: *P Broen* DATE APPROVED: *8/23/2011*

7.3 VEHICLE COMPLETION CONDITION REPORT

CONTRACT NO.: *DTNH22-08-D-00098*
DATE: *9/27/2011*

Vehicle VIN: *KNAGM4A7XB5173985* NHTSA NO.: *CB0516*
Model Year: *2011* Odometer Reading: *57* Miles
Make: *Kia* Body Style: *Passenger Car*
Model: *Optima* Body Color: *Red*
Manufacture Date: *7/11* Dealer: *Automotive Allies*
GVWR (kg/lb) *1950 (4299)* Price: *Leased*

LIST OF FMVSS TESTS PERFORMED BY THIS LAB: *126*

☒ THERE ARE NO DENTS OR OTHER INTERIOR OR EXTERIOR FLAWS

☒ THE VEHICLE HAS BEEN PROPERLY MAINTAINED AND IS IN RUNNING CONDITION

☒ THE GLOVE BOX CONTAINS AN OWNER'S MANUAL, WARRANTY DOCUMENT, CONSUMER INFORMATION, AND EXTRA SET OF KEYS

☒ PROPER FUEL FILLER CAP IS SUPPLIED ON THE TEST VEHICLE

REMARKS:

Equipment that is no longer on the test vehicle as noted on Vehicle Arrival Condition Report:

None

Explanation for equipment removal:

Test Vehicle Condition:

As -delivered, like-new

RECORDED BY: *J Lenkeit* DATE RECORDED: *9/27/2011*

APPROVED BY: *P Broen* DATE APPROVED: *9/27/2011*

7.4 SINE WITH DWELL TEST RESULTS

2011 Kia Optima
NHTSA No.: *CB0516*
Date of Test : *9/7/2011*
Date Created: *9/7/2011*

Lateral Stability Test Series No. 1 – Counterclockwise Initial Steer Direction

File	SWA @ 5deg Ct	MES	Time @ 5deg	COS	Time @ COS	MOS	Time @ MOS	YRR1	YR1	YRR 1 Ct	YRR 175	YR175	YRR17 5 Ct	2nd Yaw Peak	2nd Yaw Peak Ct	Lat Disp	Lat. Acc. 1.07 s	1st SWA Peak	1st SWA Peak Ct	2nd SWA Mean
	(deg)	(mph)	(s)		(s)		(sec)	(%)	(deg/s)		(%)	(deg/s)		(deg/s)		(ft)	(g)	(deg)		(deg)
24	711	50.76	3.546	1091	5.448	847	4.228	-2.44	-0.32	1291	-1.85	-0.24	1441	13.09	951	-3.99	0.34	42.08	776	41.91
25	709	50.92	3.539	1091	5.448	847	4.227	-1.52	-0.27	1291	-1.62	-0.28	1441	17.56	941	-5.16	0.41	57.09	775	56.96
27	708	50.26	3.534	1091	5.447	847	4.227	-0.51	-0.11	1291	-0.31	-0.07	1441	21.43	938	-6.52	0.47	70.96	775	70.93
28	708	50.39	3.531	1090	5.445	847	4.226	-1.93	-0.49	1290	-1.60	-0.41	1440	25.29	941	-7.59	0.50	84.94	775	84.91
29	707	50.24	3.529	1091	5.446	847	4.226	-0.59	-0.16	1291	-0.23	-0.06	1441	26.71	936	-8.30	0.57	98.99	775	98.85
30	707	50.19	3.528	1091	5.447	847	4.226	-1.40	-0.40	1291	-0.77	-0.22	1441	28.55	935	-8.64	0.62	112.73	775	112.66
31	707	50.46	3.526	1091	5.446	847	4.226	-0.24	-0.07	1291	-0.45	-0.14	1441	31.10	932	-8.85	0.68	126.94	775	126.74
32	707	50.43	3.526	1091	5.446	847	4.226	-0.31	-0.11	1291	0.02	0.01	1441	35.00	931	-9.48	0.69	141.84	775	141.76
33	707	50.47	3.526	1091	5.446	847	4.227	-0.83	-0.32	1291	-0.99	-0.38	1441	38.65	928	-9.86	0.71	156.05	775	155.71
35	706	50.82	3.524	1090	5.444	847	4.226	-0.23	-0.09	1290	-0.59	-0.24	1440	41.00	928	-10.17	0.71	169.87	775	169.68
36	706	50.61	3.524	1090	5.445	847	4.226	-0.24	-0.10	1290	-0.04	-0.02	1440	43.53	928	-10.25	0.74	184.00	775	183.68
37	706	50.37	3.524	1090	5.445	847	4.227	-0.05	-0.02	1290	0.03	0.01	1440	42.89	927	-9.92	0.77	197.94	775	197.52
38	706	50.42	3.525	1090	5.445	847	4.227	-0.25	-0.11	1290	-0.52	-0.23	1440	43.71	928	-10.00	0.79	212.10	775	211.50
39	706	50.28	3.525	1090	5.445	847	4.227	0.58	0.26	1290	0.46	0.21	1440	45.74	925	-9.94	0.81	226.61	775	225.53
40	706	50.43	3.524	1090	5.445	847	4.227	0.05	0.03	1290	-0.22	-0.10	1440	46.04	923	-10.01	0.82	241.95	774	240.37
41	706	50.43	3.524	1090	5.445	847	4.227	0.34	0.16	1290	0.50	0.24	1440	47.70	925	-9.90	0.83	255.94	774	254.20
43	706	50.68	3.524	1090	5.445	847	4.228	0.29	0.13	1290	0.18	0.08	1440	46.70	923	-9.88	0.81	270.14	774	268.07
44	707	50.33	3.526	1091	5.448	847	4.230	-0.46	-0.22	1291	-0.63	-0.29	1441	46.81	925	-10.05	0.80	271.08	775	269.03

7.4 SINE WITH DWELL TEST RESULTS

2011 Kia Optima
NHTSA No.: *CB0516*
Date of Test : *9/7/2011*
Date Created: *9/7/2011*

Lateral Stability Test Series No. 2 – Clockwise Initial Steer Direction

File	SWA @ 5deg Ct	MES	Time @ 5deg	COS	Time @ COS	MOS	Time @ MOS	YRR1	YR1	YRR 1 Ct	YRR 175	YR175	YRR17 5 Ct	2nd Yaw Peak	2nd Yaw Peak Ct	Lat Disp	Lat. Acc. 1.07 s	1st SWA Peak	1st SWA Peak Ct	2nd SWA Mean
	(deg)	(mph)	(s)		(s)		(sec)	(%)	(deg/s)		(%)	(deg/s)		(deg/s)		(ft)	(g)	(deg)		(deg)
45	711	50.24	3.546	1091	5.449	847	4.229	-2.60	0.35	1291	-1.87	0.25	1441	-13.46	950	4.06	-0.31	42.72	776	42.60
46	709	50.44	3.538	1091	5.446	847	4.228	-1.03	0.19	1291	-1.13	0.21	1441	-18.39	955	5.29	-0.41	57.79	775	57.49
47	708	50.54	3.534	1090	5.445	847	4.227	-1.28	0.29	1290	-1.63	0.37	1440	-22.41	946	6.35	-0.45	71.68	775	71.43
48	708	50.62	3.531	1091	5.446	847	4.228	-1.44	0.34	1291	-1.12	0.27	1441	-23.89	944	6.77	-0.55	85.63	775	85.43
49	707	50.27	3.528	1090	5.445	847	4.226	-1.01	0.28	1290	-1.11	0.31	1440	-27.96	937	7.77	-0.58	99.74	775	99.35
50	707	50.60	3.527	1090	5.445	847	4.227	-0.98	0.30	1290	-0.75	0.23	1440	-30.63	940	8.22	-0.65	113.62	775	113.16
51	707	50.60	3.526	1090	5.445	847	4.228	-1.31	0.44	1290	-1.21	0.40	1440	-33.39	930	8.95	-0.65	127.75	775	127.35
52	706	50.30	3.525	1090	5.445	847	4.227	-0.70	0.26	1290	-0.41	0.15	1440	-36.73	930	9.25	-0.70	142.79	775	142.28
53	706	50.46	3.524	1090	5.445	847	4.227	-0.33	0.13	1290	-0.47	0.19	1440	-40.25	931	9.40	-0.71	156.85	775	156.26
54	706	50.76	3.524	1090	5.444	847	4.227	-0.92	0.39	1290	-0.84	0.36	1440	-42.51	933	9.56	-0.74	170.79	775	170.13
55	706	50.51	3.524	1090	5.445	847	4.228	-0.76	0.34	1290	-0.50	0.22	1440	-44.27	931	9.60	-0.76	184.88	775	184.04
56	706	50.43	3.524	1090	5.444	847	4.227	-0.70	0.33	1290	-0.62	0.29	1440	-46.19	932	9.82	-0.79	198.84	775	198.02
57	706	50.66	3.524	1090	5.444	847	4.227	-0.57	0.27	1290	-0.64	0.31	1440	-47.54	930	9.87	-0.81	212.88	775	211.99
58	706	50.23	3.524	1090	5.444	847	4.227	-0.23	0.11	1290	-0.13	0.06	1440	-48.06	929	9.77	-0.82	227.22	774	226.06
59	706	50.29	3.525	1091	5.446	847	4.228	-0.68	0.33	1291	-0.76	0.37	1441	-48.51	925	9.58	-0.83	242.46	775	240.97
60	706	50.40	3.525	1091	5.446	847	4.228	-0.78	0.39	1291	-0.68	0.33	1441	-49.41	928	9.77	-0.82	256.46	775	254.76
61	706	50.45	3.523	1091	5.446	847	4.228	0.09	-0.04	1291	0.18	-0.09	1441	-48.35	924	9.24	-0.85	270.60	774	268.58
62	706	50.17	3.524	1091	5.447	847	4.229	-0.22	0.11	1291	-0.45	0.23	1441	-51.14	926	9.59	-0.85	271.55	774	269.59

7.5 SLOWLY INCREASING STEER TEST RESULTS

2011 Kia Optima
NHTSA No.: *CB0516*
Date of Test: *9/7/2011*
Date Created: *9/7/2011*

File	EventPt	DOS	MES (mph)	Mean SPD (mph)	AYcount_3	THETAENCF_3 (deg)	AYCG_CD2_3 (g)	r_squared	ZeroBegin	ZeroEnd
11	702	1	50.441	50.266	1128	-28.475	-0.309	0.993	502	702
12	707	1	50.335	50.192	1124	-28.258	-0.285	0.992	507	707
13	700	1	50.197	50.266	1125	-28.320	-0.305	0.982	500	700
15	705	0	50.210	50.225	1121	28.252	0.303	0.995	505	705
16	681	0	49.777	50.126	1123	28.379	0.311	0.997	481	681
17	697	0	50.021	50.116	1123	28.360	0.305	0.997	497	697
					Averages	28.341	0.3030			

Scalars	Steering Angles (deg)
1.5	42
2.0	57
2.5	71
3.0	85
3.5	99
4.0	113
4.5	127
5.0	142

Scalars	Steering Angles (deg)
5.5	156
6.0	170
6.5	184
7.0	198
7.5	212
8.0	226
8.5	241
9.0	255

Scalars	Steering Angles (deg)
9.5	269
-	270

7.6 INERTIAL SENSING SYSTEM LOCATION COORDINATES

Vehicle: **2011 Kia Optima** NHTSA No.: CB0516

Wheelbase: 110.38 Inches Faro Arm S/N: U08-05-08-06636

Measurement date: 8/25/2011 Certification date: 11/7/10

CMM Measurements

Coordinate system: SAE (X,Y,Z positive forward, to the right, and downward, respectively)

Origin defined at 48" point on lateral arm of measurement fixture, projected onto the ground plane

	Ref X	Ref Y	Ref Z
M_PLANE001_Ground_Plane	-	-	0.000
M_Line_Y_Axis	2.525		0.000
M_Point_48_Ref	0.000	0.000	-
M_CIRCLE001_I_Left_Rear_Wheel_Axle	-26.993	12.699	-12.477
M_Point_IMU_side	12.961	46.693	-13.777
M_Point_ROOF	-	-	-57.578
Motion Pak reference point taken from mid height of unit left side			
Motion Pak Width = 3.05" ==> 1/2 W = 1.525			
Motion_PAK_Location	12.961	48.218	-13.777

Measurement Notes

1. The Faro arm is positioned just to the left of the vehicle, near the rear door.

2. A "centerline jig" is used in the Faro arm measurement. The jig consists of a long beam with a 4 ft lateral arm that is perpendicular to the beam. The jig is placed on the ground underneath the vehicle with the long beam positioned along the centerline of the vehicle, such that the lateral arm extends to the left, slightly forward of the left rear tire. The lateral arm has a marked indentation point which is located 48.00" from the edge of the centerline beam.

3. The Faro arm is used to make the following measurements:
   - Three points on the ground, which establishes the ground plane.
   - Two points along the lateral arm, and projected onto the ground plane. This establishes the y axis.
   - One point at the 48 inch reference point on the lateral arm. This establishes the origin.
   - Three points on the left rear wheel or wheel cover. The Faro arm then computes the center point of the wheel.
   - One point to establish the height of the highest point on the roof of the vehicle.

Coordinate Measurements Calculated for S7D (Matlab Program)

Coordinate system: X,Y,Z positive rearward, to the right, and upward, respectively

Origin defined as follows: X axis: front axle, Y axis: vehicle centerline, Z axis: ground plane

	Ref X	Ref Y	Ref Z
Motion_PAK_Location in S7D (Matlab program) coordinate system	**70.426**	**0.218**	**13.777**

Calculation Notes:

1. X axis value is the difference between the wheelbase and the calculated distance from the rear axle centerline to the IMU (the value must be positive and less than the wheelbase).

2. Y axis value is -48.00 (the Y axis offset of the measurement origin in the S7D coordinate system) plus the measured Y axis value (a negative value indicates the IMU is to the left of the vehicle centerline, and a positive value indicates it is to the right)

3. Z axis value is from the ground plane up to the center of the IMU (value must be positive).