HYUNDAI

Application for Certification - Part 1

Test Group (CBI)

- **Model Year:** 2024
- **Manufacturer Name:** Hyundai Motor Company
- **Test Group:** RHYXV01.6M13
- **Test Group Description:** 1.6 Liter / I4 Turbocharged GDI / Otto-cycle
- **Durability Group:** RHYXHHGNNM13
- **Durability Group Description:** Monolith, WU-TWC + TWC
- **Vehicle Class:** LDV
- **Applicable Standards:** FED: Tier-3 Bin30 / Tier-3 Evap
  CAL: LEV-III SULEV 30 / LEV-III Evap
- **Emission Data Vehicle:** MX5U4G6HA148A/0 (Exh.)
  MQ4U1G6HA581F/0 (Evap.)
- **Carlines Covered by Certificate**: Santa Fe Hybrid AWD, Santa Fe Hybrid FWD
- **EPA Response Requested by:** Jan 28, 2024
- **For Questions, Contact**: Lillian Klawitter
  Tel: 201-790-0276
  E-mail: lklawitter@hatci.com

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01.00 Correspondence and Communications

Please refer to Common Section 01.00.

For questions, call Lillian Klawitter (201-790-0276).

02.00 Durability Group Description

1. Durability Group Name : RHYXHHGNNM13
2. Combustion Cycle : Otto cycle / four stroke
3. Engine Type : Piston / water cooled
4. Fuel Used : Gasoline
5. Basic Fuel Metering System : Direct Injection
6. Catalyst Construction and location : See Section 02.02
7. Precious Metals in Catalyst : See Section 02.02
8. Precious Metal Loading for all Catalysts in the Durability Group : See Section 02.02
9. Range of Catalyst Grouping Statistics : See Section 02.02
10. Battery Capacity(s) : 5.5Ah
11. Battery Chemistry(s) : NCM(Nickel Cobalt Manganese, Li(NiCoMn)O2)
12. Battery Duty Cycle Usage(s) : 20 years / 300,000km
13. Battery Manufacturer : Hyundai Mobis (SK ON)
14. Battery Construction : 9 modules with 8 cells each (72 cells in total)
15. Battery Self-Discharge Information : < 3.0% @SOC60%, RT for 6 months
16. Description of the Thermal Management System
    The thermal management system for the battery is an air-cooling system, in which cabin air is blower through an inlet duct by cooling fan mounted in battery pack and expelled to outside through an outlet duct.
17. Battery Disposal Plan : Please refer to Common Section 02.00

02.01 List of Vehicles in Durability Groups

Please refer to Common Section 02.01.

02.02 Catalyst Information

Test Group Name		RHYXV01.6M13	
Catalyst Type		WU-TWC + TWC	
Brick (in a container)		Dual (Two Monoliths)	Single (One Monolith)
Substrate	Configuration	Honeycomb & Round	Honeycomb & Round
	Major Material	Ceramic	Ceramic
Active Material Composition for each brick		12.5Pt/12.5Pd/1Rh +7Pt:7Pd:1Rh	25Pt/3Rh
Active Material Loading for each brick (g)		4.8 + 2.4	1.5
Code (ID)		W2MAE5	U2M645
Volume (l)		0.4 + 0.6	1.0
Loading Rate		4.35	
Range of Catalyst Grouping Statistics		5.4	

(Note) Pd = Palladium
Pt = Platinum
Rh = Rhodium
TWC = Three Way Catalyst
WU-TWC = Warm-up Three Way Catalyst

03.00 Evaporative/Refueling Family Description

03.00.01 Evaporative/Refueling Family Name: RHYXR0137M1G

03.00.01.01 Evaporative/Refueling Family Parameters

1. Type of vapor storage device: Canister (1EA), Air cleaner (1EA)

2. Basic canister design

Evap. code	Absorption flow rate (g/hr)	Nominal working capacity (g)	Size (cc)	Material	Medium	Nominal fuel tank capacity (gal)
137M1G	15	137	2400	Plastic	Activated Carbon	17.7

3. Fuel system: Returnless fuel system

4. Type of refueling emission control system: Integrated type

5. Fillpipe seal mechanism: Liquid seal type

6. Vapor control system or method of vapor line to the canister:
    a. Fill Limit Vent valve (ORVR)
    b. Overfill Limiter (2way valve)
    c. Canister close valve

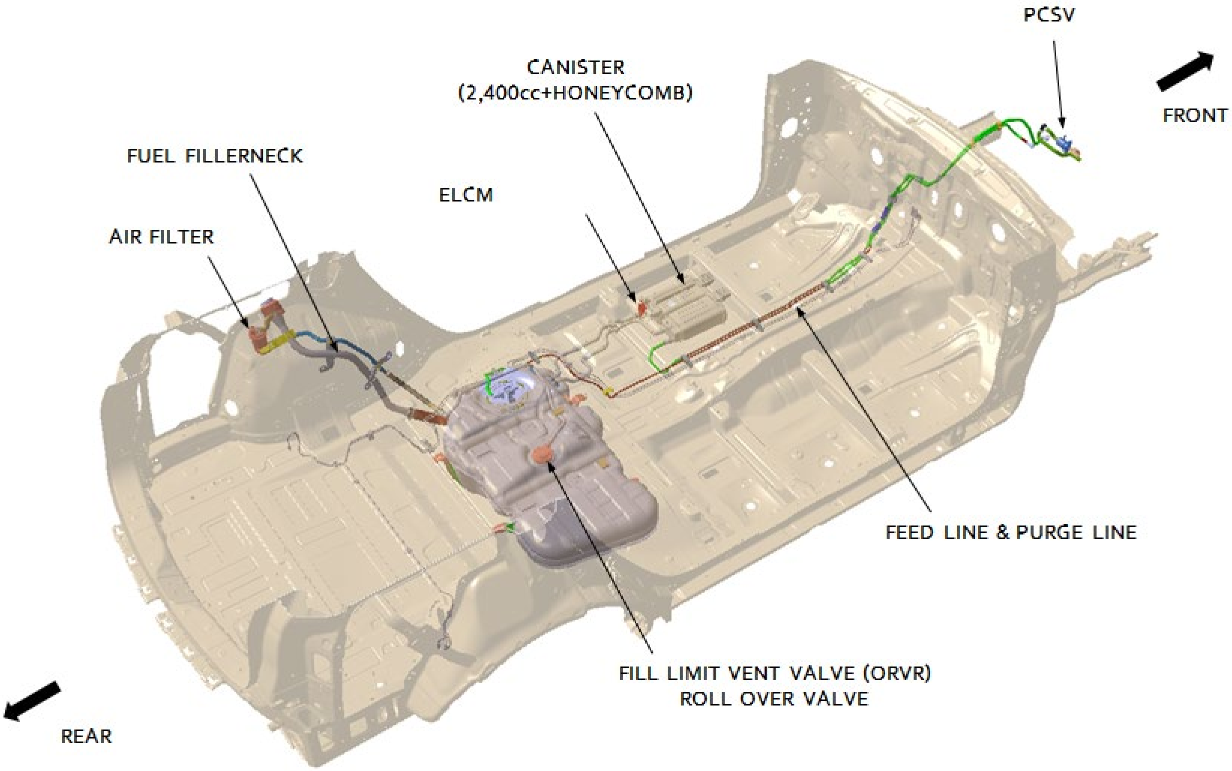
7. Purge control system
    a. Type of valve: Duty
    b. Purge control strategy: Controlled by ECU
    c. High load purge system : No
    d. Active purge system : Yes

8. Vapor hose material: Rubber

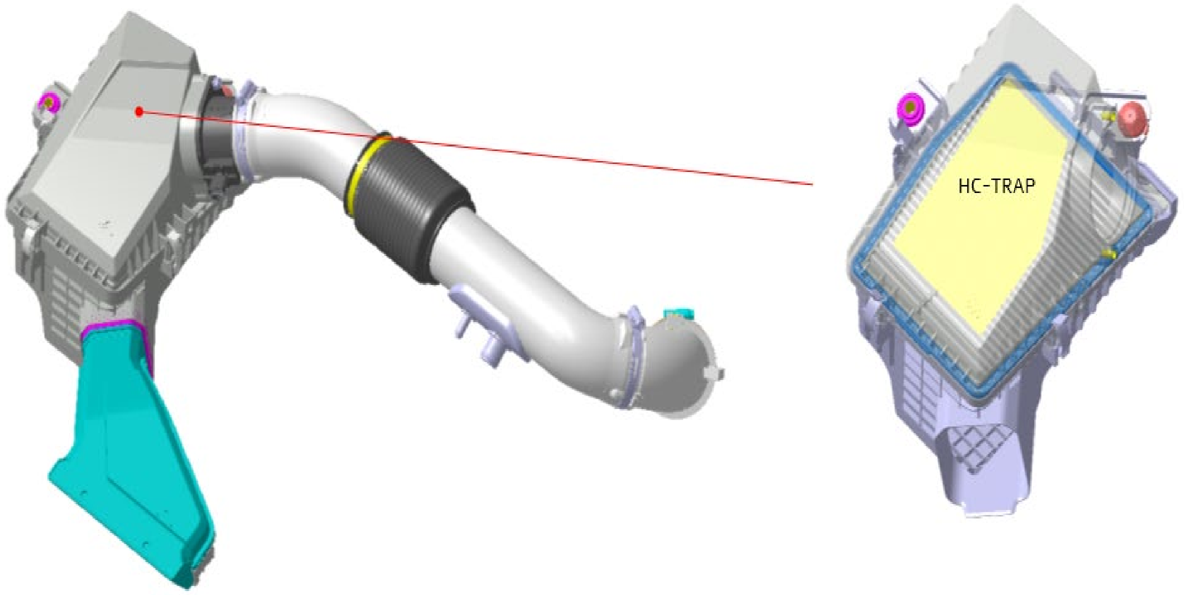
9. Fuel tank material: Plastic

10. HC-Trap:
    a. Media: Paper containing activated carbon
    b. Working capacity: 0.5g

03.00.01.02 Evaporative/Refueling Schematic



03.00.01.03 HC-TRAP Schematic



03.01 Evaporative/Refueling General Description

Please refer to Common Section 03.01.

03.02 List of Vehicles in Evaporative Families

Please refer to Common Section 03.02.

04.00 Durability Procedure Description

04.01 Exhaust Durability Vehicle Test Data

1. Dura Group Name: RHYXHHGNNM13

The exhaust durability tests were conducted according to the Test Procedure of the EPA Standard Bench aging durability procedure with modified low control temperature.

2. Bench Aging Time Calculation Result

Reference Temp.: 914°C
Amount of aging required: 38Hr
Bench Aging Time performed: 38Hr

3. Test Vehicle General Description

Vehicle ID	TM	Curb Weight	ETW	Tire Spec.
5NMS21A1BN1P98405/0	AMS6	4532 lb	4750 lb	235/60 R18

4. Test Data & Deterioration Factor

1) E10

		Emission [g/mile]				
		NMHC	NMOG	NOx	CO	PM
Additive D.F	50K DF	-	-	-	0.07	-
	120K DF	0.0025	-	-	-	-
	150K DF	-	0.0036	0.0016	0.22	0.0000

Note: 50k & 120k mile E/M will be determined using linear interpolation.

2) E0

		Emission [g/mile]			
		THC	CO	N2O	CH4
Additive D.F	120K DF	0.003	0.14	0.0010	0.0014

Note: 120k mile E/M will be determined using linear interpolation.

04.02 Evap./ORVR Durability Vehicle Test Data

(C/O from 21MY Sorento Hybrid)

1. **Evap./Refueling Family Name: RHYXR0137M1G**

2. **4K Stabilized Vehicles**

Vehicle ID: HMQ1RHUR28A/0

	Running Loss (g/mile)	3 Day HSL + DBL (g/test)	2 Day HSL + DBL (g/test)	ORVR (g/gal)
DF (150k - 4k) (Additive)	0	0	0	0

(Note) Negative DF values are reported as zero.

04.03 Exhaust Durability Test Procedure

Please refer to Common Section 04.03 for details.

04.04 Evaporative Durability Test Procedure

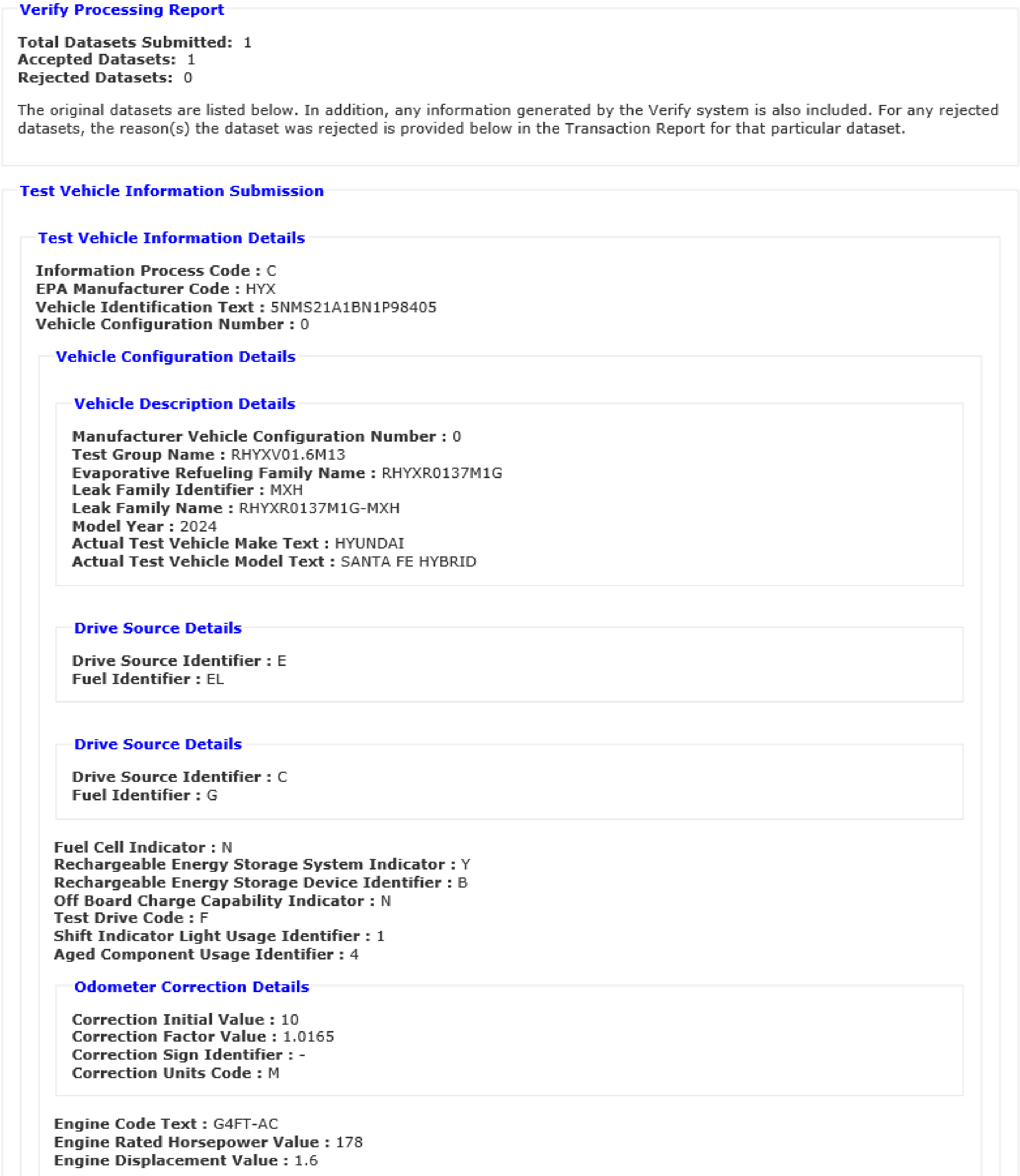
Please refer to Common Section 04.04.

05.00 Test Group Description

Test group name	:	RHYXV01.6M13
Engine displacement covered	:	1.6 L
Electric motor capacity	:	47.7 kW @1800~2100rpm
Voltage	:	270 V
Type and size of electric motor	:	Permanent magnet synchronous motor 3.82 L
Battery capacity	:	5.5 Ah
Voltage and type of battery technology	:	270 V, Lithium Ion battery
Arrangement/Number of Cylinders	:	I4
Vehicle Class(s) Covered	:	LDV
Sales Location/Emission Standard	:	FED : Tier-3 Bin 30 CAL: LEV-III SULEV 30 See CSI report for emission standard levels

06.00 Test Vehicle Description

1. Exhaust Durability Data Vehicle



Verify Processing Report

Total Datasets Submitted: 1
Accepted Datasets: 1
Rejected Datasets: 0

The original datasets are listed below. In addition, any information generated by the Verify system is also included. For any rejected datasets, the reason(s) the dataset was rejected is provided below in the Transaction Report for that particular dataset.

Test Vehicle Information Submission

Test Vehicle Information Details

Information Process Code : C
EPA Manufacturer Code : HYX
Vehicle Identification Text : 5NMS21A1BN1P98405
Vehicle Configuration Number : 0

Vehicle Configuration Details

Vehicle Description Details

Manufacturer Vehicle Configuration Number : 0
Test Group Name : RHYXV01.6M13
Evaporative Refueling Family Name : RHYXR0137M1G
Leak Family Identifier : MXH
Leak Family Name : RHYXR0137M1G-MXH
Model Year : 2024
Actual Test Vehicle Make Text : HYUNDAI
Actual Test Vehicle Model Text : SANTA FE HYBRID

Drive Source Details

Drive Source Identifier : E
Fuel Identifier : EL

Drive Source Details

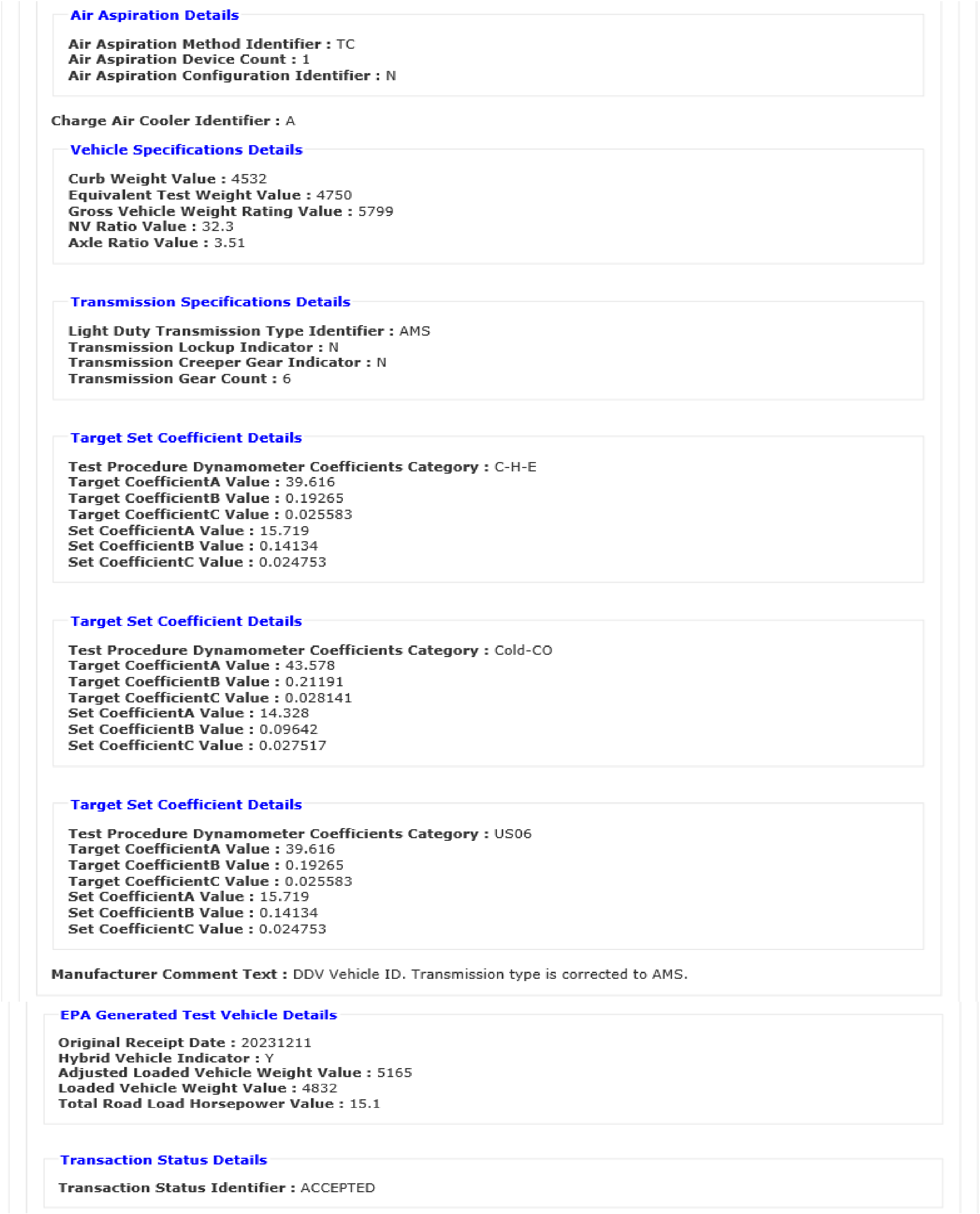
Drive Source Identifier : C
Fuel Identifier : G

Fuel Cell Indicator : N
Rechargeable Energy Storage System Indicator : Y
Rechargeable Energy Storage Device Identifier : B
Off Board Charge Capability Indicator : N
Test Drive Code : F
Shift Indicator Light Usage Identifier : 1
Aged Component Usage Identifier : 4

Odometer Correction Details

Correction Initial Value : 10
Correction Factor Value : 1.0165
Correction Sign Identifier : -
Correction Units Code : M

Engine Code Text : G4FT-AC
Engine Rated Horsepower Value : 178
Engine Displacement Value : 1.6



Air Aspiration Details

Air Aspiration Method Identifier : TC
Air Aspiration Device Count : 1
Air Aspiration Configuration Identifier : N

Charge Air Cooler Identifier : A

Vehicle Specifications Details

Curb Weight Value : 4532
Equivalent Test Weight Value : 4750
Gross Vehicle Weight Rating Value : 5799
NV Ratio Value : 32.3
Axle Ratio Value : 3.51

Transmission Specifications Details

Light Duty Transmission Type Identifier : AMS
Transmission Lockup Indicator : N
Transmission Creeper Gear Indicator : N
Transmission Gear Count : 6

Target Set Coefficient Details

Test Procedure Dynamometer Coefficients Category : C-H-E
Target CoefficientA Value : 39.616
Target CoefficientB Value : 0.19265
Target CoefficientC Value : 0.025583
Set CoefficientA Value : 15.719
Set CoefficientB Value : 0.14134
Set CoefficientC Value : 0.024753

Target Set Coefficient Details

Test Procedure Dynamometer Coefficients Category : Cold-CO
Target CoefficientA Value : 43.578
Target CoefficientB Value : 0.21191
Target CoefficientC Value : 0.028141
Set CoefficientA Value : 14.328
Set CoefficientB Value : 0.09642
Set CoefficientC Value : 0.027517

Target Set Coefficient Details

Test Procedure Dynamometer Coefficients Category : US06
Target CoefficientA Value : 39.616
Target CoefficientB Value : 0.19265
Target CoefficientC Value : 0.025583
Set CoefficientA Value : 15.719
Set CoefficientB Value : 0.14134
Set CoefficientC Value : 0.024753

Manufacturer Comment Text : DDV Vehicle ID. Transmission type is corrected to AMS.

EPA Generated Test Vehicle Details

Original Receipt Date : 20231211
Hybrid Vehicle Indicator : Y
Adjusted Loaded Vehicle Weight Value : 5165
Loaded Vehicle Weight Value : 4832
Total Road Load Horsepower Value : 15.1

Transaction Status Details

Transaction Status Identifier : ACCEPTED

2. Exhaust & Evaporative Emission Data Vehicle

Please refer to CSI report in 07.00.

07.00 Test Results

07.01 EV-CIS Certification Summary Information

Date: 12/11/2023 08:36:39 PM

Certification Summary Information Report

Manufacturer	Hyundai Motor Company	**Manufacturer Code**	HYX
Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G
Certificate Number	--	**CARB Executive Order #**	--
Certificate Issue Date	--	**Certificate Revision Date**	--
Certificate Effective Date	--	**Conditional Certificate**	--
CSI Revision #	--	**CSI Submission/Revision Date**	12/11/2023 08:36:11 PM
Model Year	2024		

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G

Test Group Information

CSI Type	Update for Correction	**Running Change Reference Number**	--
GHG Exempt Status	Not Exempt		

Drive Sources and Fuel(s)

Drive Source #1:

Combustion Engine

Fuel	Basic Fuel Metering System	Lean Burn Strategy Indicator
Gasoline	Spark Ignition Direct fuel injection	No

Drive Source #2:

Electric Motor

Fuel	Basic Fuel Metering System	Lean Burn Strategy Indicator
Electricity	--	--

Hybrid Indicator	Yes		
Multiple Fuel Storage	--	**Rechargeable Energy Storage System Indicator**	Yes
Multiple Fuel Combustion	--	**Off-board Charge Capable Indicator**	No
Fuel Cell Indicator	No	**EPA Vehicle Class**	LDV
Federal Clean Fuel Vehicle	No	**Federal Clean Fuel Vehicle Standard**	--
Federal Clean Fuel Vehicle ILEV	No	**California Partial Zero Emissions Vehicle Indicator**	No
Durability Group Name	RHYXHHGNNM13	**Durability Group Equivalency Factor**	1.0
Reduced Fee Test Group	No	**Certification Region Code(s)**	FA, CA
Complies with HD GHG 2b/3 regulations?	No		
Introduction into Commerce Date	--	**CAP2000 Conditional Certificate?**	N/A
Independent Commercial Importer?	--	**Alternative Fuel Converter Certificate?**	--
SFTP Federal Composite Compliance Identifier	Tier 3	**SFTP Tier 2 Composite CO Option**	No
SFTP LEV-III Composite Compliance Indicator	Yes		
OBD Compliance Type	CARB	**OBD Demonstration Vehicle Test Group**	RHYXT01.6L13
Test Group OBD Compliance Level	Full - no deficiencies	**Number of Test Group OBD Deficiencies**	0
OBD Deficiencies Comments	--		
Mfr Test Group Comments	The fuel for Litmus test is E0. Litmus result(Value/Threshold) City(34.2/32.6) HWY(33.3/29.7). Test No: RHYX10082583(FTP),RHYX10082577(US06),RHYX10082578(SC03),RHYX10082579(Cold CO),RHYX10082576(HWFE)		
Mfr Exhaust / Evap Standards Comments	--		

Certification Summary Information Report

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G

Evaporative/Refueling Family Information

Evaporative Summary Information Type	New	**Submission/Correction Date**	11/21/2023 01:07:47 AM
Integrated ORVR?	Yes	**Fuel(s)**	Gasoline
Multiple Fuel Storage	--		
Bladder Fuel Tank?	No		
Fuel Tank Material	Plastic	**Fuel Tank Material Description**	HDPE
Fill Pipe Seal Type	Liquid seal		
Air Intake System Vapor Storage Device?	Yes	**Air Intake System Vapor Storage Device Description**	HC-TRAP
Fuel System Vapor Storage Canister?	Yes	**Other Vapor Storage**	--
Fuel System Vapor Storage Canister(s) Total Working Capacity (grams)	137	**Number of Primary Canisters**	1
Number of Bleed Canisters	0	**Bleed Canister Total Working Capacity (grams)**	--
Mfr Evaporative/Refueling Family Comments	--		

Leak Family Details

Leak Family Indicator	Yes		
Canister Bleed Test Indicator	Yes	**Applicability of Evaporative Canister Bleed Test**	50 State
Evaporative Canister Bleed Test Comments	--		
CARB Fuel Only (Rig) Test Indicator	No	**Applicability of CARB Fuel Only (Rig) Test**	--
CARB Fuel Only (Rig) Test Comments	--		

Leak Family Name	Applicability of Leak Family Requirements	Leak Family Standard (inches)	Leak Family Description
RHYXR0137M1G-MXH	50 State	0.02	--

Models Covered by this Certificate

Carline Manufacturer	Division	Carline	Certification Region Code(s)	Drive System	Trans - Type	- # of Gears	Trans - Lockup
Hyundai Motor Company	1 - HYUNDAI MOTOR COMPANY	58 - Santa Fe Hybrid AWD	California + CAA Section 177 states	All Wheel Drive	Automated Manual-Selectable (e.g. Automated Manual with paddles)	6	No
Hyundai Motor Company	1 - HYUNDAI MOTOR COMPANY	58 - Santa Fe Hybrid AWD	Federal	All Wheel Drive	Automated Manual-Selectable (e.g. Automated Manual with paddles)	6	No
Hyundai Motor Company	1 - HYUNDAI MOTOR COMPANY	59 - Santa Fe Hybrid FWD	Federal	2-Wheel Drive, Front	Automated Manual-Selectable (e.g. Automated Manual with paddles)	6	No
Hyundai Motor Company	1 - HYUNDAI MOTOR COMPANY	59 - Santa Fe Hybrid FWD	California + CAA Section 177 states	2-Wheel Drive, Front	Automated Manual-Selectable (e.g. Automated Manual with paddles)	6	No

Certification Summary Information Report

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G

Engine Description

Hybrid Type	IC Engine/Electric Motor	**Hybrid Description**	--
Engine Type	4-Stroke Spark Ignition	**Mfr Engine Description**	--
Engine Block Arrangement	Inline	**Mfr Engine Block Arrangement Description**	--
Camless Valvetrain Indicator	No	**Oil Viscosity/Classification**	SAE 0W-20, API SN PLUS
Number of Cylinders/Rotors	4	**Mechanically Variable Compression Ratio Indicator**	N

After Treatment Device(s) (ATD)

ATD Number	ATD Type	ATD Precious Metal	Substrate Material	Substrate Construction
1	Three-way catalyst	Platinum + Palladium + Rhodium	Ceramic	Monolith
2	Three-way catalyst	Platinum + Rhodium	Ceramic	Monolith

Mfr After Treatment Device (ATD) Comments	--
Direct Ozone Reduction (DOR) Device	Not Equipped
Mfr Emission Control Device Comments	--

Engine Configuration Number 1

Engine Displacement (liters)	1.6	**Engine Rated Horsepower**	178
Number of Inlet Valves Per Cylinder	2	**Number of Exhaust Valves Per Cylinder**	2
Air Aspiration Method	Turbocharged	**Number of Air Aspiration Devices**	1
Air Aspiration Device Configuration	Single	**Charge Air Cooler Type**	Air
Air Aspiration Drive Method(s)	Mechanical		
Cylinder Deactivation	No		
Cylinder Deactivation Description	--		
Variable Valve Timing	Yes		
Variable Valve Timing System Description	Fixed 3 (Continuous Variable Valve Timing)		
Variable Valve Lift?	No		
Variable Valve Lift System Description	--		
Number of Knock Sensors	1	**Number of Air/Fuel Sensors**	2
Air/Fuel Sensor # 1 Type	Other	**Air/Fuel Sensor # 1 Description**	WR-HO2S
Air/Fuel Sensor # 2 Type	Heated oxygen	**Air/Fuel Sensor # 2 Description**	--
Mfr Air/Fuel Sensor Comments	--		
Exhaust Gas Recirculation	Yes	**Cooled Exhaust Gas Recirculation**	Yes
EGR Type	Electronic/Electric	**Exhaust Gas Recirculation Description if 'Other'**	--
Closed Loop Air Injection System	No		
Air Injection Type	--	**Air Injection Type if 'Other'**	--
Mfr Engine Configuration Comments	--		

Certification Summary Information Report

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G

Official Test Numbers

Test Group Fuel	FTP	US06	SC03	Cold CO	Highway	EPA City Litmus Value	EPA City Litmus Threshold	EPA Highway Litmus Value	EPA Highway Litmus Threshold	CREE Weighting Factor
Electricity	--	--	--	--	--	--	--	--	--	--
Gasoline	RHYX10082549	RHYX10082551	RHYX10082554	RHYX10082552	RHYX10082550	33.6	228.2	34.1	286.1	--

SFTP LEV-III Official Test Numbers

Test Group Fuel	FTP	US06	SC03
Electricity	--	--	--
Gasoline	RHYX10082549	RHYX10082551	RHYX10082554

Official Charge Depleting Test Numbers

Test Group Fuel	UDDS	Highway
Electricity	--	--

Hybrid Electric Vehicle And Fuel Cell Information

Rechargable Energy Storage System	Battery(s)	**Rechargable Energy Storage System, if Other**	--
Battery Type	Lithium Ion	**Number of Battery Packs**	1
Total Voltage of Battery Packs	270	**Battery Energy Capacity**	5.5
Battery Specific Energy	40.1	**Battery Charger Type**	On-Board
Number of Capacitors	--	**Capacitor Rating (In Farads)**	--
Mfr Capacitor Comments	--		
Hydraulic System Description	--		
Regenerative Braking Type	Electrical Regen Brake		
Regenerative Braking Source	Front Wheels	**Driver Controlled Regenerative Braking**	Yes
Mfr Regenerative Braking Description	--		
Drive Motor(s)/Generator(s)	1		
Motor/Generator Type 1	PMSM	**Rated Motor/Generator Power**	48
Mfr Fuel Cell Description	--		
Fuel Cell On-Board H2 Storage Capacity (kg)	--	**Usable H2 Fill Capacity (kg)**	--
Mfr Hybrid Electric/ Electric Vehicle Comments	--		

Certification Summary Information Report

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G

Emission Data Vehicle Information

Vehicle ID / Configuration	MX5U4G6HA148A / 0	**Manufacturer Vehicle Configuration Number**	0
Original Test Group Name	RHYXV01.6M13	**Original Evaporative/Refueling Family**	RHYXR0137M1G
Original Test Vehicle Model Year	2024		

Vehicle Model

Represented Test Vehicle Make	HYUNDAI	**Represented Test Vehicle Model**	SANTA FE HYBRID

Leak Family Details

Leak Family Identifier	MXH	**Leak Family Name**	RHYXR0137M1G-MXH

Drive Sources and Fuel System Details

Drive Source and Fuel#	Drive Source	Fuel
1	Combustion Engine	Gasoline
2	Electric Motor	Electricity

Hybrid Indicator	Yes		
Multiple Fuel Storage	--	**Multiple Fuel Combustion**	--
Fuel Cell Indicator	No	**Rechargeable Energy Storage System Indicator**	Yes
Rechargeable Energy Storage System	Battery(s)	**Rechargeable Energy Storage System, if 'Other'**	--
Off-board charge Capable Indicator	No		
Odometer Correction -- Initial	10	**Odometer Correction Factor**	1.0165
Odometer Correction Sign	- = System Miles is equal to (Test odometer reading - Initial system miles) * Correction factor		
Odometer Correction Units	Miles		
Engine Code	G4FT-AC	**Rated Horsepower**	178
Displacement (liters)	1.6		
Air Aspiration Method	Turbocharged	**Air Aspiration Method, if 'Other'**	
Number of Air Aspiration Devices	1	**Air Aspiration Device Configuration**	Single
Charge Air Cooler Type	Air	**Drive Mode While Testing**	2-Wheel Drive, Front
Shift Indicator Light Usage	Not eqipped	**Aged Emission Components**	4,000 (mi)
Curb Weight (lbs)	4532	**Equivalent Test Weight (pounds)**	4750
GVWR (lbs)	5799	**N/V Ratio**	32.3
Axle Ratio	3.51		
Transmission Type	Automated Manual- Selectable (e.g. Automated Manual with paddles)	**# of Transmission Gears**	6
Transmission Lockup	No	**Creeper Gear**	No

Certification Summary Information Report

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G

Dynamometer Coefficients:

Coefficient Category	**Target Coefficients**			**Set Coefficients**			
	A (lbf)	**B (lbf/mph)**	**C (lbf/mph**2)**	**A (lbf)**	**B (lbf/mph)**	**C (lbf/mph**2)**	**EPA Calculated Total Road Load Horse Power for City/Highway/Evap Coefficients**
City/Highway/Evap	39.616	0.19265	0.025583	15.719	0.14134	0.024753	15.1
Cold CO	43.578	0.21191	0.028141	14.328	0.09642	0.027517	N/A
US06	39.616	0.19265	0.025583	15.719	0.14134	0.024753	N/A

Emission Control Device Comments	--
Manufacturer Test Vehicle Comments	24MY MX5a HEV AWD 20inch. Rated horse power is corrected to 178 hp. Transmission type is corrected to AMS.

Certification Summary Information Report

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G
Test #	**RHYX10082549**	**Test Procedure**	**21 - Federal fuel 2-day exhaust (w/can load)**
Exhaust Test # for this Evap Test	--	**Test Fuel Type**	48 - Tier 3 E10 Regular Gasoline (9 RVP @Low Alt.)
Test Date	08/17/2023	**Fuel**	Gasoline
Fuel Batch ID	23T-01	**Fuel Calibration Number**	1
Vehicle Class	LDV/Passenger Car	**DF Type**	Mfr. Determined
Verify Test Lab ID	772-1, Jangduck-Dong		
E10 Evaporative Test Measurement Method	--		
Test Start Odometer Reading	4122	**Odometer Units**	M
4WD Test Dyno	No	**Diesel Adjustment Factor Usage**	--
State of Charge Delta	Yes		
Drive Cycle Speed Tolerance Criteria	Used Part 1066 (+/- 2.0 mph, +/- 1.0 sec)	**Road Speed Fan Usage**	Yes

Test Results

Test Result Name	Unrounded Test Result	Verify Calculated FE Equivalent Value (miles per gallon)
CO2 BAG 1 (Bag 1 Carbon Dioxide)	267	--
FE BAG 1 (Bag 1 Fuel Economy)	31.3	31.3
CO2 BAG 2 (Bag 2 Carbon Dioxide)	176	--
FE BAG 2 (Bag 2 Fuel Economy)	47.5	47.5
CO2 BAG 3 (Bag 3 Carbon Dioxide)	286	--
FE BAG 3 (Bag 3 Fuel Economy)	29.2	29.2
CO2 BAG 4 (Bag 4 Carbon Dioxide)	132	--
FE BAG 4 (Bag 4 Fuel Economy)	63.4	63.4
METHANE (CH4 - Methane)	0.0023	--
CO (Carbon Monoxide)	0.0728	--
DT-ASCR (Drive Trace Absolute Speed Change Rating)	1.44	--
DT-EER (Drive Trace Energy Economy Rating)	1.33	--
DT-IWRR (Drive Trace Inertia Work Ratio Rating)	2.01	--
MFR FE (Manufacturer Fuel Economy)	39.4512	39.4512
NOX (Nitrogen Oxide)	0.0021	--
HC-NM (Non-methane Hydrocarbon)	0.0046	--
NMOG (Non-methane organic gases)	0.0051	--
PM (Particulate Matter)	0.0006	--
HC-TOTAL (Total Hydrocarbon)	0.0069	--

Certification Summary Information Report

Test Group RHYXV01.6M13 **Evaporative/Refueling Family** RHYXR0137M1G

Test Result Name	Unrounded Test Result	Verify Calculated CREE/OPT-CREE
Carbon-Related Exhaust Emissions	212	999

Test Result Name	Unrounded Test Result	Verify Calculated CO2
Carbon dioxide	212.0611	--

Manufacturer Test Comments 24MY MX5a HEV AWD 20inch E10 - FTP

Certification Region	Useful Life	Standard Level	Emission Name	Rounded Result	RAF	NMOG/NM HC Ratio	Diesel Adjustment Factor	Add DF	Mult DF	Certification Level	Standard	Pass/Fail
Fed	120,000 miles	Federal Tier 3 Bin 30	CREE	999	--	--	--	0.229467	--	999	--	--
Fed	120,000 miles	Federal Tier 3 Bin 30	METHANE	0.0023	--	--	--	0.0014	--	0.004	0.030	Pass
Fed	150,000 miles	Federal Tier 3 Bin 30	CO	0.07	--	--	--	0.22	--	0.3	1.0	Pass
Fed	150,000 miles	Federal Tier 3 Bin 30	CO-COMP	0.29	--	--	--	0	--	0.3	4.2	Pass
Fed	150,000 miles	Federal Tier 3 Bin 30	NMOG	0.0051	--	1.10	--	0.0036	--	0.009	99.999	Pass
Fed	150,000 miles	Federal Tier 3 Bin 30	NMOG+NOX	0.0072	--	--	--	--	--	0.012	0.030	Pass
Fed	150,000 miles	Federal Tier 3 Bin 30	NMOG+NOX-COMP	0.0126	--	--	--	0	--	0.013	0.030	Pass
Fed	150,000 miles	Federal Tier 3 Bin 30	NOX	0.0021	--	--	--	0.0016	--	0.004	99.999	Pass
Fed	150,000 miles	Federal Tier 3 Bin 30	PM	0.0006	--	--	--	0.0000	--	0.001	0.003	Pass
CA	150,000 miles	California LEV-III SULEV30	CO	0.07	--	--	--	0.22	--	0.3	1.0	Pass
CA	150,000 miles	California LEV-III SULEV30	CO-COMP	0.29	--	--	--	0	--	0.3	4.2	Pass
CA	150,000 miles	California LEV-III SULEV30	NMOG	0.0051	--	1.10	--	0.0036	--	0.009	99.999	Pass
CA	150,000 miles	California LEV-III SULEV30	NMOG+NOX	0.0072	--	--	--	--	--	0.012	0.030	Pass
CA	150,000 miles	California LEV-III SULEV30	NMOG+NOX-COMP	0.0126	--	--	--	0	--	0.013	0.030	Pass
CA	150,000 miles	California LEV-III SULEV30	NOX	0.0021	--	--	--	0.0016	--	0.004	99.999	Pass
CA	150,000 miles	California LEV-III SULEV30	PM	0.0006	--	--	--	0.0000	--	0.001	0.001	Pass

NOTE: For Non-charge depleting tests, the Rounded Result for CREE/OPT-CREE Emission names are Verify-calculated values.

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Certification Summary Information Report

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G
Test #	**RHYX10082552**	**Test Procedure**	**11 - Cold CO**
Exhaust Test # for this Evap Test	--	**Test Fuel Type**	28 - Cold CO E10 Regular Gasoline (Tier 3)
Test Date	08/15/2023	**Fuel**	Gasoline
Fuel Batch ID	22D-01	**Fuel Calibration Number**	1
Vehicle Class	LDV/Passenger Car	**DF Type**	Mfr. Determined
Verify Test Lab ID	772-1, Jangduck-Dong		
E10 Evaporative Test Measurement Method	--		
Test Start Odometer Reading	4053	**Odometer Units**	M
4WD Test Dyno	No	**Diesel Adjustment Factor Usage**	--
State of Charge Delta	Yes		
Drive Cycle Speed Tolerance Criteria	Used Part 1066 (+/- 2.0 mph, +/- 1.0 sec)	**Road Speed Fan Usage**	Yes

Test Results

Test Result Name	Unrounded Test Result	Verify Calculated FE Equivalent Value (miles per gallon)
CO2 BAG 1 (Bag 1 Carbon Dioxide)	440	--
FE BAG 1 (Bag 1 Fuel Economy)	19.6	19.6
CO2 BAG 2 (Bag 2 Carbon Dioxide)	319	--
FE BAG 2 (Bag 2 Fuel Economy)	27.1	27.1
CO2 BAG 3 (Bag 3 Carbon Dioxide)	300	--
FE BAG 3 (Bag 3 Fuel Economy)	28.8	28.8
CO (Carbon Monoxide)	0.2013	--
DT-ASCR (Drive Trace Absolute Speed Change Rating)	0.33	--
DT-EER (Drive Trace Energy Economy Rating)	0.55	--
DT-IWRR (Drive Trace Inertia Work Ratio Rating)	-3.43	--
MFR FE (Manufacturer Fuel Economy)	25.5039	25.5039
NOX (Nitrogen Oxide)	0.0061	--
HC-NM (Non-methane Hydrocarbon)	0.0279	--
HC-TOTAL (Total Hydrocarbon)	0.0331	--

Test Result Name	Unrounded Test Result	Verify Calculated CO2
Carbon dioxide	338.7149	--

Manufacturer Test Comments 24MY MX5a HEV AWD 20inch E10 - 20F

Certification Summary Information Report

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G

Certification Region	Useful Life	Standard Level	Emission Name	Rounded Result	RAF	NMOG/NM HC Ratio	Diesel Adjustment Factor	Add DF	Mult DF	Certification Level	Standard	Pass/Fail
Fed	50,000 miles	Federal Tier 3 Bin 30	CO	0.20	--	--	--	0.07	--	0.3	10.0	Pass
Fed	120,000 miles	Federal Tier 3 Bin 30	HC-NM	0.03	--	--	--	0.0025	--	0.0	0.3	Pass
CA	50,000 miles	California LEV-III SULEV30	CO	0.20	--	--	--	0.07	--	0.3	10.0	Pass

Certification Summary Information Report

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G

Test #	**RHYX10082553**	**Test Procedure**	**52 - Fed. fuel 50 F exh.**
Exhaust Test # for this Evap Test	--	**Test Fuel Type**	48 - Tier 3 E10 Regular Gasoline (9 RVP @Low Alt.)
Test Date	09/12/2023	**Fuel**	Gasoline
Fuel Batch ID	23T-01	**Fuel Calibration Number**	1
Vehicle Class	LDV/Passenger Car	**DF Type**	Mfr. Determined
Verify Test Lab ID	772-1, Jangduck-Dong		
E10 Evaporative Test Measurement Method	--		
Test Start Odometer Reading	4687	**Odometer Units**	M
4WD Test Dyno	No	**Diesel Adjustment Factor Usage**	--
State of Charge Delta	Yes		
Drive Cycle Speed Tolerance Criteria	Used Part 1066 (+/- 2.0 mph, +/- 1.0 sec)	**Road Speed Fan Usage**	Yes

Test Results

Test Result Name	Unrounded Test Result	Verify Calculated FE Equivalent Value (miles per gallon)
CO (Carbon Monoxide)	0.1029	--
DT-ASCR (Drive Trace Absolute Speed Change Rating)	2.35	--
DT-EER (Drive Trace Energy Economy Rating)	1.9	--
DT-IWRR (Drive Trace Inertia Work Ratio Rating)	3.66	--
MFR FE (Manufacturer Fuel Economy)	36.0429	36.0429
NOX (Nitrogen Oxide)	0.0024	--
HC-NM (Non-methane Hydrocarbon)	0.0078	--
NMOG (Non-methane organic gases)	0.0086	--
HC-TOTAL (Total Hydrocarbon)	0.0114	--

Test Result Name	Unrounded Test Result	Verify Calculated CO2
Carbon dioxide	232.3831	--

Manufacturer Test Comments 24MY MX5a HEV AWD 20inch E10 - 50F

Certification Summary Information Report

Test Group RHYXV01.6M13 **Evaporative/Refueling Family** RHYXR0137M1G

Certification Region	Useful Life	Standard Level	Emission Name	Rounded Result	RAF	NMOG/NM HC Ratio	Diesel Adjustment Factor	Add DF	Mult DF	Certification Level	Standard	Pass/Fail
CA	4,000 miles	California LEV-III SULEV30	CO	0.10	--	--	--	--	--	0.1	1.0	Pass
CA	4,000 miles	California LEV-III SULEV30	NMOG	0.0086	--	1.10	--	--	--	0.009	99.999	Pass
CA	4,000 miles	California LEV-III SULEV30	NMOG+NOX	0.0110	--	--	--	--	--	0.011	0.060	Pass
CA	4,000 miles	California LEV-III SULEV30	NOX	0.0024	--	--	--	--	--	0.002	99.999	Pass

Certification Summary Information Report

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G
Test #	**RHYX10082583**	**Test Procedure**	**21 - Federal fuel 2-day exhaust (w/can load)**
Exhaust Test # for this Evap Test	--	**Test Fuel Type**	61 - Tier 2 Cert Gasoline
Test Date	08/27/2023	**Fuel**	Gasoline
Fuel Batch ID	22M-01	**Fuel Calibration Number**	1
Vehicle Class	LDV/Passenger Car	**DF Type**	Mfr. Determined
Verify Test Lab ID	772-1, Jangduck-Dong		
E10 Evaporative Test Measurement Method	--		
Test Start Odometer Reading	4360	**Odometer Units**	M
4WD Test Dyno	No	**Diesel Adjustment Factor Usage**	--
State of Charge Delta	Yes		
Drive Cycle Speed Tolerance Criteria	Used Part 1066 (+/- 2.0 mph, +/- 1.0 sec)	**Road Speed Fan Usage**	Yes

Test Results

Test Result Name	Unrounded Test Result	Verify Calculated FE Equivalent Value (miles per gallon)
CO2 BAG 1 (Bag 1 Carbon Dioxide)	275	--
FE BAG 1 (Bag 1 Fuel Economy)	32.4	32.4
CO2 BAG 2 (Bag 2 Carbon Dioxide)	105	--
FE BAG 2 (Bag 2 Fuel Economy)	84.9	84.9
CO2 BAG 3 (Bag 3 Carbon Dioxide)	279	--
FE BAG 3 (Bag 3 Fuel Economy)	31.9	31.9
CO2 BAG 4 (Bag 4 Carbon Dioxide)	128	--
FE BAG 4 (Bag 4 Fuel Economy)	69.7	69.7
METHANE (CH4 - Methane)	0.0029	--
CO (Carbon Monoxide)	0.0794	--
DT-ASCR (Drive Trace Absolute Speed Change Rating)	1.49	--
DT-EER (Drive Trace Energy Economy Rating)	1.23	--
DT-IWRR (Drive Trace Inertia Work Ratio Rating)	2.12	--
MFR FE (Manufacturer Fuel Economy)	45.7003	45.7003
NOX (Nitrogen Oxide)	0.0018	--
N2O (Nitrous Oxide)	0.0003	--
HC-NM (Non-methane Hydrocarbon)	0.0057	--
NMOG (Non-methane organic gases)	0.0059	--
HC-TOTAL (Total Hydrocarbon)	0.0084	--

Test Result Name	Unrounded Test Result	Verify Calculated CREE/OPT-CREE
Carbon-Related Exhaust Emissions	195	195

Certification Summary Information Report

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G

Test Result Name	Unrounded Test Result	Verify Calculated CO2
Carbon dioxide	194.8639	--

Manufacturer Test Comments 24MY MX5a HEV AWD 20inch E0 - FTP

Certification Region	Useful Life	Standard Level	Emission Name	Rounded Result	RAF	NMOG/NM HC Ratio	Diesel Adjustment Factor	Add DF	Mult DF	Certification Level	Standard	Pass/Fail
Fed	120,000 miles	Federal Tier 3 Bin 30	CREE	195	--	--	--	0.229467	--	195	--	--
Fed	120,000 miles	Federal Tier 3 Bin 30	METHANE	0.0029	--	--	--	0.0014	--	0.004	0.030	Pass
Fed	120,000 miles	Federal Tier 3 Bin 30	N2O	0.0003	--	--	--	0.0010	--	0.001	0.010	Pass
Fed	150,000 miles	Federal Tier 3 Bin 30	CO	0.08	--	--	--	0.22	--	0.3	1.0	Pass
Fed	150,000 miles	Federal Tier 3 Bin 30	NMOG	0.0059	--	1.10	--	0.0036	--	0.010	99.999	Pass
Fed	150,000 miles	Federal Tier 3 Bin 30	NMOG+NOX	0.0077	--	--	--	--	--	0.013	0.030	Pass
Fed	150,000 miles	Federal Tier 3 Bin 30	NOX	0.0018	--	--	--	0.0016	--	0.003	99.999	Pass
CA	150,000 miles	California LEV-III SULEV30	CO	0.08	--	--	--	0.22	--	0.3	1.0	Pass
CA	150,000 miles	California LEV-III SULEV30	NMOG	0.0059	--	1.10	--	0.0036	--	0.010	99.999	Pass
CA	150,000 miles	California LEV-III SULEV30	NMOG+NOX	0.0077	--	--	--	--	--	0.013	0.030	Pass
CA	150,000 miles	California LEV-III SULEV30	NOX	0.0018	--	--	--	0.0016	--	0.003	99.999	Pass

NOTE: For Non-charge depleting tests, the Rounded Result for CREE/OPT-CREE Emission names are Verify-calculated values.

Certification Summary Information Report

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G
Test #	**RHYX10082550**	**Test Procedure**	**3 - HWFE**
Exhaust Test # for this Evap Test	--	**Test Fuel Type**	48 - Tier 3 E10 Regular Gasoline (9 RVP @Low Alt.)
Test Date	08/17/2023	**Fuel**	Gasoline
Fuel Batch ID	23T-01	**Fuel Calibration Number**	1
Vehicle Class	LDV/Passenger Car	**DF Type**	Mfr. Determined
Verify Test Lab ID	772-1, Jangduck-Dong		
E10 Evaporative Test Measurement Method	--		
Test Start Odometer Reading	4136	**Odometer Units**	M
4WD Test Dyno	No	**Diesel Adjustment Factor Usage**	--
State of Charge Delta	Yes		
Drive Cycle Speed Tolerance Criteria	Used Part 1066 (+/- 2.0 mph, +/- 1.0 sec)	**Road Speed Fan Usage**	Yes

Test Results

Test Result Name	Unrounded Test Result	Verify Calculated FE Equivalent Value (miles per gallon)
CO (Carbon Monoxide)	0.0299	--
DT-ASCR (Drive Trace Absolute Speed Change Rating)	2.3	--
DT-EER (Drive Trace Energy Economy Rating)	0.38	--
DT-IWRR (Drive Trace Inertia Work Ratio Rating)	3.38	--
MFR FE (Manufacturer Fuel Economy)	38.7361	38.7361
NOX (Nitrogen Oxide)	0.001	--
HC-NM (Non-methane Hydrocarbon)	0	--
NMOG (Non-methane organic gases)	0	--
HC-TOTAL (Total Hydrocarbon)	0.0001	--

Test Result Name	Unrounded Test Result	Verify Calculated CREE/OPT-CREE
Carbon-Related Exhaust Emissions	216	999

Test Result Name	Unrounded Test Result	Verify Calculated CO2
Carbon dioxide	215.8643	--

Manufacturer Test Comments 24MY MX5a HEV AWD 20inch E10 - HWY

Certification Summary Information Report

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G

Certification Region	Useful Life	Standard Level	Emission Name	Rounded Result	RAF	NMOG/NM HC Ratio	Diesel Adjustment Factor	Add DF	Mult DF	Certification Level	Standard	Pass/Fail
Fed	120,000 miles	Federal Tier 3 Bin 30	CREE	999	--	--	--	0.229467	--	999	--	--
Fed	150,000 miles	Federal Tier 3 Bin 30	NMOG	0.0000	--	1.03	--	0.0036	--	0.004	99.999	Pass
Fed	150,000 miles	Federal Tier 3 Bin 30	NMOG+NOX	0.0010	--	--	--	--	--	0.006	0.030	Pass
Fed	150,000 miles	Federal Tier 3 Bin 30	NOX	0.0010	--	--	--	0.0016	--	0.003	99.999	Pass
CA	150,000 miles	California LEV-III SULEV30	NMOG	0.0000	--	1.03	--	0.0036	--	0.004	99.999	Pass
CA	150,000 miles	California LEV-III SULEV30	NMOG+NOX	0.0010	--	--	--	--	--	0.006	0.030	Pass
CA	150,000 miles	California LEV-III SULEV30	NOX	0.0010	--	--	--	0.0016	--	0.003	99.999	Pass

NOTE: For Non-charge depleting tests, the Rounded Result for CREE/OPT-CREE Emission names are Verify-calculated values.

Certification Summary Information Report

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G
Test #	**RHYX10082576**	**Test Procedure**	**3 - HWFE**
Exhaust Test # for this Evap Test	--	**Test Fuel Type**	61 - Tier 2 Cert Gasoline
Test Date	08/27/2023	**Fuel**	Gasoline
Fuel Batch ID	22M-01	**Fuel Calibration Number**	1
Vehicle Class	LDV/Passenger Car	**DF Type**	Mfr. Determined
Verify Test Lab ID	772-1, Jangduck-Dong		
E10 Evaporative Test Measurement Method	--		
Test Start Odometer Reading	4375	**Odometer Units**	M
4WD Test Dyno	No	**Diesel Adjustment Factor Usage**	--
State of Charge Delta	Yes		
Drive Cycle Speed Tolerance Criteria	Used Part 1066 (+/- 2.0 mph, +/- 1.0 sec)	**Road Speed Fan Usage**	Yes

Test Results

Test Result Name	Unrounded Test Result	Verify Calculated FE Equivalent Value (miles per gallon)
CO (Carbon Monoxide)	0.0743	--
DT-ASCR (Drive Trace Absolute Speed Change Rating)	4.05	--
DT-EER (Drive Trace Energy Economy Rating)	0.5	--
DT-IWRR (Drive Trace Inertia Work Ratio Rating)	5.57	--
MFR FE (Manufacturer Fuel Economy)	45.0177	45.0177
NOX (Nitrogen Oxide)	0.0004	--
HC-NM (Non-methane Hydrocarbon)	0	--
NMOG (Non-methane organic gases)	0	--
HC-TOTAL (Total Hydrocarbon)	0.0001	--

Test Result Name	Unrounded Test Result	Verify Calculated CREE/OPT-CREE
Carbon-Related Exhaust Emissions	198	198

Test Result Name	Unrounded Test Result	Verify Calculated CO2
Carbon dioxide	197.8053	--

Manufacturer Test Comments 24MY MX5a HEV AWD 20inch E0 - HWY

Certification Summary Information Report

Test Group RHYXV01.6M13 **Evaporative/Refueling Family** RHYXR0137M1G

Certification Region	Useful Life	Standard Level	Emission Name	Rounded Result	RAF	NMOG/NMHC Ratio	Diesel Adjustment Factor	Add DF	Mult DF	Certification Level	Standard	Pass/Fail
Fed	120,000 miles	Federal Tier 3 Bin 30	CREE	198	--	--	--	0.229467	--	198	--	--
Fed	150,000 miles	Federal Tier 3 Bin 30	NMOG	0.0000	--	1.03	--	0.0036	--	0.004	99.999	Pass
Fed	150,000 miles	Federal Tier 3 Bin 30	NMOG+NOX	0.0004	--	--	--	--	--	0.006	0.030	Pass
Fed	150,000 miles	Federal Tier 3 Bin 30	NOX	0.0004	--	--	--	0.0016	--	0.002	99.999	Pass
CA	150,000 miles	California LEV-III SULEV30	NMOG	0.0000	--	1.03	--	0.0036	--	0.004	99.999	Pass
CA	150,000 miles	California LEV-III SULEV30	NMOG+NOX	0.0004	--	--	--	--	--	0.006	0.030	Pass
CA	150,000 miles	California LEV-III SULEV30	NOX	0.0004	--	--	--	0.0016	--	0.002	99.999	Pass

NOTE: For Non-charge depleting tests, the Rounded Result for CREE/OPT-CREE Emission names are Verify-calculated values.

Certification Summary Information Report

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G

Test #	**RHYX10082551**	**Test Procedure**	**90 - US06**
Exhaust Test # for this Evap Test	--	**Test Fuel Type**	48 - Tier 3 E10 Regular Gasoline (9 RVP @Low Alt.)
Test Date	08/17/2023	**Fuel**	Gasoline
Fuel Batch ID	23T-01	**Fuel Calibration Number**	1
Vehicle Class	LDV/Passenger Car	**DF Type**	Mfr. Determined
Verify Test Lab ID	772-1, Jangduck-Dong		
E10 Evaporative Test Measurement Method	--		
Test Start Odometer Reading	4157	**Odometer Units**	M
4WD Test Dyno	No	**Diesel Adjustment Factor Usage**	--
State of Charge Delta	Yes		
Drive Cycle Speed Tolerance Criteria	Used Part 1066 (+/- 2.0 mph, +/- 1.0 sec)	**Road Speed Fan Usage**	Yes

Test Results

Test Result Name	Unrounded Test Result	Verify Calculated FE Equivalent Value (miles per gallon)
CO2 BAG 1 (Bag 1 Carbon Dioxide)	443	--
FE BAG 1 (Bag 1 Fuel Economy)	18.9	18.9
CO2 BAG 2 (Bag 2 Carbon Dioxide)	291	--
FE BAG 2 (Bag 2 Fuel Economy)	28.7	28.7
CO (Carbon Monoxide)	0.0569	--
DT-ASCR (Drive Trace Absolute Speed Change Rating)	-2.12	--
DT-EER (Drive Trace Energy Economy Rating)	-0.45	--
DT-IWRR (Drive Trace Inertia Work Ratio Rating)	-3.43	--
MFR FE (Manufacturer Fuel Economy)	25.8205	25.8205
NOX (Nitrogen Oxide)	0.0053	--
HC-NM (Non-methane Hydrocarbon)	0.0047	--
NMOG (Non-methane organic gases)	0.0048	--
PM (Particulate Matter)	0.0013	--
HC-TOTAL (Total Hydrocarbon)	0.0074	--

Test Result Name	Unrounded Test Result	Verify Calculated CO2
Carbon dioxide	324.4861	--

Manufacturer Test Comments 24MY MX5a HEV AWD 20inch E10 - US06

Certification Summary Information Report

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G

Certification Region	Useful Life	Standard Level	Emission Name	Rounded Result	RAF	NMOG/NM HC Ratio	Diesel Adjustment Factor	Add DF	Mult DF	Certification Level	Standard	Pass/Fail
Fed	150,000 miles	Federal Tier 3 Bin 30	CO	0.0569	--	--	--	0.22	--	0.277	99.999	Pass
Fed	150,000 miles	Federal Tier 3 Bin 30	NMOG	0.0048	--	1.03	--	0.0036	--	0.008	99.999	Pass
Fed	150,000 miles	Federal Tier 3 Bin 30	NMOG+NOX	0.0101	--	--	--	--	--	0.015	99.999	Pass
Fed	150,000 miles	Federal Tier 3 Bin 30	NOX	0.0053	--	--	--	0.0016	--	0.007	99.999	Pass
Fed	150,000 miles	Federal Tier 3 Bin 30	PM	0.0013	--	--	--	0.0000	--	0.001	0.006	Pass
CA	150,000 miles	California LEV-III SULEV30	CO	0.0569	--	--	--	0.22	--	0.277	99.999	Pass
CA	150,000 miles	California LEV-III SULEV30	NMOG	0.0048	--	1.03	--	0.0036	--	0.008	99.999	Pass
CA	150,000 miles	California LEV-III SULEV30	NMOG+NOX	0.0101	--	--	--	--	--	0.015	99.999	Pass
CA	150,000 miles	California LEV-III SULEV30	NOX	0.0053	--	--	--	0.0016	--	0.007	99.999	Pass
CA	150,000 miles	California LEV-III SULEV30	PM	0.0013	--	--	--	0.0000	--	0.001	0.006	Pass

Certification Summary Information Report

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G
Test #	**RHYX10082554**	**Test Procedure**	**95 - SC03**
Exhaust Test # for this Evap Test	--	**Test Fuel Type**	48 - Tier 3 E10 Regular Gasoline (9 RVP @Low Alt.)
Test Date	08/18/2023	**Fuel**	Gasoline
Fuel Batch ID	23T-01	**Fuel Calibration Number**	1
Vehicle Class	LDV/Passenger Car	**DF Type**	Mfr. Determined
Verify Test Lab ID	772-1, Jangduck-Dong		
E10 Evaporative Test Measurement Method	--		
Test Start Odometer Reading	4173	**Odometer Units**	M
4WD Test Dyno	No	**Diesel Adjustment Factor Usage**	--
State of Charge Delta	Yes		
Drive Cycle Speed Tolerance Criteria	Used Part 1066 (+/- 2.0 mph, +/- 1.0 sec)	**Road Speed Fan Usage**	Yes

Test Results

Test Result Name	Unrounded Test Result	Verify Calculated FE Equivalent Value (miles per gallon)
CO (Carbon Monoxide)	0.0688	--
DT-ASCR (Drive Trace Absolute Speed Change Rating)	1.47	--
DT-EER (Drive Trace Energy Economy Rating)	1.34	--
DT-IWRR (Drive Trace Inertia Work Ratio Rating)	1.75	--
MFR FE (Manufacturer Fuel Economy)	23.6995	23.6995
NOX (Nitrogen Oxide)	0.0043	--
HC-NM (Non-methane Hydrocarbon)	0.0012	--
NMOG (Non-methane organic gases)	0.0012	--
HC-TOTAL (Total Hydrocarbon)	0.004	--

Test Result Name	Unrounded Test Result	Verify Calculated CO2
Carbon dioxide	353.1541	--

Manufacturer Test Comments 24MY MX5a HEV AWD 20inch E10 - SC03

Certification Summary Information Report

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G

Certification Region	Useful Life	Standard Level	Emission Name	Rounded Result	RAF	NMOG/NM HC Ratio	Diesel Adjustment Factor	Add DF	Mult DF	Certification Level	Standard	Pass/Fail
Fed	150,000 miles	Federal Tier 3 Bin 30	CO	0.0688	--	--	--	0.22	--	0.289	99.999	Pass
Fed	150,000 miles	Federal Tier 3 Bin 30	NMOG	0.0012	--	1.03	--	0.0036	--	0.005	99.999	Pass
Fed	150,000 miles	Federal Tier 3 Bin 30	NMOG+NOX	0.0055	--	--	--	--	--	0.011	99.999	Pass
Fed	150,000 miles	Federal Tier 3 Bin 30	NOX	0.0043	--	--	--	0.0016	--	0.006	99.999	Pass
CA	150,000 miles	California LEV-III SULEV30	CO	0.0688	--	--	--	0.22	--	0.289	99.999	Pass
CA	150,000 miles	California LEV-III SULEV30	NMOG	0.0012	--	1.03	--	0.0036	--	0.005	99.999	Pass
CA	150,000 miles	California LEV-III SULEV30	NMOG+NOX	0.0055	--	--	--	--	--	0.011	99.999	Pass
CA	150,000 miles	California LEV-III SULEV30	NOX	0.0043	--	--	--	0.0016	--	0.006	99.999	Pass

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G

Emission Data Vehicle Information

Vehicle ID / Configuration	MQ4U1G6HA581F / 0	**Manufacturer Vehicle Configuration Number**	0
Original Test Group Name	MKMXV01.6J13	**Original Evaporative/Refueling Family**	MKMXR0137J1G
Original Test Vehicle Model Year	2021		

Vehicle Model

Represented Test Vehicle Make	KIA	**Represented Test Vehicle Model**	SORENTO HYBRID

Leak Family Details

Leak Family Identifier	MQH	**Leak Family Name**	MKMXR0137J1G-MQH

Drive Sources and Fuel System Details

Drive Source and Fuel#	Drive Source	Fuel
1	Combustion Engine	Gasoline
2	Electric Motor	Electricity

Hybrid Indicator	Yes		
Multiple Fuel Storage	--	**Multiple Fuel Combustion**	--
Fuel Cell Indicator	No	**Rechargeable Energy Storage System Indicator**	Yes
Rechargeable Energy Storage System	Battery(s)	**Rechargeable Energy Storage System, if 'Other'**	--
Off-board charge Capable Indicator	No		
Odometer Correction -- Initial	0	**Odometer Correction Factor**	0.9976
Odometer Correction Sign	- = System Miles is equal to (Test odometer reading - Initial system miles) * Correction factor		
Odometer Correction Units	Miles		
Engine Code	G4FT-AC	**Rated Horsepower**	177
Displacement (liters)	1.6		
Air Aspiration Method	Turbocharged	**Air Aspiration Method, if 'Other'**	
Number of Air Aspiration Devices	1	**Air Aspiration Device Configuration**	Single
Charge Air Cooler Type	Air	**Drive Mode While Testing**	2-Wheel Drive, Front
Shift Indicator Light Usage	Not eqipped	**Aged Emission Components**	4,000 (mi)
Curb Weight (lbs)	4065	**Equivalent Test Weight (pounds)**	4250
GVWR (lbs)	5578	**N/V Ratio**	32.3
Axle Ratio	3.51		
Transmission Type	Automated Manual- Selectable (e.g. Automated Manual with paddles)	**# of Transmission Gears**	6
Transmission Lockup	No	**Creeper Gear**	No

Certification Summary Information Report

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G

Dynamometer Coefficients:

	Target Coefficients			Set Coefficients			
Coefficient Category	**A (lbf)**	**B (lbf/mph)**	**C (lbf/mph**2)**	**A (lbf)**	**B (lbf/mph)**	**C (lbf/mph**2)**	**EPA Calculated Total Road Load Horse Power for City/Highway/Evap Coefficients**
City/Highway/Evap	33.96	0.01277	0.027097	12.811	0.05451	0.025975	13.6

Emission Control Device Comments --

Manufacturer Test Vehicle Comments SORENTO HYBRID 21MY 17" EVAP-correct TM type(SA to AMS)

Test #	**MKMX10064838**	**Test Procedure**	**38 - CA fuel 3-day evap.**
Exhaust Test # for this Evap Test	MKMX10064829	**Test Fuel Type**	46 - CARB LEV3 E10 Regular Gasoline
Test Date	04/29/2020	**Fuel**	Gasoline
Fuel Batch ID	19E-03	**Fuel Calibration Number**	1
Vehicle Class	N/A	**DF Type**	Mfr. Determined
Verify Test Lab ID	772-1, Jangduck-Dong		
E10 Evaporative Test Measurement Method	Calculated (1.08 x FID Total Hydrocarbons)		
Test Start Odometer Reading	2250	**Odometer Units**	M
4WD Test Dyno	No	**Diesel Adjustment Factor Usage**	--
State of Charge Delta	Yes		
Drive Cycle Speed Tolerance Criteria	Used Part 86 (+/- 2 mph, +/- 1 sec)	**Road Speed Fan Usage**	No

Test Results

Test Result Name	Unrounded Test Result	Verify Calculated FE Equivalent Value (miles per gallon)
HC-TOTAL-EQUIV (Total Hydrocarbon equivalent - Evap only)	0.2141	--

Manufacturer Test Comments 3DBL

Certification Region	Useful Life	Standard Level	Emission Name	Rounded Result	Add DF	Certification Level	Standard	Pass/Fail
Fed	150,000 miles	Federal Tier 3 Evap	HC-TOTAL-EQUIV	0.2141	0.0000	0.214	0.300	Pass
CA	150,000 miles	California LEV-III Zero Evap (Option 2)	HC-TOTAL-EQUIV	0.2141	0.0000	0.214	0.300	Pass

Certification Summary Information Report

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G
Test #	**MKMX10064840**	**Test Procedure**	**27 - California fuel 2-day evap**
Exhaust Test # for this Evap Test	MKMX10064831	**Test Fuel Type**	46 - CARB LEV3 E10 Regular Gasoline
Test Date	04/14/2020	**Fuel**	Gasoline
Fuel Batch ID	19E-03	**Fuel Calibration Number**	1
Vehicle Class	N/A	**DF Type**	Mfr. Determined
Verify Test Lab ID	772-1, Jangduck-Dong		
E10 Evaporative Test Measurement Method	Calculated (1.08 x FID Total Hydrocarbons)		
Test Start Odometer Reading	2185	**Odometer Units**	M
4WD Test Dyno	No	**Diesel Adjustment Factor Usage**	--
State of Charge Delta	Yes		
Drive Cycle Speed Tolerance Criteria	Used Part 86 (+/- 2 mph, +/- 1 sec)	**Road Speed Fan Usage**	No

Test Results

Test Result Name	Unrounded Test Result	Verify Calculated FE Equivalent Value (miles per gallon)
HC-TOTAL-EQUIV (Total Hydrocarbon equivalent - Evap only)	0.2418	--

Manufacturer Test Comments 2DBL

Certification Region	Useful Life	Standard Level	Emission Name	Rounded Result	Add DF	Certification Level	Standard	Pass/Fail
Fed	150,000 miles	Federal Tier 3 Evap	HC-TOTAL-EQUIV	0.2418	0.0000	0.242	0.300	Pass
CA	150,000 miles	California LEV-III Zero Evap (Option 2)	HC-TOTAL-EQUIV	0.2418	0.0000	0.242	0.300	Pass

Certification Summary Information Report

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G
Test #	**MKMX10064839**	**Test Procedure**	**37 - California Fuel Running Loss**
Exhaust Test # for this Evap Test	MKMX10064829	**Test Fuel Type**	46 - CARB LEV3 E10 Regular Gasoline
Test Date	04/29/2020	**Fuel**	Gasoline
Fuel Batch ID	19E-03	**Fuel Calibration Number**	1
Vehicle Class	N/A	**DF Type**	Mfr. Determined
Verify Test Lab ID	772-1, Jangduck-Dong		
E10 Evaporative Test Measurement Method	Calculated (1.08 x FID Total Hydrocarbons)		
Test Start Odometer Reading	2250	**Odometer Units**	M
4WD Test Dyno	No	**Diesel Adjustment Factor Usage**	--
State of Charge Delta	Yes		
Drive Cycle Speed Tolerance Criteria	Used Part 86 (+/- 2 mph, +/- 1 sec)	**Road Speed Fan Usage**	No

Test Results

Test Result Name	Unrounded Test Result	Verify Calculated FE Equivalent Value (miles per gallon)
HC-TOTAL-EQUIV (Total Hydrocarbon equivalent - Evap only)	0.0002	--

Manufacturer Test Comments RL

Certification Region	Useful Life	Standard Level	Emission Name	Rounded Result	Add DF	Certification Level	Standard	Pass/Fail
Fed	150,000 miles	Federal Tier 3 Evap	HC-TOTAL-EQUIV	0.000	0.000	0.00	0.05	Pass
CA	150,000 miles	California LEV-III Zero Evap (Option 2)	HC-TOTAL-EQUIV	0.000	0.000	0.00	0.05	Pass

Certification Summary Information Report

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G
Test #	**MKMX10064841**	**Test Procedure**	**24 - Federal fuel refueling test (ORVR)**
Exhaust Test # for this Evap Test	MKMX10064824	**Test Fuel Type**	48 - Tier 3 E10 Regular Gasoline (9 RVP @Low Alt.)
Test Date	03/19/2020	**Fuel**	Gasoline
Fuel Batch ID	19T-02	**Fuel Calibration Number**	1
Vehicle Class	N/A	**DF Type**	Mfr. Determined
Verify Test Lab ID	772-1, Jangduck-Dong		
E10 Evaporative Test Measurement Method	Calculated (1.08 x FID Total Hydrocarbons)		
Test Start Odometer Reading	2114	**Odometer Units**	M
4WD Test Dyno	No	**Diesel Adjustment Factor Usage**	--
State of Charge Delta	--		
Drive Cycle Speed Tolerance Criteria	Used Part 1066 (+/- 2.0 mph, +/- 1.0 sec)	**Road Speed Fan Usage**	No

Test Results

Test Result Name	Unrounded Test Result	Verify Calculated FE Equivalent Value (miles per gallon)
HC-TOTAL-EQUIV (Total Hydrocarbon equivalent - Evap only)	0.0304	--

Manufacturer Test Comments ORVR

Certification Region	Useful Life	Standard Level	Emission Name	Rounded Result	Add DF	Certification Level	Standard	Pass/Fail
Fed	150,000 miles	Federal Tier 3 Evap	HC-TOTAL-EQUIV	0.030	0.000	0.03	0.20	Pass
CA	150,000 miles	California LEV-III Zero Evap (Option 2)	HC-TOTAL-EQUIV	0.030	0.000	0.03	0.20	Pass

Certification Summary Information Report

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G

Test #	**MKMX10064842**	**Test Procedure**	**65 - Evap Canister Bleed Test**
Exhaust Test # for this Evap Test	--	**Test Fuel Type**	46 - CARB LEV3 E10 Regular Gasoline
Test Date	03/24/2020	**Fuel**	Gasoline
Fuel Batch ID	19E-03	**Fuel Calibration Number**	1
Vehicle Class	N/A	**DF Type**	Mfr. Determined
Verify Test Lab ID	772-1, Jangduck-Dong		
E10 Evaporative Test Measurement Method	Calculated (1.08 x FID Total Hydrocarbons)		
Test Start Odometer Reading	2141	**Odometer Units**	M
4WD Test Dyno	No	**Diesel Adjustment Factor Usage**	--
State of Charge Delta	--		
Drive Cycle Speed Tolerance Criteria	Used Part 1066 (+/- 2.0 mph, +/- 1.0 sec)	**Road Speed Fan Usage**	No

Test Results

Test Result Name	Unrounded Test Result	Verify Calculated FE Equivalent Value (miles per gallon)
HC-TOTAL (Total Hydrocarbon)	0.0077	--

Manufacturer Test Comments BLEED-CORRECT E10 MEASUREMENT METHOD

Certification Region	Useful Life	Standard Level	Emission Name	Rounded Result	Add DF	Certification Level	Standard	Pass/Fail
Fed	150,000 miles	Federal Tier 3 Evap	HC-TOTAL	0.0077	0.0000	0.008	0.020	Pass
CA	150,000 miles	California LEV-III Zero Evap (Option 2)	HC-TOTAL	0.0077	0.0000	0.008	0.020	Pass

Certification Summary Information Report

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G
Test #	**MKMX10064832**	**Test Procedure**	**67 - Leak Test - Port Near Canister**
Exhaust Test # for this Evap Test	--	**Test Fuel Type**	48 - Tier 3 E10 Regular Gasoline (9 RVP @Low Alt.)
Test Date	03/13/2020	**Fuel**	Gasoline
Fuel Batch ID	19T-02	**Fuel Calibration Number**	1
Vehicle Class	N/A	**DF Type**	Mfr. Determined
Verify Test Lab ID	772-1, Jangduck-Dong		
E10 Evaporative Test Measurement Method	--		
Test Start Odometer Reading	2045	**Odometer Units**	M
4WD Test Dyno	No	**Diesel Adjustment Factor Usage**	--
State of Charge Delta	--		
Drive Cycle Speed Tolerance Criteria	Used Part 1066 (+/- 2.0 mph, +/- 1.0 sec)	**Road Speed Fan Usage**	No

Test Results

Test Result Name	Unrounded Test Result	Verify Calculated FE Equivalent Value
LEAK-DIA (Effective Leak Diameter (inches))	0	--

Manufacturer Test Comments Leak Test Port Near Canister

Certification Region	Useful Life	Standard Level	Emission Name	Rounded Result	Add DF	Certification Level	Standard	Pass/Fail
Fed	150,000 miles	Federal Tier 3 Evap	LEAK-DIA	0.0000	0.0000	0.000	0.020	Pass
CA	150,000 miles	California LEV-III Zero Evap (Option 2)	LEAK-DIA	0.000	0.000	0.00	0.02	Pass

Certification Summary Information Report

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G
Test #	**MKMX10064837**	**Test Procedure**	**68 - Leak Test - Port Near Fuel Pipe**
Exhaust Test # for this Evap Test	--	**Test Fuel Type**	48 - Tier 3 E10 Regular Gasoline (9 RVP @Low Alt.)
Test Date	03/13/2020	**Fuel**	Gasoline
Fuel Batch ID	19T-02	**Fuel Calibration Number**	1
Vehicle Class	N/A	**DF Type**	Mfr. Determined
Verify Test Lab ID	772-1, Jangduck-Dong		
E10 Evaporative Test Measurement Method	--		
Test Start Odometer Reading	2045	**Odometer Units**	M
4WD Test Dyno	No	**Diesel Adjustment Factor Usage**	--
State of Charge Delta	--		
Drive Cycle Speed Tolerance Criteria	Used Part 1066 (+/- 2.0 mph, +/- 1.0 sec)	**Road Speed Fan Usage**	No

Test Results

Test Result Name	Unrounded Test Result	Verify Calculated FE Equivalent Value
LEAK-DIA (Effective Leak Diameter (inches))	0	--

Manufacturer Test Comments Leak Test Port Near Fuel Pipe

Certification Region	Useful Life	Standard Level	Emission Name	Rounded Result	Add DF	Certification Level	Standard	Pass/Fail
Fed	150,000 miles	Federal Tier 3 Evap	LEAK-DIA	0.0000	0.0000	0.000	0.020	Pass
CA	150,000 miles	California LEV-III Zero Evap (Option 2)	LEAK-DIA	0.000	0.0000	0.00	0.02	Pass

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G

Fuel Properties

Fuel Batch ID	**23T-01**	**Fuel Calibration Number**	**1**
Test Fuel Type	48 - Tier 3 E10 Regular Gasoline (9 RVP @Low Alt.)	**Fuel Batch Calibration Date**	09/29/2022
Fuel Batch Calibration Effective Date	08/07/2023	**Fuel Batch Calibration Ineffective Date**	08/07/2026
Carbon Weight Fraction NMHC	--	**Carbon Weight Fraction HC**	--
Exhaust Carbon Weight Fraction	--	**Fuel Methanol Volume Fraction**	--
Fuel Density (grams/cubic ft)	--	**Fuel Specific Gravity**	0.74
Fuel Ethanol Volume Percent (%)	9.8	**Fuel Net Heating Value (BTU / lb)**	18779
Fuel Blend Carbon Weight Fraction	0.824	**Weight Fraction CO2**	--
Fuel Batch ID	**19E-03**	**Fuel Calibration Number**	**1**
Test Fuel Type	46 - CARB LEV3 E10 Regular Gasoline	**Fuel Batch Calibration Date**	08/08/2019
Fuel Batch Calibration Effective Date	10/29/2019	**Fuel Batch Calibration Ineffective Date**	10/29/2022
Carbon Weight Fraction NMHC	--	**Carbon Weight Fraction HC**	--
Exhaust Carbon Weight Fraction	--	**Fuel Methanol Volume Fraction**	--
Fuel Density (grams/cubic ft)	--	**Fuel Specific Gravity**	0.75
Fuel Ethanol Volume Percent (%)	9.6	**Fuel Net Heating Value (BTU / lb)**	17917
Fuel Blend Carbon Weight Fraction	0.827	**Weight Fraction CO2**	--
Fuel Batch ID	**22M-01**	**Fuel Calibration Number**	**1**
Test Fuel Type	61 - Tier 2 Cert Gasoline	**Fuel Batch Calibration Date**	02/14/2022
Fuel Batch Calibration Effective Date	02/14/2022	**Fuel Batch Calibration Ineffective Date**	02/14/2025
Carbon Weight Fraction NMHC	--	**Carbon Weight Fraction HC**	--
Exhaust Carbon Weight Fraction	--	**Fuel Methanol Volume Fraction**	--
Fuel Density (grams/cubic ft)	--	**Fuel Specific Gravity**	0.743
Fuel Ethanol Volume Percent (%)	--	**Fuel Net Heating Value (BTU / lb)**	18435
Fuel Blend Carbon Weight Fraction	0.867	**Weight Fraction CO2**	--
Fuel Batch ID	**19T-02**	**Fuel Calibration Number**	**1**
Test Fuel Type	48 - Tier 3 E10 Regular Gasoline (9 RVP @Low Alt.)	**Fuel Batch Calibration Date**	06/05/2019
Fuel Batch Calibration Effective Date	12/10/2019	**Fuel Batch Calibration Ineffective Date**	12/10/2022
Carbon Weight Fraction NMHC	--	**Carbon Weight Fraction HC**	--
Exhaust Carbon Weight Fraction	--	**Fuel Methanol Volume Fraction**	--
Fuel Density (grams/cubic ft)	--	**Fuel Specific Gravity**	0.744
Fuel Ethanol Volume Percent (%)	9.8	**Fuel Net Heating Value (BTU / lb)**	17949
Fuel Blend Carbon Weight Fraction	0.826	**Weight Fraction CO2**	--
Fuel Batch ID	**22D-01**	**Fuel Calibration Number**	**1**
Test Fuel Type	28 - Cold CO E10 Regular Gasoline (Tier 3)	**Fuel Batch Calibration Date**	07/29/2021

Certification Summary Information Report

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G
Fuel Batch Calibration Effective Date	05/10/2022	**Fuel Batch Calibration Ineffective Date**	05/10/2025
Carbon Weight Fraction NMHC	--	**Carbon Weight Fraction HC**	--
Exhaust Carbon Weight Fraction	--	**Fuel Methanol Volume Fraction**	--
Fuel Density (grams/cubic ft)	--	**Fuel Specific Gravity**	0.742
Fuel Ethanol Volume Percent (%)	9.9	**Fuel Net Heating Value (BTU / lb)**	17925
Fuel Blend Carbon Weight Fraction	0.828	**Weight Fraction CO2**	--

Certification Summary Information Report

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G

Consolidated List of Standards

Exhaust Standards

Cert Region	Federal	**Cert/In-Use Code**	Cert
Vehicle Class	LDV/Passenger Car	**Standard Level**	Federal Tier 3 Bin 30
Fuel	Gasoline	**Test Procedure**	Federal fuel 2-day exhaust (w/can load)

Useful Life	Emission Name	Rounded Result	RAF	NMOG / NMHC	Upward Diesel Adjustment Factor	Downward Diesel Adjustment Factor	Mult DF	Add DF	Std
120,000 miles	CREE	--	--	--	--	--	--	0.229467	999
120,000 miles	METHANE	--	--	--	--	--	--	0.0014	0.030
120,000 miles	N2O	--	--	--	--	--	--	0.0010	0.010
150,000 miles	CO	--	--	--	--	--	--	0.22	1.0
150,000 miles	CO-COMP	--	--	--	--	--	--	0	4.2
150,000 miles	HCHO	--	--	--	--	--	--	--	0.004
150,000 miles	NMOG	--	--	1.10	--	--	--	0.0036	99.999
150,000 miles	NMOG+NOX	--	--	--	--	--	--	0	0.030
150,000 miles	NMOG+NOX-COMP	--	--	--	--	--	--	0	0.030
150,000 miles	NOX	--	--	--	--	--	--	0.0016	99.999
150,000 miles	PM	--	--	--	--	--	--	0.0000	0.003

Cert Region	California + CAA Section 177 states	**Cert/In-Use Code**	Cert
Vehicle Class	LDV/Passenger Car	**Standard Level**	California LEV-III SULEV30
Fuel	Gasoline	**Test Procedure**	SC03

Useful Life	Emission Name	Rounded Result	RAF	NMOG / NMHC	Upward Diesel Adjustment Factor	Downward Diesel Adjustment Factor	Mult DF	Add DF	Std
150,000 miles	CO	--	--	--	--	--	--	0.22	99.999
150,000 miles	NMOG	--	--	1.03	--	--	--	0.0036	99.999
150,000 miles	NMOG+NOX	--	--	--	--	--	--	0	99.999
150,000 miles	NOX	--	--	--	--	--	--	0.0016	99.999

Certification Summary Information Report

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G

Cert Region	Federal	**Cert/In-Use Code**	Cert
Vehicle Class	LDV/Passenger Car	**Standard Level**	Federal Tier 3 Bin 30
Fuel	Gasoline	**Test Procedure**	HWFE

Useful Life	Emission Name	Rounded Result	RAF	NMOG / NMHC	Upward Diesel Adjustment Factor	Downward Diesel Adjustment Factor	Mult DF	Add DF	Std
120,000 miles	CREE	--	--	--	--	--	--	0.229467	999
150,000 miles	NMOG	--	--	1.03	--	--	--	0.0036	99.999
150,000 miles	NMOG+NOX	--	--	--	--	--	--	0	0.030
150,000 miles	NOX	--	--	--	--	--	--	0.0016	99.999

Cert Region	Federal	**Cert/In-Use Code**	Cert
Vehicle Class	LDV/Passenger Car	**Standard Level**	Federal Tier 3 Bin 30
Fuel	Gasoline	**Test Procedure**	Cold CO

Useful Life	Emission Name	Rounded Result	RAF	NMOG / NMHC	Upward Diesel Adjustment Factor	Downward Diesel Adjustment Factor	Mult DF	Add DF	Std
50,000 miles	CO	--	--	--	--	--	--	0.07	10.0
120,000 miles	HC-NM	--	--	--	--	--	--	0.0025	0.3

Cert Region	California + CAA Section 177 states	**Cert/In-Use Code**	Cert
Vehicle Class	LDV/Passenger Car	**Standard Level**	California LEV-III SULEV30
Fuel	Gasoline	**Test Procedure**	Fed. fuel 50 F exh.

Useful Life	Emission Name	Rounded Result	RAF	NMOG / NMHC	Upward Diesel Adjustment Factor	Downward Diesel Adjustment Factor	Mult DF	Add DF	Std
4,000 miles	CO	--	--	--	--	--	--	--	1.0
4,000 miles	HCHO	--	--	--	--	--	--	--	0.008
4,000 miles	NMOG	--	--	1.10	--	--	--	--	99.999
4,000 miles	NMOG+NOX	--	--	--	--	--	1	--	0.060
4,000 miles	NOX	--	--	--	--	--	--	--	99.999

Certification Summary Information Report

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G

Cert Region	California + CAA Section 177 states	**Cert/In-Use Code**	Cert
Vehicle Class	LDV/Passenger Car	**Standard Level**	California LEV-III SULEV30
Fuel	Gasoline	**Test Procedure**	Federal fuel 2-day exhaust (w/can load)

Useful Life	Emission Name	Rounded Result	RAF	NMOG / NMHC	Upward Diesel Adjustment Factor	Downward Diesel Adjustment Factor	Mult DF	Add DF	Std
150,000 miles	CO	--	--	--	--	--	--	0.22	1.0
150,000 miles	CO-COMP	--	--	--	--	--	--	0	4.2
150,000 miles	HCHO	--	--	--	--	--	--	--	0.004
150,000 miles	NMOG	--	--	1.10	--	--	--	0.0036	99.999
150,000 miles	NMOG+NOX	--	--	--	--	--	--	0	0.030
150,000 miles	NMOG+NOX-COMP	--	--	--	--	--	--	0	0.030
150,000 miles	NOX	--	--	--	--	--	--	0.0016	99.999
150,000 miles	PM	--	--	--	--	--	--	0.0000	0.001

Cert Region	Federal	**Cert/In-Use Code**	Cert
Vehicle Class	LDV/Passenger Car	**Standard Level**	Federal Tier 3 Bin 30
Fuel	Gasoline	**Test Procedure**	SC03

Useful Life	Emission Name	Rounded Result	RAF	NMOG / NMHC	Upward Diesel Adjustment Factor	Downward Diesel Adjustment Factor	Mult DF	Add DF	Std
150,000 miles	CO	--	--	--	--	--	--	0.22	99.999
150,000 miles	NMOG	--	--	1.03	--	--	--	0.0036	99.999
150,000 miles	NMOG+NOX	--	--	--	--	--	--	0	99.999
150,000 miles	NOX	--	--	--	--	--	--	0.0016	99.999

Cert Region	Federal	**Cert/In-Use Code**	Cert
Vehicle Class	LDV/Passenger Car	**Standard Level**	Federal Tier 3 Bin 30
Fuel	Gasoline	**Test Procedure**	US06

Useful Life	Emission Name	Rounded Result	RAF	NMOG / NMHC	Upward Diesel Adjustment Factor	Downward Diesel Adjustment Factor	Mult DF	Add DF	Std
150,000 miles	CO	--	--	--	--	--	--	0.22	99.999
150,000 miles	NMOG	--	--	1.03	--	--	--	0.0036	99.999
150,000 miles	NMOG+NOX	--	--	--	--	--	--	0	99.999
150,000 miles	NOX	--	--	--	--	--	--	0.0016	99.999
150,000 miles	PM	--	--	--	--	--	--	0.0000	0.006

Certification Summary Information Report

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G

Cert Region	California + CAA Section 177 states	**Cert/In-Use Code**	Cert
Vehicle Class	LDV/Passenger Car	**Standard Level**	California LEV-III SULEV30
Fuel	Gasoline	**Test Procedure**	US06

Useful Life	Emission Name	Rounded Result	RAF	NMOG / NMHC	Upward Diesel Adjustment Factor	Downward Diesel Adjustment Factor	Mult DF	Add DF	Std
150,000 miles	CO	--	--	--	--	--	--	0.22	99.999
150,000 miles	NMOG	--	--	1.03	--	--	--	0.0036	99.999
150,000 miles	NMOG+NOX	--	--	--	--	--	--	0	99.999
150,000 miles	NOX	--	--	--	--	--	--	0.0016	99.999
150,000 miles	PM	--	--	--	--	--	--	0.0000	0.006

Cert Region	California + CAA Section 177 states	**Cert/In-Use Code**	Cert
Vehicle Class	LDV/Passenger Car	**Standard Level**	California LEV-III SULEV30
Fuel	Gasoline	**Test Procedure**	HWFE

Useful Life	Emission Name	Rounded Result	RAF	NMOG / NMHC	Upward Diesel Adjustment Factor	Downward Diesel Adjustment Factor	Mult DF	Add DF	Std
150,000 miles	NMOG	--	--	1.03	--	--	--	0.0036	99.999
150,000 miles	NMOG+NOX	--	--	--	--	--	--	0	0.030
150,000 miles	NOX	--	--	--	--	--	--	0.0016	99.999

Cert Region	California + CAA Section 177 states	**Cert/In-Use Code**	Cert
Vehicle Class	LDV/Passenger Car	**Standard Level**	California LEV-III SULEV30
Fuel	Gasoline	**Test Procedure**	Cold CO

Useful Life	Emission Name	Rounded Result	RAF	NMOG / NMHC	Upward Diesel Adjustment Factor	Downward Diesel Adjustment Factor	Mult DF	Add DF	Std
50,000 miles	CO	--	--	--	--	--	--	0.07	10.0

Evaporative/Refueling Standards

Evaporative/Refueling Family	RHYXR0137M1G	**Cert Region**	California + CAA Section 177 states
Cert/In-Use Code	Cert	**Standard Level**	California LEV-III Zero Evap (Option 2)
Test Procedure	California Fuel Running Loss		

Fuel	Useful Life	Emission Name	Rounded Result	Std	Add DF
Gasoline	150,000 miles	HC-TOTAL-EQUIV	--	0.05	0.000

Certification Summary Information Report

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G

Evaporative/Refueling Family RHYXR0137M1G **Cert Region** Federal
Cert/In-Use Code Cert **Standard Level** Federal Tier 3 Evap
Test Procedure California Fuel Running Loss

Fuel	Useful Life	Emission Name	Rounded Result	Std	Add DF
Gasoline	150,000 miles	HC-TOTAL-EQUIV	--	0.05	0.000

Evaporative/Refueling Family RHYXR0137M1G **Cert Region** California + CAA Section 177 states
Cert/In-Use Code Cert **Standard Level** California LEV-III Zero Evap (Option 2)
Test Procedure Federal fuel refueling test (ORVR)

Fuel	Useful Life	Emission Name	Rounded Result	Std	Add DF
Gasoline	150,000 miles	HC-TOTAL-EQUIV	--	0.20	0.000

Evaporative/Refueling Family RHYXR0137M1G **Cert Region** California + CAA Section 177 states
Cert/In-Use Code Cert **Standard Level** California LEV-III Zero Evap (Option 2)
Test Procedure CA fuel 3-day evap.

Fuel	Useful Life	Emission Name	Rounded Result	Std	Add DF
Gasoline	150,000 miles	HC-TOTAL-EQUIV	--	0.300	0.0000

Evaporative/Refueling Family RHYXR0137M1G **Cert Region** Federal
Cert/In-Use Code Cert **Standard Level** Federal Tier 3 Evap
Test Procedure Federal fuel refueling test (ORVR)

Fuel	Useful Life	Emission Name	Rounded Result	Std	Add DF
Gasoline	150,000 miles	HC-TOTAL-EQUIV	--	0.20	0.000

Evaporative/Refueling Family RHYXR0137M1G **Cert Region** Federal
Cert/In-Use Code Cert **Standard Level** Federal Tier 3 Evap
Test Procedure CA fuel 3-day evap.

Fuel	Useful Life	Emission Name	Rounded Result	Std	Add DF
Gasoline	150,000 miles	HC-TOTAL-EQUIV	--	0.300	0.0000

Certification Summary Information Report

Test Group RHYXV01.6M13 **Evaporative/Refueling Family** RHYXR0137M1G

Evaporative/Refueling Family RHYXR0137M1G **Cert Region** Federal
Cert/In-Use Code Cert **Standard Level** Federal Tier 3 Evap
Test Procedure California fuel 2-day evap

Fuel	Useful Life	Emission Name	Rounded Result	Std	Add DF
Gasoline	150,000 miles	HC-TOTAL-EQUIV	--	0.300	0.0000

Evaporative/Refueling Family RHYXR0137M1G **Cert Region** Federal
Cert/In-Use Code Cert **Standard Level** Federal Tier 3 Evap
Test Procedure Evap Canister Bleed Test

Fuel	Useful Life	Emission Name	Rounded Result	Std	Add DF
Gasoline	150,000 miles	HC-TOTAL	--	0.020	0.0000

Evaporative/Refueling Family RHYXR0137M1G **Cert Region** California + CAA Section 177 states
Cert/In-Use Code Cert **Standard Level** California LEV-III Zero Evap (Option 2)
Test Procedure Leak Test - Port Near Fuel Pipe

Fuel	Useful Life	Emission Name	Rounded Result	Std	Add DF
Gasoline	150,000 miles	LEAK-DIA	--	0.02	0.0000

Evaporative/Refueling Family RHYXR0137M1G **Cert Region** California + CAA Section 177 states
Cert/In-Use Code Cert **Standard Level** California LEV-III Zero Evap (Option 2)
Test Procedure Evap Canister Bleed Test

Fuel	Useful Life	Emission Name	Rounded Result	Std	Add DF
Gasoline	150,000 miles	HC-TOTAL	--	0.020	0.0000

Evaporative/Refueling Family RHYXR0137M1G **Cert Region** California + CAA Section 177 states
Cert/In-Use Code Cert **Standard Level** California LEV-III Zero Evap (Option 2)
Test Procedure California fuel 2-day evap

Fuel	Useful Life	Emission Name	Rounded Result	Std	Add DF
Gasoline	150,000 miles	HC-TOTAL-EQUIV	--	0.300	0.0000

Certification Summary Information Report

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G

Evaporative/Refueling Family RHYXR0137M1G
Cert Region Federal
Cert/In-Use Code Cert
Standard Level Federal Tier 3 Evap
Test Procedure Leak Test - Port Near Canister

Fuel	Useful Life	Emission Name	Rounded Result	Std	Add DF
Gasoline	150,000 miles	LEAK-DIA	--	0.020	0.0000

Evaporative/Refueling Family RHYXR0137M1G
Cert Region California + CAA Section 177 states
Cert/In-Use Code Cert
Standard Level California LEV-III Zero Evap (Option 2)
Test Procedure Leak Test - Port Near Canister

Fuel	Useful Life	Emission Name	Rounded Result	Std	Add DF
Gasoline	150,000 miles	LEAK-DIA	--	0.02	0.000

Evaporative/Refueling Family RHYXR0137M1G
Cert Region Federal
Cert/In-Use Code Cert
Standard Level Federal Tier 3 Evap
Test Procedure Leak Test - Port Near Fuel Pipe

Fuel	Useful Life	Emission Name	Rounded Result	Std	Add DF
Gasoline	150,000 miles	LEAK-DIA	--	0.020	0.0000

Glossary

Useful Life

4	4,000 miles	120	120,000 miles
50	50,000 miles	150	150,000 miles
100	100,000 miles		

Emission Name

HC-TOTAL	Total Hydrocarbon	N2O	Nitrous Oxide
CO	Carbon Monoxide	SPITBACK	Spitback Hydrocarbon in grams
CO2	Carbon dioxide	AMP-HRS	Integrated Amp-hours
CREE	Carbon-Related Exhaust Emissions	START-SOC	System Start State of Charge Watt-hours
OPT-CREE	Optional Carbon-Related Exhaust Emissions	END-SOC	System End State of Charge Watt-hours
NOX	Nitrogen Oxide	ACT-DISTANCE	Actual Distance Driven (miles)
PM	Particulate Matter	AS-VOLT	Average System Voltage
PM-COMP	SFTP Composite Particulate Matter	CO2 BAG 1	Bag 1 Carbon Dioxide
HC-NM	Non-methane Hydrocarbon	CO2 BAG 2	Bag 2 Carbon Dioxide
OMHCE	Organic material Hydrocarbon Equivalent	CO2 BAG 3	Bag 3 Carbon Dioxide
OMNMHCE	Organic material non-methane HC equivalent	CO2 BAG 4	Bag 4 Carbon Dioxide
NMOG	Non-methane organic gases	NMOG+NOX	Non-methane organic gases plus Nitrogen Oxides
HCHO	Formaldehyde	NMOG+NOX-COMP	SFTP Composite Non-methane Organic Gases + Nitrogen Oxides
H3C2HO	Acetaldehyde	DT-IWRR	Drive Trace Inertia Work Ratio Rating
HC-NM+NOX	SFTP Non-methane Hydrocarbon + Nitrogen Oxides for US06 or SC03	DT-ASCR	Drive Trace Absolute Speed Change Rating
HC-NM+NOX-COMP	SFTP Composite Non-methane Hydrocarbon + Nitrogen Oxides	DT-EER	Drive Trace Energy Economy Rating
CO-COMP	SFTP Composite Carbon Monoxide	COMB-CREE	Combined Carbon-Related Exhaust Emissions
ETHANOL	C2H5OH - Ethanol	COMB-OPT-CREE	Combined Optional Carbon-Related Exhaust Emissions
FE BAG 1	Bag 1 Fuel Economy	HC-TOTAL-EQUIV	Total Hydrocarbon equivalent - Evap only
FE BAG 2	Bag 2 Fuel Economy	METHANE-COMB	Combined CH4 for HD 2b/3 vehicles only
FE BAG 3	Bag 3 Fuel Economy	N2O-COMB	Combined Nitrous Oxide for HD 2b/3 vehicles only
FE BAG 4	Bag 4 Fuel Economy	LEAK-DIA	Effective Leak Diameter (inches)
MFR FE	Manufacturer Fuel Economy	LEAK-GAS CAP	Gas Cap Leakage (cc/min)
HC	Hydrocarbon for Running Loss and ORVR	CO2-COMB	Combined Carbon Dioxide for HD 2b/3 Vehicles Only
METHANE	CH4 - Methane	KW-HRS	Integrated DC KW-HRS
METHANOL	CH3OH - Methanol		

Certification Region

CA	California + CAA Section 177 states	FA	Federal

Exhaust Emission Standard Level

B1	Federal Tier 2 Bin 1	L3ULEV340	California LEV-III ULEV340
B2	Federal Tier 2 Bin 2	L3ULEV250	California LEV-III ULEV250
B3	Federal Tier 2 Bin 3	L3ULEV200	California LEV-III ULEV200
B4	Federal Tier 2 Bin 4	L3SULEV170	California LEV-III SULEV170

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G
B5	Federal Tier 2 Bin 5	L3SULEV150	California LEV-III SULEV150
B6	Federal Tier 2 Bin 6	L3LEV630	California LEV-III LEV630
B7	Federal Tier 2 Bin 7	L3ULEV570	California LEV-III ULEV570
B8	Federal Tier 2 Bin 8	L3ULEV400	California LEV-III ULEV400
B9	Federal Tier 2 Bin 9	L3ULEV270	California LEV-III ULEV270
B10	Federal Tier 2 Bin 10	L3SULEV230	California LEV-III SULEV230
B11	Federal Tier 2 Bin 11	L3SULEV200	California LEV-III SULEV200
HDV1	HDV1 (Federal HD chassis Class 2b GVW 8501-10000)	T3B160	Federal Tier 3 Bin 160
HDV2	HDV2 (Federal HD chassis Class 3 GVW 10001-14000)	T3B125	Federal Tier 3 Bin 125
L2	California LEV-II LEV	T3B110	Federal Tier 3 Transitional Bin 110
L2OP	California LEV-II LEV Optional	T3B85	Federal Tier 3 Transitional Bin 85
U2	California LEV-II ULEV	T3SULEV30	Federal Tier 3 Transitional LEV-II SULEV30 Carryover
S2	California LEV-II SULEV	T3B70	Federal Tier 3 Bin 70
ZEV	California ZEV	T3B50	Federal Tier 3 Bin 50
OT	Other	T3B30	Federal Tier 3 Bin 30
T1	Federal Tier 1	T3B20	Federal Tier 3 Bin 20
PZEV	California PZEV	T3B0	Federal Tier 3 Bin 0
L2LEV160	California LEV-II LEV160	HDV2B395	Federal Tier 3 HD Class 2b Transitional Bin 395
L2ULEV125	California LEV-II ULEV125	HDV2B340	Federal Tier 3 HD Class 2b Transitional Bin 340
L2SULEV30	California LEV-II SULEV30	HDV2B250	Federal Tier 3 HD Class 2b Bin 250
L2LEV395	California LEV-II LEV395	HDV2B200	Federal Tier 3 HD Class 2b Bin 200
L2ULEV340	California LEV-II ULEV340	HDV2B170	Federal Tier 3 HD Class 2b Bin 170
L2LEV630	California LEV-II LEV630	HDV2B150	Federal Tier 3 HD Class 2b Bin 150
L2ULEV570	California LEV-II ULEV570	HDV2B0	Federal Tier 3 HD Class 2b Bin 0
L3LEV160	California LEV-III LEV160	HDV3B630	Federal Tier 3 HD Class 3 Transitional Bin 630
L3ULEV125	California LEV-III ULEV125	HDV3B570	Federal Tier 3 HD Class 3 Transitional Bin 570
L3ULEV70	California LEV-III ULEV70	HDV3B400	Federal Tier 3 HD Class 3 Bin 400
L3ULEV50	California LEV-III ULEV50	HDV3B270	Federal Tier 3 HD Class 3 Bin 270
L3SULEV30	California LEV-III SULEV30	HDV3B230	Federal Tier 3 HD Class 3 Bin 230
L3SULEV20	California LEV-III SULEV20	HDV3B200	Federal Tier 3 HD Class 3 Bin 200
L3LEV395	California LEV-III LEV395	HDV3B0	Federal Tier 3 HD Class 3 Bin 0
Transmission Type Code			
AMS	Automated Manual- Selectable (e.g. Automated Manual with paddles)	M	Manual
A	Automatic	OT	Other
AM	Automated Manual	SA	Semi-Automatic
CVT	Continuously Variable	SCV	Selectable Continuously Variable (e.g. CVT with paddles)
Drive System Code			
4	4-Wheel Drive	P	Part-time 4-Wheel Drive
F	2-Wheel Drive, Front	A	All Wheel Drive

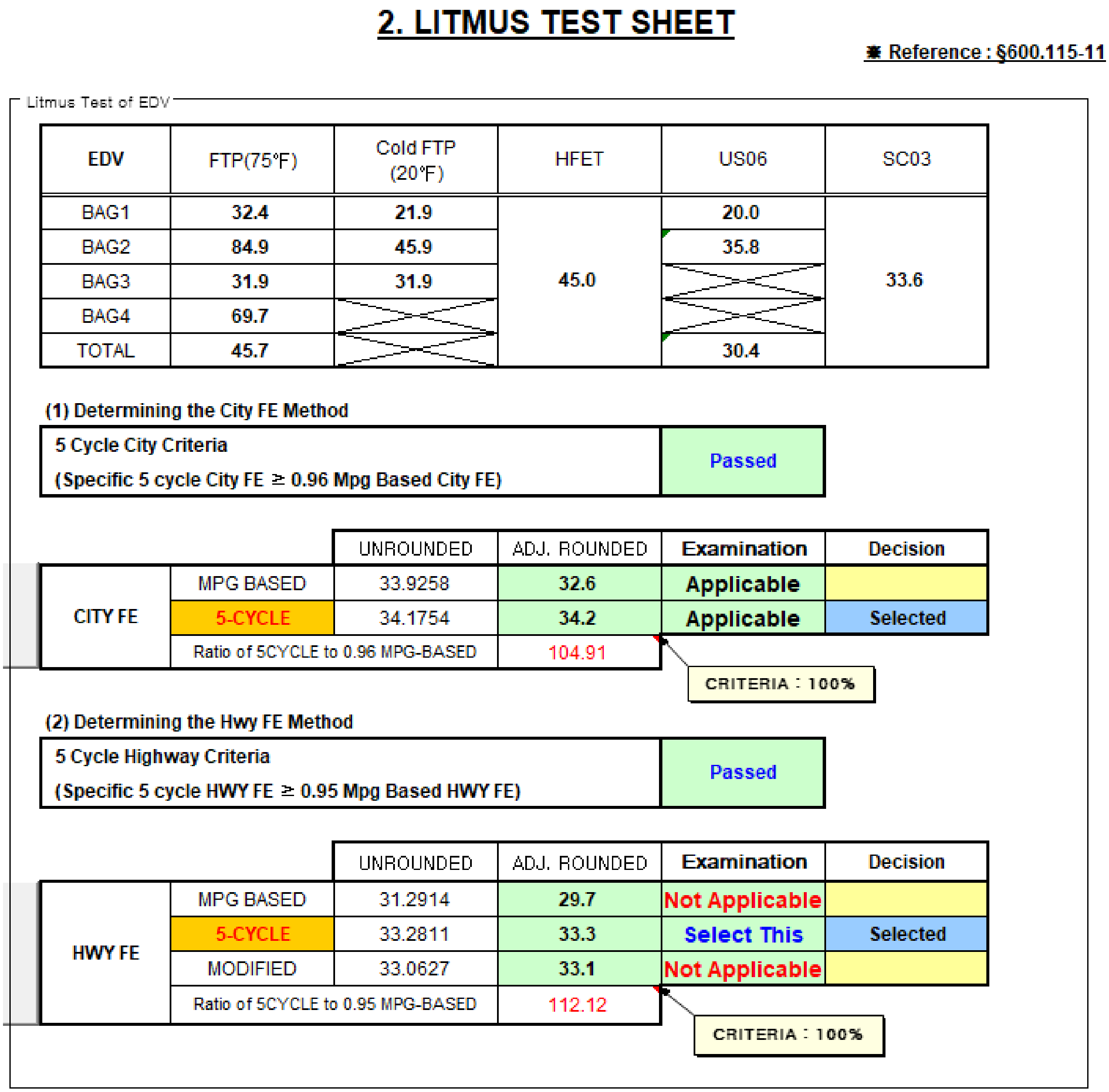
Certification Summary Information Report

Test Group	RHYXV01.6M13	**Evaporative/Refueling Family**	RHYXR0137M1G
R	2-Wheel Drive, Rear		

Additional Terms and Acronyms

AFC	Alternative Fuel Converter	ICI	Independent Commercial Importer
CSI	Certificate Summary Information	ORVR	Onboard Refueling Vapor Recovery
DF	Deterioration Factor	SIL	Shift Indicator Light
Evap	Evaporation, Evaporative	Trans	Transmission

07.02 Litmus Test Sheet



2. LITMUS TEST SHEET

※ Reference : §600.115-11

Litmus Test of EDV

EDV	FTP(75℉)	Cold FTP (20℉)	HFET	US06	SC03
BAG1	32.4	21.9	45.0	20.0	33.6
BAG2	84.9	45.9		35.8	
BAG3	31.9	31.9			
BAG4	69.7				
TOTAL	45.7			30.4	

(1) Determining the City FE Method

5 Cycle City Criteria (Specific 5 cycle City FE ≥ 0.96 Mpg Based City FE)	Passed

		UNROUNDED	ADJ. ROUNDED	Examination	Decision
CITY FE	MPG BASED	33.9258	32.6	Applicable	
	5-CYCLE	34.1754	34.2	Applicable	Selected
	Ratio of 5CYCLE to 0.96 MPG-BASED		104.91		

CRITERIA : 100%

(2) Determining the Hwy FE Method

5 Cycle Highway Criteria (Specific 5 cycle HWY FE ≥ 0.95 Mpg Based HWY FE)	Passed

		UNROUNDED	ADJ. ROUNDED	Examination	Decision
HWY FE	MPG BASED	31.2914	29.7	Not Applicable	
	5-CYCLE	33.2811	33.3	Select This	Selected
	MODIFIED	33.0627	33.1	Not Applicable	
	Ratio of 5CYCLE to 0.95 MPG-BASED		112.12		

CRITERIA : 100%

08.00 Emission Compliance Statement

Please refer to Common Section 08.00.

09.00 OBD System Description

The on-board diagnostic (OBD) system complies with 40 CFR 86.1806-05, 86.1806-17 per the compliance option allowing demonstration of compliance with California OBD II requirements in Title 13 California Code of Regulation 1968.2 (13 CCR 1968.2) approved on July 31, 2013.

Please refer to OBD application uploaded in EV-CIS system.

10.00 Description of Alternate-Fueled Vehicles: Not Applicable

11.01 Overview

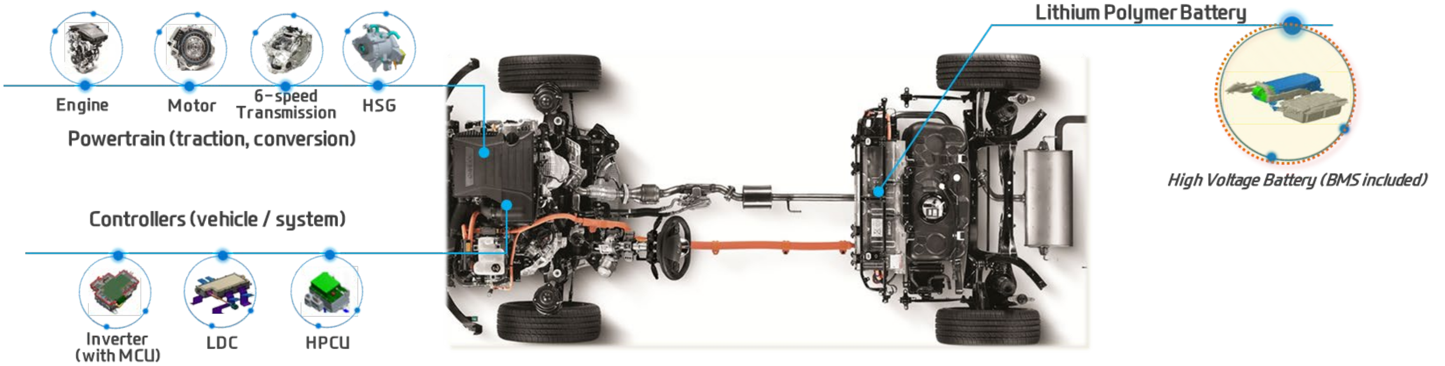
11.01.01 System configuration

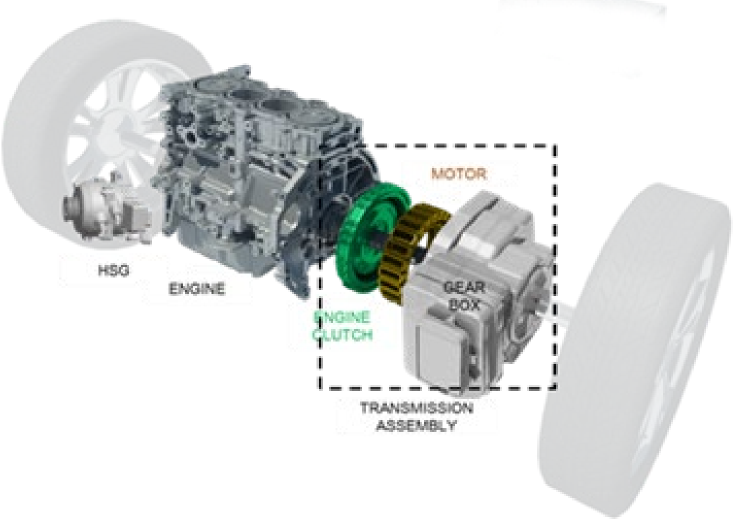
11.01.01.01 Hybrid system

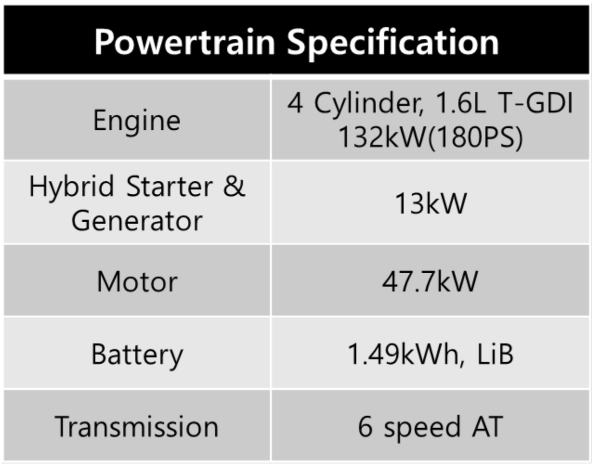
A hybrid electric vehicle (HEV) is a type of vehicle that combines a conventional internal combustion engine (ICE) with an electric propulsion system. The electric powertrain can impart several benefits, including better fuel economy than traditional vehicles or better performance in certain conditions. This system also uses regenerative braking control for converting the kinetic energy of the vehicle into electric energy. This energy can be stored for later use in powering the vehicle.

The hybrid powertrain system uses a multi-gear transmission with Transmission-Mounted Electrical Device (TMED) including a traction motor and an engine clutch in place of a torque converter. In addition, a hybrid starter & generator (HSG) is employed to start the engine and charge the high voltage battery. The power control unit is equipped with an inverter that performs power conversion between a high voltage battery and an electric motor and a low voltage DC to DC converter that converts high voltage of the main battery to low voltage (12V). In the plug-in hybrid vehicle, an on board charger is equipped so that it can charge the main battery using external power source.

In most driving conditions, hybrid powertrain system operates as what is commonly referred to as a parallel hybrid system. The engine and the electric motor are both connected to the mechanical transmission and can simultaneously transmit power to drive the wheels. In some cases, this hybrid system can also operate as what is commonly referred to as a series hybrid system. In this instance, the engine and the HSG generate electric energy, and the electric motor transmits power to the wheels.



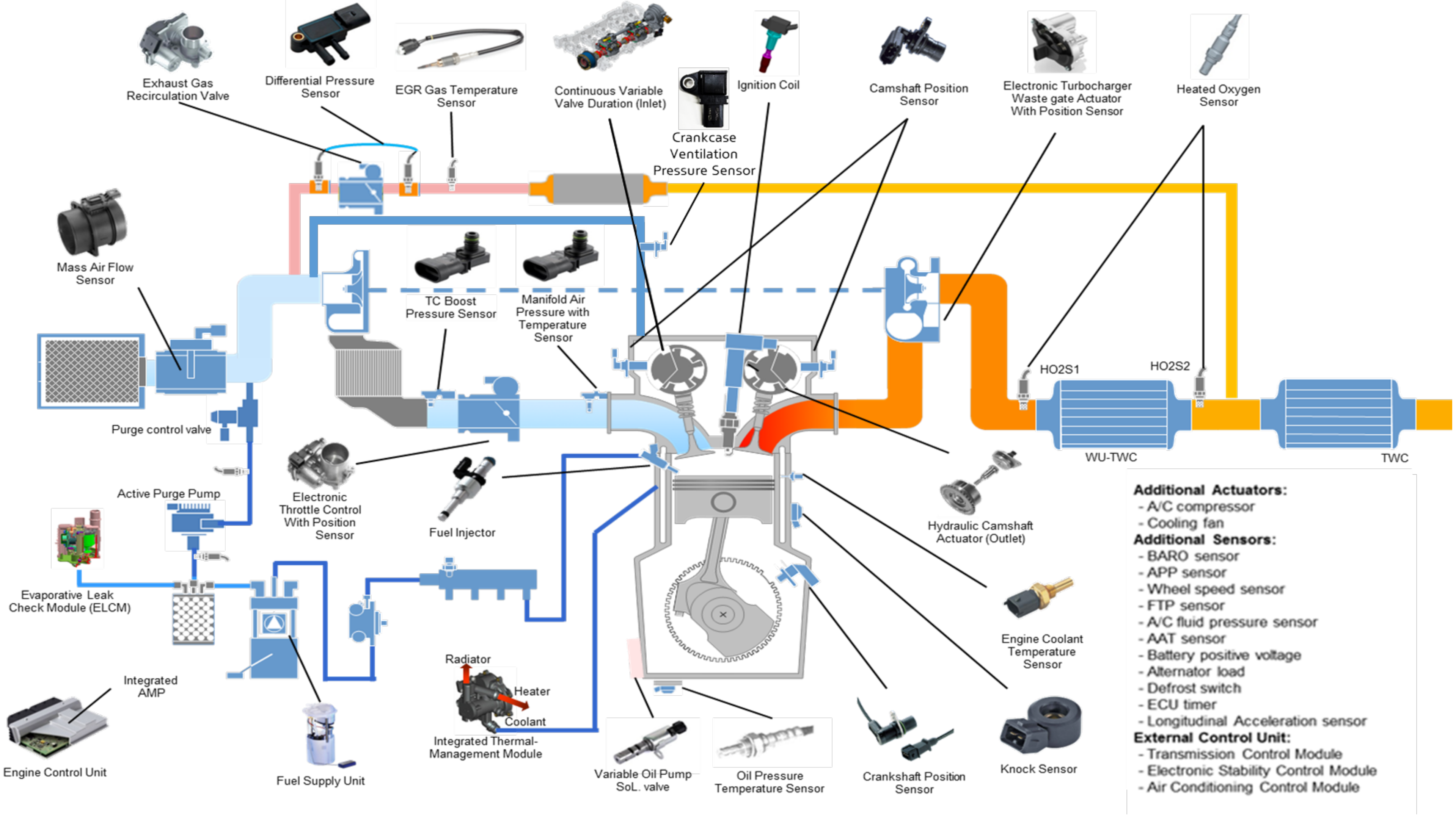




Powertrain Specification	
Engine	4 Cylinder, 1.6L T-GDI 132kW(180PS)
Hybrid Starter & Generator	13kW
Motor	47.7kW
Battery	1.49kWh, LiB
Transmission	6 speed AT

11.01.01.02 Engine system

This system uses existing engine family (refer to gasoline vehicle) for implementing hybrid



Additional Actuators:
- A/C compressor
- Cooling fan

Additional Sensors:
- BARO sensor
- APP sensor
- Wheel speed sensor
- FTP sensor
- A/C fluid pressure sensor
- AAT sensor
- Battery positive voltage
- Alternator load
- Defrost switch
- ECU timer
- Longitudinal Acceleration sensor

External Control Unit:
- Transmission Control Module
- Electronic Stability Control Module
- Air Conditioning Control Module

11.01.02 Sensed parameters vs. controlled parameters matrix (Engine only)

		Parameter controlled								Model												
	Abbreviation	Fuel control	Ignition control	Cylinder valve timing control	Exhaust gas recirculation (EGR) valve control	Wastegate control	Engine cooling control	Evaporative emission canister purge control	Idle control	Desired torque	Relative load	Catalyst oxygen storage	Catalyst temperature	Exhaust gas temperature	Mass flow rate through EVAP canister purge valve	Fuel density	Engine oil temperature	Exhaust mass flow	Exhaust pressure	Residual gas	EGR ratio setpoint	Engine Roughness
Engine coolant temperature	ECT	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	
Intake air temperature	IAT	X	X		X	X		X			X	X	X	X		X	X	X	X	X	X	
Manifold absolute pressure	MAP				X	X				X	X	X	X	X	X	X	X	X	X	X		
Boost pressure	BP					X																
Ambient air temperature	AAT				X		X						X			X	X		X			
Mass air flow	MAF				X						X		X	X						X		
Fuel rail pressure	FRP	X																				
Barometric pressure	BARO	X	X	X	X	X		X	X	X	X	X			X	X	X	X	X	X	X	
Crankshaft position	CKP	X	X	X	X	X	X	X		X	X	X	X	X		X	X	X	X	X		X
Camshaft position (inlet)	CMP_IN			X	X						X								X	X		
Camshaft position (outlet)	CMP_OUT			X	X						X								X	X		
Accelerator pedal position	APP	X		X	X					X											X	
Throttle position	TP				X						X											
EGR valve position	EGRP		X																		X	
Heated O2 sensor 1	HO2S1	X										X	X	X					X		X	
Heated O2 sensor 2	HO2S2	X										X									X	
Knock sensor	KS		X		X																X	
Wheel speed	WSS	X			X		X						X	X		X	X		X		X	
Battery positive voltage	B+			X	X			X													X	
Blower switch							X															
ECU time		X																				
CAN - Hybrid control unit request		X							X	X												
Model - Desired Torque							X			■												
Model - Relative load		X	X	X	X	X		X	X	X	■	X	X	X	X	X	X	X	X		X	
Model - Catalyst oxygen storage		X										■										
Model - Catalyst temperature		X											■									
Model - Exhaust gas temperature		X				X					X		X	■							X	
Model - Mass flow rate through EVAP canister purge valve		X													■						X	
Model - Fuel density																■						
Model - Engine oil temperature		X		X		X											■				X	
Model - Exhaust mass flow											X	X	X	X				■				
Model - Exhaust pressure					X	X					X								■			
Model - Residual gas			X								X								X	■		
Model - EGR ratio setpoint					X																■	
Model - Engine Roughness	ER																					■

11.01.03 Abbreviations and acronyms

Acronym	Definition
A/C	Air Conditioning
A/F	Air Fuel Ratio
AAT	Ambient Air Temperature
APP	Accelerator Pedal Position
B+	Battery Positive Voltage
BARO	Barometric Pressure
BP	Boost Pressure
CKP	Crankshaft Position
CMP_IN	Camshaft Position (inlet)
CMP_OUT	Camshaft Position (outlet)
ECT	Engine Coolant Temperature
ECU	Engine Control Unit
EGR	Exhaust Gas Recirculation
EGRP	EGR Valve Position
ER	Engine Roughness
ESC	Electronic Stability Control Unit
FRP	Fuel Rail Pressure
FTP	Fuel Tank Pressure
GDI	Gasoline Direct Injection
GHG	Greenhouse Gas
HO2S1	Heated Oxygen Sensor 1
HO2S2	Heated Oxygen Sensor 2
IAT	Intake Air Temperature
ITM	Integrated Thermal-management Module
KS	Knock Sensor
LOT	Catalyst Light-Off Temperature
MAF	Mass air flow
MAP	Manifold Absolute Pressure
TCU	Transmission Control Unit
TP	Throttle Position
TWC	Three Way Catalytic Converter
VIM	Variable Intake Manifold
VS	Vehicle Speed
VVT	Variable Valve Timing
WG	Wastegate
WSS	Wheel Speed Sensor
WU-TWC	Warm Up Three Way Catalytic Converter

11.01.04 Justification codes

Justification / rationale Code
A. Substantially included during regulated test procedures
B. Engine/Emission system protection
C. Protection against accident
D. Engine starting stabilization
E. OBD intrusive monitor
F. Base operation
G. Electric propulsion system protection

11.02 Engine base controls / AECDs

11.02.01 Fuel control

The lambda control is normally controlled as closed loop by the fuel injection system including the oxygen sensors. It is responsible for controlling the content of the catalytic converter feed gas and ultimately determines the exhaust gases like HC, CO, and NOx. The closed loop control system makes adjustments to injection duration based on signals from the exhaust oxygen sensor. During closed loop control, the ECU keeps the air-fuel mixture modulated around the ideal 14.7 to 1 ratio (stoichiometry). By precisely controlling fuel delivery, the oxygen content of the exhaust stream is held within a narrow range that supports efficient operation of the three-way catalytic converter. During closed loop operation, the ECU uses the oxygen sensor signal to determine the exact concentration of oxygen in the exhaust gas. From this signal, the ECU determines whether the mixture is richer or leaner than the ideal air/fuel ratio.

Target lambda coordination

The basic target lambda is stoichiometric air/fuel ratio (i.e. lambda=1.0). And the target lambda can be coordinated during the condition as follows:

- Oxygen sensor diagnosis – refer to OBD document
- Component overheating protection
- Catalyst purge
- Driver’s request torque interface

Mixture calculation

The mixture control calculates the relative fuel mass for the relative air charge which is required for combustion at a lambda value =1.0. The variables of the relative air charge and the relative fuel mass have been standardized such that 100% air charging require 100% fuel for the combustion at a lambda value =1.0. The complete relative fuel mass should be corrected the following factors:

- The compensation for any air leakage is made as a form of additive fuel adaption value which is adapted lambda deviation during idle condition.
- The target relative fuel mass are then corrected with dividing by the associated target lambda value.
- The lambda control maintains this commanded lambda value and compensates any deviation by means of the lambda sensor feedback control gain.
- The increase or reduction in the fuel mass flow required during dynamic load changes is accounted for by the additive intervention.
- Long-term deviations from the desired lambda value are also adapted and are included as a multiplier in the factor controller adaptation.
- Finally, the part of the fuel, which is conducted from the canister purge valve through evaporation into the intake manifold, is subtracted from the relative fuel mass which has been associated to the desired lambda

value by the precedent calculations.

Injection time conversion

The injector characteristic value is a constant factor for a conversion of fuel mass into effective injection duration. This conversion factor is valid only in certain circumstances with respect to engine displacement and injector flow rate. Thus, the following correction factors are required.

- Fuel density correction: The change of fuel density depending on the temperature is also corrected. For higher fuel temperatures the injection times have to be longer to inject the same amount of fuel mass as at low temperatures.

GDI injection mode

The injection process of the GDI engine utilizes several different modes, depending on engine operation conditions.

1. Homogeneous injection: Normal operating injection mode

2. Homogeneous split injection

   The GDI operation mode of "homogeneous split" is a strategy for fast heating of the primary catalytic converter. Due to the late secondary injection the air-fuel mixture inside the combustion chamber can be ignited and burn effectively at very late ignition angles and cold engine temperatures. Thus a large amount of heat is transferred to the catalytic converter while at the same time a good exhaust gas composition is achieved.

3. Start injection

   During cold starts, the fuel is injected into the cylinder during the compression stroke and the fuel being injected is heated by the air. This means that the fuel mixture does not need to be as rich as it does in a conventional PFI (port fuel injection) system. During the cold start, fuel pressure is increased to produce fine droplets through the injector. The smaller droplets are easier to ignite, thus improving starting characteristics. Less fuel and easier burning work to reduce cold engine emission levels.

For more details, refer to AECD *<u>'11.03.07 Combustion mode strategy'</u>*

Injection mode	Intake	Compression	Power	Exhaust
Homogeneous injection (single)	🟦	⚡		
Homogeneous injection (double)	🟦 🟦	⚡		
Homogeneous injection (triple)	🟦 🟦 🟦	⚡		
Homogeneous split injection (double)	🟦	🟦 ⚡		
Homogeneous split injection (triple)	🟦	🟦 🟦 ⚡		
GDI start injection (single)		🟦 ⚡		
GDI start injection (double)		🟦 🟦 ⚡		
GDI start injection (triple)		🟦 🟦 🟦 ⚡		

🟦 Fuel injection ⚡ Ignition

Injection angle control

The injection angle can be maintained by controlling a start of injection angle as well as an end of it. These control methods are chosen by the injection mode, as described in "Injection mode". During normal operation mode (Homogeneous injection), the injection is controlled by a start angle which is defined as a map of engine speed and relative load. If the engine is operated under the homogeneous split injection mode, the first injection is controlled by the start of injection and the followings are controlled by the end of injection angles. These angles are all defined as maps of engine speed and relative load.

For more details, refer to AECD *‘11.02.01.12 Injection angle’*

Fuel cut off control

Deceleration fuel cut off is a kind of engine operation mode, in which the injection as well as combustion does not take place, or in other words, the engine is in a non-fired mode. This function determines the working ranges and limits for the engine in which an overrun fuel cut off is allowed.

The following status is necessary to generate the condition of readiness for overrun fuel cut off:

- The engine speed is above the overrun fuel cut off speed threshold
- The idle condition has been set

When all of the above conditions are set, the fuel cut off condition is only set after an activation delay time. This depends on engine temperature and speed. The delay time is necessary for prevent fuel cut off during gear shifting.

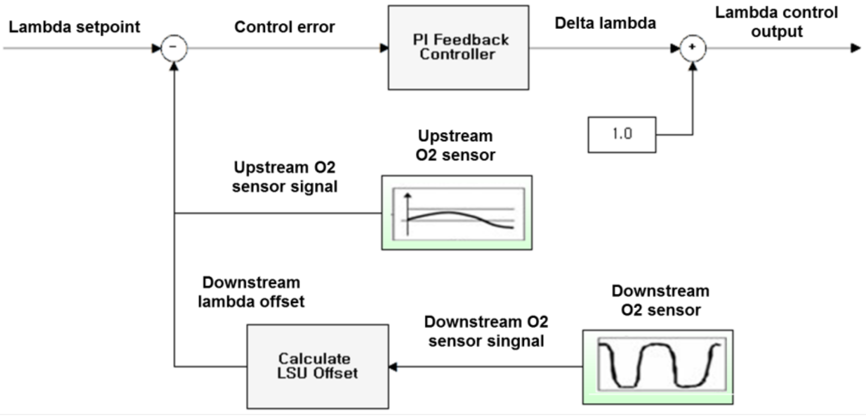
For more details, refer to AECD *‘11.02.01.10 Fuel cut off for component protection’*, AECD *’11.06.02.02 SOC management – critical high band’*

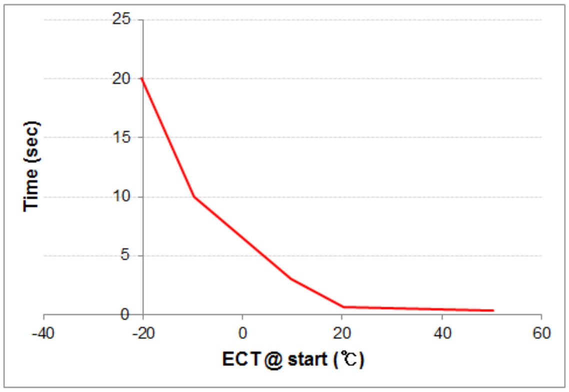
Injector fuel mass control

The aim of the injector fuel mass control is to ensure that injectors for each cylinder inject the same amount of fuel mass exactly as required. The injector fuel mass control consists of the dynamic feedback control of injection timings, called Valve Controlled Injection (VCI) and the static fuel quantity compensation control, called Qstatic Adaptation.

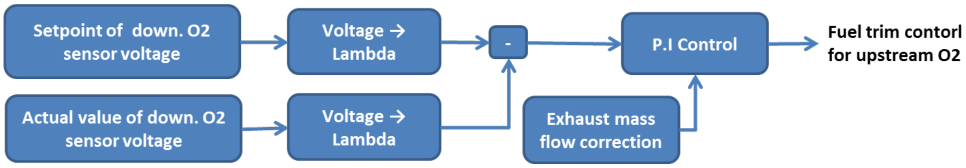
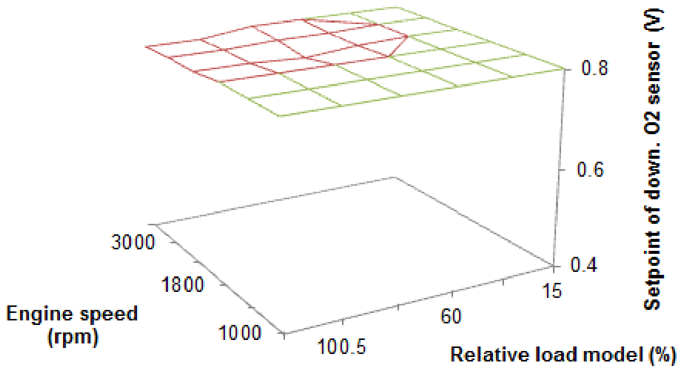
- Valve Controlled Injection (VCI): VCI is a control method of the injector opening duration using the multiple derivatives of injector voltage signals to detect actual injection valve timings and to realize accurate fuel metering even for small injection amounts in turn.
- Qstatic Adaptation: The injected fuel amount is physically correlated with the rail pressure drop over the injection event in principle. The injection amount is then relatively corrected over different cylinders by comparing rail pressure drop amounts for different cylinders while the overall injection amount from all cylinders is kept unchanged.

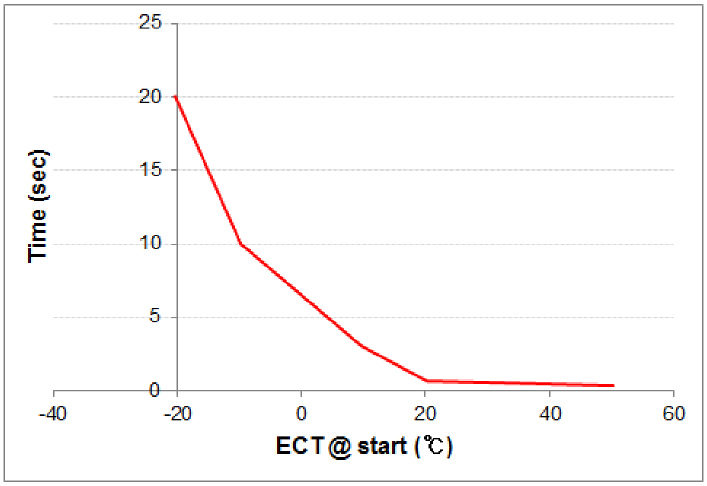
11.02.01.01 Air-fuel ratio (A/F) feedback (HO2S1)

Title : Air-fuel ratio (A/F) feedback (HO2S1)	
Purpose	**Base operation** The air-fuel ratio feedback control maintains the air fuel ratio at a preset value to keep the optimum catalyst efficiency and reduced emission.
Action: Functional Description	The air-fuel ratio (A/F) feedback (HO2S1) corrects the injected fuel based on the exhaust gas oxygen concentration and deviation from stoichiometric operation (towards rich or lean) as a closed loop controls. *Air-fuel ratio (A/F) feedback (HO2S1) control 
Parameters (I/O)	**IN** - Heated O2 sensor (Linear) (HO2S1) - Heated O2 sensor (Binary) (HO2S2) - Heated O2 sensor (Linear) (HO2S1) readiness[1] - Heated O2 sensor (Binary) (HO2S2) readiness[1] - OBD fault detection (HO2S1, Fuel injector, Catalyst damage misfire)[2] - Lambda setpoint[3] - Catalyst temperature model[4] - Engine speed = f(CKP) - Fuel cut off for component protection[5] **OUT** - Air-fuel ratio controller value[6]
Entry Conditions	**Activating Condition** Sensor operation readiness is reached. after dew point has been reached and the ceramic temperature of upstream O2 sensor > 685℃ **Deactivating Condition** Interruption during fuel cut off[7] **or** OBD fault detection (HO2S1, Injector, Catalyst damage misfire)[8]

In-use Frequency	This is a base control and generally active unless overwritten by other AECDs. * air-fuel feedback control (HO2S1) active time (via ECT) under normal condition. 
Emission impact	This is a part of base emission control and included in all regulated test cycles and therefore accounted for by the test.
Justification	A. Substantially included during regulated test procedures: FTP75, US06, SC03, HwFET, FTP75@-7°C F. Base operation
Reference	1. Oxygen sensor heating strategy 2. OBD Document 3. Enrichment for torque demand, Enrichment for component protection, Catalyst purge 4. Exhaust system temperature determination 5. Fuel cut off for component protection 6. Air-fuel ratio (A/F) feedback (HO2S2), Air-fuel ratio adaptation, Canister purge 7. Fuel cut off for component protection 8. OBD Document

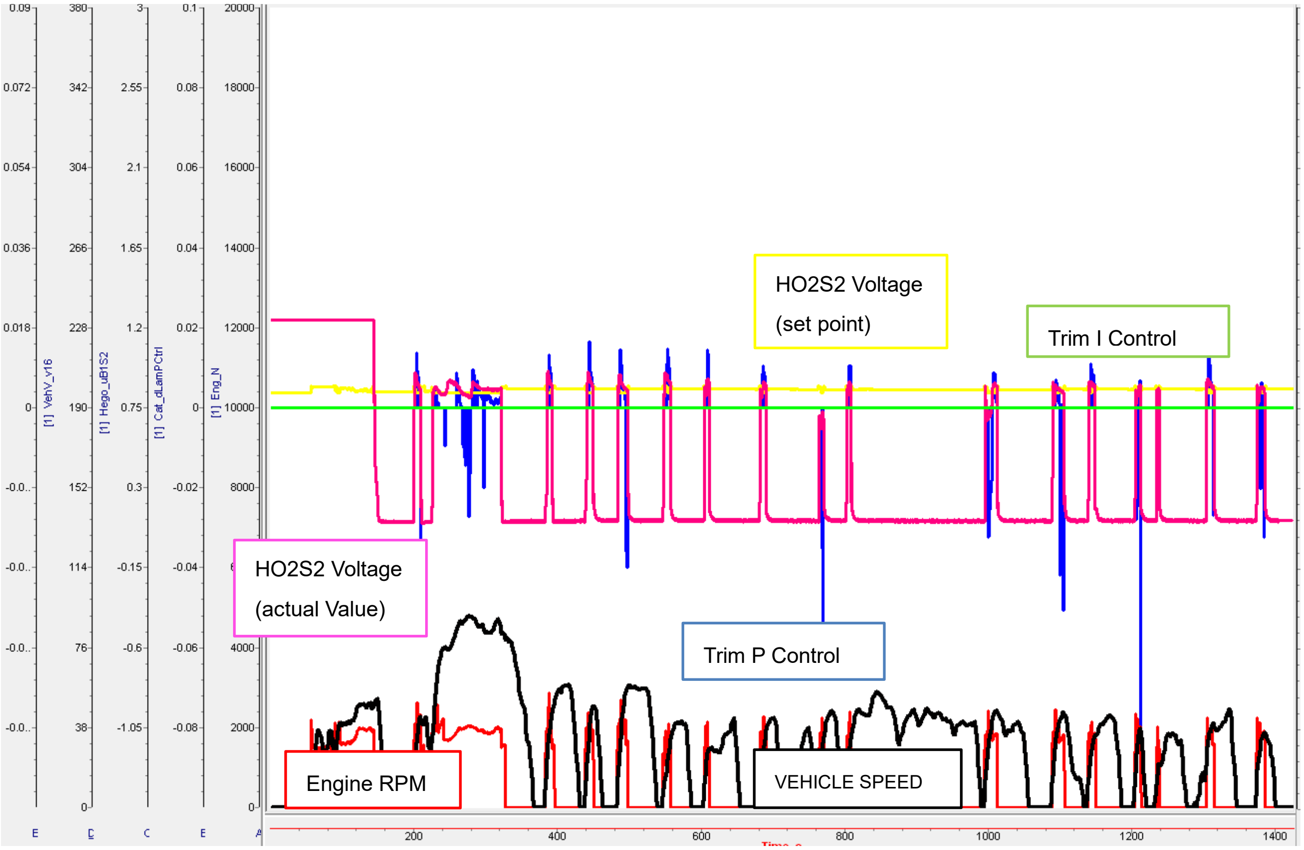
11.02.01.02 Air-fuel ratio (A/F) feedback (HO2S2)

Title : Air-fuel ratio (A/F) feedback (HO2S2)	
Purpose	**Base operation:** The fuel trim based on downstream oxygen sensor is used to compensate for long term components variation that can potentially affect closed-loop emission control performance, especially the upstream oxygen sensor stoichiometric point shifting due to aging.
Action: Functional Description	The basic principle to compensate such sensor stoichiometric point shifting is to bias the fuel delivery system to slightly lean or rich side, until the downstream oxygen sensor indicates that the exhaust air-fuel ratio returns to desired richness.  *Setpoint of downstream O2 sensor voltage (0.82~0.88V) 
Parameters (I/O)	**IN** - Engine speed = f(CKP) - Relative load model - Heated O2 sensor (Binary) (HO2S2) - Heated O2 sensor (Linear) (HO2S1) - Heated O2 sensor (Binary) (HO2S2) readiness[1] - Heated O2 sensor (Linear) (HO2S1) readiness[1] - Catalyst temperature model[2] - Fuel cut off[3] **OUT**

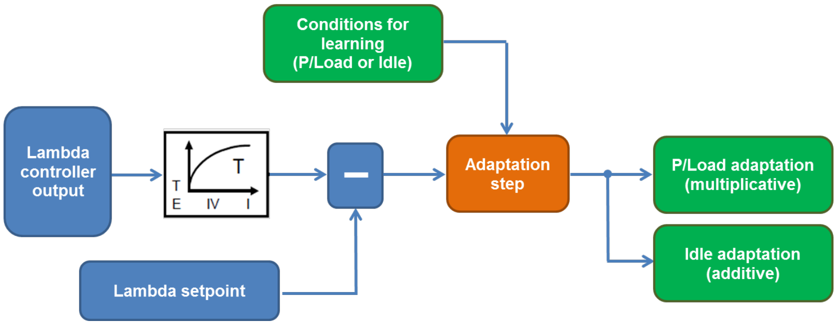
	- Trim controller value (P+I Gain) = fuel trim (Lambda value) (-0.05 < and < 0.05) - Trim controller value adaption (I Gain) (-0.03 < and < 0.03) - OBD Fault detection[4]
Entry Conditions	**Activating Condition** Heated O2 sensor (Binary) (HO2S2) readiness[5] **and** Heated O2 sensor (Linear) (HO2S1) readiness[5] **and** Catalyst enrichment function is not active[6] **and** Catalyst purge inactive **and** Air-fuel ratio controller value in normal range (-25% < normal range < +25%)[7] **and** 350℃< Catalyst temperature model < 925℃[8] **and** No overheating protection with rich lambda is active[9] **Deactivating Condition** Fuel cut off[10]
In-use Frequency	This is a base control and generally always active unless overwritten by other AECDs. * air-fuel feedback control (HO2S2) active time (via ECT) under normal condition. 
Emission impact	This is a part of base emission control and included in all regulated test cycles and therefore accounted for by the test.
Justification	A. Substantially included during regulated test procedures : FTP75, US06, SC03, HwFET, FTP75@-7°C F. Base operation

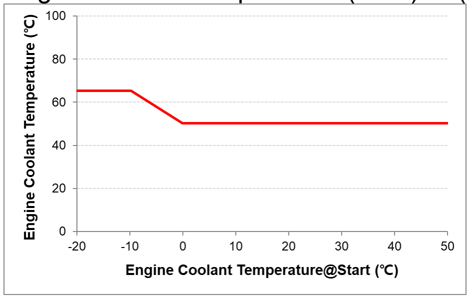
Reference	1. Oxygen sensor heating strategy 2. Exhaust system temperature determination 3. Fuel cut off for component protection 4. OBD Document 5. Oxygen sensor heating strategy 6. Enrichment component protection, Catalyst purge, Enrichment for torque demand 7. Air-fuel ratio (A/F) feedback (HO2S1) 8. Exhaust system temperature determination 9. Enrichment component protection 10. Fuel cut off for component protection

* Heated O2 sensor (Binary) (HO2S2) feedback control during FTP mode

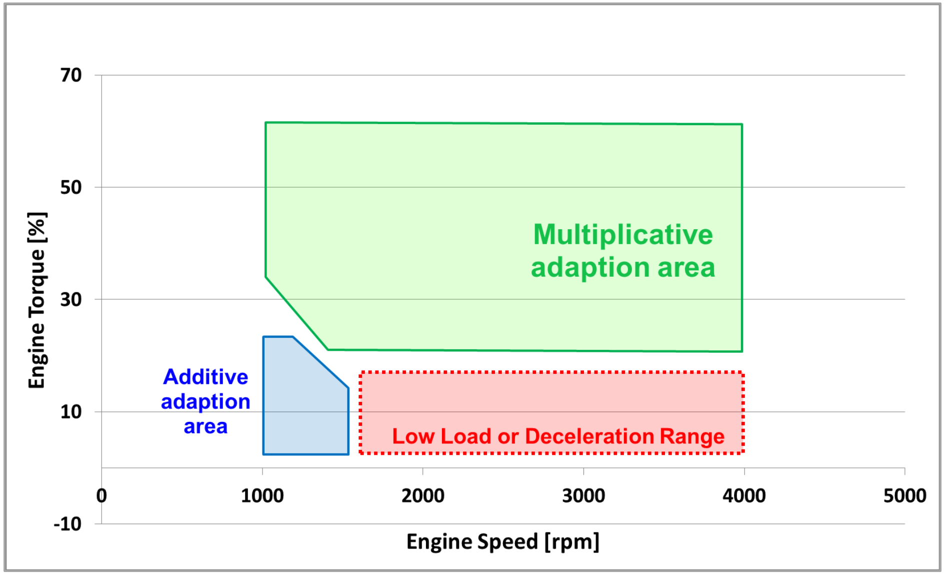


11.02.01.03 Air-fuel ratio adaptation

Title : Air-fuel ratio adaptation	
Purpose	**Base operation** Compensation serial production tolerances of components (E.g. fuel system, MAP sensor, etc.)
Action: Functional Description	Adaptation of air-fuel ratio control deviation from stoichiometric operation by a fuel mass offset in idle speed and a fuel mass factor in part load. The additive and multiplicative air-fuel ratio adaptations are used for calculating the injection time for all engine operating states. 
Parameters (I/O)	**IN** - Engine speed = f(CKP) - Relative load model - Air-fuel ratio controller value[1] - Heated O2 sensor (Linear) (HO2S1) - Lambda setpoint[2] - Engine coolant temperature (ECT) - Intake air temperature (IAT) - Accelerator pedal position (APP) - Vehicle speed = f(WSS) - Fuel cut off[3] - Canister purge active[4] **OUT** - Multiplicative Air-fuel ratio adaptation - Additive Air-fuel ratio adaptation

<table>
<tr><td>Entry Conditions</td><td>Activating Condition
Engine coolant temperature (ECT) ≥ f(Engine coolant temperature @ start)


and
Intake air temperature (IAT) ≤ 84.75℃
and
Air-fuel ratio feedback controller active[5]
Limited Dynamic conditions
1) Engine speed = f(CKP)
2) Mass fuel flow

* Additive & Multiplicative adaption area


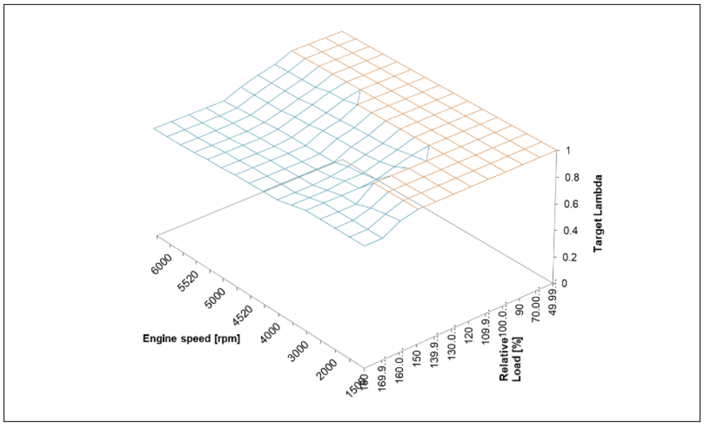
Deactivating Condition
Canister purge active[6]
Fuel cut off[7]
Enrichment for component protection active[8]
Catalyst purge active[9]</td></tr>
<tr><td>In-use Frequency</td><td>This is a base control and generally active unless overwritten by other AECDs.</td></tr>
<tr><td>Emission impact</td><td>This is a part of base emission control and included in all regulated test cycles and therefore accounted for by the test.</td></tr>
</table>

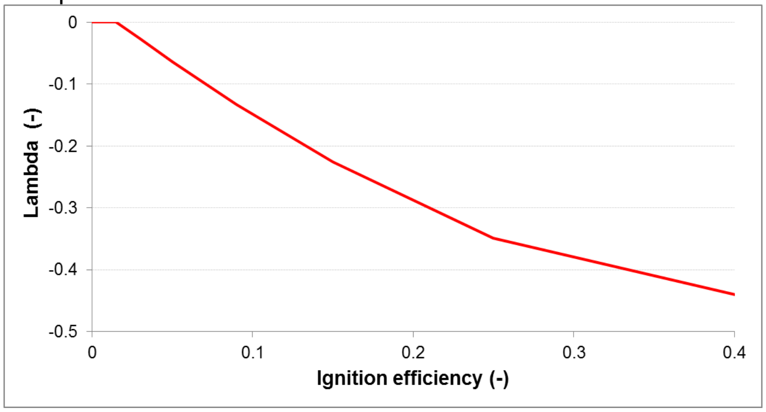
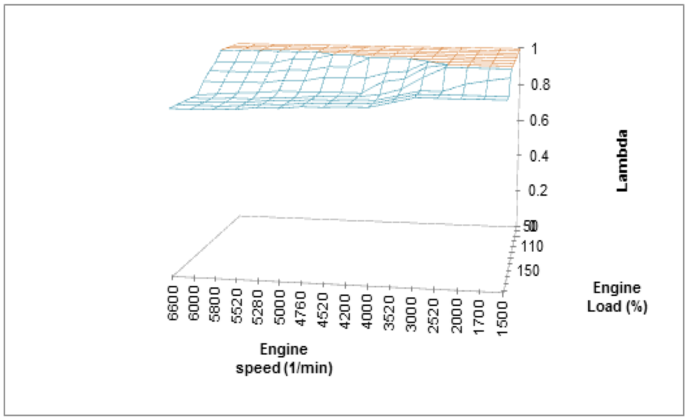
Justification	A. Substantially included during regulated test procedures FTP75, US06, SC03, HwFET, FTP75@-7℃ F. Base operation
Reference	1. Air-fuel ratio feedback (HO2S1) 2. Enrichment for torque demand, Enrichment for component protection Catalyst purge 3. Fuel cut off for component protection 4. AECD Canister purge 5. Air-fuel ratio feedback (HO2S1) 6. Canister purge 7. Fuel cut off for component protection 8. Enrichment for component protection 9. Catalyst purge

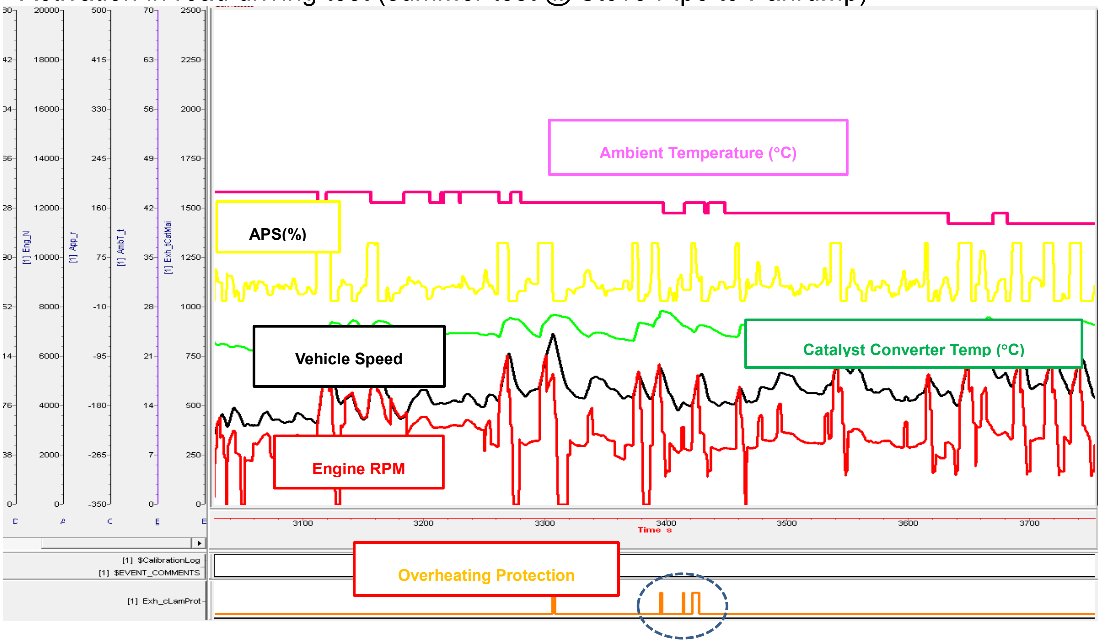
11.02.01.04 Enrichment for torque demand

Title: Enrichment for torque demand	
Purpose	**Protection against accident** When the hybrid control unit requests maximum engine torque, torque demand enrichment is used. This will help driver safety and could prevent accidents when the driver is merging into traffic, passing another vehicle, etc…
Action: Functional Description	The need for torque demand is determined by hybrid control unit and then engine control unit sets the lambda setpoint to minimum lambda value of 0.85. Enrichment level depends on fueling map. For more details, refer to *<u>AECD '11.06.04.05 HEV operation in high-load'</u>*
Parameters (I/O)	**IN** - hybrid control unit request[1] - Engine speed = f(CKP) - Engine coolant temperature (ECT) **OUT** **-** Lambda setpoint : depends on Engine Speed and ECT[2] : Driver request lambda enrichment (minimum : 0.85)
Entry Conditions	**Activating Condition/Deactivating Condition** hybrid control unit request[3]
In-use Frequency	- For more details, refer to HEV operation in high-load[4]
Emission impact	May momentarily increase NMHC and CO emission while active.
Justification	C = Protection against accident
Reference	1. HEV operation in high-load 2. Air-fuel ratio (A/F) feedback (HO2S1), Air-fuel ratio adaptation 3. HEV operation in high-load 4. HEV operation in high-load

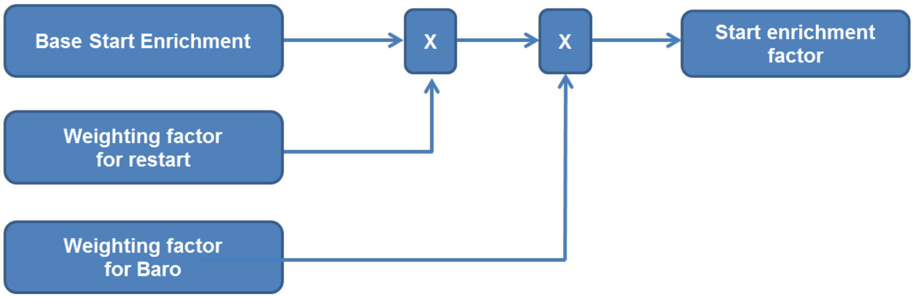
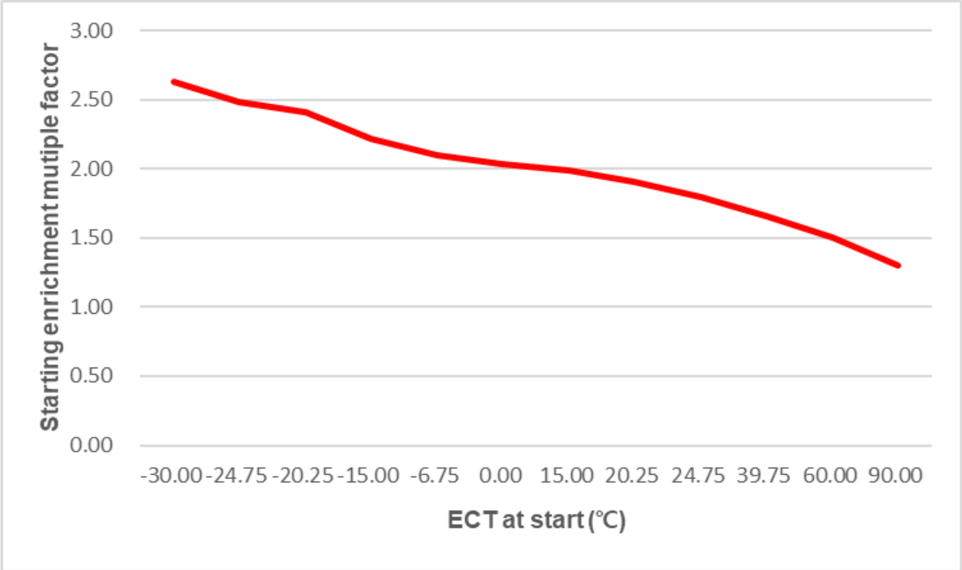
11.02.01.05 Enrichment component protection

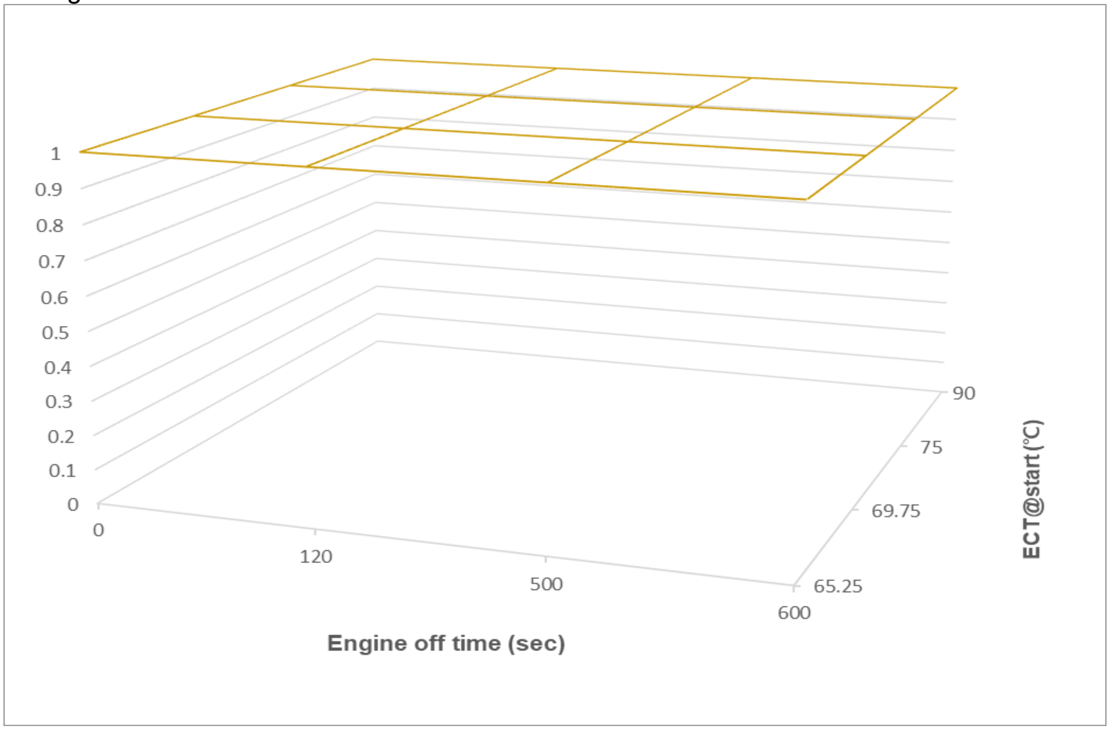
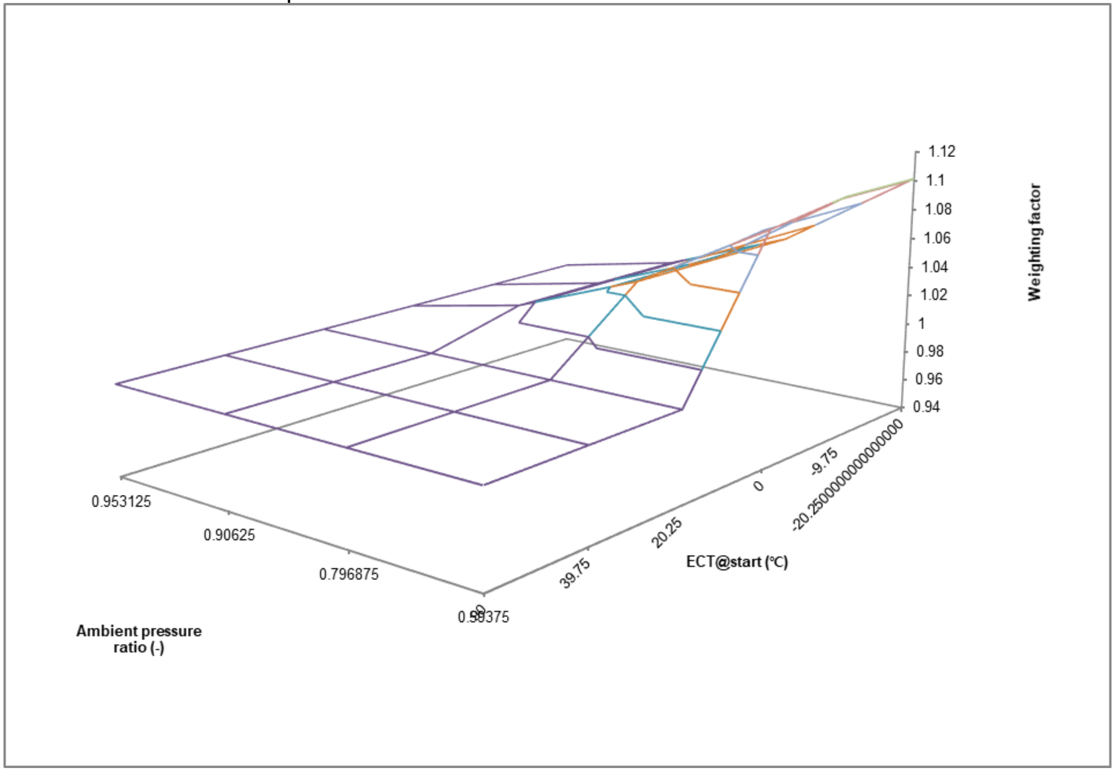
Title : Enrichment component protection	
Purpose	**Engine/component Protection** Protection of components in exhaust gas system (exhaust manifold, O2 sensor, catalyst) against thermal overheating. Because operating under heavy loads and high engine speeds can result in excessively hot exhaust temperatures, there is a potential to overheat emission components
Action: Functional Description	Lambda setpoint enrichment to reduce exhaust temperature. High exhaust gas temperature can be decreased by an enrichment of the air/fuel mixture. By this enrichment, cylinder charge gets more fuel than necessary for a stoichiometric combustion.
Parameters (I/O)	**IN** - Engine Speed = f(CKP) - Relative load model - Exhaust gas temperature model[1] - Catalyst temperature model[1] - Ignition angle **OUT** - Lambda setpoint[2] = Nominal Lambda setpoint for component protection + Weighted Offset Lambda setpoint for ignition angle (Map A * Map B) * Nominal Lambda setpoint for component protection Map 

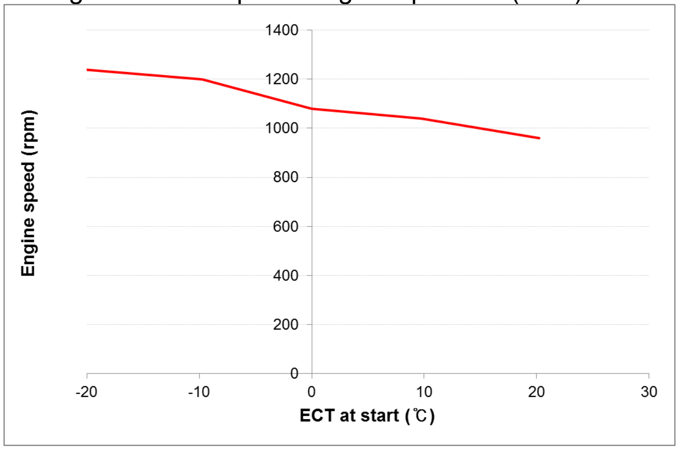
	* Weighted Offset Lambda setpoint for ignition angle - Map A  - Map B 
Entry Conditions	**Activating Condition** Exhaust gas temperature model[4] ≥ 950℃ **or** Catalyst temperature model[4] ≥ 980℃ **Deactivating Condition** Exhaust gas temperature model[4] < 950℃ **and** Catalyst temperature model[4] < 980℃ **or** Fuel cut off activate[5]

In-use Frequency	- Activation in road driving test (summer test @ Stove Pipe to Pahrump) 
Emission impact	May momentarily increase HC and CO emission while active, and is accounted.
Justification	B. Engine/Emission system protection.
Reference	1. Exhaust system temperature determination 2. Air-fuel ratio (A/F) feedback (HO2S1) Air-fuel ratio adaptation Exhaust system temperature determination 4. Exhaust system temperature determination 5. Fuel cut off for component protection

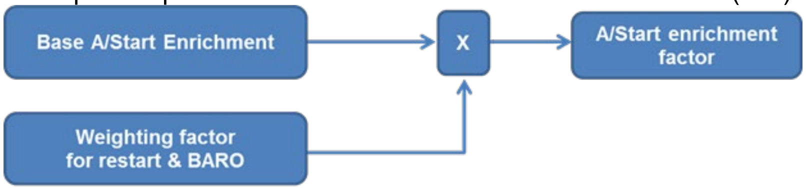
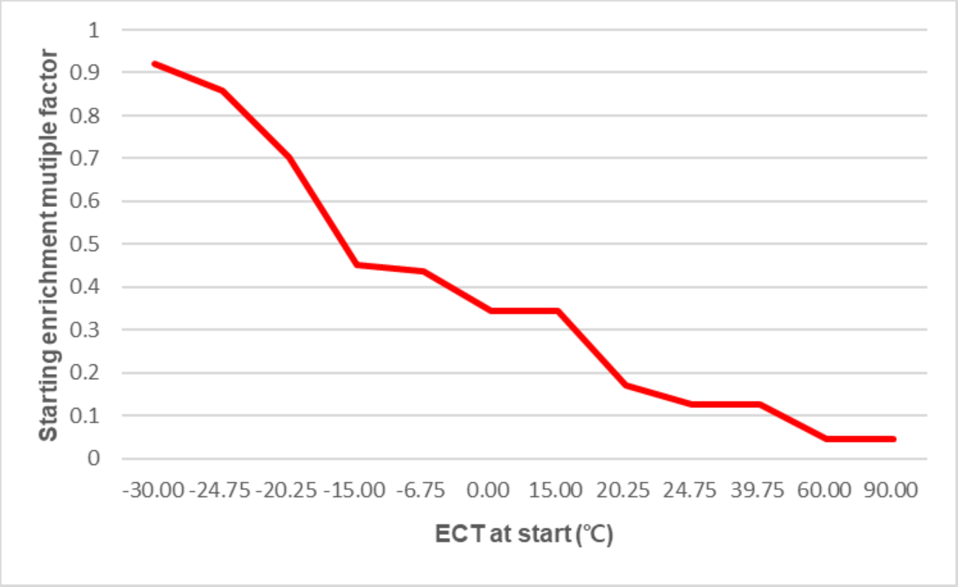
11.02.01.06 Enrichment for starting

Title : Enrichment for starting	
Purpose	**Engine Starting** In comparison with normal operation, the fuel mixture must be enriched during start because fuel atomization is not performed well. Starting enrichment is needed to ensure complete combustion. In case of restart, enrichment must be reduced, because the air-fuel ratio is too rich.
Action: Functional Description	Starting enrichment factor is used until the start is completed. 
Parameters (I/O)	**IN** - Engine speed = f(CKP) - Intake air temperature (IAT) - Engine coolant temperature (ECT) - ECU time - Fuel rail pressure (FRP) - Combustion mode[1] **OUT** - A/Fuel Ratio = 'Normal' quantity(lambda=1) * Starting enrichment factor ※ Base start enrichment 

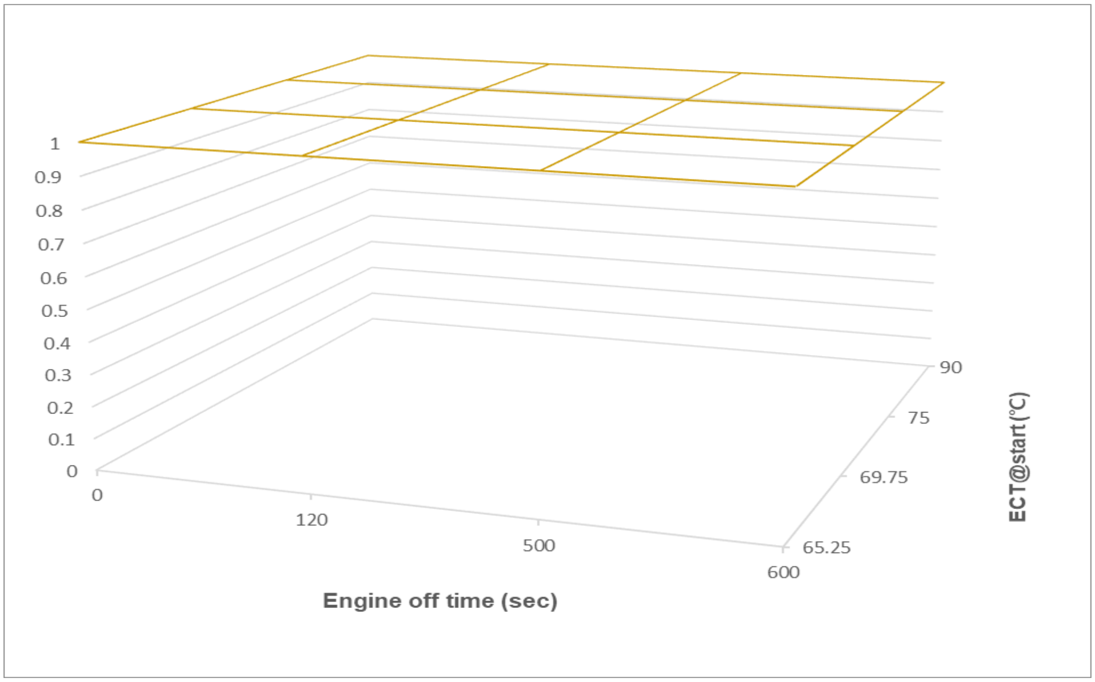
	* Weight factor for restart  * Factor for Barometric pressure 

Entry Conditions	**Activating Condition** Engine start * Engine start : 0 rpm < Engine speed < f(ECT)  **Deactivating Condition** Complete engine start (Engine speed > f(ECT))
In-use Frequency	It is active only starting duration, After start, it becomes deactivated.
Emission impact	May momentarily increase HC and CO emission while active.
Justification	A. Substantially included during regulated test procedures : FTP75, US06, SC03, HwFET, FTP75@-7℃ D. Engine starting stabilization.
Reference	1. Combustion mode

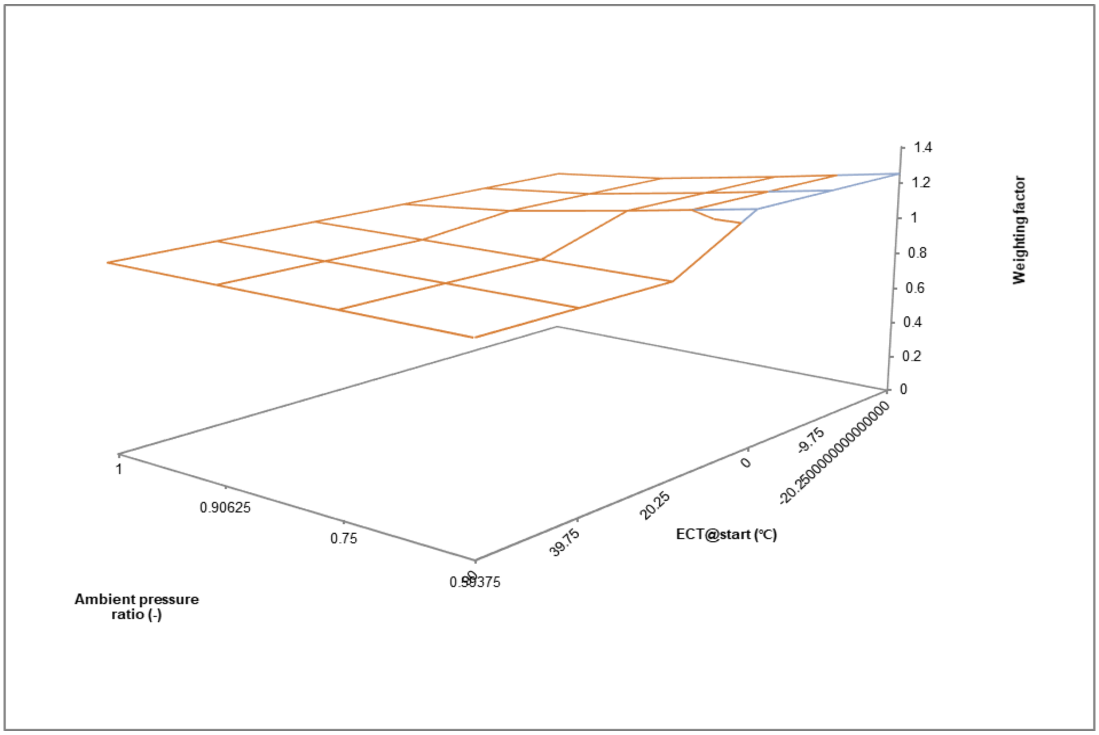
11.02.01.07 Open loop enrichment for after starting

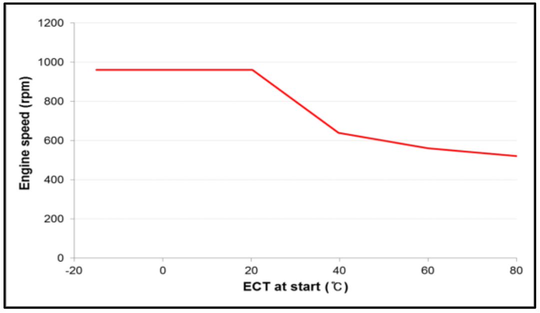
Title : Open loop enrichment for after starting	
Purpose	**After engine starting** In comparison with normal operation, the fuel mixture must be enriched during after start because fuel atomization isn’t performed well.
Action: Functional Description	Fuel enrichment after engine start. During the post start, enrichment factor is normally dependent on the coolant temperature. The open loop enrichment ends as soon as the air-fuel ratio (A/F) feedback control begins. 
Parameters (I/O)	**IN** - Engine speed = f(CKP) - Engine coolant temperature (ECT) - Barometric pressure (BARO) - ECU time - Engine speed = f(CKP) - Relative load model - Air-fuel ratio (A/F) control active[1] **OUT** - Air-fuel ratio = ‘Normal’ quantity * (1.0 + After start enrichment factor) * Base After start enrichment 

* Weight factor = Factor #1 * Factor #2
  - Factor #1 : restart factor



  - Factor #2 : BARO factor



Entry Conditions	**Activating Condition** After engine start.[2] * Engine start : 0rpm < Engine speed < f(ECT)  **Deactivating Condition** Air-fuel ratio (A/F) feedback control active[3]
In-use Frequency	After Air-fuel ratio (A/F) feedback control is active, the open loop enrichment after engine start is deactivated.
Emission impact	This is part of base emission control and included in a regulated test cycle and therefore accounted for by the test.
Justification	A. Substantially included during a regulated test procedure : FTP75@-7°C D. Engine starting stabilization.
Reference	1. Air-fuel ratio (A/F) feedback (HO2S1) 2. Enrichment for starting 3. Air-fuel ratio (A/F) feedback (HO2S1)

11.02.01.08 Fuel compensation for fuel property - N/A

11.02.01.09 Catalyst purge

Title : Catalyst purge

Purpose

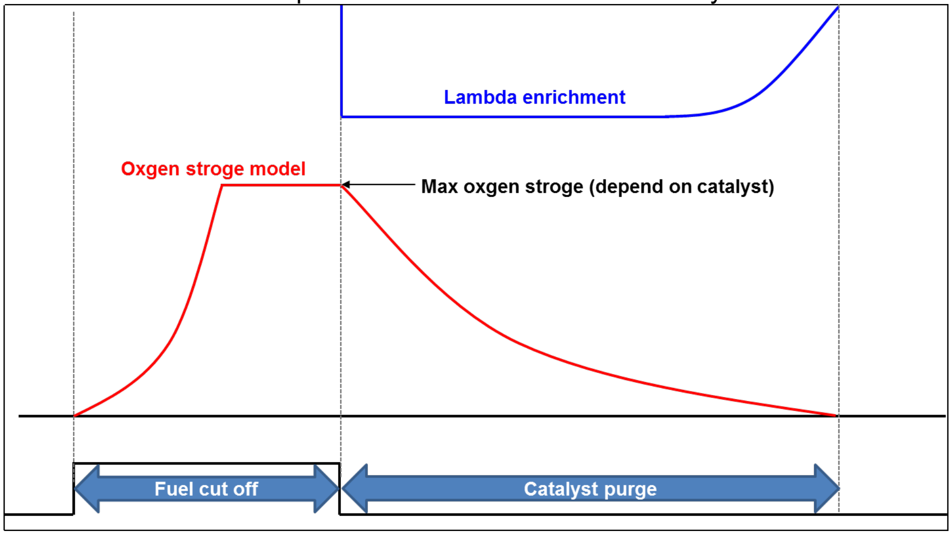
Emission reduction

Catalyst Purge is activated through the lambda enrichment to reduce the Oxygen storage of Catalyst

Action: Functional Description

Set lambda setpoint to rich

The fuel enrichment depends on the O2 mass in the catalyst and exhaust mass flow.



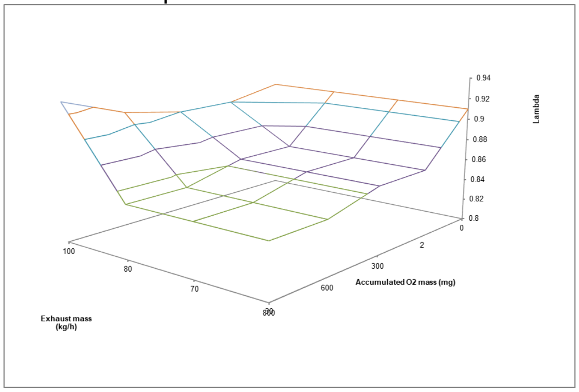
Parameters (I/O)

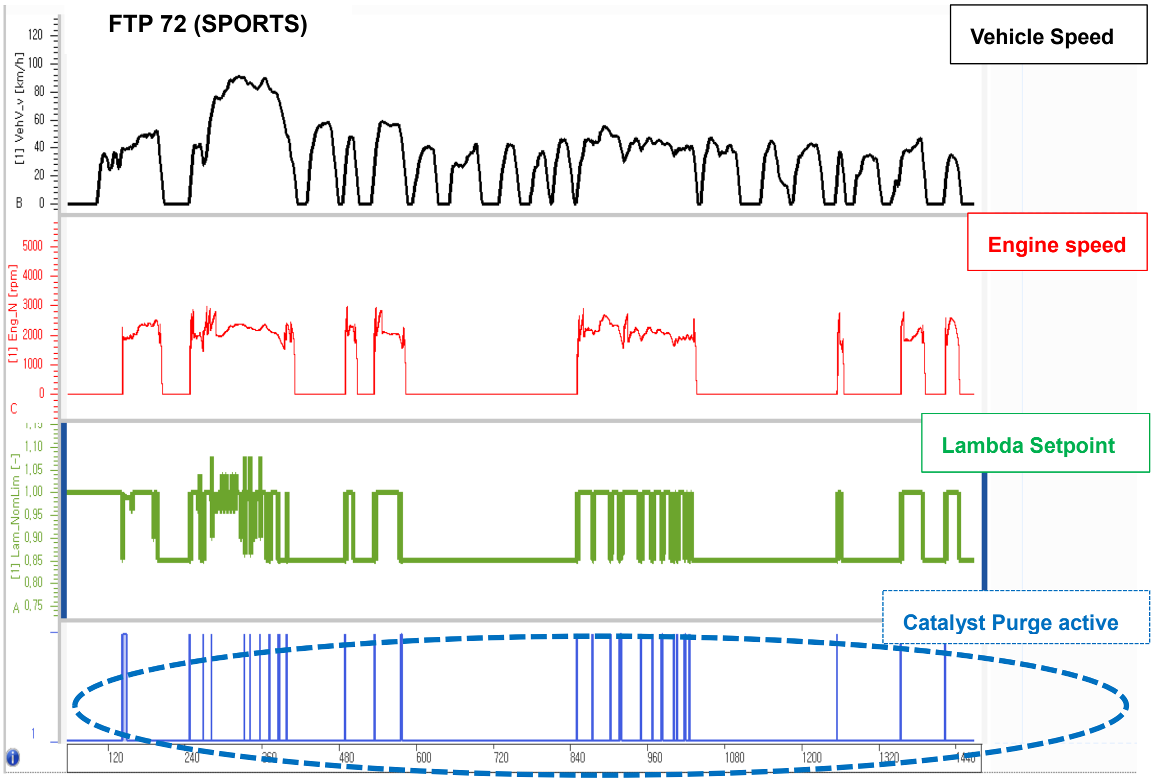
IN

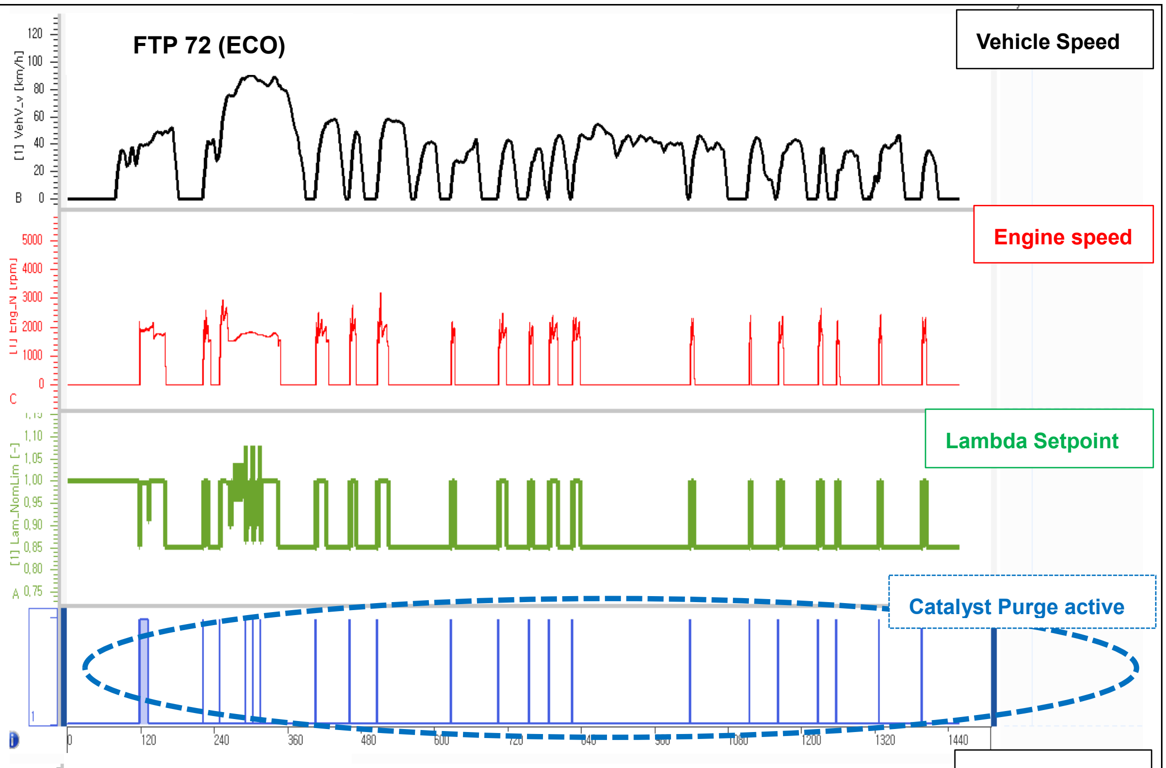
- Engine speed = f(CKP)
- Catalyst temperature model[1]
- Fuel cut off[2]
- Relative load model
- Heated O2 sensor (Binary) (HO2S2)[1]
- Heated O2 sensor (Binary) (HO2S2) operation readiness
- Oxygen storage model

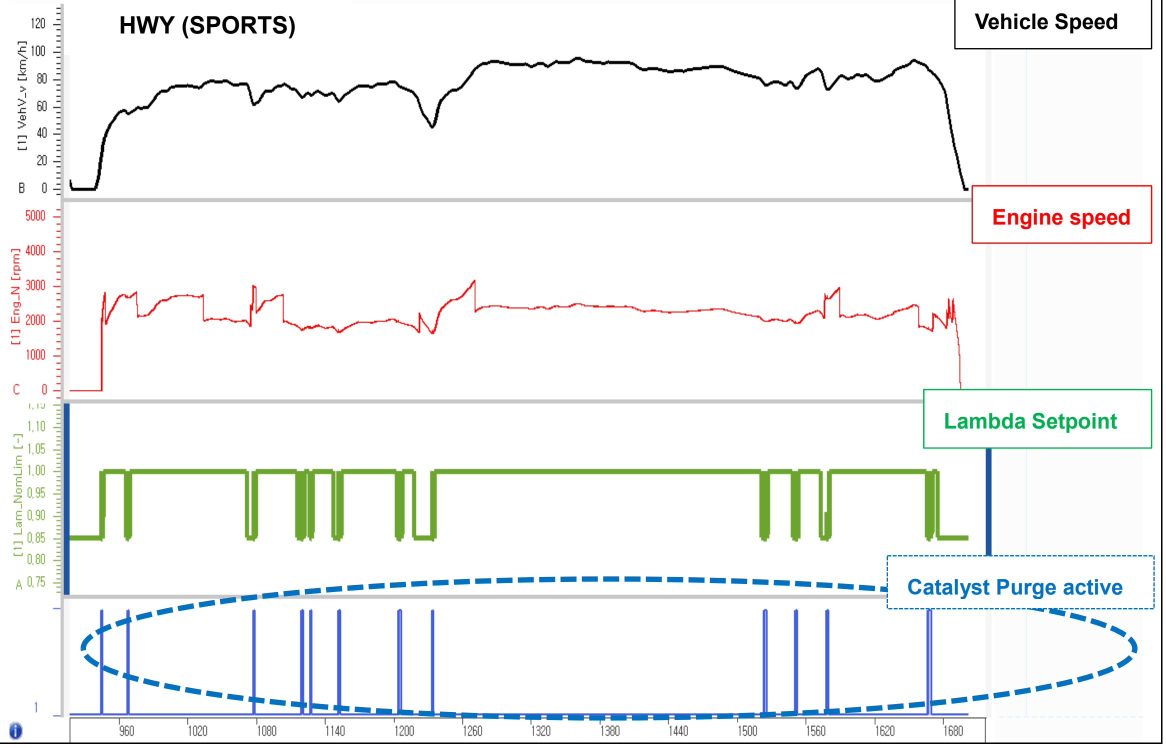
OUT

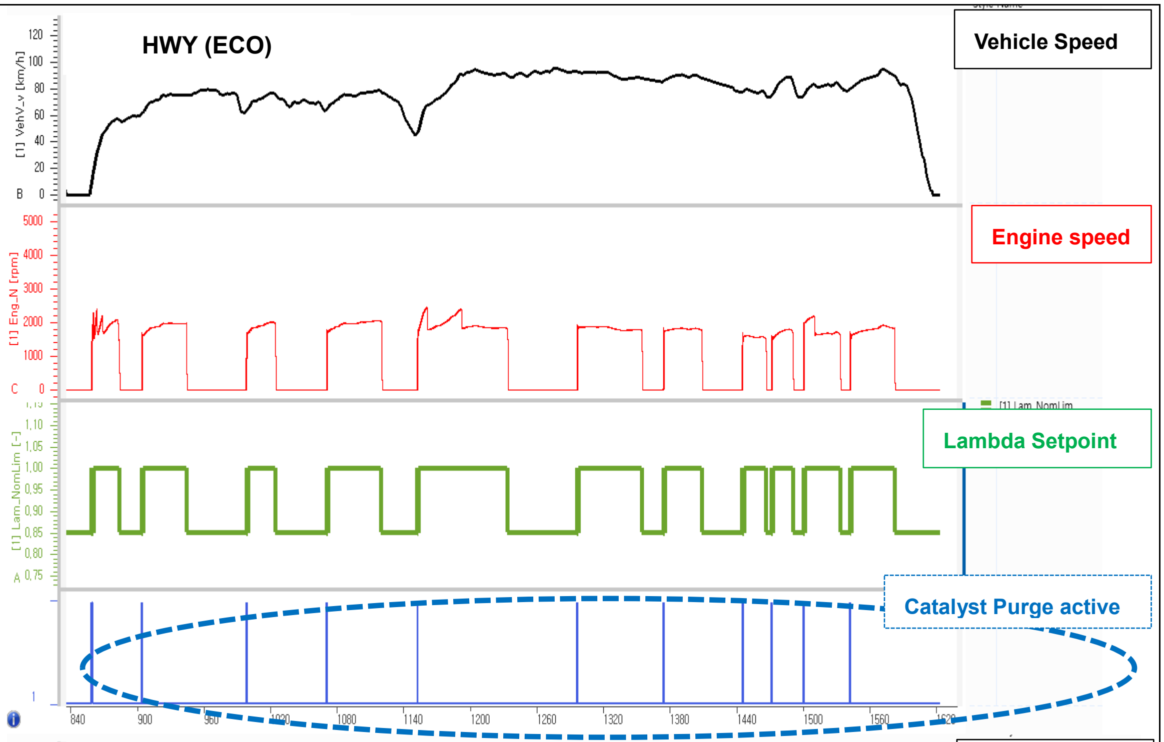
- Lambda setpoint[3]

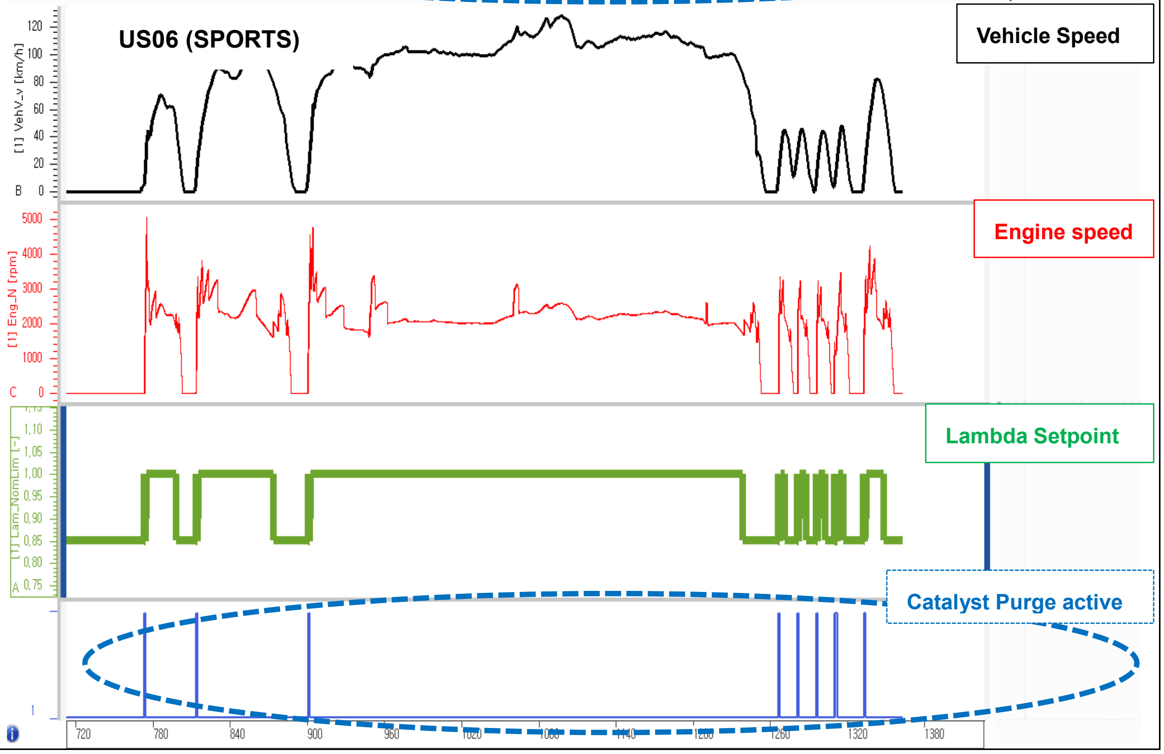


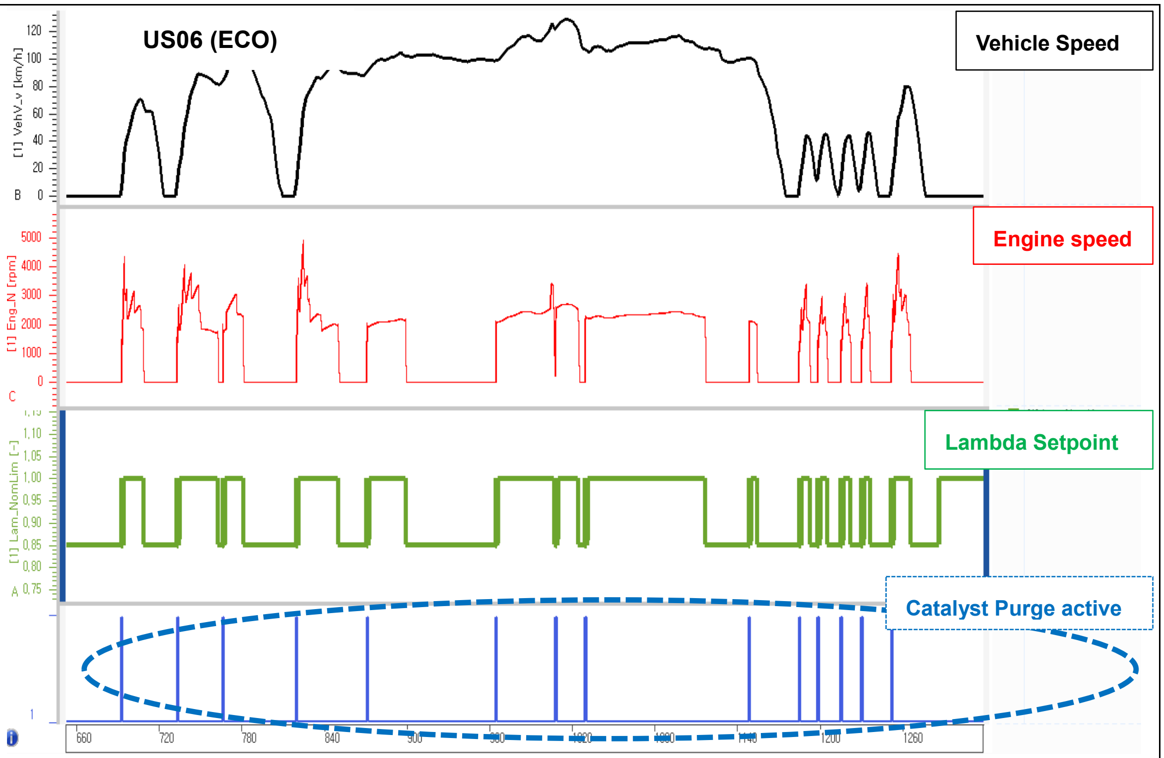
Entry Conditions	**Activating Condition** After fuel cut-off is deactivated[2] or engine is re-started. **and** Integrated oxygen mass stored during fuel cut off phase > 0g **and** Heated O2 sensor (Binary) (HO2S2)< Lean Threshold (0.6V) **and** Not Heated O2 sensor (Binary) (HO2S2) Error[3] **and** Heated O2 sensor (Binary) (HO2S2) state = Normal heating[4] **Deactivating Condition** Heated O2 sensor (Binary) (HO2S2) > Rich Threshold (0.78V) **or** Integrated oxygen mass stored during fuel cut off phase = 0g
In-use Frequency	This is a base control and generally always active after fuel cut off. See FTP72 and US06 cycles below. 


FTP 72 (ECO)
Vehicle Speed
[1] VehV_v [km/h]
120
100
80
60
40
20
B 0
Engine speed
[1] Eng_N [rpm]
5000
4000
3000
2000
1000
C 0
Lambda Setpoint
[1] Lam_NomLim [-]
1,10
1,05
1,00
0,95
0,90
0,85
0,80
A 0,75
Catalyst Purge active
1
0
120
240
360
480
600
720
840
960
1080
1200
1320
1440


HWY (SPORTS)
Vehicle Speed
[1] VehV_v [km/h]
120
100
80
60
40
20
B 0
Engine speed
[1] Eng_N [rpm]
5000
4000
3000
2000
1000
C 0
Lambda Setpoint
[1] Lam_NomLim [-]
1,10
1,05
1,00
0,95
0,90
0,85
0,80
A 0,75
Catalyst Purge active
1
960
1020
1080
1140
1200
1260
1320
1380
1440
1500
1560
1620
1680


HWY (ECO)
Vehicle Speed
Engine speed
Lambda Setpoint
Catalyst Purge active
[1] VehV_v [km/h]
[1] Eng_N [rpm]
[1] Lam_NomLim [-]
120
100
80
60
40
20
B 0
5000
4000
3000
2000
1000
C 0
1,10
1,05
1,00
0,95
0,90
0,85
0,80
A 0,75
1
840
900
960
1020
1080
1140
1200
1260
1320
1380
1440
1500
1560
1620


US06 (SPORTS)
Vehicle Speed
Engine speed
Lambda Setpoint
Catalyst Purge active
[1] VehV_v [km/h]
[1] Eng_N [rpm]
[1] Lam_NomLim [-]
120
100
80
60
40
20
B 0
5000
4000
3000
2000
1000
C 0
1,10
1,05
1,00
0,95
0,90
0,85
0,80
A 0,75
1
720
780
840
900
960
1020
1080
1140
1200
1260
1320
1380



Continuously active when entry conditions are met.
Number of engagements in the emission test modes:

E/M Mode		FTP-4Bag Mode	HWY Mode	US06 Mode
Operation Count	SPORTS	57	12	8
	ECO	42	11	14

Emission impact

This is a part of base emission control and included in all regulated test cycles and therefore accounted for by the test.

Justification

A. Substantially included during regulated test procedures :
FTP75, US06, SC03, HwFET, FTP75@-7°C
F. Base operation

Reference

1. Air-fuel ratio (A/F) feedback (HO2S2)
2. Fuel cut off for component protection
3. OBD Document
4. Oxygen sensor heating strategy

11.02.01.10 Fuel cut off for component protection

Title : Fuel cut off for component protection	
Purpose	**Component protection** The fuel cutoff is required for torque reduction for component protection.
Action: Functional Description	**Fuel injectors shut off** 1. to protect an engine when the engine speed exceeds a maximum allowable speed. 2. when a vehicle speed exceeds a maximum allowable speed due to tire speed rating. 3. when limp-home control occurs due to misfire
Parameters (I/O)	**IN** - Catalyst temperature (modeled) - Hybrid Control Unit Request - OBD Fault detection (catalyst damage misfire)[1] **OUT** - Fuel cut off
Entry Conditions	**Activating Condition** At detecting catalyst damage (catalyst temperature > 1050℃) due to multiple misfire **or** Hybrid Control Unit Request **Deactivating Condition** All of the activating conditions are no longer met.
In-use Frequency	Estimated to be rare due to extreme conditions.
Emission impact	There is no emission effect because fuel is cut off.
Justification	B. Engine emission system protection
Reference	1. OBD Document

11.02.01.11 Fuel cut off for GHG - N/A

11.02.01.12 Injection angle

Title : Injection angle	
Purpose	**Base operation :** The adjustment of the Injection angle optimizes engine operation. - Stabilized combustion - Fuel efficiency - Lower emissions
Action: Functional Description	Adjustment of injection angle and split ratio of multiple injection in specific operation. (See attached figures)
Parameters (I/O)	**IN** - Engine speed = f(CKP) - Relative load model - Engine oil temperature model - Engine coolant temperature (ECT) - Intake air temperature (IAT) - Combustion mode[1] - Lambda setpoint - Injection counter **OUT** - Number of injection - Injection angle - Injection fraction
Entry Conditions	**Activating Condition** Activated when engine runs according to the combustion mode.
In-use Frequency	This is a base control and generally always active.
Emission impact	This is a part of base emission control and included in all regulated test cycles and therefore accounted for by the test.
Justification	A. Substantially included during regulated test procedures FTP75, US06, SC03, HwFET, FTP75@-7°C F. Base operation
Reference	1. Combustion Mode strategy

Figure 1. SH1 Mode Injection (1x compression stroke)

Base Angle

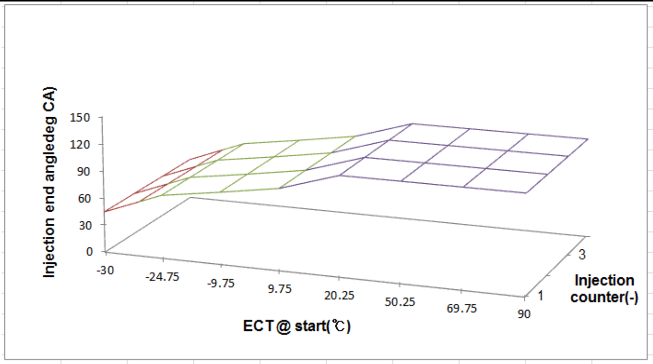
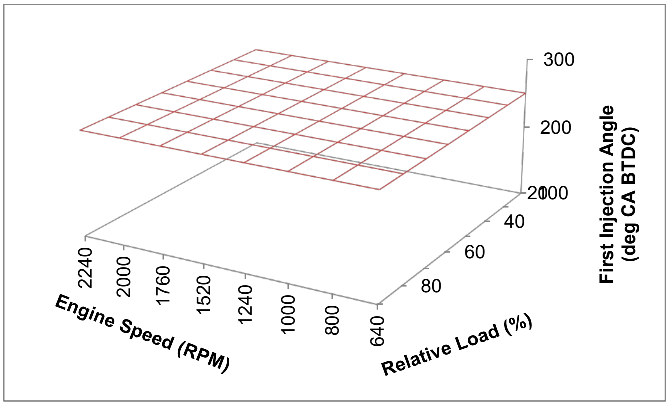
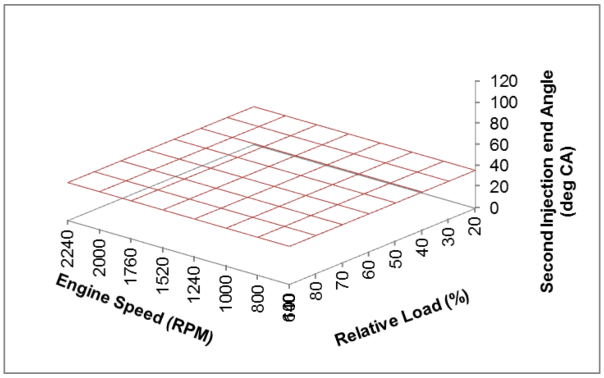


Figure 2. HP2 Mode Injection (1x compression stroke, 1x intake stroke)

First Injection



Second Injection



Second Injection Fraction

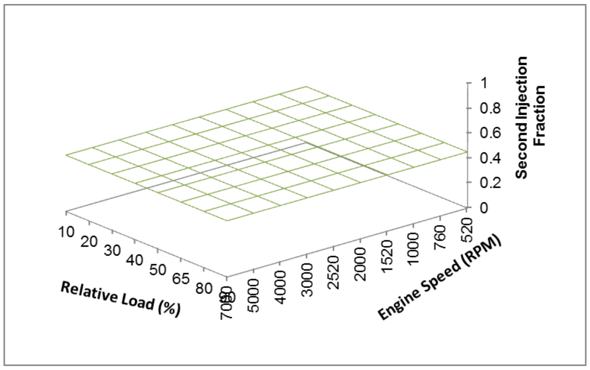
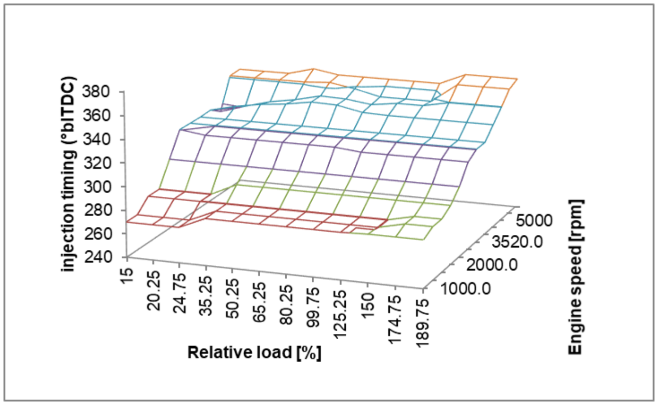


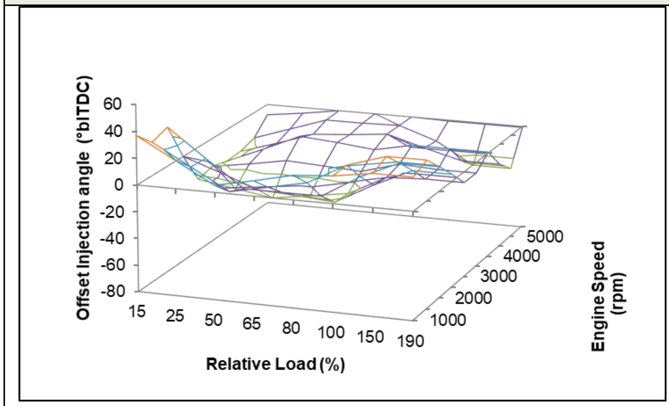
Figure 3. HO1 Mode Injection (1x intake stroke)

Base Angle

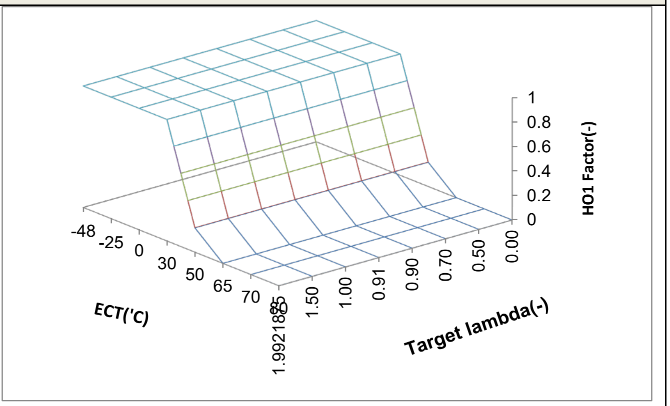


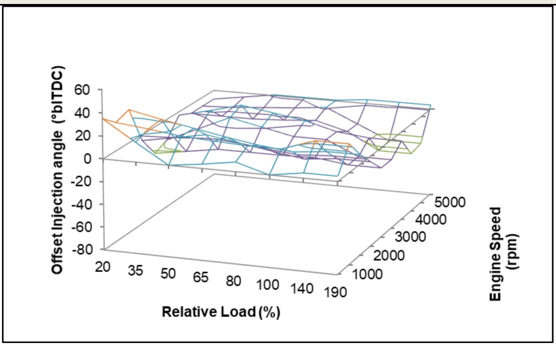
Offset for Target Lambda

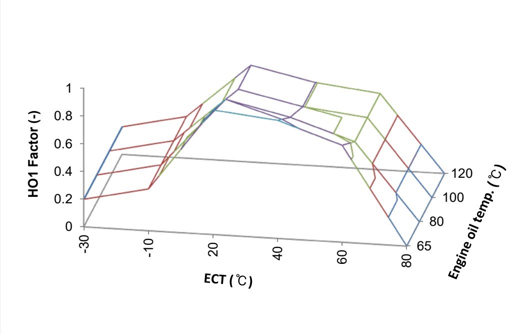
HO1 Offset_1



HO1 Factor_1



<table>
<tr><th colspan="2">Offset for Engine Coolant / Oil Temperature</th></tr>
<tr><th>HO1 Offset_2</th><th>HO1 Offset_2</th></tr>
<tr><td>


</td><td>


</td></tr>
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Figure 4. HO2 Mode Injection (2x intake stroke)

<table>
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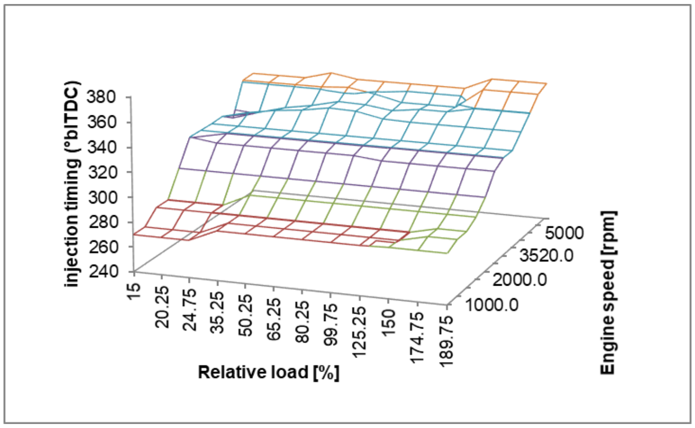
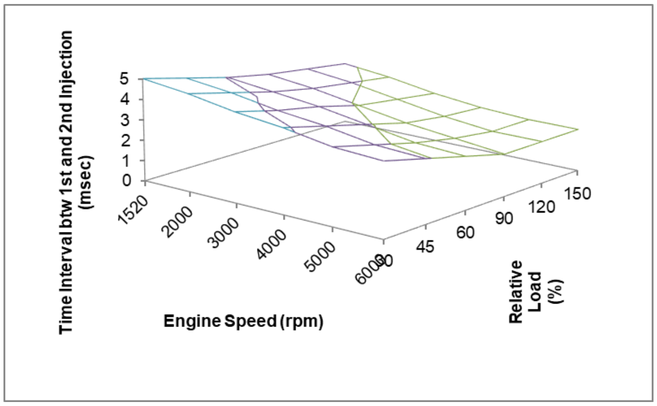
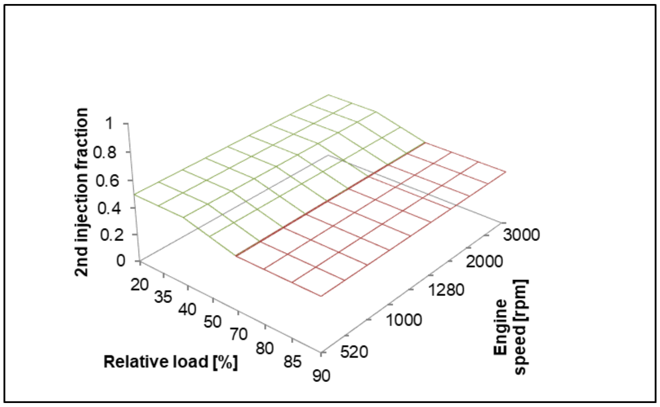
<tr><td colspan="2">


</td></tr>
<tr><th colspan="2">Second Injection</th></tr>
<tr><th>Time Interval
between First Injection and Second Injection</th><th>Second Injection Fraction</th></tr>
<tr><td>


</td><td>


</td></tr>
</table>

Figure 5. HO3 Mode Injection (3x intake stroke)

<table>
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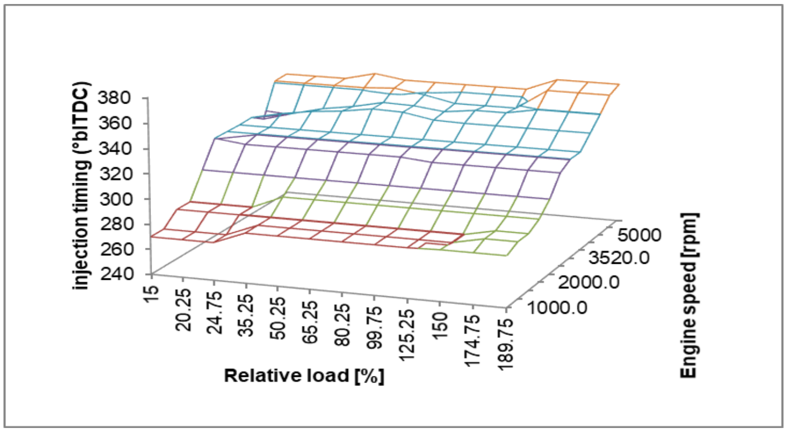
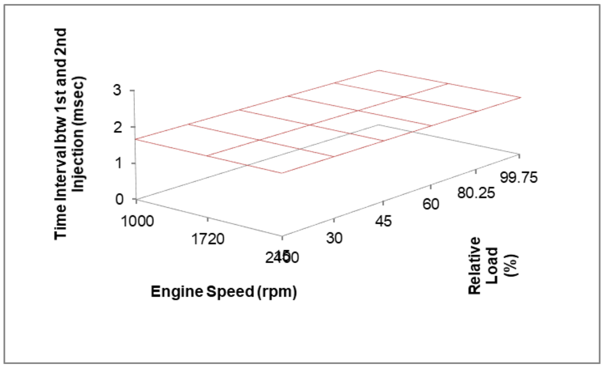
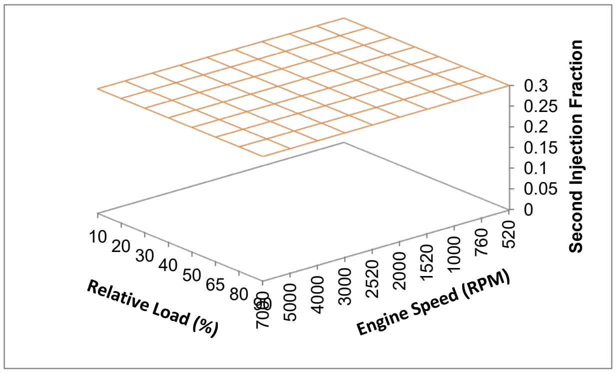
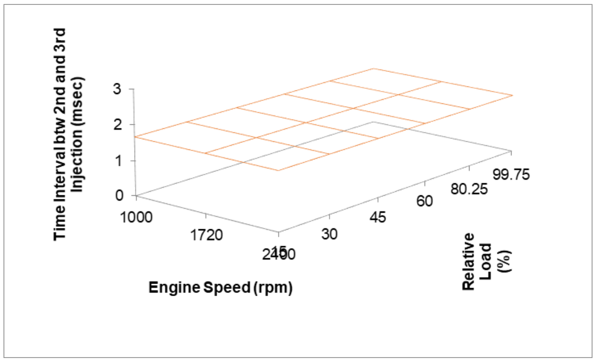
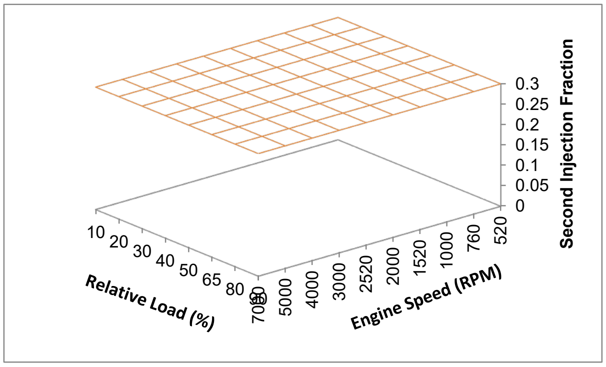
<tr><td colspan="2">
</td></tr>
<tr><th colspan="2">Second Injection</th></tr>
<tr><th>Time Interval
between First Injection and Second Injection</th><th>Second Injection Fraction</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><th colspan="2">Third Injection</th></tr>
<tr><th>Time Interval
between Second Injection and Third Injection</th><th>Third Injection Fraction</th></tr>
<tr><td>
</td><td>
</td></tr>
</table>

11.02.01.13 Fuel rail pressure (High)

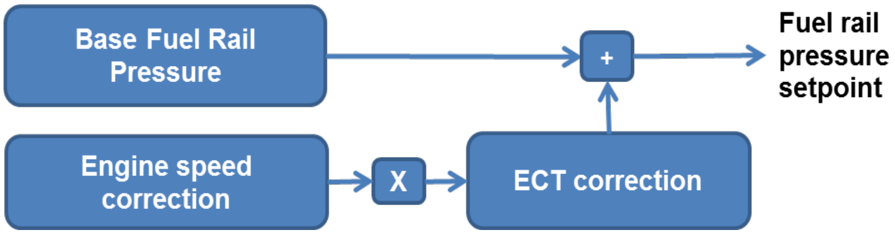
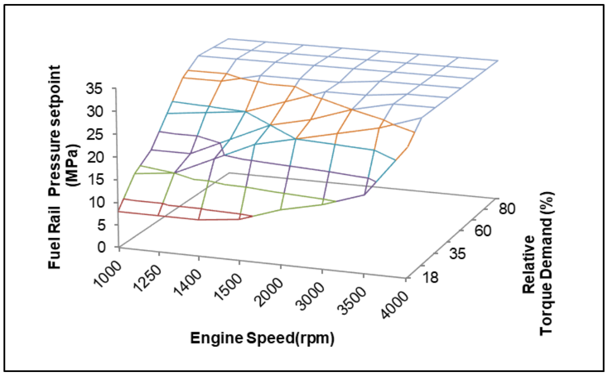
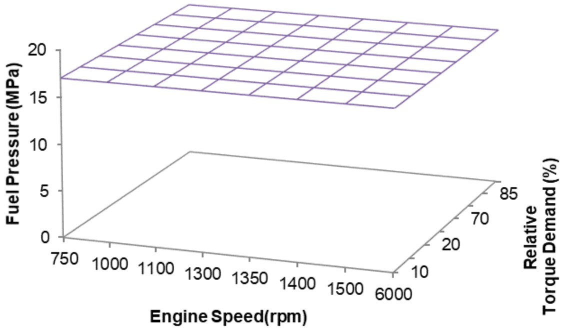
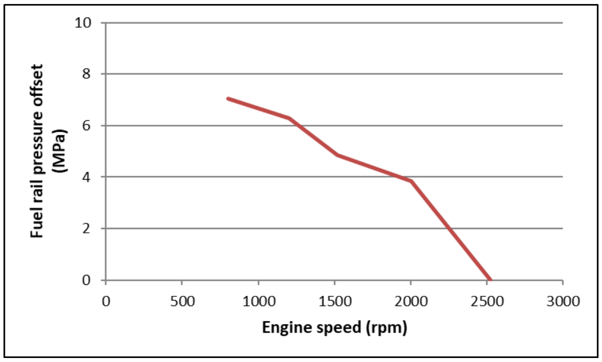
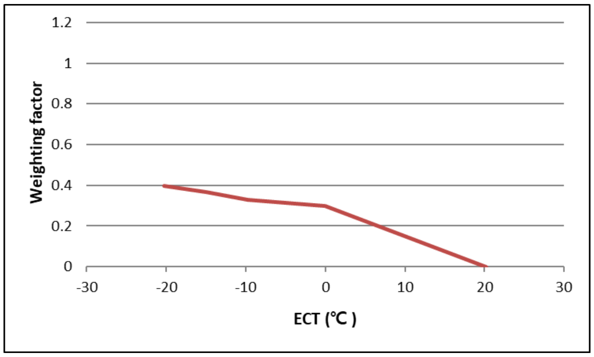
Title : Fuel rail pressure (high)	
Purpose	**Base Operation** Adjust the fuel pressure optimizing engine fuel efficiency, emission.
Action: Functional Description	Basic fuel pressure setpoint is determined based on engine operation states and/or combustion mode. 
Parameters (I/O)	**IN** - Engine speed = f(CKP) - Relative load model - Engine coolant temperature (ECT) - Combustion mode [1] **OUT** - Fuel rail pressure setpoint (see attached figures)
Entry Conditions	**Activating Condition** Activated when engine runs according to the combustion mode.
In-use Frequency	This is a base control and always active.
Emission impact	This is a base control and always active.
Justification	A. Substantially included during regulated test procedures FTP75, US06, SC03, HwFET, FTP75@-7°C F. Base operation
Reference	1. Combustion mode strategy

Figure 1. Fuel Rail Pressure Setpoint (See Combustion Mode)

<table>
<tr><th colspan="2">Fuel rail pressure setpoint</th></tr>
<tr><th>HO1 / HO2 combustion mode</th><th>HP2 combustion mode</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><th>Offset pressure</th><th>Correction factor</th></tr>
<tr><td>
</td><td>
</td></tr>
</table>

11.02.01.14 Acceleration / deceleration compensation - N/A

11.02.02 Ignition control

The aim of the ignition control is to ensure spark generation inside the ignition-plugs at a given crank angle with the correct energy in order to ignite the air fuel mixture at the correct time. The desired ignition angle is calculated from the desired torque using the inverted torque model. For that purpose, a desired value for the ignition efficiency is calculated by dividing the desired torque by the optimum torque. The optimum torque is the torque which the engine could deliver theoretically at an ignition efficiency of 100%. The desired value for the ignition efficiency is converted into an ignition angle offset using a predetermined curve. To get the desired ignition angle, this offset has to be subtracted of the optimum ignition angle where the engine could deliver theoretically the optimum torque. This desired ignition angle is limited between the latest permissible ignition angle and the basic ignition angle, which is the earliest possible angle.

Latest ignition angle

The latest permissible ignition angle is restricted by flammability, which means misfires can occur when the ignition angle is retarded more than the latest ignition angle. The latest ignition angle is the output of an engine speed and the relative load dependent map. It is corrected by the following factors:

- If the injection mode of homogeneous split for GDI system is active (refer to AECD *’11.4.07 Combustion mode strategy’*), the retarded ignition angle map is adopted instead of the base characteristic map, which depends on engine speed and relative load.
- When the catalyst is heated, the combustion limit is calculated from map which depends on engine speed and relative load.
- The combustion limit is dependent upon the engine coolant temperature and the air-fuel mixture ratio.

Basic ignition angle

The most-advanced basic ignition angle describes knocking limit and is calculated from pre-controlled map and knock control intervention. The pre-controlled basic angle is formed directly from the engine speed and relative load dependent characteristic map. It is corrected by the following factors:

- If the system has a variable camshaft adjustment, the influence of a variable residual gas quantity on the basic ignition angle is corrected.
- The lambda dependency of the basic ignition angle is taken into account via the corrections of the knock limit by lambda. The calculation is carried out using the map depending on engine speed and lambda.
- Delta ignition angle from engine temperature correction.
- Ignition retard of knock control.

If torque intervention is not required, the earliest possible ignition angle is given as output. In the case of fuel cut off, the latest possible ignition angle is given as output. During start, the ignition angle for the start condition is given as the output.

11.02.02.01 Base ignition angle

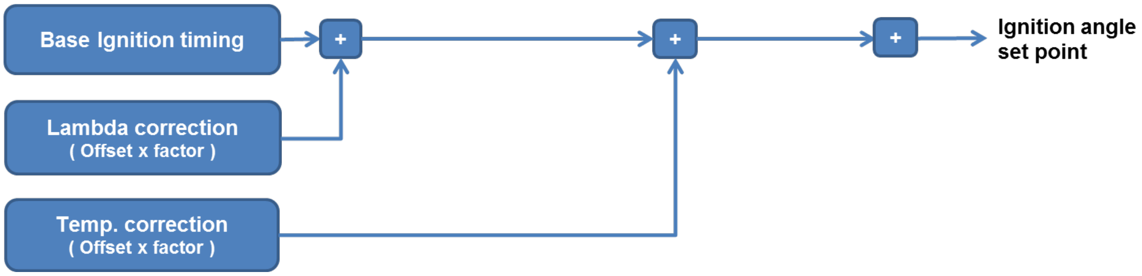
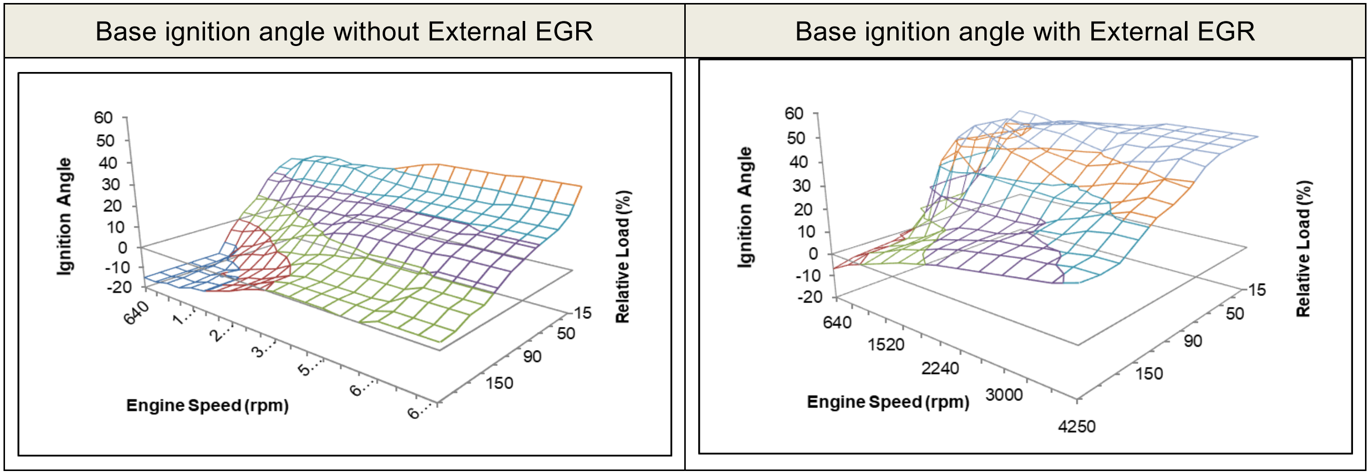
Title : Base ignition angle	
Purpose	**Base operation** Ignition angle is determined to operate the engine under most efficient conditions.
Action: Functional Description	**Ignition angle setpoint** Base ignition angle is based on a current engine operating point. In addition, the ignition angle is corrected by other operating conditions. (see attached figures) 
Parameters (I/O)	**IN** - Engine Speed = f(CKP) - Relative load model - Barometric pressure (BARO) - Engine Coolant Temperature (ECT) - Intake Air Temperature (IAT) - Lambda setpoint - Internal EGR - External EGR rate - Knock Sensor (KS)[1] - Combustion mode[2] **OUT** - Ignition angle[3] (basic + correction map)
Entry Conditions	**Activating Condition** The strategy is calculated under all engine running (engine speed > 32rpm).
In-use Frequency	This is a base control and always active.
Emission impact	This is part of base emission control and included in all regulated test cycles and therefore accounted for by the test.
Justification	A. Substantially included during regulated test procedures FTP75, US06, SC03, HwFET, FTP75@-7°C F. Base operation
Reference	1. Knock control 2. Combustion mode strategy 3. Exhaust system temperature determination

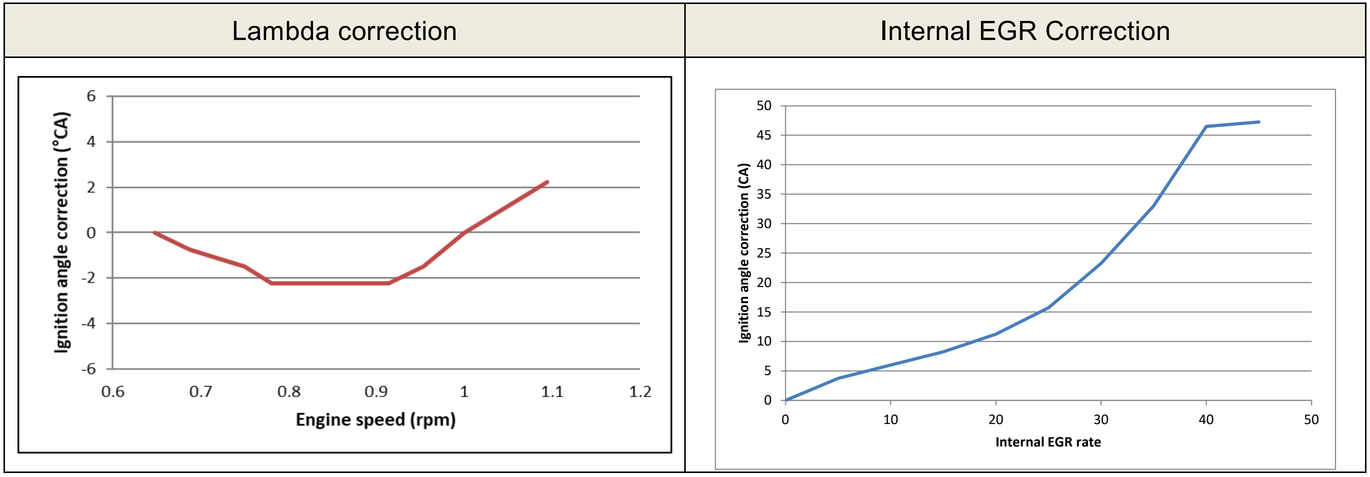
Figure 1. Base ignition angle with or without External EGR



Base ignition angle without External EGR

Base ignition angle with External EGR

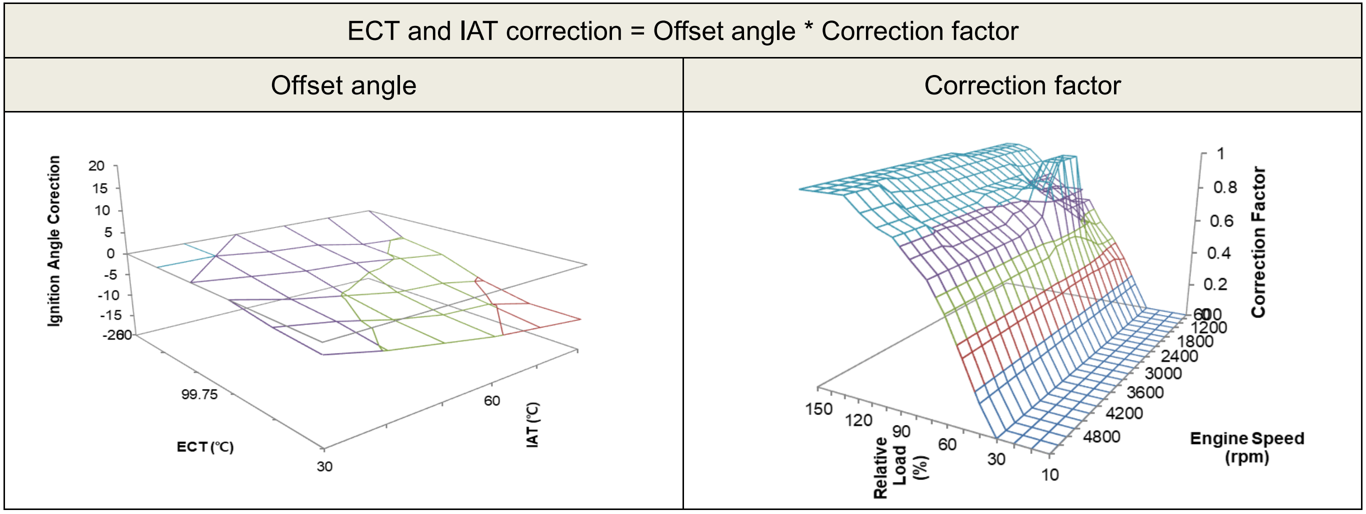
Figure 2. Lambda and Internal EGR Correction



Lambda correction

Internal EGR Correction

Figure 3. Temperature Correction ignition angle

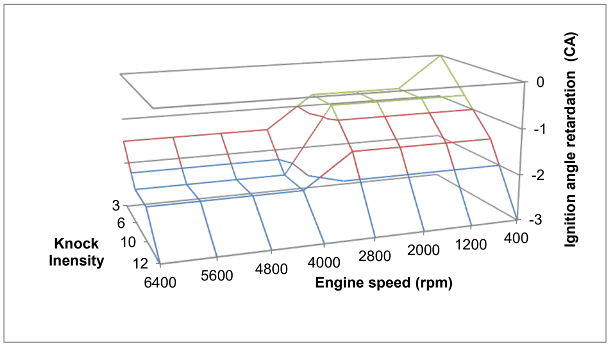
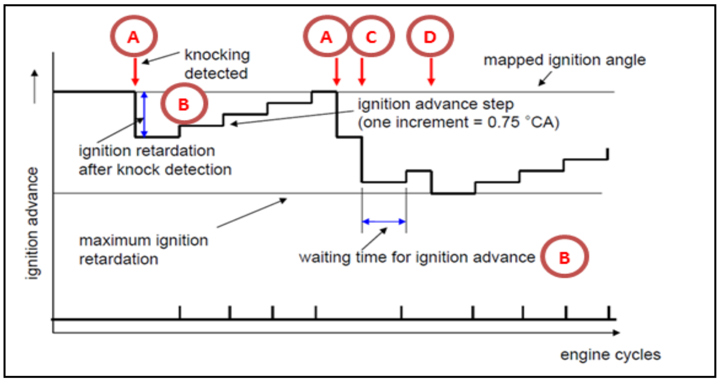


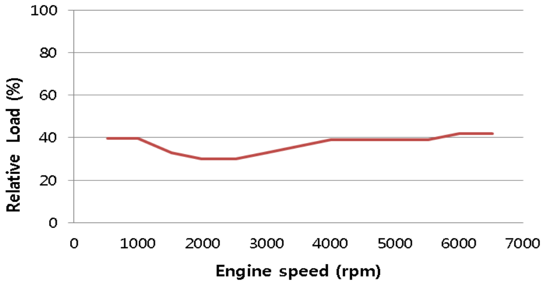
ECT and IAT correction = Offset angle * Correction factor

Offset angle

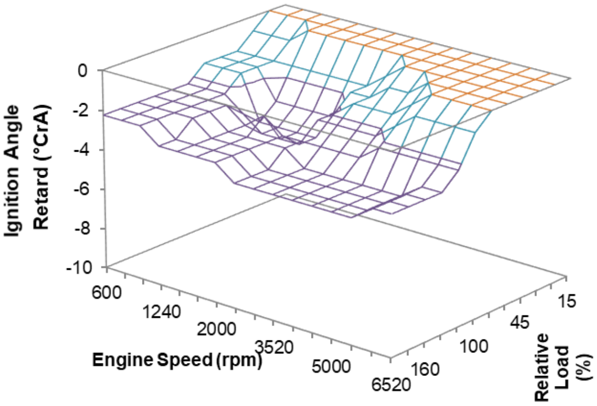
Correction factor

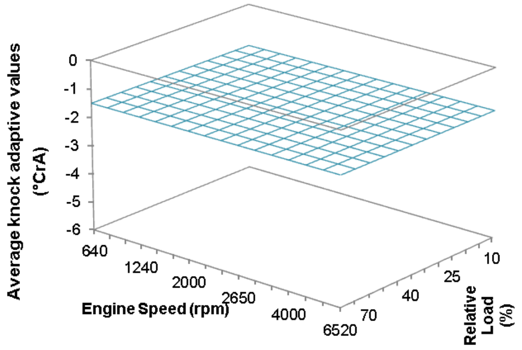
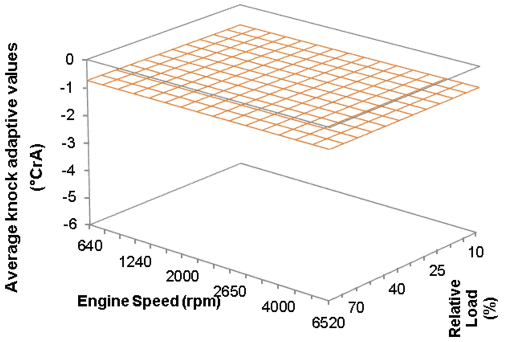
11.02.02.02 Knock control

Title : Knock control	
Purpose	**Engine/Component Protection** Preventing the engine components, *i.e.* cylinder head, piston, etc…, from damage due to engine knock.
Action: Functional Description	**Ignition angle adjustment** Spark retardation Is executed when knocking is detected up to maximum 9degCA The actions will be deactivated if knock is not detected. (see attached figures) * Ignition angle retard function A: If knocking is detected, ignition angle is retarded.  B: If no more engine knock is detected, ignition angle is advanced gradually to the base ignition angle by 0.75degCA after a delay (5 sec). C: If there is continuous engine knock, ignition angle is retarded additionally. D: If there is engine knock during ignition recovery(advance), ignition angle is retarded again. 
Parameters (I/O)	**IN** - Knock Sensor (KS) - Engine speed = f(CKP) - Relative load model - Engine Coolant Temperature (ECT) **OUT** - Adjustment Ignition angle

Entry Conditions	**Activating Condition** Engine coolant temperature > 40℃ **and** Relative load model > f(rpm)  **Deactivating Condition** If there is no more engine knock, ignition angle is advanced gradually to the base ignition angle by 0.75 crk after a delay. (see graph above)
In-use Frequency	This is a base control and always active.[2]
Emission impact	Fuel economy test result differences between comparing 91 RON and 96 RON operation is within 3%, and there are no emission increase (beyond normal test variability) using 91 RON fuel when tested on the FTP test cycle.[3]
Justification	B. Engine System Protection
Reference	1. Base Ignition Angle, Global Knock Adaptation 2. Compiled with VPCD 97-01 3. Compiled with VPCD 97-01

11.02.02.03 Global knock adaptation

Title : Global knock adaptation	
Purpose	**Engine/Component protection:** Adaptation to different markets’ fuel quality to avoid damage the cylinder head and piston due to engine knock.
Action: Functional Description	**Ignition angle adjustment** Adjusting basic ignition angle based on the calculated fuel quality. The following procedure is activated, in order 1. Knock sensors detect engine knock. 2. Adapt knock and estimate fuel quality with averaged knock adaptation value; and then 3. Correct basic ignition angle by estimated fuel quality (Delta ignition angle map * Factor of delta ignition angle)
Parameters (I/O)	**IN** - Knock Sensors (KS)[1] - Engine Speed (CKP) - Relative load model - Engine coolant temperature (ECT) **OUT** - Adjusted basic ignition angle[2] 
Entry Conditions	**Activating Condition** Engine coolant temperature : > 60℃ **and** Relative load model > 30%

	Average knock adaptation value > f(Engine speed, Relative load model)  **Deactivating Condition** Average knock adaptation value < f(Engine speed, Relative load model) 
In-use Frequency	Regular gasoline (RON 91) is recommended. Some activation for fuel with a quality of RON 91 or lower may occur.[3]
Emission impact	Fuel economy test result differences between comparing 91 RON and 96 RON operation is within 3%, and there are no emission increase using 91 RON fuel when tested on the FTP test cycle.[4]
Justification	B. Engine/Emission System Protection
Reference	1. Knock control, Base Ignition angle 2. Base ignition angle 3. Complied with VPCD 97-01 4. Complied with VPCD 97-01

11.02.03 Cylinder valve timing control

In internal combustion engines, variable valve actuation (VVT, VVL, VVD) is the process of altering the timing of a valve lift event, and it can improve power performance, fuel economy, and emissions. Combination of the CVVD (Continuously Variable Valve Duration) system and CVVT (Continuously Variable Valve Timing) system can help to control valve open/close timing independently by changes in valve duration and phasing. The valves within an internal combustion engine are used to control the flow of the intake and exhaust gases in-and-out of the combustion chamber. The timing, duration, and lift of these valve events have a significant impact on engine performance. Without variable valve timing or variable valve lift or variable valve duration, the valve timing will be the same for all engine speeds and conditions. An engine equipped with a variable valve timing actuation system can allow performance to be improved over the engine operating range.

The variable camshaft adjustment is achieved by a phase adjustment of the camshaft with respect to the crankshaft. The camshaft is adjusted by changing the angle position of the camshaft relative to the crankshaft. The position controller receives an actual angle position from the camshaft sensor (phase sensor) and balances the difference between target and actual angle with a duty cycle as the output. The camshaft phasing is realized by means of an actuator that works with the electrical motor or engine oil (system dependency equipped). The CVVD adaptation is achieved by counting control shaft revolution. The CVVD controller receives actual revolution from left stop position to right stop position and adjusts end to end position. The first adaptation process is worked during EOL test. After EOL, the adaptation process is enabled during fuel cut off condition. Additionally if charge, engine speed, coolant temperature and so on conditions are fulfilled, the fuel cut off adaptation process is worked. The valve duration control is realized by means of an electrical motor.

Target valve timing

The target valve timing is assigned by each configuration's map. The desired value assignment can be assigned by the maps only when the camshaft adjustment and CVVD adaption have been enabled. If camshaft adjustment and CVVD adaptation have not been enabled, then the reference position is output for the desired value. The valve open/close timing is selected by different maps depending on driving, idling, and catalyst heating activation. Each map is formed directly from the engine speed and relative load.

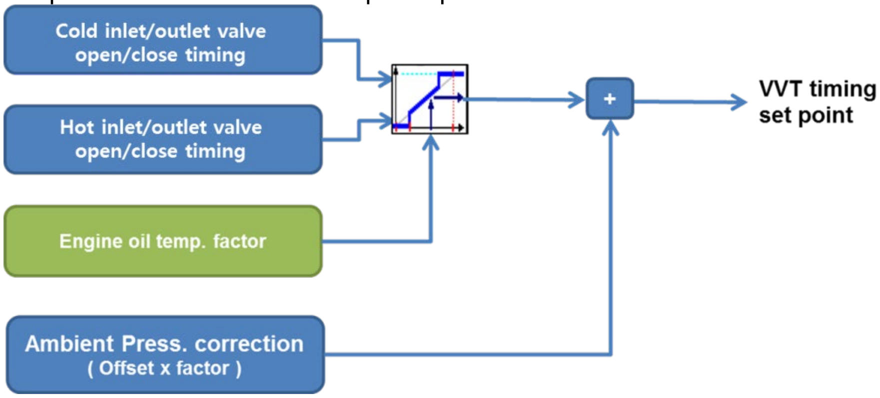
Enable condition

The valve timing control enable condition is determined by considering the engine oil temperature value, battery voltage, and engine speed. An adjustment enable is given when the actuator hardware is able to realize a target value demand for adjustment under the given engine operating conditions.

An enable of the camshaft adjustment may take place only when no inhibiting faults are present for the adjustment. Inhibiting faults are when during the check of the alignment camshaft with crankshaft in reference position of the camshaft, a fault was detected or when there is a fault in the battery voltage detection of the phase sensor. Additionally, the adaptation of the camshaft and crankshaft alignment must have occurred.

11.02.03.01 Variable valve timing

<table>
<tr><th colspan="2">Title : Variable valve timing</th></tr>
<tr><td>Purpose</td><td>Base operation :

Adjustment of valve timing for emission reduction, improving fuel consumption, and optimizing full load performance.</td></tr>
<tr><td>Action:
Functional Description</td><td>Inlet/outlet valve timing adjustment
Adjustment of inlet/outlet valve timing depends on engine speed, engine load, and engine oil temperature and acceleration pedal position.

(see attached figures)</td></tr>
<tr><td>Parameters (I/O)</td><td>In
- Engine speed = f(CKP)
- Relative load model
- Engine coolant temperature (ECT)
- Engine oil temperature model
- Battery voltage (B+)
- Camshaft position inlet (CMP_IN)
- Camshaft position outlet (CMP_OUT)
- Barometric pressure (BARO)

Out
- Inlet valve open/close timing setpoint
- outlet valve open/close timing setpoint</td></tr>
<tr><td>Entry Conditions</td><td>Activating Condition
10V < Battery voltage < 16V
and
Engine oil temperature model > -5℃
and
Accumulated crankshaft rev. > f(ECT)</td></tr>
</table>

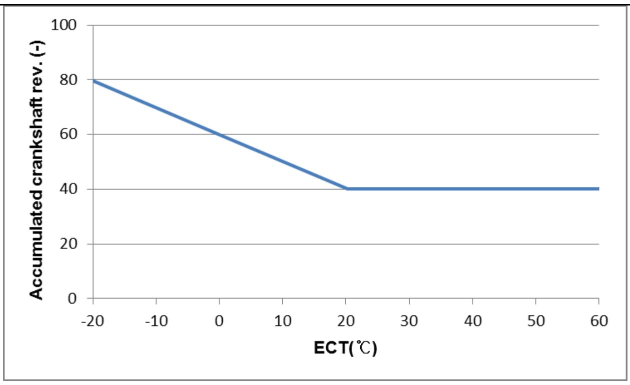
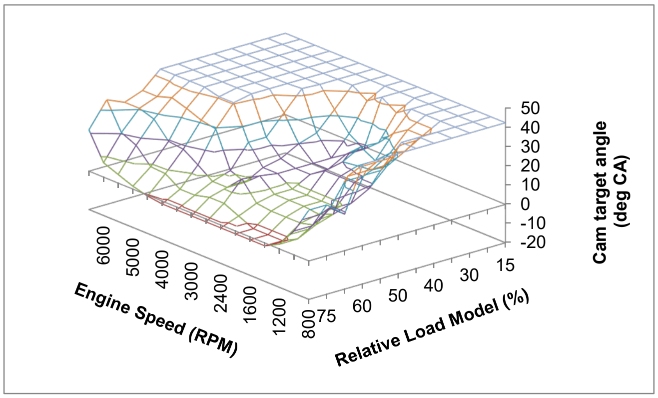
	 **Deactivating Condition** Engine oil temperature model > 140℃
In-use Frequency	This is a base control and generally always active.
Emission impact	This is part of base emission control and included in all regulated test cycles and therefore accounted for by the test.
Justification	A. Substantially included during regulated test procedures FTP75, US06, SC03, HwFET, FTP75@-7°C F. Base Operation
Reference	

Figure 1. Adjustment inlet/outlet valve timing
(Positive value means retard and Negative value means advance)

<table>
<tr><th colspan="2">Inlet valve timing</th></tr>
<tr><td>Cold VVT timing</td><td>Hot VVT Timing</td></tr>
<tr><td>


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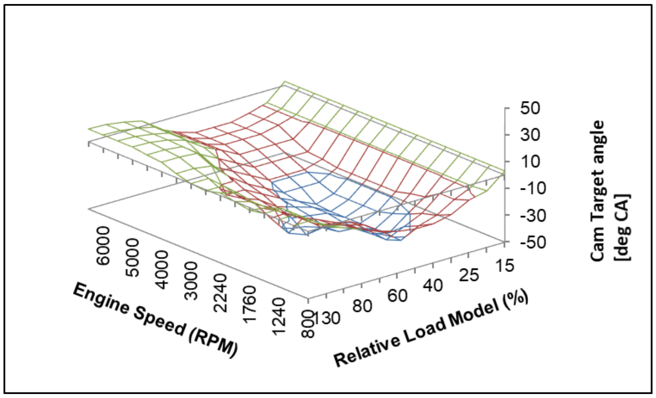
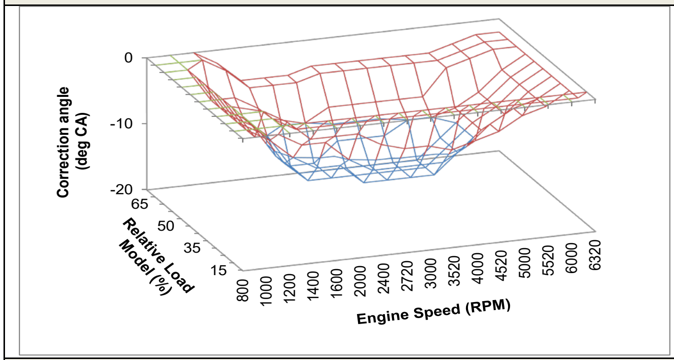
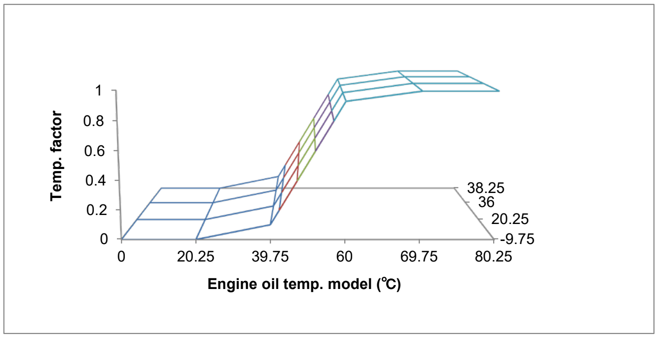
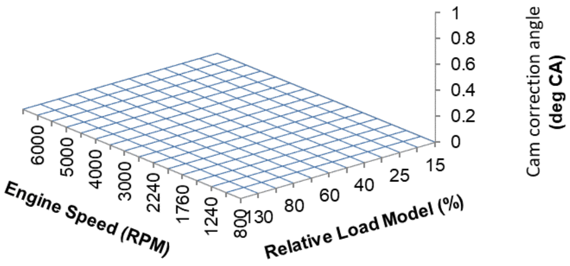


</td></tr>
<tr><td>Low Barometer</td><td>Engine oil temp. and ECT factor</td></tr>
<tr><td>


</td><td>


</td></tr>
<tr><td colspan="2">Altitude offset (Correction angle * Ignition angle correction factor)</td></tr>
<tr><td>


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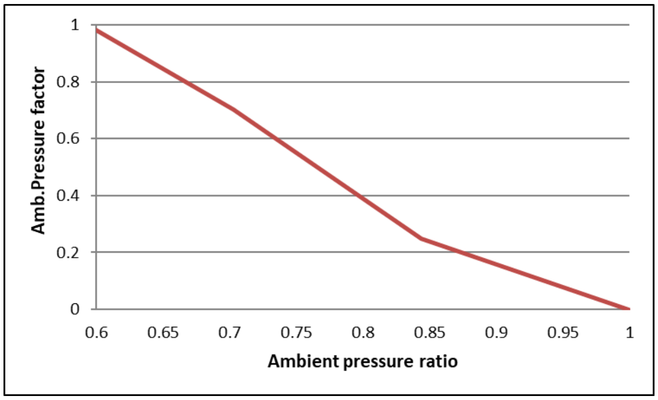
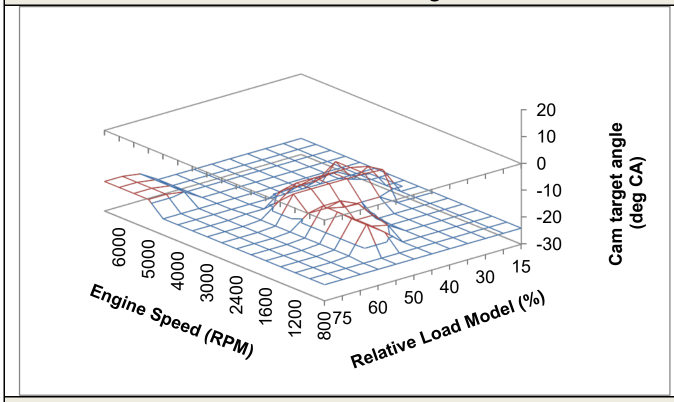


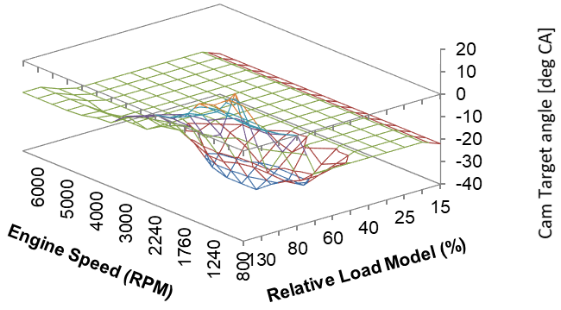
</td></tr>
</table>

Outlet valve timing

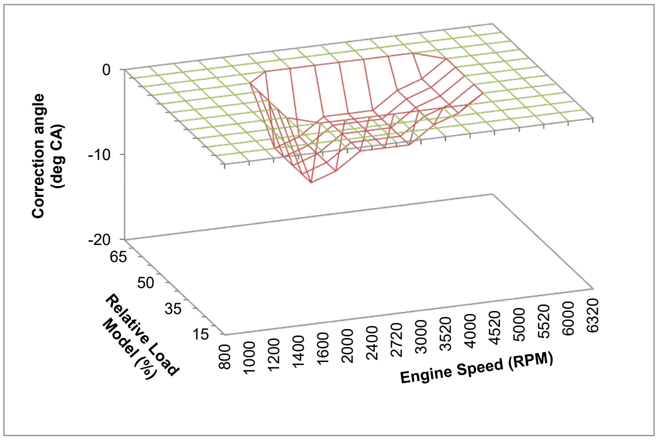
Cold VVT timing



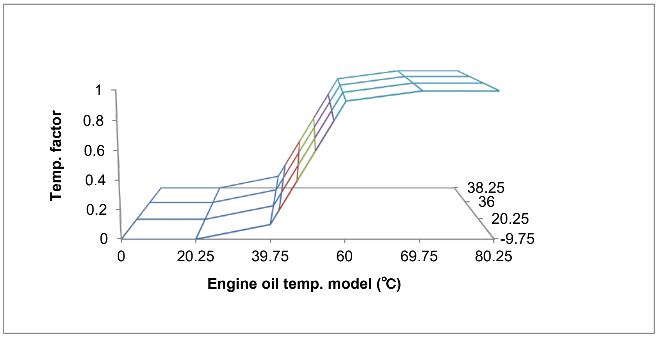
Hot VVT Timing



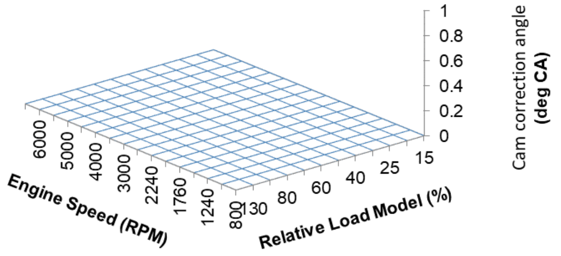
Low Barometer

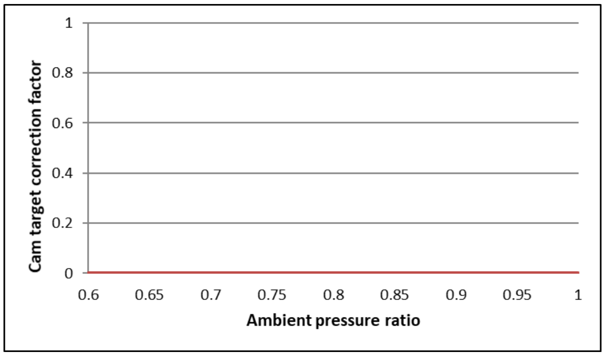


Engine oil temp. and ECT factor



Altitude offset (Correction angle * Ignition angle correction factor)





11.02.04 Exhaust gas recirculation (EGR) valve control

In internal combustion engines, exhaust gas recirculation (EGR) is a nitrogen oxide (NOx) emissions reduction technique, as well as a fuel economy improvement measure. The EGR works by recirculating a portion of an engine's exhaust gas back to the engine cylinders. In a gasoline engine, this inert exhaust displaces the amount of combustible matter in the cylinder. This dilutes the O2 in the incoming air stream and provides inert gases to the combustion to act as absorbents of combustion heat to reduce peak in-cylinder temperatures. Because NOx forms primarily when a mixture of nitrogen and oxygen is subjected to high temperature, the lower combustion chamber temperatures caused by EGR reduces the amount of NOx the combustion generates.

EGR valve position control: The desired position of the EGR valve is calculated out of the desired flow over the valve and a flow model considering the temperatures and the pressures upstream and downstream of the EGR valve. The actual position of the EGR valve is measured with a sensor, to which production tolerances are adapted. The actual mass flow over EGR valve is calculated depending on the EGR valve position, the pressure upstream and downstream of the EGR valve, and the temperature of the EGR gas. A second value of the mass flow over the EGR valve is calculated out of the change in the intake manifold pressure. This second mass flow value is used for adaptation and diagnostics. Diagnostic functions monitor the EGR valve position, the position sensor, and the EGR system.

Desired EGR rate: The desired EGR inert gas rate in the cylinder is calculated depending on the engine operating point.

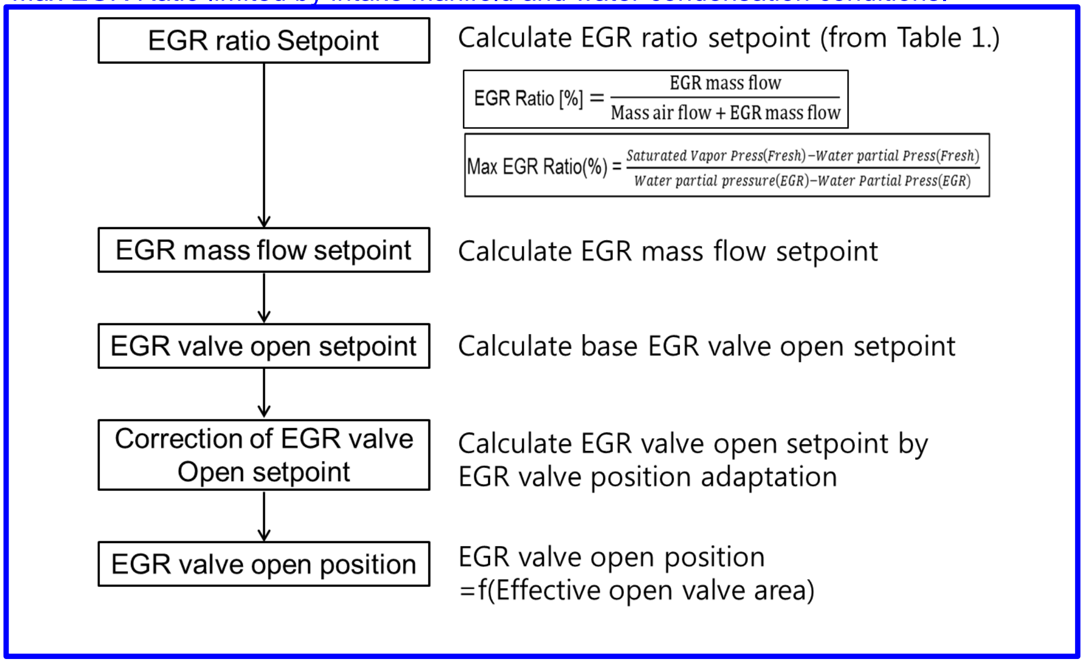
11.02.04.01 EGR valve control

<table>
<tr><td colspan="2">Title : Exhaust Gas Recirculation</td></tr>
<tr><td>Purpose</td><td>Base Operation

- Improvement of fuel efficiency

- Reduction of raw NOx emission
</td></tr>
<tr><td>Action:
Functional
Description</td><td>EGR valve control according to the EGR ratio setpoint

Max EGR Ratio limited by intake manifold and water condensation conditions.



Exhaust gas recirculation helps decrease combustion temperature and reduce pumping loss during intake stroke. EGR is a substantial engine feature for:

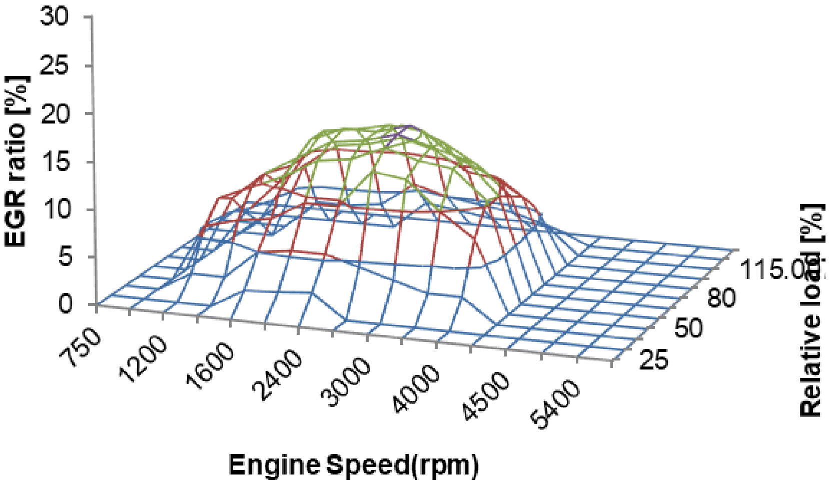
- Improvement of fuel efficiency by advancing ignition angle and reducing pumping loss during intake stroke.

- Reduction of raw NOx emission by decreasing combustion temperature.
</td></tr>
</table>

Parameters (I/O)

IN

- EGR ratio setpoint



- EGR cannot be used at low engine speed because of low exhaust gas pressure condition and at high engine speed because of the EGR valve damage possibility by high exhaust gas temperature.

- At low loads, low manifold pressure can make strong vacuum force that can cause excessive EGR flow. At high loads, EGR valve can be damaged by high exhaust gas temperature.

- Engine Coolant Temperature (ECT)
- Intake Air Temperature (IAT)
- Ambient Air Temperature (AAT)
- BARO (MAP, IAT, CKP, TP, CMP_IN/OUT, VS)
- Engine Speed (CKP)
- Mass Air Flow (MAF)

- Manifold Absolute Pressure (MAP)
- Exhaust Gas Pressure
- Ignition Angle (CKP, MAP, IAT, TP, CMP IN/OUT, BARO, VCM, ECT, KS)[1]
- Vehicle Speed (WSS)
- Accelerator pedal position (APP)
- Battery voltage (B+)

OUT

- EGR valve open position (See attached figures)

Entry Conditions	**Activating Condition** Lambda feedback control (O2S1, O2S2)[2] **and** 1000 rpm < Engine speed < 4200 rpm **and** 27 % < Relative load model < 62 % **and** 50℃ < Engine coolant temperature (ECT) < 120℃ **and** -48℃ < intake manifold temperature **and** 2.25℃ < Ambient Air Temperature (AAT) **and** Vehicle speed (VS) >= 15KPH (9.3MPH) **and** 10V < Battery voltage < 16V: **Deactivating Condition** If any of activating conditions are not met. **or** Ambient Air Temperature (AAT) <= 2.25℃ • Reason for preventing water condensation due to EGR gas in low temperature **or** Catalyst heating • Reason for combustion stability / catalyst heating performance **or** After fuel cut off (0.1s) • Reason for control exact EGR rate due to accumulated oxygen **or** Front O2 sensor diagnosis and catalyst diagnosis • Reason for misdiagnosis probability **or** Accumulation of air flow after starting < 0.35g • Reason for Elimination of disturbance by residual air **or** Full load request • Reason for Prevent hardware failure at high temperatures **or** Vehicle speed < 5KPH (3.1MPH) • Reason for Improves vehicle drivability due to sudden change in ignition timing **or** - EGR exhaust temperature > 200℃ • Reason for protect EGR valve and hose
In-use Frequency	Continuously active when entry conditions are met.

Emission impact	May momentarily decrease raw NOx emission while active.
Justification	A. Substantially included during regulated test procedures FTP75, US06, SC03, HwFET,
Reference	1. Ignition Angle Base Control 2. Air-fuel ratio (A/F) feedback control strategy

Figure 1. EGR Rate correction factor

EGR Correction factor based on AAT and ECT

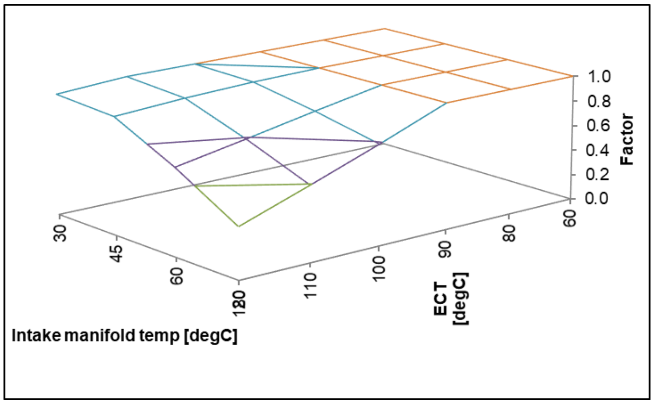
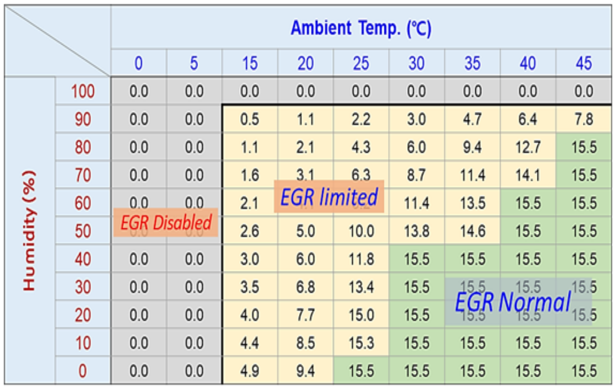


Figure 2. EGR target Rate based on AAT and humidity

EGR target Rate(%) based on AAT and humidity



	Ambient Temp. (℃)								
Humidity (%)	0	5	15	20	25	30	35	40	45
100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
90	0.0	0.0	0.5	1.1	2.2	3.0	4.7	6.4	7.8
80	0.0	0.0	1.1	2.1	4.3	6.0	9.4	12.7	15.5
70	0.0	0.0	1.6	3.1	6.3	8.7	11.4	14.1	15.5
60	0.0	0.0	2.1	[illegible]	[illegible]	11.4	13.5	15.5	15.5
50	0.0	0.0	2.6	5.0	10.0	13.8	14.6	15.5	15.5
40	0.0	0.0	3.0	6.0	11.8	15.5	15.5	15.5	15.5
30	0.0	0.0	3.5	6.8	13.4	15.5	15.5	15.5	15.5
20	0.0	0.0	4.0	7.7	15.0	15.5	15.5	15.5	15.5
10	0.0	0.0	4.4	8.5	15.3	15.5	15.5	15.5	15.5
0	0.0	0.0	4.9	9.4	15.5	15.5	15.5	15.5	15.5

11.02.05 Wastegate control

On turbo-charged internal combustion engines, efficiency can be reached by increasing the gas pressure before the cylinder intake. This boost pressure is controlled with a wastegate (WG). The task of WG control is to realize the requested actuator position dependent on the engine operating states and the driver request. For this purpose, the final wastegate set-point includes all necessary functions for the closed-loop boost pressure actuator position control and the corresponding diagnosis functions.

Base boost pressure

The base boost pressure is defined as the pressure at operating points where the pressure within the WG actuator is maximum controlled open and throttle is at wide open position. Its value mainly depends on engine speed, with influences of ambient pressure and intake air temperature. Engine individual tolerances are learned in module basic boost pressure adaptation and are coordinated here. This base boost pressure is the lower limit for the desired boost pressure value, below which the boost pressure control cannot intervene.

Desired boost pressure

The desired boost pressure is derived from the air charge control. If the desired boost pressure is lower than that of downstream air filter, it is raised for a faster response of the turbo charger. It means that the boost pressure control activates the air charge control only when the desired boost pressure is greater than the base boost pressure.

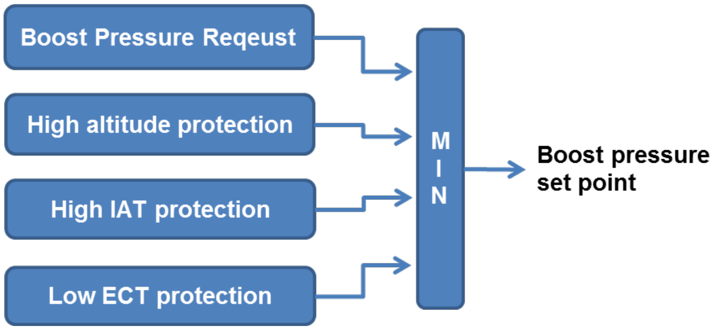
Target WG valve position control

If the desired target boost pressure is larger than the base boost pressure, the required compressor power can be derived using the target boost pressure. The base of the pre-control of WG is the power provided by the turbine which has to be equal to the power consumed by the compressor. This is the underlying idea of the feed forward control of the boost pressure package. The power of turbine and the compressor can be calculated by the temperature model of upstream turbine/compressor, efficiency of turbine/compressor, air mass flow rate through turbine/compressor, pressure ratio at turbine/compressor, and specific heat capacity.

Considering the above calculations, the desired compressor power using the desired boost pressure and the desired mass flow over the compressor can be computed. This power has to be provided by the turbine. Based on the known power from above can be solved for the necessary mass flow over the turbine to set this power utilizing known actual values.

The duty cycle for the electric WG actuator is necessary for reaching the desired lift of the WG flap. The position of the electric WG flap is controlled by PID closed loop controllers.

11.02.05.01 Turbo charger boost control and protection

Title : Turbo charger boost control and protection	
Purpose	**Engine/Component Protection:** Protection of turbocharger against over-speeding and avoiding damage from engine knock or pre-ignition.
Action: Functional Description	**Boost pressure setpoint (Torque limitation)** Torque limitation: - to avoid turbocharger over-speeding at high altitude. - to avoid the damage from engine knock at high intake air temperature. - to avoid pre-ignition at low engine coolant and oil temperatures. 
Parameters (I/O)	**In** - Engine speed = f(CKP) - Intake air temperature (IAT) - Barometric pressure (BARO) - Relative load model - Engine coolant temperature (ECT) - Engine oil temperature model **Out** - Boost pressure setpoint (see attached figures)[1]
Entry Conditions	This is a base control and generally active setting boost pressure and protecting turbocharger.
In-use Frequency	This is a base control and generally active. Turbo charger boost control actuator activated @ US06 cycle.

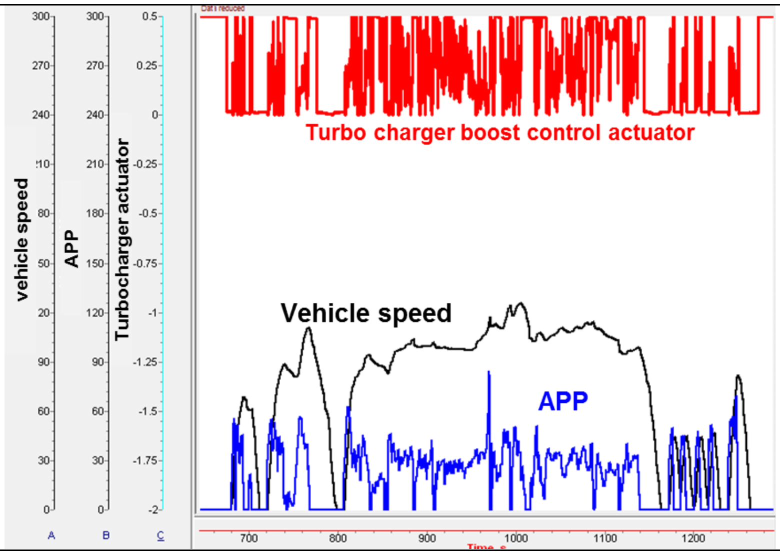
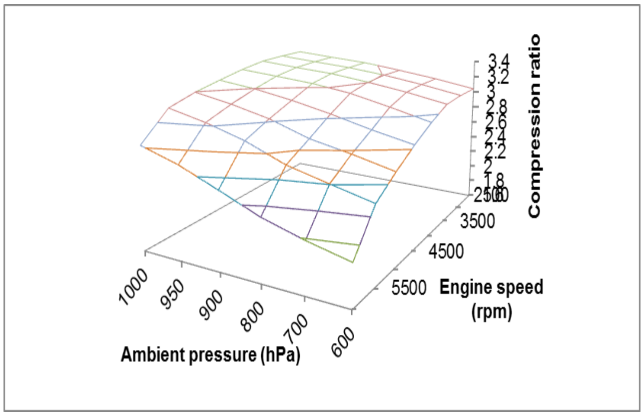
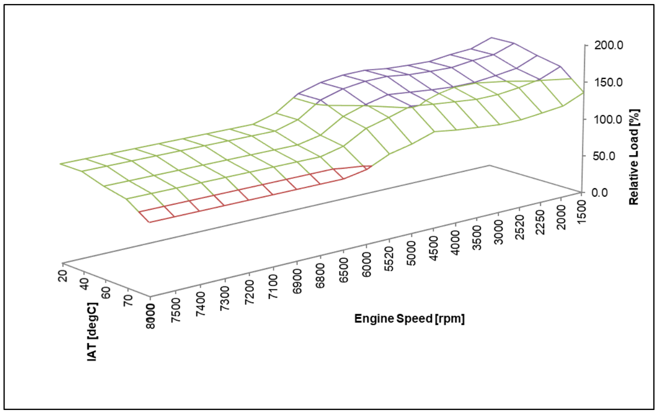
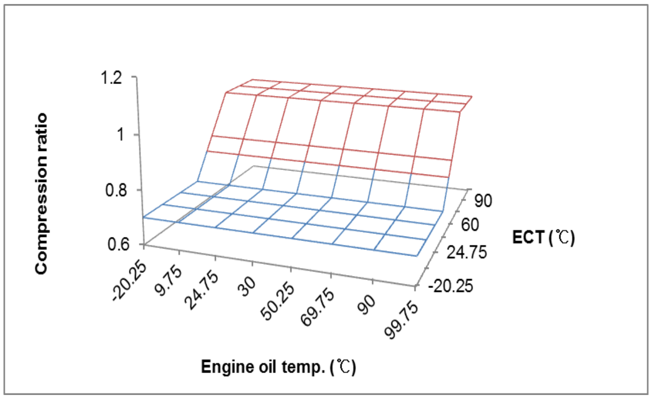
	
Emission impact	This is part of base emission control and included in all regulated test cycles and therefore accounted for by the test.
Justification	A. Substantially included during regulated test procedures: FTP75, US06, SC03, HwFET, FTP75@-7°C B. Engine System Protection F. Base Control
Reference	1. Torque set-point strategy

Figure 1. Boost pressure setpoint(Torque limitation)

High altitude protection	High intake air temperature protection
	
Low engine coolant and oil temperatures protection	
	

11.02.06 Port flap control - N/A

11.02.06.01 Variable charge motion - N/A

11.02.07 Variable intake manifold control - N/A

11.02.07.01 Variable intake manifold (VIM) - N/A

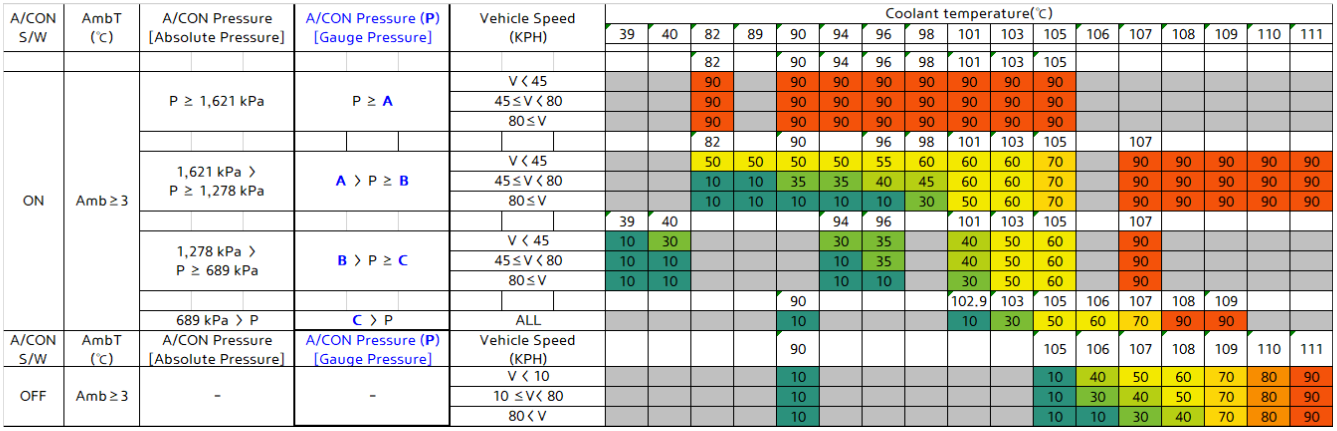
11.02.08 Engine cooling control

Internal combustion engines are cooled by circulating coolant through the engine block where it is heated, and then through a radiator where it loses heat to the atmosphere. The engine coolant is then returned to the engine. A typical automotive cooling system comprises:

- a series of channels cast into the engine block and cylinder head, surrounding the combustion chambers with circulating liquid to carry away heat;
- a radiator, consisting of many small tubes equipped with a honeycomb of fins to transfer heat rapidly, that receives and cools hot liquid from the engine;
- a water pump, usually of the centrifugal type, to circulate the liquid through the system;
- a thermostat to control temperature by varying the amount of liquid going to the radiator;
- a fan to draw fresh air through the radiator.

Cooling fan control: The operation of the cooling fan is determined by considering the following conditions.

- Engine coolant temperature
- Thermal system cooling demand (A/C)
- A/C fluid pressure
- Vehicle speed
- Request of Other controller (Motor Control Unit, Battery Management Unit, Hybrid Control Unit, ETC.)



A/CON S/W	AmbT (℃)	A/CON Pressure [Absolute Pressure]	A/CON Pressure (P) [Gauge Pressure]	Vehicle Speed (KPH)	Coolant temperature(℃)																
					39	40	82	89	90	94	96	98	101	103	105	106	107	108	109	110	111
							82		90	94	96	98	101	103	105						
ON	Amb≥3	P ≥ 1,621 kPa	P ≥ A	V < 45			90		90	90	90	90	90	90	90						
				45≤V<80			90		90	90	90	90	90	90	90						
				80≤V			90		90	90	90	90	90	90	90						
							82		90		96	98	101	103	105		107				
		1,621 kPa > P ≥ 1,278 kPa	A > P ≥ B	V < 45			50	50	50	50	55	60	60	60	70		90	90	90	90	90
				45≤V<80			10	10	35	35	40	45	60	60	70		90	90	90	90	90
				80≤V			10	10	10	10	10	30	50	60	70		90	90	90	90	90
					39	40				94	96		101	103	105		107				
		1,278 kPa > P ≥ 689 kPa	B > P ≥ C	V < 45	10	30				30	35		40	50	60		90				
				45≤V<80	10	10				10	35		40	50	60		90				
				80≤V	10	10				10	10		30	50	60		90				
									90				102.9	103	105	106	107	108	109		
		689 kPa > P	C > P	ALL					10				10	30	50	60	70	90	90		
A/CON S/W	AmbT (℃)	A/CON Pressure [Absolute Pressure]	A/CON Pressure (P) [Gauge Pressure]	Vehicle Speed (KPH)					90						105	106	107	108	109	110	111
OFF	Amb≥3	-	-	V < 10					10						10	40	50	60	70	80	90
				10 ≤V< 80					10						10	30	40	50	70	80	90
				80 < V					10						10	10	30	40	70	80	90

A/C: Air conditioner, AAT: Ambient air temperature, VS: Vehicle speed, ECT: Engine coolant temperature

Integrated thermal-management module (ITM): ITM is a system that determines the path of coolant. The coolant is typically used to control the engine temperature, but is also used to maintain the transmission fluid temperature and provide the heat source for the cabin heater. When the coolant temperature is low, the ITM cuts off all connected valves, such as the automatic transmission fluid, cabin heaters, and radiators, allowing the coolant to flow only through the engine to get a faster warm-up condition.

11.02.08.01 Electrical thermostat heating - N/A

11.02.08.02 Integrated Thermal Management (ITM) System Coolant Control

The ITM system controls engine coolant flow electromechanically rather than mechanically as with a traditional thermostat. This system controls and optimizes coolant flow to separate devices depending on various engine states. The ITM module and system architecture are shown in figures 1 & 2.

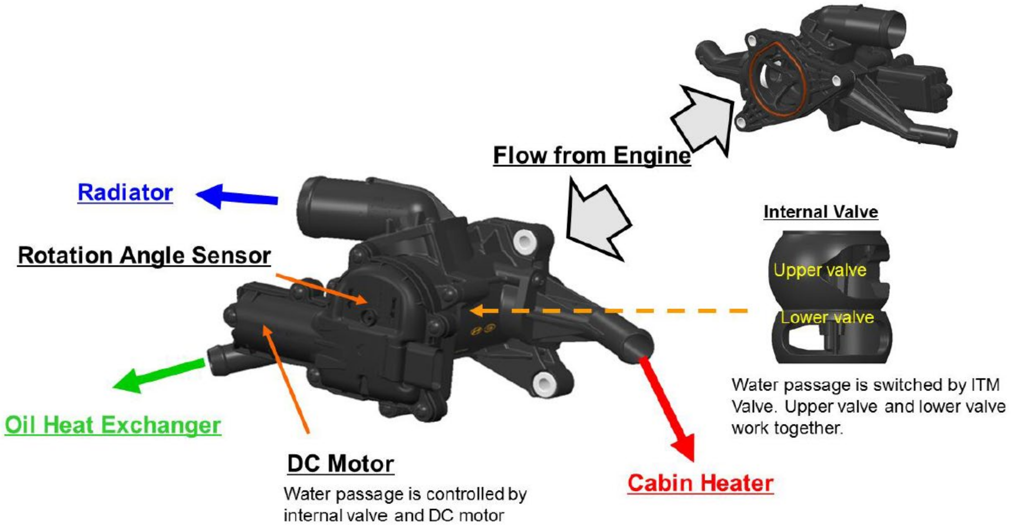


Figure 1. ITM Module Layout

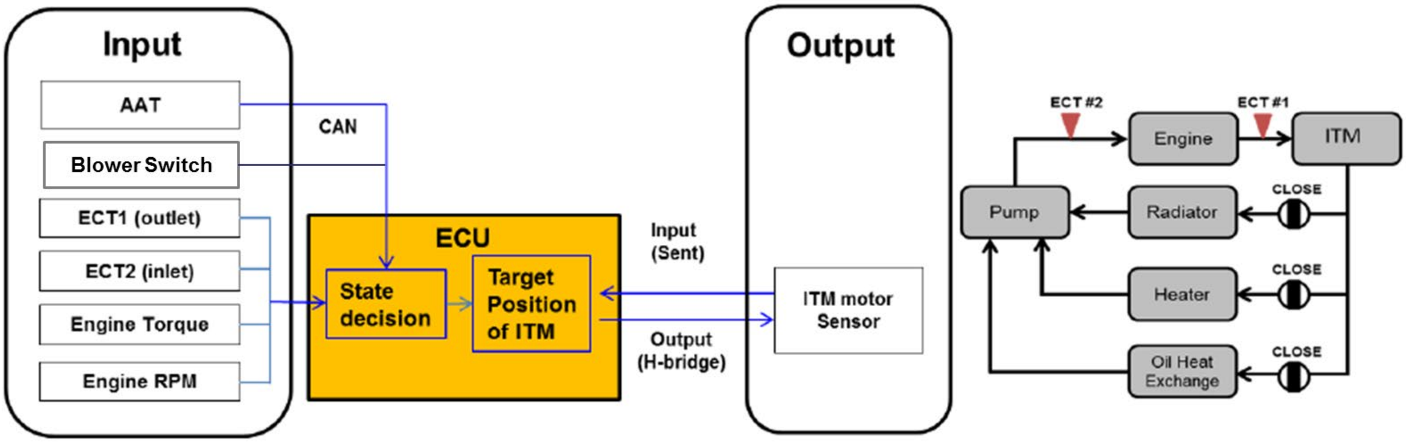


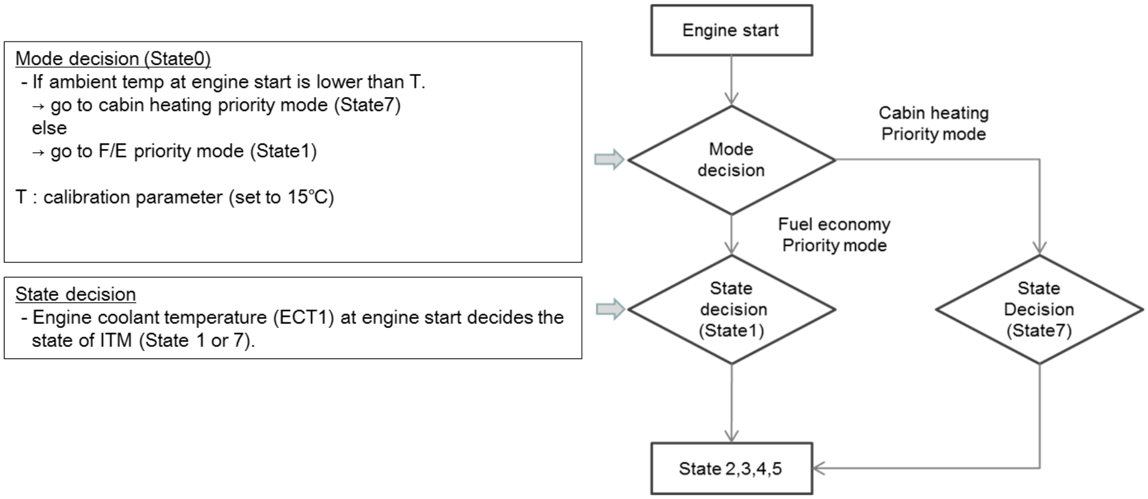
Figure 2. ITM System Architecture

■ITM System Architecture Description

- ITM’s electric valve position is controlled using an electric motor.
- ECT1 is engine outlet coolant temperature
- Used for engine control
- Emission control (fuel, ignition timing)
- Enable condition of other monitors
- Used for control of the ITM valve
- ECT2 is engine inlet coolant temperature
- Used to correct the ITM valve in control phase

■Control Strategy of the ITM system

Ambient air temperature at initial engine start determines the mode; Fuel Economy Priority vs. Cabin Heating Priority. Once the mode is decided, the engine coolant temperature (ECT1) and cabin blower switch signal determine the state. See figure 3.



Mode decision (State0)
- If ambient temp at engine start is lower than T.
  → go to cabin heating priority mode (State7)
  else
  → go to F/E priority mode (State1)

T : calibration parameter (set to 15℃)

State decision
- Engine coolant temperature (ECT1) at engine start decides the state of ITM (State 1 or 7).

Figure 3. ITM Control Strategy Mode/State Decision Flow Chart

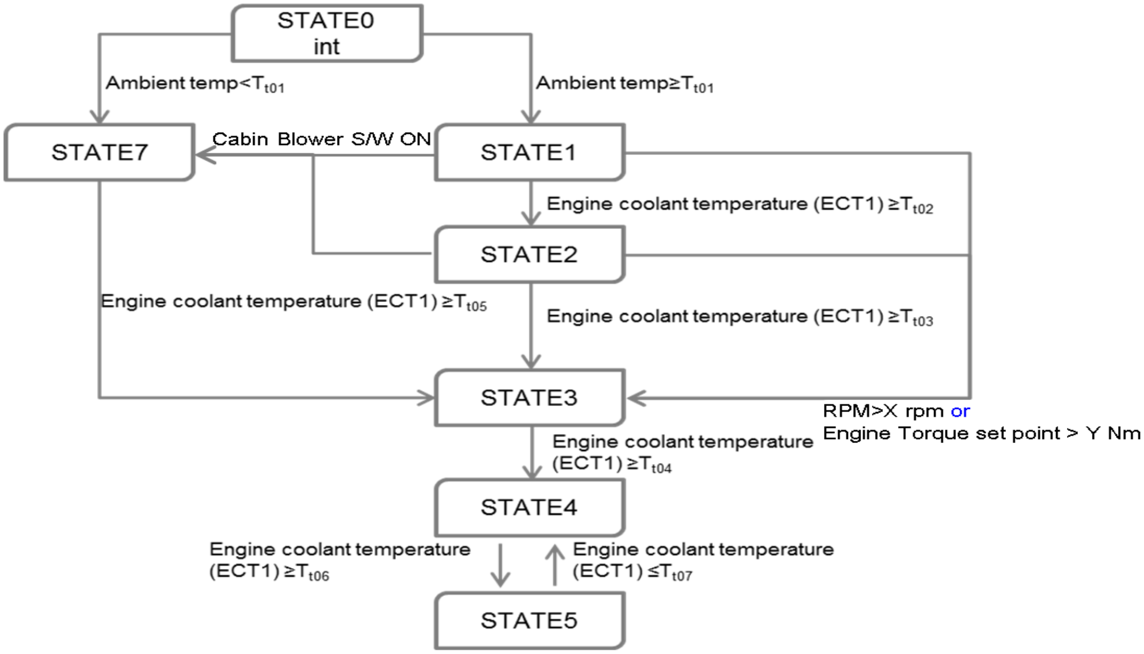
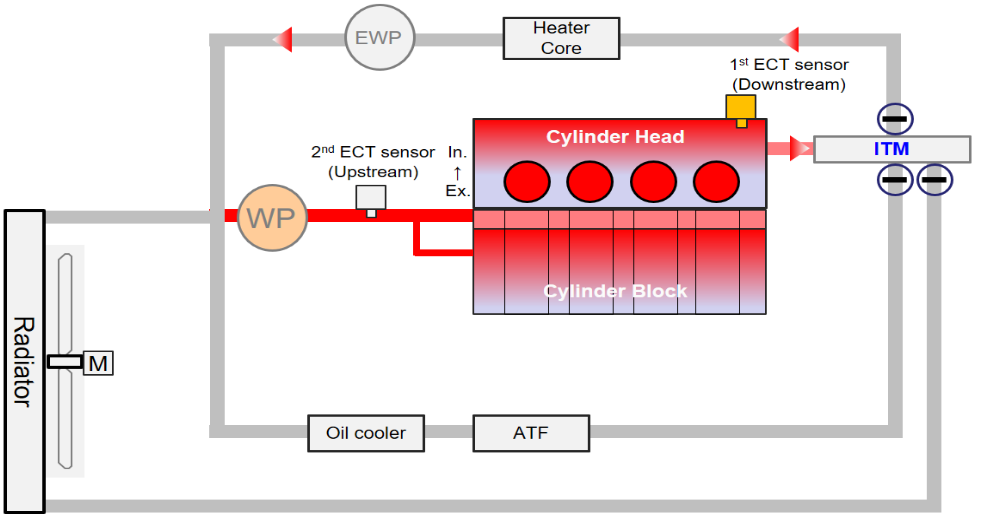


Figure 4. Control Flow Chart of the ITM System:

See table below for a description of each state.

State	Definition	Control Characteristics
STATE1	Flow Stop	Stop the coolant flow of all ports for rapid engine warm-up
STATE2	Heat Exchanger control	After coolant stop is deactivated (State1), the logic warms up coolant giving a partial flow to heat exchanger (Auto Transmission Fluid Warmer)
STATE3	Fuel economy priority	After State2, the logic warms up coolant giving a partial flow to heat exchanger (Auto Transmission Fluid Warmer) for Fuel economy
STATE4	Temperature control	Engine coolant temperature (ECT1 & ECT2) control to target temperature (calibration table) by adjusting radiator valve opening
STATE5	Forced cooling	If the engine coolant temperature (ECT1) deviates too much from target temperature, ITM controls the flow for maximizing the radiator coolant flow
STATE7	Cabin Heating	Maximize the heater-core coolant flow for rapid warmup of cabin

- Valve position of the ITM System
  - State 1: Flow Stop

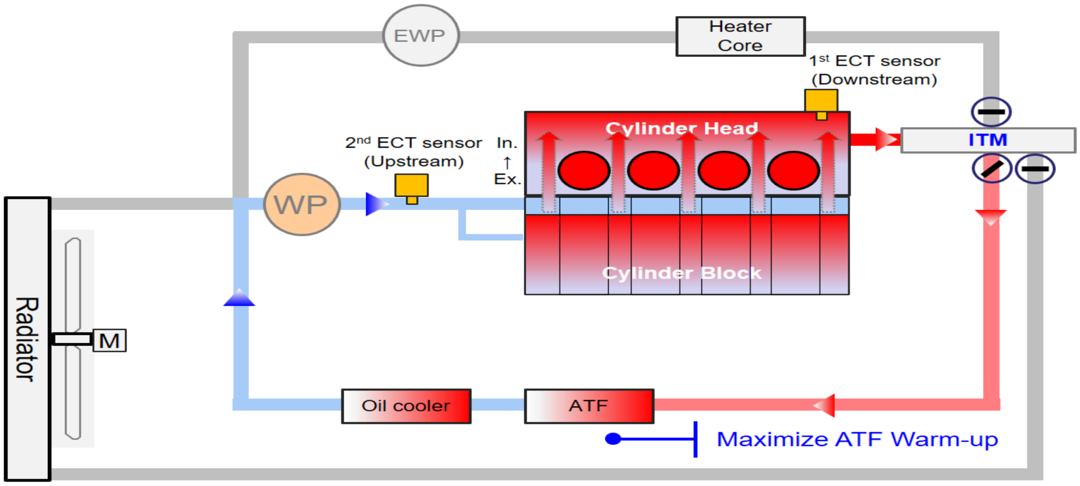


※ ATF : Auto Transmission Fluid Warmer, WP : Water Pump, EWP : Electronic Water Pump, M : Motor

※ Deactivation Condition

① Blower Switch ON **or**
② Engine Coolant Temperature Threshold **or**
③ Desired torque

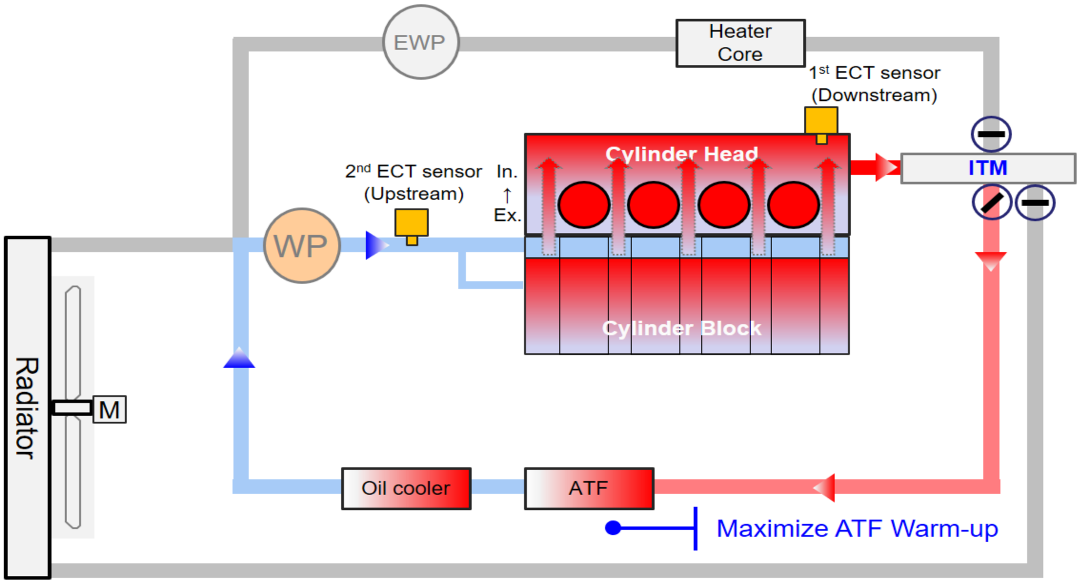
- State 2: Heat Exchanger Control



※ Deactivation Condition

① Blower Switch ON **or**
② Engine Coolant Temperature Threshold **or**
③ Desired torque

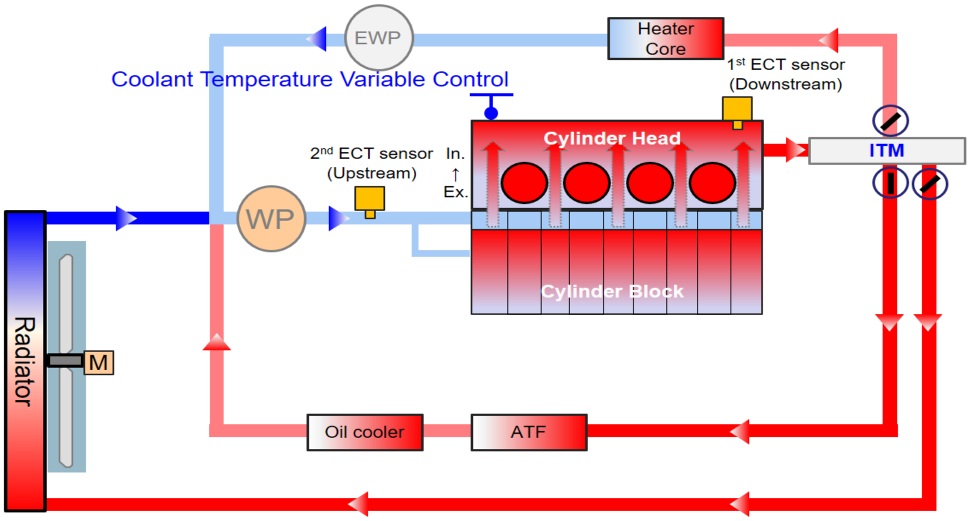
- State 3: Fuel economy priority mode



※ Deactivation Condition

① Engine Coolant Temperature Threshold

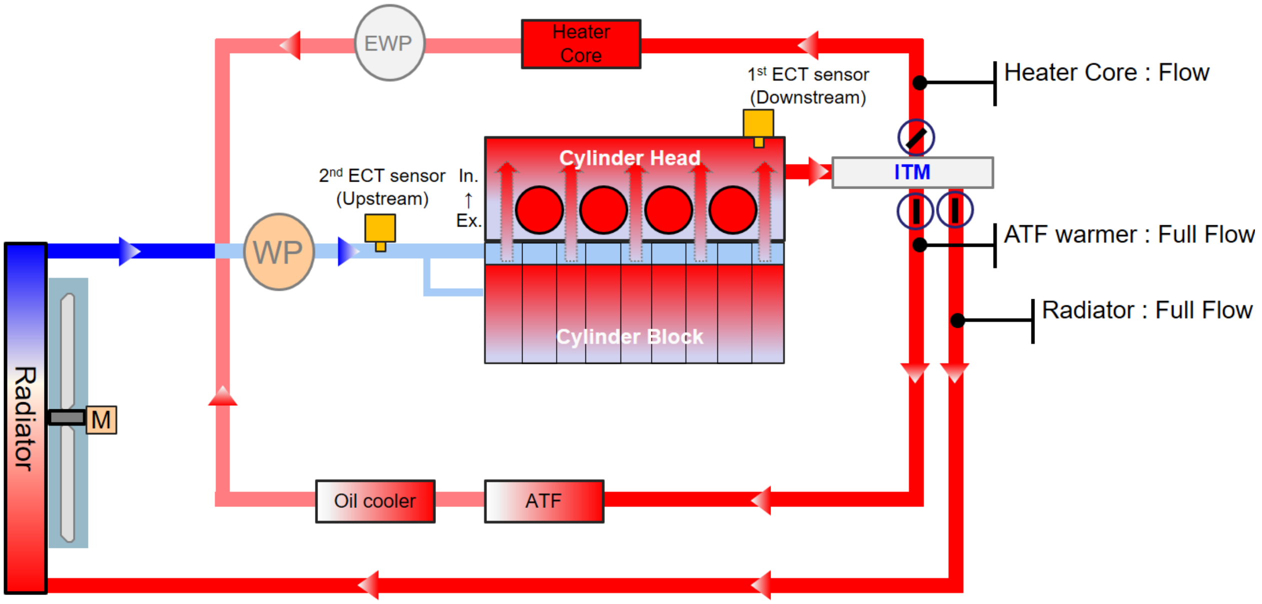
- State 4: Temperature control



※ Deactivation Condition

① Engine Coolant Temperature Threshold

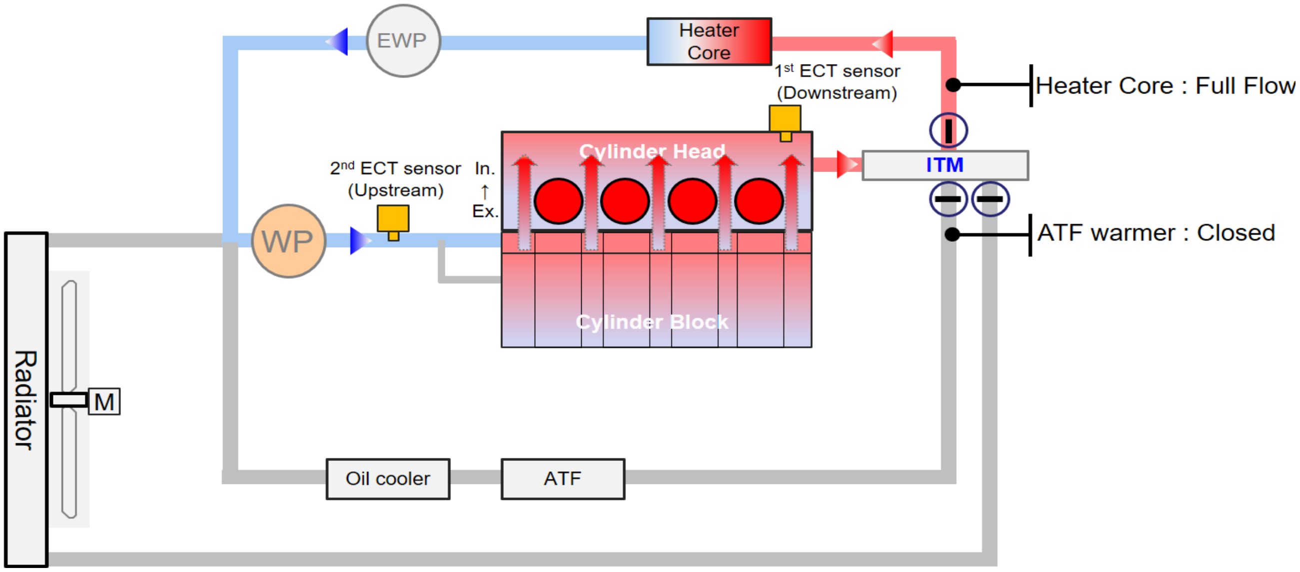
- State 5: Forced cooling



※ Deactivation Condition

① Engine Coolant Temperature Threshold

- State 7: Cabin Heating Priority Mode



※ Deactivation Condition

① Engine Coolant Temperature Threshold

11.02.08.02.01 ITM Fast Warm-up

Title : Fast warm-up

Purpose

GHG Emission reduction

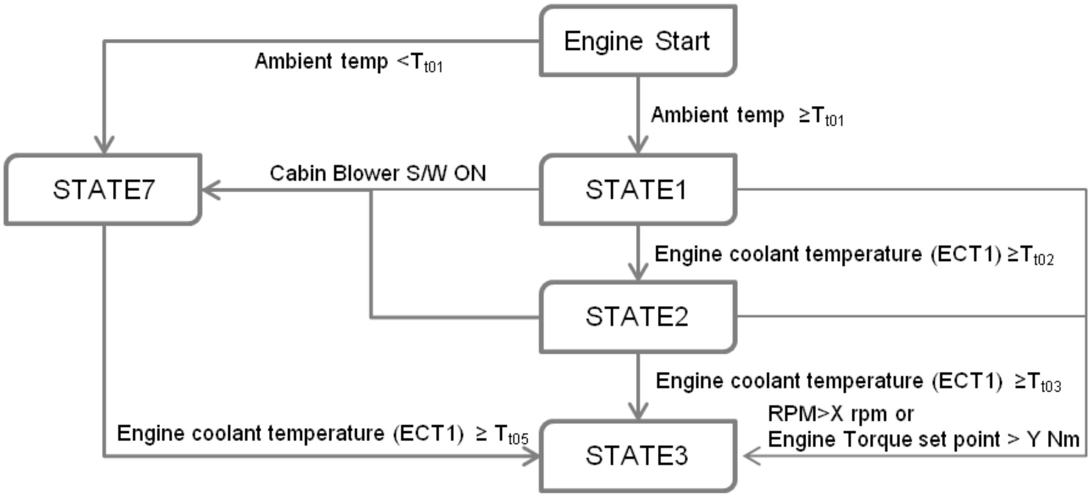
ITM increases engine coolant temperature as fast as possible by directing coolant flow only to required components (i.e. decreases heat loss to other components

Action: Functional Description

- Depending on Engine Speed, torque, vehicle speed, and ambient air temperature, target engine coolant temperature will be changed by the coolant port opening control.

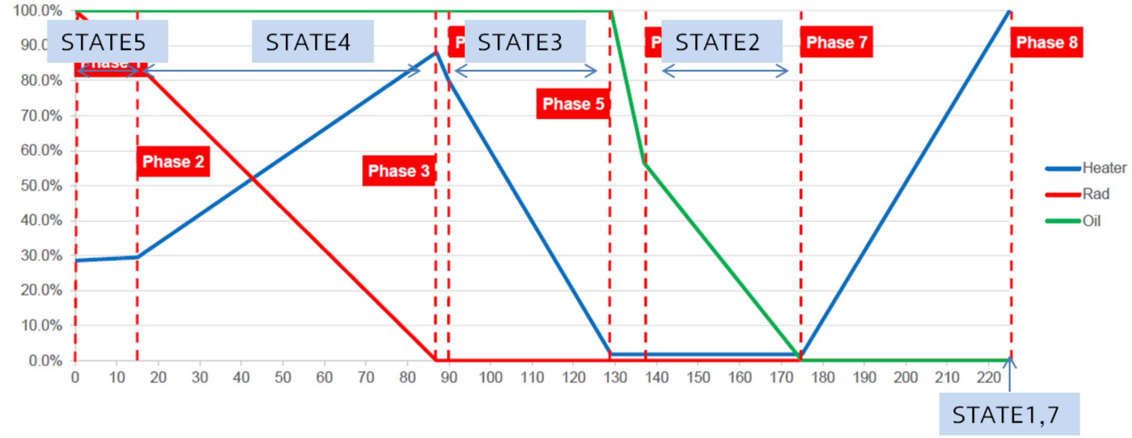
MODE	state	State definition	Description
Fast Warm-up	State1	EHRS control	All ITM ports are closed to realize fast engine warm-up.
	State2	Warm up Automatic Transmission Fluid (ATF)	Open ATF port to get heat exchange to ATF.
	State3	Warmup heater	Open ATF & heater port to get heat exchange to heater

Control Flow



T_{t01} = 15 ℃, T_{t02} = 65.25 ℃ T_{t03} = Ambient Temp<39.75℃ : 80.25 ℃, Ambient Temp>39.75℃ : 75 ℃ ,RPM> 3,700 RPM, TQ > 200 Nm

ITM valve angle (See State 1 ~ 3)

	 ITM coolant temperature increases fast with Exhaust Heat Recovery System.(State1).
Parameters (I/O)	**IN** - Engine speed = f(CKP) - Engine coolant temperature (ECT) - Ambient air temperature (AAT) - Blower S/W - Desired torque model **OUT** - ITM valve angle
Entry Conditions	**Activating Condition** - Ambient Air Temperature > 15 ℃ **Deactivating Condition** - Heater Blower S/W on **or** - Engine speed > 3,700 RPM **or** - Desired torque model [1] > 200 Nm
In-use Frequency	Whenever Ambient Air Temperature or Engine Coolant Temperature (ECT1) at initial engine start > 15 ℃.
Emission impact	This is a part of base emission control and included in FTP test cycles and therefore accounted for by the test
Justification	A. Substantially included during regulated test procedures : FTP75 F. Base operation
Reference	1. Torque Setpoint Strategy

11.02.08.02.02 ITM Coolant Temperature Control

Title : ITM Coolant Temperature control

Purpose

GHG Emission reduction

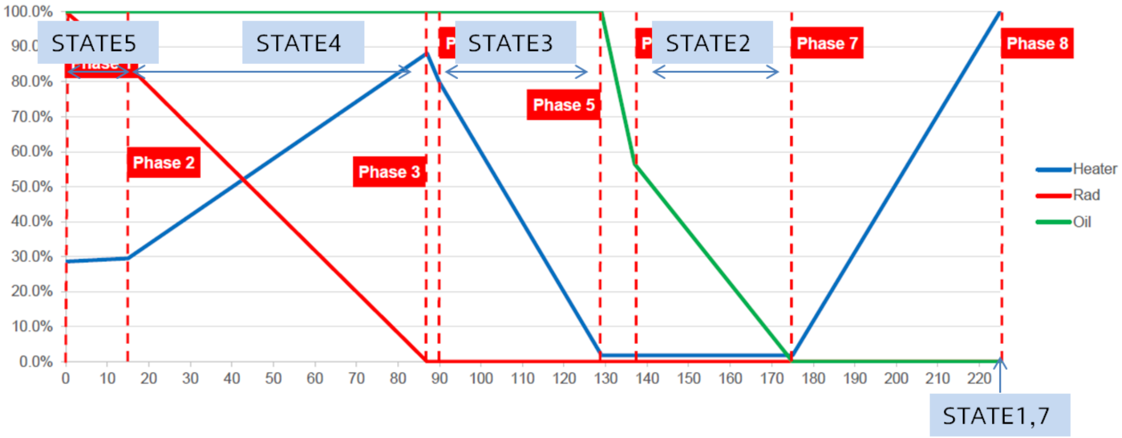
To increase fuel economy, engine coolant temperature is elevated during mild environmental conditions and operation. The ITM system will set a target engine coolant temperature based on both engine operation and environmental conditions.

Action: Functional Description

- Depending on engine speed, engine torque, vehicle speed, and ambient air temperature, target engine coolant temperature will be changed.

State	State definition	Description
State4	Engine coolant temp control	If engine coolant temp is close to target engine coolant temp, PID control of radiator port will be active.

- ITM valve angle (See State 4)



- Engine Coolant target temperature (Min value of figure 1 and figure 2)

Parameters (I/O)

IN
- Engine speed = f(CKP)
- Engine coolant temperature (ECT)
- Ambient air temperature (AAT)
- Vehicle speed = f(WSS)
- Desired torque model

OUT
- ITM Valve angle
- Engine coolant target temperature (select lower value of figure 1 and 2 below)

Entry Conditions

Activating Condition

- Engine Coolant temperature (ECT1) > 90℃(Ambient Temp<39.75℃), (ECT1) > 84.75℃(Ambient Temp>39.75℃)

Deactivating Condition

- Engine Coolant temperature (ECT1) > 108 ℃

In-use Frequency	This is part of base emission control and included in all regulated test cycles and therefore accounted for by the test.
Emission impact	May momentarily increase CO2 emission
Justification	A. Substantially included during regulated test procedures : FTP75, Cold FTP, US06, SC03, HWY F. Base operation
Reference	

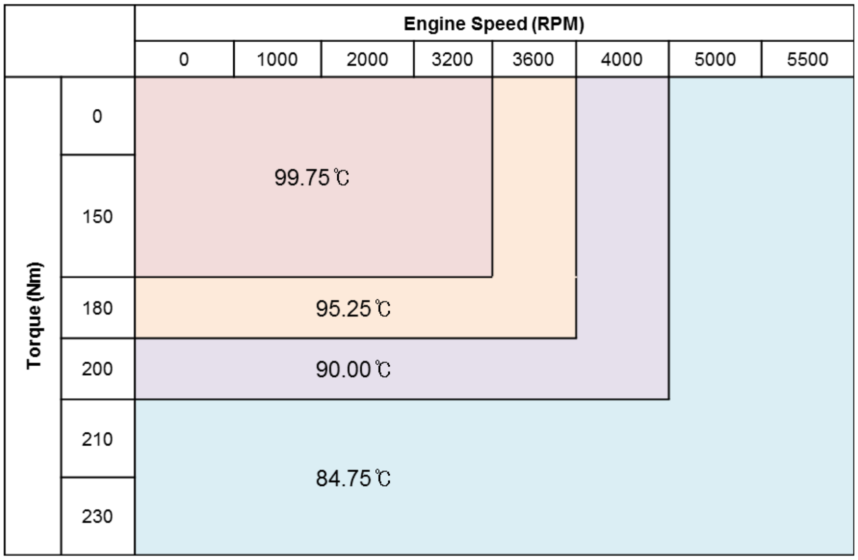


Figure 1 Engine speed vs. Torque Engine coolant map

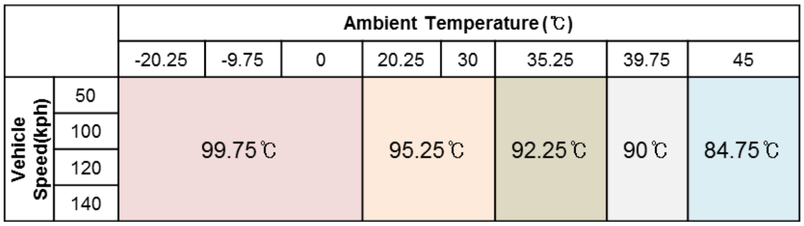


Figure 2 Vehicle speed vs. Ambient Air temperature Engine coolant map

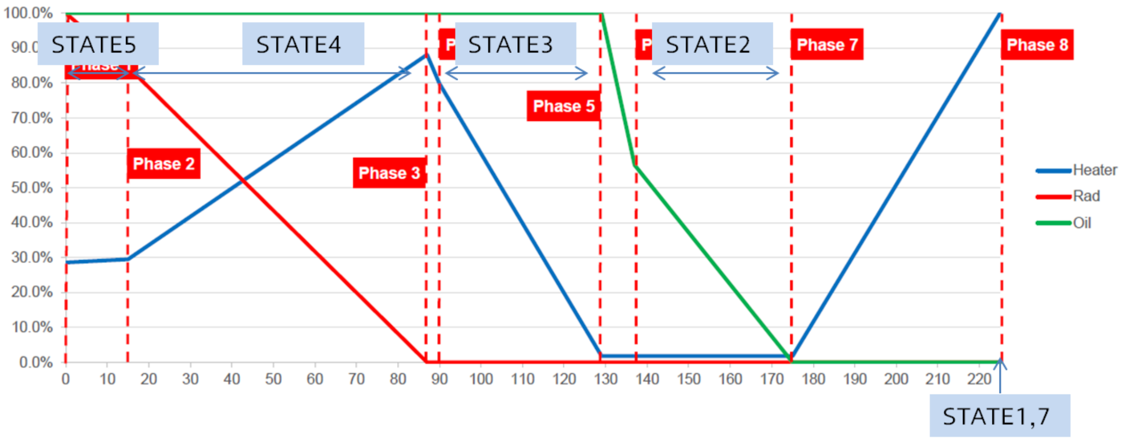
11.02.08.02.03 ITM Forced coolant cooling

<table>
<tr><td colspan="2">**Title : ITM Forced coolant cooling**</td></tr>
<tr><td>**Purpose**</td><td>**Engine/Emission system protection**
To avoid engine knocking and overheating, the ITM system will open all available ports for maximum cooling.</td></tr>
<tr><td>**Action: Functional Description**</td><td>

- Open every port for cooling

<table>
<tr><th>State</th><th>State definition</th><th>Description</th></tr>
<tr><td>State5</td><td>Forced coolant cooling</td><td>When engine coolant temperature cannot be controlled, the ITM moves to state5 to open every port including radiator, heater, and ATF.</td></tr>
</table>

- ITM valve angle (See State 5)

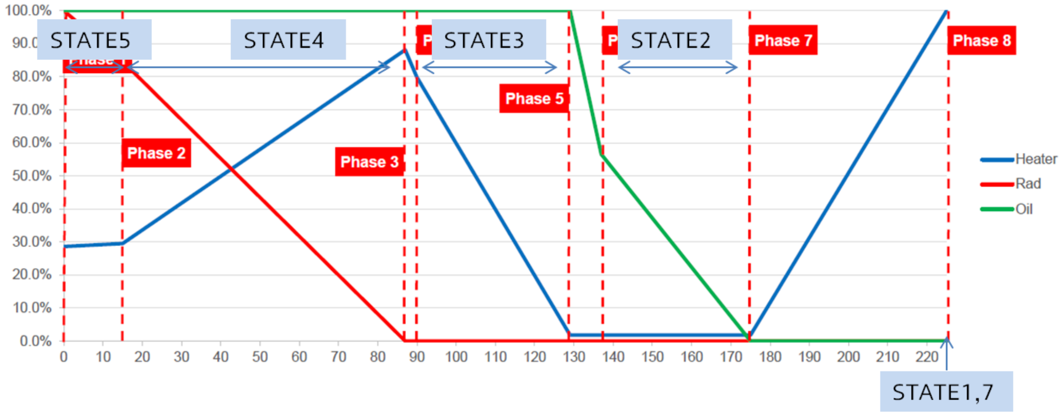


</td></tr>
<tr><td>**Parameters (I/O)**</td><td>**IN**
- Engine coolant temperature (ECT1)

OUT
- ITM valve angle</td></tr>
<tr><td>**Entry Conditions**</td><td>**Activating Condition**
- Engine Coolant temperature (ECT1) > 108 ℃

Deactivating Condition
- Engine Coolant temperature (ECT1) ≤ 104.25 ℃</td></tr>
<tr><td>**In-use Frequency**</td><td>Rare due to high speed, high load</td></tr>
<tr><td>**Emission impact**</td><td>It does not affect emission control system since it reduces temperature of overheated engine.</td></tr>
<tr><td>**Justification**</td><td>B. Engine/Emission system protection</td></tr>
<tr><td>**Reference**</td><td></td></tr>
</table>

11.02.08.02.04 Cabin Heating Priority mode

Title : Cabin Heating Priority mode	
Purpose	**Comfort/occupant feature** To enhance cabin heating and defrosting capability, the ITM system will open a valve to the heater core for transferring maximum engine heat to the heater core.
Action: Functional Description	If ambient air temperature falls below a predetermined value, the ITM system goes to the maximum heater state and opens the heater port fully.
Parameters (I/O)	**IN** - Ambient air temperature (AAT) - Engine coolant temperature(ECT) **OUT** - ITM valve angle (See State 7) 
Entry Conditions	**Activating Condition** - Ambient Air Temperature or Engine Coolant Temperature (ECT1) at initial engine start ≤15℃ **Deactivating Condition** - Engine coolant Temperature (ECT1) ≥99.75℃
In-use Frequency	Whenever Ambient Air Temperature or Engine Coolant Temperature (ECT1) at initial engine start ≤15℃
Emission impact	May momentarily increase CO2 emission
Justification	A. Substantially included during regulated test procedures : FTP @ -7℃
Reference	

11.02.09 Canister purge control

Canister purge is needed to purge the fuel vapors generated from the fuel storage tank that have been stored in the evaporative canister. If the fuel tank would be a closed system, this would cause strong over pressure and under pressure in the tank which then could lead to damage of the fuel tank or fuel system components. Therefore, it is necessary to vent the fuel tank by creating a connection to its surroundings. In order to avoid fuel vapor to escape into the environment, the activated carbon canister is used to filter these vapors. As the loading capacity of the filter is limited, the filter must be periodically purged to allow for continuous storage capability. Therefore the canister purge solenoid valve that is positioned between the canister and the air duct in front of the compressor is opened and the canister purge pump that is positioned between the canister and the PCV is operated by the engine management system to allow for purging of stored vapors. The canister purging functionality represents the regeneration process of the canister. In order to avoid a breakthrough which would result in fuel vapor escaping into the environment, this functionality ensures that the activated carbon canister is purged with air and the fuel carried along is purposefully entered in the combustion process.

Mass flow through the canister purge control valve (PCV)

To prevent drivability and emission problems, the opening of the canister purge solenoid valve and the operating of canister purge pump and so the purge flow for canister purge must be controlled. With the evaporative emission control function the opening of the canister purge solenoid valve is controlled depending upon the fuel mass stored in the canister.

Canister load is calculated using the differential pressure across the pump when the purge pump is operating.

The more hydrocarbons in the purge gas, the higher the density of the purge flow rate, and thus the differential pressure across the canister pump increases. The opening period of canister purge solenoid valve is controlled in dependence on the canister load.

PCV PWM duty

Canister purging is physically based on a desired value for the air mass flow which flows through the EVAP canister purge valve. This desired mass flow is converted into component dependent variables. The actual duty cycle is determined by the following steps;

Calculation of the demanded duty cycle using the desired mass flow rate through the EVAP canister purge valve

Correction of the duty cycle to compensate delay time caused by battery voltage and coil temperature of the valve. These dependencies are corrected by a battery voltage and intake air temperature.

Canister Purge Pump Speed

In order to perform the canister purge, a difference pressure between the PCV must be formed. The canister purge pump builds upstream pressure of the canister purge valve, the purge flow is through the PCV when the PCV is opened. The speed of the purge pump is calculated by the target purge flow rate.

Enable condition

Following input values are used for the EVAP canister purge valve activation.

The canister purge control is disabled at trailing fuel cut off and enabled again with a delay.

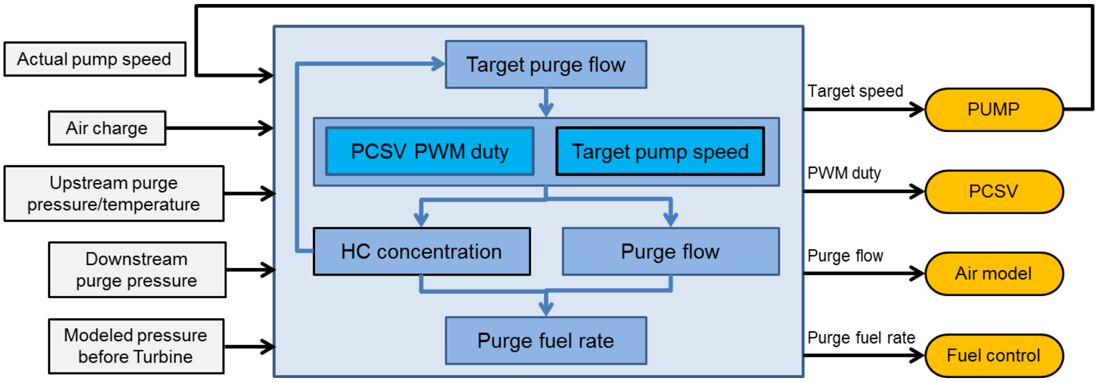
The engine temperature must be above the threshold value.

The intake air temperature must be above the threshold value during idling.

Battery voltage within threshold to protect the EVAP canister purge valve output variable.

For high fuel tank under pressure, the EVAP canister purge valve can be closed to prevent damage to the fuel tank.

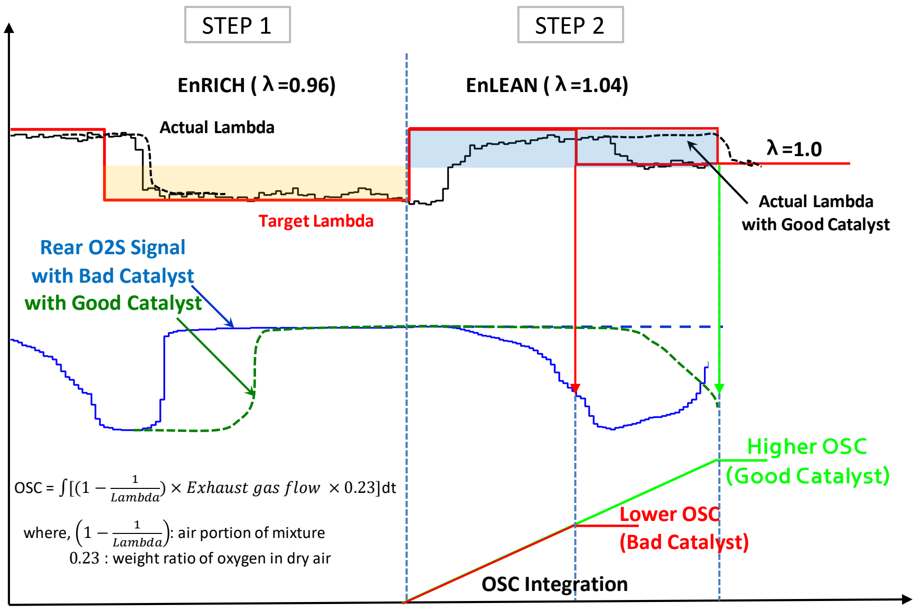
11.02.09.01 Canister purge

Title : Canister purge	
Purpose	**Emission reduction:** Purge of evaporative HC gas from canister and fuel tank
Action: Functional Description	Purge valve control considering combustion stability and drivability. Purged evaporative HC gas is sent to engine intake system for combustion. 
Parameters (I/O)	**IN** - Engine Speed =f(CKP) - Relative load model - Barometric pressure (BARO) - Engine Coolant Temperature (ECT) - Air-fuel ratio controller value[1] - Intake air temperature (IAT) - Battery voltage (B+) - Fuel cut off[2] - Active Purge Pump actual speed **OUT** - EVAP canister purge valve PWM duty - Active Purge Pump target speed
Entry Conditions	**Activating Condition** Engine Coolant Temperature (ECT) > 30℃ **and** Air-fuel ratio (A/F) feedback control active[3] **and** Intake air temperature (IAT) > 0℃ **and** 9V < battery voltage (B+) < 16V **Deactivating Condition** Fuel cut off[4] **or** Air-fuel ratio adaptation active

In-use Frequency	This is a base control and generally always active unless overwritten by other AECDs.
Emission impact	EVAP Emission reduction.
Justification	A. Substantially included during regulated test procedures: FTP75, US06, SC03, HwFET, FTP75@-7°C
Reference	1. Air-fuel ratio (A/F) feedback (HO2S1) 2. Fuel cut off for component protection

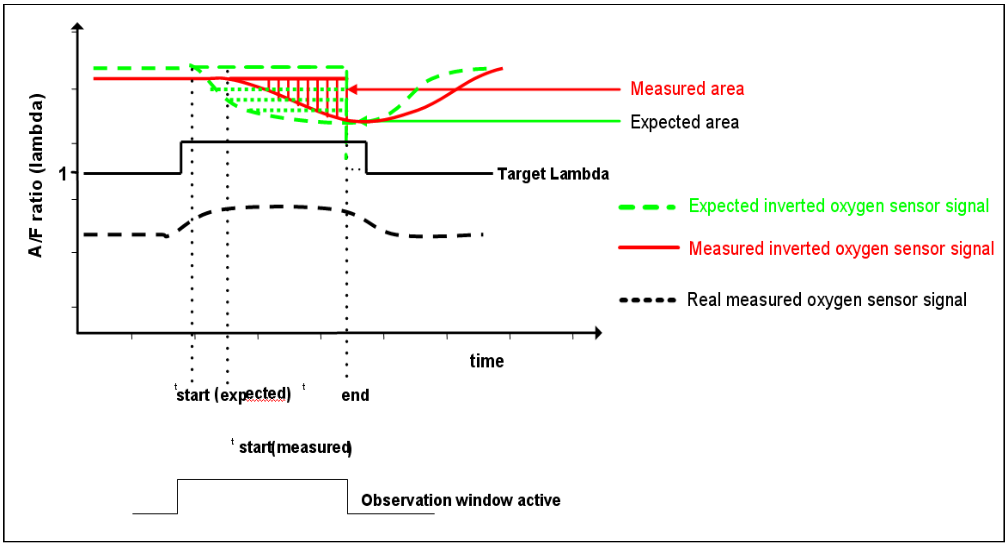
11.03. OBD intrusive

11.03.01. Catalyst monitoring

Title : Catalyst monitoring	
Purpose	**OBD intrusive monitor** The OBD II system shall monitor the catalyst system for proper conversion capability.
Action: Functional Description	Catalyst monitoring process has the following 2 steps; 1) Rich mixture is filled-in until the downstream O2S signal transit to rich phase. 2) Lean mixture is introduced and the oxygen mass is calculated up to the downstream O2S signal transit to lean phase. The OSC (Oxygen Storage Capacity) can be defined as following $\mathrm{OSC} = \int \left[\left(1 - \frac{1}{Lambda}\right) \times Exhaust\ gas\ flow\ \times 0.23 \right] dt$ where, (1-1/lambda) : air portion of mixture, 0.23 : weight ratio of oxygen in dry air 

Parameters (I/O)	**IN** - Engine speed = f(CKP) - Relative load model - Catalyst temperature model[1] - Heated O2 sensor (Linear) (HO2S1) - Heated O2 sensor (Binary) (HO2S2) - Air-fuel ratio (A/F) control active[2] **OUT** - Lambda setpoint[3] - Catalyst Monitor Index = $\frac{\text{Actual OSC(mg)}}{\text{OSC from Threshold Catalyst(mg)}}$ - OBD Fault detection[4]
Entry Conditions	**Activating Condition** 1320rpm < Engine speed < 2600rpm **and** 30% < Relative load model < 80% **and** 530℃ < Catalyst temperature model < 850℃ **and** ΔCatalyst temperature model < 40℃ **and** Air-fuel ratio (A/F) control active **Deactivating Condition** If any of activating conditions are not met.
In-use Frequency	Maximum one time per driving.
Emission impact	This is a part of OBD monitoring and included in all regulated test cycles, therefore accounted for by the test.
Justification	A. Substantially included during regulated test procedures: FTP75, US06, SC03, HwFET, FTP75@-7°C E. OBD intrusive monitor
Reference	1. Oxygen sensor heating strategy 2. OBD Document 3. Enrichment for torque demand, Enrichment for component protection, Catalyst purge 4. Exhaust system temperature determination 5. Fuel cut off 6. Canister purge 7. Air-fuel ratio (A/F) feedback (HO2S2)

11.03.02. Heated O2 sensor (Linear) (HO2S1) monitoring

Title : Heated O2 sensor (Linear) (HO2S1) monitoring	
Purpose	**OBD intrusive monitor** The OBD II system shall monitor the response rate, and any other parameter which can affect emissions of all oxygen sensors for malfunction.
Action: Functional Description	The oxygen sensor signal dynamic monitoring detects greater deviations of the dynamic behavior of the sensor signal compared to the nominal behavior, controlled by the lambda controller. The change of the dynamic behavior is caused by extreme aging of the sensor or a low sensor temperature which slows down the sensor compared to the nominal behavior. The monitoring is based on an amplitude criterion, i.e. the relation between the amplification of the oxygen sensor and the model is monitored and detects the malfunction. The monitor uses step-changes (Rich-Lean & Lean-Rich) of the injected fuel quantity. When such an event occurs, the measured oxygen sensor signal is compared to the expected one. Starting with the reaction to the fuel step, the area between the inverted signal and a horizontal line through the start value is determined for both the expected and the measured signal, and the quotient between measured and expected area is computed. The slower the oxygen sensor is, the smaller the quotient of the areas. Quotient of the areas = Actual Area (measured Area) / Expected Area  (Compute quotient of measured and expected area)
Parameters (I/O)	**IN** - Engine speed = f(CKP) - Relative load model - Catalyst temperature model[1] - Air-fuel ratio (A/F) control active[2] - Heated O2 sensor (Linear) (HO2S1)

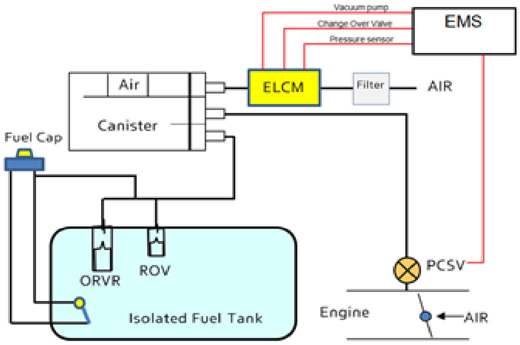
	- Heated O2 sensor (Binary) (HO2S2) - Fuel cut off[3] - Engine coolant temperature (ECT) - EVAP canister purge active[4] - HO2S1 ceramic temperature - ECU time **OUT** - Lambda setpoint[5] - Quotient of the areas = Actual Area (measured Area) / Expected Area - OBD Fault detection[6]
Entry Conditions	**Activating Condition** 1200rpm < Engine speed < 3520rpm **and** 25% < Relative load model < 65% **and** 400℃ < Catalyst temperature model **and** Air-fuel ratio (A/F) control active **and** Fuel cut off inactive **and** HO2S1 ceramic temperature > 685℃ **and** Engine coolant temperature (ECT) > 50℃ **Deactivating Condition** If any of activating conditions are not met.
In-use Frequency	Rare due to only activation with OBD fault detected (P2097 or P2096)
Emission impact	During the rich shift to lean monitoring, causing HC and CO increase. During the lean shift to rich monitoring, causing NOx increase.
Justification	A. Substantially included during regulated test procedures: FTP75, US06, SC03, HwFET, FTP75@-7°C E. OBD intrusive monitor
Reference	1. Oxygen sensor heating strategy 2. OBD Document 3. Air-fuel ratio (A/F) feedback (HO2S1) 4. Exhaust system temperature determination 5. Fuel cut off 6. Canister purge 7. Enrichment for torque demand, Enrichment for component protection, Catalyst purge 8. OBD Document

11.03.03. Heated O2 sensor (Binary) (HO2S2) monitoring

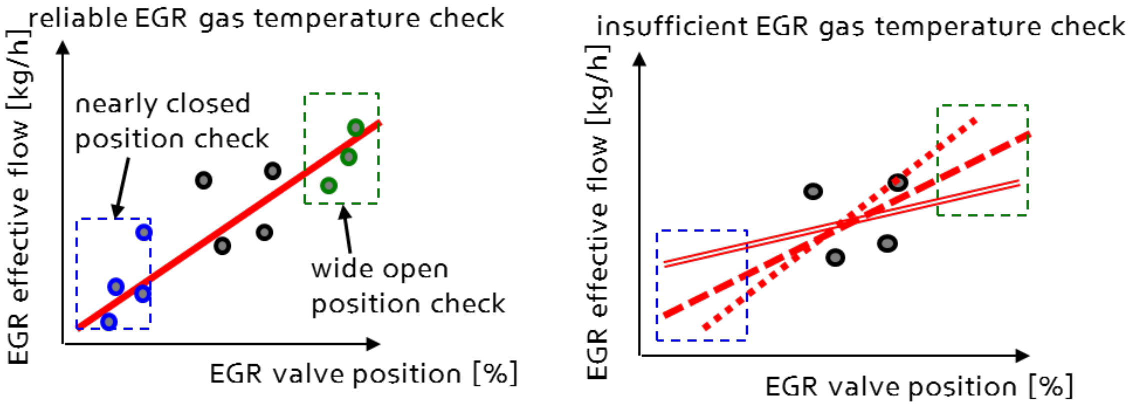
Title : Heated O2 sensor (Binary) (HO2S2) monitoring	
Purpose	**OBD intrusive monitor** The OBD II system shall monitor the response rate, and any other parameter which can affect emissions of all oxygen sensors for malfunction.
Action: Functional Description	Rationality check, stuck lean/rich (Oscillation check) During normal engine operation the normalized A/F ratio and therefore the downstream oxygen sensor signal voltage is oscillating about the set point value. If the measured downstream oxygen sensor signal voltage remains permanently below or above the set point value for a calibrated period of time, an oscillation check is triggered. This test function applies a rich A/F ratio if the voltage was below the set point value or a lean A/F ratio if the voltage was above the set point value. If the downstream oxygen sensor signal voltage, after the lean or rich A/F ratio application, does not cross the set point value in the expected direction, a malfunction is detected and a stuck rich or a stuck lean fault is set.
Parameters (I/O)	**IN** - Engine speed = f(CKP) - Relative load model - Exhaust gas temperature[1] - Air-fuel ratio (A/F) control active[2] - Heated O2 sensor (Linear) (HO2S1) - Heated O2 sensor (Binary) (HO2S2) - Heated O2 sensor (Binary) (HO2S2) operation readiness[3] - Air mass flow model - HO2S2 heating voltage[3] - ECU time **OUT** - Lambda setpoint[4] (Lambda setpoint = 1.1 for 8 sec, Lambda setpoint = 0.8 for 8 sec) - OBD Fault detection[5]
Entry Conditions	**Activating Condition** Heated O2 sensor (Binary) (HO2S2) > 0.76~0.82V for 95 sec **and** Air-fuel ratio (A/F) control active **and** 1200rpm < Engine speed < 3520rpm **and** 18% < Relative load model < 65% **and** Air mass flow model > 6kg/h **and** Exhaust gas temperature (around HO2S2) > 150℃ **and** HO2S2 heating voltage > 9.2V **and** Heated O2 sensor (Binary) (HO2S2) operation readiness

	Deactivating Condition If any of activating conditions are not met.
In-use Frequency	Rare due to only activate when heated O2 sensor (Binary) (HO2S2) > 0.76~0.82V .3for 95sec.
Emission impact	During the rich shift to lean monitoring, causing HC and CO increase. During the lean shift to rich monitoring, causing NOx increase.
Justification	E. OBD intrusive monitor
Reference	1. Air-fuel ratio (A/F) feedback (HO2S1) 2. Air-fuel ratio (A/F) feedback (HO2S2) 3. Oxygen sensor heating strategy 4. OBD document 5. Exhaust system temperature determination 6. Fuel cut off 7. Canister purge 8. Enrichment for component protection , Air-fuel ratio (A/F) feedback (HO2S1) 9. OBD document

11.03.04. Evaporative system leak monitoring

Title : Evaporative system monitoring	
Purpose	**OBD intrusive monitor** The OBD II system shall monitor the complete evaporative system for vapor leaks to the atmosphere. This monitoring is activated during the vehicle 5hour later soak (key off) and the pump in ELCM makes fuel system to vacuum through canister. So this monitoring does not affect the emission increase.
Action: Functional Description	The ELCM leak detection function permits the detection of leaks in the evaporative emission control system with a diameter of 0.5 mm and more. ECU wakes up after the defined soaking time and activates ELCM. If there is a sufficient pressure or vacuum buildup in the fuel tank, the tank is sealed and there is no leak. In such a case, isolation valve lefts normal closed position and leakage of canister system is monitored with absolute pressure sensor of ELCM, located at canister. If the tank pressure is near atmosphere, then the isolation valve is commanded open and leakage of overall system including fuel tank system and canister system is monitored.  Figure 9: System overview
Parameters (I/O)	
Entry Conditions	
In-use Frequency	For more details, refer to OBD document
Emission impact	This monitoring does not affect the emission increase. This monitoring is activated after key off and the pump in ELCM makes fuel system to vacuum through canister.
Justification	E. OBD intrusive monitor Regulatory Required.
Reference	1. OBD document

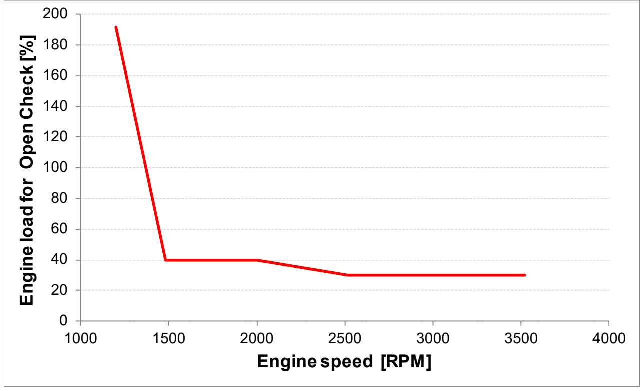
11.03.05 EGR flow monitoring

Title : EGR flow monitoring	
Purpose	**OBD intrusive monitor:** The OBD II system shall monitor the EGR system on vehicles so-equipped for low and high flow rate malfunctions.
Action: Functional Description	EGR flow is detectable by measuring EGR gas temperature increasing rate when exhaust pressure is high. When vehicle is accelerating, increased engine load causes high exhaust gas pressure and temperature and if EGR valve is open, EGR gas temperature increases a lot. Otherwise, if EGR valve is closed when vehicle is accelerating, EGR gas temperature increases a little. By evaluate this EGR gas temperature increasing rate, EGR flow can be detected. From several EGR gas temperature checks, correlation between EGR effective flow and EGR valve position is estimated. This relationship can be modeled as follows; EGR effective flow = **A** x EGR valve position + **B** Where, **A** : Flow gradient per unit valve position [kg/h/%] **B** : Effective flow offset [kg/h] To estimate reliable relationship, EGR gas temperature check should be performed in various EGR valve positions NCLOSED times at nearly closed position and NOPEN times at wide open position. This temperature measurement is attempted in normal EGR control conditions and/or in propulsion driving condition intrusively. 
Parameters (I/O)	**In** - Engine speed - Engine load (LOAD_ABS) - EGR gas temperature - EGR valve position for target EGR ratio **Out** - Effective EGR flow per average EGR valve position - OBD Fault detection[1]

<table>
<tr>
<td>Entry Conditions</td>
<td>
Activating Condition

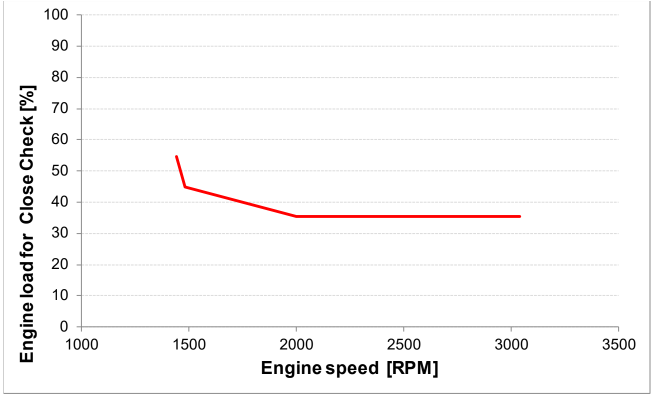
(1) Valve Close Diagnosis
- 1240 rpm ≤ Engine speed ≤ 10200 rpm
and

- f(Engine speed) ≤ Engine load (LOAD_ABS) ≤ 129.75 %

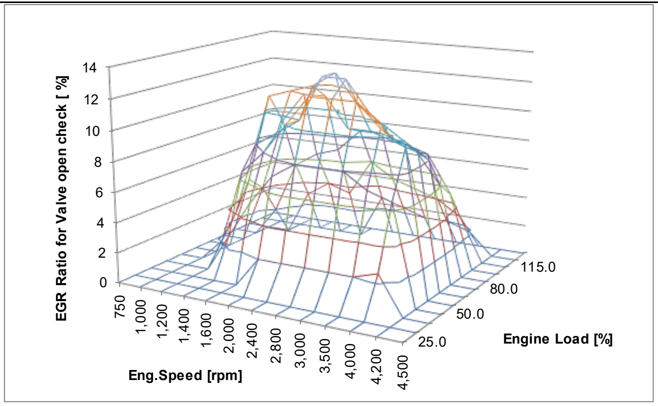


and
- EGR gas temperature > 120 ℃
and
- Target EGR ratio = 0 %
and
EGR valve closed time during measurement > 10 sec

(2) Valve Open Diagnosis
- 1240 rpm ≤ Engine speed ≤ 4000 rpm
and
- f(Engine speed) ≤ Engine load (LOAD_ABS) ≤ 191.25 %



and
- EGR gas temperature > 160 ℃
and
- Target EGR ratio = f (Engine speed, Engine load) %
</td>
</tr>
</table>

	 and [EGR valve closed time during measurement > 20 sec or ΔEGR gas temp.(Max-Min) > 10 ℃] **Deactivating Condition** - If any of activating conditions are not met. or - Each number of temperature measurement is reached to maximum number
In-use Frequency	Maximum one time per driving cycle
Emission impact	This is part of the OBD monitoring and included in a regulated test cycle, therefore accounted for by the test.
Justification	A. Substantially included during regulated test procedures: US06, SC03, HwFET E. OBD intrusive monitor
Reference	1. OBD document

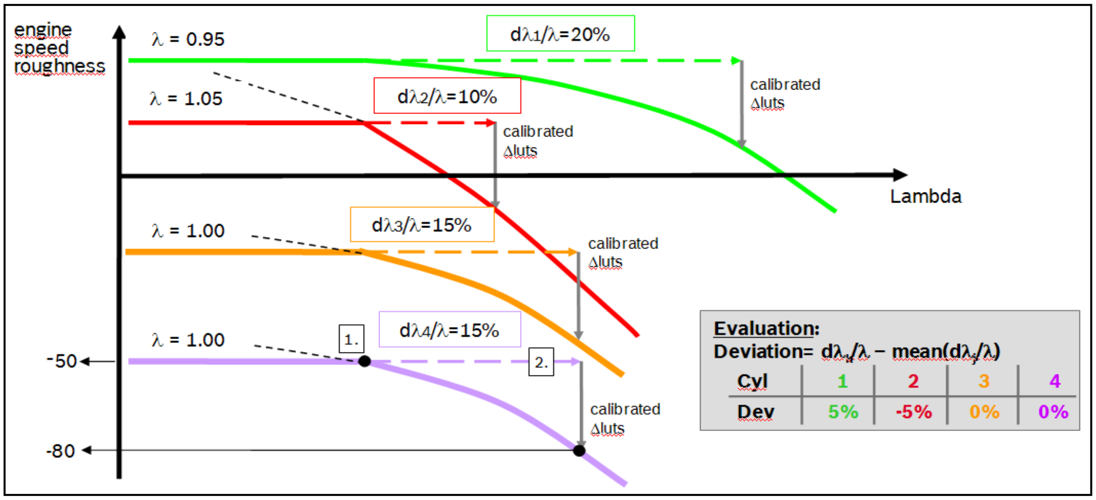
11.03.06 Air-Fuel Ratio Cylinder imbalance monitoring

<table>
<tr><td colspan="2">Title : Air-Fuel Ratio Cylinder imbalance monitoring</td></tr>
<tr><td>Purpose</td><td>OBD intrusive monitor
The OBD II system shall monitor the cylinder to cylinder air-fuel ratio imbalance</td></tr>
<tr><td>Action: Functional Description</td><td>

A/F-cylinder Imbalance is corrected by cylinder specific injection correction calculated and learned via the amount of engine roughness deviation with cylinder-specific lambda modulation.

The test cylinders are enleaned successively by the components till the unsteady run signal has changed by a certain calibrated value. At the same time of enleaning individual test cylinders, the remaining cylinders are enriched so that the global lambda of 1.0 within an exhaust-gas bank is not changed. After testing all the cylinders, the quantity change of all cylinders required for changing the unsteady run signal is compared with one another and calculated based on the deviation from the mean value of a cylinder individual correction value.

If the amount of the injection correction factor is greater than a threshold the system stores a DTC for the specific cylinder.



※ Physical Background – nonlinear change of engine roughness versus lambda:

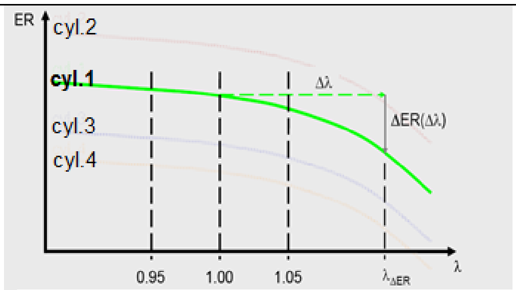
Generally Engine Roughness (ER) correlates with A/F-ratio. Absolute ER-values show a cylinder-to-cylinder variance. Relative ER-values (ΔER) show same behaviour for all cylinders.

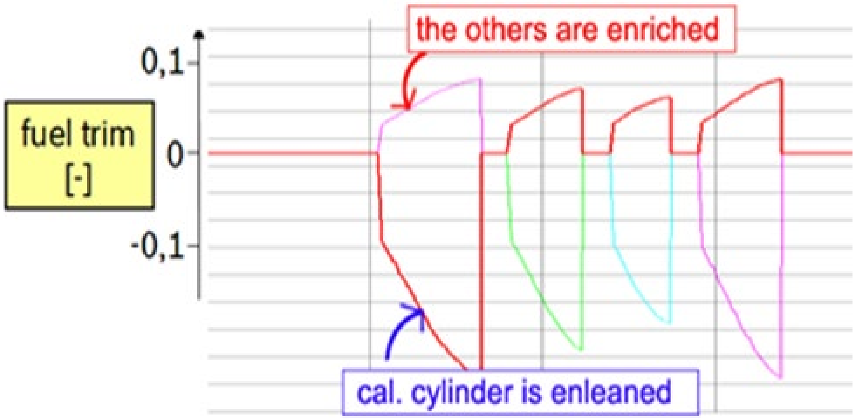
This relation between A/F-ratio changes (Δλ) and ΔER is evaluated to determine the actual lambda of a cylinder. Therefore on one cylinder the A/F-ratio is shifted stepwise to lean while the other cylinders are shifted to rich. The overall engine lambda keeps equal to 1.0 during this period.

Starting at unknown A/F-ratio with known absolute ER-value the A/F-ratio set point is shifted lean until a certain ΔER set point is reached. ΔER set point is taken from an engine speed and load dependent table. The Δλ is derived from how much the injection time needs to be corrected to reach the ΔER set point.

When this procedure has been executed on all cylinders for each cylinder individually the needed correction and a new adaptive value are calculated.

</td></tr>
</table>





※ Process of adaption

- Coordination of the steps to be executed at the moment
- Filtering and storing of the unsteady run values for each cylinder
- Selection of the current bank and the current cylinder in the respective operation mode
- Selective enleaning of individual cylinders in the calibrated sequence and calculation of the associated ramp increase
- Evaluation of the enleaning end values

※ A/F Ratio Cylinder Imbalance Monitoring

If the sum of the old adaptive value and the needed correction exceed a certain threshold or the new adaptive value exceeds a certain threshold, a DTC is stored for the affected cylinder.

- A/F deviation of specific cylinder > High Threshold
  OR A/F deviation of specific cylinder < Low Threshold

Parameters (I/O)

IN

- Engine Coolant temperature (ECT).
- Catalyst temperature (model)
- Engine speed
- Engine load
- Barometric pressure (BARO)
- Gear Position
- Air-fuel ratio (A/F) control active

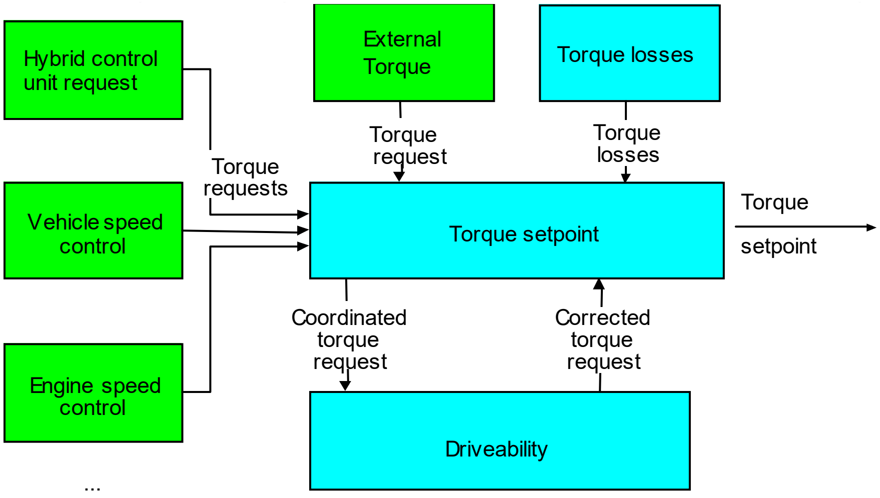
OUT

- OBD fault detection (P219C, P219D, P219E, P219F)

Entry Conditions	**Activating Condition** - ECT > 55°C - Catalyst Temperature > 500 °C - Engine Speed > 1320 rpm - Engine Load > 30 % - BARO > 74.5 kPa - Engaged Gear > 3 - Fuel System Status = close loop - Rough road detection = Not detected - Gear change = No - Circuit Error of Upstream O2S = Not detected. **Deactivating Condition** - If any of activating conditions are not met.
In-use Frequency	Once per driving cycle after cold start.
Emission impact	This is a part of OBD monitoring and included in all regulated test cycles, therefore accounted for by the test.
Justification	A. Substantially included during regulated test procedures: FTP75, US06, SC03, HwFET, FTP75@-7°C E. OBD intrusive monitor
Reference	1. OBD Document 2. Exhaust system temperature determination 3. Air-fuel ratio (A/F) feedback (HO2S1)

11.04 Other strategies

11.04.01 Torque setpoint strategy

Title : Torque setpoint strategy	
Purpose	**Base operation:** Adjust engine torque according to driver's request hybrid control unit request, auxiliary or external torque request**.**
Action: Functional Description	Torque setpoint is calculated by Torque requests and Torque Losses (Friction, Air Conditioner, Generator) Coordinated by drivability (TCU, ESC) 
Parameters (I/O)	**IN** - Engine Speed = f(CKP) - Relative load model - Generator Load - Hybrid control unit (HCU) request[1] - External Torque Request : a) Transmission Unit (TCU) b) Stability Control Unit (ESP) **OUT** - Torque setpoint (Relative load model, Ignition angle)[2]
Entry Conditions	**Activating Condition** This is a base control and always active.
In-use Frequency	This is a base control and always active.
Emission impact	This is part of base emission control and included in all regulated test cycles and therefore accounted for by the test.

Justification	A. Substantially included during regulated test procedures FTP75, US06, SC03, HwFET, FTP75@-7°C F. Base operation
Reference	1. SOC management – critical low band SOC management – critical high band Engine engagement and torque control strategy HEV operation based on traction energy Idle operation on charging high voltage battery HEV operation control in sport mode 2. Combustion Mode strategy, Base Ignition angle

11.04.02 Idle control strategy

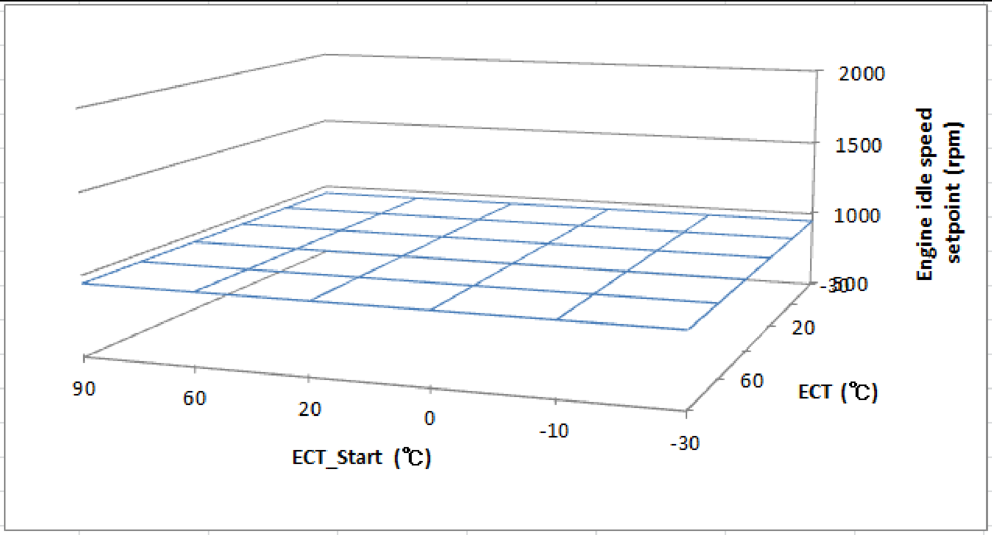
Title : Idle control strategy	
Purpose	**Base operation** Stabilize engine speed in idle condition
Action: Functional Description	Adjustment of engine idle speed setpoint and control to minimize the deviation setpoint and current engine speed by torque controller. All actions will be deactivated if engine operating condition is out of idle.
Parameters (I/O)	**IN** - Barometric pressure (BARO) - Engine coolant temperature (ECT) - Hybrid control unit (HCU) request[1] **OUT** - Engine Idle speed setpoint[1] - Torque control[2]
Entry Conditions	**Activating Condition** Accelerator pedal position < 0.1% **and** Fuel cut off not active **or** hybrid control unit (HCU) request[3] **Deactivating Condition** Accelerator pedal position >= 0.1% **or** Fuel cut off active **or** hybrid control unit (HCU) request[3]
In-use Frequency	Continuously active in idle condition.
Emission impact	This is part of base emission control and included in all regulated test cycles and therefore accounted for by the test.
Justification	A. Substantially included during regulated test procedures FTP75, US06, SC03, HwFET, FTP75@-7°C F. Base Operation
Reference	1. Engine engagement and torque control strategy, 2. Torque setpoint strategy, Fuel cut off for component protection 3. Engine engagement and torque control strategy, Idle operation on charging high voltage battery

Table 1. Engine Idle speed setpoint (Max selection)

Parameter	Engine coolant temperature	Ambient pressure	Catalyst Heating request	HCU request
Map	Map #1	Map #2	Map #3	-

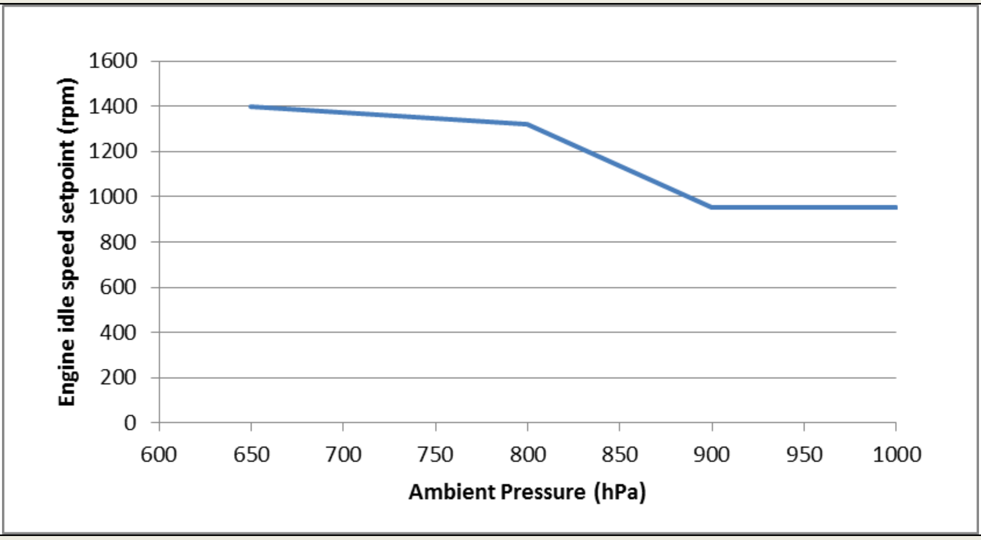
Engine coolant temperature

Map #1



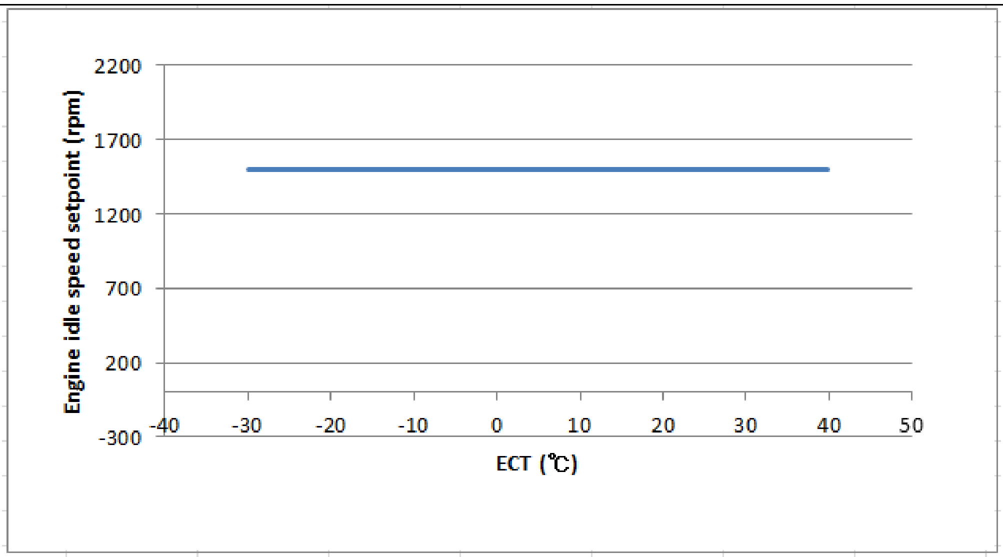
Ambient pressure

Map #2



Catalyst Heating

Map #3



4. Engine idle speed setpoint by hybrid control unit

For more information, refer to *<u>'11.06.04.03 Idle operation on charging high voltage battery'</u>*

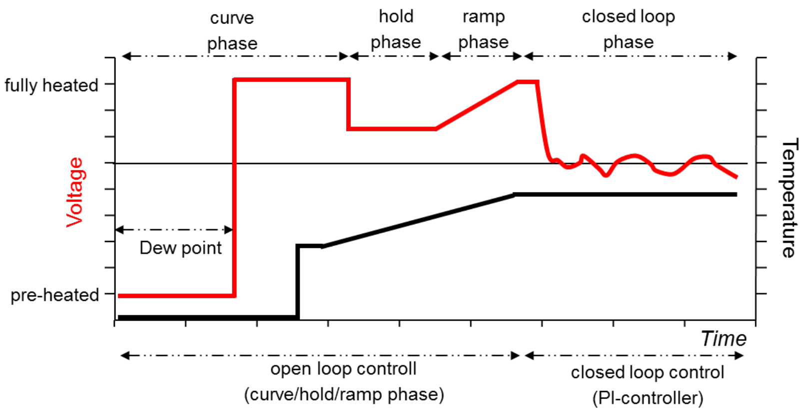
11.04.03 Oxygen sensor heating strategy

11.04.03.01 Oxygen sensor heating strategy

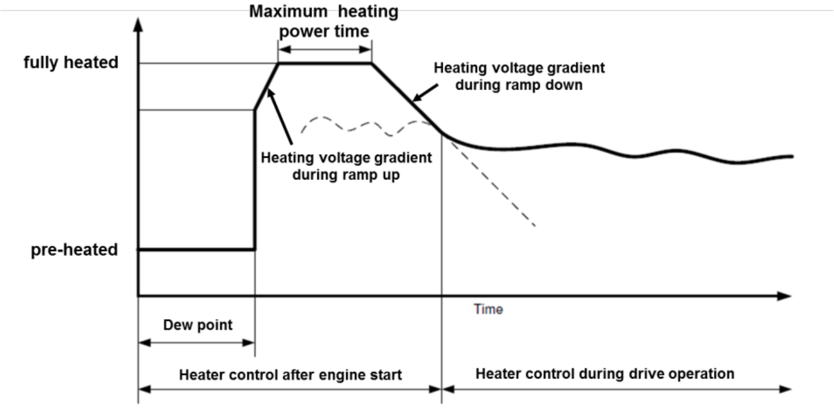
<table>
<tr><td colspan="2">Title : Oxygen sensor heating strategy</td></tr>
<tr><td>Purpose</td><td>Base operation:
The goal of the heater control shall be to control the oxygen sensor heating such that the optimal operating temperature is reached.</td></tr>
<tr><td>Action:
Functional Description</td><td>
The ceramic of HO2S1/2 sensors are preheated for protecting O2 sensor until dew point end is detected.

After dew-point has been reached, oxygen sensor heating is activated for HO2S1 and HO2S2 to reach closed loop operation (readiness).

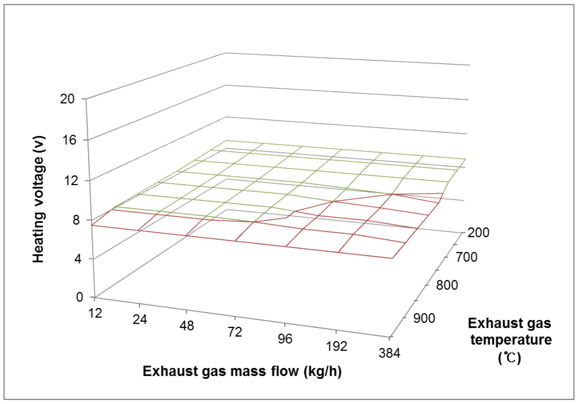
* Upstream O2 sensor (linear) heating management



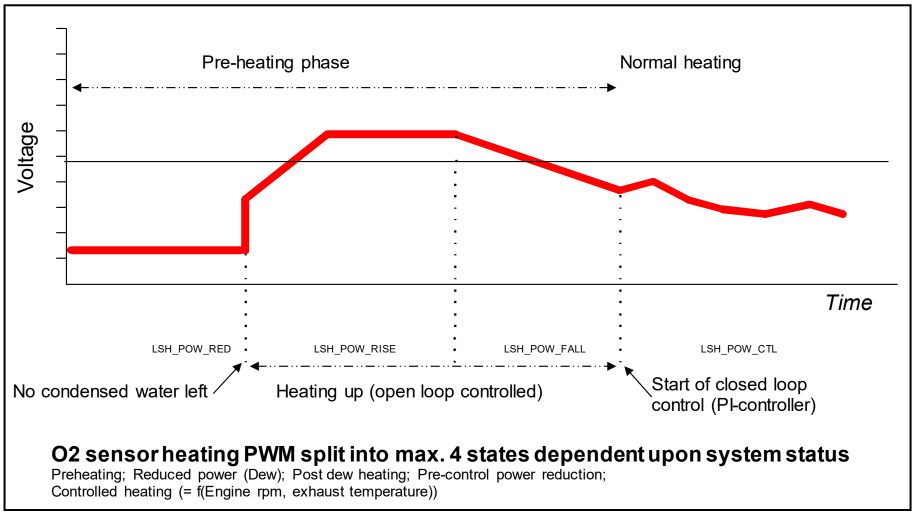
* Downstream O2 sensor (binary) heating management



</td></tr>
<tr><td>Parameters (I/O)</td><td>IN
- Internal resistance of sensor element
(oxygen sensor tip temperature)
- Exhaust gas mass flow model</td></tr>
</table>

	- Exhaust gas temperature model[1] - OBD Fault detection (HO2S1, HO2S2)[2] - Dew point detected[3] - Target HO2S1 ceramic temperature. 800℃ **OUT** - HO2S1 heater PID-controller value - Control voltage for HO2S2 heating  - Sensor operation readiness
Entry Conditions	**Activating Condition** After engine start. **Deactivating Condition** Fault detection (HO2S1, HO2S2)[4]
In-use Frequency	This is a base control and always active.
Emission impact	This is part of base emission control and included in all regulated test cycles and therefore accounted for by the test.
Justification	A. Substantially included during regulated test procedures FTP75, US06, SC03, HwFET, FTP75@-7°C F. Base Operation
Reference	1. Dewpoint detection 2. Exhaust system temperature determination 3. OBD Document 4. Air-fuel ratio (A/F) feedback (HO2S1) 5. Air-fuel ratio (A/F) feedback (HO2S2) 6. OBD Document

11.04.03.02 Oxygen sensor heating (HO2S1) strategy before engine cold start

Title : Oxygen sensor heating (HO2S1) strategy before engine cold start	
Purpose	**Base operation:** The oxygen sensor heating is to ensure proper operation of the oxygen sensor by controlling the appropriate ceramic temperature.
Action: Functional Description	The ceramic of oxygen sensor heating is activated for upstream O2 sensor to reach closed loop operation before engine cold start. * Every oxygen sensor has an individual heating resistance. *** Upstream Oxygen sensor (linear) heating management**  **O2 sensor heating PWM split into max. 4 states dependent upon system status** Preheating; Reduced power (Dew); Post dew heating; Pre-control power reduction; Controlled heating (= f(Engine rpm, exhaust temperature))
Parameters (I/O)	**IN** - Heated O2 sensor (Linear) (HO2S1) - OBD Fault Detection.[1] *HO2S1 tip temperature setpoint = 800℃ - Intake manifold temperature @ hybrid ready - Ambient air temperature @ hybrid ready - Engine coolant temperature @ hybrid ready - Engine off time @ hybrid ready **OUT** - Control voltage for HO2S1 heating - request motor only drive to HCU[2]
Entry Conditions	**Activating Condition** After hybrid ready

	And (Ambient air temperature @ hybrid ready > 8.25℃ **and** 149℃ > Intake manifold temperature @ hybrid ready > 8℃ **and** 143℃ > Engine coolant temperature @ hybrid ready > 8.25℃) **and** 15V >Battery Voltage @ hybrid ready >10V **and** HEV Start enable **and** O2 sensor (HO2S1) Tip Temperature < 790℃ **Deactivating Condition** O2 sensor can be controlled close-loop **or** OBD fault detection[3] **or** hybrid control unit request[4]
In-use Frequency	Once per drive cycle at hybrid system ready
Emission impact	Emission reduction
Justification	A. Substantially included during regulated test procedures FTP75, US06, SC03, HwFET, FTP75@-7°C @ hot transient D. Engine starting stabilization
Reference	1. OBD Document 2. Engine engagement and torque control strategy 3. OBD Document 4. SOC management – critical low band

11.04.04 Dewpoint detection strategy

Title : Dewpoint detection strategy

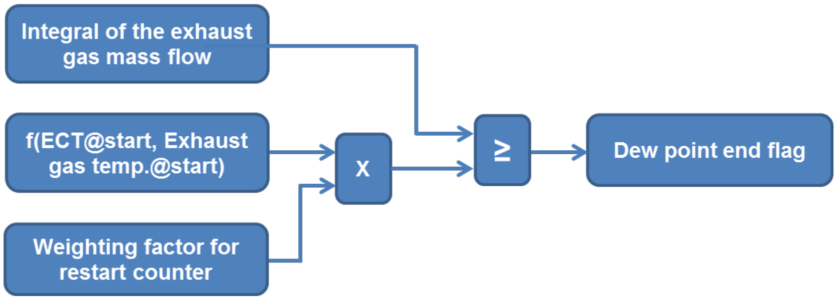
Purpose

Engine/Component protection:

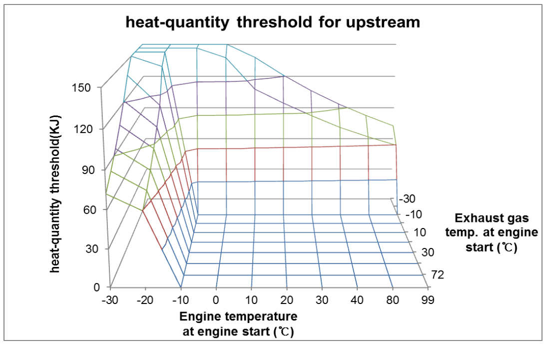
Protection of oxygen sensor elements against water splash.

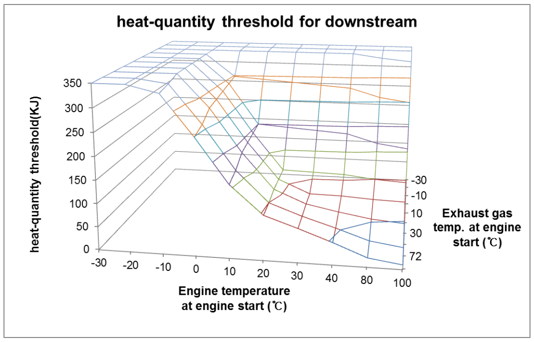
Action: Functional Description

This is necessary because the oxygen sensors can only be heated with full power if there is no risk of thermal shock due to water drops. Therefore for each sensor (up/down stream) a dew-point end flag is set when the dew phase is over.
The weighted integral of the Mass air flow (model) is calculated If this calculated value is above the following thresholds then the dew-point end flag is set.
In case the dew-point has not been reached before engine stops the threshold a weighted integral of the Mass air flow (model) will be increased for the next engine start.
In case the dewpoint has not been reached before engine stops the threshold of accumulated amount of heat will be weighted by cold engine start counter.



- Heat quantity threshold





- Weighting factor for restart counter

In case of the dew point has not been reached before engine stops, counter increases up to 6.

Parameters (I/O)	**IN** - Exhaust mass flow - Engine coolant temperature (ECT) - Exhaust gas temperature model[1] - ECU time **OUT** - Dew point end flag[2]
Entry Conditions	**Activating Condition** After engine start. **Deactivating Condition** Dewpoint detection limit reached.
In-use Frequency	Just once per each driving cycle.
Emission impact	This is part of base emission control and included in all regulated test cycles and therefore accounted for by the test.
Justification	A. Substantially included during regulated test procedures FTP75, SC03, FTP75@-7°C B. Engine System Protection F. Base operation
Reference	1. Oxygen sensor heating strategy

11.04.05 Catalyst heating strategy

When the catalyst is cold and inactive, it is necessary to reach the catalyst light-off temperature (LOT) as quickly as possible.

Injection and ignition control

An effective catalyst heating method is ignition retard. It is used after the starting phase to bring the catalytic converter up to operating temperature. Prior to LOT, the engine runs less efficiently to generate energy to heat the catalyst. This is accomplished by increasing the air mass and delaying the ignition timing.

When catalyst heating is needed, the required engine efficiency is set based on the current desired torque and the engine speed. Based on this setting, the desired throttle position and ignition angle is determined. The required engine efficiency is weighted by the engine start temperature, the engine running roughness, the weighting factor for torque reserve, and the catalyst heating factor.

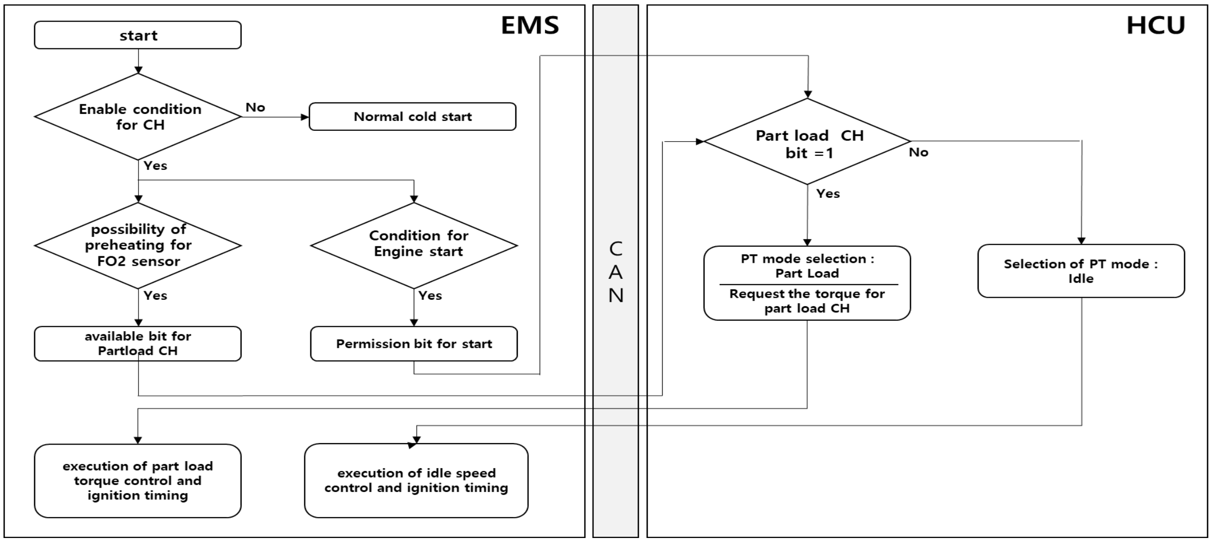
Two operation modes of catalyst heating

In the temperature range where the linear oxygen sensor heating is feasible, the 'Part load Catalytic Heating' is prioritized. The engine rpm is dependent on the vehicle speed and gear shift, and at this point, the air mass and ignition timing are controlled to a predetermined operating point for optimal catalytic heating. During part load catalytic heating, when the driven torque is no longer needed (such as during braking), the control mode switches to 'idle Catalytic Heating' ' performing additional catalytic heating needed.
In addition, in environments where preheating of the oxygen sensor is not possible, specifically at ambient temperatures below 8 degrees Celsius, a conventional form of idle catalytic heating control is implemented.

Strategy 1 : Part load Catalyst Heating (ENG clutch lock-up state)

"In conditions where preheating of the upstream oxygen sensor is possible, Priority is given to performing Part Load Catalytic Heating (PL CH), and it is implemented through collaborative control between the Engine Management System (EMS) and the Hybrid Control Unit (HCU).

■ As an illustrative diagram to aid understanding, logical errors can be ignored



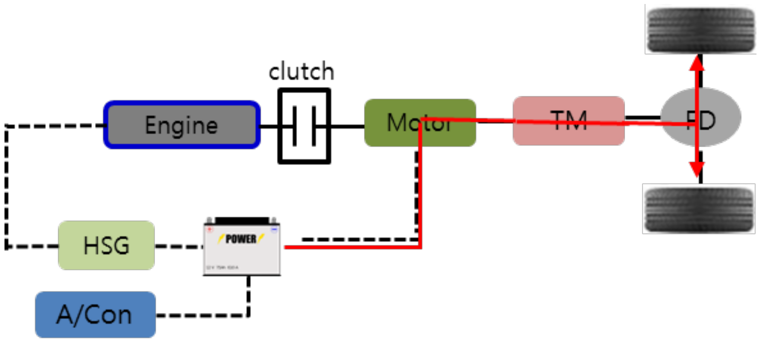
Strategy 2 : Idle Catalyst Heating (ENG clutch open state)

There is also a traditional idle catalytic heating control. It involves operating the engine at a specific operating point with the engine clutch in the open position to heat the catalyst. This control is performed in low-temperature conditions where preheating of the front oxygen sensor is not possible (the entire range below 8℃), and it is also performed when the battery state of charge (SOC) is insufficient.

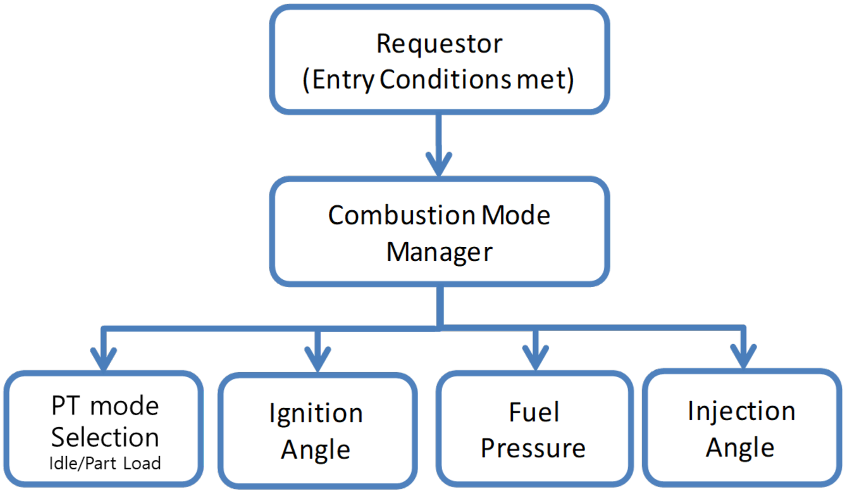
Enable condition

Since the catalyst temperature is subject to uncertainty during the start phase, the need for catalyst heating is determined based on engine coolant, intake air temperature and Catalyst temperature(modeled)

Motor only driving and clutch control (for hybrid and plug-in hybrid)



Hybrid vehicle powertrain has transmission, motor (for driving and regenerating), (engine) clutch, engine and HSG (Hybrid Starter and Generator). In the catalytic heating condition, the system will choose one of the two strategies mentioned earlier.

<table>
<tr><td colspan="2">**Title : Catalyst heating strategy**</td></tr>
<tr><td>**Purpose**</td><td>**Emission reduction:**
Increase of exhaust gas temperature to achieve a fast catalyst light-off and O2 sensor operation</td></tr>
<tr><td>**Action: Functional Description**</td><td>This catalyst light off is achieved by elevating the catalyst bed temperature to a value where these exothermic reactions become self-sustaining. There are three separate components of this catalyst light-off strategy, which are used to promote a more rapid catalyst temperature rise with stable combustion following engine start.
 </td></tr>
</table>

Parameters (I/O)

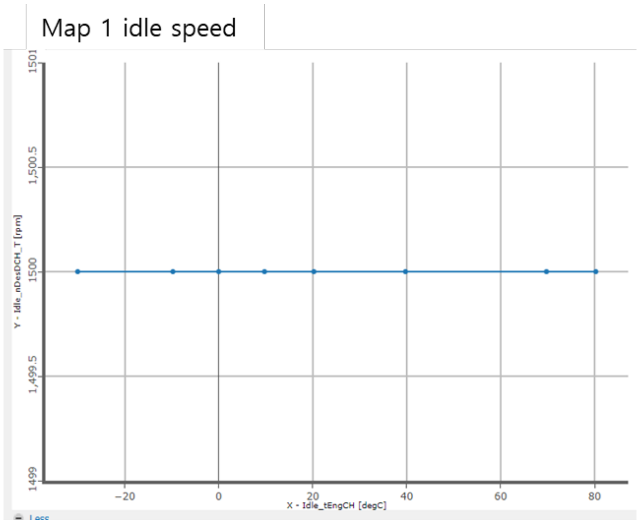
IN

- Engine Speed = f(CKP)
- Mass air flow
- Engine Coolant Temperature (ECT)
- Catalyst Temperature model[1]
- Barometric Pressure
- ECU time
- Vehicle Speed = f(WSS)
- Gear
- Hybrid control unit request

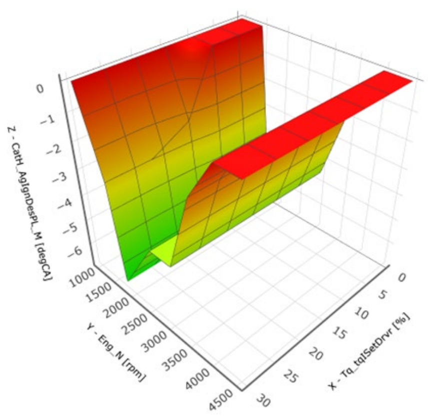
OUT

- Motor only driving request to hybrid control unit[2]
  OR.
- Catalyst heating state active(input for combustion mode)

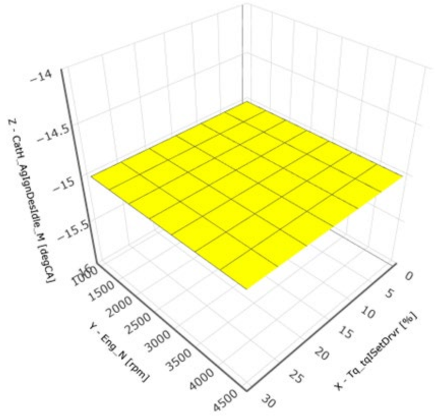
	strategy 1 (Part Load)	strategy 2 (Idle)
Engine speed	depends on vehicle speed	MAP 1
ignition angle	MAP 2	MAP 3 and MAP 4
torque	MAP 5	speed control



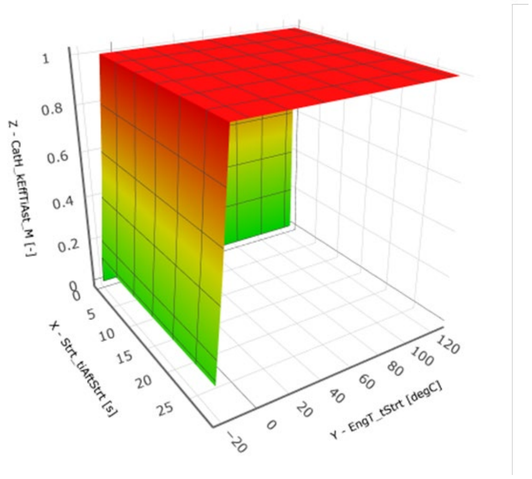
Map 2 ignition angle for Part load CH



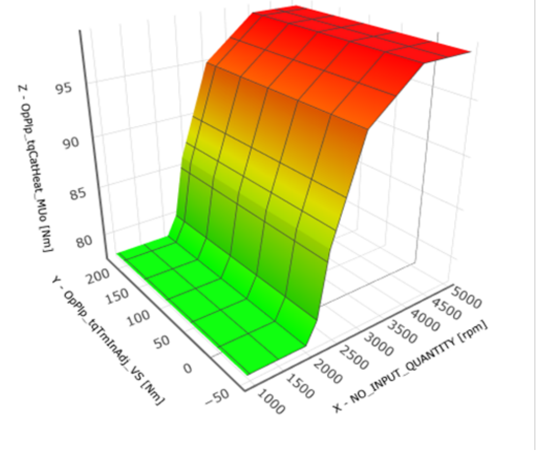
Map 3 ignition angle for Idle CH



Map 4 weighting factor for efficiency of Ignition



Map 5 requested engine torque during PL CH



Entry Conditions

Activating Condition

Engine coolant temperature (ECT) at start < 50℃

and

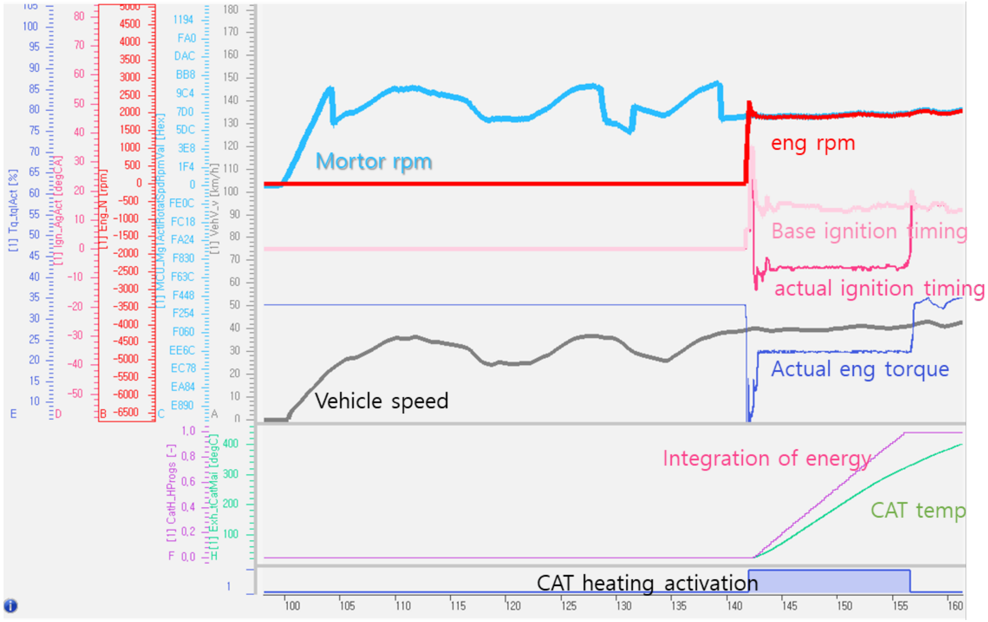
Ambient pressure > 750hPa

Deactivating Condition

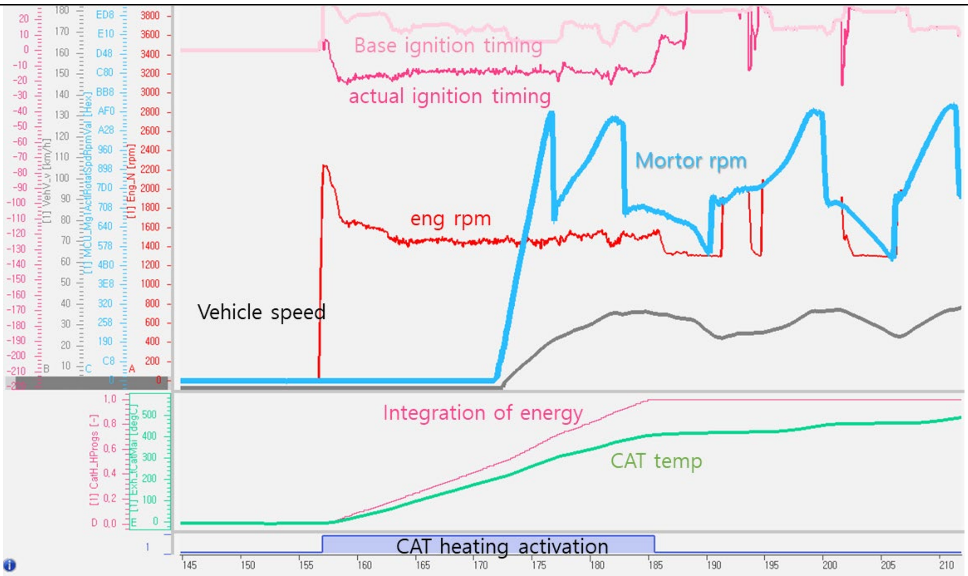
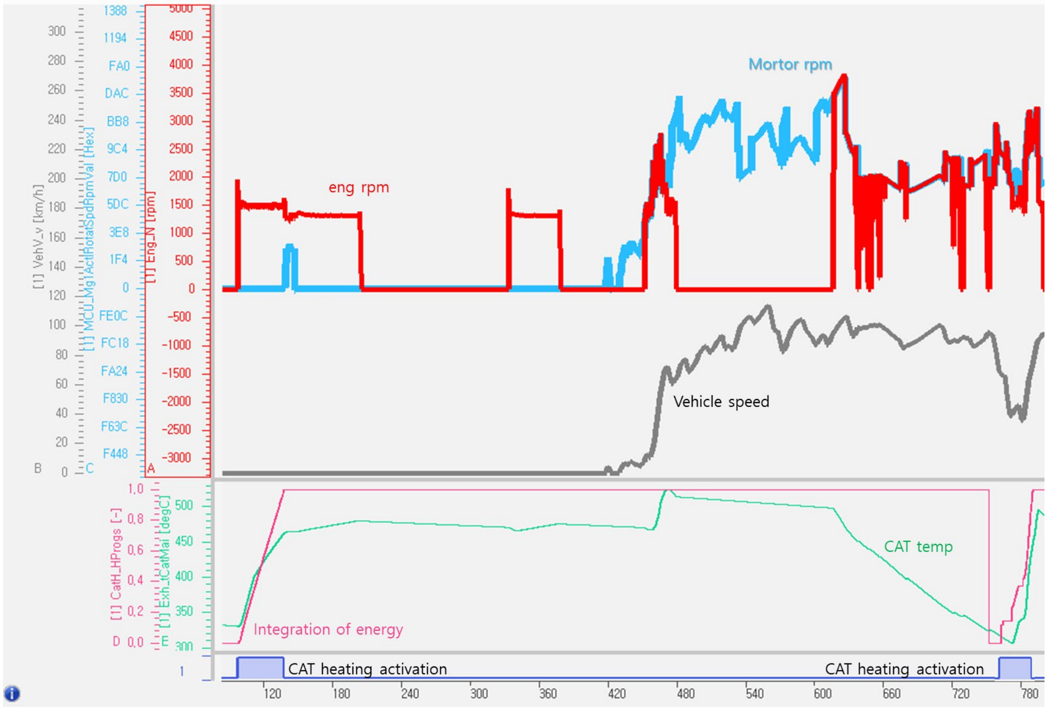
- Energy Integration > graph1

1. This value was determined from the measured catalyst temperature under the worst case condition

<PL CH @ FTP 72, 50°F>

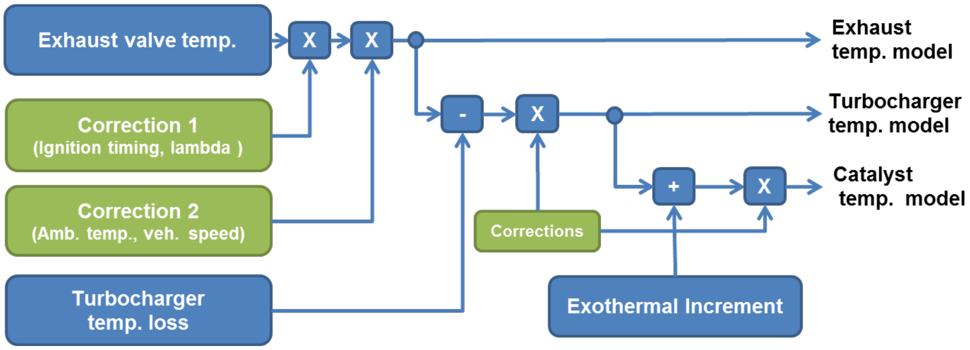
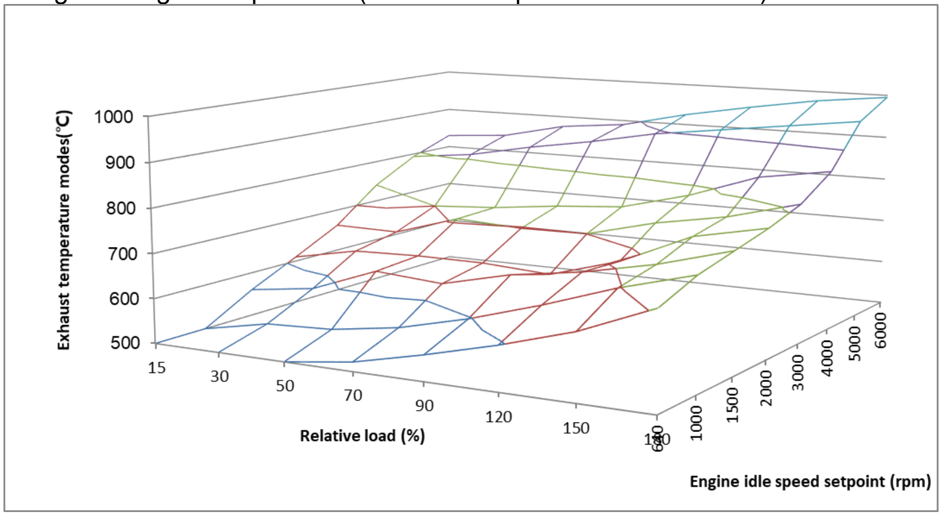


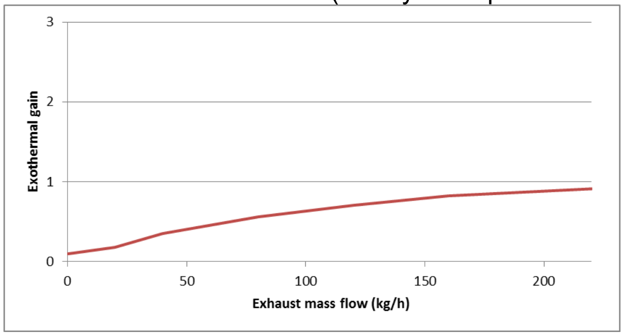
<IDLE CH @ FTP 72, 20°F>

	 **or** hybrid control unit request[8]
In-use Frequency	Minimum once per driving cycle with re-entry condition * Re-entry condition of catalyst heating is that catalyst temperature model is below 330℃ 

Emission impact	Emission reduction
Justification	A. Substantially included during regulated test procedures FTP75, FTP75@-7°C C. Protection against accident (Deactivation : lack of Battery power in cold condition) G. Electric propulsion system protection
Reference	1. Exhaust system temperature determination 2. Engine engagement and torque control strategy 3. Idle control strategy 4. Base ignition angle 5. Fuel rail pressure 6. Injection angle 7. Exhaust system temperature determination 8. SOC management – critical low band

11.04.06 Exhaust system temperature determination

Title : Exhaust system temperature determination	
Purpose	**Base Operation** Modeling the exhaust gas temperature is used for 1. Component overheating protection : exhaust pipe, catalyst 2. O2 sensor heater management
Action: Functional Description	Modeling the exhaust gas temperature, exhaust pipe, catalyst 
Parameters (I/O)	**IN** - Engine Speed = f(CKP) - Relative load model - Vehicle speed = f(WSS) - Engine coolant temperature (ECT) - Intake air temperature (IAT) - Ambient air temperature (AAT) - Ignition angle^2 - Lambda setpoint * Engine out gas temperature (Exhaust temperature base model) 

	* Exothermic reaction table (Catalyst temperature model correction)  **OUT** All modeled exhaust gas and exhaust component temperatures[3] (Exhaust gas temperature model, Catalyst temperature model)
Entry Conditions	The strategy is calculated under all engine running.
In-use Frequency	This is a base control and generally always active.
Emission impact	N/A
Justification	A. Substantially included during regulated test procedures FTP75, US06, SC03, HwFET, FTP75@-7°C F. Base Operation
Reference	1. Air-fuel ratio (A/F) feedback (HO2S1) 2. Base Ignition angle 3. Oxygen sensor heating strategy, Catalyst heating Strategy, Enrichment Component Protection

11.04.07 Combustion mode strategy

Title : Combustion mode strategy

Purpose

Base Operation

Adjust the combustion mode to improve the engine performance
- Stabilized combustion
- Fuel efficiency
- Low emission

Action: Functional Description

Switching combustion modes for optimized operation
(see attached figures)

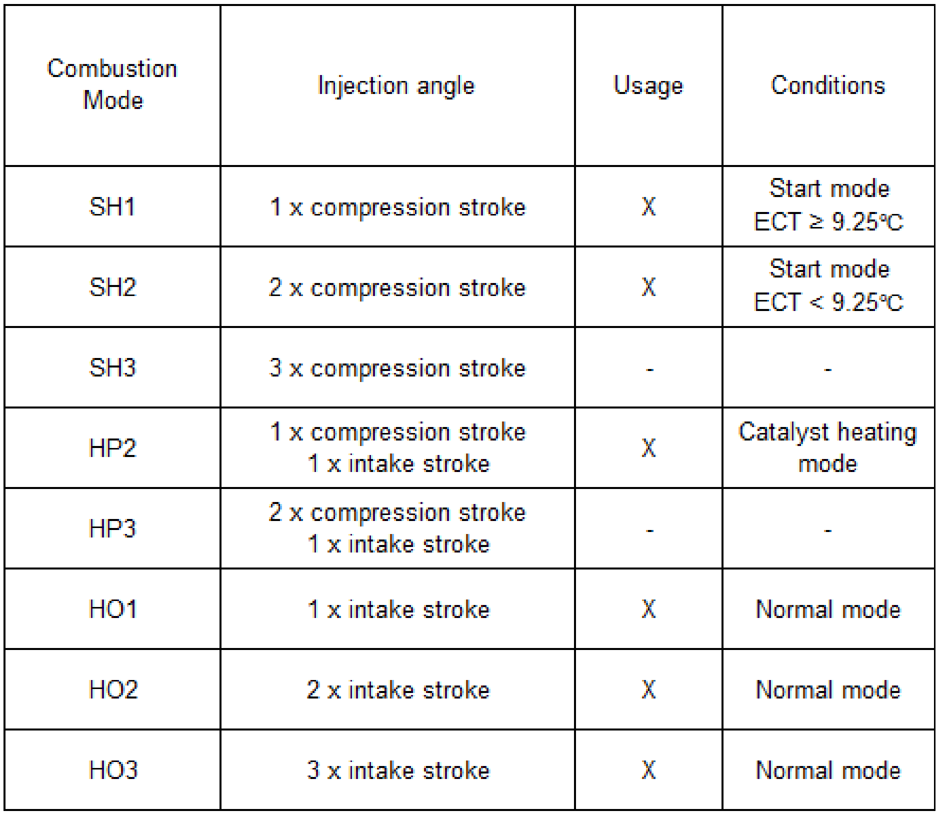
Parameters (I/O)

IN
- Engine speed = f(CKP)
- Relative load model
- Engine coolant temperature (ECT)
- Air-fuel ratio controller value1
- Catalyst heating active2
- Engine start

OUT
- Combustion Mode^{3}

Entry Conditions

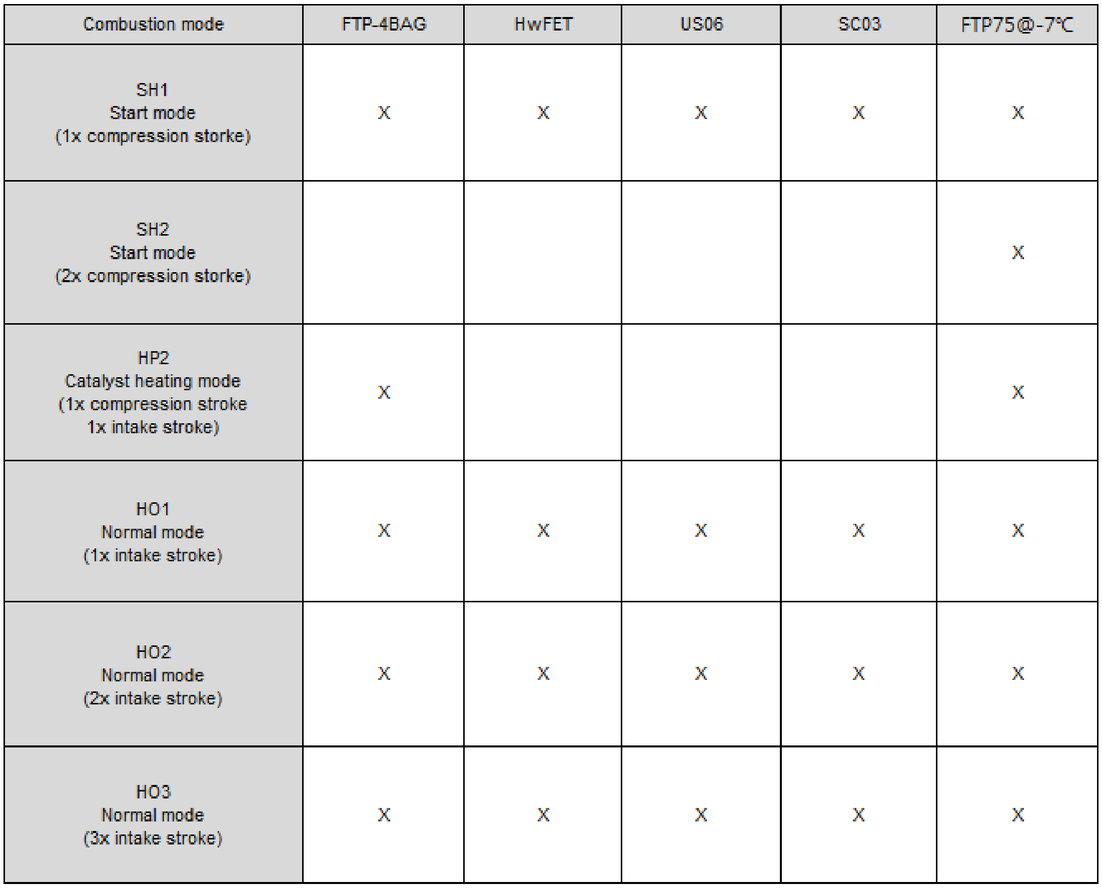
Activating Condition



Combustion Mode	Injection angle	Usage	Conditions
SH1	1 x compression stroke	X	Start mode ECT ≥ 9.25℃
SH2	2 x compression stroke	X	Start mode ECT < 9.25℃
SH3	3 x compression stroke	-	-
HP2	1 x compression stroke 1 x intake stroke	X	Catalyst heating mode
HP3	2 x compression stroke 1 x intake stroke	-	-
HO1	1 x intake stroke	X	Normal mode
HO2	2 x intake stroke	X	Normal mode
HO3	3 x intake stroke	X	Normal mode

In-use Frequency

This is part of base emission control and included in all regulated test cycles and therefore accounted for by the test.
The combustion mode used for each emission test cycles as below.



Combustion mode	FTP-4BAG	HwFET	US06	SC03	FTP75@-7℃
SH1 Start mode (1x compression storke)	X	X	X	X	X
SH2 Start mode (2x compression storke)					X
HP2 Catalyst heating mode (1x compression stroke 1x intake stroke)	X				X
HO1 Normal mode (1x intake stroke)	X	X	X	X	X
HO2 Normal mode (2x intake stroke)	X	X	X	X	X
HO3 Normal mode (3x intake stroke)	X	X	X	X	X

Emission impact

This is part of base emission control and included in all regulated test cycles and therefore accounted for by the test.

Justification

A. Substantially included during regulated test procedures
FTP75, US06, SC03, HwFET, FTP75@-7°C
F. Base Operation

Reference

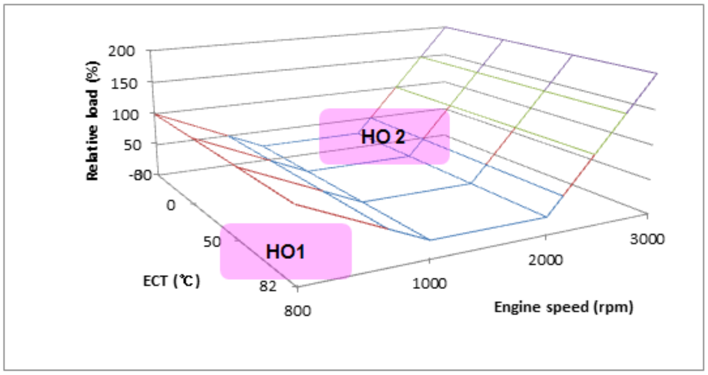
1. Torque setpoint strategy
2. Catalyst heating strategy
3. Fuel rail pressure, Injection angle

Figure 1. Combustion mode

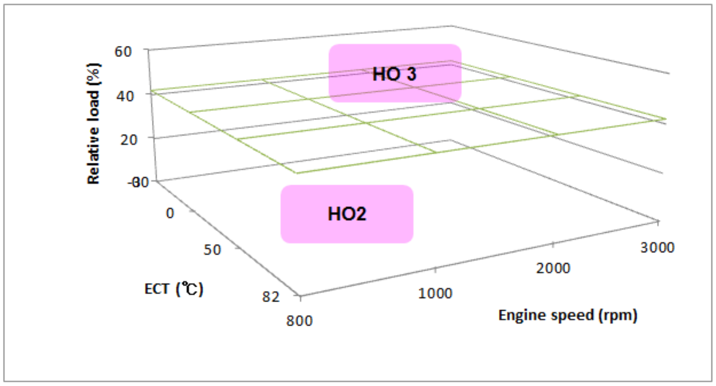
Combustion Mode	Injection angle	Usage	Conditions	Change parameters by combustioon mode			
				Ignition angle	Fuel rail pressure	Injection angle	number of injections
SH1	1 x compression stroke	X	Start mode ECT ≥ 9.25℃	X	X	X	1
SH2	2 x compression stroke	X	Start mode ECT < 9.25℃	X	X	X	2
SH3	3 x compression stroke	-	-	-	-	-	-
HP2	1 x compression stroke 1 x intake stroke	X	Catalyst heating mode	X	X	X	2
HP3	2 x compression stroke 1 x intake stroke	-	-	-	-	-	-
HO1	1 x intake stroke	X	Normal mode	X	X	X	1
HO2	2 x intake stroke	X	Normal mode			X	2
HO3	3 x intake stroke	X	Normal mode			X	3

Figure 2. Combustion mode of normal condition (HOx)

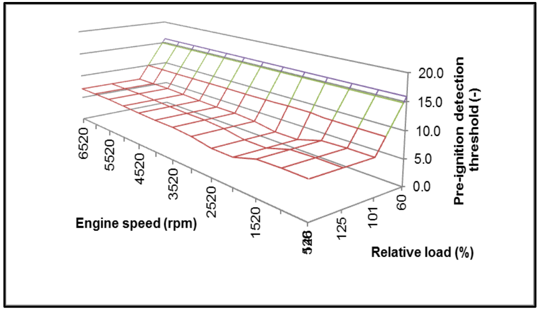
- HO2 combustion mode: 1000 < RPM < 3600



- HO3 combustion mode: 1120 < RPM < 2100



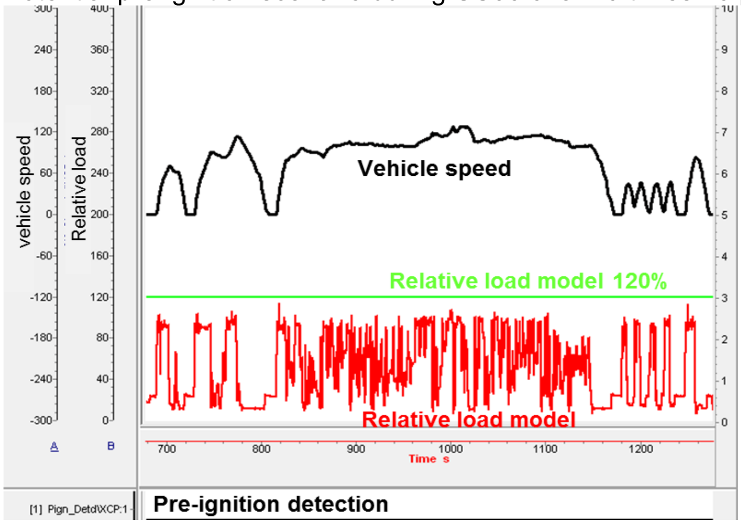
11.04.08 Pre-ignition protection strategy

<table>
<tr><th colspan="2">Title : Pre-ignition protection strategy</th></tr>
<tr><td>Purpose</td><td>Engine/component Protection
Preventing the engine components (cylinder head, piston, etc.…) from damage due to pre-ignition.</td></tr>
<tr><td>Action: Functional Description</td><td>Enrichment → Reduction of engine load → Camshaft control
(see attached figures)</td></tr>
<tr><td>Parameters (I/O)</td><td>In
- Knock sensors (KS)
- Engine speed = f(CKP)
- Relative load model
- Engine coolant temperature (ECT)
- Camshaft position inlet (CMP_IN)
- Camshaft position outlet (CAM_OUT)
- Crankshaft position (CKP)
Out :
- Lambda setpoint[1]
- Camshaft setpoint[2]
- Torque reduction[3]</td></tr>
<tr><td>Entry Conditions</td><td>Activating condition
- Engine coolant temperature > 70℃
and
- Relative load model > f(rpm)
<table>
<tr><td>RPM</td><td>1520</td><td>2000</td><td>2520</td><td>3000</td><td>4000</td><td>5000</td><td>6000</td></tr>
<tr><td>Load</td><td>120</td><td>120</td><td>120</td><td>120</td><td>120</td><td>120</td><td>120</td></tr>
</table>
and
- Pre-ignition detected
*knock sensor value > f(rpm, relative load)


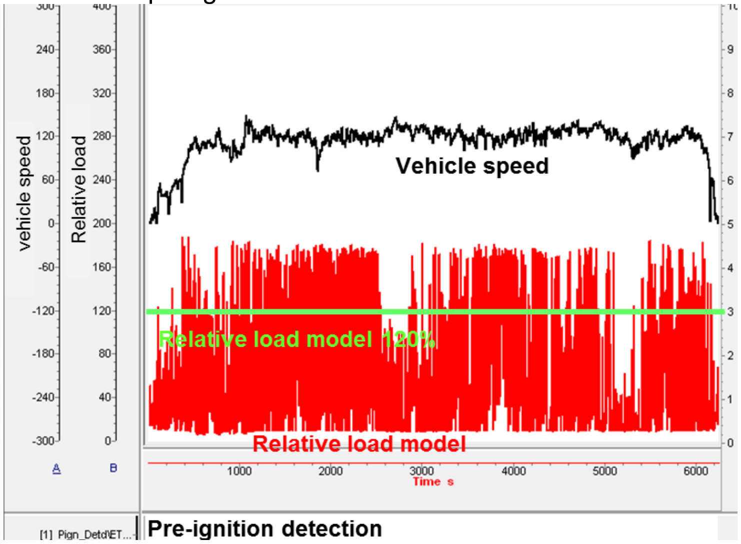
Deactivating condition
Pre-ignition does not appear furthermore.</td></tr>
</table>

In-use Frequency

Rare due to unusual cause of pre-ignition.
Potential pre-ignition scenario during US06 over 10 times no pre-ignition detect.



Below is a graph of internal testing of U.S. highway driving (1hr).
There is no pre-ignition detect.



Emission impact

May momentarily increase CO and NMHC emission.

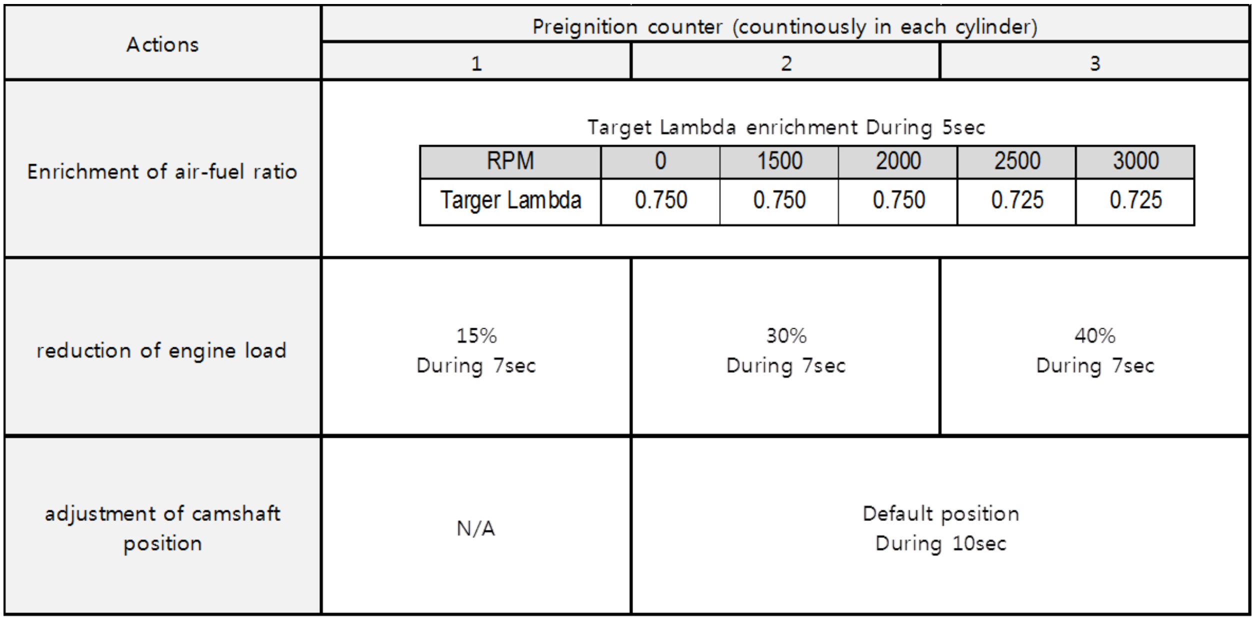
Justification

B. Engine/Emission system protection

Reference

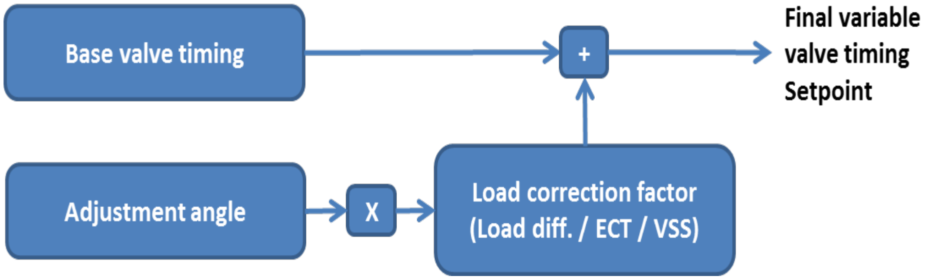
1. Air-fuel ratio (AFR) feedback (HO2S1)
   Air-fuel ratio adaptation
   Injection angle
   Base Ignition angle
   Exhaust system temperature determination
2. Variable valve timing
3. Torque set-point strategy

Figure 1. Pre-ignition protection actions



<table>
<tr><th rowspan="2">Actions</th><th colspan="3">Preignition counter (countinously in each cylinder)</th></tr>
<tr><th>1</th><th>2</th><th>3</th></tr>
<tr><td>Enrichment of air-fuel ratio</td><td colspan="3">Target Lambda enrichment During 5sec
<table>
<tr><th>RPM</th><th>0</th><th>1500</th><th>2000</th><th>2500</th><th>3000</th></tr>
<tr><td>Targer Lambda</td><td>0.750</td><td>0.750</td><td>0.750</td><td>0.725</td><td>0.725</td></tr>
</table></td></tr>
<tr><td>reduction of engine load</td><td>15%
During 7sec</td><td>30%
During 7sec</td><td>40%
During 7sec</td></tr>
<tr><td>adjustment of camshaft position</td><td>N/A</td><td colspan="2">Default position
During 10sec</td></tr>
</table>

11.04.09 Scavenging strategy

Title : Scavenging strategy	
Purpose	**Protection against accident** Avoid putting the driver in a dangerous situation when turbocharger lag typically happens.
Action: Functional Description	Valve overlap is increased by inlet/outlet valve timing adjusting. During valve overlap, lambda closed loop controlled. 
Parameters (I/O)	**In** - Engine speed = f(CKP) - Relative load model - Accelerator pedal position (APP) - Transmission gear information (GEAR) - Transmission slope information (SLOP) - Engine coolant temperature (ECT) - Vehicle speed = f(WSS) **Out** - Adjustment inlet/outlet valve timing setpoint[1]
Entry Conditions	**Activating Condition** - Accelerator pedal position > 85% and - ECT > 0℃ and - Load difference (Target – Actual) > 30% (depend on engine rpm) **Deactivating Condition** - any of activating condition is no longer met

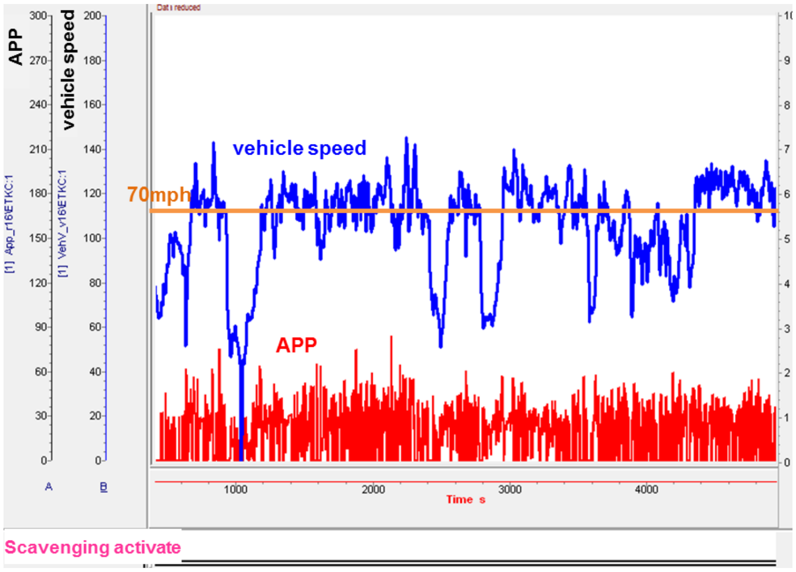
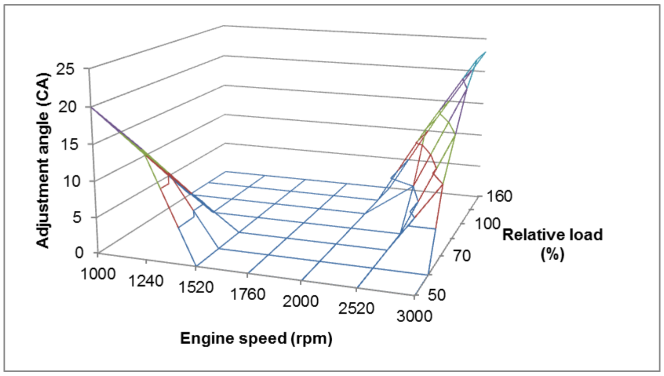
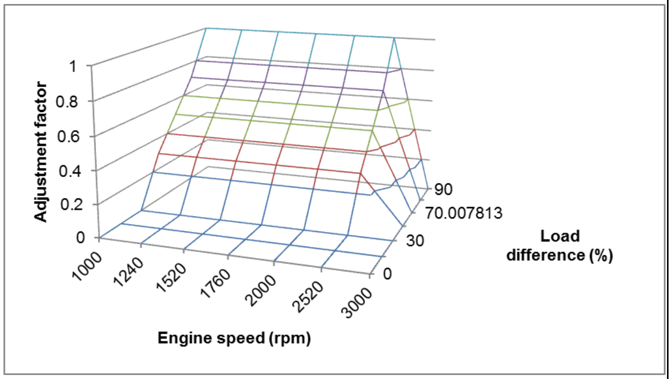
In-use Frequency	Estimated to be rare due to full load condition (APP > 85%). Below is a graph of internal testing of U.S. highway driving (1hr 15min). Scavenging was not activated during the internal test. Therefore, it is believed to be a rare occasion when engaged. 
Emission impact	May momentarily increase NMHC and CO emission while active. (Lambda enrichment for torque demand is also activated when scavenging is activated.)
Justification	C. Protection against accident.
Reference	1. Variable valve timing

Figure 1. Adjustment of inlet/outlet valve timing for scavenging

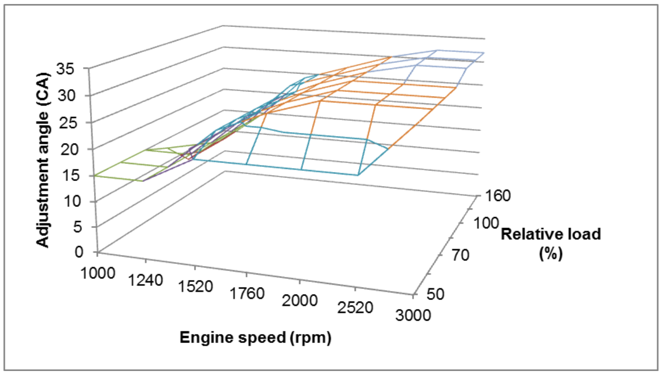
Inlet valve timing adjustment



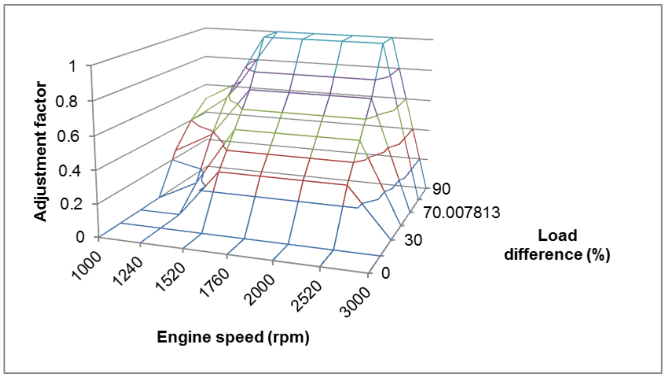
Load difference factor (Inlet)



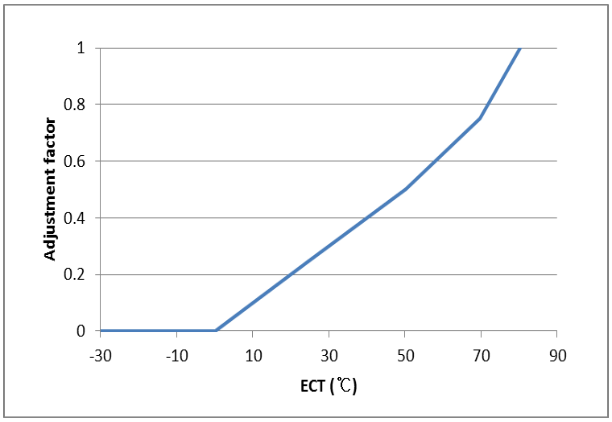
Outlet valve timing adjustment



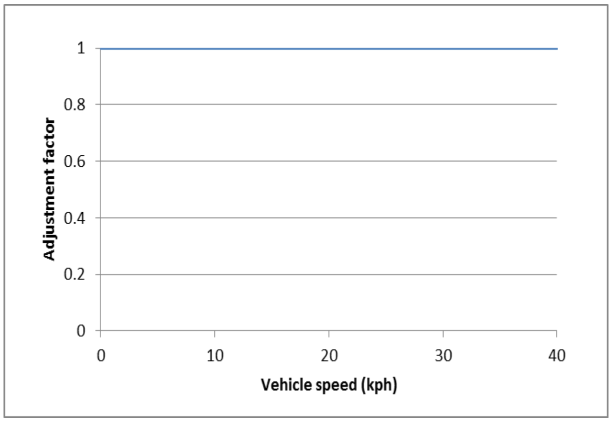
Load difference factor (Outlet)



Engine coolant temperature factor



Vehicle speed factor



11.04.10 Engine warm-up strategy

Title : Engine warm-up strategy	
Purpose	**Base Operation** - In order to reduce the exhaust emission (cold start) caused by the frequent engine on/off. - Increase the engine efficiency
Action: Functional Description	Request the hybrid control unit (HCU) to keep the engine on[1]
Parameters (I/O)	**IN** - Engine coolant temperature (ECT) **OUT** - Request the hybrid control unit (HCU) to keep the engine on[2]
Entry Conditions	**Activating Condition** Engine coolant temperature (ECT) < 30℃ **Deactivating Condition** Engine coolant temperature (ECT) > 48℃
In-use Frequency	Minimum once per driving cycle at cold start.
Emission impact	Emission reduction
Justification	A. Substantially included during regulated test procedures FTP75, FTP75@-7°C F. Base Operation
Reference	1. Engine engagement and torque control strategy 2. Engine engagement and torque control strategy

11.04.10.01 Engine warm-up strategy for Engine Oil Dilution State

Title : Engine warm-up strategy for Engine Oil Dilution State	
Purpose	**Base Operation** - A control to evaporate and control fuel components accumulated in engine oil. - It determines the accumulation of fuel components in engine oil and performs control to maintain engine start-up to heal the oil dilution state.
Action: Functional Description	1. Request the hybrid control unit (HCU) for engine on 2. Increase engine oil control target pressure
Parameters (I/O)	**IN** - Engine coolant temperature (ECT) - Engine Oil temperature (OilT) - Engine speed = f(CKP) - Engine Control State - Vehicle Speed **OUT** - Request the hybrid control unit (HCU) for engine on - Increase engine oil control target pressure
Entry Conditions	**Activating Condition** - Engine coolant temperature (ECT) > 80℃ - Moving average value of Engine Oil Temperature (OilT) > 85℃ - Counter* of driving times determined to be cold > 20 *Condition for counter increase : ① AAT < 10℃ and driving distance < 10km ② AAT < 10℃ and OilT < 60℃ *Condition for counter reset : ① Success of healing mode (Accumulated healing control mode operation time > 600s) ② OilT > 80℃ under normal mode - Accumulated mileage > 1000 Km (The accumulated mileage is reset when the healing mode is “off”.) **Deactivating Condition** - Accumulated healing mode operation time > 600s
In-use Frequency	Estimated to be rare because it is activated only when the cold operation conditions are repeated and accumulated.
Emission impact	May increase CO2 emission while active.

Justification	B. Engine/Emission system protection
Reference	1. Engine engagement and torque control strategy

11.05 Fuel economy related controls

11.05.01 Transmission shift pattern for hybrid vehicle

The shift pattern of the transmission is determined by transmission control unit (TCU). Specific to hybrid vehicles, the shift pattern can be changed upon the request of the hybrid control unit to maintain the hybrid system such as cooling down the engine clutch, maintaining the SOC of a high-voltage battery within the normal range, etc. Thus the hybrid control system requests TCU to select hybrid system specified shift pattern. The hybrid system specified shift pattern logic is classified as follows.

- ECO: General shift pattern for better fuel efficiency in ECO mode
- SPORT: Increase engine speed for better vehicle performance in sports mode
- SMART: When the driver selects MY DRIVE mode, the driver can select SMART in MY DRIVE mode from the infotainment for the powertrain mode. The shift pattern for SMART in MY DRIVE mode is automatically selected as one of the aforementioned ECO and SPORT modes by TCU in accordance with determining driver’s behavior based on the fuzzy logic which has inputs as accelerator position, shift lever position, G-sensor and vehicle speed
- UPHILL shift pattern: Increase engine speed to obtain additional traction power at uphill
- Cabin heating function: Increase engine speed to increase engine coolant temperature for cabin heating at low temperature
- LFU prevention: Prohibit upshift and hold low gear when accelerator pedal is released quickly during acceleration in order to improve re-acceleration performance and response (LFU: Lift Foot Upshift)
- Heavy braking function: High BPS Downshift to low gear occurs earlier than low BPS downshift rpm in the shift pattern during braking. The maximum value of the normal shift pattern and the regenerative braking pattern determines the shift point for (P)HEV
- Downhill function: This function makes downshift with brake pedal operation on the downhill to prevent busy shift as bps tip-in/out. Using this function, the downshift occurs at a lower vehicle speed than the flat regenerative braking pattern, and the upshift occurs at a higher vehicle speed.
- Curve function: Prohibit upshift when the lateral G is above a set value. Upshift prevention is lifted when engine rpm reaches a set value. Set rpm will be higher with higher lateral acceleration.
- High speed shift pattern: Increase hysteresis of up and down shifting points at a high speed to prevent busy shifting, in order to increase powertrain efficiency
- High traction driving shift pattern: Increase engine speed to obtain high engine power to prevent excessive use of SOC in high traction driving mode
- Charge sustaining shift pattern: Increase engine speed for charging the battery

- Shift pattern for extreme condition of high voltage battery: Increase engine speed for compensate for low battery power in extreme condition
- Engine clutch protection: Increase engine speed to protect for engine clutch against high temperature

Determination of shift patterns

- A shift pattern is determined through following chart.

High priority →

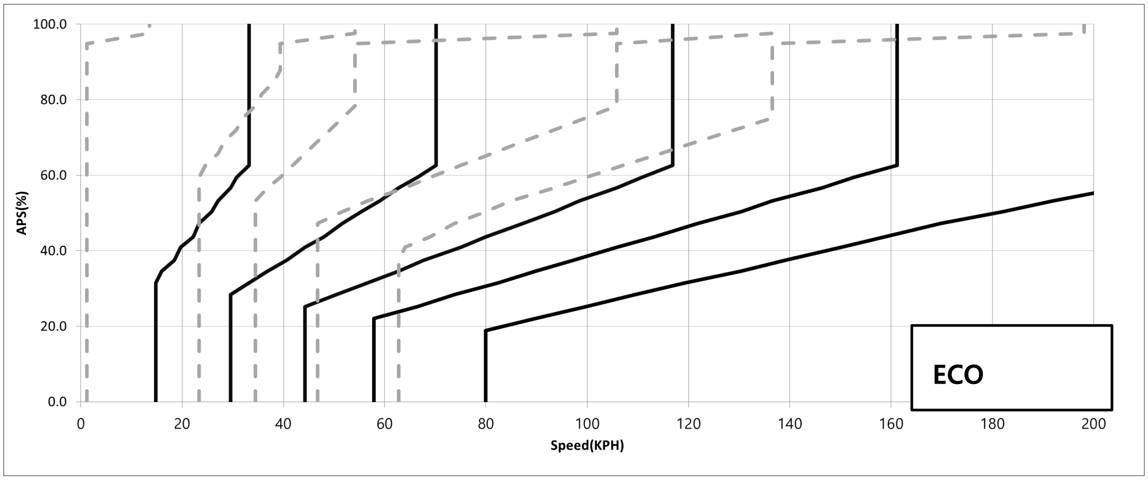
High priority ↓

SMART ←→

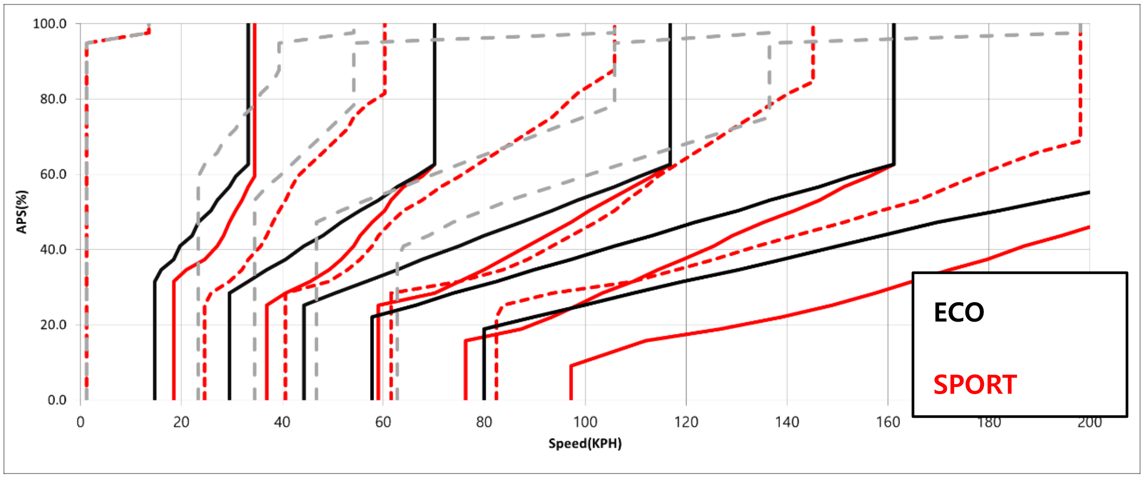
	Driver Selectable Mode							
	ECO				Sports			
Slope Condition	Normal	Uphill 1	Uphill 2	Uphill 3	Normal	Uphill 1	Uphill 2	Uphill 3
ECO	ECO	ECO Uphill1	ECO Uphill2	ECO Uphill2	Sports	Sports Uphill 1	Sports Uphill 2	Sports Uphill 3
High speed	HWY	ECO Uphill1	ECO Uphill2	ECO Uphill3	Sports	Sports Uphill 1	Sports Uphill 2	Sports Uphill 3
Charge sustaining	Charge sustaining	Charge sustaining Uphill1	Charge sustaining Uphill2	Charge sustaining Uphill3	Sports Uphill 1	Sports Uphill 2	Sports Uphill 3	Sports Uphill 3
Cabin heating	Cabin heating	ECO Uphill1	ECO Uphill2	ECO Uphill3	Sports	Sports Uphill 1	Sports Uphill 2	Sports Uphill 3
Extreme Condition	Extreme temperature	ECO Uphill3	ECO Uphill3	ECO Uphill3	Sports Uphill 1	Sports Uphill 2	Sports Uphill 3	Sports Uphill 3
High traction driving	High traction driving	High traction driving Uphill	High traction driving Uphill	High traction driving Uphill	High traction driving	High traction driving Uphill	High traction driving Uphill	High traction driving Uphill
Engine clutch protection	Engine clutch protection	Engine clutch protection	Engine clutch protection	Engine clutch protection	Engine clutch protection	Engine clutch protection	Engine clutch protection	Engine clutch protection

11.05.01.01 COMFORT shift pattern - N/A

11.05.01.02 ECO shift pattern

Title : ECO shift pattern	
Purpose	General shift pattern for better fuel efficiency in ECO mode
Action: Functional Description	See shift pattern below 
Parameters (I/O)	**IN** - Driver Selectable Mode **OUT** - Shift map selection
Entry Conditions	**Activating Condition** Driver Selectable Mode = 'ECO mode' **Deactivating Condition** Driver Selectable Mode ≠ 'ECO mode'
Reference	

11.05.01.03 SPORT shift pattern

Title : Sports shift pattern	
Purpose	Increase engine speed For better vehicle performance in sports mode
Action: Functional Description	Select Sports shift map to increase engine speed. 
Parameters (I/O)	**IN** - Driver Selectable Mode **OUT** - Shift map selection
Entry Conditions	**Activating Condition** Driver Selectable Mode = ‘Sports mode’ **Deactivating Condition** Driver Selectable Mode ≠ ‘Sports mode’
Reference	

11.05.01.04 SPORT+ shift pattern - N/A

11.05.01.05 UPHILL shift pattern

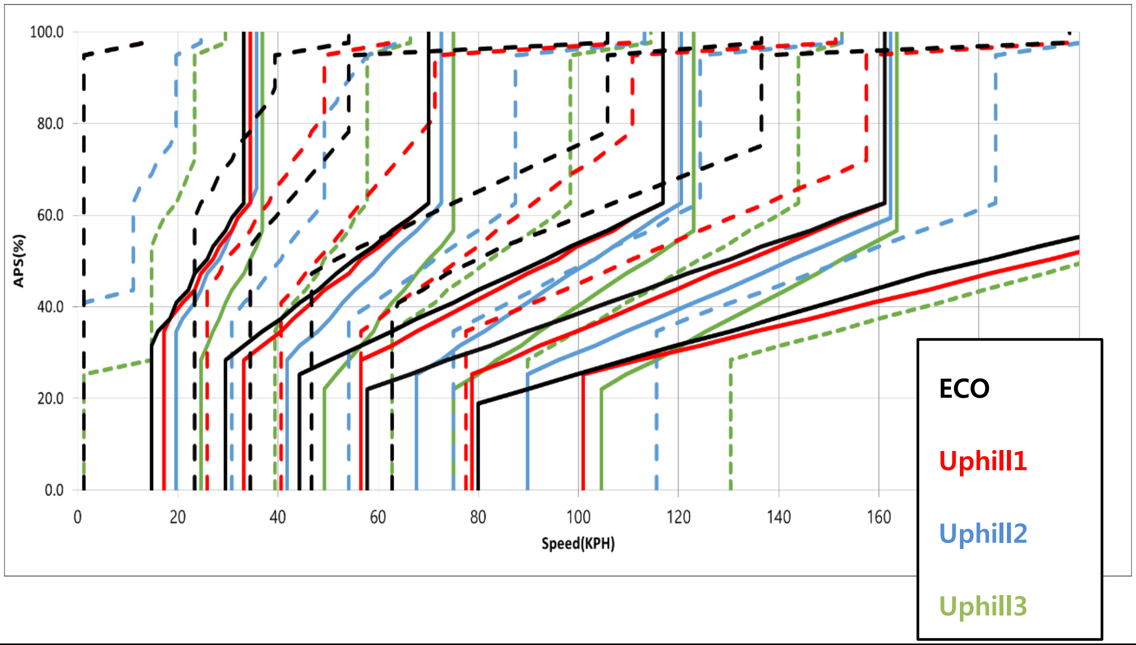
Title : Uphill shift pattern

Purpose

To obtain additional traction power at uphill.

Action: Functional Description

Select uphill shift map to increase engine speed.



Parameters (I/O)

IN

- Road slope
- Current Gear

OUT

- Shift map selection

Entry Conditions

Activating Condition

- Road slope > 5~7% (depend on current gear, see the below table)

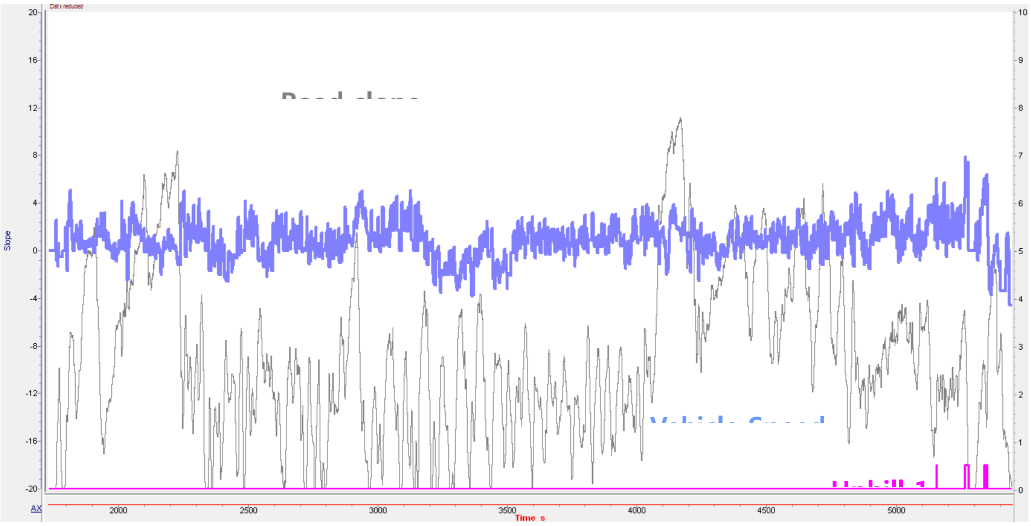
Deactivating condition

- Road slope < 3.5~4.5% (depend on current gear, see the below table)

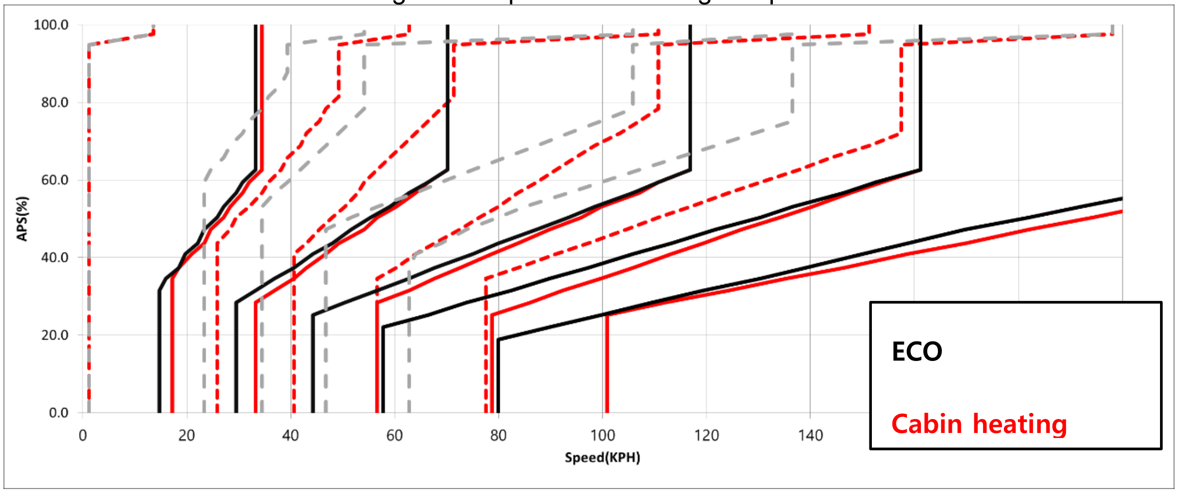
Table the entry condition

Current Gear		1st Gear			2nd gear			3rd~6th gear		
Pattern		Uphil1	Uphil2	Uphill3	Uphil1	Uphil2	Uphill3	Uphil1	Uphil2	Uphill3
Slope	Activation	7	10	15	6	9	14	5	9	14
(%)	Deactivation	4.5	7	12	3.5	6	11	3.5	7	11

The pattern is interpolated between normal and Up1, Up1 and Up2, Up2 and Up3 according to road gradient.

Further information	Road driving test result @ LA urban 
Reference	

11.05.01.06 Cabin heating function

Title : Cabin heating function	
Purpose	Enhance cabin heating and defrosting capability by delayed shifting point in extreme cold conditions.
Action: Functional Description	Select Extreme cold cabin heating shift map to increase engine speed. 
Parameters (I/O)	**IN** - Engine coolant temperature - Ambient air temperature - Transmission Oil temperature **OUT** - Shift map selection
Entry Conditions	**Activating Condition** - Ambient air temperature < -10℃ and (Engine coolant temperature < 45℃ or Transmission Oil temperature < 10℃) **Deactivating Condition** - Ambient air temperature > -7℃ or (Engine coolant temperature > 70℃ and Transmission Oil temperature > 15℃)
Reference	

11.05.01.07 Transmission temperature protection function – N/A

11.05.01.08 Heavy braking function

Title : Heavy braking function

Purpose

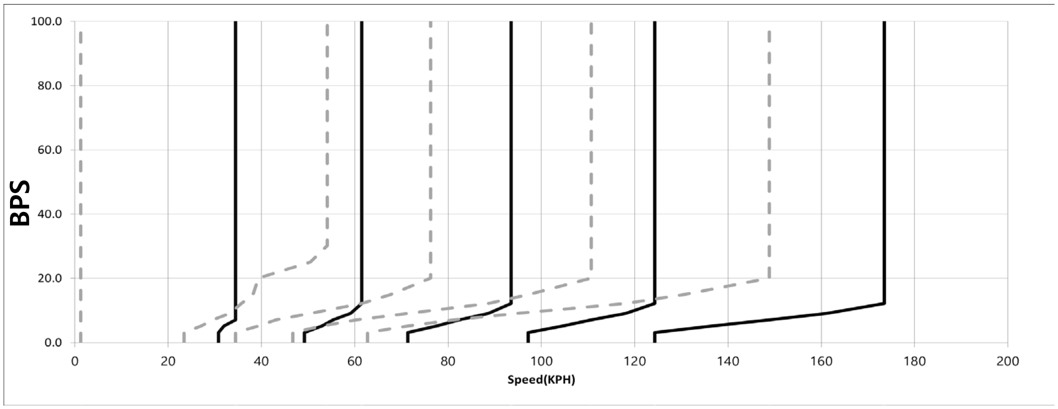
To improve re-acceleration performance and response right after heavy deceleration

To improve regenerative braking efficiency considering brake depth for (P)HEV.

Action: Functional Description

High BPS Downshift to low gear occurs earlier than low BPS downshift rpm in the shift pattern during braking.

The maximum value of the normal shift pattern and the regenerative braking pattern determines the shift point for (P)HEV



Parameters (I/O)

IN
- APS, BPS, TM output SPD

OUT
- Target gear

Entry Conditions

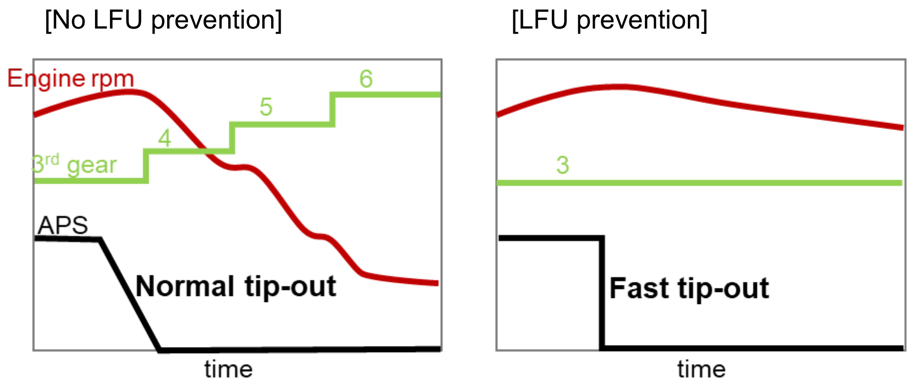
Activating Condition (AND)
- APS < set value (below table)
- TM input Torque < 10Nm

Deactivating Condition (OR)
- APS > set value (below table)
- TM input Torque > set value (below table)

APS	Act	TmOutSpd	0	992	2016	3008	4512	6016
		Value(%)	0	7.1	7.1	6.7	5.9	5.1
	Deact.	TmOutSpd	0	992	2016	3008	4512	6016
		Value(%)	0	7.1	7.1	6.7	5.9	5.1
TM input Torque	Act	10Nm						
	Deact.	TmInSpd	0	992	2016	3008	4512	6016
		Value(Nm)	0	15	15	10	10	10

Reference

11.05.01.09 LFU prevention

Title : LFU (Lift Foot Upshift) prevention	
Purpose	To improve re-acceleration performance and response by holding low gear when tip-out
Action: Functional Description	Upshift is prohibited when quick accelerator pedal release is detected. If upshift is prevented, transmission remains in low gear and high rpm for better re-acceleration performance.  [No LFU prevention] [LFU prevention]
Parameters (I/O)	**IN** - APS gradient, APS, Gear, Engine rpm **OUT** - Target gear
Entry Conditions	**Activating Condition (AND)** - APS < 5.1% - APS gradient > 2607~6585%/s (Higher value with low gear) - Engine rpm < 2500~3500 for ECO, and 4800~5920 for SPORT (depends on road gradient and gear, Higher value with high road gradient) **Deactivating Condition (OR)** - APS > 5.1% - elapsed time > 1.0~2.0s (depends on APS and gear)
Reference	

11.05.01.10 Downhill function

Title : Downhill function (Downhill Regenerative braking shift pattern for (P)HEV)

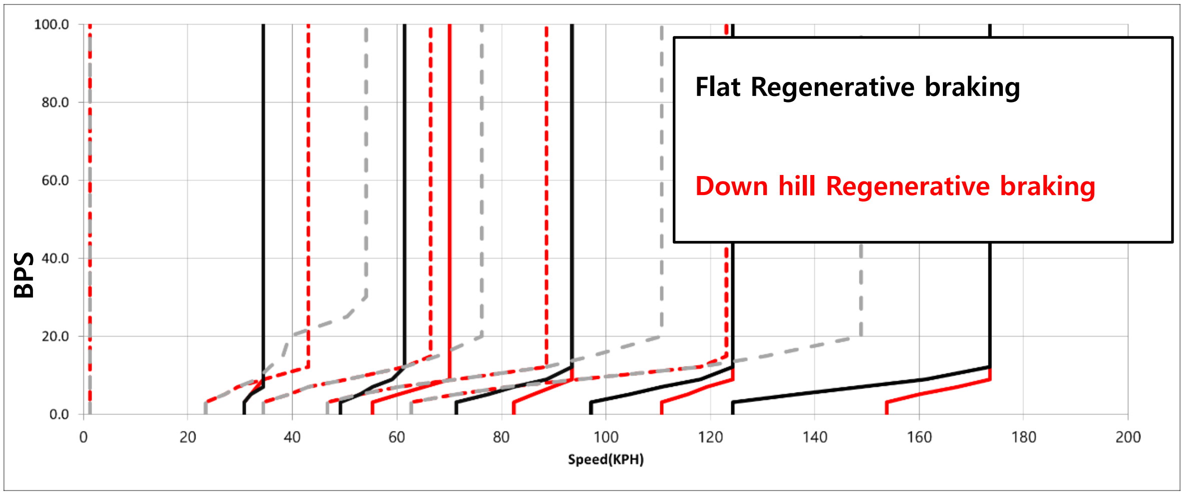
Purpose

To prevent busy shift as bps tip-in /out according to road gradient when downhill coasting

Action: Functional Description

This function makes downshift with brake pedal operation on the downhill to prevent busy shift as bps tip-in/out.

Using this function, the downshift occurs at a lower vehicle speed than the flat regenerative braking pattern, and the upshift occurs at a higher vehicle speed.



Parameters (I/O)

IN
- Road gradient, BPS, TM output Speed

OUT
- Target gear

Entry Conditions

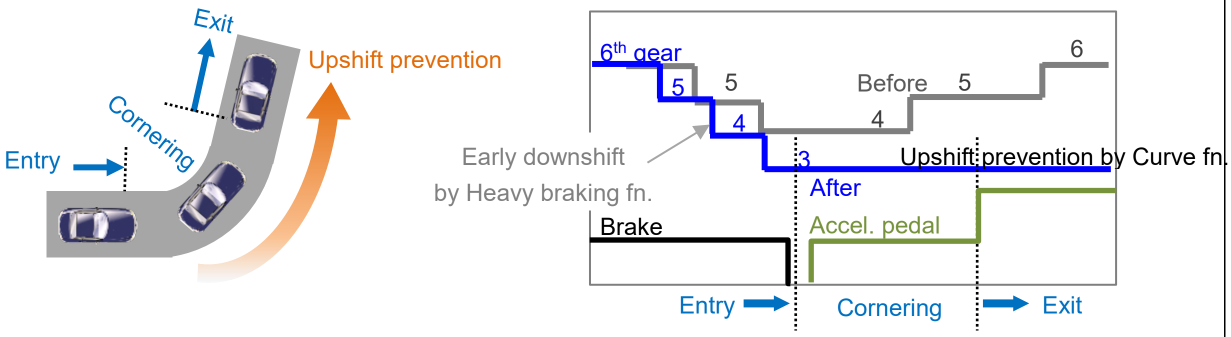
Activating Condition (AND)
- APS < set value (below table)
- TM input Torque < 10Nm
- Road Gradient < -4%

Deactivating Condition (OR)
- APS > set value (below table)
- TM input Torque > set value (below table)
- Road Gradient > -1%

APS	Act	TmOutSpd	0	992	2016	3008	4512	6016
		Value(%)	0	7.1	7.1	6.7	5.9	5.1
	Deact.	TmOutSpd	0	992	2016	3008	4512	6016
		Value(%)	0	7.1	7.1	6.7	5.9	5.1
TM input Torque	Act	10Nm						
	Deact.	TmInSpd	0	992	2016	3008	4512	6016
		Value(Nm)	0	15	15	10	10	10

Reference

11.05.01.11 Curve function

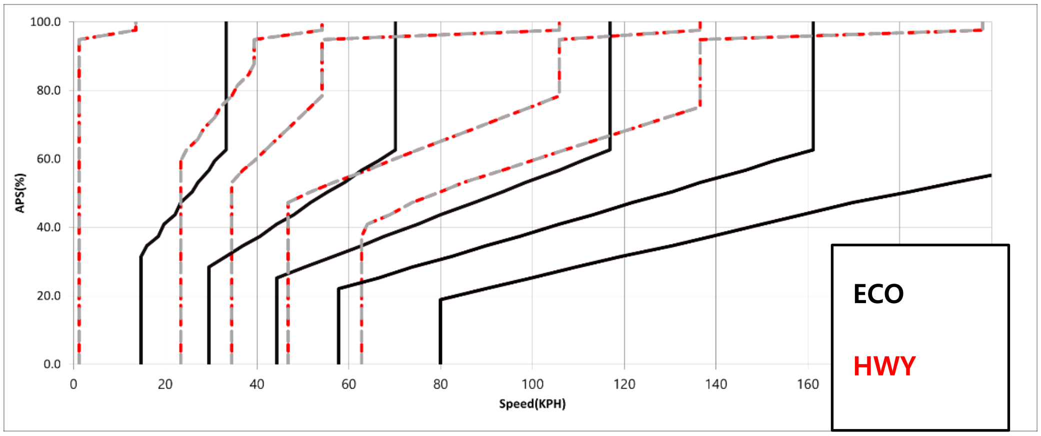
<table>
<tr><th colspan="2">Title : Curve function</th></tr>
<tr><td>Purpose</td><td>To improve re-acceleration performance and response after turning with high lateral G</td></tr>
<tr><td>Action:
Functional Description</td><td>Prohibit upshift when the lateral G is above a set value.
Upshift prevention is lifted when engine rpm reaches a set value. Set rpm will be higher with higher lateral acceleration.
[Curve function]

 </td></tr>
<tr><td>Parameters (I/O)</td><td>IN
- Steering angle, gear, T/M input rpm, vehicle speed
OUT
- Target gear
※ T/M input rpm is equal to engine rpm when lock-up engine clutch engaged</td></tr>
<tr><td>Entry Conditions</td><td>Activating Condition(AND)
- Vehicle Speed > 15kph
- T/M input rpm < 5500rpm
- Cur gear >= 2
- lateral acceleration speed > 3m/s^2
Deactivating Condition(OR)
- T/M input rpm > set value (below table)
- lateral acceleration speed < 2m/s^2
- Vehicle Speed < 15kph
- Cur Gear = 1
- elapsed time > 1.0~2.0s (depends on APS and gear)
<table>
<tr><th colspan="2" rowspan="2"></th><th colspan="5">Lateral acceleration(m/s^2)</th></tr>
<tr><th>0</th><th>2</th><th>5</th><th>7.5</th><th>10</th></tr>
<tr><td rowspan="6">Cur gear</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>2</td><td>2000</td><td>2500</td><td>3000</td><td>3250</td><td>3750</td></tr>
<tr><td>3</td><td>2250</td><td>2750</td><td>3250</td><td>3500</td><td>4000</td></tr>
<tr><td>4</td><td>2250</td><td>2750</td><td>3250</td><td>3500</td><td>4000</td></tr>
<tr><td>5</td><td>2250</td><td>2750</td><td>3250</td><td>3500</td><td>4000</td></tr>
<tr><td>6</td><td>2250</td><td>2750</td><td>3250</td><td>3500</td><td>4000</td></tr>
</table></td></tr>
<tr><td>Reference</td><td></td></tr>
</table>

11.05.01.12 Kick down shift for fast tip-in – N/A

11.05.01.13 Lock up clutch control – N/A

1.05.01.14 High speed shift pattern

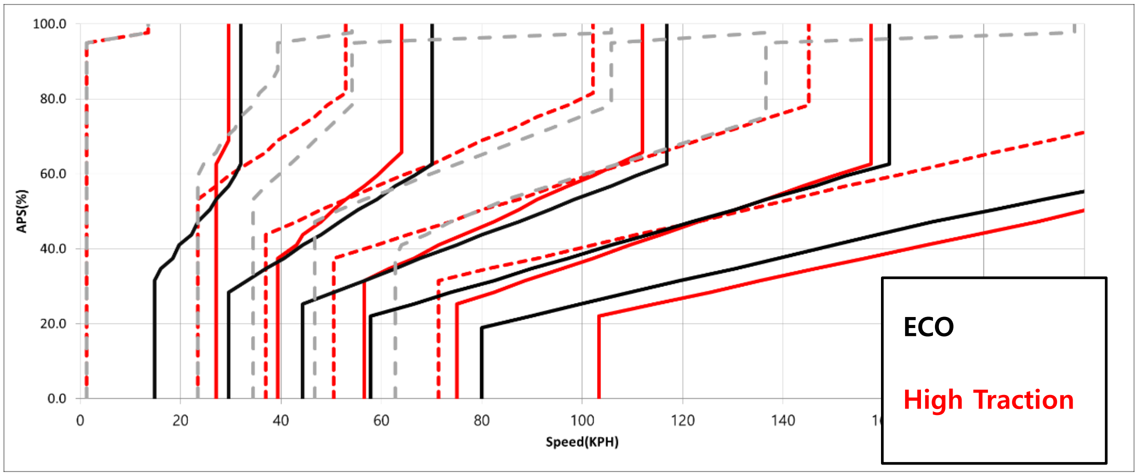
<table>
<tr><td colspan="2">Title : High speed shift pattern</td></tr>
<tr><td>Purpose</td><td>To prevent busy shifting and obtain engine power to charge the battery in highway driving condition</td></tr>
<tr><td>Action: Functional Description</td><td>Select high speed shift map to Increase hysteresis of up and down shifting


</td></tr>
<tr><td>Parameters (I/O)</td><td>IN
- Driver selectable mode
- Control priority
OUT
- Shift map selection</td></tr>
<tr><td>Entry Conditions</td><td>Activating Condition

Driver selectable mode = ‘ECO mode’
and
Control priority = ‘High speed driving’

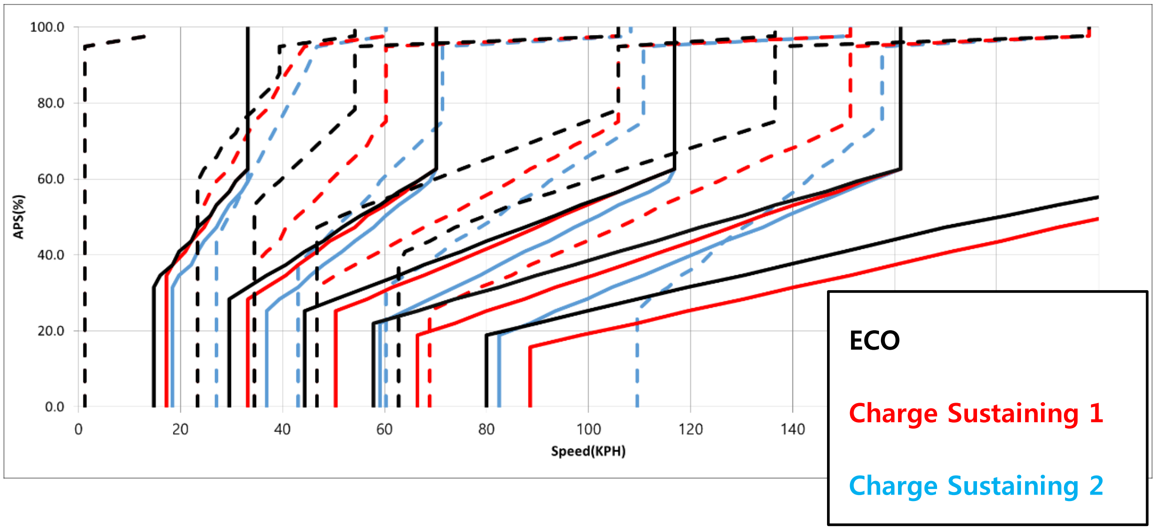
Deactivating Condition
Driver selectable mode ≠ ‘ECO mode’
or
Control priority ≠ ‘High speed driving’</td></tr>
<tr><td>Reference</td><td></td></tr>
</table>

11.05.01.15 High traction driving shift pattern

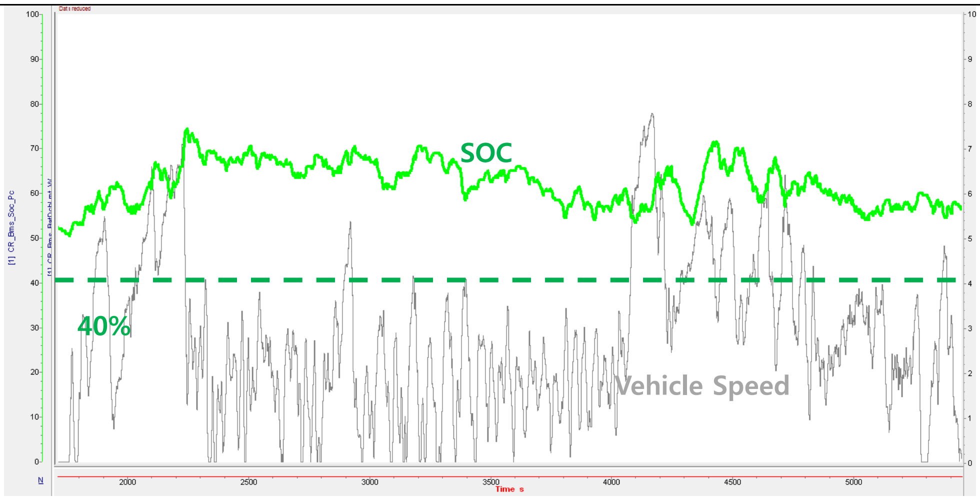
Title : High traction driving shift pattern	
Purpose	To prevent busy shifting and lack of SOC in high traction driving mode
Action: Functional Description	Select high traction shift map to increase engine speed. 
Parameters (I/O)	**IN** - Control priority **OUT** - Shift map selection
Entry Conditions	**Activating Condition** Control priority = ‘High traction driving’ **Deactivating Condition** Control priority ≠ ‘High traction driving’
Reference	

11.05.01.16 High auxiliary electric power shift pattern – N/A

11.05.01.17 Charge sustaining shift pattern

<table>
<tr><td colspan="2">Title : Charge sustaining shift pattern</td></tr>
<tr><td>Purpose</td><td>Charging the battery to prevent the SOC from entering the critical low band.</td></tr>
<tr><td>Action: Functional Description</td><td>Select charge sustaining shift map to increase engine speed.

</td></tr>
<tr><td>Parameters (I/O)</td><td>IN
- SOC of the High-Voltage Battery
OUT
- Shift map selection</td></tr>
<tr><td>Entry Conditions</td><td>Activating Condition
1. Charge Sustaining 1
- SOC of the High-Voltage Battery < 35%
2. Charge Sustaining 2
- SOC of the High-Voltage Battery < 28%

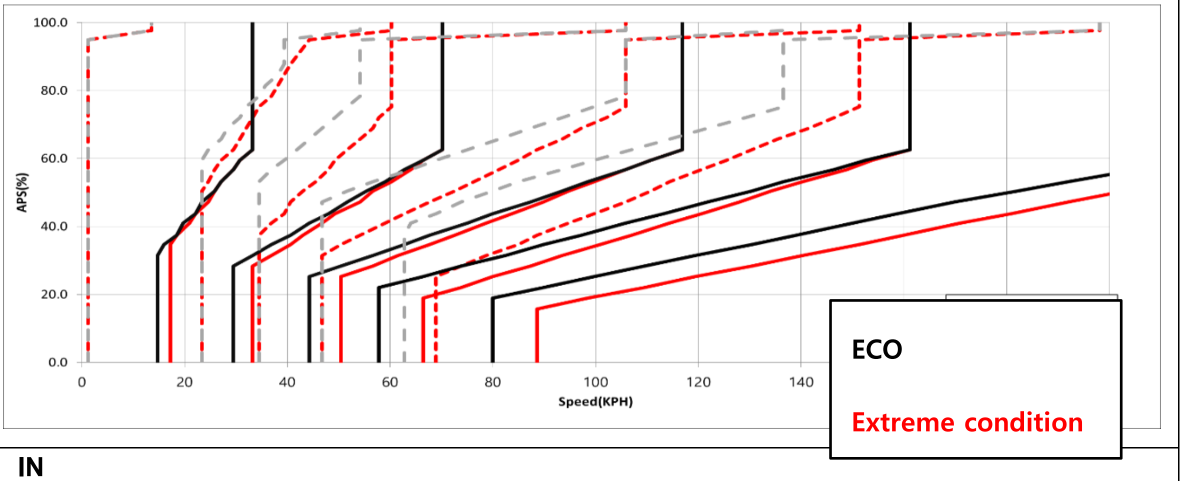
Deactivating Condition
1. Charge Sustaining 1
- SOC of the High-Voltage Battery > 40%
2. Charge Sustaining 2
- SOC of the High-Voltage Battery > 33%</td></tr>
<tr><td>Further information</td><td>Road driving test result : Estimated to be rare because SOC is normally above 40%</td></tr>
</table>

	Data reduced [1] CR_Bms_Soc_Pc [1] CR_Bms_BatDchLmt_W 100 90 80 70 60 50 40 30 20 10 0 10 9 8 7 6 5 4 3 2 1 0 SOC 40% Vehicle Speed N 2000 2500 3000 3500 4000 4500 5000 Time s
Reference	

11.05.01.18 Shift pattern for extreme condition of high voltage battery

<table>
<tr><td colspan="2">Title : Shift pattern for extreme condition of high-voltage battery</td></tr>
<tr><td>Purpose</td><td>To change the shift pattern to accommodate the extreme condition</td></tr>
<tr><td>Action: Functional Description</td><td>

Select the below shift map to increase engine speed for compensate for low battery power



</td></tr>
<tr><td>Parameters (I/O)</td><td>

IN

- Battery discharge power

OUT

- Shift map selection

</td></tr>
<tr><td>Entry Conditions</td><td>

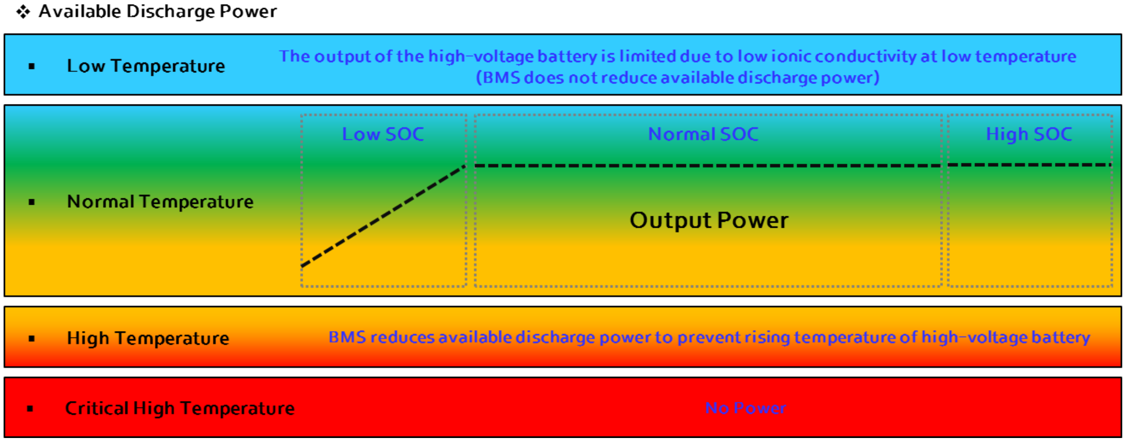
Activating Condition

- BMS-determined available battery discharge power < 8 W

Deactivating Condition

- BMS-determined available battery discharge power > 104 W

</td></tr>
<tr><td>Further information</td><td>



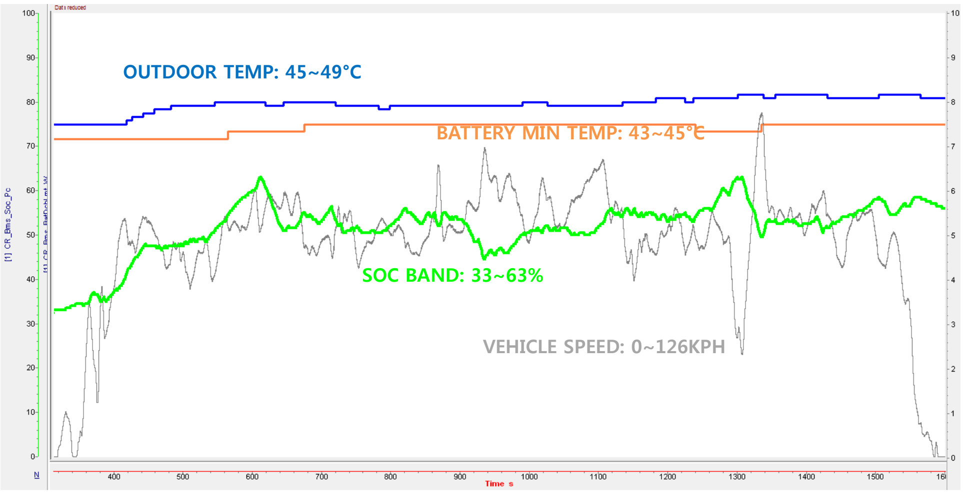
The output of the high-voltage battery is limited due to low ionic conductivity at low temperature (BMS does not reduce available discharge power)

BMS reduces available discharge power to prevent rising temperature of high-voltage battery

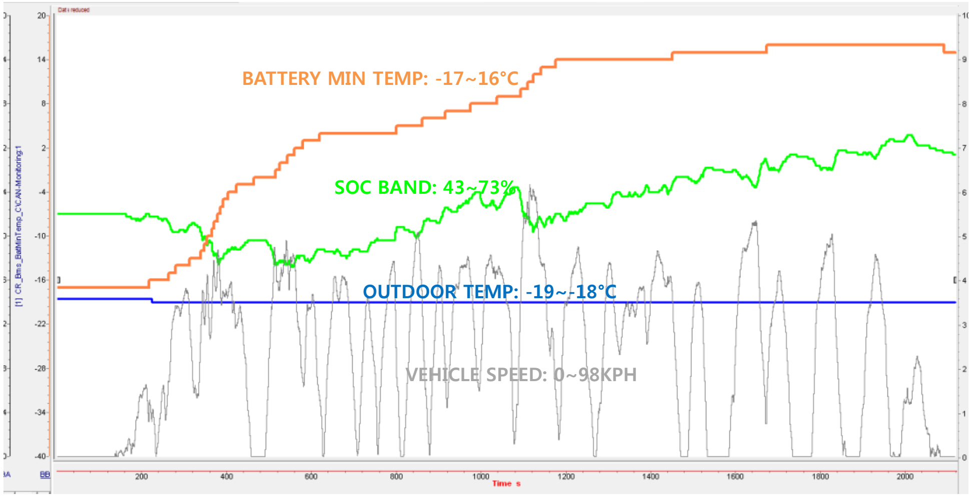
It occurs in the extreme condition (low temperature -30℃ or high temperature 57℃)

Real driving test @ Death valley (high ambient air temperature)

</td></tr>
</table>



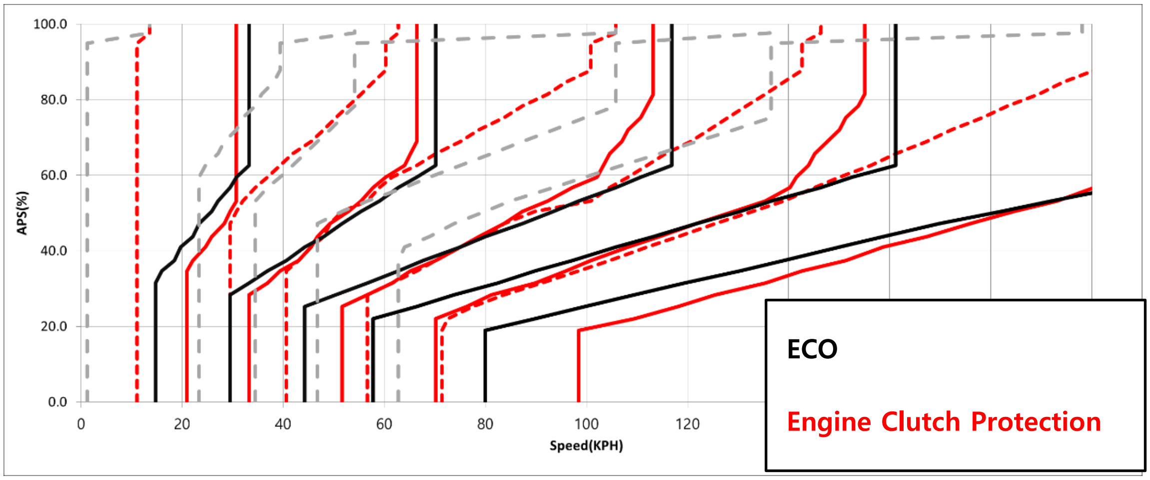
Real driving test @ Alaska (low ambient air temperature)



Reference

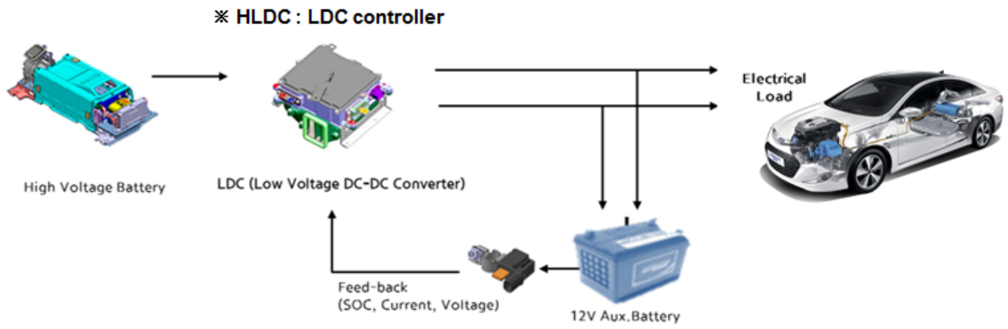
11.05.01.19 PHEV Charge Depleting shift pattern – N/A

11.05.01.20 Engine clutch protection

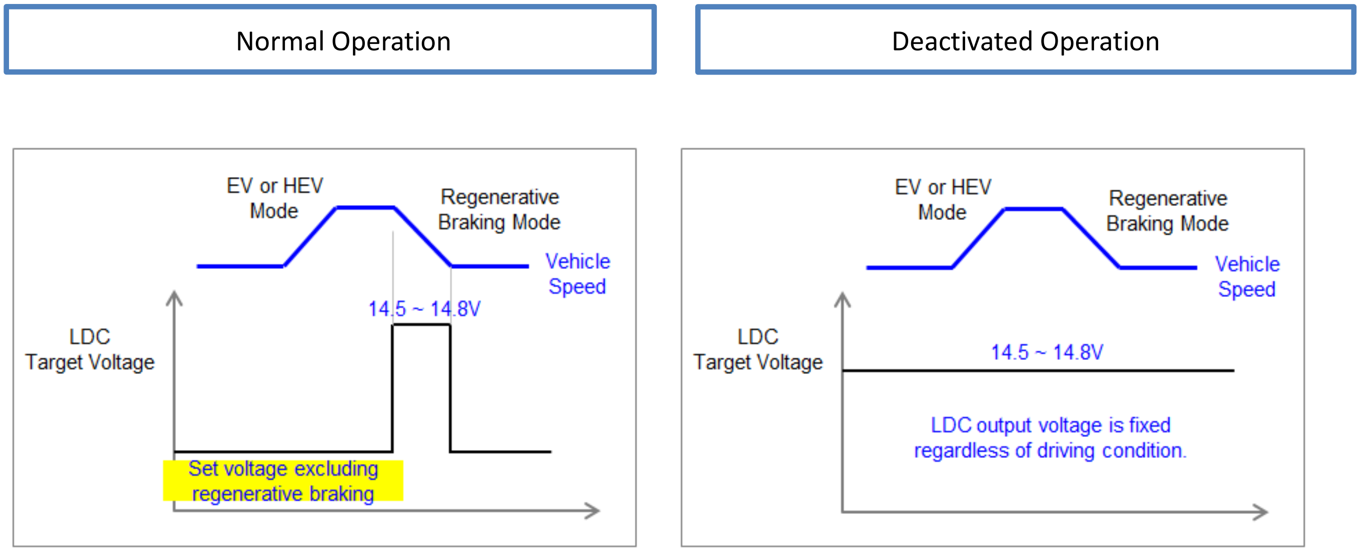
Title : Engine clutch protection	
Purpose	To protect for engine clutch against high temperature
Action: Functional Description	See shift pattern below 
Parameters (I/O)	**IN** - Engine clutch temperature - Motor rotating speed **OUT** - Shift map selection
Entry Conditions	**Activating Condition** Engine clutch temperature > 200℃ **Deactivating Condition** Engine clutch temperature < 180℃ **or** Motor rotating speed > 2000 rpm
Reference	

11.05.02 Low voltage battery control

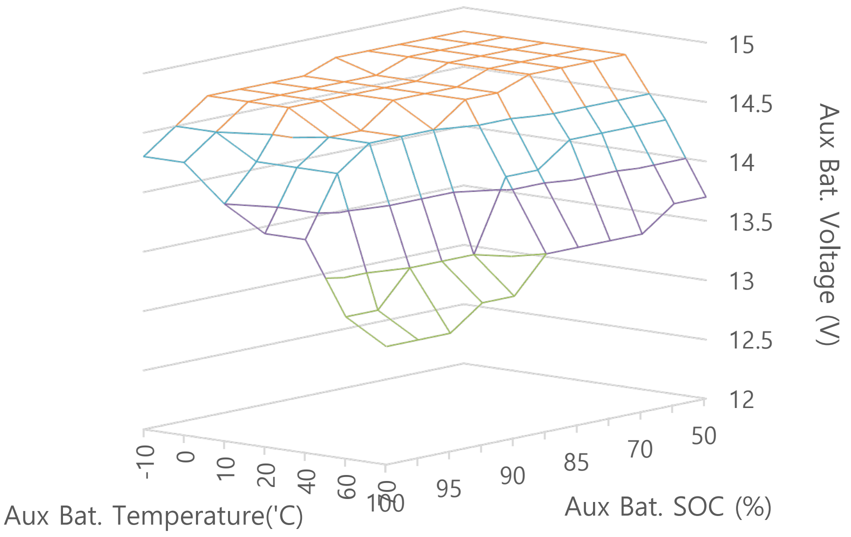
LDC supplies the electrical power to vehicle electrical systems in HEV instead of the alternator. It is important to optimize the output power of the LDC to improve system efficiency. In order to achieve this, the LDC's output voltage is controlled as below.



[Low Voltage Control for auxiliary Battery] Equipped



Set voltage excluding regenerative braking



Low voltage battery control is the control normally active unless other protection modes that require the driver's safety are activated.

Constant voltage output request from other system

- Max blower operation
- Radiator cooling fan operation
- Head lamps operation
- Wipers operation
- Rear Window Defogger operation
- Delivery Mode (except for Aux. battery in high temperature)
- Sports driving Mode

11.05.03 Idle Stop & Go Reengagement - N/A

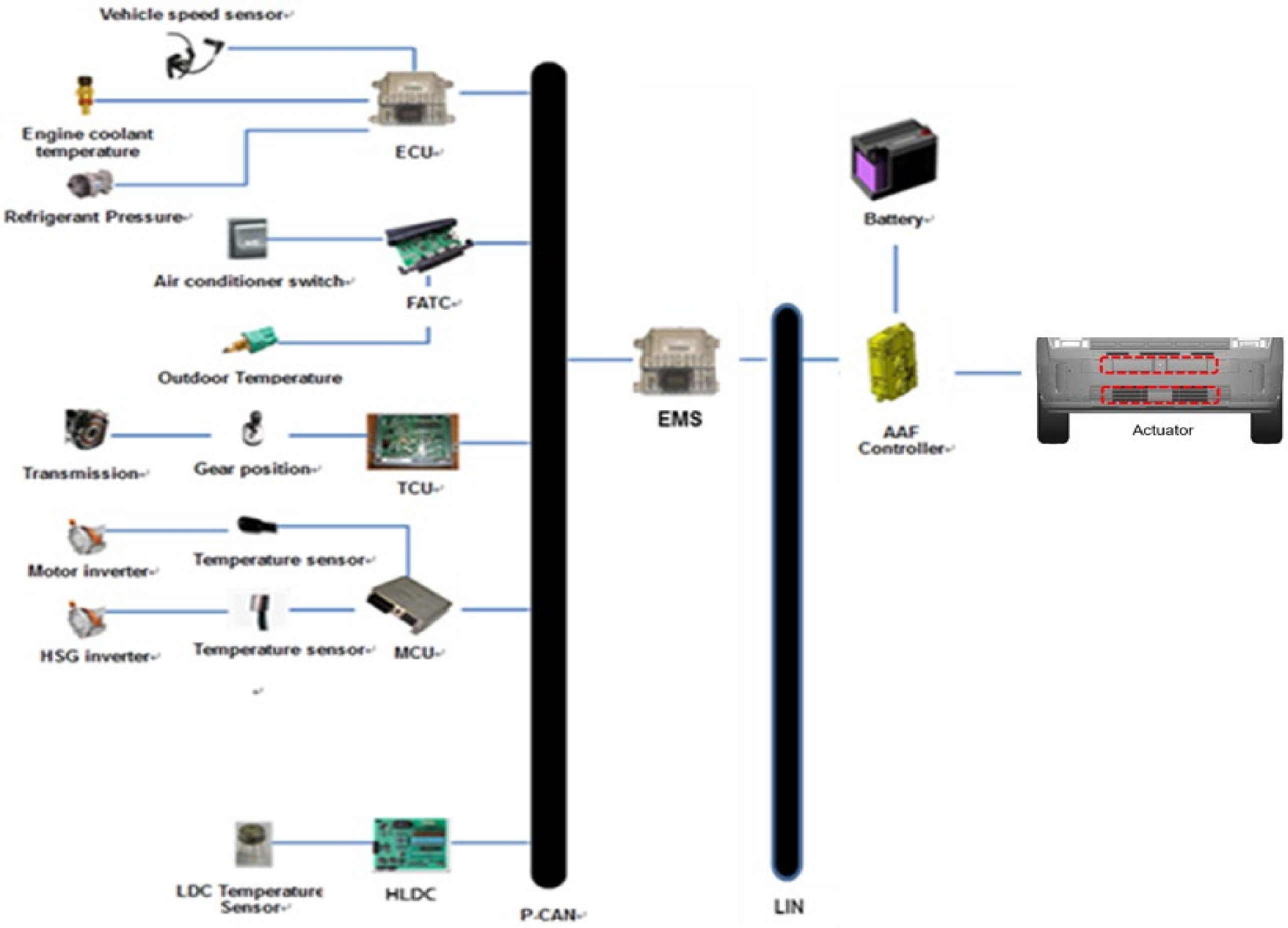
11.05.04 Neutral control - N/A

11.05.05 Active air flap

Active air flap system has a flap, which can be open and closed, between radiator and radiator grill. The flap is closed while the vehicle maneuver fast in order to reduce the air drag and improve driving stability. If the temperature of engine room increases to certain degree that might cause some thermal damages, the flap is open and cool down the engine room.

- Flap is open in high temperature condition by checking temperature of main parts (engine coolant temperature, motor inverter temperature, HSG inverter temperature, LDC temperature, transmission oil temperature)
- Flap is open when the air-conditioner is on to regulate the pressure of refrigerant
- Flap is closed to ree air drag and improve fuel economy

System configuration



Details

- **AAF fail-safety mode**

  The flap necessarily has to be open in case of any malfunction of any part of AAF system in order to protect parts from thermal damage.

- **Engine thermostat diagnosis mode**

ECU thermostat diagnosis process requires certain amount of air flow. So the flap is open in advance.

- **Safe mode**
  The flap is open in advance to prevent adherence that can be caused by high speed driving wind (over 150KPH(93.2MPH))

- **High-fan mode**
  The flap is open if the fan state is high

- **Normal mode**
  AAF control by temperatures: engine coolant, transmission oil, motor inverter, HSG inverter and LDC
  AAF is open if the temperature of any of above parts is higher than open reference temperature. Otherwise AAF is closed. These reference temperatures use hysteresis in order to prevent frequent opening and closing.

- **High engine load mode**
  If the vehicle needs excessive driving performance, such as rapid acceleration, while the flap is closed, the temperature of main parts can increase dramatically. In order to prevent thermal damages on parts, Open/close reference temperature has to be lowered. So in high engine load mode, all the open/close reference temperature tables are adjusted by revision map.

- **High vehicle speed mode**
  In the high vehicle speed mode, the flap is more likely to be closed in order to reduce the air drag.

- **Air conditioner mode**
  AAF in air conditioner mode is controlled by fan state and the pressure of refrigerant (APT). The flap is open when the fan is faster than ‘low’ state(A/C switch ON and compressor power>0W) or when the pressure of refrigerant is higher than reference pressure. Otherwise, the flap is closed.

- **Intercooler Efficiency prior mode**
  If the temperature of intercooler outlet is too high, while the flap is closed, the power of engine can be decreased. In order to make a driver-demand power without deduction of engine power, the flap is open when acceleration pedal value is higher than reference.

- **Low vehicle speed mode**
  While the vehicle maneuver slowly, the control range, which opens flap, is widened in order to cool down.

- **Intake air temperature control mode**
  AAF is open if intake air temperature is higher than open reference temperature and AAF is closed if the intake air temperature is lower than close reference temperature. The open/close reference temperature uses hysteresis in order to prevent frequent opening and closing.
  The open/close reference temperature varies from HEV mode to EV mode. The HEV/EV mode is determined by engine speed.

- **Upper and lower flap separation control mode**
  When the vehicle has two flaps, upper and lower, the above modes can be operated to each flap separately.

AECD Title : Active air flap	
Purpose	Active Air Flap system has a flap, which can be open and closed, between radiator and radiator grill. The flap is closed while the vehicle maneuver fast in order to reduce the air drag and improve driving stability. If the temperature of engine room increases to certain degree that might cause some thermal damages, the flap is open and cool down the engine room.
Action: Functional Description	AAF is normally closed but the flap is open only to cool down or prevent any malfunction of hardware that could happen because of thermal damages. The conditions that open AAF are listed below. AAF open/close threshold condition - Engine coolant temperature - Motor inverter temperature condition - HSG inverter temperature condition - LDC temperature condition - Transmission oil temperature condition - High engine load condition - High vehicle speed condition - Air conditioner status condition - Safe mode condition - High fan mode condition - AAF control mode by intake air temperature - Low speed mode condition - AAF fail safety mode condition - Acceleration pedal position
Parameters (I/O)	**IN** - Vehicle speed - Engine speed - Engine coolant temperature - Cooling/condenser fan on/off status - Cooling/condenser fan state - Active air flap open request by ECU - Calculated load value by ECU - APT(Refrigerant) value - Engine oil temperature - Intake air temperature - A/C request switch - A/C compressor consumption power - Motor inverter temperature - HSG inverter temperature - LDC fault status - LDC temperature - Ambient air temperature - Transmission oil temperature - Acceleration pedal position - Engine oil temperature - Cruise control status

	OUT - Actuator flap open status - AAF mode status
Entry Conditions	**Activating(AAF Open) / Deactivating(AAF Close) Conditions** 1. AAF fail-safety mode condition **Activating condition** If bellow error conditions are set, AAF opens **Deactivating condition** If bellow error conditions aren't set, AAF doesn't open ① P-Can bus off error ② Delay error of CAN signal reception ③ CAN timeout error ④ Input sensed signal error 2. Safe mode condition **Activating condition** Vehicle speed > 150 km/h (93.2 mile/h) **Deactivating condition** Vehicle speed ≤ 140 km/h (87.0 mile/h) 3. High fan mode condition **Activating condition** ECU fan status = 'High' **Deactivating condition** ECU fan status ≠ 'High' 4. Normal mode 1) Engine coolant temperature condition **Activating condition** Engine coolant temperature > open threshold **Deactivating condition** Engine coolant temperature ≤ close threshold

[Flap 1]

Ambient air temperature(°C)	-40	25	30	38	38.5	39	39.5	40	45	50
Open threshold (engine coolant temperature(°C))	99.5	99.5	99.5	99.5	95.5	87	76	62	52	45
Close threshold (engine coolant temperature(°C))	96.0	95	93.5	93.5	85	74	60	44	32	25

[Flap 2]

Ambient air temperature(°C)	-40	25	30	38	38.5	39	39.5	40	45	50
Open threshold (engine coolant temperature(°C))	99.5	99.5	99.5	99.5	95.5	87	76	62	52	45
Close threshold (engine coolant temperature(°C))	96.0	95	93.5	93.5	85	74	60	44	32	25

2) Motor inverter temperature condition

Activating condition

Motor inverter temperature > open threshold

Deactivating condition

Motor inverter temperature ≤ close threshold

[Flap 1]

Ambient air temperature(°C)	-40	0	10	38	38.5	39	39.5	40	45	50
Open threshold (engine coolant temperature(°C))	100	100	105	105	103	99	95	90	83	74
Close threshold (engine coolant temperature(°C))	95	95	100	100	96	92	87	80	70	60

[Flap 2]

Ambient air temperature(°C)	-40	0	10	38	38.5	39	39.5	40	45	50
Open threshold (engine coolant temperature(°C))	100	100	105	105	103	99	95	90	83	74
Close threshold (engine coolant temperature(°C))	95	95	100	100	96	92	87	80	70	60

3) HSG inverter temperature condition

Activating condition

HSG inverter temperature > open threshold

Deactivating condition

HSG inverter temperature ≤ close threshold

[Flap 1]

Ambient air temperature(°C)	-40	0	10	38	38.5	39	39.5	40	45	50
Open threshold (HSG inverter temperature(°C))	71	71	71	71	68	63	57	50	44	35
Close threshold (HSG inverter temperature(°C))	65	65	65	65	60	54	47	40	31	20

[Flap 2]

Ambient air temperature(°C)	-40	0	10	38	38.5	39	39.5	40	45	50
Open threshold (HSG inverter temperature(°C))	71	71	71	71	68	63	57	50	44	35
Close threshold (HSG inverter temperature(°C))	65	65	65	65	60	54	47	40	31	20

4) LDC temperature condition

Activating condition

LDC temperature > open threshold

Deactivating condition

LDC temperature ≤ close threshold

[Flap 1]

Ambient air temperature(°C)	-40	0	10	38	38.5	39	39.5	40	45	50
Open threshold (LDC temperature(°C))	71	71	71	71	68	63	57	50	44	35
Close threshold (LDC temperature(°C))	65	65	65	65	60	54	47	40	31	20

[Flap 2]

Ambient air temperature(°C)	-40	0	10	38	38.5	39	39.5	40	45	50
Open threshold (LDC temperature(°C))	71	71	71	71	68	63	57	50	44	35
Close threshold (LDC temperature(°C))	65	65	65	65	60	54	47	40	31	20

5) Transmission oil temperature condition

Activating condition

Transmission oil temperature >Activating Threshold

Deactivating condition

Transmission oil temperature ≤Deactivating Threshold

[Flap 1]

Ambient air temperature(°C)	-40	0	10	38	38.5	39	39.5	40	45	50
Activating(Open) Transmission oil temperature (°C)	110	110	110	110	106	98	90	80	70	60
Deactivating(Close) Transmission oil temperature (°C)	100	100	100	100	90	82	70	60	50	10

[Flap 2]

Ambient air temperature(°C)	-40	0	10	38	38.5	39	39.5	40	45	50
Activating(Open) Transmission oil temperature (°C)	110	110	110	110	106	98	90	80	70	60
Deactivating(Close) Transmission oil temperature (°C)	100	100	100	100	90	82	70	60	50	10

5. High engine load mode (correction value)

When this mode is activated, open/close thresholds are adjusted by below correction value.

Open/close threshold = normal mode open/close threshold + correction value

Activating condition

Engine speed ≥ 3500rpm

and

Engine load by ECU ≥ 70.2%

and

maintain condition for more than 5 seconds

Deactivating condition

Engine speed < 3300rpm

or

Engine load by ECU < 54.6%

Correction value
Open correction value : -10°C
Close correction value : -10°C

6. High vehicle speed mode (correction value)
When this mode is activated, open/close thresholds are adjusted by below correction value.
Open/close threshold = base mode open/close threshold + correction value
Activating condition
Vehicle speed ≥ 80km/h (49.7mile/h)
and maintain condition for more than 5 seconds

Deactivating condition
Vehicle speed < 75km/h (46.6mile/h)
and maintain condition for more than 5 seconds

Correction value
1) The temperature threshold of normal mode

① Engine coolant temperature correction

Open correction value: +5.5°C

Close correction value: +5.5°C

② Motor inverter temperature correction:

Open correction value: +2°C
Close correction value: +4°C

③ HSG inverter temperature correction:

Open correction value: +2°C

Close correction value: +4°C

④ LDC temperature condition correction:

Open correction value: +2°C

Close correction value: +4°C

⑤ Transmission oil temperature condition correction:

Open correction value: +0°C

Close correction value: +6°C

2) The refrigerant pressure threshold of air conditioner mode

Open correction value: +1380 hPa

Close correction value: +2068 hPa

7. Air conditioner status condition

1) ECU fan speed condition

Activating condition

ECU fan speed status ≥ Low speed status

and

A/C switch on

and

A/C compressor power > 0W

Deactivating condition : If activating condition is not satisfied

2) Refrigerant pressure condition

Activating condition

Refrigerant pressure > open threshold

Deactivating condition

Refrigerant pressure ≤ close threshold

[Flap 1]

Ambient air temperature(°C)	-40	0	10	38	38.5	39	39.5	40	45	50
Open threshold (Refrigerant pressure(hPa))	13790	13790	13790	13790	11032	8964	7584	6206	5516	4826
Close threshold (Refrigerant pressure(hPa))	10342	10342	10342	10342	8274	6206	4826	3448	2758	2068

[Flap 2]

Ambient air temperature(°C)	-40	0	10	38	38.5	39	39.5	40	45	50
Open threshold (Refrigerant pressure(hPa))	13790	13790	13790	13790	11032	8964	7584	6206	5516	4826

Close threshold (Refrigerant pressure(hPa))	10342	10342	10342	10342	8274	6206	4826	3448	2758	2068

8. Low speed mode condition

Activating condition

- Vehicle speed ≤ 55km/h
  and (Engine coolant temperature > Open threshold
  or Engine oil temperature > Open threshold)
- and maintain condition for more than 5 seconds

Deactivating condition

- Vehicle speed ≥ 65km/h
  or (if activated by coolant temperature) Engine coolant temperature ≤ Close threshold
  or (if activated by oil temperature) Engine oil temperature ≤ Close threshold
- and maintain condition for more than 5 seconds

[Flap 1]

Ambient air temperature(°C)	-40	25	30	38	38.5	39	39.5	40	45	50
Open threshold (engine coolant temperature(°C))	80	80	80	80	80	80	80	80	80	80
Close threshold (engine coolant temperature(°C))	70	70	70	70	70	70	70	70	70	70

[Flap 2]

Ambient air temperature(°C)	-40	25	30	38	38.5	39	39.5	40	45	50
Open threshold (engine coolant temperature(°C))	80	80	80	80	80	80	80	80	80	80
Close threshold (engine coolant temperature(°C))	70	70	70	70	70	70	70	70	70	70

[Flap 1]

Ambient air temperature(°C)	-40	25	30	38	38.5	39	39.5	40	45	50

Open threshold (engine oil temperature(°C))	85	85	85	85	85	85	85	85	85	85
Close threshold (engine oil temperature(°C))	80	80	80	80	80	80	80	80	80	80

[Flap 2]

Ambient air temperature(°C)	-40	25	30	38	38.5	39	39.5	40	45	50
Open threshold (engine oil temperature(°C))	85	85	85	85	85	85	85	85	85	85
Close threshold (engine oil temperature(°C))	80	80	80	80	80	80	80	80	80	80

9. AAF control mode by intake air temperature

Activating condition

Intake air temperature > Open threshold

Deactivating condition

Intake air temperature ≤ Close threshold

1) [Flap1] in the HEV Mode

Ambient air temperature(°C)	-40	-10	0	10	20	25	30	38	40	50
Open threshold (intake air temperature(°C))	57	57	57	57	57	57	57	57	55	55
Close threshold (engine oil temperature(°C))	47	47	47	47	47	47	53	53	50	50

2) [Flap1] in the EV Mode

Ambient air temperature(°C)	-40	-10	0	10	20	25	30	38	40	50
Open threshold (intake air temperature(°C))	62	62	62	62	62	62	62	62	60	60

Close threshold (engine oil temperature(°C))	47	47	47	47	47	47	53	53	50	50

3) [Flap2] in the HEV Mode

Ambient air temperature(°C)	-40	-10	0	10	20	25	30	38	40	50
Open threshold (intake air temperature(°C))	57	57	57	57	57	57	57	57	55	55
Close threshold (engine oil temperature(°C))	47	47	47	47	47	47	53	53	50	50

4) [Flap2] in the EV Mode

Ambient air temperature(°C)	-40	-10	0	10	20	25	30	38	40	50
Open threshold (intake air temperature(°C))	62	62	62	62	62	62	62	62	60	60
Close threshold (engine oil temperature(°C))	47	47	47	47	47	47	53	53	50	50

10. Intercooler efficiency prior control mode

Activating condition

Not active cruise control operating

Acceleration pedal position > Open threshold

Deactivating condition

If activation condition is not satisfied.

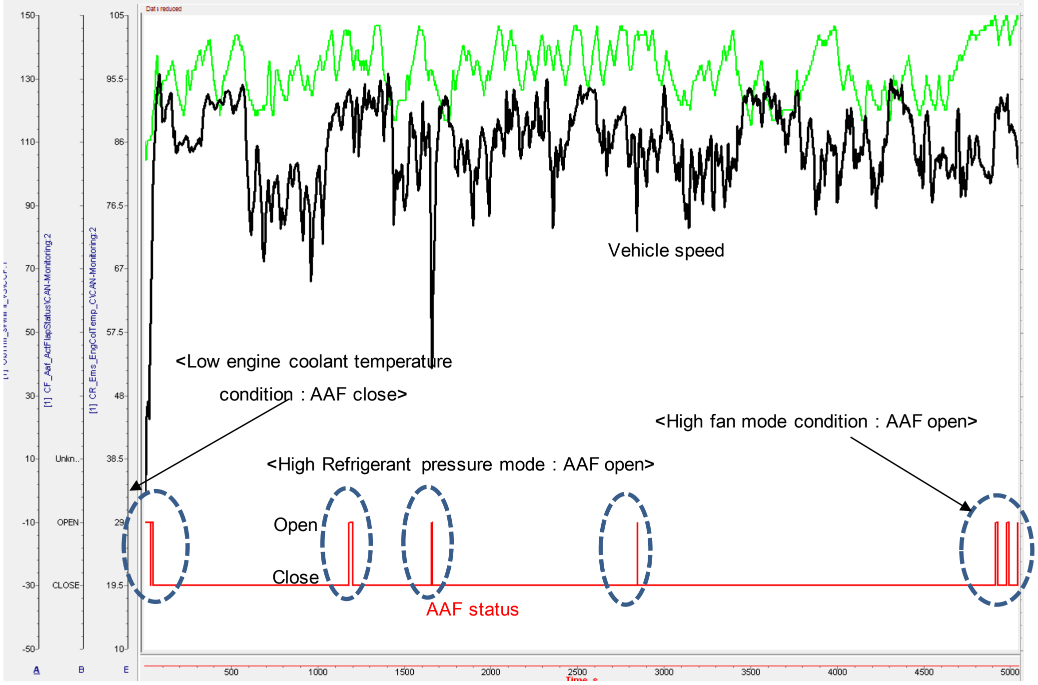
[Flap 1]

Open threshold = 92

[Flap 2]

Open threshold = 92

In-use Frequency	AAF operation by engine coolant temperature and vehicle speed during normal driving

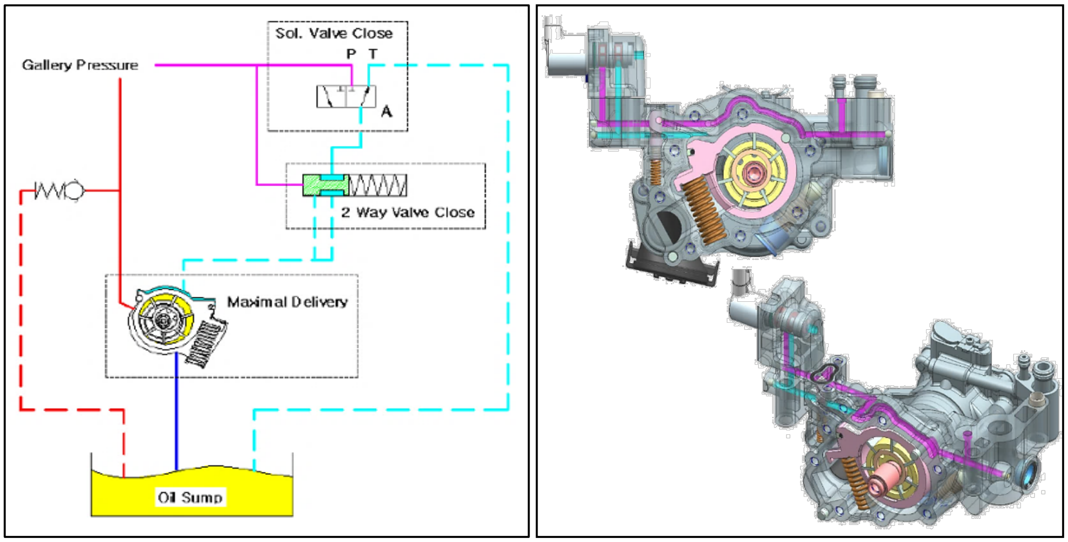
	
Emission impact	CO2 improvement
Justification	A. Substantially included during regulated test procedures FTP75, HwFET, US06, SC03,FTP75@-7℃ F. Base control
Reference	

11.05.06 Exhaust heat recovery system (EHRS) – N/A

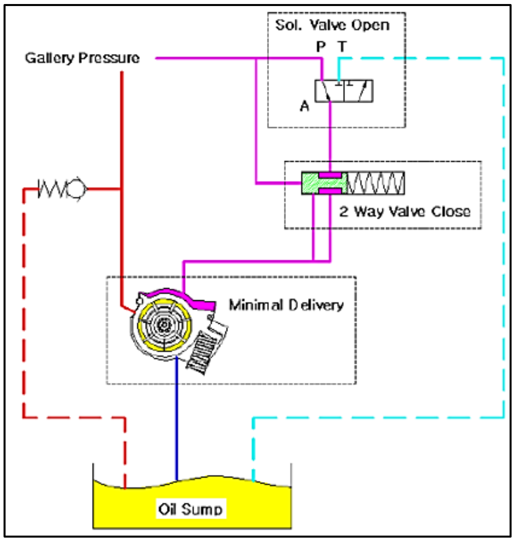
11.05.07 Variable Displacement Oil Pump System

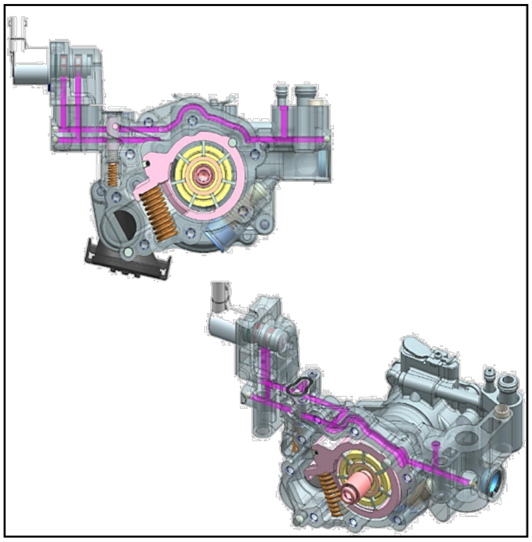
Variable Displacement Oil Pump System is an electronic oil pressure feedback control system which controls oil pressure of the engine lubrication system. The system runs according to engine operating condition by integrating variable oil pump, sensors and control logic. Variable Displacement Oil Pump System is controlled by proportional solenoid valve using hydraulic pressure of the engine oil and mapped according to the rpm, torque and oil temperature. The Variable Displacement Oil Pump System is beneficial for fuel economy by reducing oil pressure during normal driving condition.

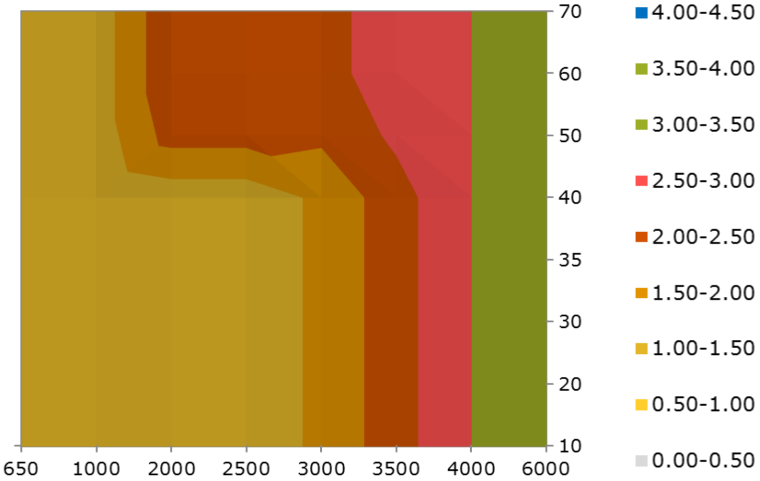
<Solenoid Off – High pump displacement>



<Solenoid On – Low pump displacement>







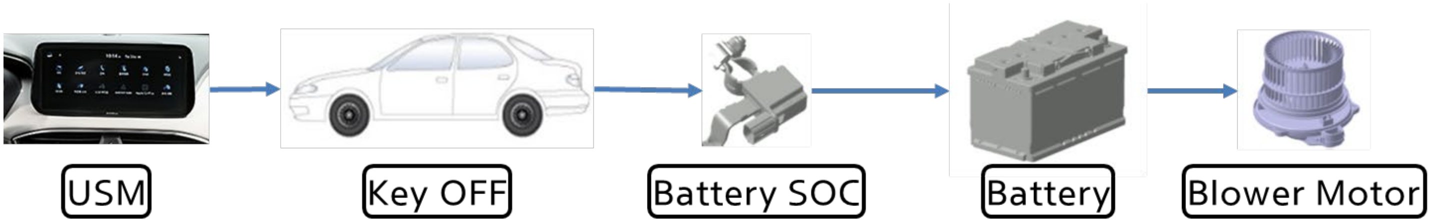
Axis: x (Engine speed, RPM) y (Required torque demand, %), z (engine oil pressure, bar)

The Variable Displacement Engine engagement and torque control strategy System control is a base control generally active except extreme low temperature of engine oil reduces to ensure reliability.

Deactivation condition: engine oil temperature < - 20 ℃

11.05.08 Active Cabin Ventilation

The active cabin ventilation function uses a mechanical device during parking to exhaust hot air inside the vehicle to cool the inside temperature of the vehicle. The function can be activated by the operator setting the operating time via the USM(User Setting Mode) setting. It works only once through the one-time setup of the USM, and if driver want further operation afterwards, driver must set it up again through the USM.

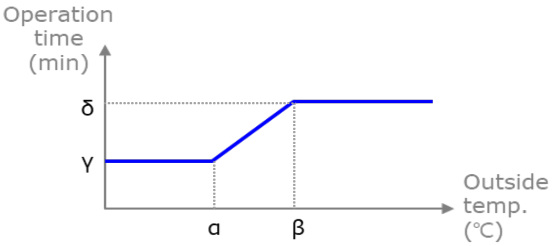


Entry conditions (AND conditions)

- KEY OFF
- The active cabin ventilation function is selected through USM
- When specific ambient temperature condition is met.

Operating specifications

The display and operating specifications at the time of KEY OFF and when the active cabin ventilation function is set after KEY OFF are defined as follows. When the key is off, the blower symbol is displayed to notify the active cabin ventilation function setting status. When the active cabin ventilation function reaches the set time after KEY OFF, it operates as follows.



※ α / β / γ / δ : Cal. value

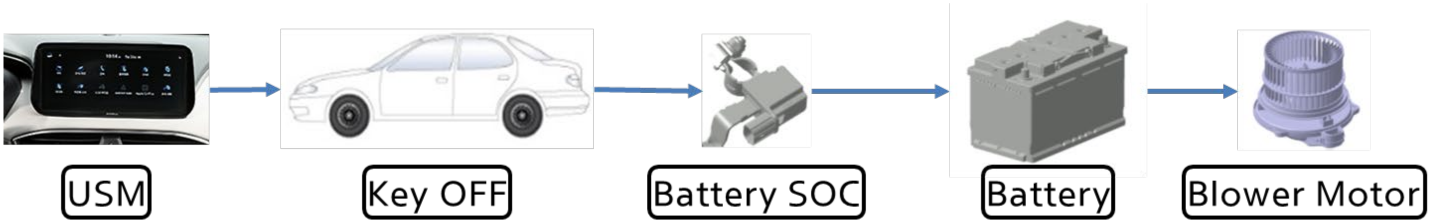
1) In order to notify the active cabin ventilation function, blink the blower symbol ON / OFF repeatedly.
2) The blower is operated by manual two-stage voltage.
3) It operates in the fresh air mode.
4) It operates in vent mode.
5) Temp door operates in the set state when the key is off.

Deactivation condition (OR condition)

- KEY ON
- When the active ventilation operation time has elapsed.

11.05.09 After Blower

The After Blower function uses a mechanical ventilating device during parking to prevent mold formation of the evaporator. The function can be activated by the operator setting via the USM(User Setting Mode) setting.



Action: Functional Description

The display and operating specifications at the time of KEY OFF and when the after blower function is set after KEY OFF are defined as follows. When the key is off, the blower symbol is displayed to notify the after blower function setting status. When the after blower function reaches 30 minutes after KEY OFF, it operates as follows

1. In order to notify the after blower function, display the blower symbol on the LCD.
2. Specific Operation
   - Air intake (Circulation) : It’s operated on fresh air mode(outside air circulation).
   - Fan speed : The blower is operated on level 3 of manual fan speed control mode.
   - Mode (Blower Direction) : It’s operated in previous mode when the key is off.
   - Temperature : Temp door is operated in previous setting when the key is off.

Activating conditions (AND condition)

- KEY OFF
- The After Blower function is selected through USM
- Specific SOC condition is met and SOC is valid.
- When specific ambient temperature condition is met.
- When e-Comp is operated more than certain time.

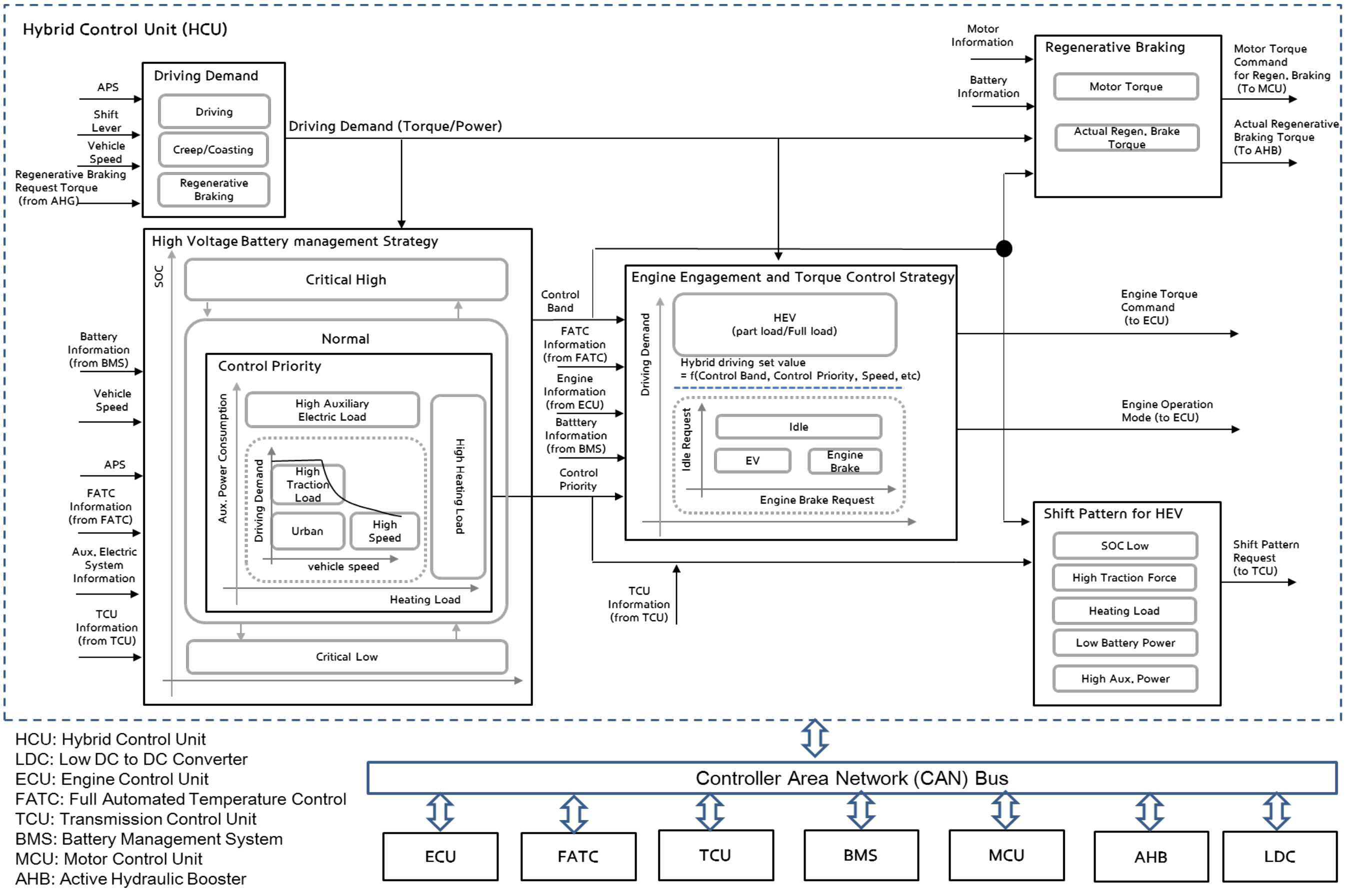
Deactivating condition (OR condition)

- KEY ON
- When the After Blower function time has elapsed
- When entering reservation/remote air conditioning logic

11.06 Hybrid controls

11.06.01 Hybrid control overview

The objective of the hybrid control system is to determine how to use electric power and the engine to maximize the efficiency of the overall system. The main function of the hybrid control system is to determine when the engine turns on or off (engine operation mode), and where the engine operates (engine torque, shift pattern). The function is based on the driving demand, the high voltage battery status, and driving conditions (control priority) considering cabin-heating demand, auxiliary electrical power consumption and road condition. In addition, regenerative braking and LDC control are also the main roles in the hybrid control system. Also, the hybrid control system performs control for exhaust gas reduction of the engine and control for stable operation of the high-voltage battery. The following figure and paragraphs describe a block diagram of the hybrid control system and summary of each function, respectively.



HCU: Hybrid Control Unit
LDC: Low DC to DC Converter
ECU: Engine Control Unit
FATC: Full Automated Temperature Control
TCU: Transmission Control Unit
BMS: Battery Management System
MCU: Motor Control Unit
AHB: Active Hydraulic Booster

<Configuration of hybrid control system>

Driving demand

Driving demand, which is calculated from driver’s operation of acceleration pedal position, brake pedal position, shift lever position, vehicle speed, regenerative braking request torque, etc., is defined by the hybrid control system as the target value that the power source should output to drive the wheels. The driving demand is used as a reference value for engine operation.

High-voltage battery SOC management

One of the most important roles of the hybrid control system is to obtain stable operation of the high-voltage battery so that the SOC is maintained in the normal range. This function monitors the SOC and driving conditions, and classifies the high voltage battery strategy in 3 bands: critical high SOC, normal SOC, and critical low SOC. Based on the SOC, the set point of the engine on/off and the engine operating point are calibrated to maintain the SOC in the normal SOC range.

Control priority

Fuel economy of a vehicle is affected by the driving environment. In particular, HEVs have two different power sources, and it is necessary to optimize the powertrain control in consideration of the driving environment. Thus, this function considers the most influential factors of the fuel economy of the HEV and determines the priority into five levels. The purpose of the prioritization is to determine the optimal set point of the engine start/stop and the optimal engine operating point. This prioritization sets a target that is used in other strategies.

Engine engagement and torque control strategy

This function defines the engine operation mode as EV, HEV, idle, and engine brake, and controls the engine system accordingly. In order to determine the operation mode, it is necessary to consider control priority and high voltage battery SOC strategy, etc. In addition, system demands such as emission and system protection are considered.

Regenerative braking control

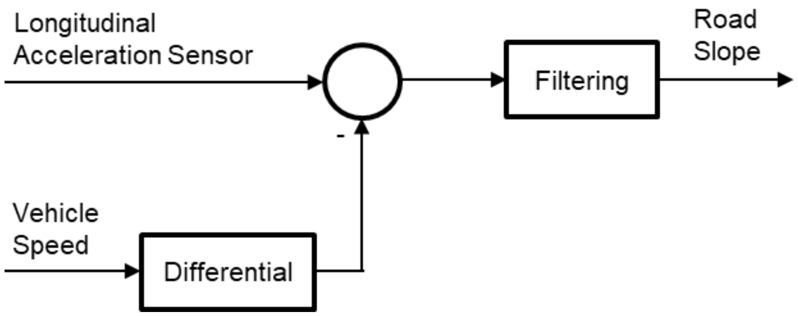
A hybrid system has an electric motor to convert kinetic energy to electrical energy when braking, and stores the energy in the high voltage battery. To manage, the Active Hydraulic Brake (AHB) system coordinates braking torque demand between mechanical and regenerative braking, and the hybrid control system determines motor torque command and actual regenerative braking torque.

Transmission shift pattern request

The shift pattern of the transmission is determined by transmission control unit (TCU). Specific to hybrid vehicles, the shift pattern can be changed upon the request of the hybrid control unit to maintain the hybrid system such as cooling down the engine clutch, maintaining the SOC of a high-voltage battery within the normal range, etc. Thus the hybrid control system requests TCU to select hybrid system specified shift pattern.

Road Slope Estimation

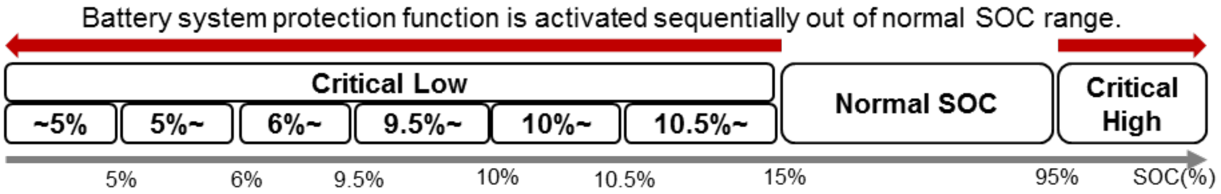
Road slope is estimated by a longitudinal acceleration sensor. The longitudinal acceleration sensor includes sensor noise, longitudinal acceleration term and slope term. In order to extract the slope term, it is necessary to eliminate sensor noise and longitudinal acceleration term from the longitudinal acceleration sensor value. Following figure shows how to estimate the road slope based on the longitudinal acceleration sensor.



The road slope is converted to the road slope level so that each function can use the discrete quantity of the road slope. Following table shows the road slope level regarding estimated road slope range.

11.06.02 High voltage battery SOC management

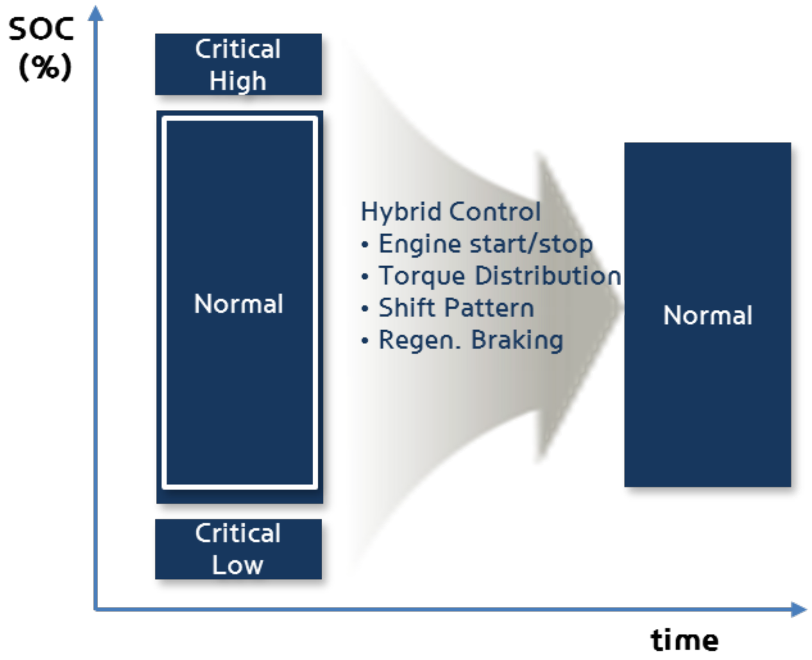
One of the most important roles of the hybrid control system is to maintain stable operation of the high-voltage battery. If the high voltage battery is overcharged or completely discharged repeatedly, this will shorten the life of the high voltage battery. Thus, the normal SOC band is defined, and if the SOC of the high voltage battery is out of the normal band, the battery system protection function is performed. The following figure provides more detail of the protection function.

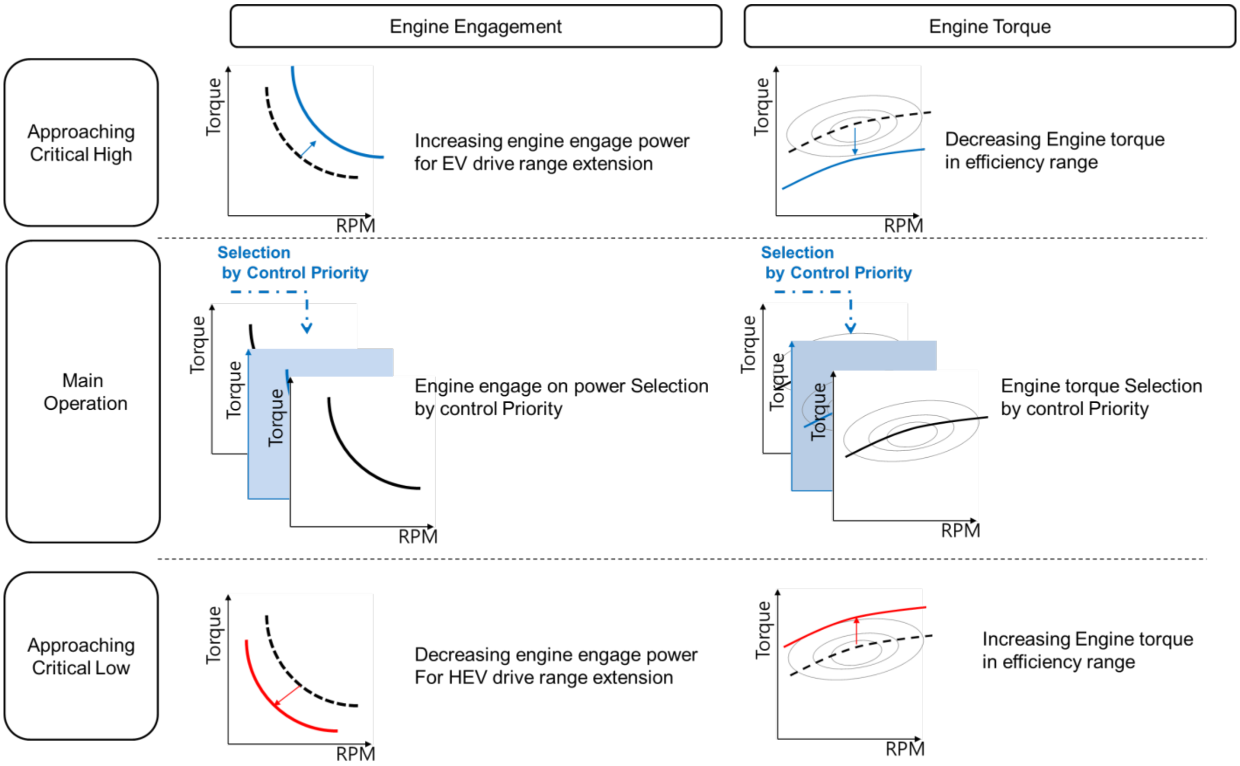


Band	SOC	Battery system protection function
Critical high	95%~	EV operation as much as possible, regenerative braking is prohibited.
Normal	15%~95%	Normal operation
Critical low	10.5% ~15%	Discharge of electric motor and HSG is limited.(Engine cranking is allowed) "Battery SOC is low" warning sign is illuminated if it is once illuminated. "Battery SOC is low" warning sign is disabled after SOC reaches 15%.
	10%~10.5%	Warning in a cluster as “Battery SOC is low” illuminated Battery discharge of the electric motor and HSG is prohibited.
	9.5%~10%	Battery discharge of A/C and LDC is prohibited. Vehicle speed is limited.
	6%~9.5%	Warming in the cluster as “Do not drive”
	5%~6%	High voltage battery relay is switched off.
	~5%	Vehicle stops operating.

In addition to the battery protection function, we classify the high voltage battery strategy as 3-band so that the hybrid control system obtains high fuel economy and system protection. Based on these criteria, the set point of the engine start/stop and the engine operating point are calibrated to keep the SOC in the normal SOC band.

- **Normal band**
  Within this band, the hybrid control system can mainly focus on the fuel economy rather than the system protection. Various calculations and strategies are employed to maximize the vehicle operation. All control parameters such as the set point of the engine start/stop, engine operating point, shift pattern, etc. are selected to the optimal values considering the driving environment. The kinetic energy of the vehicle is converted into electric energy as much as possible when braking. As the battery SOC approaches either the critical high or critical low band, the control parameters are adjusted in order to prevent the SOC from escaping the normal band in advance.





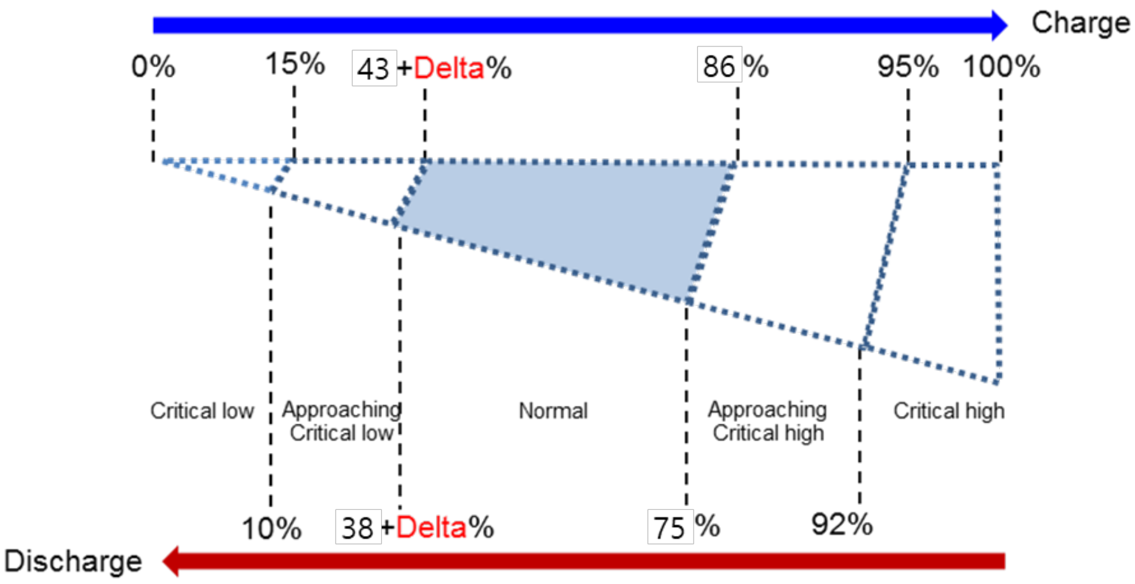
- **Critical low band (refer to AECD *"11.06.02.01 SOC management - critical low band"*)**
  The hybrid system in the critical low band is controlled to charge the high voltage battery much faster than the low band. The methods used to raise the SOC become more aggressive the lower the SOC becomes.

- **Critical high band (refer to AECD *"11.06.02.02 SOC management - critical high band"*)**
  In the band of critical high, the hybrid system is controlled to consume the electric energy as much as possible so that the SOC moves into the normal range quickly.

SOC band selection

Below is a figure that demonstrates the SOC band selection. The transition within the Normal band is not fixed, but is variable ("Delta"). Items considered are road slope, auxiliary electric power consumption, ambient correction factor, vehicle average speed, among others.

Band	Activating/Deactivating condition
Critical high	Activating condition: SOC ≥ 95% Deactivating condition: SOC ≤ 92% * No correction of environment condition
Approaching critical high	Activating condition: SOC ≥ 86% Deactivating condition: SOC ≤ 75% * No correction of environment condition
Main	Activating condition: SOC ≥ (43 + Delta*)% Deactivating condition: SOC ≤ (38 + Delta)%,
Approaching critical low	Activating condition: SOC ≥ 15% Deactivating condition: SOC ≤ 10%
Critical low	Activating condition: SOC ≤ 10% Deactivating condition: SOC ≥ 15% * No correction of environment condition



Delta is calculated by below.
Delta* = Map1 + Map2

Map 1: correction value of vehicle resistance index derived from ambient correction factor and auxiliary electric power

Vehicle resistance index1)	0	1	2	3	4	5
Correction value (%)	0	0	0	0	2	3

1) Vehicle resistance index
an index of the vehicle load according to auxiliary electric power and ambient correction factor.

Vehicle resistance index		Auxiliary electric power(w)		
		0~1600	1600~5600	5600~
Ambient correction factor	0.9~1.0	0	1	3
	0.8~0.9	2	3	3
	~0.8	3	4	5

Map 2: correction value in consideration of vehicle speed index and road slope level.

Correction value (%)		Vehicle speed index2)					
		0	1	2	3	4	5
Road slope level3)	-4	-3	-3	-3	-5	-5	-5
	-3	-3	-3	-3	-5	-5	-5
	-2	0	0	0	0	0	-3
	-1	0	0	0	0	0	0
	0	0	0	0	0	0	0
	1	0	0	0	2	2	3
	2	2	2	2	2	2	3
	3	8	8	8	8	8	8
	4	12	12	12	12	12	12

2) Vehicle speed index

Average vehicle speed(kph)	0~11	11~25	25~65	65~78	78~95	95~
Vehicle speed index	0	1	2	3	4	5

3) Road slope level

Road slope (%)	~-12	-12~ -7.5	-7.5~ -3.7	-3.7~ -2.2	-2.2 2.2	2.2~3.7	3.7~ 7.5	7.5~ 12	12~
Level	-4	-3	-2	-1	0	1	2	3	4

11.06.02.01 SOC management – critical low band

AECD Title : SOC management – critical low band

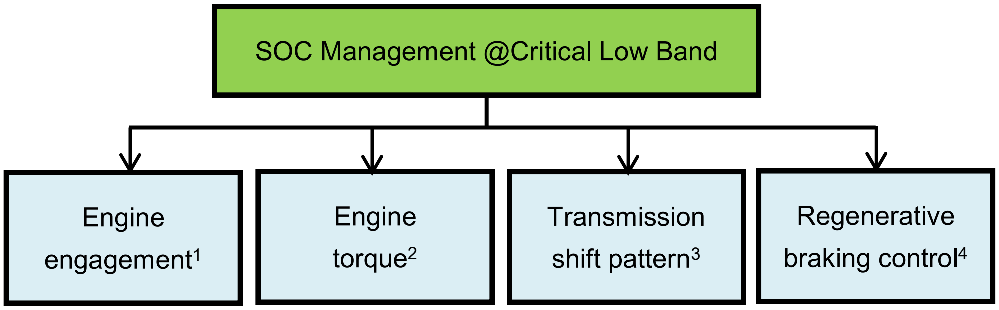
Purpose

To protect high voltage battery at the critical low SOC level

Action: Functional Description

Below are the controls that are simultaneously performed for system protection at the critical low SOC level.

- Engine engagement control is switched to the control map of the critical low SOC status.
- Engine torque is increased according to the torque map for critical low SOC status.
- Transmission shifting point is selected as Charge sustaining SOC pattern to increase charging power.
- Regenerative Braking is prioritized to recover as much energy as possible.



Engine engagement control :

- HEV operation condition : Driving demand power > Table1. (at Gear = D)

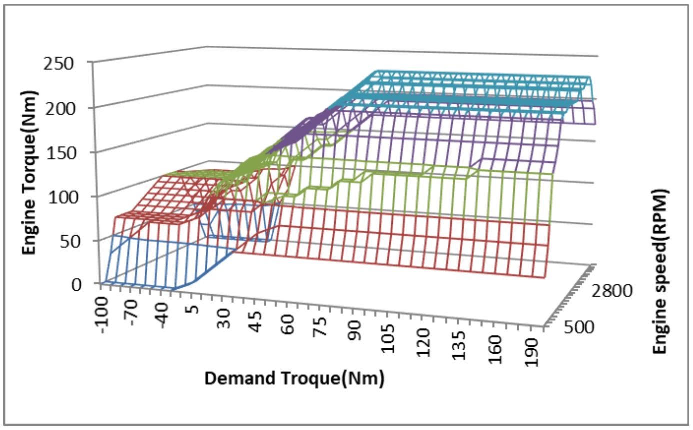
9	10	25	45	80	100	120	140	160	180	200
1304	1304	3000	3000	3000	3000	3000	3000	3000	3000	3000

- Idle operation condition : Driving demand power < Table2. (at Gear = D)

9	10	25	45	80	100	120	140	160	180	200
0	0	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000

Engine torque control :

- Engine base torque



	X axis : Driving demand torque, y-axis: Engine speed Transmission shift pattern : - shift pattern for SOC Low 'Oxygen sensor heating strategy before engine cold start'[5] is restricted due to relying on motor only traction.
Parameters (I/O)	**IN** - State Of Charge (SOC) **OUT** - SOC management band = 'critical low band' - Engine engagement[6] - Engine torque[7] - Shifting pattern request[8]
Entry Conditions	**Activating Condition** SOC ≤ 10% **Deactivating Condition** SOC ≥ 15%
In-use Frequency	The situation of critical low SOC in the real world driving is not appearing except there is empty fuel condition or system has a problem. Also, cluster warning lamp is turned on at the critical low SOC band.
Emission impact	CO2 Emission is increased because engine operation is continuously maintained for vehicle protection.
Justification	G. Electric propulsion system protection
Reference	1. Engine engagement and torque control strategy 2. Engine engagement and torque control strategy 3. Transmission shift pattern 4. Regenerative braking control 5. Oxygen sensor heating strategy before engine cold start 6. Engine engagement and torque control strategy 7. Engine engagement and torque control strategy 8. Transmission pattern

11.06.02.02 SOC management- critical high band

AECD Title : SOC management- critical high band

Purpose

To protect High voltage battery at the critical high SOC level

Action: Functional Description

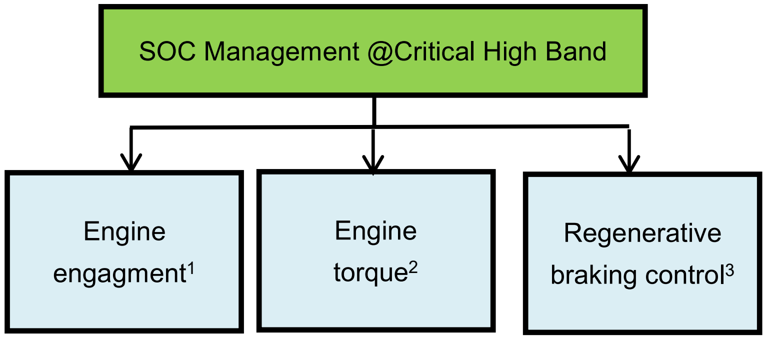
Below are the controls that are simultaneously performed for system protection at the critical high SOC level.

- Engine engagement control is switched to the control map for the critical high SOC status.

- Engine torque is decreased by the torque map for critical high SOC status.

- Regenerative braking is prohibited to protect the battery.

- Engine brake operation is activated at down hill.



Engine engagement control :

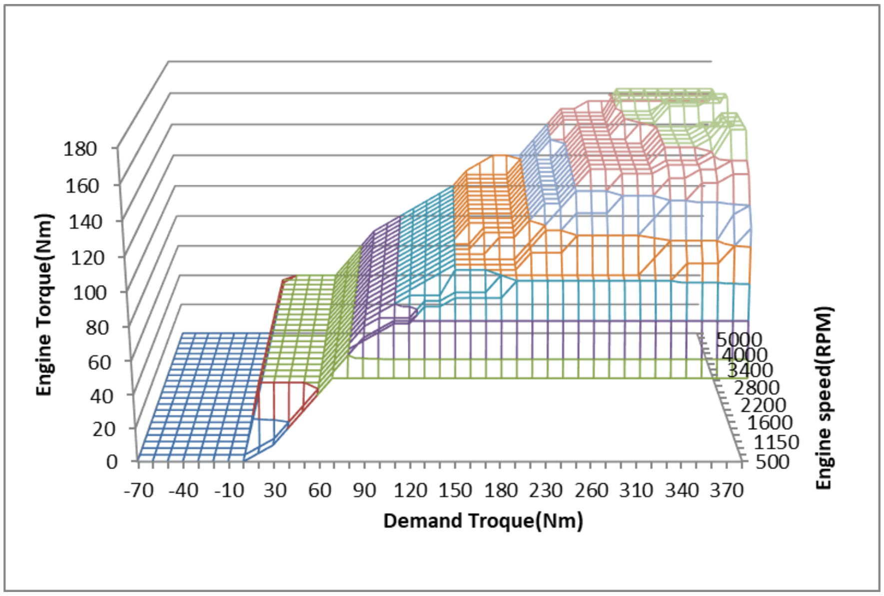
- HEV operation condition: Driving demand power > Table1. (at Gear = D)

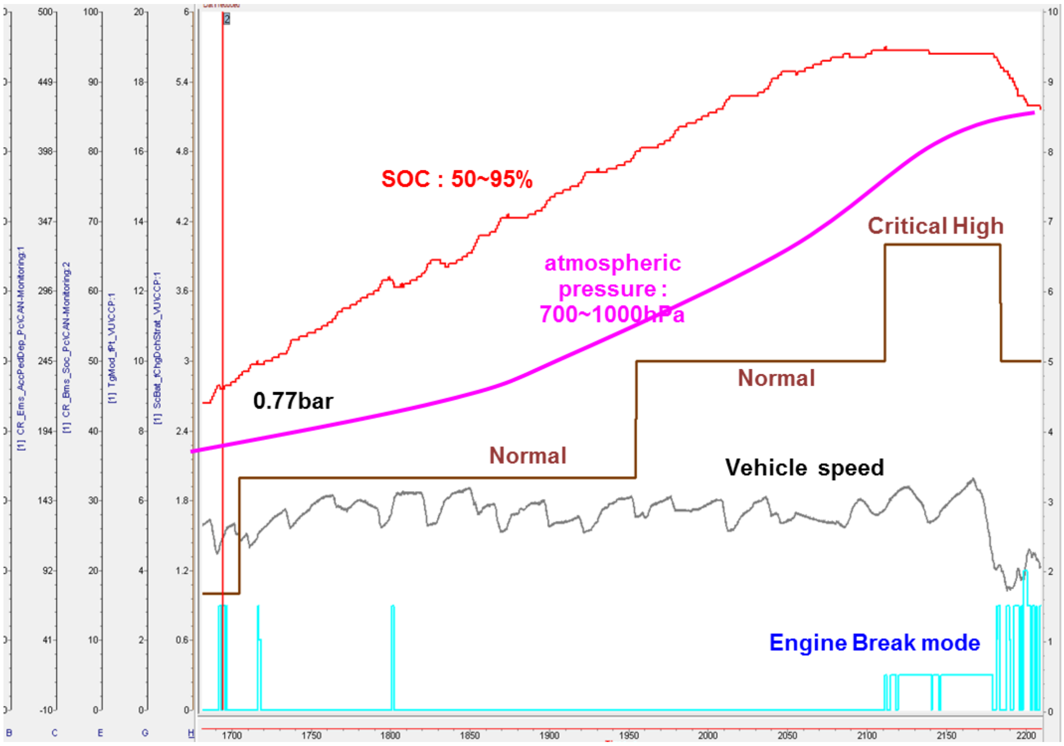
9	10	25	45	80	100	120	140	160	180	200
36000	38000	42000	42000	42000	42000	42000	42000	42000	42000	42000

- Idle operation condition: Driving demand power < Table2. (at Gear = D)

9	10	25	45	80	100	120	140	160	180	200
26000	28000	32000	32000	32000	32000	32000	32000	32000	32000	32000

Engine torque Control :

	 X axis : Driving demand torque, y-axis: Engine speed Regeneration brake is restricted in critical high SOC band. Engine brake operation (fuel cut off control) is activated to protect the high-voltage battery from over-charging risk.
Parameters (I/O)	**IN** - State Of Charge (SOC) **OUT** - SOC management band = 'critical high band' - Engine engagement[4] - Engine torque[5] - Shifting pattern request[6] - Regenerative braking control is prohibited
Entry Conditions	**Activating Condition** SOC ≥ 95% **Deactivating Condition** SOC ≤ 92%
In-use Frequency	The situation of critical high SOC in the real world driving is not appear except long distance downhill (It happens to drive about 11km on Big bear downhill side).

	
Emission impact	Emission and CO2 is improved by EV driving.
Justification	G. Electric propulsion system protection
Reference	1. Engine engagement and torque control strategy 2. Engine engagement and torque control strategy 3. Regenerative braking control 4. Engine engagement and torque control strategy 5. Engine engagement and torque control strategy 6. Transmission pattern

11.06.03 Control priority

Fuel economy of a vehicle is affected by the driving environment. In particular, HEVs have two different power sources, and it is necessary to optimize the powertrain control in consideration of the driving environment. Thus, this function considers the most influential factors of the fuel economy of the HEV and determines the priority into five levels. The purpose of the prioritization is to determine the optimal set point of the engine start/stop and the optimal engine operating point. This prioritization sets a target that is used in other strategies.

- **High heating load**
  In this mode, there is no electric device for heating cabin; therefore, the system is reliant on the thermal energy of the engine coolant. To minimize energy loss, such as frequent engine start/stop and idle operation during winter season, control parameters are optimized focusing on the high load situation for heating the cabin.

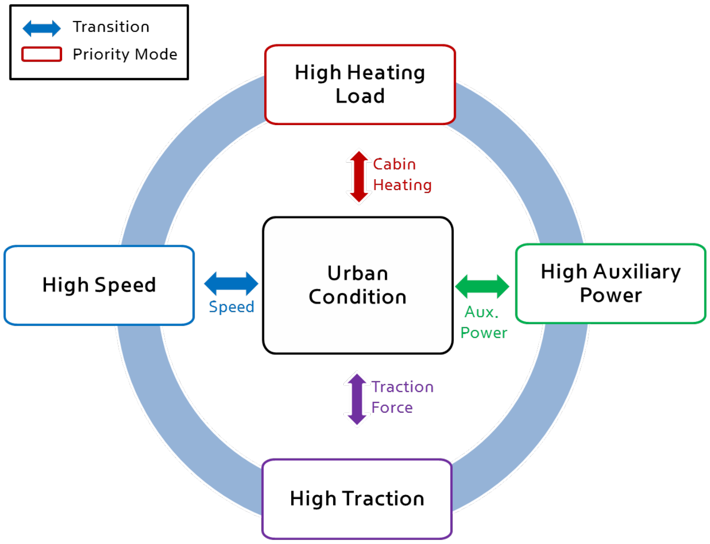
- **High auxiliary electric system power**
  Auxiliary electric system primarily consists of a high voltage A/C compressor, a low DC to DC converter, a high voltage electric oil pump (AT only), and A/C compressor consumption power. In summer season, the fuel economy is worse than spring or fall season due to additional energy consumption from A/C. In order to minimize the energy loss due to the A/C operation, control parameters are optimized in consideration of the A/C operation situation so that the SOC remains in the normal range.

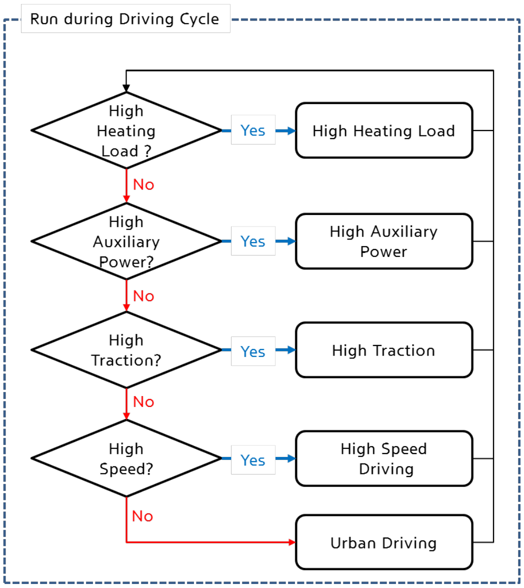
- **High traction driving**
  In this situation, higher traction loads are requested by the hybrid control system. An example is a high acceleration event. Control parameters are optimized in a similar manner to the high auxiliary electric system load.

- **High speed driving**
  At high speeds, the vehicle travels at a constant speed primarily at high speeds. The control parameters are optimized in consideration of such driving characteristics.

- **Urban driving**
  In the urban driving, the vehicle travels at a relatively low speed and repeats acceleration and deceleration, which causes the inefficient engine operation such as frequent start and stop of the engine. The control parameters are optimized in consideration of such driving characteristics.

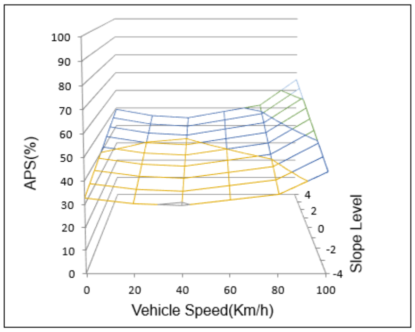
Selection mechanism of control priority


Transition
Priority Mode
High Heating Load
Cabin Heating
High Speed
Speed
Urban Condition
Aux. Power
High Auxiliary Power
Traction Force
High Traction

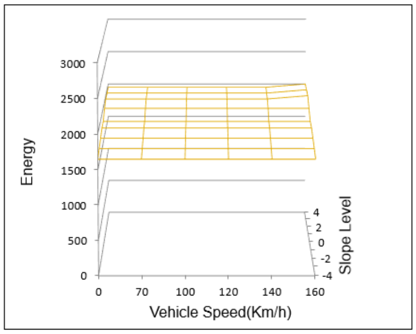

Run during Driving Cycle
High Heating Load ?
Yes
High Heating Load
No
High Auxiliary Power?
Yes
High Auxiliary Power
No
High Traction?
Yes
High Traction
No
High Speed?
Yes
High Speed Driving
No
Urban Driving

	Activating condition	**Deactivating condition**
High heating load	- Blower switch: on and temperature condition target temp. of FATC – ambient air temp. > 22°C	- Blower switch: off or temperature condition target temp. of FATC – ambient air temp. ≤ 17°C
High aux. power	- Auxiliary electric power > 1.25 kW * Normal operation of auxiliary electric power consumption is 300~400W	- Auxiliary electric power ≤ 1.30 kW
High traction driving	- Acceleration pedal position ≥ Map #1 And the number of high acceleration request for 60 seconds ≥ 2 - Driving demand energy per unit distance ≥ Map #2 * Driver demand energy = Target engine energy + Target motor energy	- Acceleration pedal position ≤ Map #1 And the number of high acceleration request for 60 seconds < 2 - Driving demand energy per unit distance ≤ Map #3
High speed driving	- Average vehicle speed for 1 minute > 65KPH(40.4MPH)	- Average vehicle speed for 1 minute ≤ 63KPH(39.1MPH)

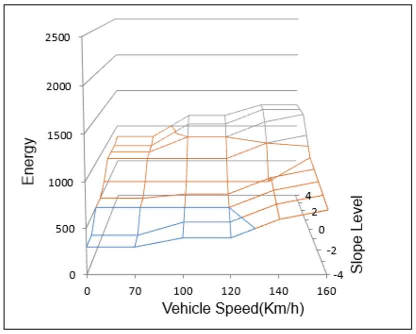
Map #1



Map #2



Map #3



Hybrid control regarding control priority

- Priority #1: High heating load

  ① Engine engage:

  HEV operation is prioritized over idle operation in order to get sufficient thermal energy for heating the cabin.
  This means that engine and electric motor are both engaged.

  ② Engine torque:

  Engine torque is decreased from the normal engine optimal operation value to prevent overcharging of the battery.

  ③ Transmission shift pattern: set as ECO pattern (default setting).

- Priority #2: High auxiliary load

  ① Engine engage:

  HEV operation is prioritized compared to urban driving to compensate the auxiliary power.

  ② Engine torque:

  Engine torque is increased from urban driving to maintain the high-voltage battery SOC considering the high auxiliary load

  ③ Transmission shift pattern:

  Transmission shift point is basically delayed to prevent discharging of the battery by high auxiliary load.

- Priority #3: High traction driving

  ① Engine engage:

  HEV operation is prioritized compared to urban driving to satisfy driver’s high demand power.

  ② Engine torque:

  Engine torque is increased from urban driving to maintain the high-voltage battery SOC considering the high traction driving.

  ③ Transmission shift pattern:

  Transmission shift point is delayed from the urban driving to maintain the high-voltage battery SOC considering driver’s high demand power.

- Priority #4: High speed driving

  ① Engine engage:

  HEV operation is prioritized compared to urban driving to prevent frequent engine on/off.

  ② Engine torque:

  Engine torque is set in the same manner of the urban driving.

③ Transmission shift pattern:

HWY shift pattern is applied and it focus on preventing busy shift and discharging of high voltage battery on the high speed. The hysteresis between up-shift line and down-shift line is expanded, and higher gear upshift is delayed.

- Priority #5: Urban driving

① Engine engage:

The starting point of the engine optimized for the stop & go driving conditions is determined.

② Engine torque:

Engine torque is set on the optimal operating torque.

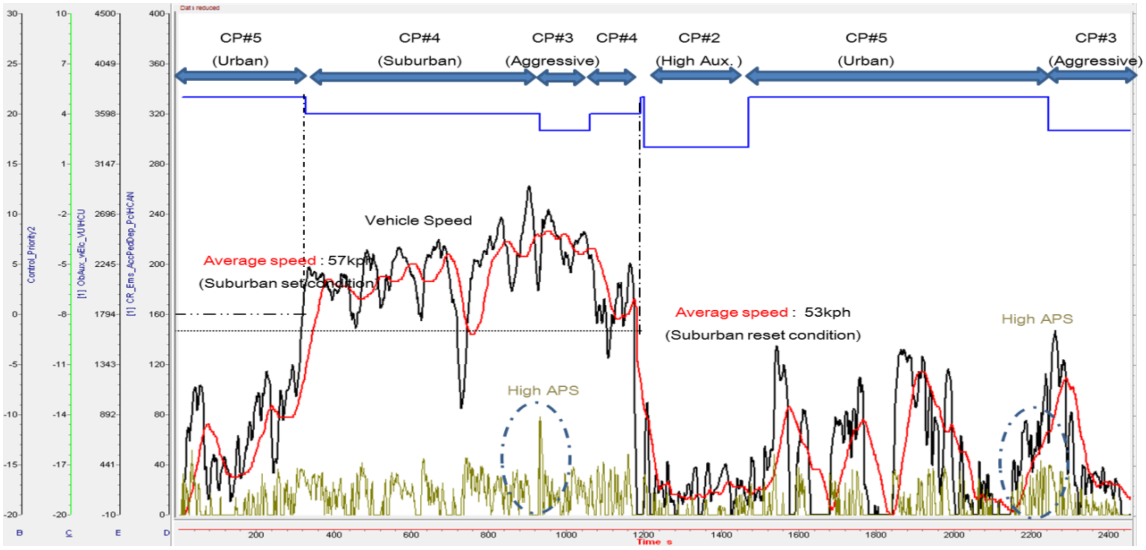
③ Transmission shift pattern:

Transmission shift pattern is set to ECO pattern.

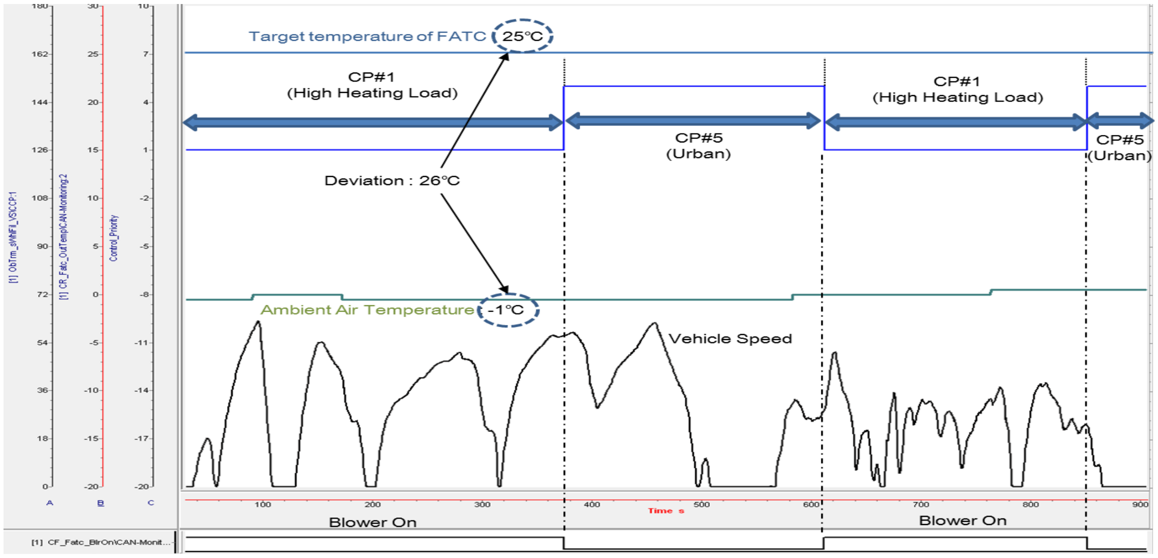
Control Priority observed in regulatory test cycles

Control Priority	Related cycles				
	FTP	HwFET	US06	SC03	FTP@-7
Urban	X	X	X	X	
High speed	X	X	X		
High traction force			X		
High auxiliary power				X	
High heating load					X

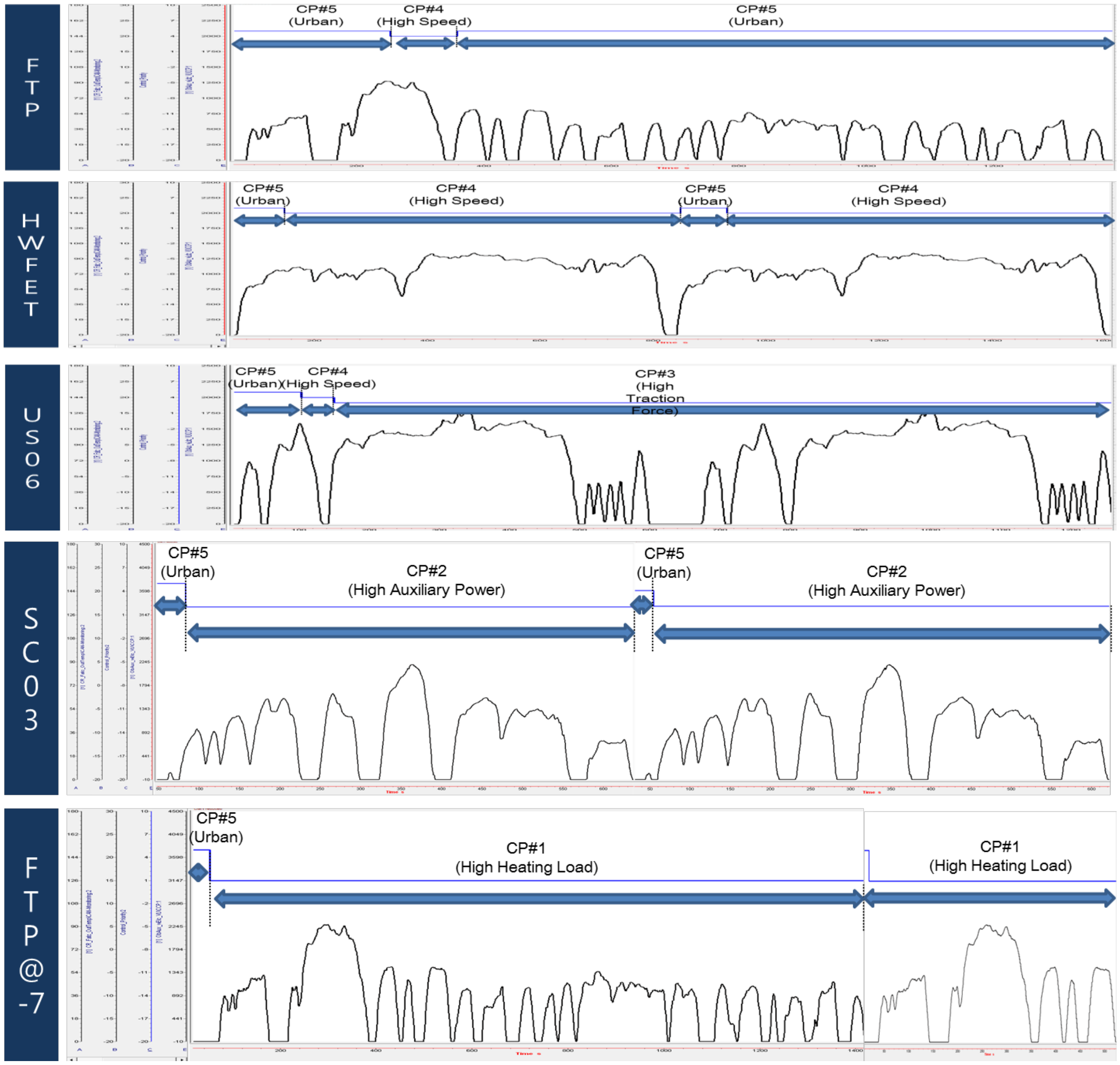
1) Control priority @ Real driving test



2) Control priority @ Real driving test

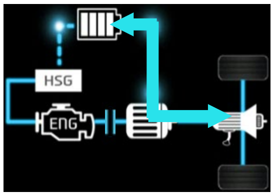
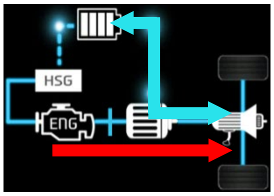
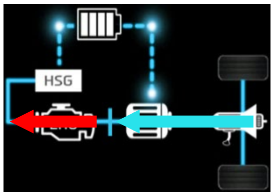
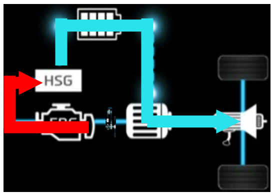


3) Control Priority @ regulatory test cycles



11.06.04 Engine engagement and torque control strategy

This function defines the engine operation mode as EV, HEV, idle, and engine brake, and controls the engine system accordingly. In order to determine the operation mode, it is necessary to consider certain conditions, such as control priority and high voltage battery SOC management strategy. In addition, system demands such as emission and system protection are considered. The following figure describes each engine operation mode briefly.

Mode	Description	Power flow
EV operation (Engine Off)	Run only on electric motor Engine clutch is not engaged	
HEV operation	The engine and the electric motor are both engaged and transmit power to drive the wheels Engine clutch is engaged. Engine operates part load or full load regarding the driving demand	
Engine brake operation	The engine transmits the negative torque to the wheels. Fueling is cut off. Engine clutch is engaged	
Idle operation	The engine is operating at a set speed. Engine clutch is disengaged.	

EV operation

In the EV operation, the vehicle is driven by the electric motor. In order to separate the engine from the drive shaft, the engine clutch is not engaged.

HEV operation

In the HEV operation, the engine clutch is engaged so that the engine and the electric motor are used to drive the vehicle simultaneously. The following items list situations that typically require the HEV operation.

- HEV operation based on traction energy

When the driving demand energy exceeds energy threshold of the engine-on, the HEV operation is activated. The threshold of the engine-on is determined by the high-voltage battery management strategy, the control priority, among others.

- HEV operation to delay the engine disengagement

  The purpose of delaying engine disengagement under no input of an accelerator is to avoid frequent engine-start/stop and charge the high voltage battery at high engine efficiency. The delay time to disengage the engine is determined by the control priority, high-voltage battery management strategy, vehicle, etc.

- HEV operation for the engine management

  The ECU may also request engine warm-up. For further information, refer to '*AECD:11.04.10 Engine warm-up strategy*'. In that instance, the HEV operation is prioritized.

- HEV operation during cabin heating request

  When the full automated temperature control (FATC) requests the engine-on for heating the cabin, the HEV operation is activated as much as possible rather than the idle operation to minimize inefficient engine operation.

- HEV operation in High Load

  When the hybrid system needs increased power output of the engine as described in *'AECD: 11.06.04.05 HEV Operation in High Load'*, HEV operation is activated, and enrichment request for torque demand is transmitted to the ECU.

Idle operation

In the idle operation, the engine operates at a specific RPM. Instead, the driving demand is realized by the electric motor only. In order to separate the engine from the drive shaft, the engine clutch is not engaged. The following items list situations that typically require the idle operation.

- Idle operation for heating the catalyst and warming-up the engine coolant.

  This operation is described in the section, '*AECD:11.04.10 Engine warm-up strategy*'

- Idle operation for cabin heating

  The heating system monitors the cabin and ambient temperature to determine whether the engine needs to be engaged.

- Idle operation for charging the high voltage battery

  When the SOC of the high voltage battery is less than the predetermined value, the engine is started to charge the high voltage battery in order to maintain the SOC within the normal range. For further information, refer to *'11.06.04.03 Idle operation on charging high voltage battery'*.

Idle operation for maintenance and test mode

- Idle operation for checking the engine start:
  This function is to check the engine start when the driver applies the accelerator pedal when the shift lever is in the "Park" position.

- Idle operation for user-charge mode:
  This function is activated when the driver purposefully wants to charge the high voltage battery. The idle operation is activated when the driver applies the accelerator pedal and the brake pedal simultaneously when the vehicle is in the "Park" position.

- PHEV engine maintenance mode(N/A)

HEV or idle operation for system limitation

As described in sections *‘AECD:11.06.04.06 Idle operation at extreme battery discharge condition’*, *‘AECD: 11.06.04.07 HEV operation request at extreme battery discharge condition’*
When the maximum available power of the high voltage battery and the electric motor is limited due to extreme low or hot temperature, the engine operates to satisfy the driving demand and protect the hybrid system.

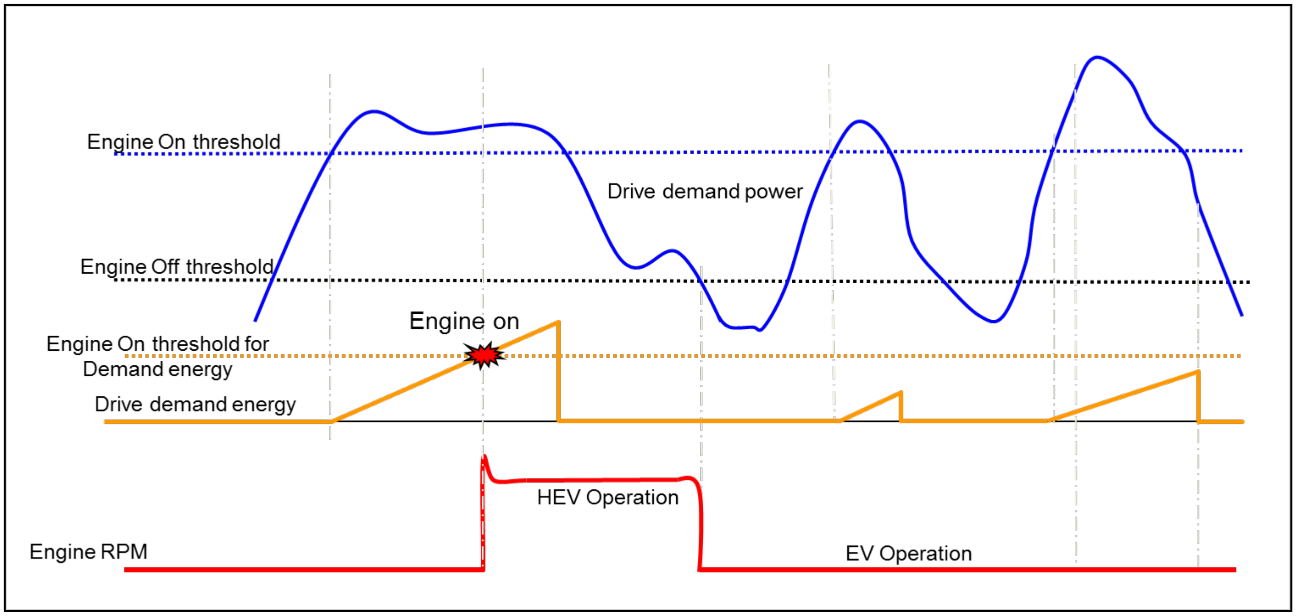
Engine brake operation

Engine brake operation (Fuel cut-off) occurs when the engine brake is required to generate a negative torque on the drive shaft. This mode is entered in this instance. For further information, refer to section *‘AECD: 11.06.02.02 SOC management - critical high band’*

11.06.04.01 HEV operation based on traction energy

The HEV operation decision is based on the SOC management value, control priority, and battery charge/discharge using the driver demand power. To avoid the frequent engine on/off of the engine, the demand energy level is monitored.

See engine on/off determination graph below:



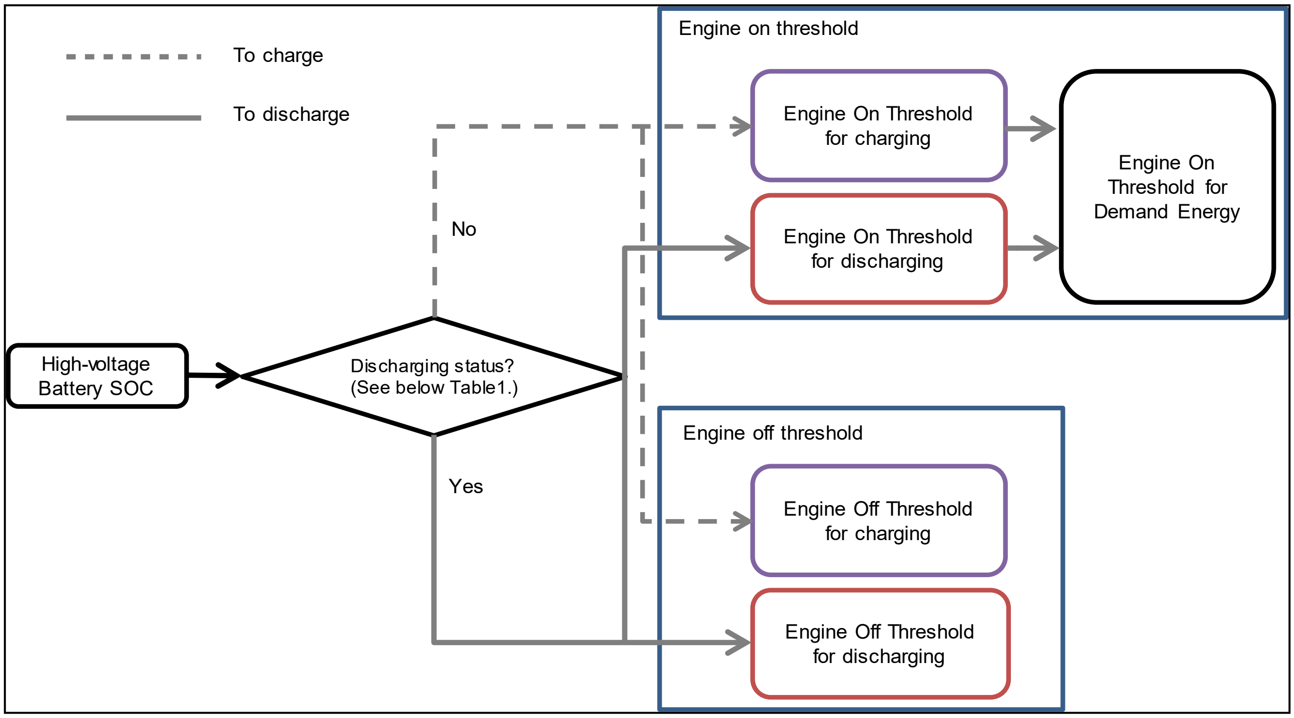


Table1. Criteria for charge and discharge strategy in main operation band of the battery.

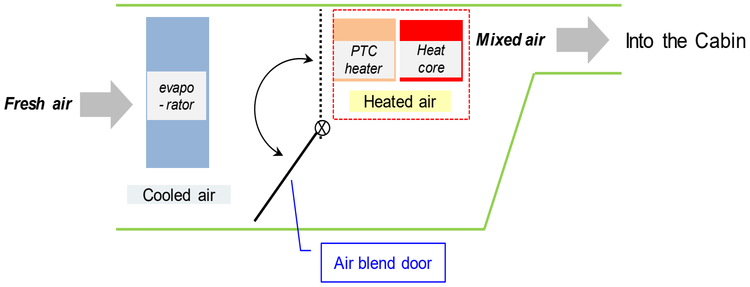
Criteria for engine on/off threshold				SOC	
Control priority	Cabin heating index[1]	Vehicle speed index[2]	Engine coolant index[3]	Entry condition for charging	Entry condition for discharging
High heating load	1			40	50
	2			40	50
	3			45	50
High auxiliary power		0		52	57
		1		52	57
		2		52	57
High traction		0		45	53
		1		45	53
		2		45	53
High speed		0		45	55
		1		57	70
		2		45	60
Urban			0	63	76
			1	63	76

1) Cabin heating index is calculated by the following 3-step according to heating load.

- 1st step
  Index calculation by combination of blower step and temp door level as below table.

		Temp Door Level	
		0 ~ 3	4 ~ 6
Blower Step	0 ~ 3	1	2
	4 ~ 9	2	3

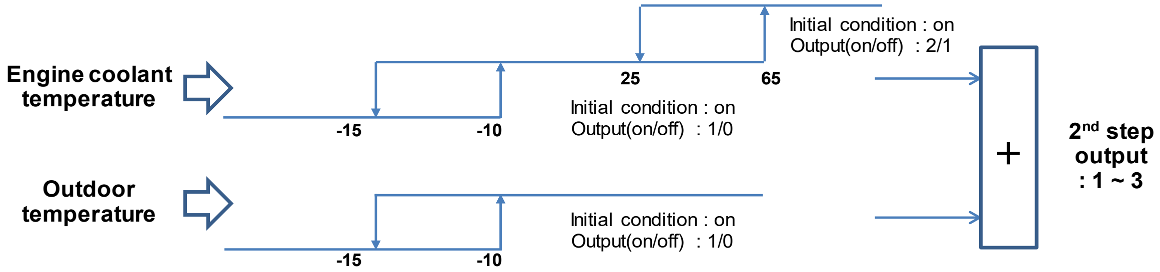
※ Temp door level : Cold (0) ~ Hot (6)



Temp door level : The blend door’s level for mixing cooled and heated air

2nd step

Index calculation by combination of engine coolant temperature and outdoor temperature as below.



- 3rd step
  Index calculation by combination of 1st step and 2nd step outputs as below table.

1st step output

2nd step output

	0	1	2	3	4
1	1	1	3	3	3
2	1	1	2	3	3
3	1	1	2	3	3

Cabin heating index
(Heating load comparison : 1 > 2 > 3)

2) Vehicle speed mode is divided into three groups as vehicle speed index

Average vehicle speed [kph]	0~13	13~27	27~67	67~80	80~97	97~
Vehicle speed index	0	0	0	1	2	2

3) Engine coolant Index is determined by the following inequalities

Engine coolant Index 0: Engine coolant temperature < Off threshold

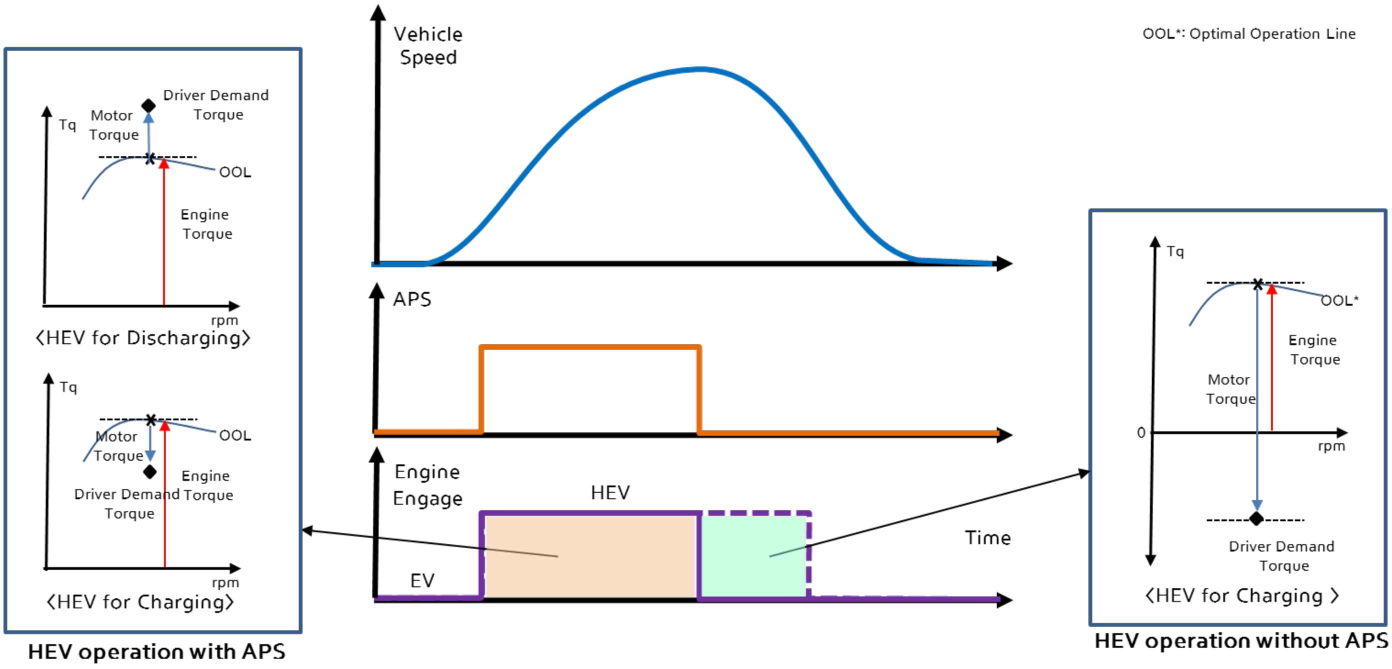
Engine coolant Index 1: Engine coolant temperature > On threshold

Initial value of ‘Engine coolant index’ is 1

Ambient temperature	-10	-4	0	5	10	15	20	25	30	35
On threshold	94	94	94	94	94	94	94	94	94	94
Off threshold	30	30	30	30	30	30	30	30	30	60

11.06.04.02 HEV operation to delay the engine disengagement

The purpose of delaying engine disengagement under zero acceleration pedal position is to avoid frequent engine-start/stop and charge the high voltage battery at high engine efficiency. In HEV operation, the engine is engaged to the drive shaft so that the electric motor can generate electricity with engine power output. Also, the electric motor has larger generating capacity than the HSG. This control can also prevent inefficient engine operation by repeated engine on/off when driving demand changes frequently.



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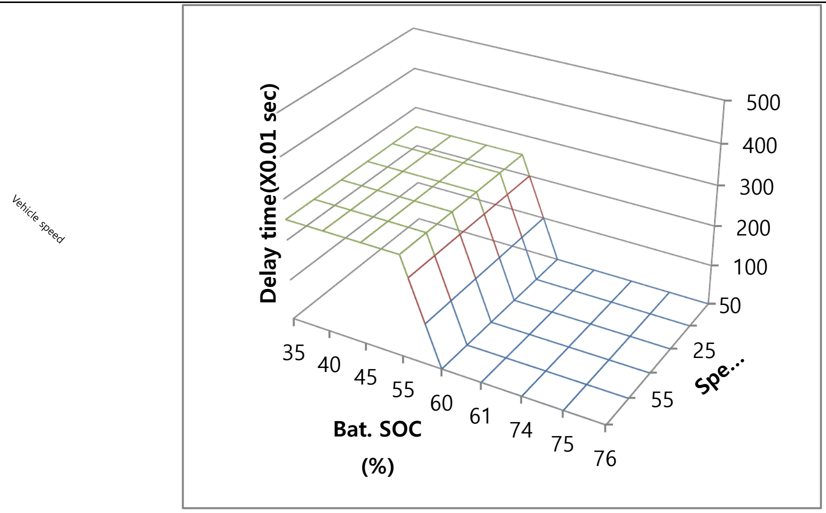
Title : HEV operation to delay the engine disengagement	
Entry condition	**Activating condition** - Acceleration pedal position = 0% - 1300rpm < motor speed < 4300rpm - and shift lever position = ‘Drive’ - and engine clutch state = ‘lock-up state’ - and {Control priority ='High traction' } and High-voltage battery SOC < 45% - and {Control priority ='Urban' or 'High speed' or 'High heating load' or 'High auxiliary power'} and High-voltage battery SOC < 48% - and HEV mode switch is not CD mode(N/A) **Deactivating condition** - Motor speed > 4300 + 200(hysteresis) rpm - or Motor speed < 1300 - 150(hysteresis) rpm - or {Control priority ='High traction'} High-voltage battery SOC > 45% + 5% - or {Control priority ='Urban' or 'High speed' or 'High heating load' or 'High auxiliary power'} High-voltage battery SOC > 48% + 5% - or Gear step <= ‘2nd step’ - or Brake Torque >= 200Nm - or time after activating condition > delay time map1) * factor

Delay time and factor map

1) Delay time

Delay time of the engine disengagement control is determined by several elements such as control priority, road slop index, vehicle index, SOC, etc. The following table shows the structure of determining the engine disengagement delay time.

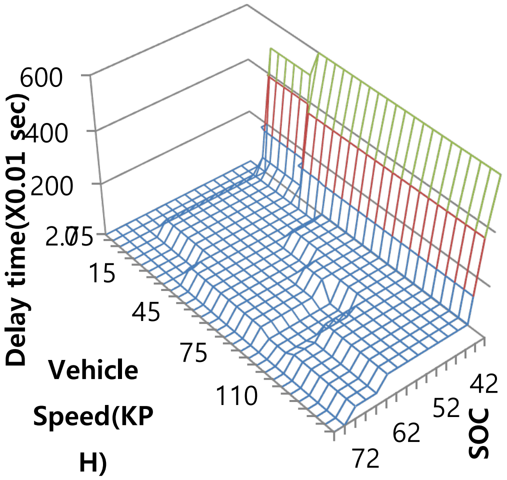
Control priority #1



Min : 0.0sec

Max : 2.5 sec

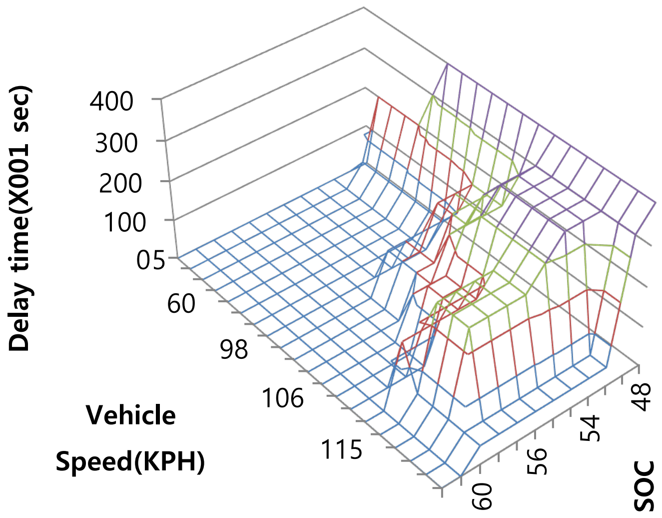
Control priority #2



Min : 0.0sec

Max : 6.0 sec

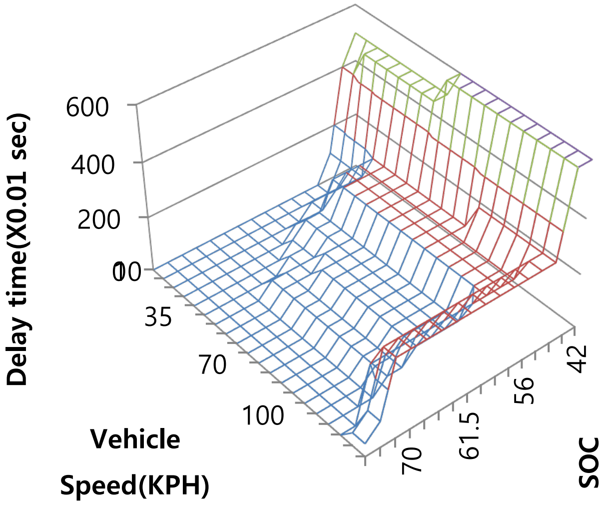
Control priority #3



Min : 0.0sec

Max : 4.0sec

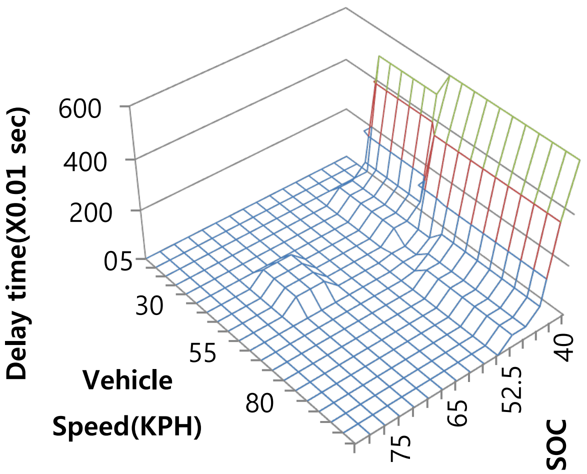
Control priority #4



Min : 0.0sec

Max : 6.0sec

Control priority #5



Min : 0.0sec

Max : 6.0sec

2) factor

		Vehicle speed index					
		0	1	2	3	4	5
Road slope level	-4	0.1	0.1	0.1	0.1	0.1	0.1
	-3	0.1	0.1	0.1	0.1	0.1	0.1
	-2	0.1	0.1	0.1	0.1	0.1	0.1
	-1	0.3	0.3	0.3	0.3	0.3	0.3
	0	1.0	1.0	1.0	1.0	1.0	1.0
	1	1.2	1.2	1.2	1.2	1.2	1.2
	2	1.2	1.2	1.2	1.2	1.2	1.2
	3	1.2	1.2	1.2	1.2	1.2	1.2
	4	1.2	1.2	1.2	1.2	1.2	1.2

Average vehicle speed(kph)	0~13	13~27		27~67	67~80	80~97	97~
Vehicle speed index	0	1		2	3	4	5

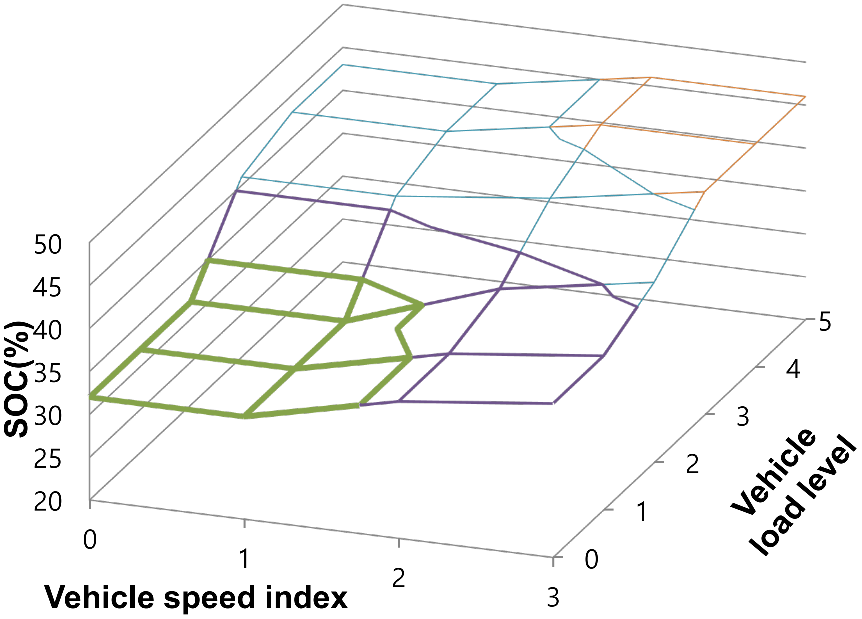
Road slope(%)	~-11	-11~-6.5	-6.5~-3	-3~-1.6	-1.6~1.6	1.6~3	3~6.5	6.5~11	11~
Level	-4	-3	-2	-1	0	1	2	3	4

11.06.04.03 Idle operation on charging high voltage battery.

As the SOC approaches the critical low band, the hybrid control system prioritizes a strategy to increase the SOC closer to the desired point in the Normal range. The order of the strategy is below:

Strategy:

- Driving mode: Idle operation
- Engine target power = 8.5kW
- Engine torque = Engine target power / (engine speed * 2π / 60))
- Engine target speed = 1280 rpm

Band	Activation/Deactivation Condition
Engine Start and Idling Control	**Activating Condition:** High-voltage battery SOC < <Map 1. Map 1.  **Deactivating Condition**: High-voltage SOC > Map 1. + 5%

11.06.04.04 Idle and HEV operation during the catalyst heating request

When there is a request from the ECU to heat the catalyst, two main strategies are used as described in section '*AECD: 11.04.05 Catalyst heating strategy'*. In brief, the catalyst heating request is prioritized and the engine is used to heat the catalyst. The hybrid control system turns on the engine to effectuate the fast heating of the catalyst.

Strategy 1: Idle operation

- Engine target power = 3.1kW
- Engine torque = Engine target power / (ENG SPD x 2π/60)

Strategy 2: HEV operation

11.06.04.05 HEV operation in high load

AECD Title: HEV operation in high load. (Related to AECD: 11.02.01.04 Enrichment for torque demand)

Purpose

When the driver needs the maximum engine torque and motor torque such as merging into traffic, uphill and passing another vehicle including battery low power situation.

The power of the engine is limited by the air density due to altitude and intake air temperature and the power of the motor is limited by SOC of high voltage battery.

Action: Functional Description

Enrichment request is activated and transmitted to ECU[1]

Depending on the high-voltage battery SOC, the acceleration pedal position condition for enrichment entry is differentiated. In particular, if high-voltage SOC band is critical low, turn off the A/C and mitigate the entry condition of the enrichment to protect the system from battery overload.

Parameters (I/O)

IN

- Accelerator pedal position (APP)
- Air density correction factor from ECU
- Battery discharge available power
- Motor speed
- High-voltage battery SOC (SOC)
- Transmission available max power
- Engine max power
- Motor max power

OUT

- Enrichment request for torque demand[2]

Entry Conditions

Activating Condition

Enrichment request is set when APP > APP On-threshold for enrichment
If system power ratio* < 0.7, APP On-threshold for enrichment < 92%
Else if system power ratio > 0.7, APP On-threshold for enrichment = 92%

APP On-threshold

System power ratio	0.3	0.5	0.7	0.8	0.9	1.0
APP	60	75	92	92	92	92

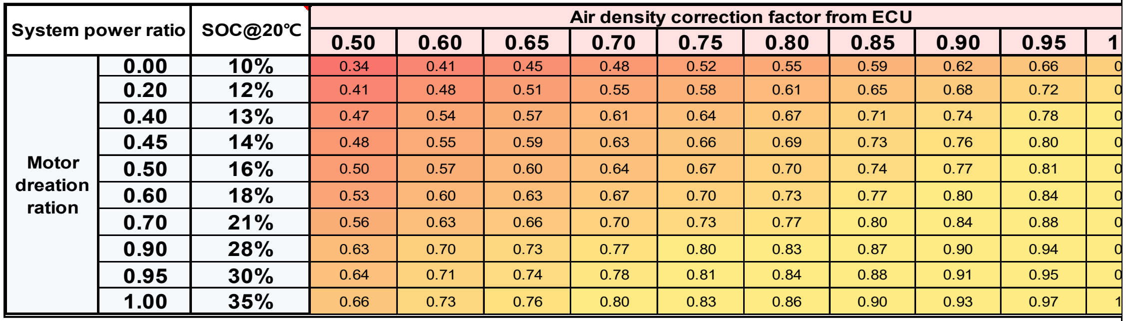
Deactivating Condition

APP Off-threshold

System power ratio	0.3	0.5	0.7	0.8	0.9	1.0
APP	50	64	80	80	80	80

* system power ratio(Map1)

system power ratio = system available power$^{1)}$@real time / system max power$^{2)}$@Ideal



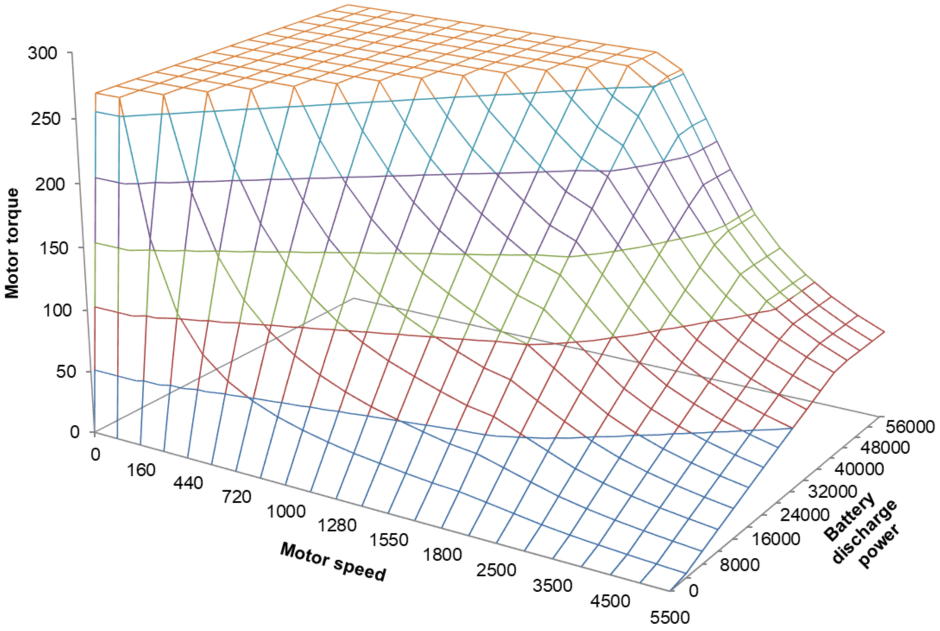
System power ratio		SOC@20℃	Air density correction factor from ECU									
			0.50	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1
Motor dreation ration	0.00	10%	0.34	0.41	0.45	0.48	0.52	0.55	0.59	0.62	0.66	0
	0.20	12%	0.41	0.48	0.51	0.55	0.58	0.61	0.65	0.68	0.72	0
	0.40	13%	0.47	0.54	0.57	0.61	0.64	0.67	0.71	0.74	0.78	0
	0.45	14%	0.48	0.55	0.59	0.63	0.66	0.69	0.73	0.76	0.80	0
	0.50	16%	0.50	0.57	0.60	0.64	0.67	0.70	0.74	0.77	0.81	0
	0.60	18%	0.53	0.60	0.63	0.67	0.70	0.73	0.77	0.80	0.84	0
	0.70	21%	0.56	0.63	0.66	0.70	0.73	0.77	0.80	0.84	0.88	0
	0.90	28%	0.63	0.70	0.73	0.77	0.80	0.83	0.87	0.90	0.94	0
	0.95	30%	0.64	0.71	0.74	0.78	0.81	0.84	0.88	0.91	0.95	0
	1.00	35%	0.66	0.73	0.76	0.80	0.83	0.86	0.90	0.93	0.97	1

1) system available power@real time
= Air density correction factor from ECU * Engine max power
+ Motor power deration factor$^{3)}$ * Motor max power

2) system max power@Ideal = Engine max power + Motor max power

3) motor power deration factor = motor torque(MAP2) / motor max torque(Table2)

Map 2. Motor torque



(x-axis: battery discharge power, y-axis: motor speed)

Table 2. motor max torque

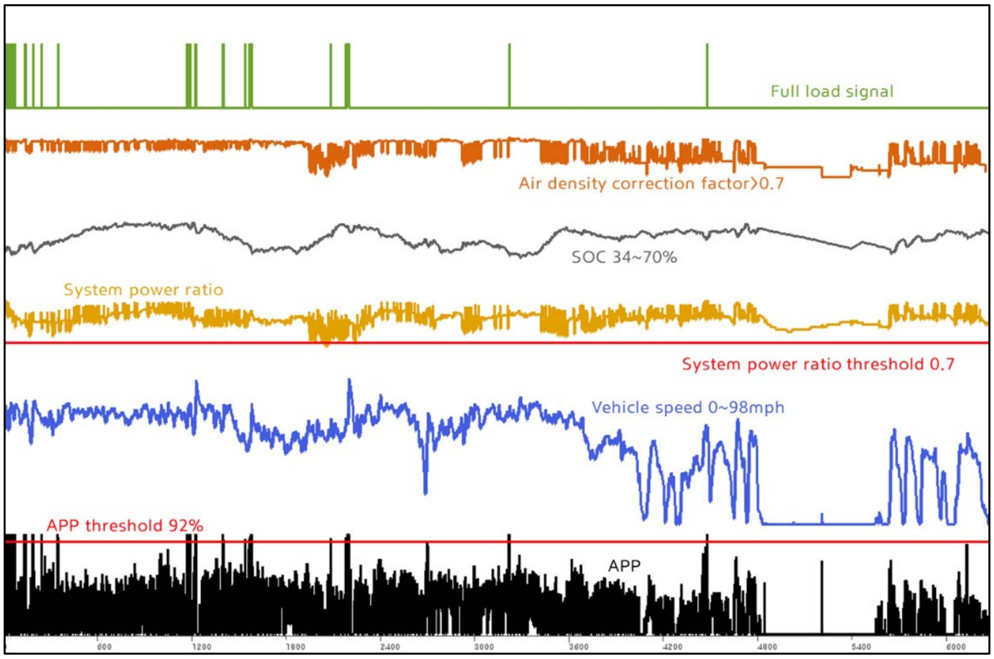
Motor speed	0	1700	1800	2100	2500	3000	3500	4000	4500	5000	5500
Torque	264	264	253	217	179	146	123	105	91	80	71

In-use Frequency

APP is under 80% in normal driving condition. We can more deactivate enrichment by APP because hybrid system uses battery power for assisting vehicle traction force.

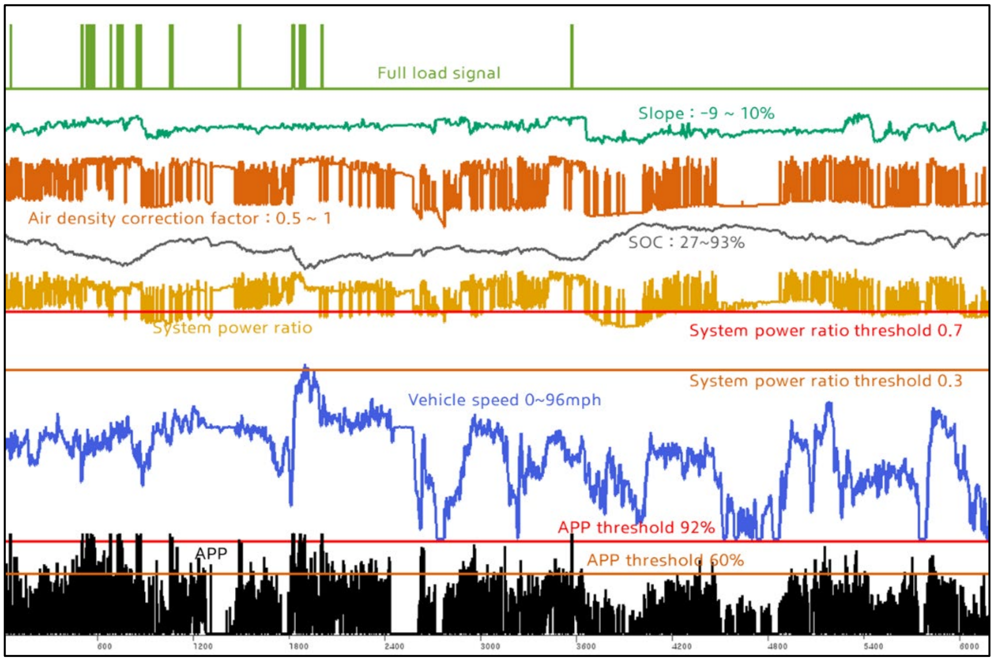
Case 1: APP > 92% at system power ratio range [0.7 ~ 1]

Below is a graph of internal testing of U.S. highway driving (under 3,300ft, 100 min). Enrichment for torque demand was rarely activated during the internal test. Therefore, it is believed to be a rare occasion when engaged.



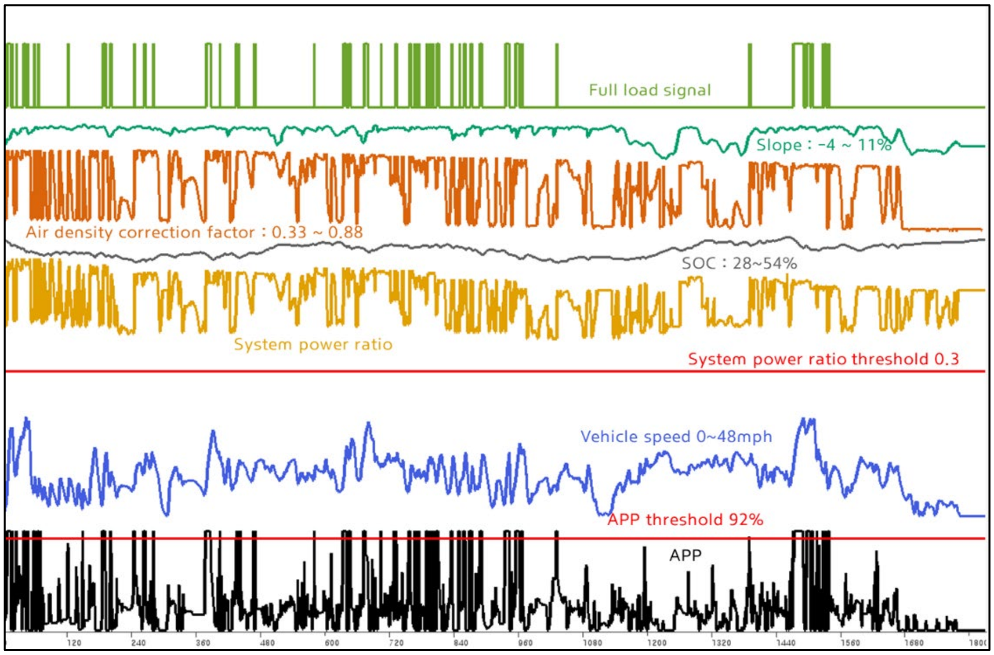
Case 2: APP > 60~92% determined interpolation of system power ratio range [0.3 ~ 0.7]

Below is a graph of internal testing of Silverthrone, CO, U.S uphill driving (100 min). Vehicle is driven over 6,500ft and uphill in normal driving mode. Hi-voltage battery SOC is sustained over 40% in uphill grade 6%.



Case 3: APP > 60% at system power ratio range [0 ~ 0.3]

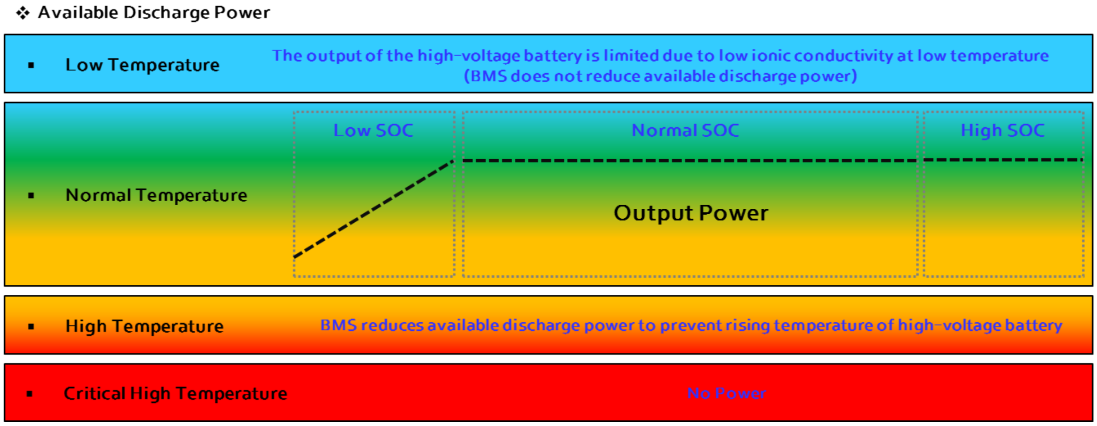
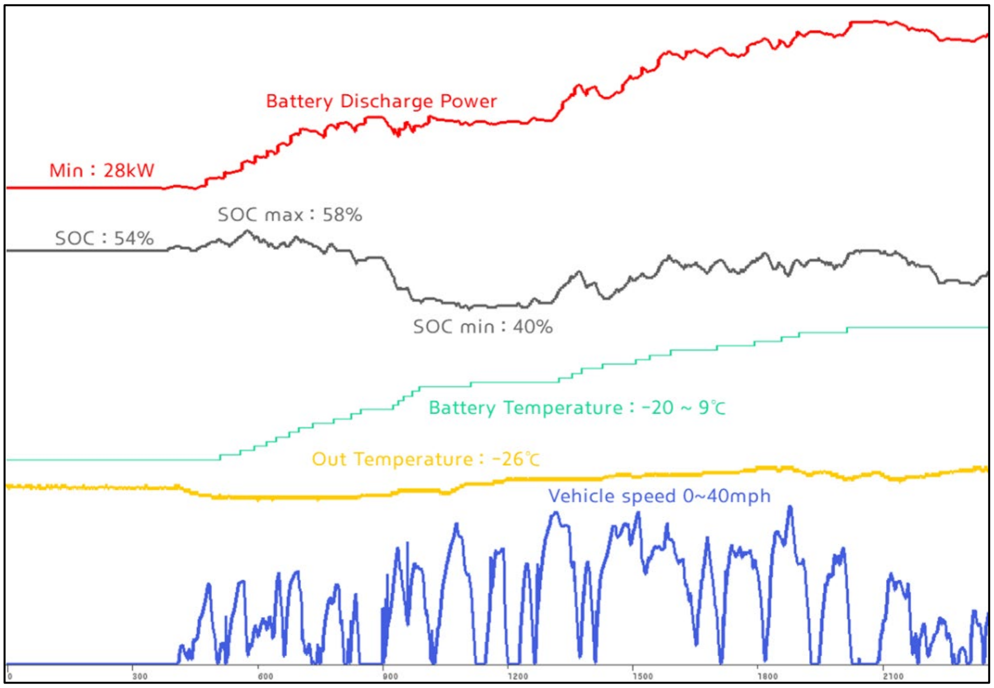
Below is a graph of internal testing of Pikespeak, U.S. uphill driving (30 min). Vehicle is driven over 14,000ft and uphill in High traction mode. But system power ratio is above 0.3. Therefore, it is believed to be a rare occasion of case 3.



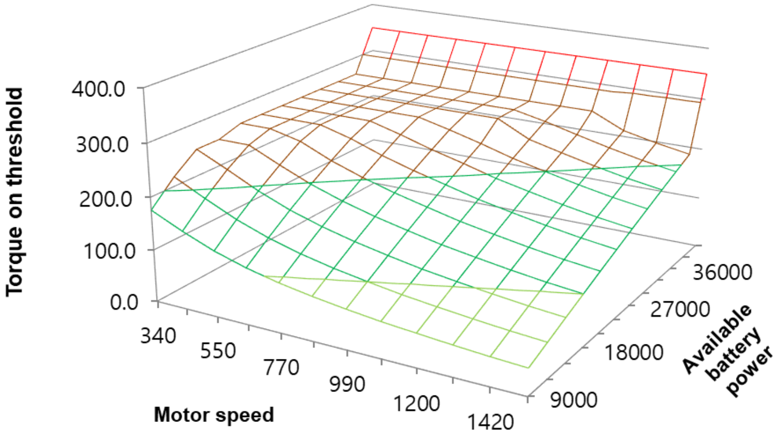
Emission impact	Increasing Emission value when activation conditions are met. Case 3 is extremely rare condition. In order to protect to battery, full load is activated.
Justification	G. Electric propulsion system protection
Reference	1. Enrichment for torque demand 2. Enrichment for torque demand

11.06.04.06 Idle operation at extreme battery discharge condition

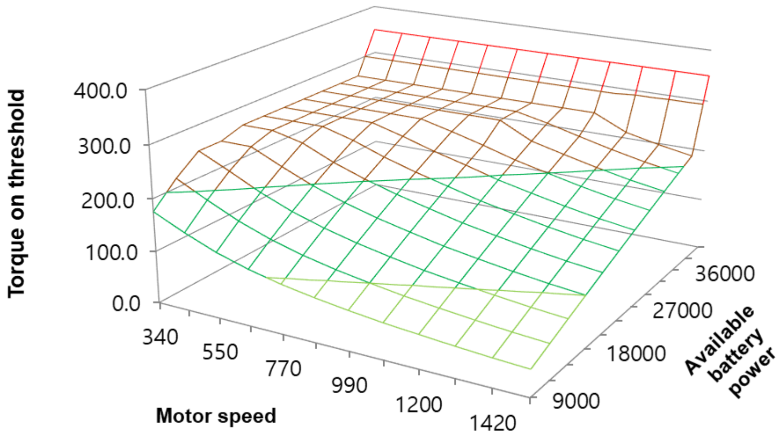
<table>
<tr><td colspan="2">AECD Title : Idle operation at extreme battery discharge condition.</td></tr>
<tr><td>Purpose</td><td>To provide traction power in the low speed range when the high-voltage discharge power limited.
* the maximum discharge power is varied by SOC and temperature of high-voltage battery</td></tr>
<tr><td>Action: Functional Description</td><td>1. Engine idle operation is activated.
2. To secure the motor driving force, demand charge power is determined to the maximum charge amount HSG available
demand power at extreme battery discharge condition =
<table>
<tr><td>Engine speed(RPM)</td><td>800</td><td>920</td><td>1200</td><td>1420</td><td>1600</td><td>3000</td></tr>
<tr><td>Power(kW)</td><td>3</td><td>5</td><td>8.504</td><td>8.504</td><td>8.504</td><td>0</td></tr>
</table></td></tr>
<tr><td>Parameters (I/O)</td><td>IN
- Battery discharge available power (BATDCHPWR)
- Vehicle speed
- Motor speed
- Brake switch signal
OUT
- Engine engagement control[1]
- Demand power at extreme battery discharge condition[2]</td></tr>
<tr><td>Entry Conditions</td><td>Activating Condition
Battery discharge available power (BATDCHPWR) < 18kW
Deactivating Condition
Battery discharge available power (BATDCHPWR) > 20kW</td></tr>
<tr><td>In-use Frequency</td><td>It hardly occurs that the discharge power of high-voltage battery is less than 18kW.
Battery available discharge power is limited under 18kW in the following conditions.
- High voltage battery temperature is below -20℃ at 30% of high voltage battery SOC
- High voltage battery temperature is higher than 57℃.</td></tr>
</table>

	 Real driving test @ Alaska (low outside temperature) 
Emission impact	Increasing CO2 value when activation conditions are met.
Justification	G. Electric propulsion system protection
Reference	1. Engine engagement control 2. HEV operation request at extreme battery discharge condition

11.06.04.07 HEV operation request at extreme battery discharge condition

AECD Title: HEV operation request at extreme battery discharge condition.	
Purpose	To prioritize HEV operation due to system limitation * the maximum discharge power is varied by SOC and temperature of high voltage battery
Action: Functional Description	If the engine clutch can be engaged, HEV operation is activated. Otherwise idle operation is activated.
Parameters (I/O)	**IN** - Shift lever position - Vehicle speed - Motor rotational speed - System demand power - Battery discharge available power - Motor discharge power - Auxiliary electric power - demand power at extreme battery discharge condition[1] **OUT** - Engine engagement control[2]
Entry Conditions	**Activating Condition** ① Driver demand torque > torque on threshold by battery available power. Battery available power = Battery discharge available power + demand power at extreme battery discharge condition[1] – Auxiliary electric power 1) when catalyst heating request is activated  < Torque threshold at catalyst heating> [x-axis: Available battery power , y-axis: motor speed)

2) when catalyst heating is deactivated



< Torque threshold at shift lever position = D>

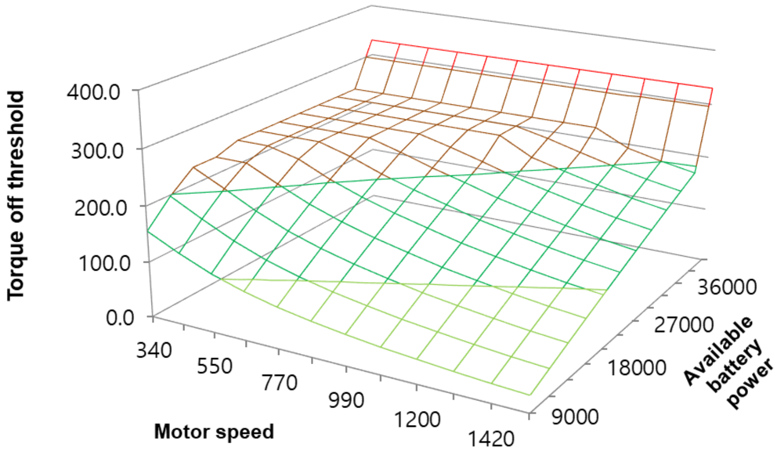
[x-axis: Available battery power , y-axis: motor speed)

Deactivating condition

① Driver demand torque < torque off threshold by battery available power.

Torque off threshold = Torque on threshold – delta torque

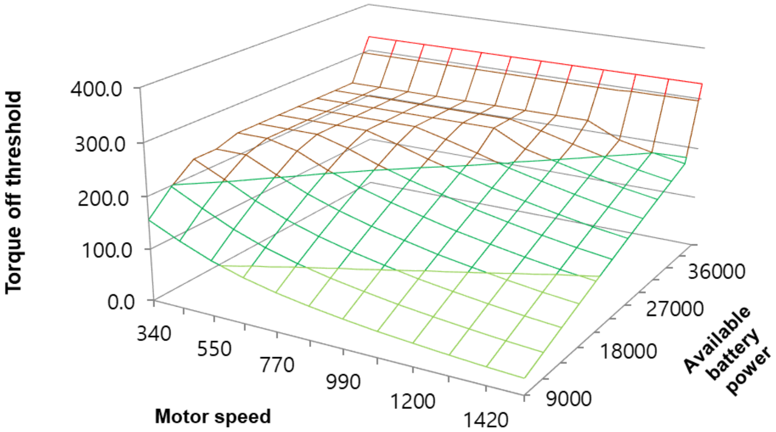
1) when catalyst heating is activated



< Torque off threshold at catalyst heating>

[x-axis: Available battery power , y-axis: motor speed)

2) when catalyst heating is deactivated



< Torque off threshold >

[x-axis: Available battery power , y-axis: motor speed)

In-use Frequency

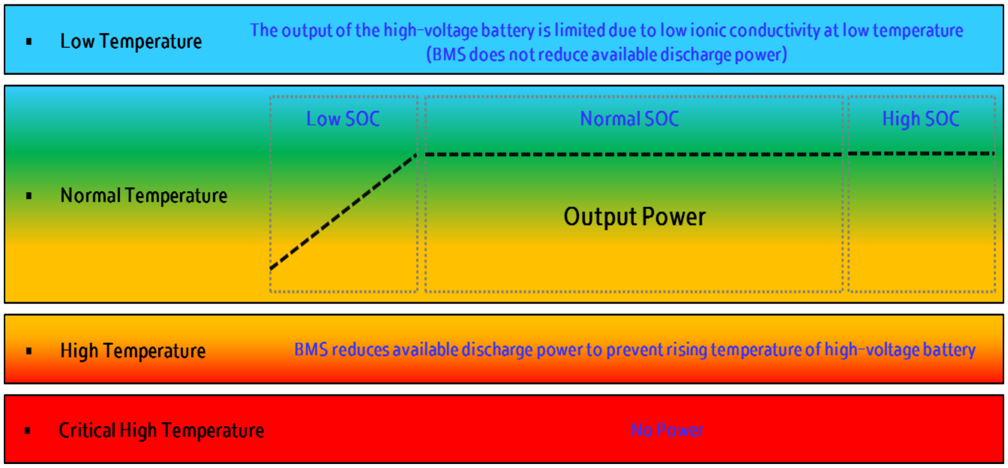
It hardly occurs that the discharge power of high-voltage battery is less than 15kW.

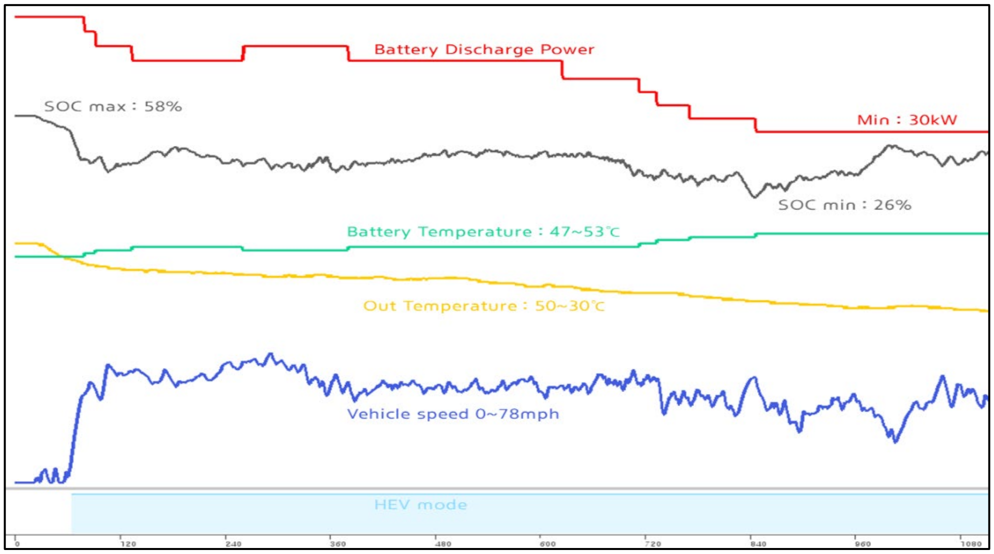
Battery available discharge power is limited under 15kW in the following conditions.

- High voltage battery temperature is below -20℃at 30% of high voltage battery SOC.

- High voltage battery temperature is higher than 55℃.

❖ Available Discharge Power



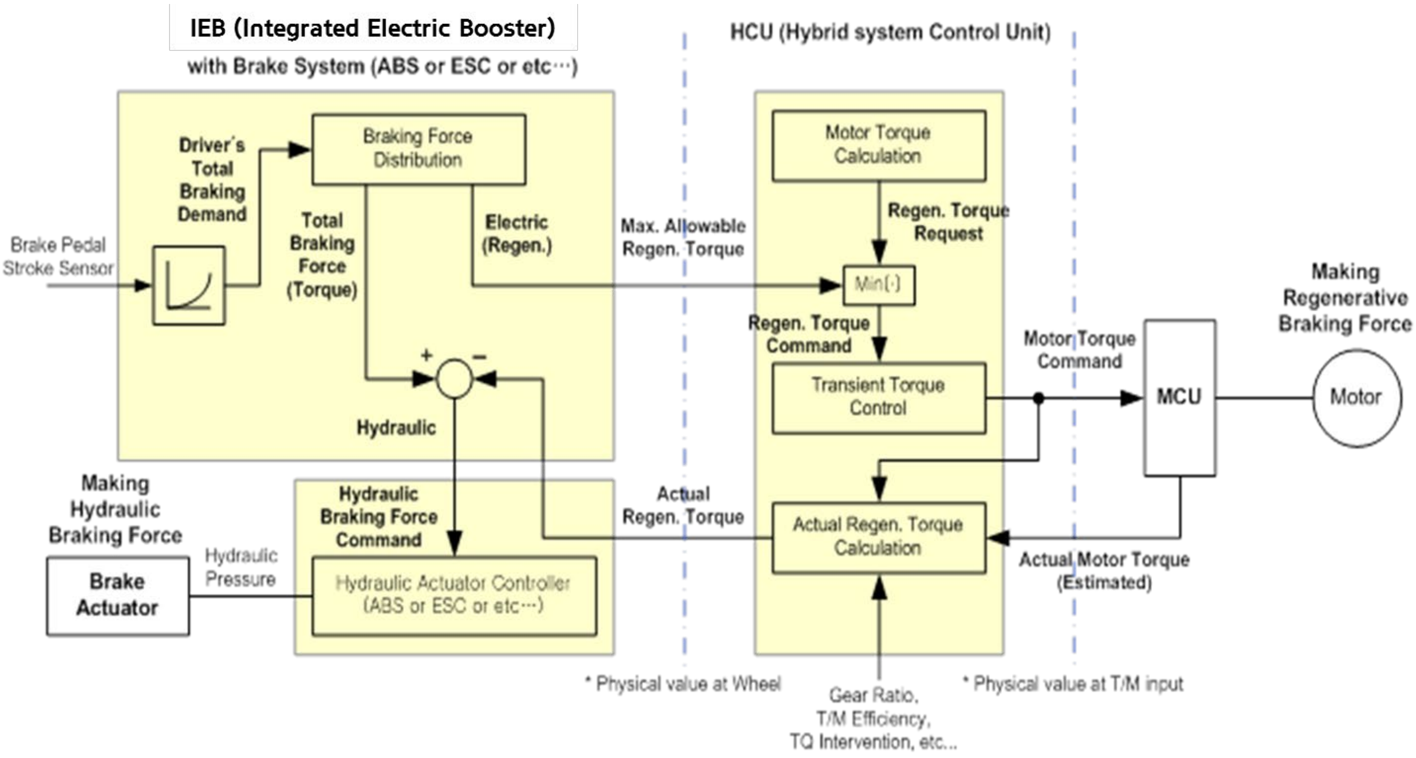
	Real driving test @ Death valley 
Emission impact	Increasing CO2 value when activation conditions are met.
Justification	G. Electric propulsion system protection
Reference	1. Idle operation at extreme battery discharge condition 2. Engine engagement control

11.06.05 Regenerative braking control

The hybrid system provides regenerative braking through an electric motor. An ICE vehicle performs braking by converting kinetic energy to thermal energy through a friction brake, but this system has an electric motor that can serve as a generator: converting kinetic energy to electric energy, and stores the converted energy in the high voltage battery. However, if a driver requests braking torque larger than is available through regenerative torque, the braking force is provided by a traditional friction brake. The regenerative braking system is configured as follows:

The Integrated Electric Booster (IEB) consists of several braking systems. It is responsible for controlling the brake system, and calculates the total braking torque based on the depth of braking pedal. Then, it distributes total braking torque to hydraulic torque (for the friction brake) and regenerative torque.

HCU (Hybrid Control Unit) receives the calculated regenerative torque from IEB and transmits a torque command with consideration for electric power system (eg. Motor, Battery). With the command, MCU (Motor Control Unit) performs a power generation control for a motor and then transmits actual torque to HCU. HCU calculates actual regenerative braking and then transmits the result to IEB, and IEB calibrates hydraulic braking force with total braking force and actual regenerative braking force.



11.06.06 Driver selectable mode

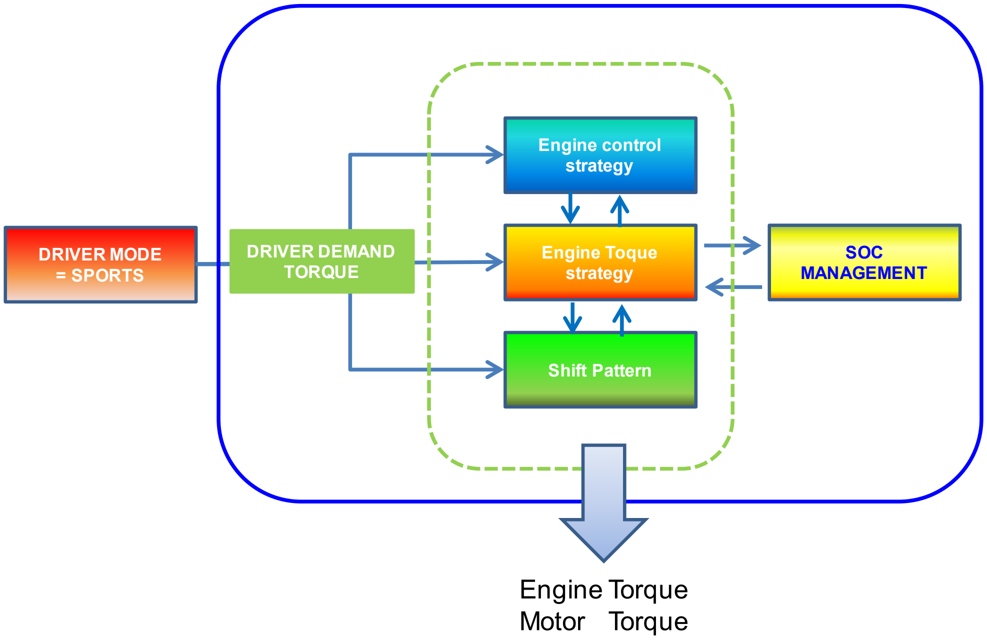
11.06.06.01 HEV operation control in sport mode

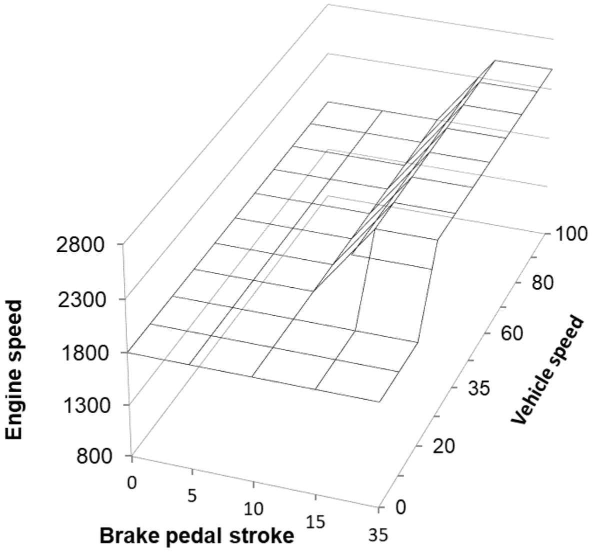
Multimode is configured as ECO/SPORT/MY DRIVE/SNOW modes. The ECO mode is set to default mode. The other modes are optional features provided to the driver.

When the driver selects the SPORT mode, the selected mode control determines the driver's requested torque for required performance and controls the engine on/off, engine torque, and shift pattern and control the SOC management optimally.

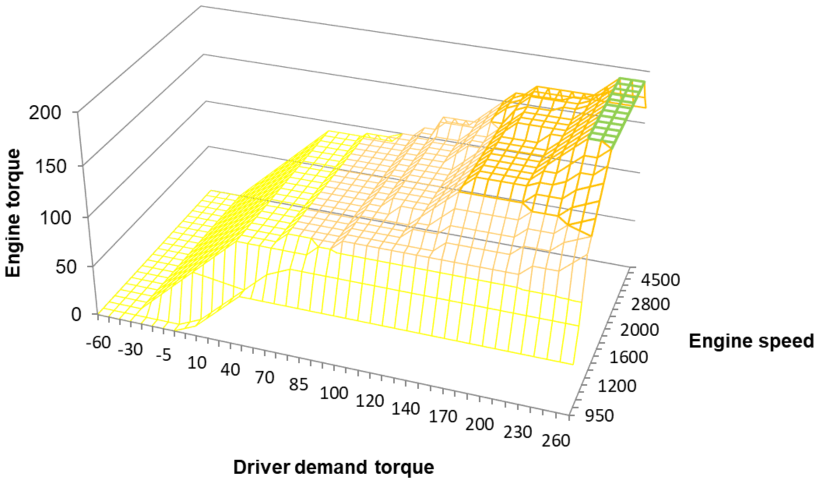
When the driver selects the MY DRIVE mode, the drive mode depends on the powertrain mode selected by the driver. The driver can select ECO/SPORT/SMART for MY DRIVE mode for MY DRIVE mode from the infotainment. When driver select SMART mode for MY DRIVE mode, most of the powertrain control is same as the default ECO mode except shift pattern, the shift pattern is automatically selected as one of the aforementioned ECO and SPORT modes by TCU in accordance with determining driver's behavior based on the fuzzy logic which has inputs as accelerator position, shift lever position, G-sensor and vehicle speed.

When the driver selects the SNOW mode, the selected mode prevents vehicle slip of the vehicle through controlling the driver's demand torque, engine torque, and shift pattern.



AECD Title: HEV operation control in sport mode	
Purpose	For drivability by driver select To provide the driver with sporty driving ability when the sport mode selected by the driver.
Action: **Functional Description**	When the driver selects the sport mode, the sport mode control determines the driver's requested torque for sporty driving performance and controls the engine on/off strategy, engine torque, and shift pattern and control the SOC management optimally. 1. Hybrid operation to delay the engine disengagement Engine speed > Map1 of Vehicle Speed and Brake pedal stroke depth : Engine is disengagement  <Map 1> 2. Engine torque strategy - Determine engine torque operation point for using motor power, because sport mode is easier to make to approaching critical high SOC due to keep on engine engagement strategy. If SOC management = approaching critical high & Sport mode, : Engine torque MAP for sport mode

X axis : Driving demand torque, y-axis: Engine speed

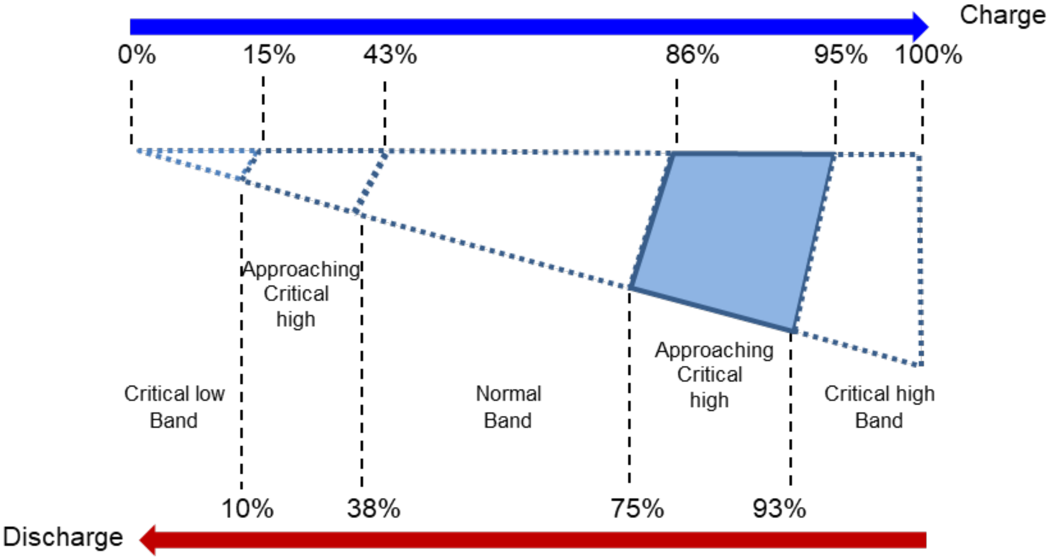


3. Transmission Shift Pattern : Sports Shift Pattern

- In order to ensure the maximum driving force of the engine, sport pattern is applied.

4. High voltage battery SOC Management

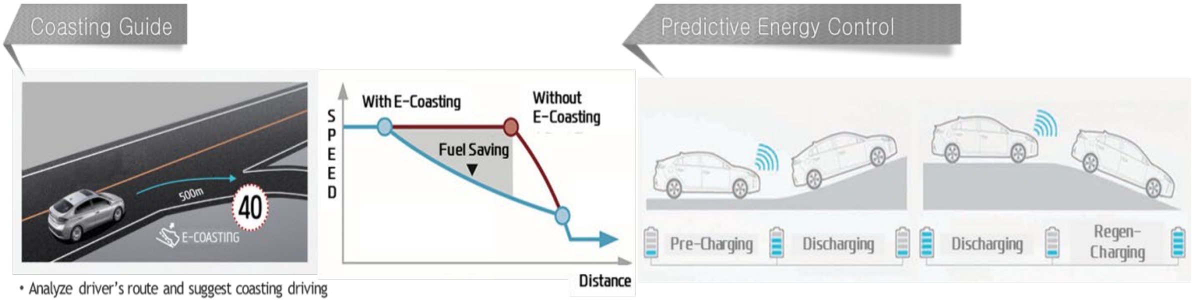
- SOC management = approaching critical high band is changed.



Parameters **(I/O)**	**IN** - Driver selectable mode **OUT** - Engine engagement control[1] - Engine torque[2] - SOC management – approaching critical high[3]
Entry Conditions	**Activating Condition:** Driver select mode = ‘Sports mode’ **Deactivating Condition:** Driver select mode ǂ ‘Sports mode’
In-use Frequency	When driver selects the sports mode. ECO mode is default.
Emission impact	CO2 would be increased. Worst case emission meets regulatory guidance.
Justification	F. Base operation
Reference	1. Engine engagement and torque control 2. Engine engagement and torque control 3. High voltage battery SOC management

11.06.07 Eco-driving assistant system (Eco-DAS)

Eco-DAS provides fuel efficient driving information and energy control with drivers by GPS predicting driving route. The Eco-DAS consists of two technologies: coasting guide control and predictive energy control. The coasting guide control aims at maximizing fuel economy by coaching the driver on when to coast as well as adjusting coasting torque automatically. Predictive Energy Control, meanwhile, uses the navigation system to anticipate topographical changes on the road ahead and actively manage energy flow, seamlessly determining when its best to recharge the battery and when its best to expend stored energy to optimize overall efficiency.

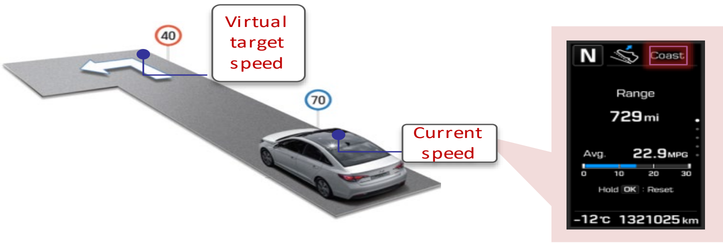


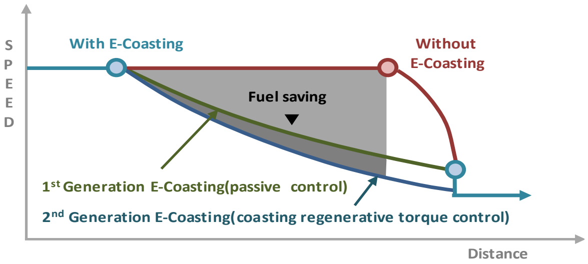
• Analyze driver's route and suggest coasting driving

11.06.07.01 Coasting guide control

The Coasting guide control provides the information when to coast based on looking ahead information from the navigation system and adjusts coasting regenerative torque so that the vehicle speed can reach the target speed.

- When the GPS predicts the situation that vehicle has to decelerate (heading to intersection, downhill, JC, IC, TG, Left/Right turn, etc.), it recommends driver coasting so the vehicle may not loss any unnecessary energy by braking or accelerating.
- 1st generation ‘Coasting guide control’ is just provide information (recommend driver coasting) with driver. However 2nd generation ‘Coasting guide control’ controls the coasting regenerative torque by using the information about target vehicle speed and current vehicle speed.





- When the driver sets the destination in the navigation, ‘Coasting guide control’ is only activated
- Activation condition

1) When driver set the destination in the navigation
2) And target point is located within 2km
3) And driver take off accelerator pedal
4) And driver doesn’t press the brake pedal
5) And road slope (by G-value of the longitudinal sensor value) is less than 2.3%

- Deactivation condition

1) When driver doesn’t set the destination in the navigation
2) Or target point is located over 2km
3) Or driver presses accelerator pedal
4) Or driver presses the brake pedal
5) Or road slope (by G-value of the longitudinal sensor value) is higher than 2.3%

11.06.07.02 Predictive energy control – N/A

12.00 Description of Vehicles Covered by Certificate and Test Parameters

12.01 Vehicle Parameters

Carline		58	59
Model Name		Santa Fe Hybrid AWD	Santa Fe Hybrid FWD
Vehicle Classification		LDV	LDV
Emission control System description	Type, number and configuration of catalyst(s)	See Sec. 02.02	See Sec. 02.02
	EGR Type	Electronic	Electronic
	Air pump type	N/A	N/A
	Fuel system type	DFI	DFI
	Intake air aspiration method	Turbocharger, Charge Air Cooler	Turbocharger, Charge Air Cooler
	Other	-	
Engine Code		G4FT-AC	G4FT-AC
Number of valves per cylinder		4	4
Engine Displacement (L)		1.6	1.6
Sales area		50-State	50-State
Transmission and overdrive		AMS6 (Overdrive)	AMS6 (Overdrive)
SIL		N/A	N/A
Tire		255/45R20 (PIRELLI/KUMHO[*1]) 235/60R18 (GOODYEAR/ KUMHO[*1])	255/45R20 (PIRELLI/ KUMHO[*1]) 235/60R18 (GOODYEAR/ KUMHO[*1])
N/V Ratios		32.3	32.3
ETW(lb)		4750	4750 (20'' tire) 4500 (18'' tire)
Elec. Dyno. Target Coefficient		Please refer to 12.02.01.	Please refer to 12.02.01.
Fuel tank volume(gal)		17.7	17.7

*1) Canada only

12.02 Test Parameters

12.02.01 Test Parameters

T/M Items			AMS6			
Model			Santa Fe Hybrid AWD		Santa Fe Hybrid FWD	
ETW			4750	4750	4750	4500
Tire			255/45R20 (PIRELLI / KUMHO^{*1})	235/60R18 (GOODYEAR / KUMHO^{*1})	255/45R20 (PIRELLI / KUMHO^{*1})	235/60R18 (GOODYEAR / KUMHO^{*1})
Single Roll	Elec. Dyno. Target Coefficient	A	39.616	35.974	38.829	31.781
		B	0.19265	0.06386	0.02779	0.03064
		C	0.025583	0.024986	0.025199	0.024803
Shift Schedule IDs			Please refer to 12.02.03			
Evap. Code			137M1G			
Canister Loading	Flow Rate(g/hr)		15 (3DBL only) / 40			
	Capacity (g)		137			
Running Loss Fuel Tank Temp.			Please refer to 12.02.05			
Transmission Test Mode(s)			EM: Sport FE: Eco			
Advanced technology system test mode(s)			N/A			

*1) Canada only

12.02.02 Engine Starting Procedures

Please refer to Common Section 12.02.02.

12.02.03 Shift Schedules

Please refer to Common Section 12.02.03.01

12.02.04 Transmission / Advanced Technology System Test Modes

Please refer to Common Section 12.02.04.

12.02.05 Running Loss Fuel Tank Temperature Profile

(C/O from 21MY Sorento Hybrid)

Fuel Temperature Profile tests were conducted according to “California Evaporative Emission Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles,” adopted August 5, 1999 (last amended September 2, 2015).

Test Vehicle Description

Vehicle	Engine	T/M	Fuel Tank		Fuel	
			Capacity.	Material	Type	RVP
Sorento Hybrid	1.6L	AMS6	67L	Plastic	CARB LEV-III	7.2 psi

Ambient Conditions

PROCEDURE	DESCRIPTIONS	REQUIREMENTS
DRAIN & REFILL	Fuel : CARB LEV-III (RVP : 7.2psi)	6.9 ~ 7.2 psi
	Fuel Level : 26.8L (7.08Gal)	40% of Fuel Tank Volume
	Date & Time : 19:30, JAN 23, 2019	
	Odometer : 205mile	
PARKING	Date & Time : 19:40, JAN 23, 2019	
	Location: North Bourke, NSW	
	Orientation : South	
	Odometer : 208mile	
DRIVING START	Date & Time : 16:45, JAN 24, 2019	
	Ambient Temp. 109.7 °F	Tamb,o >= 95°F
	Road Temp. : 143.3°F	Tsur,I >= 135°F or Tsur-Tamb > 30°F
	Cloud Cover : 0%	Cmax <= 25%
	Wind Speed : 11.0 mph	Wmax <= 15mph
DRIVING END	Date & Time : 17:56, JAN 24, 2019	
	Ambient Temp. : 109.5 °F	Tamb,I >= Tamb,o-2°F
	Road Temp. : 135.5°F	Tsur,I >= 135°F or Tsur-Tamb > 30°F
	Cloud Cover : 0%	Cmax <= 25%
	Wind Speed : 7.0 mph	Wmax <= 15mph

(Note) I: instantaneous measurement, o: initial measurement

Profile Data Summary

(Temp. = Temperature(°C))

Fuel Tank Temperature

Cycle Status	Actual Time (sec)	Fuel 1 (°C)	Fuel 2 (°C)	Fuel Average (°C)	Vapor Temp (°C)	Pressure (in H2O)
Start first UDDS	0	39.7	39.9	39.8	39.9	0
End first 505 sec	510	40.7	40.8	40.7	41.4	0.1
End first UDDS	1380	42.6	42.6	42.6	43.7	0
End first idle	1500	42.6	42.7	42.6	44	0
End first NYCC	2100	43.8	43.9	43.8	44.1	0
End second NYCC	2700	45.0	45.1	45.0	44.5	0
End second idle	2820	45.1	45.3	45.2	44.4	0
End second 505	3330	46.0	46.1	46.0	45.4	0.1
End second UDDS	4170	46.9	47.0	46.9	46.1	-1.2
End third idle	4320	46.8	47.0	46.9	46	0

Ambient Condition

Cycle Status	Actual Time (sec)	Ambient Temp (°F)	Road Temp (°F)	Delta Temp (°F)	Wind Speed (mph)	Cloud Cover (%)
Start first UDDS	0	109.7	143.3	33.6	11.0	0
End first 505 sec	540	108.7	143.1	34.4	7.0	0
End first UDDS	1380	109.5	142.7	33.2	4.0	0
End first idle	1500	109.8	142.5	32.7	6.0	0
End first NYCC	2100	109.2	139.2	30.0	12.0	0
End second NYCC	2700	109.1	138.0	28.9	5.0	0
End second idle	2820	109.3	138.0	28.8	6.0	0
End second 505	3300	107.7	138.3	30.6	9.0	5%
End second UDDS	4140	109.0	135.5	26.5	2.0	0
End third idle	4320	109.5	135.5	26.0	7.0	0

Measured FTTP Data

Time [sec]	Fuel 1 [°C]	Fuel 2 [°C]	Fuel AV [°C]	Vapor [°C]	Pressure (in H2O)
0	39.9	39.7	39.8	39.9	0.0
30	40.0	39.8	39.9	40	-0.1
60	40.0	39.8	39.9	39.9	0.0
90	40.0	39.9	40.0	40	0.1
120	40.1	39.9	40.0	40.1	0.0
150	40.1	40.0	40.1	40.2	0.0
180	40.2	40.1	40.2	40.3	0.1
210	40.2	40.1	40.2	40.2	0.0
240	40.3	40.2	40.3	40.4	0.0
270	40.3	40.2	40.3	40.4	0.1
300	40.4	40.2	40.3	40.5	0.0
330	40.5	40.4	40.5	40.8	0.1
360	40.5	40.4	40.5	40.8	-0.1
390	40.6	40.5	40.6	40.9	0.1
420	40.7	40.5	40.6	41	-1.1
450	40.7	40.6	40.7	41.2	0.1
480	40.7	40.7	40.7	41.2	0.1
510	40.8	40.7	40.8	41.5	0.1
540	40.9	40.8	40.9	41.6	0.0
570	40.9	40.8	40.9	41.8	0.1
600	41.0	40.9	41.0	41.9	0.1
630	41.0	41.0	41.0	42	0.1
660	41.1	41.0	41.1	42.2	-0.4
690	41.1	41.0	41.1	42.1	0.1
720	41.2	41.1	41.2	42.1	-0.2
750	41.2	41.2	41.2	42.1	-4.4
780	41.3	41.2	41.3	42.2	-3.7
810	41.3	41.3	41.3	42.3	0.0
840	41.4	41.3	41.4	42.4	0.0
870	41.5	41.4	41.5	42.3	0.0
900	41.5	41.5	41.5	42.5	0.1
930	41.6	41.5	41.6	42.6	-0.3
960	41.7	41.6	41.7	42.7	0.2
990	41.8	41.7	41.8	42.8	0.0
1020	41.8	41.8	41.8	42.8	0.0
1050	41.9	41.8	41.9	42.9	0.0
1080	42.0	41.9	42.0	43	0.1
1110	42.0	42.0	42.0	42.9	0.1

1140	42.1	42.1	42.1	43.2	-1.1
1170	42.2	42.1	42.2	43.2	0.1
1200	42.3	42.2	42.3	43.3	0.1
1230	42.3	42.2	42.3	43.4	0.0
1260	42.3	42.3	42.3	43.4	0.0
1290	42.4	42.4	42.4	43.6	0.0
1320	42.5	42.4	42.5	43.7	0.1
1350	42.5	42.5	42.5	43.6	0.0
1380	42.6	42.6	42.6	43.7	0.0
1410	42.6	42.6	42.6	43.8	0.0
1440	42.7	42.6	42.7	44	0.0
1470	42.7	42.6	42.7	44	0.0
1500	42.7	42.6	42.7	44.1	0.0
1530	42.8	42.7	42.8	44	0.1
1560	42.9	42.8	42.9	43.9	0.0
1590	42.9	42.8	42.9	43.7	0.0
1620	43.0	42.9	43.0	43.8	0.0
1650	43.0	43.0	43.0	43.8	-0.1
1680	43.1	43.0	43.1	43.8	0.0
1710	43.2	43.1	43.2	43.9	-0.9
1740	43.3	43.2	43.3	44.1	0.0
1770	43.3	43.2	43.3	44.1	0.0
1800	43.4	43.3	43.4	44.2	0.0
1830	43.4	43.4	43.4	44.1	0.0
1860	43.5	43.4	43.5	44.2	0.0
1890	43.5	43.4	43.5	44	0.0
1920	43.6	43.5	43.6	44.2	-0.1
1950	43.7	43.6	43.7	44.2	-0.1
1980	43.7	43.6	43.7	44.2	0.0
2010	43.7	43.6	43.7	44.2	-3.2
2040	43.8	43.7	43.8	44.2	0.0
2070	43.9	43.8	43.9	44.2	0.0
2100	43.9	43.8	43.9	44.2	0.0
2130	44.0	43.8	43.9	44.1	-0.2
2160	44.0	43.9	44.0	44.1	-1.0
2190	44.1	44.0	44.1	44.2	0.0
2220	44.2	44.1	44.2	44.2	0.1
2250	44.2	44.2	44.2	44.2	0.0
2280	44.3	44.2	44.3	44.3	-0.3
2310	44.4	44.3	44.4	44.3	-0.2
2340	44.5	44.4	44.5	44.4	0.1
2370	44.6	44.5	44.6	44.4	0.0

2400	44.6	44.5	44.6	44.5	0.0
2430	44.7	44.6	44.7	44.5	0.0
2460	44.7	44.6	44.7	44.4	0.0
2490	44.7	44.7	44.7	44.3	0.0
2520	44.8	44.7	44.8	44.4	0.0
2550	44.9	44.8	44.9	44.6	0.0
2580	44.9	44.8	44.9	44.5	0.0
2610	44.9	44.8	44.9	44.5	-9.6
2640	45.0	44.9	45.0	44.6	0.0
2670	45.1	45.0	45.1	44.7	0.0
2700	45.1	45.0	45.1	44.6	0.0
2730	45.2	45.0	45.1	44.6	0.0
2760	45.2	45.0	45.1	44.5	0.0
2790	45.2	45.1	45.2	44.6	0.0
2820	45.3	45.1	45.2	44.4	0.0
2850	45.4	45.2	45.3	44.6	-8.6
2880	45.4	45.3	45.4	44.5	-0.1
2910	45.4	45.4	45.4	44.5	-2.1
2940	45.5	45.3	45.4	44.7	-1.7
2970	45.6	45.5	45.6	44.8	0.0
3000	45.6	45.5	45.6	44.8	0.0
3030	45.7	45.5	45.6	44.9	-4.7
3060	45.7	45.6	45.7	44.8	-10.0
3090	45.7	45.6	45.7	44.9	-10.0
3120	45.8	45.6	45.7	45	-6.6
3150	45.9	45.8	45.9	45.3	0.1
3180	45.9	45.8	45.9	45.3	-7.0
3210	45.9	45.9	45.9	45.5	-0.1
3240	46.0	45.9	46.0	45.4	-2.5
3270	46.1	45.9	46.0	45.4	0.0
3300	46.1	46.0	46.1	45.6	-10.0
3330	46.1	46.0	46.1	45.5	0.1
3360	46.2	46.0	46.1	45.5	0.0
3390	46.2	46.0	46.1	45.5	0.3
3420	46.2	46.0	46.1	45.6	-0.2
3450	46.2	46.1	46.2	45.7	0.0
3480	46.3	46.1	46.2	45.9	-7.1
3510	46.3	46.1	46.2	45.7	0.0
3540	46.3	46.2	46.3	45.7	0.0
3570	46.4	46.2	46.3	45.7	-0.4
3600	46.4	46.2	46.3	45.7	-2.0
3630	46.4	46.3	46.4	45.7	0.0

3660	46.4	46.3	46.4	45.8	0.1
3690	46.5	46.4	46.5	45.8	0.0
3720	46.5	46.4	46.5	45.8	0.0
3750	46.6	46.4	46.5	45.8	-0.9
3780	46.6	46.5	46.6	45.9	0.0
3810	46.7	46.5	46.6	45.9	0.0
3840	46.7	46.5	46.6	46.2	0.0
3870	46.7	46.6	46.7	46.1	0.0
3900	46.7	46.6	46.7	46.2	0.0
3930	46.8	46.6	46.7	46.2	-0.3
3960	46.8	46.6	46.7	46.1	0.0
3990	46.8	46.7	46.8	46.1	0.0
4020	46.8	46.7	46.8	46.2	0.0
4050	46.9	46.7	46.8	46.4	0.0
4080	46.9	46.7	46.8	46.2	0.1
4110	46.9	46.8	46.9	46.3	0.0
4140	46.9	46.8	46.9	46.4	-0.1
4170	47.0	46.9	47.0	46.2	-1.2
4200	47.0	46.8	46.9	46.1	0.0
4230	47.0	46.8	46.9	46.1	0.0
4260	47.0	46.8	46.9	46.1	0.0
4290	47.0	46.8	46.9	46.3	0.0
4320	45.4	45.3	45.4	44.5	-0.1

13.00 Projected Sales

Please refer to Common Section 13.00.

14.00 Request for Certification

Ms. Kathryn Kochunas
Certification Division
Mobile Source Pollution Control
U.S. Environmental Protection Agency
2000 Traverwood Drive
Ann Arbor, Michigan

Subject: Request for Certificate of Conformity for 2024 Model Year Test Group RHYXV01.6M13/Evaporative Family RHYXR0137M1G

Dear Ms. Kathryn Kochunas:

Hyundai Motor Company requests that EPA issue a Certificate of Conformity for the above subject test group.

All vehicles within the above mentioned test group comply with the applicable regulations contained in 40 CFR86.1844-01(d), (14) including the provisions of 40 CFR Parts 85, 86 and 600. This test group also complies with California Air Resources Board, Final Regulation Order, Sections 1961.2 and 1961.3 (1962.2 and 1962.3 for zero-emission vehicles) Title 13, California Code of Regulations.

The Part 1 Application for Certification has been prepared in accordance with the standardized format recommended by EPA via its guidance document CD-14-19 (LDV/LDT/OCO/LIMO) Subject: Certification Application Reporting Guidance, dated November 24, 2014.

If you have any questions in regard to the Certificate of Conformity do not hesitate to contact Lillian Klawitter at lklawitter@hatci.com or 201-790-0276.

Sincerely,

B. R. Yoon
General Manager
Regulation & Certification Team 2
Hyundai Motor Company

Ms. Robin U. Lang, Chief
Emissions Certification and Compliance Division
California Air Resources Board
4001 Iowa Ave.
Riverside, California 92507

Subject: Request for Certificate of Conformity for 2024 Model Year Test Group RHYXV01.6M13/Evaporative Family RHYXR0137M1G

Dear Ms. Robin U. Lang:

Hyundai Motor Company requests that California Air Resources Board (CARB) issue an Executive Order for the above subject test group.

All vehicles within the above mentioned test group comply with the applicable regulations contained in 40 CFR86.1844-01(d), (14) including the provisions of 40 CFR Parts 85, 86 and 600. This test group also complies with California Air Resources Board, Final Regulation Order, Sections 1961.2 and 1961.3 (1962.2 and 1962.3 for zero-emission vehicles) Title 13, California Code of Regulations.

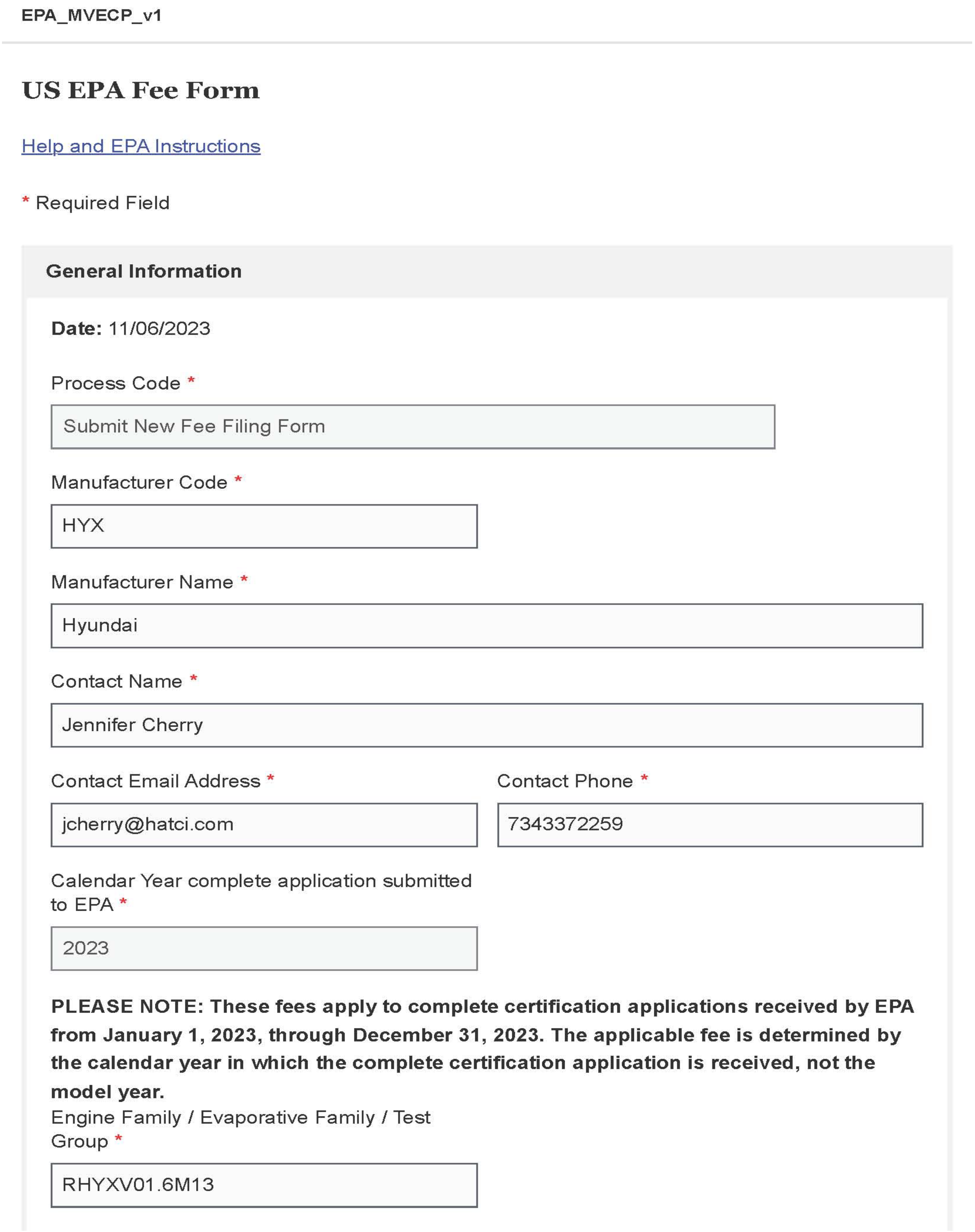
The Part 1 Application for Certification has been prepared in accordance with the standardized format recommended by EPA via its guidance document CD-14-19 (LDV/LDT/OCO/LIMO) Subject: Certification Application Reporting Guidance, dated November 24, 2014.

If you have any questions in regard to the Certificate of Conformity do not hesitate to contact Lillian Klawitter at lklawitter@hatci.com or 201-790-0276.

Sincerely,

B. R. Yoon
General Manager
Regulation & Certification Team 2
Hyundai Motor Company

15.00 Other Information
15.01 Certification Fee Filing Form



EPA_MVECP_v1

US EPA Fee Form

Help and EPA Instructions

* Required Field

General Information

Date: 11/06/2023

Process Code *
Submit New Fee Filing Form

Manufacturer Code *
HYX

Manufacturer Name *
Hyundai

Contact Name *
Jennifer Cherry

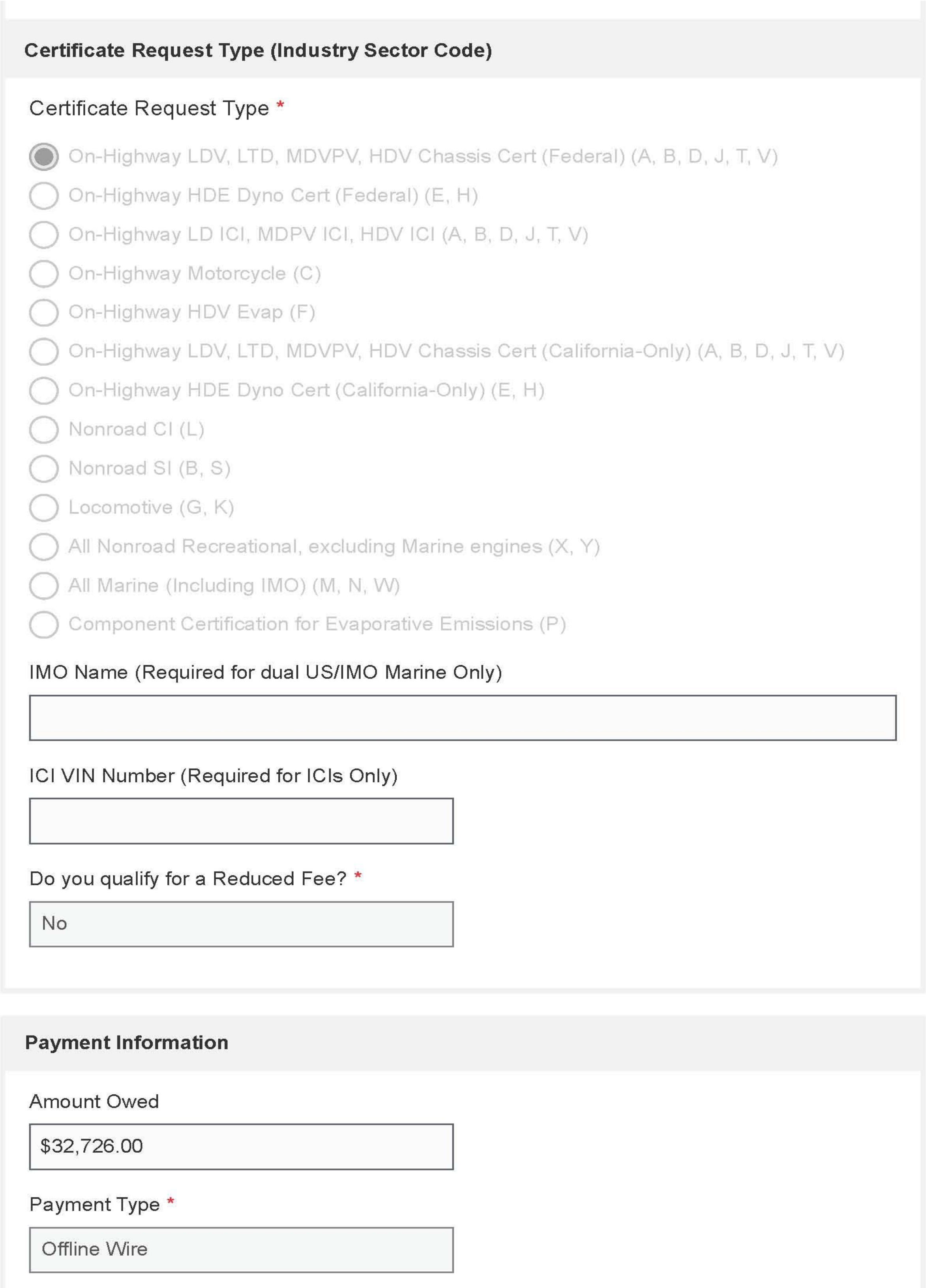
Contact Email Address *
jcherry@hatci.com

Contact Phone *
7343372259

Calendar Year complete application submitted to EPA *
2023

PLEASE NOTE: These fees apply to complete certification applications received by EPA from January 1, 2023, through December 31, 2023. The applicable fee is determined by the calendar year in which the complete certification application is received, not the model year.

Engine Family / Evaporative Family / Test Group *
RHYXV01.6M13



Certificate Request Type (Industry Sector Code)

Certificate Request Type *

- ● On-Highway LDV, LTD, MDVPV, HDV Chassis Cert (Federal) (A, B, D, J, T, V)
- ○ On-Highway HDE Dyno Cert (Federal) (E, H)
- ○ On-Highway LD ICI, MDPV ICI, HDV ICI (A, B, D, J, T, V)
- ○ On-Highway Motorcycle (C)
- ○ On-Highway HDV Evap (F)
- ○ On-Highway LDV, LTD, MDVPV, HDV Chassis Cert (California-Only) (A, B, D, J, T, V)
- ○ On-Highway HDE Dyno Cert (California-Only) (E, H)
- ○ Nonroad CI (L)
- ○ Nonroad SI (B, S)
- ○ Locomotive (G, K)
- ○ All Nonroad Recreational, excluding Marine engines (X, Y)
- ○ All Marine (Including IMO) (M, N, W)
- ○ Component Certification for Evaporative Emissions (P)

IMO Name (Required for dual US/IMO Marine Only)

ICI VIN Number (Required for ICIs Only)

Do you qualify for a Reduced Fee? *

No

Payment Information

Amount Owed

$32,726.00

Payment Type *

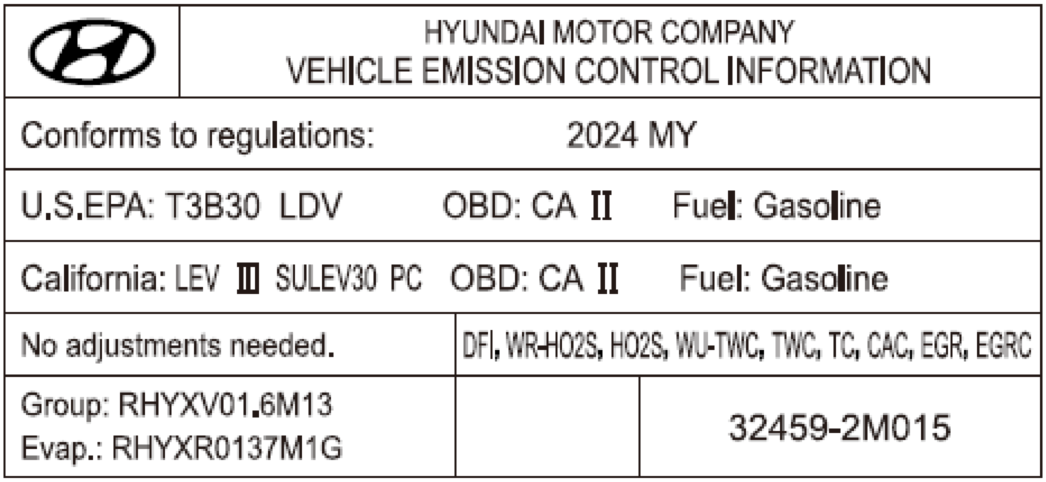
Offline Wire

Comments

EPA Form Number 3520-29
OMB Control No. 2060-0545
Approval expires 12/31/2022

The public reporting and recordkeeping burden for this collection of information is estimated to average 12 minutes per response. Send comments on the Agency's need for this information, the accuracy of the provided burden estimates, and any suggested methods for minimizing respondent burden, including through the use of automated collection techniques to the Director, Collection Strategies Division, U.S. Environmental Protection Agency (2822T), 1200 Pennsylvania Ave., NW, Washington, D.C. 20460. Include the OMB control number in any correspondence. Do not send the completed forms to this address.

15.02 Vehicle Emission Control Information (VECI) Label



HYUNDAI MOTOR COMPANY
VEHICLE EMISSION CONTROL INFORMATION

Conforms to regulations: 2024 MY

U.S.EPA: T3B30 LDV OBD: CA II Fuel: Gasoline

California: LEV III SULEV30 PC OBD: CA II Fuel: Gasoline

No adjustments needed. DFI, WR-HO2S, HO2S, WU-TWC, TWC, TC, CAC, EGR, EGRC

Group: RHYXV01.6M13
Evap.: RHYXR0137M1G

32459-2M015

15.03 ORVR Safety Statement

Hyundai Motor Company is using standard technology in all 2024MY vehicles ORVR systems. In accordance with EPA Guidance Letter CISD-06-06, ORVR applications will not be submitted.

15.04 New Technology System Description

Please refer to Common Section 15.04.

15.05 Engine Oil Information

Please refer to Common Section 15.05

16.00 California ARB Information

16.01 Exhaust Emission Control System (Tune-up label)

Test Group Name	Model	Exhaust Emission Control System
RHYXV01.6M13	Santa Fe Hybrid AWD Santa Fe Hybrid FWD	DFI, WR-HO2S, HO2S, WU-TWC, TWC, TC, CAC, EGR, EGRC, OBD-II

Note:		
	DFI	: Direct Fuel Injection
	WR-HO2S	: Wide Range/Linear/Air-Fuel Ratio Heated Oxygen Sensor
	HO2S	: Heated Oxygen Sensor
	WU-TWC	: Warm up Three Way Catalyst System
	TWC	: Three Way Catalyst System
	TC	: Turbocharger
	CAC	: Charge Air Cooler
	EGR	: Exhaust Gas Recirculation
	EGRC	: EGR Cooler
	OBD II	: On-Board Diagnostics II

(use abbreviations per SAE J1930 Oct 08)

16.02 Test Procedures

Please refer to Common Section 16.02.

16.03.00 Fill Pipe Access Zones Statement and Specifications

16.03.01 Fill Pipe Access Zones Statement

Please refer to Common Section 16.03.01.

16.04.00 Request for Certificate

Please refer to 14.00.

16.04.01 Statement of Compliance

Please refer to Common Section 16.04.01.

16.04.02 Supplemental Data Sheet

Please refer to E-cert data.

16.05.00 Emission Testing Waiver Statement

Please refer to Common Section 16.05.00.

16.06.00 Projected Sales

Please refer to Common Section 13.00.

16.07.00 OBD-II System Description

Please refer to section 09.00.

16.08.00 New Technology System Description

Please refer to Common Section 15.04.

16.09.00 Environmental Performance Label

Pursuant to CALIFORNIA ENVIRONMENTAL PERFORMANCE LABEL SPECIFICATIONS FOR 2009 AND SUBSEQUENT MODEL YEAR PASSENGER CARS, LIGHT-DUTY TRUCKS, AND MEDIUM-DUTY PASSENGER VEHICLES (adopted May 2, 2008, last amended September 2, 2015), 2012, Hyundai complies Environmental Performance Label requirement by affixing the Federal Fuel Economy and Environment Label in accordance to 40 CFR Parts 85, 86, and 600 as promulgated on July 6, 2011.

16.10.00 AECD General Statements

The vehicles contained in this test group are not equipped with a defeat device and are not equipped with alternative mapping strategies. Furthermore, all AECDs have been declared and described in the application.

As described in our application, the vehicle's transmission is not part of any AECD. However, the transmission gear is an input for the emissions control strategy, as described in that application. The ECU does not provide an output to the TCU to control emissions strategy.

When driving conditions on the road can be properly represented on the dynamometer, the transmission will perform in the same manner. However, there are some different driving conditions, such as an uphill or downhill grade, extreme heat or extreme cold conditions, heavy braking, and curved road driving conditions, which cannot be appropriately represented on the dynamometer. In these conditions where necessary to protect the transmission or to prevent an unnatural shift pattern, a different shift pattern may be executed. It is our understanding that this is commonly used throughout the industry.

The Hyundai-Kia American Technical Center and the Hyundai Motor Group Research and Development Center in Namyang, Korea have endeavored to respond based on our understanding of the regulatory definition of an AECD, the past certification reviews of AECDs conducted by ARB, existing guidance regarding AECDs issued by ARB, and, of course, EPA’s and ARB’s increased interest in this area. We will continue to monitor guidance issued by ARB regarding the level of information and detail desired in a certification application, and will continue to evaluate AECD issues to ensure transparency with respect to our vehicle and engine performance.

16.11.00 California warranty compliance

Please refer to Common Section 16.11.00.

16.12.00 Description of the Propulsion System: Not Applicable

16.13.00 ZEV Compliance: Not Applicable

17.00.00 Service of Process

Please refer to Common Section 01.00.