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Vehicle Technology Assessment, Model Development, and Validation of a 2019 Acura MDX Sport Hybrid

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16. Abstract

NHTSA sets Corporate Average Fuel Economy (CAFE) standards for passenger cars, light trucks, and medium-duty vehicles, and contracted Argonne National Laboratory to conduct full vehicle simulations using Argonne's Autonomie software to provide input into the CAFE model to determine the contribution of vehicle technologies on fuel economy. The vehicle benchmarked in this report is a 2019 Acura MDX Sport Hybrid equipped with a 3.0 V6 variable valve timing and lift electronic control (VTEC) engine coupled through a 7-speed dual clutch transmission and a three-motor hybrid system. The hybrid system consists of a single front electric motor integrated into the transmission supported by two additional electric motors at the rear wheels, allowing for multiple modes of hybrid operation as well as torque vectoring to improve overall vehicle handling. The focus of the evaluation is to understand the use of critical powertrain components and the corresponding impact on vehicle fuel economy and efficiency.

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Definitions and Abbreviations

Acronym	Description
2WD	two-wheel drive
4WD	four-wheel drive
AKI	anti-knock index
AMTL	Advanced Mobility Technology Laboratory (Argonne)
Autonomie	Argonne full vehicle simulation software at www.autonomie.net/
Argonne	Argonne National Laboratory
ASR	absolute speed change rating
AVTE	Advanced Vehicle Testing Evaluation (previous U.S. DOE activity)
BEV	battery electric vehicle
BTU	British thermal unit
CAN	controller area network
CAFE	Corporate Average Fuel Economy
ccps	cubic centimeters per second
CEd	positive driven cycle energy
CFR	Code for Federal Regulation
D3	Downloadable Dynamometer Database (www.anl.gov/d3)
DAQ	data acquisition system
DFCO	deceleration fuel cut-off
DFI	direct fuel injected
DI	direct Injection
DOHC	double overhead cam
DR	distance rating
EGR	exhaust gas recirculation system
ER	energy rating
EER	energy economy rating
FTP	Federal test procedure (EPA defined)
gps	grams per second
HC	hydrocarbon
HEV	hybrid electric vehicle
Highway or HWFET	EPA certification testing: Highway dynamometer driving cycle
inH20	inches of water
inHg	inches of mercury
kPa	kilopascal
LA92	California unified driving schedule
lb-ft	Foot-pounds
lbm	pound-mass
LHV	lower heating value
MBT	maximum brake torque
N	newton
NA	naturally aspirated
Nm	newton-meters (torque)
NOx	oxides of nitrogen
PFI	port fuel injected
RMS	root mean squared

RWD	Rear-wheel drive
SAE	Society of Automotive Engineers
SC03	EPA certification test (air conditioning test)
scfm	standard cubic feet per minute
SSS	steady speed stairs
TCC	torque converter clutch
TCU	transmission control unit
UDDS	EPA certification test: Urban dynamometer driving schedule (FTP-72)
US06	EPA certification test: US06 dynamometer driving schedule
Volpe	Volpe National Transportation Systems Center
VSR	Vehicle Systems Research
VTC	valve timing control
VTEC	variable valve timing and lift electronic control

Symbols	Description
$F_{chassis}$	force obtained from the dynamometer
J_{TC}	Inertia of torque converter
$P_{acc_{mech}}$	power of accessory load
r_t	radius of tire
$R_{xy}(\tau)$	cross-correlation over the range of lags between two signals (x, y)
$T_{acc_{mech}}$	torque of accessory load
T_{eng}	torque of engine
$T_{fd,in}$	torque in of final drive
$T_{fd,out}$	torque out of final drive
$T_{gb,in}$	torque in of gearbox
$T_{gb,out}$	torque out of the gearbox
T_{ratio}	torque ratio of torque converter
$T_{TC,in}$	torque in of torque converter
$T_{TC,out}$	torque out of torque converter
$T_{trq\_cpl,out}$	torque out of torque-coupling
$T_{wheel,brake}$	brake torque of wheel
$T_{wheel,loss}$	torque loss of wheel
$T_{wheel,out}$	torque out of wheel
$v_{chassis}$	linear speed of vehicle
γ_{fd}	ratio of the final drive
η_{fd}	transfer coefficient of final drive
τ	displacement, also known as lag
ω_{eng}	rotational speed of engine
$\omega_{gb,out}$	rotational speed out of gearbox
ω_{ratio}	speed ratio of turbine speed to impeller speed for torque converter
ω_{TC}	rotational speed of impeller for torque converter
ω_{wheel}	rotational speed of wheel

1. Executive Summary

The National Highway Traffic Safety Administration (NHTSA) is an agency within of the U.S. Department of Transportation (DOT) that sets Corporate Average Fuel Economy (CAFE) standards for passenger cars, light trucks, and fuel efficiency standards for medium-duty and heavy-duty engines and vehicles. NHTSA has contracted Argonne to conduct full vehicle simulation using Autonomie (www.autonomie.net/) to provide input into the CAFE model to determine minimum average fuel economy (FE). Autonomie relies on vehicle and component data for model development and validation. Argonne's Advanced Mobility Technology Laboratory (AMTL) provides the laboratory test data for use in Autonomie. In this collaborative effort NHTSA funded Argonne to perform a vehicle benchmark, resulting in an extensive dataset, analysis, model development and validation with Argonne's Autonomie to assess the fuel saving technologies of this advanced powertrain.

The vehicle benchmarked in this report is a 2019 Acura MDX Sport Hybrid equipped with a 3.0 V6 Variable Valve Timing and Lift Electronic Control (VTEC) engine coupled through a 7-speed dual clutch transmission (DTC) and a three-motor hybrid system. The hybrid system consists of a single front electric motor integrated into the transmission supported by two additional electric motors at the rear wheels, allowing for multiple modes of hybrid operation as well as torque vectoring to improve overall vehicle handling. The focus of the evaluation is to understand the use of critical powertrain components and the corresponding impact on vehicle fuel economy and efficiency. Vehicle instrumentation focuses on providing critical data for support in model development and validation and on direct analysis of vehicle operation in the report. Testing is performed on a chassis dynamometer in a controlled laboratory environment across a range of drive cycles and testing temperatures. The combination of focused testing and in-depth instrumentation allows for a detailed performance characterization of powertrain components.

The analysis in this report is separated into several sections. Initial discussions provide a basis for vehicle instrumentation and setup throughout the testing program. Discussions then focus on vehicle-level operation, fuel economy, and efficiency results on certification drive cycles, followed by the impact of high-level changes such as test temperature, test methodology, and test fuel. To close, component operation and model development and validation are discussed.

2. Introduction and Background

Argonne performed a technology assessment of a 2019 Acura MDX Sport Hybrid based on vehicle evaluation, modeling, and simulation. The vehicle evaluation focused on developing an understanding of the powertrain operation and corresponding fuel economy, based on a combination of in-depth instrumentation and focused testing, which resulted in a comprehensive dataset. This dataset of hundreds of time-resolved vehicle signals provided a basis for direct analysis, informed the refinement of Argonne's Autonomie software, and enabled validation of the vehicle specific technologies (www.autonomie.net). This dataset will be made publicly available through the Advanced Mobility Technology Laboratory's Downloadable Dynamometer Database (D3) at www.anl.gov/d3.

3. Test Vehicle Description

3.1. Vehicle Specifications

The 2019 Acura MDX features the sport hybrid "super-handling" all-wheel drive (SH-AWD) system, developed by Honda, a system similar to other previous Acura models, including a sedan and super sport vehicle. The powertrain consists of a 143-kW engine coupled to a 7-speed dual clutch transmission (DCT) and a 35-kW electric motor in the front and two 27-kW electric motors on the rear axle, called a twin motor unit (TMU). The TMU is capable of driving each of the rear wheels independently, thus replacing the rear differential. The 3.0L V6 engine is port fuel injected and has the ability to operate on only a single bank of three cylinders for efficiency improvements at specific loads [1]. The powertrain architecture is shown in Figure 1. The combination of the motors and the engine make it possible to deliver driving force at the wheels in multiple operational modes from either the engine, electric motors, or combinations enabling continuous operation either a 2WD or 4WD mode. An overview of the vehicle's technical specifications can be found in Table 1.

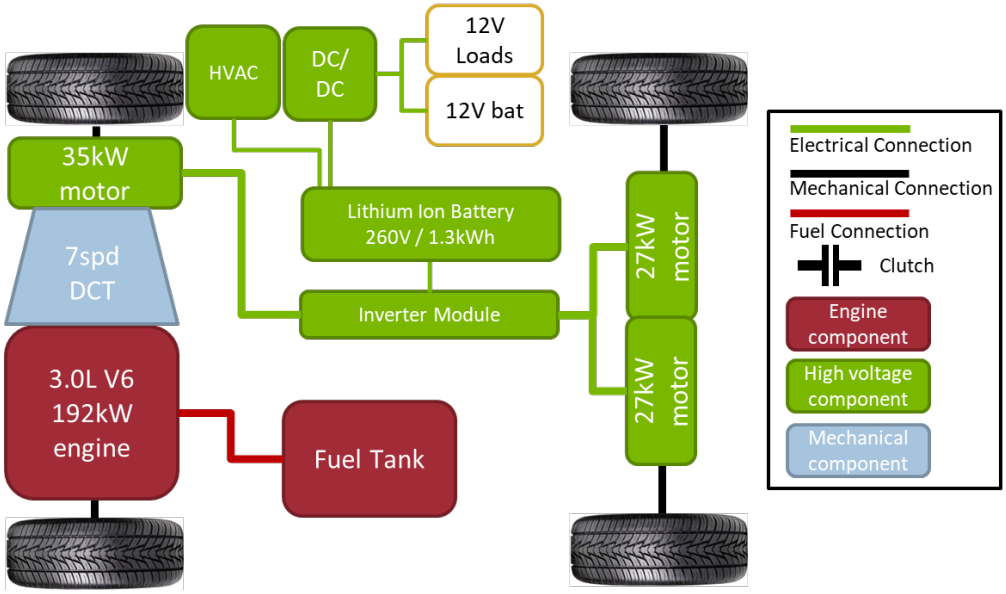

Figure 1. 2019 Acura MDX Sport Hybrid powertrain architecture

Table 1. Technical specifications of the MY2019 Acura MDX Sport Hybrid test vehicle

Test vehicle	**2019 Acura MDX Sport Hybrid** **3.0L V6 with dual clutch transmission**
VIN	5J8YD7H54KL000411
Engine	3.0 liter, V6, i-VTEC®, SOHC 24-Valve 192 kW (257 hp) @ 6300 rpm 296 Nm (218 ft*lbf)@ 5000 rpm Compression ratio 10.5 :1 Port injection
Transmission	7-speed DCT Ratio range: 4.40-0.62 Differential gear ratio: 3.83 245/50 R20 tires
Electric Motor	**Front:** DC brushless, permanent magnet 148 Nm @ 500-2,000 rpm 35 kW @ 3,000 rpm 7950 rpm (max) **Rear (TMU):** DC brushless, permanent magnet (x2) 73 Nm @ 0 -2,000 rpm (146 Nm combined) 27 kW @ 4,000 rpm (54 kW combined) 11,000 rpm (max)
HV Battery	Lithium-ion (72s4p configuration) 260 V, 1.3 kWh Air cooling
Climate control	Tri-zone automatic climate control
EPA label fuel economy (mpg) [1]	26 city/27 hwy/27 combined

The full vehicle build sheet of the test vehicle can be found in Appendix A: Vehicle Build Sheet.

3.2. Key Technology Features

This following section will discuss the key technology features of the vehicle, as referenced from the manufacturer (Honda) service documentation [2] and documentation from the Society of Automotive Engineers [3], unless otherwise noted. The 2019 Acura MDX Sport Hybrid is equipped with an intelligent variable valve timing and lift electronic control (i-VTEC) 3.0L V6 engine with single overhead cam (SOHC) and port injection technology, as well as the following technologies [1][2][3]:

- Variable cylinder management system

[1] Data from https://www.fueleconomy.gov

    - Two-way hydraulic system with reduced switchover pressure for improved fuel economy
    - Three-way solenoid spool valve for improved switchover response time
    - Cooperative control of hydraulic pressure, spark timing, throttle, and transmission lock-up during switchover, with reduced torque fluctuations and increased drivability
    - Three-cylinder bank valve shutoff to reduce pumping losses and engine friction
    - Thermal efficiency improvement from a more favorable engine load area
- Exhaust cleanup system
    - Separate system on each of two cylinder banks
    - High-density, 900-cell, three-way catalytic converter under the cylinder head of each bank to improve warm-up
    - EGR valve with precision control
    - 12-hole injector with improved atomization capabilities

In the 2019 Acura MDX Sport Hybrid, the engine is connected to the front motor through a 7-speed DCT featuring the following technologies.

- Dual dry-clutch
    - Operated by an electrical actuator for reduced drag
- High-capacity synchronizer
    - Compact technology, reduced transmission length
    - Press-formed steel for enhanced durability
- Idle gear cantilever structure with bearing located below the gears
    - Guaranteed rigidity
    - Reduced space between shaft (compact design)
    - Reduced overall weight
- Improved lubrication system
    - Low-viscosity automatic transmission fluid (ATF), reduced friction
    - Baffle plates on final gear and secondary shaft, reduced agitation
    - Oil gutter plate that allows for efficient lubrication even with low fluid surface
    - Oil suction inlet realized as a single piece with secondary baffle plate, reduced amount of oil and reduced agitation resistance
- Gear system efficient design
    - First gear planetary and located on the interior side of the motor
    - Odd-numbered stages located on main shaft for efficient electric vehicle (EV) drive and regeneration and minimum number of engagements
    - Even-numbered stages located on secondary shaft
    - Simple inter-gear structure to minimize power losses and guarantee sharp response and acceleration

A rear mounted Traction Motor Unit (TMU) incorporates two electric motors, and replaces the rear differential and features the following technologies

- Torque vectoring
    - Increased responsiveness of the vehicle during deceleration while turning
    - Stable dynamics even on low radius corner situations
    - Increased steering stability of the vehicle during acceleration while turning
- Redesigned cooling system

    - Dedicated ATF cooler and electric oil pump used for brake control and cooling
    - TMU housing constitutes the oil passage

The parallel-hybrid vehicle powertrain is documented as allowing the vehicle to operate under seven different driving modes.

- EV Launch- Acceleration at takeoff
    - Traction Motor Unit (TMU) supplies driving force to rear wheels
- Engine Drive - Low acceleration at low speeds
    - Engine drive vehicle, front motor acts as a generator
- EV Cruising- Cruising at low and medium speeds in urban areas
    - Rear TMU drives vehicle
- Power Acceleration- Aggressive accelerations
    - Engine drives vehicle with rear TMU assisting
- Engine Cruising- Highspeed cruising
    - Engine drives vehicle
- Regeneration- Deceleration
    - All three front and rear electric motors act as generators, storing energy in HV battery
- AWD Mode- Slippery conditions
    - Four-wheel drive mode, engine drives front wheels and TMU rear.

Other unique features of the vehicle include the following.

- A water cooled 12V DC-DC converter for increased fuel efficiency
- A waterproof structure allowing the power control unit, consisting of the battery pack to be located under the floor of the cabin
- Unique li-ion cells in an 18-cell stack configuration for reduced area and weight

The use of these technologies resulted in a vehicle with a fuel economy notable within its respective vehicle class as discussed in the following section.

3.3. Overview of Comparison Vehicles and Preliminary Analysis

This section provides a brief comparison of the 2019 Acura MDX with other vehicles released in the same vehicle category for the 2019 model year (MY). The 2019 Acura MDX falls into the mid-size luxury crossover SUV class. For 2019 the MDX was offered in four trim levels or packages: standard, technology, advanced, and A-Spec. Two powertrain configurations were offered, one conventional and one hybrid. The standard powertrain is a 3.5L, V6 engine coupled to a 9-speed automatic transmission driving the front wheels. Optional powertrain configurations include optional all-wheel drive coupled to the standard powertrain and the sport hybrid with "super-handling" all-wheel drive (SH-AWD). In the sport hybrid configuration, the vehicle is equipped with a 3.0L, V6 engine coupled to a three-motor hybrid system.

To provide insight into trends for similar vehicles in this category, the test vehicle was compared with vehicles within the same market segment — specifically those with three rows of seating and a starting manufacturer's suggested retail price (MSRP) of $44,000 to $61,000. With vehicles selected based on these broad criteria, all powertrain combinations and trim levels with a rated power of less than 350 hp, based on data available in the EPA Vehicle Test Car List

database [4] were considered. A summary of the resulting list of comparable vehicles (all MY2019) follows.

- *Acura MDX Sport Hybrid (test vehicle)*
- Audi Q7
- Infiniti QX60
- Volvo XC90 (both plug-in hybrid and conventional powertrains)
- Mercedes-Benz GLE400
- BMW X5
- Land Rover Discovery
- Lexus RX350L

The full list of selected vehicles used for this comparison can be found in Appendix B: Subset of Vehicles Used for Comparative Analysis.

Though the vehicles compared are all in the same class, vehicle weight and power varied widely within this class as a variety of optional powertrains and trim levels were available. Within the sample set, variations in a model lineup will result in repeated tests if the powertrain or vehicle weight is significantly affected by the change. An example would be the 2019 Acura MDX, where variations in drive combination (front wheel drive vs all-wheel drive) require separate testing. In addition, a change in package, from the sport hybrid with advanced package to the sport hybrid with technology package, resulted in additional test configurations for comparison. Within this summary, the variations for all vehicle models chosen were considered.

A first point of comparison is the vehicle mass and overall powertrain power. The distribution of vehicle weight and power available, separated by unique vehicle test IDs, is displayed in Figure 2.

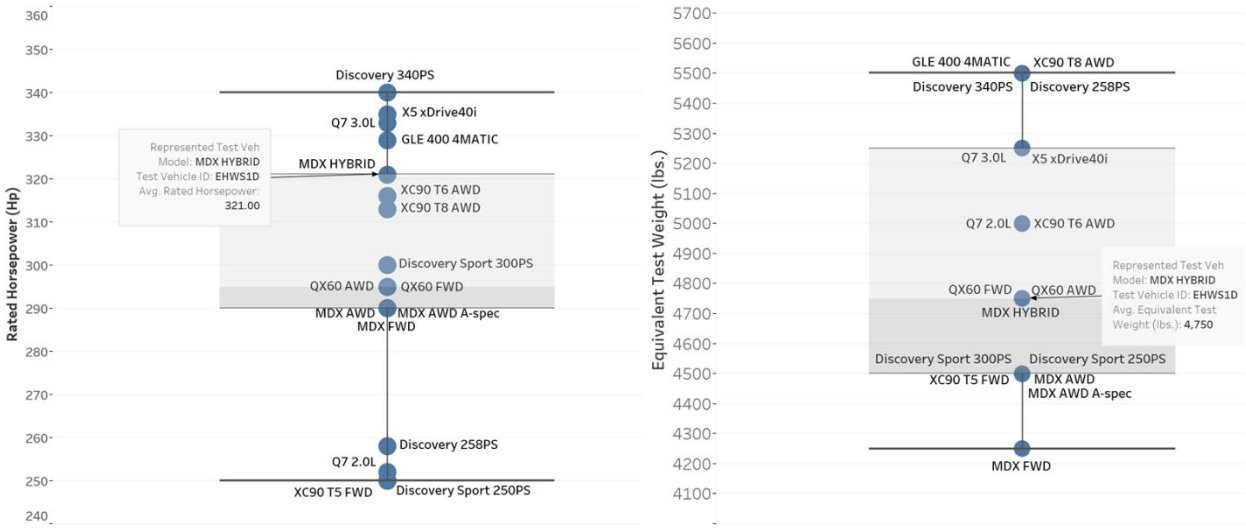

Figure 2. Distribution of horsepower and equivalent test weight among comparable vehicles in test group

At 240 kW (321 hp), the total powertrain power available from the test vehicle is at the border of the third quartile, well above the median of the comparison group of 220 kW (295 hp). It is worth noting that the power of the MDX hybrid was modified from the power listed in the

comparison tables to capture the total system power of 240 kW (321 hp) rather than just the engine-only power. Though the hybrid system results in a considerable increase in system power, it results in only a moderate increase in test weight. The equivalent test weight (ETW) of the vehicles ranges from 4250lbs to 5500lbs, with a median test weight of 4,750 lbs.

Like vehicle weight and powertrain power, fuel economy in this category varies considerably based on powertrain and trim selection. A comparison of the unadjusted fuel economy on the fuel test procedure (FTP) cycle can be seen in Figure 3: Distribution of unadjusted FTP fuel economy for comparison vehicles.

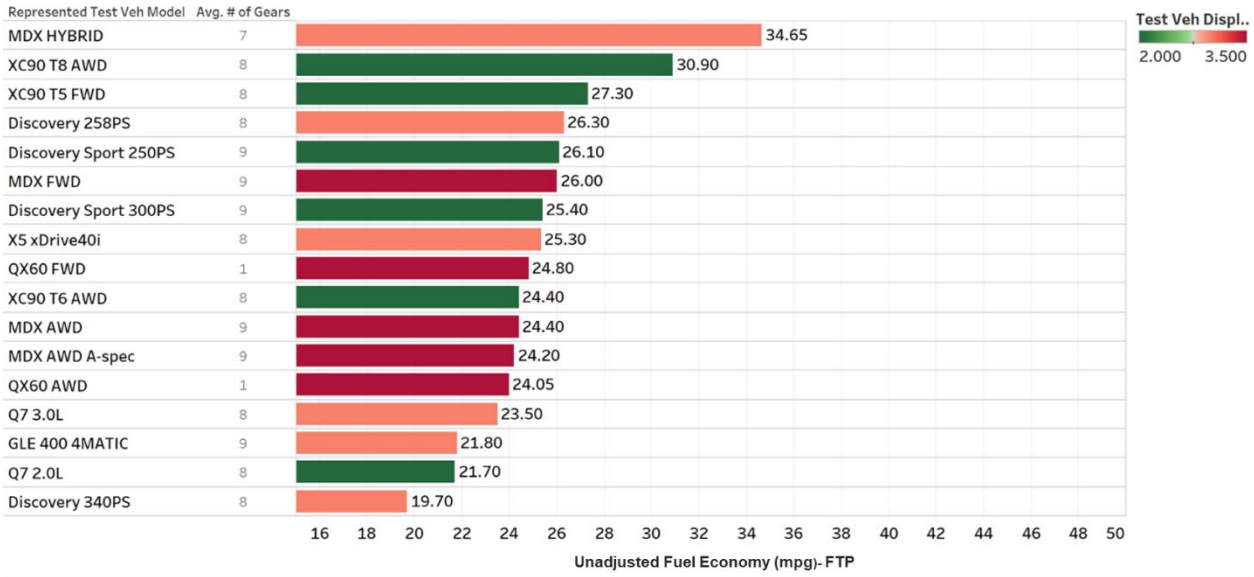

Figure 3. Distribution of unadjusted FTP fuel economy for comparison vehicles

Within the comparison group, the Acura MDX Sport Hybrid demonstrates considerably higher fuel economy on the FTP cycle than other vehicles with conventional powertrains. On this cycle, which simulates operation in a city, regenerative braking, and flexibility in powertrain operation enabled by the hybrid powertrain, can produce large improvements in vehicle efficiency.

Engine displacement within the group ranged from 2.0 L to 3.5 L, with a general trend toward improved FTP cycle fuel economy in vehicles with downsized, turbocharged 2.0 L engines. All conventional vehicles within the comparison were equipped with at least an 8-speed transmission, providing high flexibility in engine loading. Note that although larger displacement powertrains are available on several comparison vehicle models, these powertrains were not considered due to the power limitation of 350 hp established to focus the comparison.

Unadjusted fuel economy on the highway fuel economy driving (HWFET) cycle for the 2019 Acura MDX Sport Hybrid is displayed in Figure 4 alongside that of comparison vehicles.

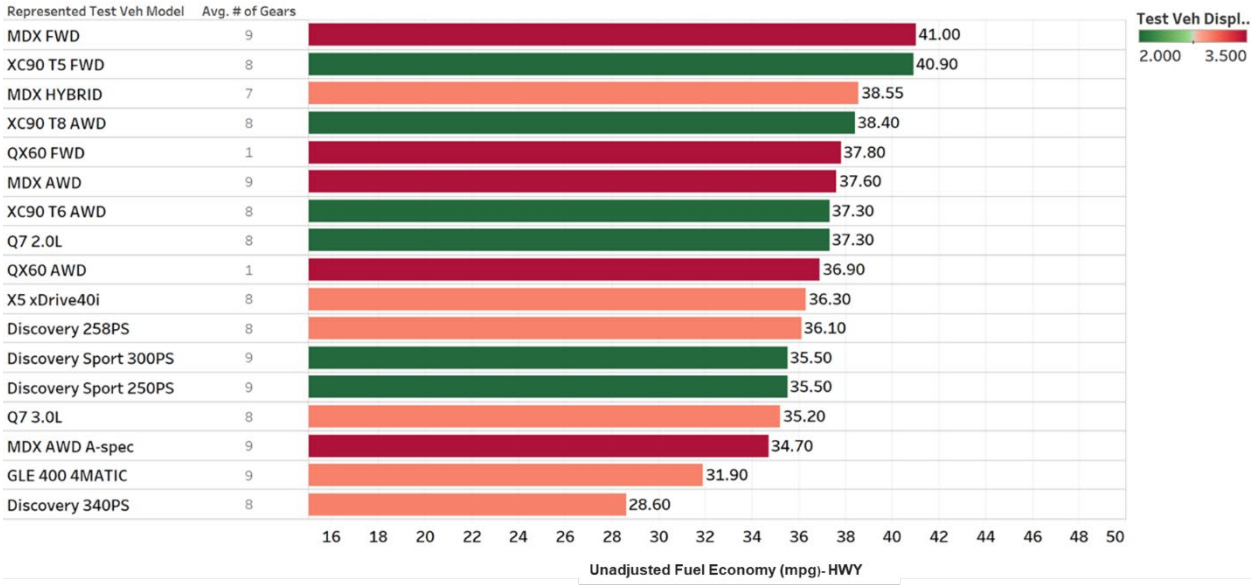

Figure 4. Distribution of unadjusted HWFET fuel economy for comparison vehicles

The Acura MDX Sport Hybrid has a highway fuel economy of 38.6 mpg, third highest of all vehicles in this comparison. The Volvo XC90 T5 FWD and Acura MDX FWD, both of a lighter test weight class and with less available power, were the only two vehicles to display a higher highway fuel economy. The hybrid powertrain in the Acura MDX Sport Hybrid displays high efficiency and unique features within its class, warranting further research and investigation.

4. Testing Overview

4.1. General Testing Overview

4.1.1. Vehicle Procurement and Break In

Vehicle trim level selection involved an extensive review of available vehicle options that could affect vehicle energy use. Two systems determined to have a high impact on consistent vehicle operation included automatic climate control and advanced driver assistance features such as adaptive cruise control. As testing was performed at ambient temperatures above and below 23 °C, automatic climate control offers insights into the climate control system operations that may impact vehicle energy consumption. At above-ambient (hot) temperatures, the high-voltage air conditioning compressor puts a load on the powertrain with varying cooling demands by controlled cabin temperature and airflow. At low temperatures, the climate control system directly impacts the rate at which fluid temperatures rise, as coolant flow is routed to heater core in the passenger cabin, reducing waste heat available for the powertrain. Because the vehicle is equipped with a hybrid powertrain, coolant temperatures also directly affect engine operation, generally increasing the amount of "engine on" operation until sufficient temperature is reached. Though advanced driver assistance features are likely to affect energy use when in operation, the analysis of these impacts was outside of the scope of this study.

A review of the 2019 Acura MDX trim levels found that the "technology" trim level provided all the desired features, and it was chosen for the test vehicle. The test vehicle was purchased new from an Acura dealership, providing a known (near zero mile) baseline of vehicle maintenance and operation history.

A new vehicle must be broken in for stability, for consistent losses of tires and moving and rotating components, and to ensure catalyst degreening. An industry standard of 4,000 miles (6,437 km) has been established for proper vehicle break-in [5][6][7]. On the test vehicle, those preliminary 4,000 miles (6,437 km) were completed through a combination of on-road and on-dynamometer operation. Controller-area-network (CAN)-based vehicle instrumentation was completed prior to break-in, providing data for preliminary results and instrumentation validation and refinement.

4.2. Extended Testing Overview

4.2.1. Vehicle Dynamometer Setup

4.2.1.1. Testing Overview

The following sections provide details of the vehicle setup and an overview of the test methodology specific to this test vehicle. Argonne's test methodology report [8] provides further information on the vehicle test methodology and facility. As the vehicle drives all four wheels, it requires the use of a four-wheel drive chassis dynamometer to capture realistic vehicle operation, which was accomplished with the use of Argonne's 4WD chassis dynamometer. During vehicle debugging on the dynamometer, the vehicle was found to trigger fault codes related to a mismatch of measured and calculated longitudinal acceleration. This fault code directly affected vehicle operation, limiting engine-off operation, regenerative braking, and other controls. In

most testing efforts, faults of this type are resolved by enabling a “dyno mode” provided by the vehicle manufacturer.

To this end, the manufacturer was contacted, and a specialized service tool was delivered for vehicle evaluation during testing. Unfortunately, when in operation, this system disabled the communication of some diagnostic messages of interest for powertrain operation, reducing the available data and insight into overall vehicle operation. An alternative solution was found in which communication between modules on the vehicle was modified, effectively isolating the vehicle fault to a location, which did not affect overall vehicle operation. Comparative testing, consisting of hot start UDDS cycle following a conditioning cycle, was then performed with and without the communication override in place to ensure consistent vehicle operation on the chassis dynamometer. The results of the bag fuel economy between these two cycles can be seen in Table 2:

Table 2. Fuel economy (mpg) comparison on a hot start UDDS of vehicle with the manufacturer dyno mode enabled, and the Argonne Communication Bypass enabled

	Manufacturer enabled dyno mode	**Argonne Communication Bypass mode**
UDDS Hot Start Cycle Results	35.87	35.42

As fuel economy results were within 1%, and vehicle operation was not seen to be affected through this comparison testing, the communication bypass method was used for further testing, enabling collection of key data related to powertrain operation. Following these development efforts and quality control reviews of the captured vehicle data, testing could begin. The test vehicle restrained in the testing environment of the AMTL can be seen in Figure 5.

Figure 5. Vehicle mounted for full testing inside the AMTL 4WD chassis dynamometer.

4.2.2. Instrumentation

Vehicle instrumentation was developed to be sufficiently comprehensive to provide overall insight into vehicle operation and supply modeling and simulation with enough detail to develop models, calibrate control strategies, and to validate simulation results. This section describes the vehicle-specific instrumentation installed that supplements the generic facility instrumentation listed in Table 3.

Table 3. Standard data streams collected for all vehicles tested at Argonne's Advanced Mobility Technology Laboratory

Facility data	**Drive cycle input**	**Emissions data**	**Generic vehicle data**
Dyno_Spd(mph)	Drive_Schedule_Time(s)	Dilute_CH4(mg/s)	Engine_Oil_Dipstick_Temp(C)
Dyno_TractiveForce (N)	Drive_Trace_Schedule(mph)	Dilute_NOx(mg/s)	Cabin_Temp(C)
Dyno_LoadCell(N)	Exhaust_Bag ()	Dilute_COlow(mg/s)	Tire_Rear_Temp(C)
DilAir_RH(%)		Dilute_COmid(mg/s)	Tire_Front_Temp(C)
Tailpipe_Press(inH2O)		Dilute_CO2(mg/s)	
Cell_Temp(C)		Dilute_HFID(mg/s)	
Cell_RH(%)		Dilute_NMHC(mg/s)	
Cell_Press(inHg)		Dilute_Fuel(g/s)	

Analog signals in addition to the standard ones in Table 3 included a thermocouple measuring the air temperature at the radiator and a thermocouple measuring the engine under-hood temperature directly above the engine.

The following is a categorized list of important signals decoded on the vehicle communication bus, both diagnostic and broadcast messaging.

- Driver input
  - Accelerator pedal position (multiple signals)
  - Brake pedal (multiple signals)
  - Transmission PRNDL selection
- Engine
  - Engine load
  - Engine speed
  - Intake air temp
  - Deceleration fuel cutoff
  - Knock feedback
  - Spark adjustment
  - Equivalence ratio
  - Variable cylinder management (VCM) state
- Cooling system
  - Engine cylinder head temperature
  - Engine cooling fan speed
  - HVAC power consumption

- Transmission
  - Transmission temperature
  - Gear selected
  - Transmission even shaft speed
  - Transmission odd shaft speed
- Electric motor (front)
  - Motor torque
  - Motor speed
  - Motor power
- Electric motor (rear units)
  - Motor torque
  - Motor speed
  - Motor power
- High-voltage battery
  - Battery voltage
  - Battery current
  - Battery state of charge (SOC)
  - Battery temperatures

The list above is only a subset of signals collected. The complete list for the test vehicle can be found in Appendix C: 2019 Acura MDX SH Test Signals.

4.2.2.1. Facility Signal Overview

Figure 6 illustrates the general instrumentation for hybrid vehicles. On vehicles like the 2019 Acura MDX Sport Hybrid, testing integrates data streams from several sources, developing a single, time-aligned dataset at 10 Hz for later analysis.

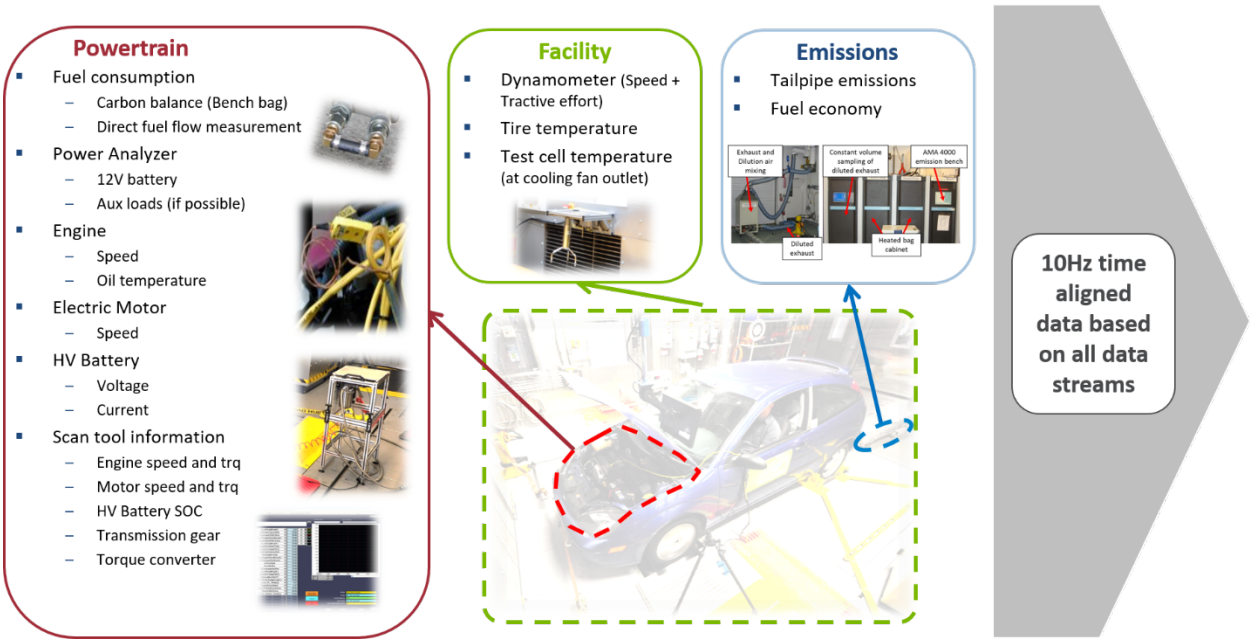

Figure 6. Overview of general instrumentation for a hybrid vehicle

The data captures the test cell conditions (ambient test cell temperature and relative humidity), the dynamometer data (vehicle speed and the tractive effort) and emissions data (bag and modal bench data: HC, CO, NOx, and CO_2).

4.2.2.2. Fuel Flow Measurements

To provide a representation of fuel consumption for multiple paths of analysis, fuel flow is measured in several different ways. The first method consists of a carbon balance from the emissions bench, providing both bag (integrated cycle) and modal (1 Hz) fuel consumption results. This emissions bench measurement provides the standard fuel flow measurement method for comparison to certification testing. To provide increased accuracy at higher transients where modal emissions calculations may be "smoothed" by flow delays in the vehicle exhaust, direct fuel flow measurements supplement measurements from the emissions bench. A Re-Sol RS840-060 fuel scale was installed in-line with the vehicle fuel supply and used a positive displacement flow meter to measure the volumetric flow rate of fuel consumed by the engine. A Coriolis fuel flow meter was routed in series with the fuel scale, providing a direct mass fuel flow rate measurement. Further specifications for the fuel flow measurement equipment can be found in the supplemental vehicle testing report [8].

An illustration of the direct fuel flow measurement arrangement on the vehicle's port fuel injection system on the test vehicle is shown in Figure 7.

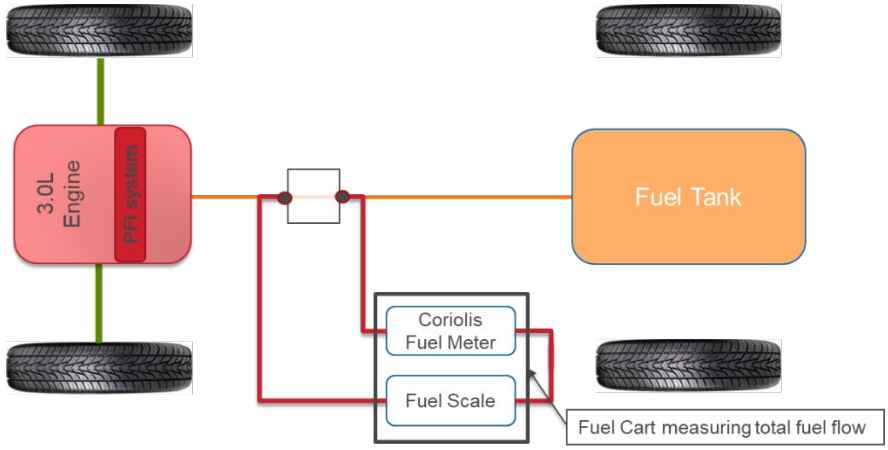

Figure 7. Direct fuel flow instrumentation of 2019 Acura MDX Sport Hybrid

4.2.2.3. Hioki Equipment Setup

Like most hybrid vehicles, the 2019 Acura MDX has two distinct working voltages. The high-voltage system operates at a nominal voltage of 260V and connects all high-voltage components including the battery pack, front electric motor, two rear electric motors, high-voltage refrigerant compressor, and the DC/DC converter. The high-voltage DC/DC provides power to a second, lower, working voltage of 12V that supports all accessory loads.

Vehicle electrical system measurements were captured with a Hioki 3390-10 power analyzer. To provide a direct measurement of bus voltage, a physical tap of the high-voltage bus was made at the main connection of the battery pack, fused, and directly routed to the power analyzer. Hioki CT6843 current probes were used for current measurements of the physical cables throughout the vehicle, with cable shielding removed as needed. On the high-voltage system, the net battery

pack current, the high-voltage refrigerant compressor current, and the DC/DC input current were directly measured. On the low voltage side, a voltage tap and current probe were located on the 12V battery. An overview of vehicle wiring, and the current probe locations can be seen in Figure 8.

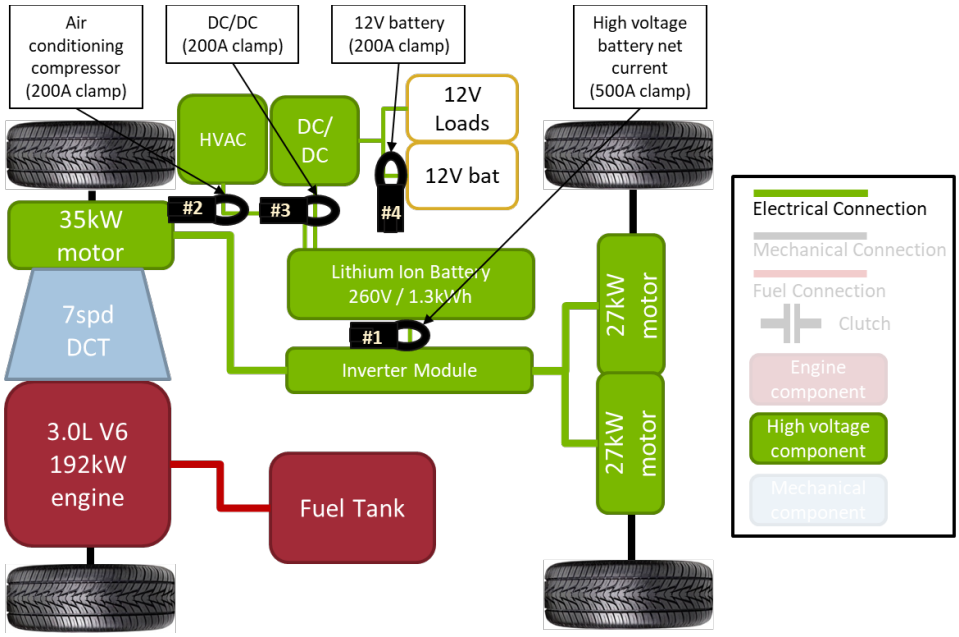

Figure 8. Wiring of Hioki power analyzer measurement on the Acura MDX Sport Hybrid

Due to time and resource constraints, it was not physically possible to install current probes at all locations that may be of interest on the vehicle. To supplement these direct measurements, additional focus was placed on decoding and collecting vehicle data directly from module-to-module CAN communication.

4.2.2.4. Controller Area Network (CAN) Signals

A core capability of the AMTL staff is the ability to decode vehicle and powertrain internal communication messages (CAN messages). Over several years, AMTL staff have developed powerful tools that enable the decoding of both broadcast and diagnostic CAN messages. These tools rely on an understanding of CAN messaging structure, the correlation of changes in CAN messages to verifiable independent instrumentation, and the ability to use the chassis dynamometer environment to safely control planned scenarios to enable the decoding of certain signals.

Capturing communication signals, whether broadcast or diagnostic, directly from the vehicle can provide a considerable amount of data that would otherwise be unattainable due to the challenges of instrumentation and the high costs associated. Once determined, these signals provide key insight into component control and operation. Though these signals offer the mentioned benefits, they do have a higher level of signal specific uncertainty as the data is developed internally at the manufacturer and varies based on the specific signals and sensors. Due to this, Argonne staff validate signals to the greatest extent possible through independent instrumentation and calculation of correlating results of similar signals.

The team decoded a significant list of vehicle messages, which are detailed in Appendix C: 2019 Acura MDX SH Test Signals. This instrumentation required locating and probing seven separate CAN networks throughout the vehicle, which were then joined to a single location for data collection, as seen in Figure 9.

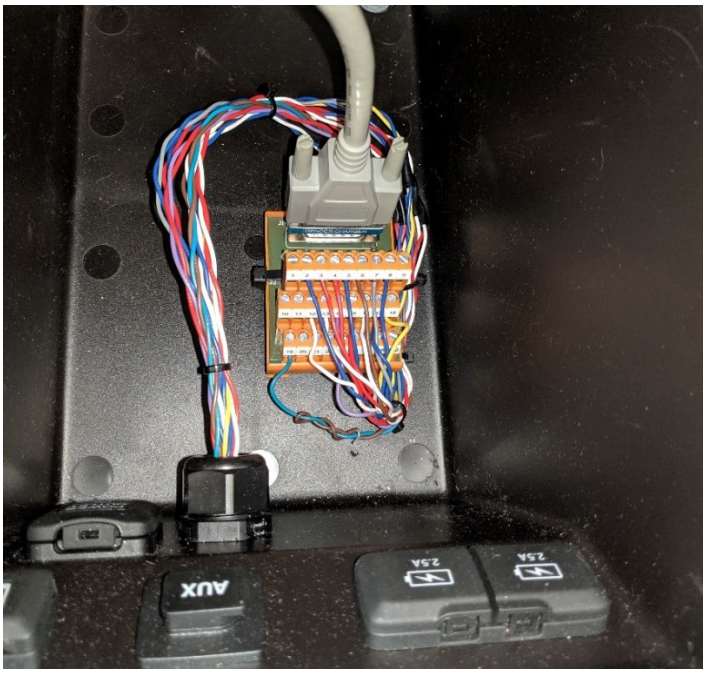

Figure 9. CAN breakout on the 2019 Acura MDX Sport Hybrid

The corresponding collection and communication of CAN messages was completed through a combination of custom and standard scripting in Intrepid Control Systems Vehicle Spy software and National Instruments LabVIEW software, located on the custom-built AMTL data acquisition system (DAQ).

4.2.3. Test Plan Execution

4.2.3.1. Overview of Testing Matrix

Table 4 provides a summary of the tests executed as part of the general test plan. The test sequence, introduced later in Figure 16, was repeated three times at 23°C °C (72 °F), two times at 35 °C (95 °F), while testing at -7 °C (20 °F) did not include repetitions. All testing at 35 °C involved emulated radiant solar energy levels of 850 W/m^2. Additional testing using a high-octane Tier 2 certification fuel on the test sequence provided data for a comparison study of the effects of octane on the vehicle in a later section.

Table 4. Summary of the executed general test plan

Test cycle/Test conditions	23 °C	35 °C + Solar Emulation*	-7 °C	23 °C High-Octane Tier 2 fuel
UDDS x 3 (cold start / hot / hot)	**3x**	**1x**	**1x**	**3x**
HWFET (pair- prep / test)	**3x**	**2x**	**1x ****	**3x**
US06 (pair- prep / test)	**3x**	**2x**	**1x**	**3x**
SC03 (pair- prep / test)		**2x**		
Steady state speed testing at 0%, 3%, 6% grade	**1x**	**1x**		**1x**
Passing 0%, 3%, 6% grade	**1x**			**1x**
Wide open throttle (WOT) x 5	**1x**			**1x**

1x- test was conducted a single time

2x- 2 tests were completed

3x – 3 tests were completed

*: Solar loading during all tests set to the level of 850 W/m2

**: Highway cycles were completed as a series of three to ensure thermal stability at low temperature

Additional testing was included to provide further insight into vehicle energy consumption and operation. The additional testing includes the following.

- 23 °C cold start idle: mapping out the idle fuel flow consumption as a function of powertrain temperature
- 23 °C cold start LA92
- 23 °C cold start JC08
- Transmission mapping through:
  - Constant accelerator tip-ins
  - Accelerator tip-ins with vehicle locked at constant speed
- High load engine and transmission mapping
- Minimum/maximum HV battery SOC swing
- Accessory load test
- Sport mode test at steady state speed
- Worldwide harmonized light vehicle test procedure (WLTP) cold start and hot start

The table in Appendix E: Test Summary summarizes all the final tests performed.

4.2.3.2. Driver Selection (Human vs Robotic)

Vehicle operation on all certification drive cycles was completed with trained human drivers. To supplement their efforts (humans can get tired after a long day of testing) and provide greater control for specific tests such as mapping or steady state speeds, Argonne uses a robot driver. A robot driver has the ability execute and subsequently precisely hold step change inputs of pedal

positions, an operation which is challenging for a human driver. The driver utilized for each specific test can be found in the test plan in Appendix E: Test Summary.

4.2.3.3. Vehicle and Test Cell Setup

Argonne's testing goal is research fidelity and data capture for the purpose of direct analysis and model development. Due to this, Argonne testing may deviate from certification testing, though standard certification drive cycles are conducted. The staff often purposefully chose to change specific aspects of the test procedures to prioritize vehicle operation in real-world conditions. Further detail on standard vehicle and test setup is discussed in separate documentation [8], which can be found in a collaborating report. For specific details on how a test was performed, please see Appendix E: Test Summary.

4.2.4. Specialized testing overview

Determination of component and controls operation and limitations is best realized by focused testing in which vehicle operation can be controlled. This section will provide an overview of the methods and testing developed specifically for the 2019 Acura MDX Sport Hybrid. Additional operational testing discussion can be found in Argonne's test methodology report [8].

4.2.4.1. Steady-State Speeds

Steady-state speed tests determine vehicle operation when the vehicle is driven at a constant speed and load point. The test cycles are a series of constant speeds that are each held for 30 seconds. Vehicle speed is increased in 10 mph increments up to 80 mph, and then decreased to a stop in 10 mph increments. Holding each speed after both increasing and decreasing from the prior speed captures variability in powertrain operation and thermal state. These cycles were repeated at varying grades to capture variations in vehicle loading at a steady state.

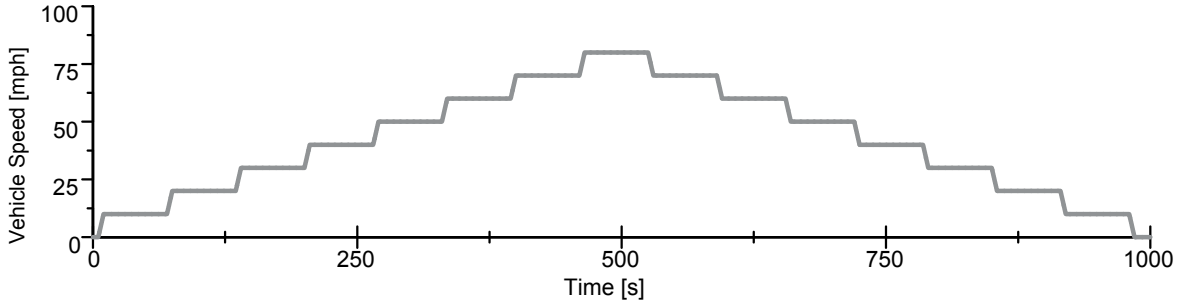

Figure 10. Overview of steady state drive cycle with preparation

Before each steady state speed cycle, the vehicle is warmed to an engine oil temperature of over 80 °C, or a temperature similar to that seen on a transient drive cycle.

Hybrid electric vehicles, like the 2019 Acura MDX Sport Hybrid, can operate in several modes. They may operate on battery power alone if enough energy and power are available in the high-voltage battery pack. Additional modes of operation are used when power is available from both the engine and the high-voltage battery pack. When the energy stored in the battery reaches a lower limit, the engine can be used to provide the tractive power to maintain the vehicle speed

while recharging the battery pack. Alternatively, the battery pack may be discharged with the engine in operation to improve efficiency. To investigate this behavior, additional steady state speed tests were performed in which a specific constant speed was maintained for a longer period of time determined by the occurrence of either multiple cycles of charge/discharge of the HV battery (generally at lower speeds), or when the HV battery state reached near-equilibrium of charge (generally at higher speeds).

4.2.4.2. Powertrain Mapping Cycles

The limits of vehicle powertrain operation are not commonly seen during operation on transient drive cycles. To properly map powertrain operation, custom cycles are used. On the 2019 Acura MDX Sport Hybrid this consisted of a combination of custom drive cycles, a robotic driver, and feedback from focused instrumentation. This mapping was performed using three separate tests, constant accelerator pedal tip-ins, dynamometer ramp cycles, and focused mapping operations.

Constant Accelerator Pedal Tip-In Test
In the first test, the dynamometer operated in road-load simulation mode, where vehicle loading is based on the dynamometer set coefficients determined following coast down testing. Following a warm-up cycle, the vehicle is accelerated with fixed accelerator pedal inputs, as shown in Figure 11.

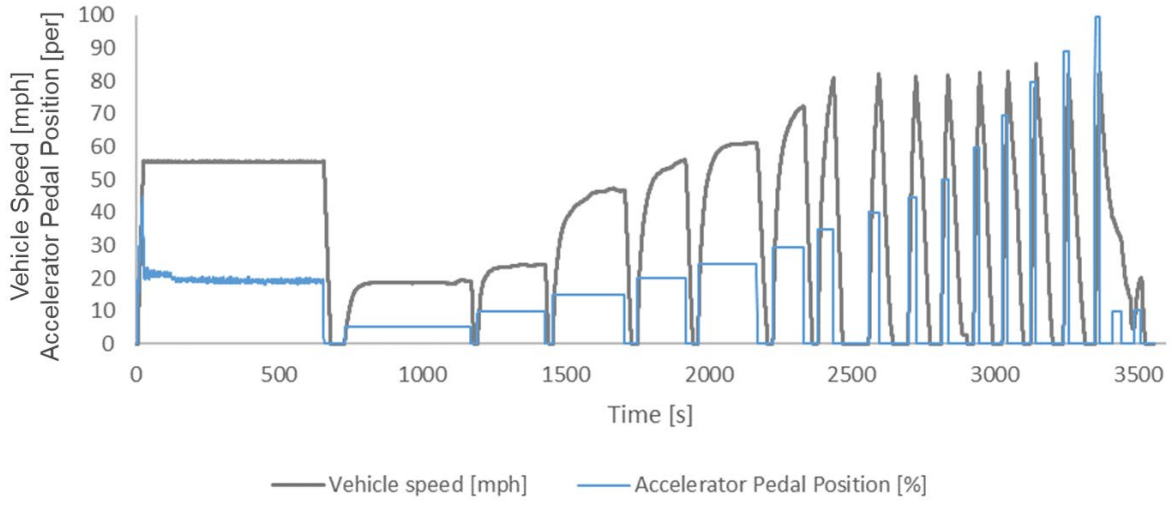

Figure 11. Vehicle acceleration with varying constant pedal inputs

This method provides a map of load demand and upshift strategy for the full range of powertrain operation. The test consists of a series of acceleration and deceleration maneuvers, each conducted with a constant acceleration pedal input. For each successive maneuver, the accelerator pedal position is increased by 5% between 0% and 50%, and by 10% between 50% and 100% (full throttle). It should be noted that as the dynamometer has a maximum speed of 80mph which was reached at the higher accelerator pedal positions.

Constant Dynamometer Acceleration Ramps With Constant Accelerator Pedal Positions
To capture transmission shifts at varying speed and load points, testing was conducted with the dynamometer placed in a mode that provides ramps of constant acceleration and deceleration at a rate of 2 mph per second. This rate was chosen as a tradeoff between an acceleration rate low

enough to provide precise shift points but high enough to avoid component overheating. During ramp cycles, the accelerator pedal input was held constant while the vehicle speed varied. An overview of the cycle can be seen in Figure 12 below.

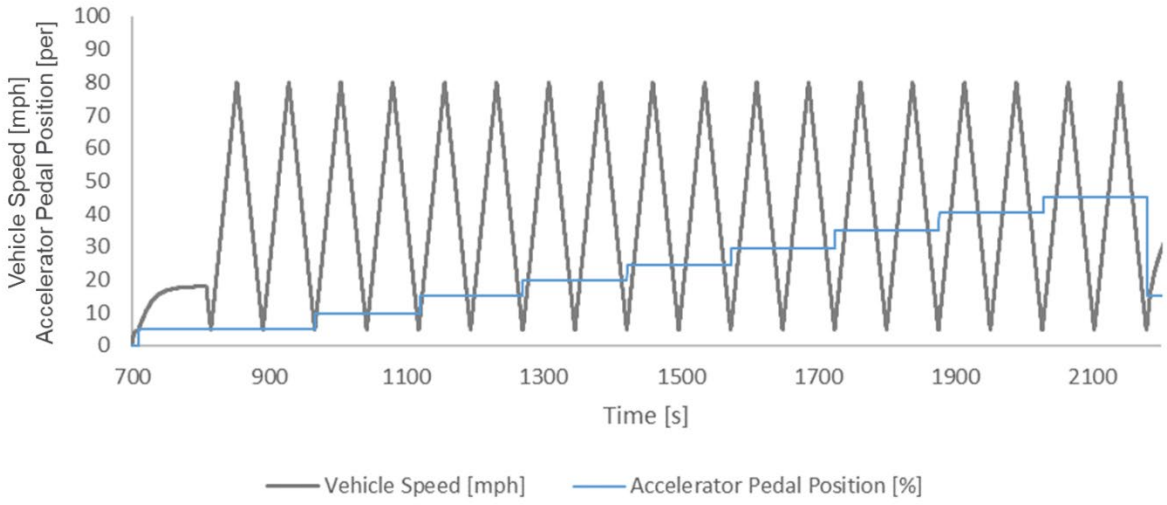

Figure 12. Constant acceleration ramp cycles with varying accelerator pedal inputs

Engine Mapping Test

The third method of powertrain mapping focused on engine mapping, in which the goal is to develop a map of varying engine speeds vs loads. Engine mapping on a chassis dynamometer is inherently more challenging than on an engine dynamometer, as powertrain — or more specifically transmission — operation, can lead to "holes" in the map caused by the torque converter operation or transmission shift commands. In addition, hybrid powertrain operation controls the engine towards high efficiency, reducing operation at many speed/load points. Though this variability is noted, insight can still be captured from comprehensive datasets combined with focused testing. For these tests, the chassis dynamometer was held at constant speeds while accelerator pedal position was varied to capture specific engine load points. An example of this engine mapping test can be seen in Figure 13.

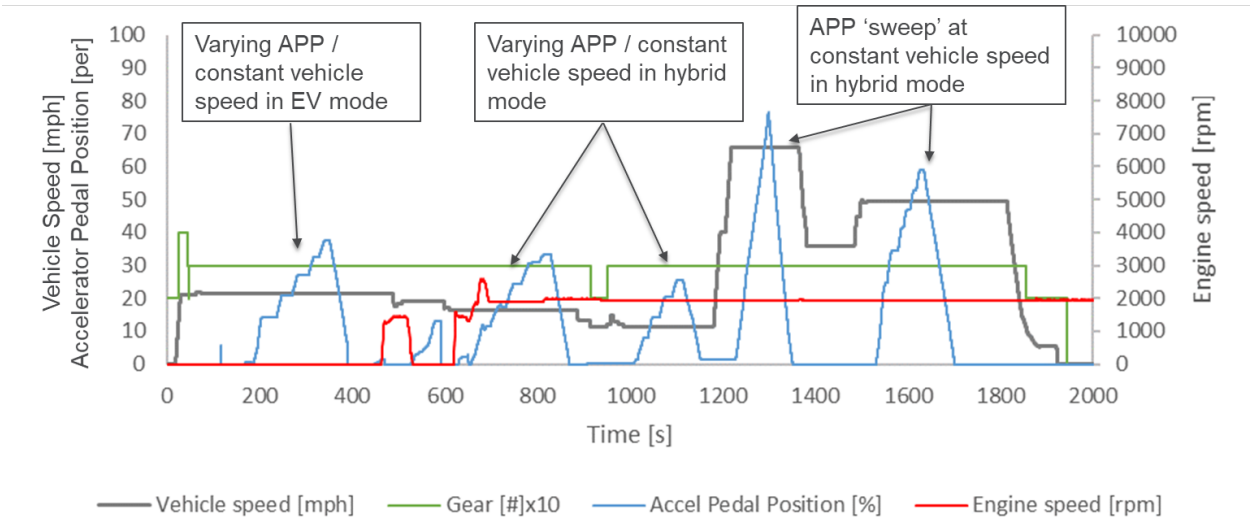

Figure 13. Example of engine mapping operation with fixed engine speed and varying pedal inputs

4.2.5. Tier 3 – 88 AKI (Low-Octane) to Tier 2 – 93 AKI (High-Octane) Fuel Comparison

One important factor in the fuel economy found during chassis dynamometer testing is the test fuel used. Test fuels vary in many ways, including energy content, octane, heating value, and others. As the 2019 Acura MDX Sport Hybrid *recommends* a minimum octane rating of 91, both high and low octane certification fuel were used during vehicle testing to provide data for comparison.

The low-octane fuel chosen was EPA Tier 3 EEE certification fuel with an octane rating of 88 AKI and 10% ethanol content. The fuel was procured from Haltermann Solutions under the product code HF2021, with two separate batches of used during testing. Table 5 and Table 6 provide the major specifications for the Tier 3 certification fuel used, and the full list of specifications may be found in Appendix D: Cert Fuel Specifications.

Table 5. Main specifications of the EPA Tier 3 EEE fuel for test (Test ID 61904015-61904038)

Fuel Name:	**HF2021 EEE Tier 3**
Ethanol content	10%
Carbon weight fraction	0.8252
Density	0.7454 (g/ml)
Net heating value	17994 (BTU/lbm)
Research octane number	92
Motor octane number	84.3
R+M/2	88.2
Sensitivity	7.7

Table 6. Main specifications of the EPA Tier 3 EEE fuel for test (Test ID 61904039-61905008)

Fuel Name:	**HF2021 EEE Tier 3**
Ethanol content	10%
Carbon weight fraction	0.825
Density	0.7463 (g/ml)
Net heating value	17994 (BTU/lbm)
Research octane number	92
Motor octane number	84.3
R+M/2	88.2
Sensitivity	7.7

The high-octane test fuel used during testing was a Tier 2 EEE high-octane certification fuel procured from Haltermann Solutions under the product code HF0437. This certification fuel type was also used during the manufacturer's certification testing, enabling a comparison to the manufacturer reported testing by ensuring consistent energy density and octane. Table 7 provides the major specifications for the Tier 2 fuel used.

Table 7. Main specifications of the EPA Tier 2 EEE fuel (Test ID 61905009-61905029)

Fuel Name:	**HF0437 EEE Tier 2**
Ethanol content	0%
Carbon weight fraction	0.8663
Density	0.743 (g/ml)
Net heating value	18623 (BTU/lbm)
Research octane number	96.8
Motor octane number	89.1
R+M/2	93.0
Sensitivity	7.7

As discussed, the fuel used during testing has a direct impact on the measured vehicle fuel economy. The Tier 2 fuel has a 3.4% higher energy content by mass than the Tier 3 fuel, which was accounted for in post-processing in all fuel economy calculations. Vehicle efficiency calculations use the actual fuel energy content and density, considering fuel variability. The specific fuel used for a test can be found in Appendix E: Test Summary.

4.2.6. Vehicle Setup

Argonne used the test weight and road load coefficients from manufacturer testing published by the EPA in the EPA Test Car List [4]. The vehicle was tested in 4WD mode with the vehicle restrained on the chassis dynamometer using vehicle mounted straps connected to test cell mounted chains at each corner of the vehicle. Prior to the start of testing, the vehicle was warmed on a series of highway cycles, and a series of coast downs for vehicle loss determination performed. The vehicle remained on the dynamometer for the duration of testing.

Table 8 provides the chassis dynamometer setup parameters for the 2019 Acura MDX Sport Hybrid. Figure 14 shows the test vehicle mounted to the chassis dynamometer.

Table 8. Chassis dynamometer target parameters for the 2019 Acura MDX Sport Hybrid test vehicle

Test weight	4,750 (lb)	
Chassis dyno setup	4WD on rolls with dyno mode	
	Target	**Set**
Road load A term	34.35 (lb)	-4.64 (lb)
Road load B term	0.2510 (lb/mph)	0.0977 (lb/mph)
Road load C term	0.0249 (lb/mph^2)	0.0009 (lb/mph^2)

Figure 14. Acura MDX Sport Hybrid test vehicle mounted to the chassis dynamometer

Further details on vehicle dynamometer coefficients used for specific tests can be found in Appendix E: Test Summary.

5. Vehicle Testing Analysis

5.1. Vehicle Operation Overview

Figure 15 shows an overview of vehicle operation on a section of the urban dynamometer driving schedule (UDDS) cycle. The vehicle launches from a stop in electric mode using the rear electric motors. The engine is started with the front electric motor, after which the engine provides the tractive power, and the rear motor power is reduced. The rear motors then provide occasional assists during acceleration during shifting events. At low steady state cruising speed, the engine is turned off, and the Twin Motor Unit (TMU) containing both rear electric motors, provides the entire tractive power. During dyno testing TMU power was evenly distributed between both rear motors as the rear wheels are at similar speeds. When the vehicle decelerates to a stop, the front motor is used for regenerative breaking along with the rear motors. Once at a set operating temperature, the engine does not idle when the vehicle is stopped.

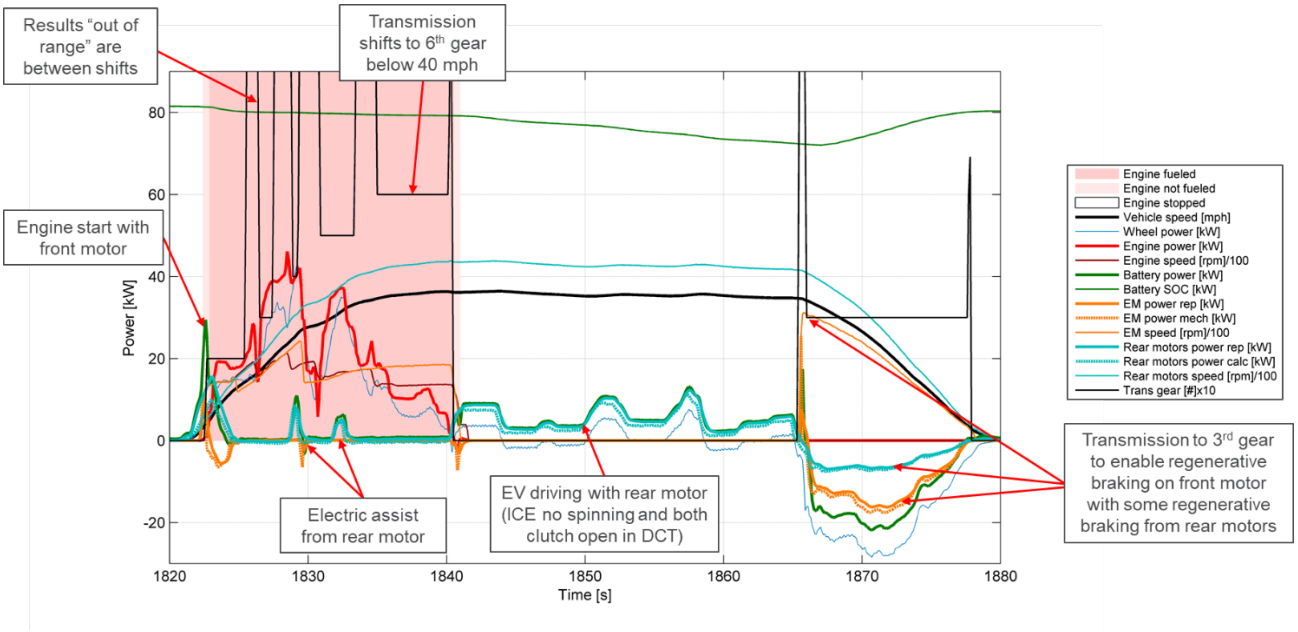

Figure 15. Overview of 2019 Acura MDX Sport Hybrid powertrain operation

5.2. Transient Cycle Results

5.2.1. Fuel Economy

5.2.1.1. Standard Fuel Economy Test Sequence Overview

The fuel economy testing described in this section focuses on the UDDS, HWFET, and US06 (high acceleration aggressive) drive cycles at 23 °C ambient temperature. The test sequence includes a cold start UDDS, a hot start UDDS, a third UDDS, a HWFET pair, and a US06 pair. The preparation for the cold start test consists of completing a UDDS cycle at 23 °C, then leaving the vehicle to thermally soak at 23 °C for over 12 hours. The overnight soak is conducted on the chassis dynamometer to allow the vehicle to remain mounted on the rolls for the duration of the testing. Figure 16 shows the sequence of drive cycles executed, which was repeated three times to capture test-to-test variability. Note that a 10-minute soak period is held between the

UDDS cycles, as shown in the figure. The fuel economy numbers in this report are based on the test phases highlighted by the green boxes. The phases for the US06 drive cycle are the split city and highway phases needed to calculate the EPA five-cycle fuel economy label [9].

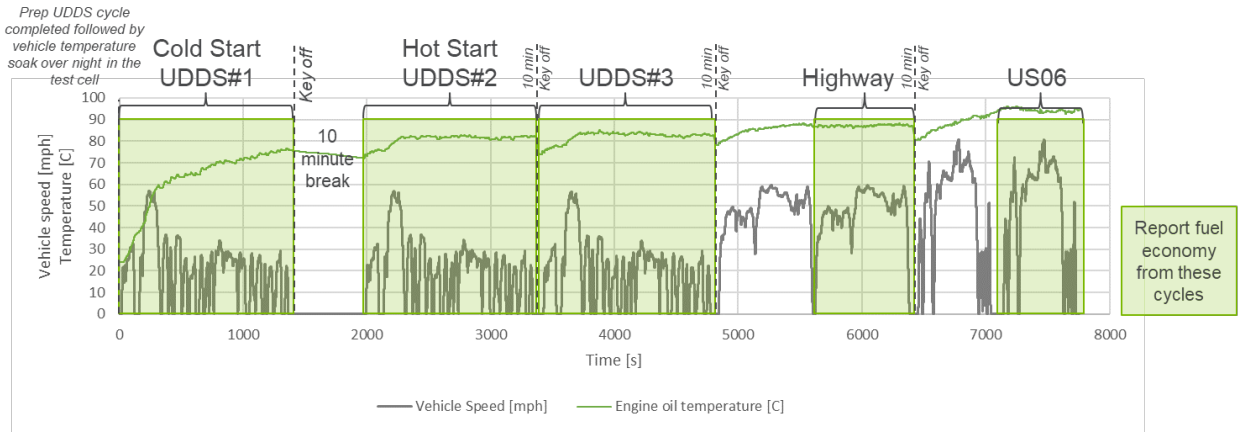

Figure 16. Daily drive cycle test sequence executed in the morning

5.2.1.2. CAFE Certification Cycle Fuel Economy Results

Figure 17 and Table 9 compare the three test sequences completed at the AMTL. On the high octane fuel, the fuel economy results of the Argonne testing differ 6% and 8% for the full fuel test procedure (FTP) and HWFET cycle, respectively. Note that the powertrain charges the battery during phases 1 and 3 and discharges the battery during phases 2 and 4 of the UDDS, which leads to lower fuel economy in phases 1 and 3 and higher fuel economy in phases 2 and 4.

Powertrain operation in hybrids, and thus the resulting fuel economy, have a higher variability than in conventional cars, as slight variations in accelerator pedal position in the same section of a drive cycles may or may not cause an engine start, affecting fuel economy results. These impacts, combined with the variations in test setup used in this testing (such as use of a variable speed vs constant speed fan), may contribute to variations leading to these test results.

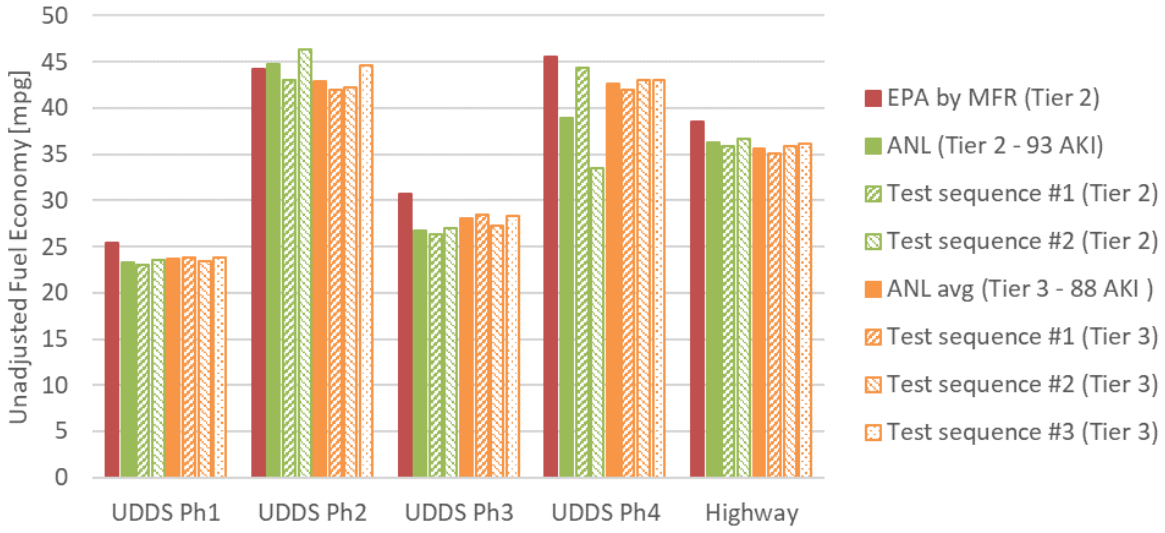

Figure 17. Raw fuel economy results: UDDS and HWFET certification cycles

Table 9. Raw fuel economy results: UDDS and HWFET certification cycles

	EPA by Mfr (Tier 2)	ANL (Tier 2– 93 AKI)	Test sequence #1 (Tier 2)	Test sequence #2 (Tier 2)	ANL avg (Tier 3 – 88 AKI)	Test sequence #1 (Tier 3)	Test sequence #2 (Tier 3)	Test sequence #3 (Tier 3)
UDDS Ph1	25.4	23.3	23.0	23.6	23.7	23.8	23.5	23.8
UDDS Ph2	44.2	44.7	43.0	46.3	42.9	41.9	42.2	44.6
UDDS Ph3	30.7	26.7	26.4	27.0	28.0	28.4	27.3	28.3
UDDS Ph4	45.6	38.9	44.4	33.4	42.7	42.0	43.0	43.1
HWFET	38.5	36.2	35.8	36.7	35.6	35.0	35.8	36.1

5.2.1.3. Tier 3 Fuel Economy Results for Standard Drive Cycles

The fuel economy results for standard drive cycles are presented in Table 10. The drive cycles include the cold start UDDS, the hot start UDDS, a third UDDS cycle, the HWFET cycle and the US06 cycle, all separated into respective phases. The third UDDS cycle is not part of the certification testing; it is performed to understand the fuel economy changes as the powertrain continues to reach higher operating temperatures, as can be seen in Figure 16. Both HWFET and US06 drive cycles were tested in phases, and the fuel economy presented is from the second cycle as shown in Figure 16.

Table 10. Raw Tier 3 – 88 AKI average of the three test sequences fuel economy results for drive cycle results

	Fuel economy (mpg)	Net energy change for the battery pack (Wh/mi)
UDDS #1 Cold Start	**30.9**	**2.3**
UDDS#1 Ph1	23.7	-48.7
UDDS#1 Ph2	42.9	47.7
UDDS#2 Hot	**34.1**	**0.7**
UDDS#2 Ph1	28.0	-47.3
UDDS#2 Ph2	42.7	44.8
UDDS#3	**34.7**	**-8.4**
UDDS#3 Ph1	28.2	-44.6
UDDS#3 Ph2	44.1	44.1
HWFET	**35.6**	**5.4**
US06	**22.7**	**7.7**

	Fuel economy (mpg)	Net energy change for the battery pack (Wh/mi)
US06 City	15.7	12.6
US06 Highway	26.0	-13.4

The full cycles, in bold type in Table 10, are charge-sustaining, as shown by the low net energy change from the battery pack over the drive cycles. The net energy charge from the battery is well below the charge-sustaining definition of 1% of fuel energy used over the drive cycle[8].

5.2.2. Vehicle Efficiency Based on Tier 3 Low Octane Fuel Testing

Vehicle efficiency is calculated by dividing the positive driven cycle energy (CEd) by the fuel energy used over the drive cycle, according to the procedure specified in the SAE J2951, "Drive Quality Evaluation for Chassis Dynamometer Testing." The positive driven cycle energy is calculated as the integration of the positive power at the wheel over the cycle [10]. Table 11 provides the calculated vehicle efficiencies for the drive cycles in each test sequence.

Table 11. Powertrain efficiencies based on J2951 positive cycle energy on Tier 3, low-octane fuel

	Test Sequence #1	Test Sequence #2	Test Sequence #3	Average
UDDS #1 Cold Start	25.5%	25.6%	26.0%	25.7%
UDDS#2 Hot Start	28.8%	28.2%	29.0%	28.7%
UDDS#3	28.2%	28.3%	29.1%	28.5%
HWFET	27.5%	28.0%	28.5%	28.0%
US06	29.6%	29.5%	29.4%	29.5%

Conventional vehicles usually have a lower efficiency in city driving, as in the UDDS cycle, due to significant idle time and low engine loads, which lead to low efficiencies. A hybrid powertrain enables short engine operation at higher efficiencies. On the UDDS hot cycle, the engine is fueled less than 30% of the time. The hybrid system relies on the electric powertrain to drive the cycle the remaining time, including regenerative braking. This results in increased vehicle efficiencies regardless of the drive cycles.

5.2.3. Ambient Temperature Impact on Fuel Economy and Vehicle Efficiency

The UDDS cycles, the HWFET cycles and the US06 cycles were also tested at -7 °C and at 35 °C with 850 W/m^2 of solar load, which are the two extreme temperature conditions for the EPA five-cycle fuel economy label [9]. Figure 18 provides the test results for those conditions and drive cycles. The details of each cycle phases are obscured to provide focus on the combined cycle results.

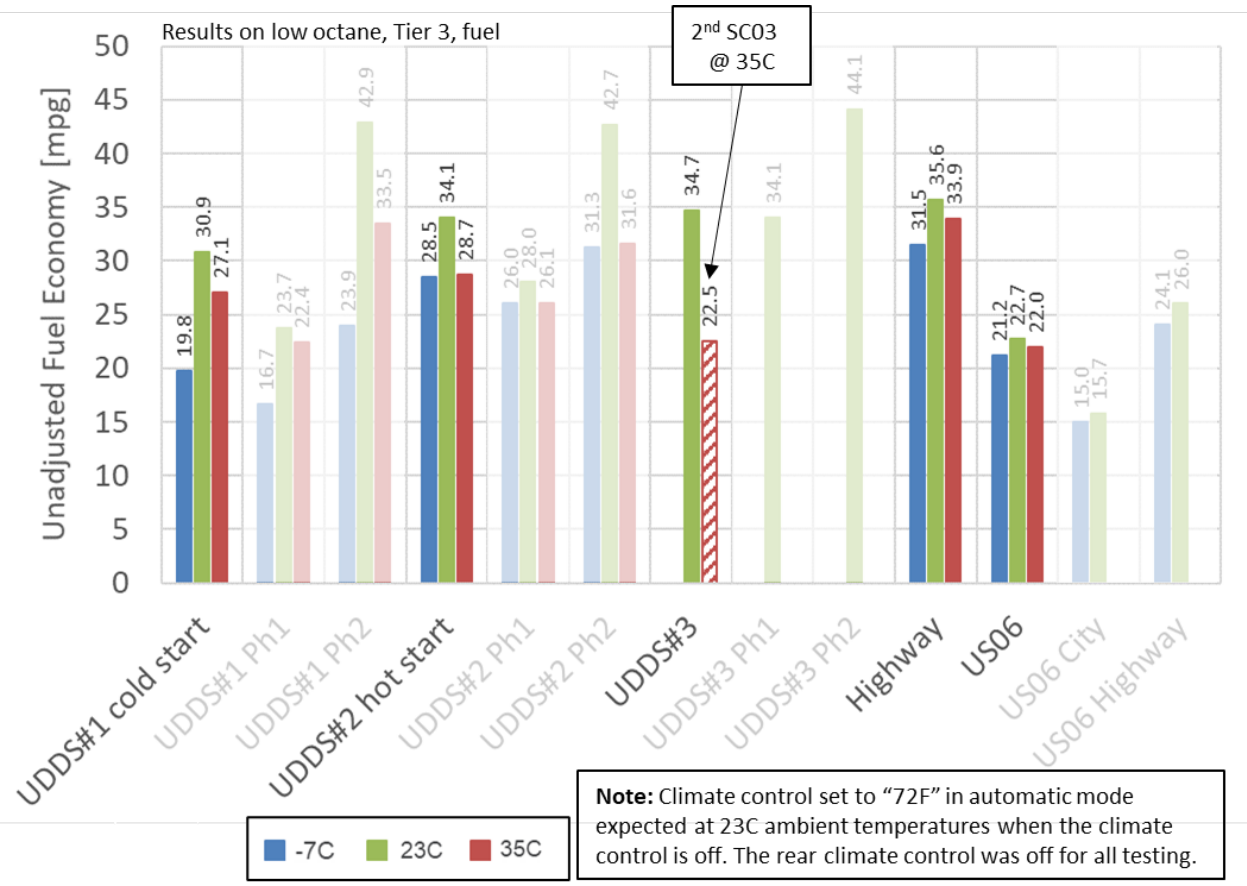

Figure 18. Raw fuel economy results for certification cycles across different temperature conditions

The fuel economy for the cold start UDDS test at -7 °C is 36% lower than the same test at 23 °C, yet the fuel economy for the second urban cycle at -7 °C is only 16% lower than the same test at 23 °C. At -7 °C, the engine is fueled for 67.9% and 37.9% of the time on the cold start and hot start UDDS tests, respectively, as compared to 40.3% and 29.4% on the same tests at 23 °C. The hybrid system runs the engine more frequently at lower loads, which generates heat to warm up the powertrain as well as the cabin.

The fuel economy in the 35 °C test conditions is also lower than in the 23 °C test conditions. At 35 °C, the fuel economy decreases by 12% and 16% for the cold start UDDS and the hot start UDDS, respectively, compared to the 23 °C test condition. The fuel economy reduction is caused by the additional power required to operate the air conditioning system to cool down the cabin. The engine is fueled 38.1% and 33.6% of the time on the cold start and hot start UDDS, respectively, and when the engine is fueled, it operates with slightly higher loads in the 35 °C testing. Note that for the 35 °C testing, the third UDDS was replaced by SC03 drive cycles [11].

Table 12 lists the calculated vehicle efficiencies for the different ambient test conditions. The impact of the cold powertrain temperatures is apparent in the -7 °C cold start efficiency. As the powertrain temperatures rise throughout the tests in the test sequence, the vehicle efficiencies at -7 °C start to approach the vehicle efficiencies at 23 °C ambient temperature. The impact of the auxiliary load from the air conditioning compressor at 35 °C is also apparent in this table. It is noteworthy that the efficiency impact of the air conditioning compressor is lower on the high-

power US06 drive cycle, as the ratio of the air conditioning power to the average wheel power is lower than the same ratio for the lower power UDDS cycle.

Table 12. Powertrain efficiencies across different ambient test conditions based on Tier 3 fuel

	-7 °C	23 °C	35 °C w/ solar
UDDS #1 Cold Start	16.5%	25.7%	22.5%
UDDS#2 Hot Start	23.6%	28.7%	23.7%
UDDS#3	N/A	28.5%	N/A
HWFET	25.0%	28.0%	26.9%
US06	27.6%	29.5%	28.4%

Figure 19 shows the engine operating areas for the cold start and hot start UDDS at each of the three ambient temperature conditions. The 23 °C plot in the middle serves as the reference. This graph shows the engine operation in a hybrid powertrain, which does not show idle fuel flow, and the engine load speed operation is clustered at higher loads and lower speeds to increase the overall average engine efficiency. At -7 °C, the engine operation is slightly shifted to lower loads. At 35 °C the engine torque is shifted upwards, which is also due to the additional loads for the HVAC operation.

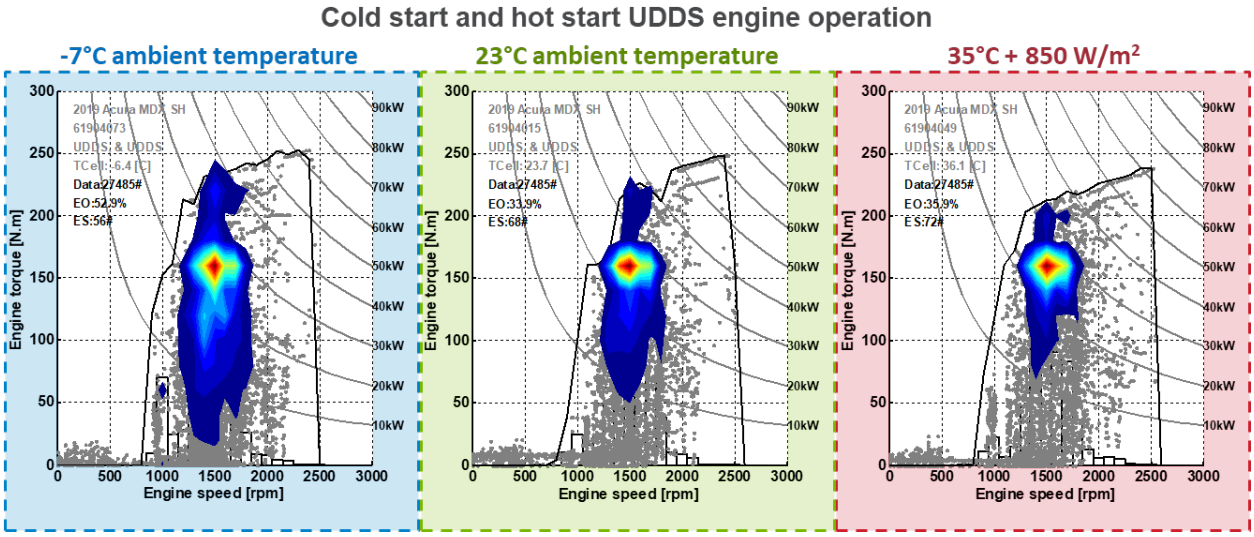

Figure 19. Engine operation on the UDDS across different temperatures

Figure 20 shows relevant powertrain and ambient temperature profiles over the completion of the test sequence. To obtain thermally stable results, three pairs of HWFET drive cycles were tested at -7 °C. These graphs also show the targeted 23 °C cabin temperature that the climate control system tries to achieve in the -7 °C and 35 °C test conditions.

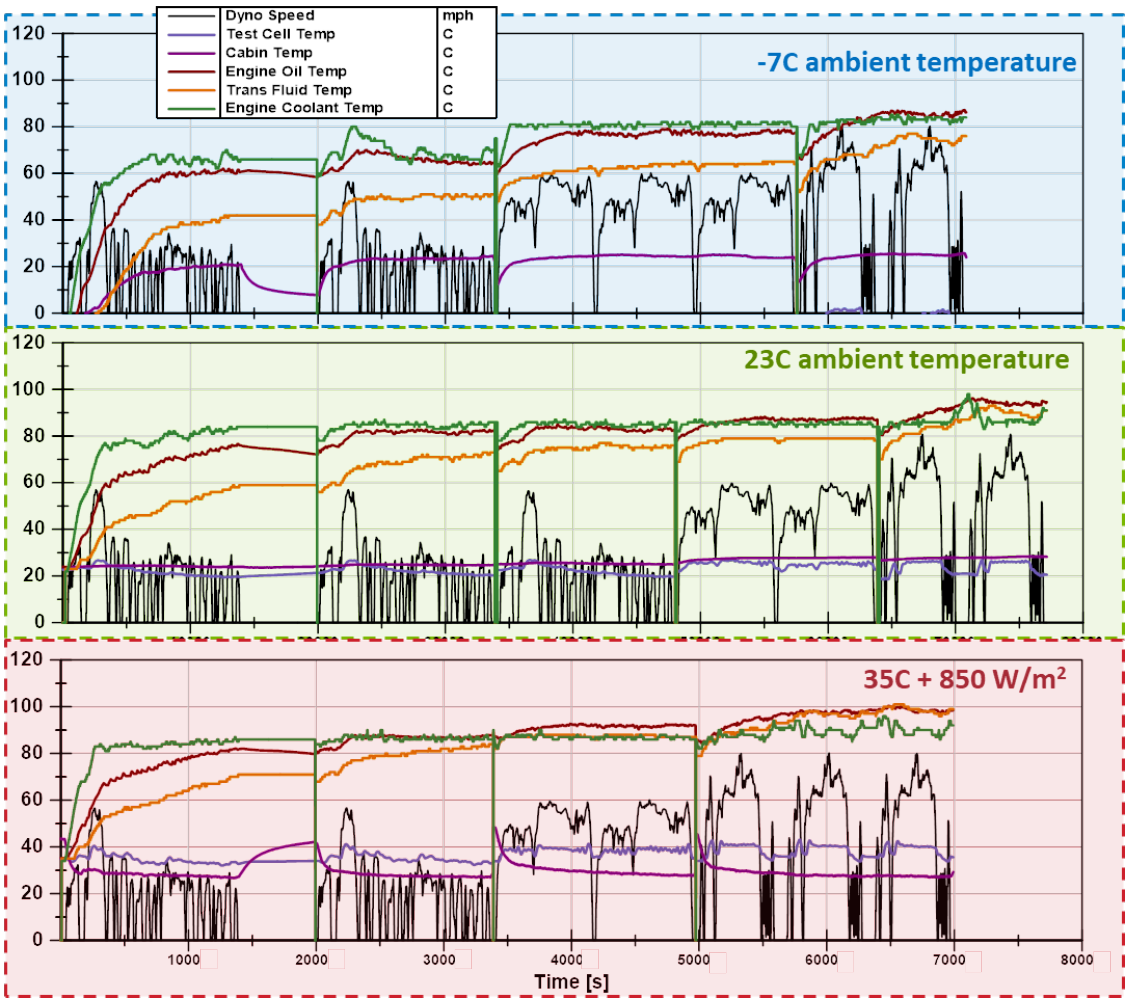

Figure 20. Powertrain and cabin temperature profiles across different temperatures

The engine oil temperature is representative of the powertrain temperature. This hybrid powertrain is somewhat sensitive to ambient temperature, as can been seen from the span of final oil temperatures across the test sequences. The engine temperature during the -7 °C test conditions is significantly lower (by over 20 °C).

5.3. Steady State Speed Fuel Economy and Efficiency

One characterization test run is the steady state speed drive cycle at different steady state speeds. With a hybrid electric powertrain, a vehicle may not continuously use its internal combustion engine and may temporarily rely on the energy stored in the battery to maintain the vehicle speed. To capture the complete behavior, the vehicle was tested at steady state speeds until the test team witnessed several cycles for repeated powertrain behavior. For each steady state speed, the vehicle efficiency, the power required at the wheel, and the engine speed are calculated.

Figure 21 and Table 13 show the test results for the low octane fuel. By using its hybrid system, the vehicle achieves high fuel economy at low speeds compared to conventional vehicles. At speeds below 55 mph, the vehicle operates at times in electric vehicle mode, using the stored energy in the battery pack. When the SOC of the battery pack gets low (~27%), the internal

combustion engine is used to maintain the vehicle speed and recharge the battery, thus increasing combustion efficiency through high engine loading.

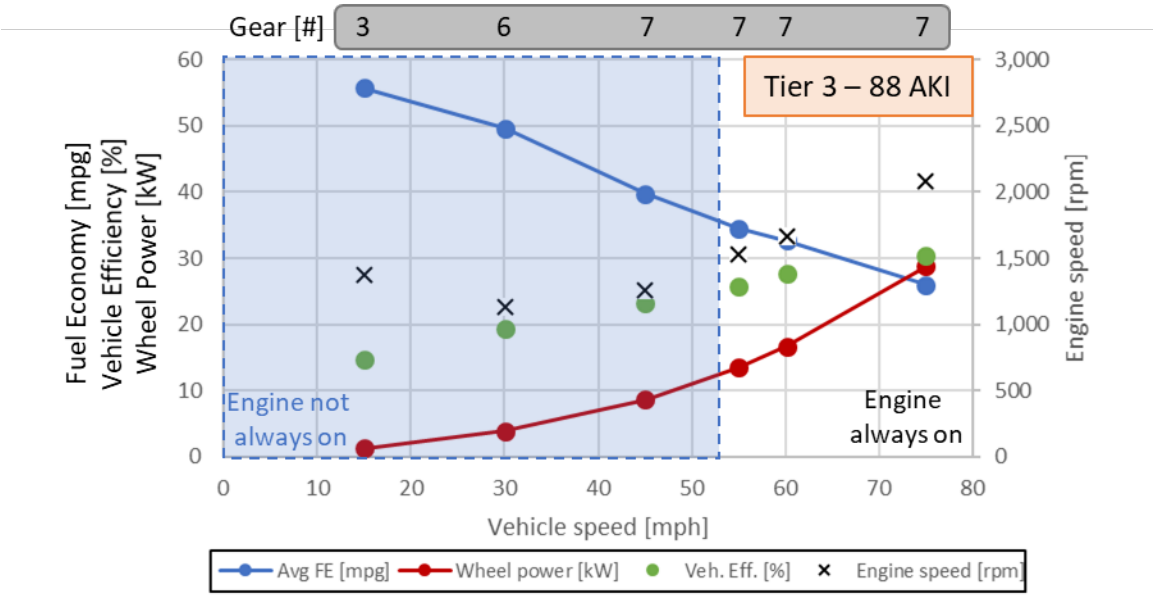

Figure 21. Steady state speed operation at 23 °C and 0% grade, Tier 3 low-octane fuel

Table 13. Summary of powertrain behavior from steady state speed testing on 0% grade with Tier 3 low-octane fuel

Avg Speed (mph)	Avg FE (mpg)	Wheel Power (kW)	Veh. Eff. (%)	Engine ON time (%)	Engine Speed (rpm)	Engine Power (kW)	Fuel Power (kW)	Engine Eff. (%)	SOC Min (%)	SOC Max (%)	Gear (#)
	Average across steady state speed				Value when engine is on						
15.0	55.7	1.3	14.8%	18.2	1,376	14.9	49.4	30.3%	27	40	3
30.1	49.6	3.8	19.4%	36.3	1,133	18.0	58.5	30.8%	27	40	6
45.0	39.8	8.6	23.2%	57.9	1,255	20.9	66.4	31.5%	27	40	7
60.1	32.7	16.7	27.6%	100	1,668	17.8	60.4	29.5%	50	51	7
75.0	26.0	28.8	30.4%	100	2,079	31.2	94.7	33.0%	50	51	7

As will be discussed in Section 5.6, additional testing was performed using a high-octane Tier 2 fuel. Testing on both fuels was conducted with the dynamometer in 4WD mode, with the vehicle remaining mounted to the dynamometer through the fuel swap. Figure 22 and Table 14 show the test results for the high-octane fuel. The vehicle still uses the hybrid system in a similar way at the test speeds of 45mph and below, with the engine cycling to improve fuel economy.

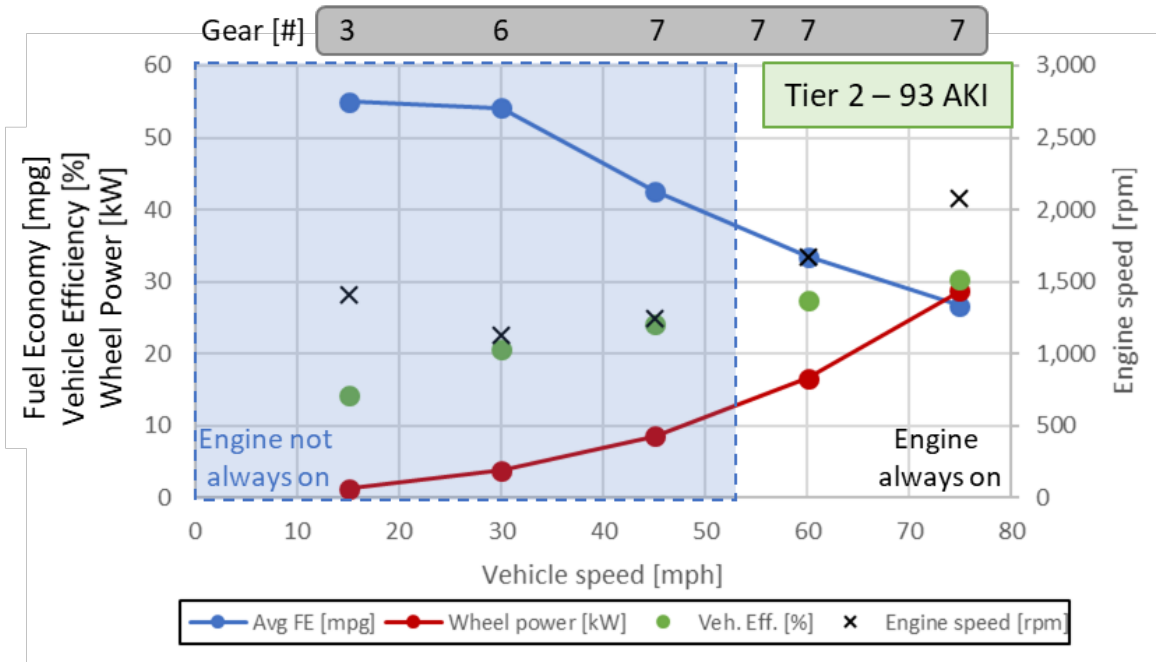

Figure 22. Steady state speed operation at 23 °C and 0 percent grade, Tier 2 high-octane fuel

Table 14. Summary of powertrain behavior from steady state speed testing on 0% grade on Tier 2 high-octane fuel

Avg Speed (mph)	Avg FE (mpg)	Wheel Power (kW)	Veh. Eff. (%)	Engine ON time (%)	Engine Speed (rpm)	Engine Power (kW)	Fuel Power (kW)	Engine Eff. (%)	SOC Min (%)	SOC Max (%)	Gear (#)
	Average across steady state speed				Value when engine is on						
15.1	54.9	1.3	14.2%	18.1	1,411	14.5	49.9	29.1%	27	40	3
30.1	54.2	3.9	20.6%	36.1	1,128	17.9	54.3	32.9%	27	41	6
45.0	42.6	8.6	24.1%	57.2	1,249	22.2	63.2	35.1%	26	41	7
60.1	33.5	16.6	27.5%	100	1,667	17.6	60.6	29.0%	50	51	7
74.9	26.7	28.8	30.3%	100	2,079	31.6	94.8	33.3%	50	51	7

The difference in fuel economy and vehicle operation using the low and high octane fuels was seen to be within the test variability, which is expected for the low load testing.

5.4. Passing Maneuver Results and General Operation

To develop an understanding of vehicle performance when a vehicle is overtaking another on a highway, Argonne has developed a test to simulate these events on a chassis dynamometer. This passing maneuver drive cycle includes accelerations from 35 to 55 mph, 55 to 65 mph, 35 to 75 mph, and 55 to 80 mph. In addition, to determine vehicle operation at higher loads, such as on an incline, this test is repeated at dynamometer grade settings of 0%, 3%, and 6%. For each passing

maneuver, the vehicle is held at an initial steady state speed, then the driver applies 100% accelerator pedal until the vehicle passes the desired end speed.

Table 15 summarizes the time it took the Acura MDX Sport Hybrid to complete each passing maneuver on both high- and low-octane fuels. It appears that the powertrain accelerates faster with the higher-octane fuel: one second faster from 55 to 80 mph on a 6% grade.

Table 15. Time duration for acceleration events

On Dynamometer Passing Maneuver Times in Seconds				
	Speed	**0% grade**	**3% grade**	**6% grade**
High-octane Tier 2 – 93 AKI	35-55	4	4.1	4.4
	55-65	2.7	2.8	2.8
	35-70	7.2	7.7	8.9
	55-80	5.8	6.7	8.2
Low-octane Tier 3 – 88 AKI	35-55	3.8	4	3.9
	55-65	2.6	2.9	2.7
	35-70	5.8	7.4	7.4
	55-80	5.8	6.6	7.2

A plot of the powertrain details for the passing maneuver from 55 mph to 80 mph is shown in Figure 23. The powertrain uses the fast response of the electric motors to speed up the beginning of the acceleration. After the driver applies 100% pedal, the rear motors provide 50 kW until the engine starts to develop more than 100 kW. After that, the rear motors reduce their power output as the engine increases power to 150 kW, after which only the engine provides the power for full acceleration.

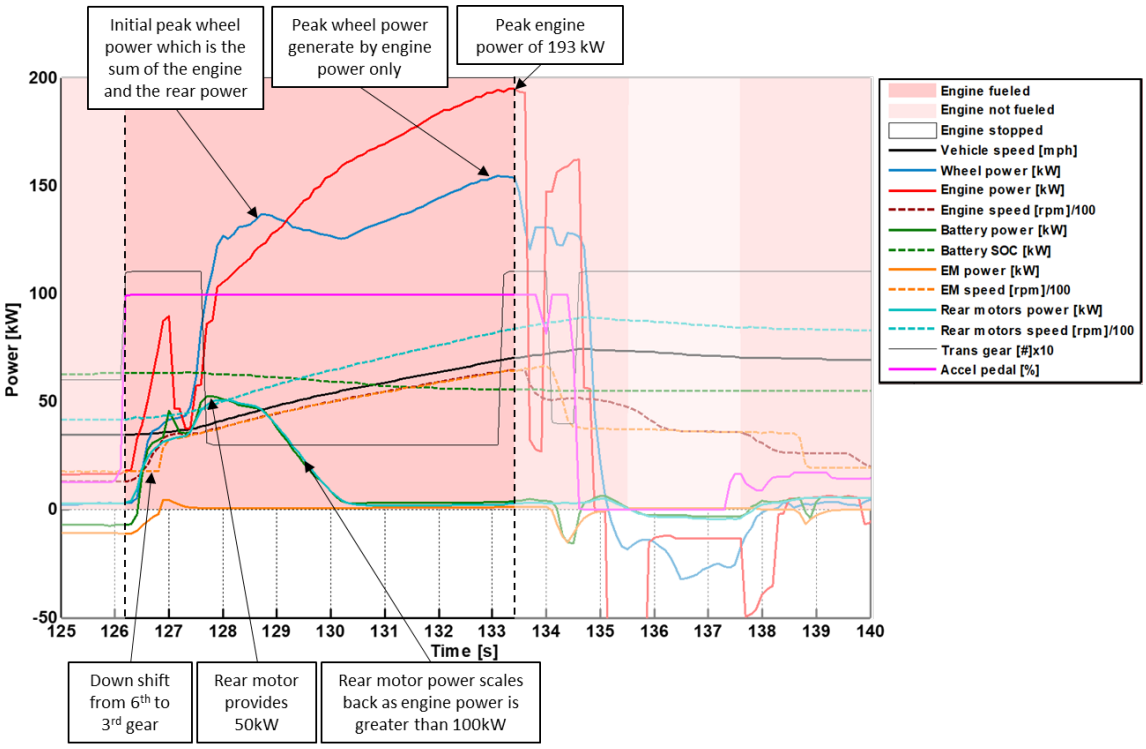

Figure 23. Powertrain operation during the 55 mph to 80 mph passing maneuver

5.5. Operation Over Maximum Acceleration

Maximum acceleration performance tests were performed on the chassis dynamometer to capture component operation. The maneuver begins with the vehicle starting from a rolling start to alleviate the traction issues of the tire on a steel roll. On the research vehicle, the vehicle initiates in EV only mode with the rear motors providing the initial power with a peak seen of 11 kW. While the rear motors are providing power for this initial launch, the engine is started, and after two seconds the engine becomes the sole power source during the acceleration until shifting events occur. During this acceleration, the powertrain behaves like a conventional vehicle, as can be seen in Figure 24. During this maximum acceleration test, the engine was found to reach a maximum speed of 6,300 rpm and produce a peak power of 193 kW.

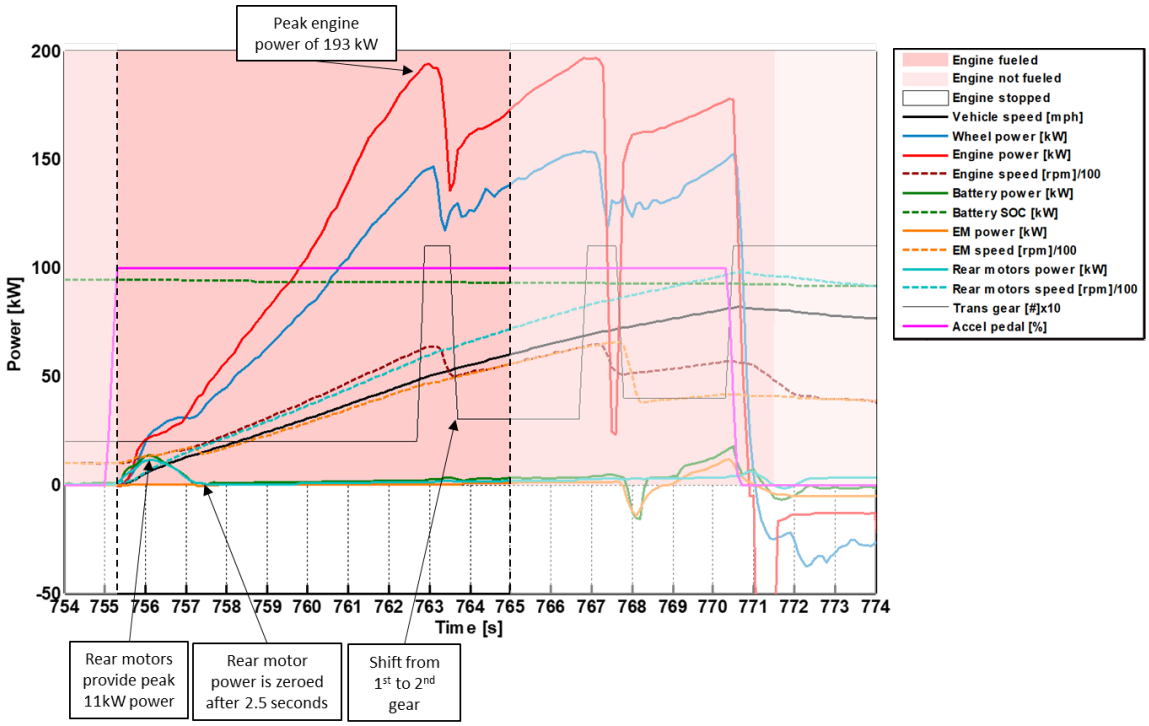

Figure 24. Powertrain operation during maximum acceleration

Argonne also tested the vehicle on a simulated 25% grade to capture operational limitations of the powertrain under high load. During this test, the vehicle is accelerated on the simulated grade until an accelerator pedal position of 100% is reached. The vehicle was then allowed to accelerate until the vehicle consistently decelerates due to a limiting available powertrain power. Beginning the maneuver, the high-voltage battery SOC was 73%, which reduced to an SOC of 20% before battery output power was reduced to zero. Following the full reduction of hybrid system power, the vehicle began to decelerate. Highlights of this test can be seen in Figure 25.

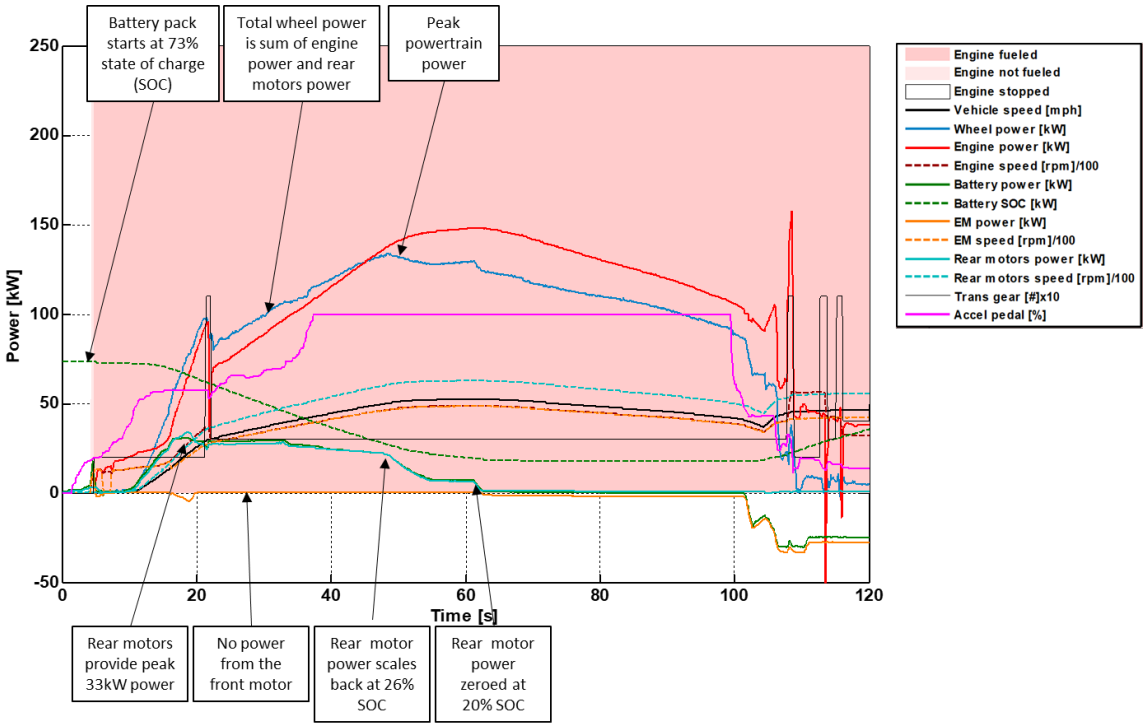

Figure 25. Acura MDX continuous power test on simulated 25% grade

5.6. Tier 3 – 88 AKI (Low-Octane) to Tier 2 – 93 AKI (High-Octane) Fuel Comparison

The 2019 Acura MDX Sport Hybrid recommends a minimum fuel octane rating of 91 RON, and EPA certification testing was performed on a high-octane fuel. Argonne tested the vehicle on both a Tier 2, high octane, and Tier 3, low octane, certification fuel to capture data on the impact of octane rating on fuel economy and performance as described in prior sections.

Though both fuels are standard test fuels, several differences should be noted including octane, energy content, and ethanol content. The Tier 3 – 88 AKI, has a volumetric energy content that is 3.4% lower than the Tier 2 – 93 AKI. Additionally, the Tier 3 fuel has an ethanol content of 10%, as compared to 0% ethanol content of the high octane, Tier 2 fuel. The specifications for the fuels are in Table 5 and Table 7, with full fuel specification sheets in Appendix D: Cert Fuel Specifications. The high octane, Tier 2, fuel represents the premium fuel, and the low octane, Tier 3, fuel represents the regular fuel in this investigation.

The fuel economy results are shown in Table 16. Since there is a 3.4% difference in energy content between the fuels, the fuel economy is also expressed in energy consumption, which is calculated using each fuel's density and heating value along with the fuel economy. Though the lower octane fuel (Tier 3 – 88 AKI) is seen to use slightly less energy, the difference was determined to be within test-to-test variability of the hybrid powertrain.

The table also includes the energy adjusted fuel economy for the high-octane fuel. The energy adjustment calculation determined the ratio of the volumetric energy content of the low and high octane fuel used to obtain an energy equivalent gallon, with the low-octane fuel as the reference. The Acura MDX fuel economy on an energy adjusted basis show that the high-octane fuel displays slightly reduced efficiency, though the vehicle had a larger, and more positive, net

energy change of the high voltage battery during low octane testing. Further testing and analysis focusing specifically on the effects of octane should be conducted for validation, which was outside of the scope of this research effort.

Table 16. Octane impact on fuel economy (mpg) on standard drive cycles at 23 °C

	Tier 2 – 93 AKI			Tier 3 – 88 AKI			Difference
	Fuel Economy (mpg)	Net energy change (Wh/mi)	Energy consumption (Wh/mi)	Fuel Economy (mpg)	Net energy change (Wh/mi)	Energy consumption (Wh/mi)	Difference based on energy consumption (%)
UDDS#1	30.9	0.0	1,091	30.9	2.3	1,063	-2.6%
UDDS#2	31.7	-2.6	1,065	34.1	0.7	963	-10.6%
HWFET#2	36.2	-0.6	931	35.6	0.3	920	-1.2%
US06#2	23.2	8.1	1,454	22.7	7.7	1,446	-0.6%

Figure 26 shows the fuel energy consumption as a function of battery net energy. The hot start UDDS with the high-octane fuel is charge gaining, while the low-octane fuel was charge depleting. This impact from hybrid system operation explains that the increased difference seen during the hot start UDDS in Table 16.

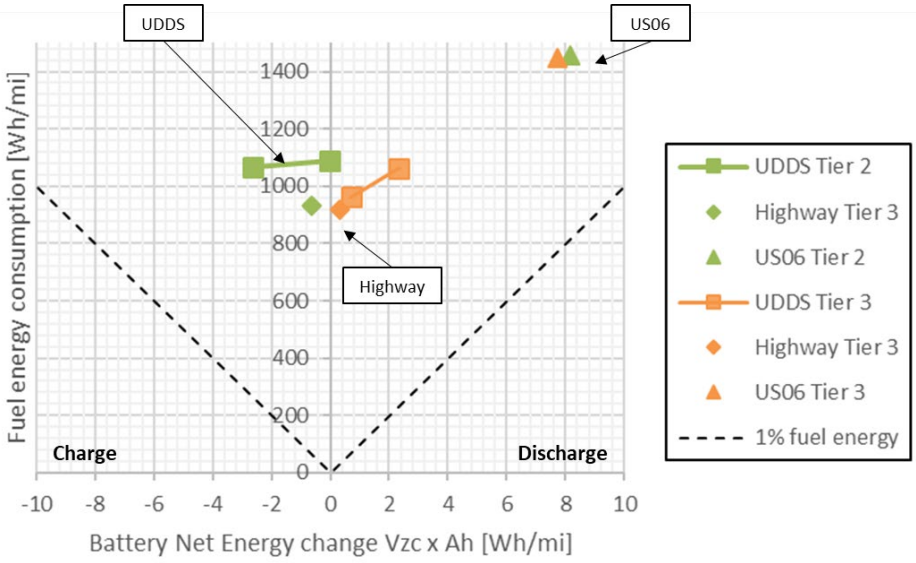

Figure 26. Fuel energy consumption as a function of battery net energy change

The vehicle efficiency calculations based on SAE J2951™[10] are shown in Table 17. The vehicle efficiencies for the Tier 2 – 93 AKI fuel are lower than for the Tier 3 – 88 AKI fuel. Again, it should be noted that it is not possible to determine the reasons (octane, energy content, other fuel specifications) for the shift without further testing and analysis focused on octane specific impacts, which was deemed out of scope for this research.

Table 17. Octane impact on vehicle efficiency

Vehicle Efficiency	Tier 2 – 93 AKI	Tier 3 – 88 AKI
UDDS#1 Cold Start	24.3%	25.7%
UDDS#2 Hot Start	27.2%	28.7%
HWFET	27.4%	28.0%
US06	29.4%	29.5%

Figure 27 shows the ignition timing for both fuels for the UDDS, HWFET, and US06 cycles as well as the passing maneuver test and maximum acceleration test. The maximum reported vehicle engine torque appears to be the same for both fuels. The higher-octane fuel shows a slightly higher maximum torque curve than the low-octane fuel. The higher torque is reflected in the higher performance shown in the maximum acceleration time in Table 15. The spark ignition timing is retarded by a few degrees at these higher loads to prevent engine knock from occurring.

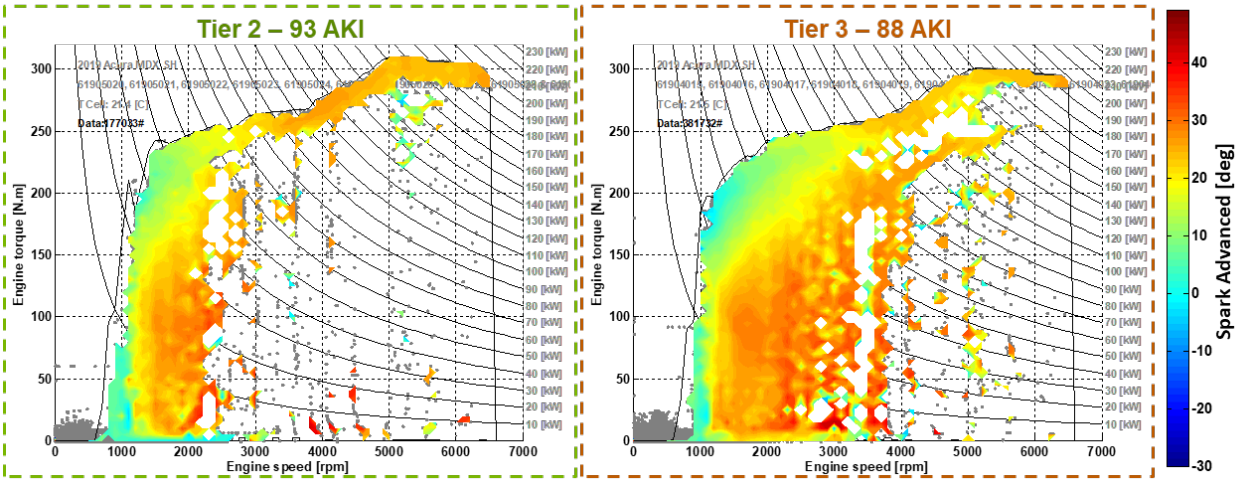

Figure 27. Spark advance comparison of high-octane Tier 2 and low-octane Tier 3 fuels

6. Component and Control Analysis

This section describes the vehicle component controls, including energy management for the hybrid powertrain, transmission shifting, engine ON and OFF conditions and detailed component control concepts. Since this vehicle has multiple electric machines, the power split between the three machines and the operation in various modes is also analyzed. Models and control calibrations developed through this analysis have been implemented in Autonomie.

6.1. Signal Calculation for Control Analysis

The vehicle component control analysis is conducted using Autonomie "Import Test Data" process. Figure 28. This process automatically changes signal names and test data units to match Autonomie nomenclature based on pre-defined conversion methods. During the test data import process, additional parameters required to analyze the component operating conditions are calculated from the test data. The vehicle configuration and signals sources are shown in Figure 28.

In Figure 28 the signals labeled in black, blue, and green are obtained directly from the test. At the energy management strategy level, the signals used to calculate the engine and battery power are critical, and directly obtained from the test. While not all signals can be recorded during testing, some can be easily calculated from the measured ones. For example, the output torque and speed of the transmission were calculated by the dyno force and speed. Transmission input signals are calculated by engine torque and speed, using assumptions of the torque converter efficiency map used in the final rulemaking) study [12]. Techniques used in the process are described in the following section.

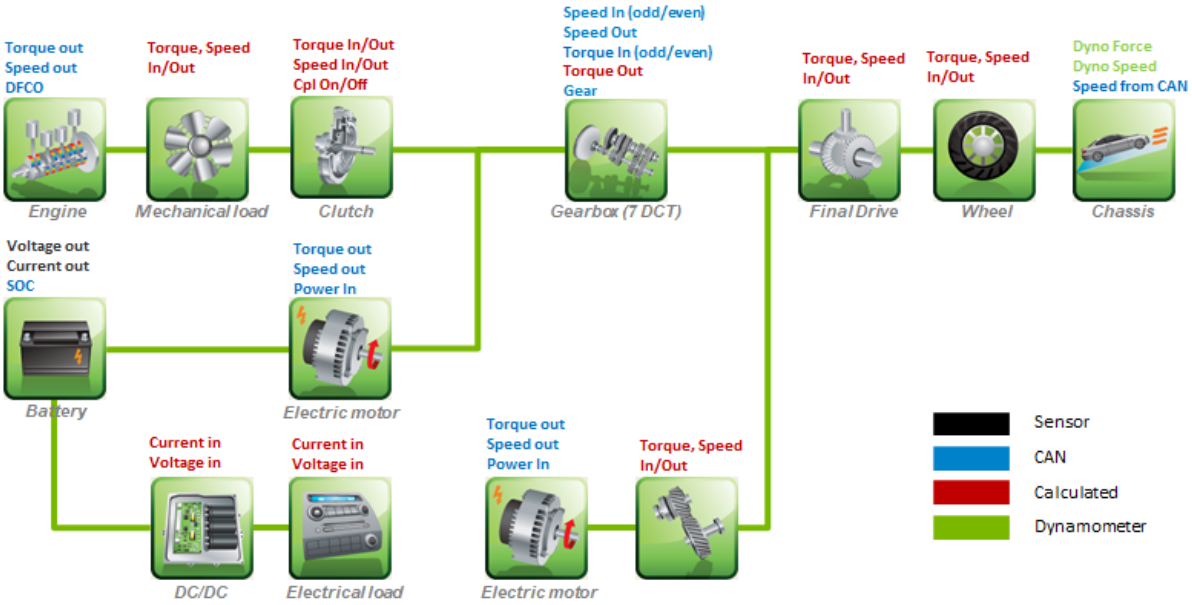

Figure 28. Schematic of the vehicle configuration

The Acura MDX has two electric machines on the rear axle, enabling better stability control using torque-vectoring techniques. However, all our tests and simulations are done with zero lateral movement. This allows us to model the two electric machines as one larger machine to simplify the analysis and modeling. Only one axle is modelled in this case, as we need those

models only for the drivetrain speed estimation. The torque losses are all included in the chassis model as part of the coefficients derived from coast-down tests.

Since not all signals can be recorded, some variables are calculated based on measured ones and additional information obtained from external sources [12]. First, the time based rotating speed, torque and of each component is calculated as shown in Figure 29.

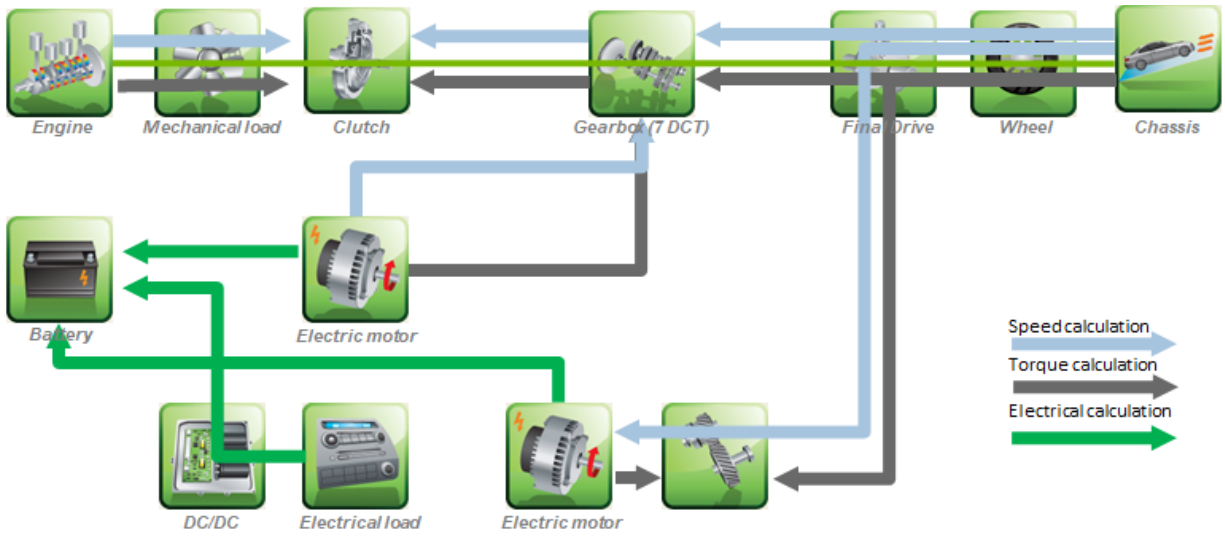

Figure 29. Calculation of missing signals for component

The wheel speed can be calculated from the speed signal obtained from the dynamometer:

$$\omega_{gb,out} = \gamma_{fd} \frac{1}{r_t} v_{chassis}$$

Equation 1

where r_t is the tire radius and γ_{fd} is the final drive ratio. Because the tire radius in driving conditions is known, the speeds can be validated by comparing the two values of $\omega_{gb,out}$ and $v_{chassis}$ by adjusting the tire radius. While there may be no discrepancy in speed for the wheel and chassis, the torque calculations should be carefully handled because each component torque measurements include uncertainties.

Figure 29 shows the flow of the calculation for torque signals. Because there is no transmission efficiency map, the torque calculation process is divided into two parts: from the transmission output to the wheel and from the engine to the transmission input. The output torque of the final drive is calculated from the force obtained from the dynamometer:

$$T_{fd,out} = T_{wheel,out} + T_{wheel,loss} - T_{wheel,brake} = r_t \cdot F_{chassis} + T_{wheel,loss} - T_{wheel,brake}$$

Equation 2

The output torque of the gearbox is calculated from $T_{fd,out}$, which can be expressed as:

$$T_{gb,out} = T_{fd,in} = \frac{1}{{\eta_{fd}}^k} \cdot \frac{1}{\gamma_{fd}} \cdot T_{fd,out}$$

Equation 3

where η_{fd} is the transfer coefficient of the final drive, and k is 1 if the power flows from the final drive to the wheel or -1 if the power flows in the other direction. These values are generic and will be applied to following calculations in this report.

$$k = \begin{cases} 1 & if\ power\ flows\ from\ power\ sources\ to\ the\ wheel \\ -1 & if\ power\ flows\ from\ the\ wheel\ to\ power\ sources \end{cases}$$

Equation 4

The torque input of the transmission is calculated from the mechanical accessory load torque and the torque-coupling torque:

$$T_{acc_{mech}} = T_{eng} - P_{acc_{mech}}/\omega_{eng}$$

Equation 5

$$T_{gb,in} = T_{acc_{mech}} + T_{trq\_cpl,out}$$

Equation 6

where $P_{acc_{mech}}$ is the mechanical accessory power required by the system.

We should note that all the equations for torque calculation are based on static equilibrium. The parameter values used in the calculations are listed in Table 18.

Table 18. Parameter values used for calculating additional signals [1]

Parameters	Values
Tire radius, r_t	0.377 m
Gear ratio range	0.62 ~ 4.4
Gear ratio of the final drive, γ_{fd}	3.833
Vehicle test weight	2,154 kg

In the Acura MDX, the rear axle is driven using the electric motor. Although the schematic diagram combines axles and wheels for simulation purposes, the test data collects each wheel torque separately. This allows us to separate the power flow to each axle. Measuring the electrical power flow into and out of the electric machines allows us to quantify the way in which electrical machines are controlled in this vehicle.

6.2. Hybrid DCT Transmission Operation

The 2019 Acura MDX Sport Hybrid employs a DCT with an integrated electric motor to drive the front wheels. Rear wheels are driven by a separate motor, thus providing AWD capability. The numerous analysis functions developed to analyze transmission operation use the integrated test data in Autonomie.

6.2.1. Gear Shift Control

In this vehicle, the engine is connected to a 7-speed DCT, and an electric machine is integrated into the DCT gearbox. The schematic diagram of the gearbox shows that the motor is always connected to clutch 1 and can start the engine when the vehicle is in neutral or in any of the odd gears. In our tests, we saw that engine starts are nearly always in neutral, with a few instances of starts while the vehicle was already in third gear.

After engine start, the vehicle always skips gear 1 and employs gear 2 and higher gears based on vehicle speed and accelerator pedal position. This leads to the assumption that gear 1, formed by the planetary gears integrated with the motor, is used only for starting the engine. In this architecture, gear 3 is nearly always used in regenerative braking. As the engine can be turned off and turned on during regenerative braking or coasting events, we see occasional engine use on events in third gear as well.

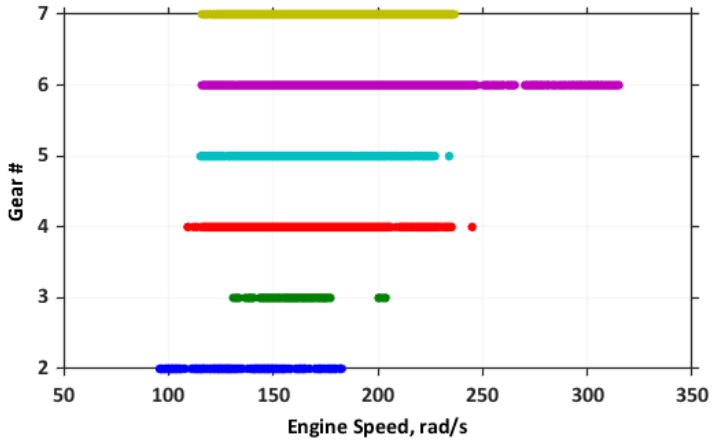

Figure 30. Engine speed and gear numbers observed during the tests

6.2.2. Transmission Operation Information

Figure 31 shows the various electric and hybrid modes this vehicle uses for negotiating drive cycles, from the data that is publicly available [3]. Motor 1 is connected to the gear shaft carrying the odd numbered gears in the dual clutch gearbox.

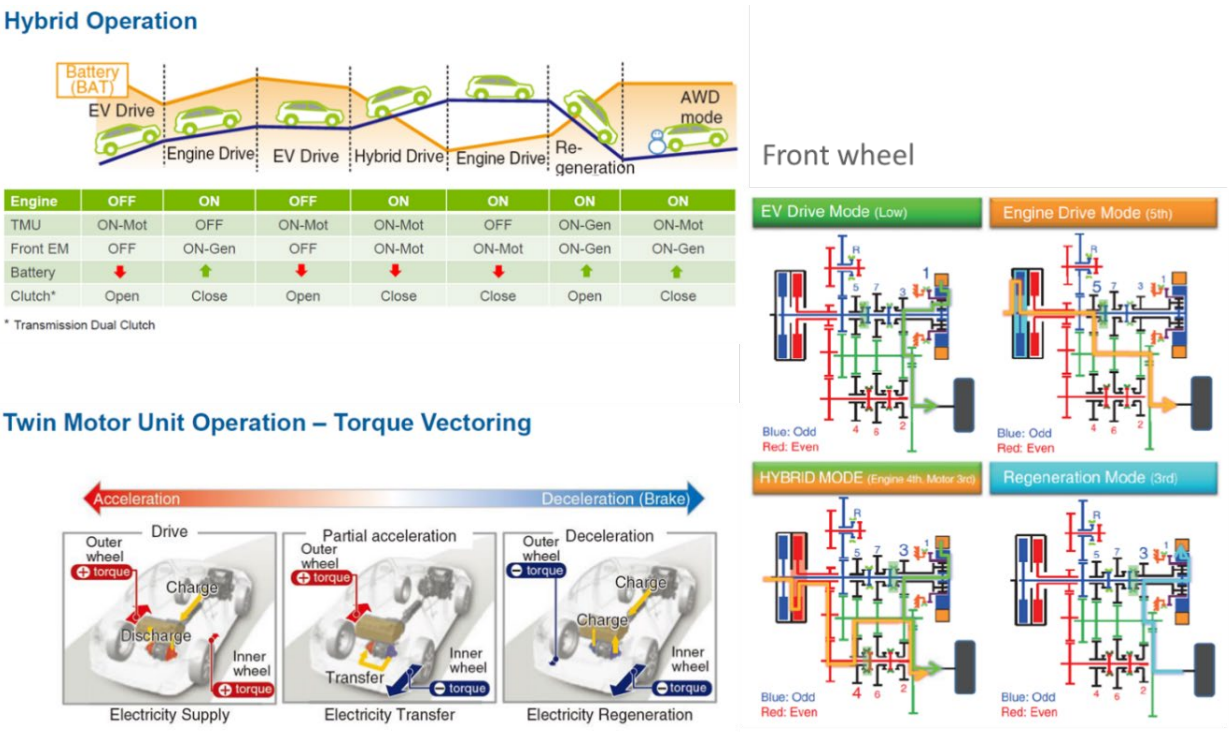

Figure 31. Overview of hybrid operating modes

Since the front motor can drive the engine only when the clutch connecting the odd gears is engaged, we expect the engine start to happen in first gear. This allows for electric launch and low speed electric operation for the vehicle.

6.3. Engine Operation

6.3.1. Fuel Rate Map

The engine fuel rate map was generated from the engine mapping test data, and is shown in Figure 32. Special engine mapping tests have been devised to create the engine map of conventional vehicles, but such efforts are not always effective in hybrids, where engine operating load can be modified using the hybrid powertrain components. In Figure 32, we see that blue dots, denoting all operating points, spanned most of the operating region of the engine, but the filtered points (red) showing steady state operating points are in a more constrained region.

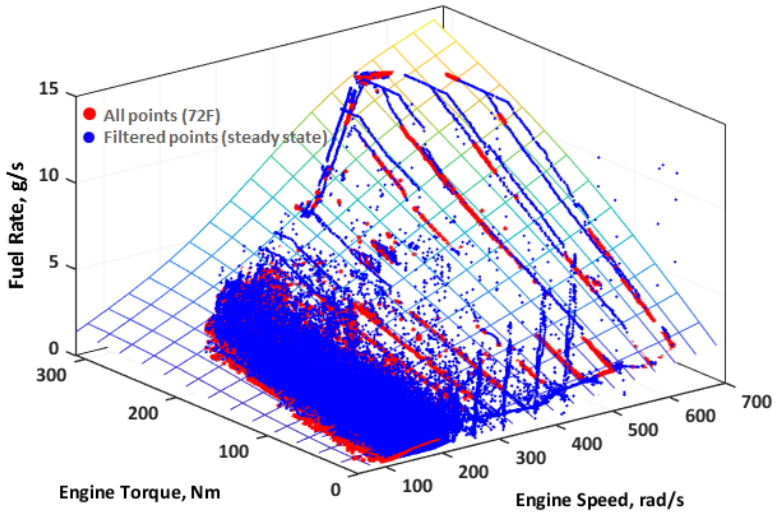

Figure 32. Engine fuel rate map of engine speed vs torque

6.3.2. Engine ON/OFF Conditions and Fuel Cutoff

The 2019 Acura MDX's hybrid architecture allows a lot of flexibility in engine operation. Across all the tests done, we saw that the vehicle uses electric power to launch in most cases. In Figure 33 the yellow points show all the instances of engine operation, but the instances of engine starts, shown as red points show that at low speeds, engine ON conditions depend on vehicle speed and wheel power demand. At higher speed operation, we see that there is a dependence on battery SOC as well.

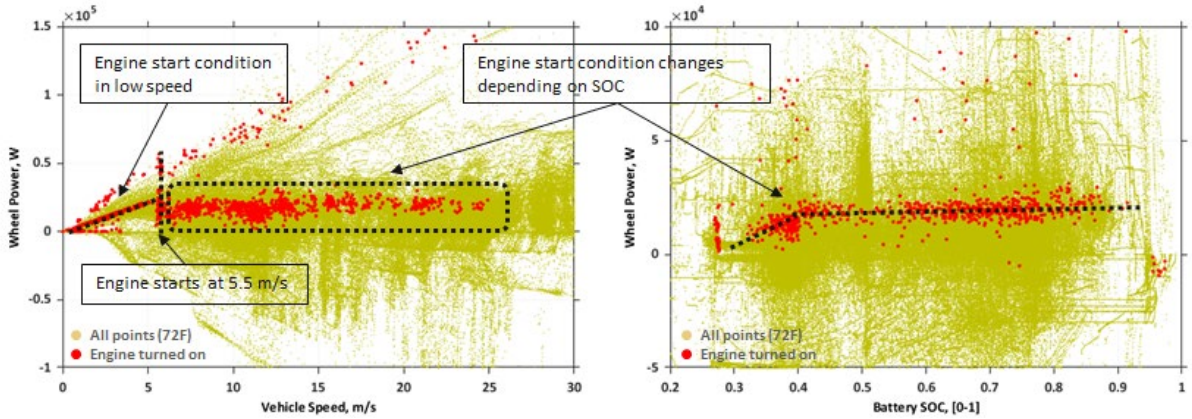

Figure 33. Engine ON instances and their dependence on vehicle operating conditions

Engine OFF conditions were difficult to predict from the wheel power alone, but when we estimated the driver torque command, it was observed that the engine is turned off whenever a deceleration torque request arises from the driver. This includes both braking and coasting events. In active braking events, fuel cutoff precedes the engine OFF event. Engine OFF is observed in conditions where the estimated braking torque requirement is around 50 Nm. Although fuel cutoff is observed in higher speed ranges, there are no engine ON or OFF scenarios at speeds above 25 m/s (56 mph). These threshold values are all likely pointing to the

drivability and safety requirements of this vehicle. Figure 34 shows the engine OFF and fuel cutoff conditions we can observe in the test data.

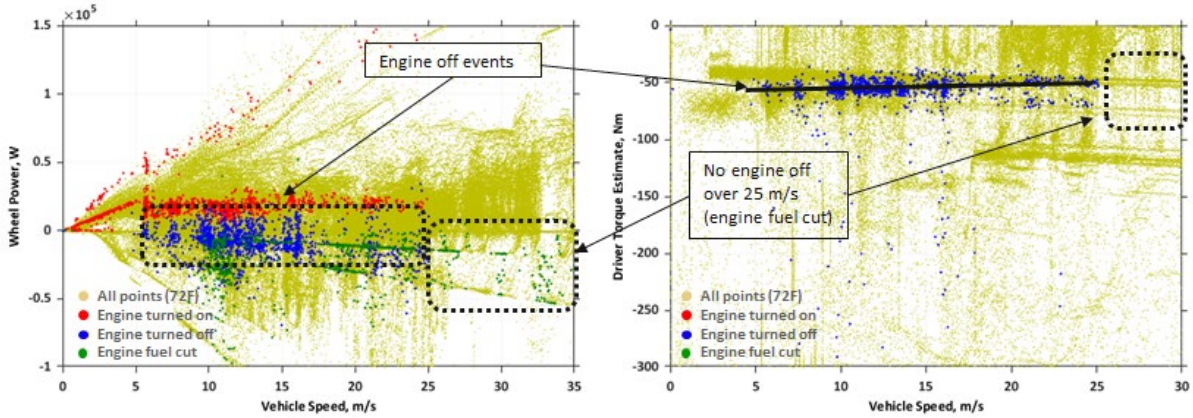

Figure 34. Engine ON/OFF and fuel cutoff instances from test data

6.4. Battery Characteristics

To simulate a HEV it is important to model the variation of battery internal resistance with respect to battery SOC and temperature. Figure 35 illustrates the information gained from the test data. The number of cells, modules, battery capacity and voltage levels are also available in published information [1].

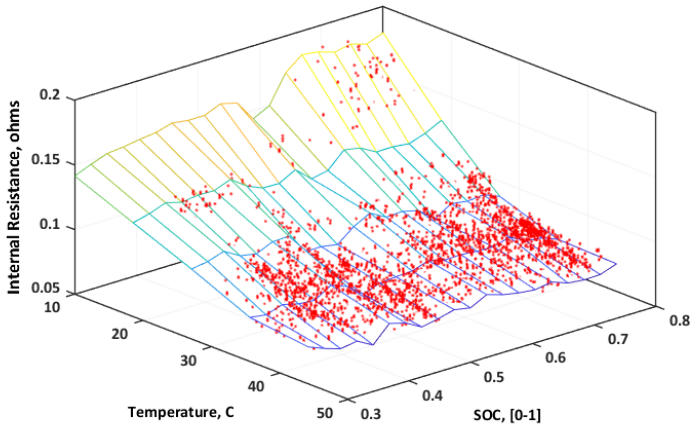

Figure 35. Battery characteristics observed from test data

6.5. Splitting the Load Between Electric Machines

An earlier version of this transmission was found in the Honda Fit Hybrid MY14, but there was no separate electric machine for driving the rear wheels in that car [10]. Having multiple electric machine simultaneously connected to the wheels raises the question of how torque demand is split between the two machines. Analysis of test data shows that this vehicle follows a rule-based strategy.

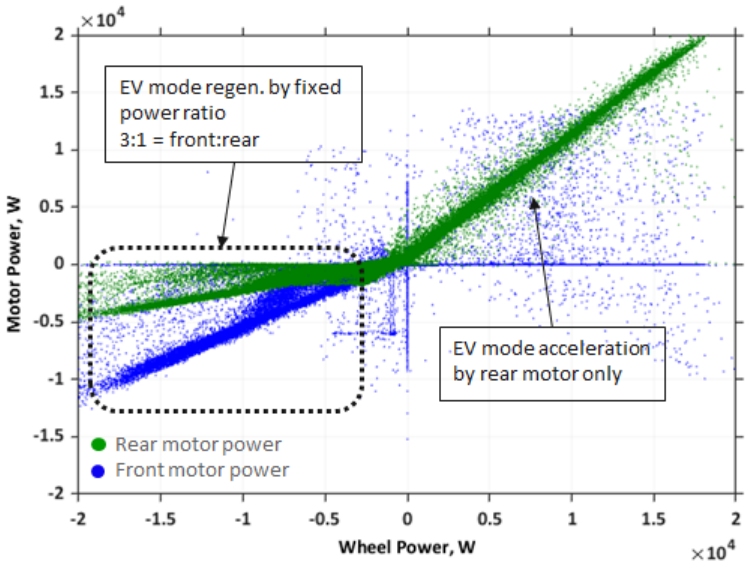

Figure 36. Power split between the two electric machines

Figure 36 shows that during electric launch and driving in EV mode, the rear motor is the only electric machine used. Use of the front motor will incur additional losses in the gear reductions. This also helps ensure that the full power of the front motor is available to start the engine whenever needed.

For regenerative braking in EV mode, the front motor is used at a higher power level than the rear motor. Engaging third gear allows the motor in front to be connected to the wheels. Since we see a few engine starts in third gear, it can be inferred that this operation using the front motor is not hindering the ability to start the engine as needed. Vehicle dynamics and drivability factors might also be contributing to the need for more braking power on the front axle.

6.6. HEV Mode Operation

Once the engine is turned on, motor operations are quite well defined. The engine is nudged to be in an ideal operating region — a narrow torque band across speeds ranging from 1,000 to 2,200 rpm. While engine speed cannot be actively controlled by this hybrid system, the engine load can be kept in the desired torque value range.

The rear motor always assists in propulsion if the torque needed from the engine exceeds the ideal torque range, and the front motor is used for engine-assisted charging if the engine torque falls slightly below the ideal torque range. In Figure 37 there is a high density of engine operating points in the region circled in red, and a marked absence of engine operation in the regions circled in green and blue. Load point adjustment is a common technique in parallel hybrids, but the extent of this technique is often limited by the battery SOC during the drive cycle.

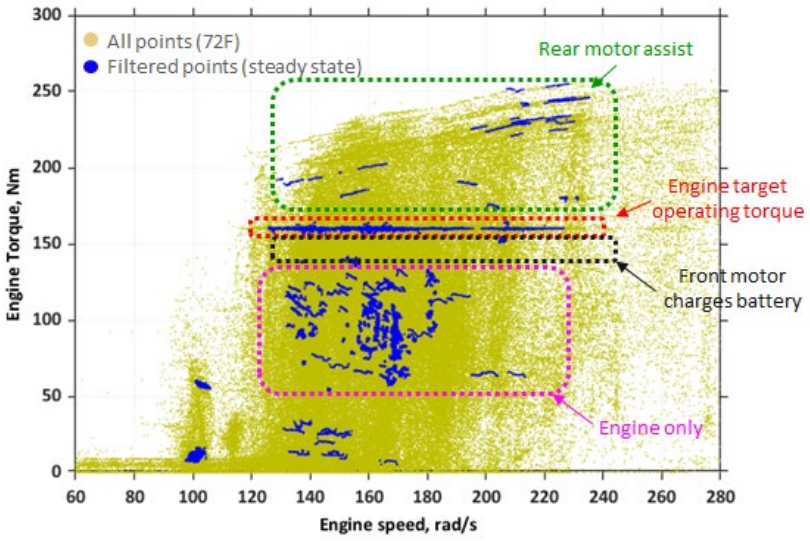

Figure 37. Engine load adjustments with electric machines

The overall control logic of the Acura MDX Sport Hybrid can be summarized as shown in Figure 38. Until the vehicle crosses a speed threshold of 5.5 m/s (12.3 mph), it operates in EV mode. The exception to this rule is a low SOC condition at the battery plus a power demand exceeding the power threshold. The rear motor is preferentially used for propulsion, as it has no further transmission losses. The front motor is used for regenerative braking, as most of the brake force is available at the front axle.

The engine is turned off if the estimated driver torque demand is negative. In high-speed operation, (where vehicle speed is over 25 m/s – 56 mph), fuel cutoff is used where engine torque is not needed, but the engine is never turned off.

Gear shifting follows the shift map identified in this study, and engine torque during driving is kept in an ideal range by employing the electric machines to achieve load point adjustments.

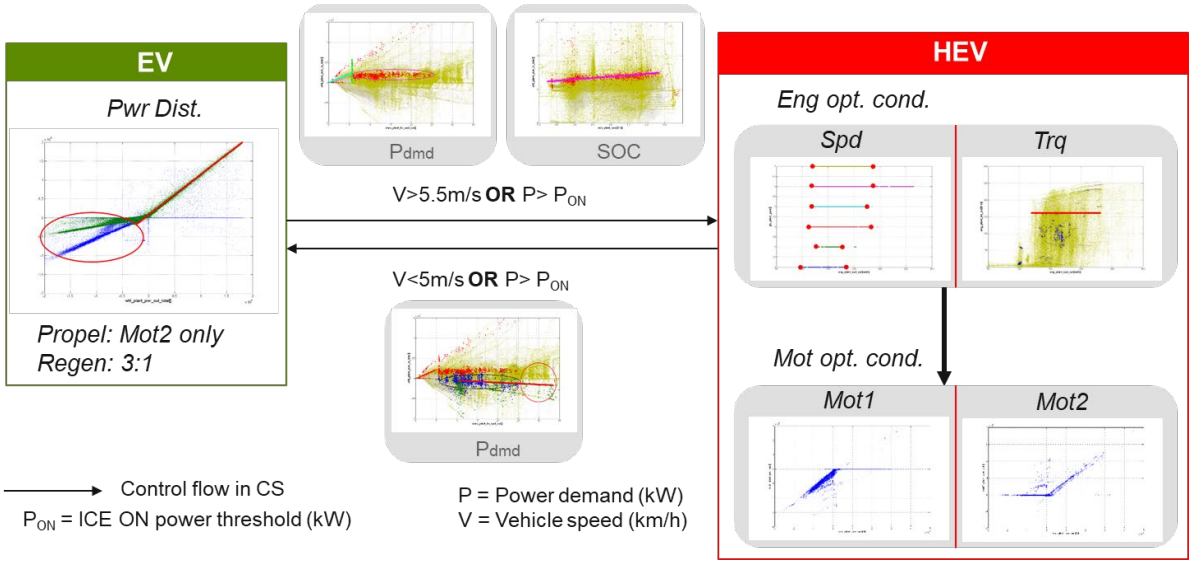

Figure 38. Overview of a rule-based control algorithm for Acura MDX hybrid powertrain

7. Model Validation

An analysis of vehicle-level controls from the test data was done to merge the separately developed vehicle component models into a vehicle simulation model. The component controls include DCT transmission controls, engine ON/OFF controls with fuel cutoff, and so on. The analyzed component models, including control models, were implemented and integrated in Autonomie to create a vehicle simulation model for the 2019 Acura MDX Hybrid. Note, however, that the vehicle model is simulated as a "warmed up" vehicle. Since all the simulations considered in this report assume a "hot start," where the engine coolant temperature is steady at around 95 °C, the cold start condition was not a factor for the simulations.

The validation process for this study is shown in Figure 39.

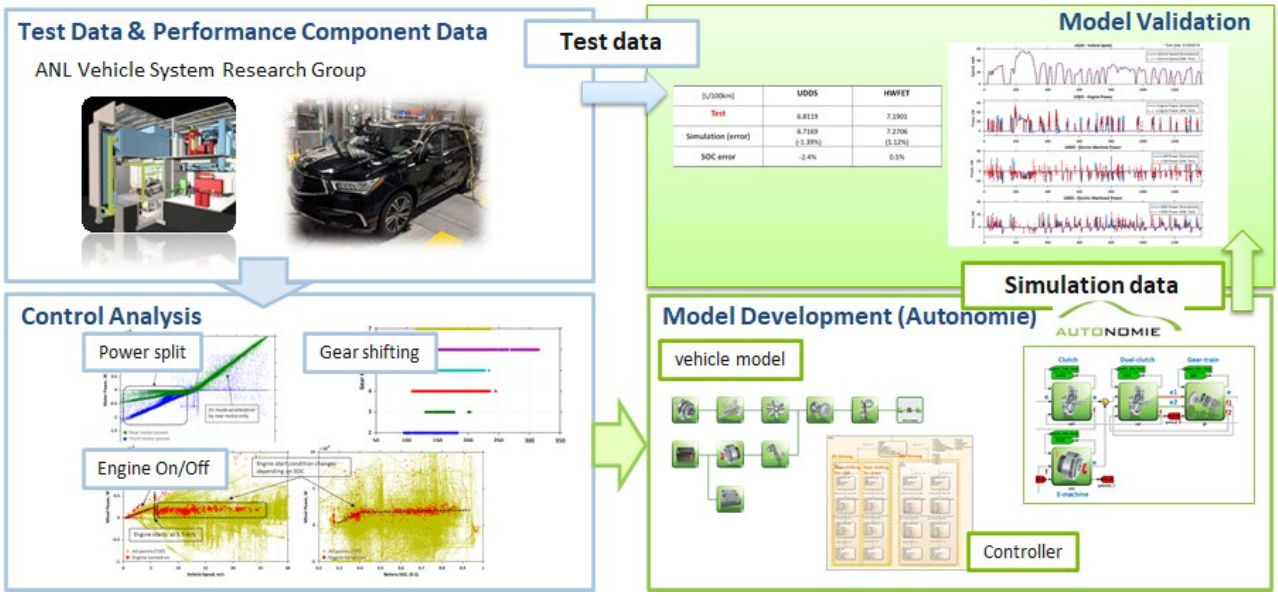

Figure 39. Validation process for 2019 Acura MDX in Autonomie

The simulation was conducted in urban dynamometer driving schedule (UDDS) and highway fuel economy test (HWFET) cycles. Figure 40 and Figure 41 show the vehicle speed, engine power, electric motor power, battery power, battery SOC, and fuel integrated of simulation results and test data, which were matched well for each cycle.

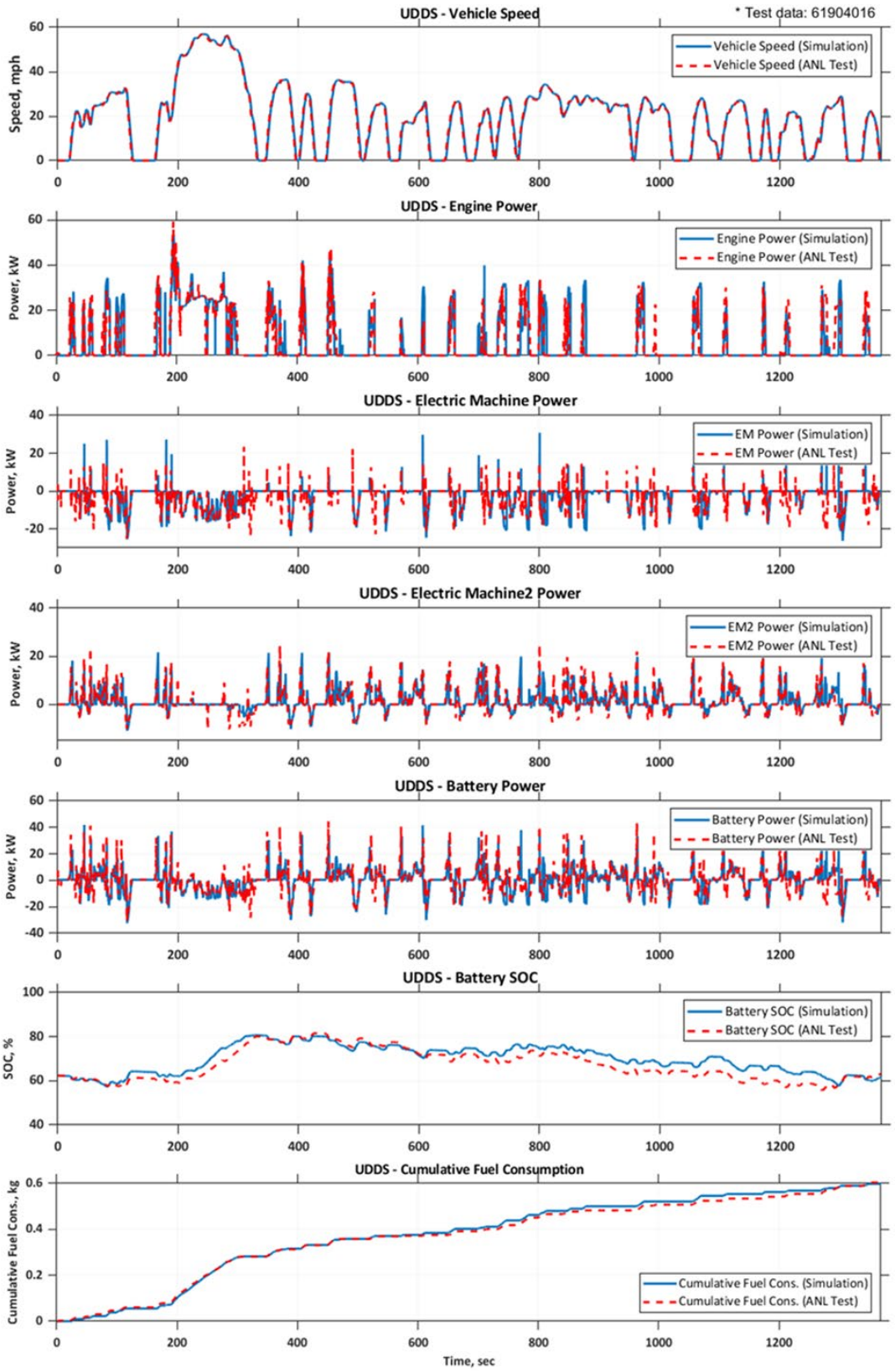

Figure 40. Simulation results and test data for UDDS cycle

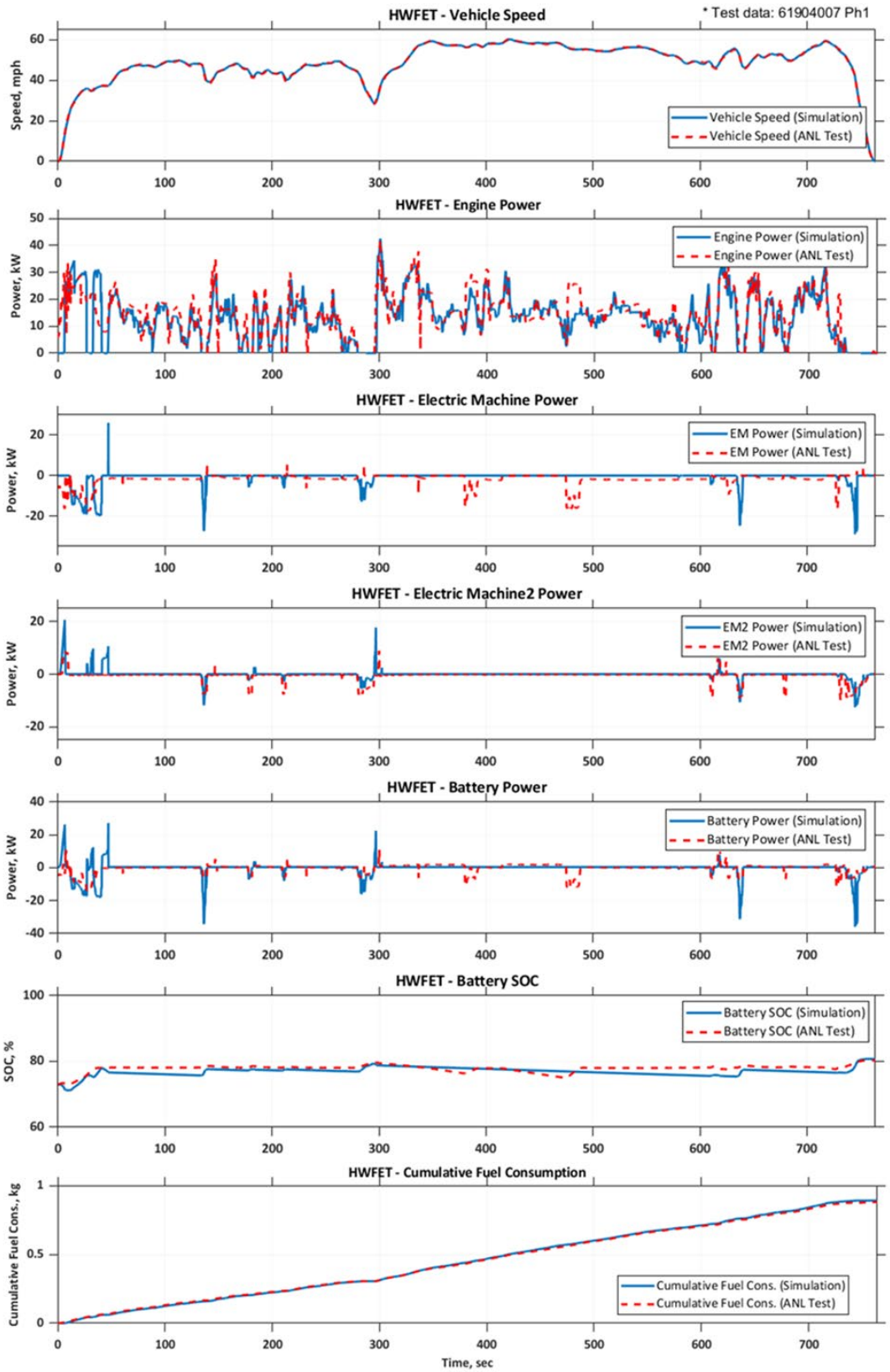

Figure 41. Simulation results and test data for HWFET cycle

Normalized cross-correlation power (NCCP) was used to compare second-by-second time-varying signal traces between test and simulation [13]. The NCCP was calculated using Equations 7 and 8 as follows: Here x and y represent individual signals.

$$NCCP = \frac{\max\{R_{xy}(\tau)\}}{\max\{R_{xx}(\tau),\ R_{yy}(\tau)\}}$$

Equation 7

$$R_{xy}(\tau) = \lim_{T\to\infty} \frac{1}{T} \int_0^T x(t) \cdot y(t-\tau)\, dt$$

Equation 8

The NCCP values of simulation results for UDDS and HWFET cycles are shown in Table 19.

Table 19. The NCCP values for UDDS and HWFET cycle

	UDDS (test data: 61904016)	**HWFET** (test data: 61904007 ph1)
Vehicle speed	0.996	0.999
Engine power	0.843	0.905
Battery SOC	0.964	0.988

The fuel consumption in the simulation results was compared to the fuel consumption in the test data to validate the simulation performance, as shown in Table 5. The test data average fuel consumption was obtained from hot start tests. The fuel consumption of the simulation was 6.71 and 7.27 L/100 km on UDDS and HWFET cycles, which differed from the test result by -1.4 % and 1.1 %, respectively.

Table 20. Fuel consumption of test data and simulation results

Fuel economy (L/100 km)	**UDDS**	**HWFET**
Test	6.81 Delta SOC: 0.57%	7.19 Delta SOC: 7.31%
Simulation (error)	6.71 (-1.4%) Delta SOC: -1.00%	7.27 (1.1%) Delta SOC: 7.74%
Test data for UDDS: 61904016 Test data for HWFET: 61904007 Ph1		

8. Conclusion

The National Highway Traffic Safety Administration (NHTSA) is an agency within the U.S. Department of Transportation (DOT) that sets Corporate Average Fuel Economy (CAFE) standards for passenger cars, light trucks and medium-duty passenger vehicles. NHTSA has contracted Argonne to conduct full vehicle simulation using Autonomie (https://www.autonomie.net/) to provide input into the CAFE model to determine minimum average fuel economy. Autonomie relies on vehicle technology assumptions for model development and validation. Argonne's Advanced Mobility Technology Laboratory (AMTL) provides the laboratory test data that informs that technology assumptions in Autonomie. NHTSA funded Argonne's AMTL to perform a benchmark of a 2019 Acura MDX Sport Hybrid to provide data to Autonomie and assess the fuel saving technologies of that powertrain.

The vehicle benchmarked in this report is a 2019 Acura MDX Sport Hybrid equipped with the 3.0 V6 VTEC engine coupled through a 7-speed dual clutch transmission to an electric motor. Two additional independent rear electric motors are used for hybrid operations and for torque vectoring, to improve the overall vehicle handling. The focus of the evaluation was to understand the use of critical powertrain components and their impact on the vehicle efficiency. The vehicle was instrumented to provide data to support the model development and validation in conjunction with providing the data for the analysis in the report. Tests were performed on a chassis dynamometer in a controlled laboratory environment across a range of certification tests, and testing temperatures. Focused testing was performed to characterize different powertrain components performance.

9. References

1. Acura Sport Hybrid SH-AWD website. www.acura.com/mdx/modals/sport-hybrid-system
2. Honda Motor Company. Acura Vehicle Service Documentation. Available online: http://estore.honda.com/service-express/subscriptions.asp.
3. Fukazu, T. and Matsuo, Y. 2017. *Development of Electric Powertrain for New Model Hybrid Sports Utility Vehicle*. SAE Technical Paper 2017-01-1158. doi:10.4271/2017-01-1158.
4. U.S. Environmental Protection Agency. *2019 Test Car List Data*. www.epa.gov/compliance-and-fuel-economy-data/data-cars-used-testing-fuel-economy.
5. Code for Feral Regulations, 40 C.F.R. §600, *Fuel Economy and Greenhouse Gas Exhaust Emissions of Motor Vehicles*,. Referenced 2021, Available online: www.ecfr.gov
6. Code for Federal Regulations, 40 C.F.R §86, subpart C., Emission Regulations for 1977 and Later Model Year New Light-Duty Vehicles and New Light-Duty Trucks and New Otto-Cycle Complete Heavy-Duty Vehicles; Test Procedures, Referenced 2021, Available online: www.ecfr.gov
7. Code for Federal Regulations. 40 CFR 86.1831-01 – *Mileage accumulation requirements for test vehicles*, July 1, 2012
8. Stutenberg K, Lohse-Busch H, Duoba M, Iliev S, Jehlik F, Di Russo M, *An Overview of Argonne's Advanced Mobility Technology Laboratory Vehicle Systems Instrumentation and Evaluation Methodology* (ANL/ESD 2021), https://anl.box.com/v/AMTL-testing-reference
9. Code for Federal Regulations. 40 CFR 600-210-12- Calculation of fuel economy and CO_2 emission values for labeling, July 1, 2012
10. Society of Automotive Engineer Ground Vehicle Standards, SAE J2951_201111, *Drive Quality Evaluation for Chassis Dynamometer Testing*, November 30, 2011
11. Code for Federal Regulations. 40 CFR 1066.845 – *AC17 air conditioning efficiency test procedure*, July 1, 2015
12. Kawai N., Ohta K., Masaoka Y., Konishi H., and Kobayashi H. *Development of 7-speed Dual Clutch Transmission for SPORT HYBRID i-DCD*. Honda R&D Technical Review Vol 26: No. 1.
13. SAE J2951_201111, Drive Quality Evaluation for Chassis Dynamometer Testing, Society of Engineers
14. Islam, E., Moawad, A., Kim, N., Rousseau, A. 2020. A Detailed Vehicle Simulation Process to Support CAFE and CO2 Standards for the MY 2021–2026 Final Rule Analysis - Section 5. Vehicle and Component Assumptions (ANL/ESD-19/9)
15. Meng, Y., Jennings, M., Tsou, P., Brigham, D. et al., Test Correlation Framework for Hybrid Electric Vehicle System Model, SAE Int. J. Engines 4(1):1046-1057, 2011, https://doi.org/10.4271/2011-01-0881

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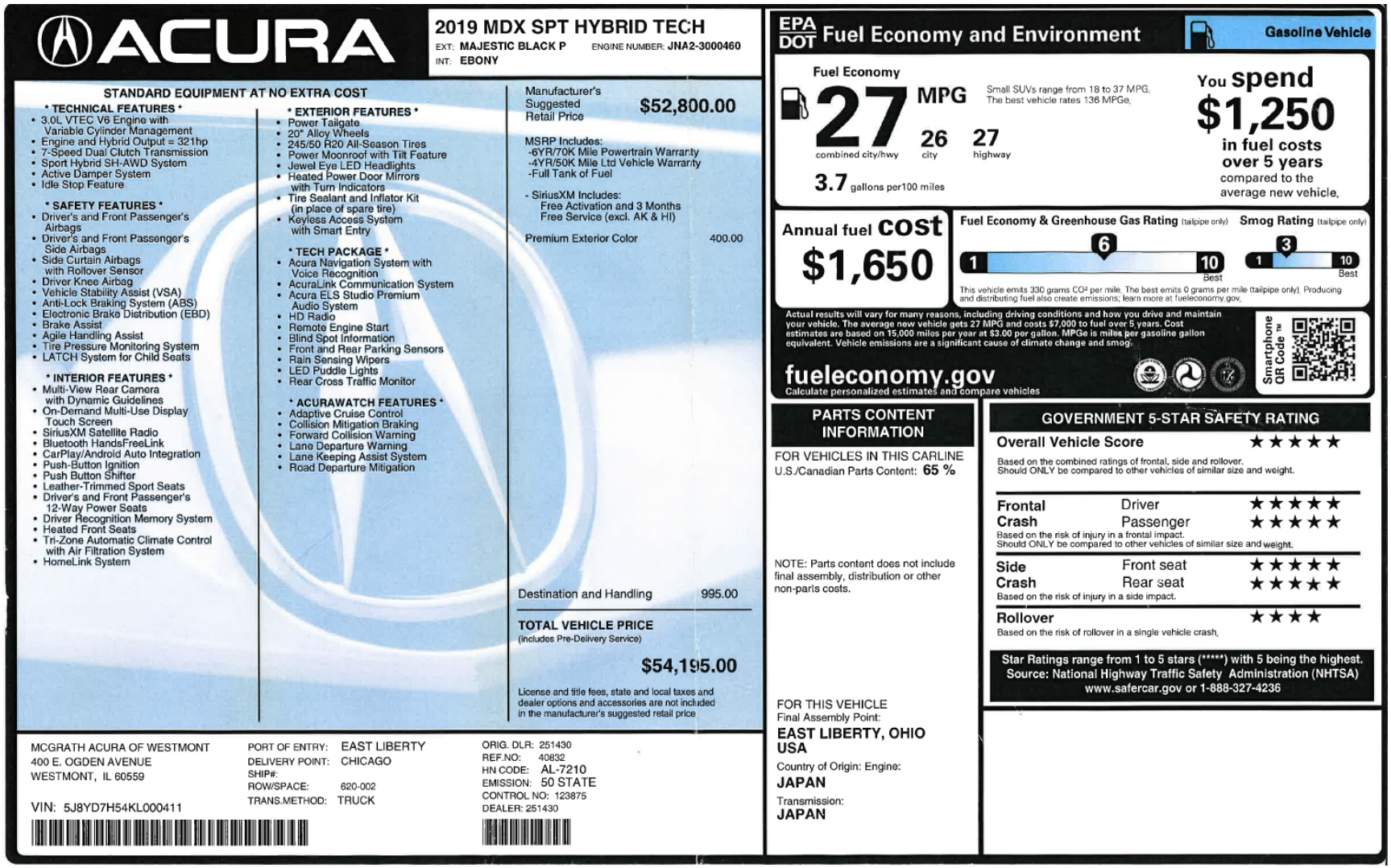
Finally, the authors want to acknowledge that this work would not have been possible without the entire team at the Center for Transportation research. Special thanks go to Mike Kern, Geoffrey Amann, and George Tsigolis for their support during the vehicle experimental instrumentation and evaluation.

Appendix A: Vehicle Build Sheet



ACURA

2019 MDX SPT HYBRID TECH

EXT: **MAJESTIC BLACK P** ENGINE NUMBER: **JNA2-3000460**
INT: **EBONY**

STANDARD EQUIPMENT AT NO EXTRA COST

*** TECHNICAL FEATURES ***
- 3.0L VTEC V6 Engine with Variable Cylinder Management
- Engine and Hybrid Output = 321hp
- 7-Speed Dual Clutch Transmission
- Sport Hybrid SH-AWD System
- Active Damper System
- Idle Stop Feature

*** SAFETY FEATURES ***
- Driver's and Front Passenger's Airbags
- Driver's and Front Passenger's Side Airbags
- Side Curtain Airbags with Rollover Sensor
- Driver Knee Airbag
- Vehicle Stability Assist (VSA)
- Anti-Lock Braking System (ABS)
- Electronic Brake Distribution (EBD)
- Brake Assist
- Agile Handling Assist
- Tire Pressure Monitoring System
- LATCH System for Child Seats

*** INTERIOR FEATURES ***
- Multi-View Rear Camera with Dynamic Guidelines
- On-Demand Multi-Use Display Touch Screen
- SiriusXM Satellite Radio
- Bluetooth HandsFreeLink
- CarPlay/Android Auto Integration
- Push-Button Ignition
- Push Button Shifter
- Leather-Trimmed Sport Seats
- Driver's and Front Passenger's 12-Way Power Seats
- Driver Recognition Memory System
- Heated Front Seats
- Tri-Zone Automatic Climate Control with Air Filtration System
- HomeLink System

*** EXTERIOR FEATURES ***
- Power Tailgate
- 20" Alloy Wheels
- 245/50 R20 All-Season Tires
- Power Moonroof with Tilt Feature
- Jewel Eye LED Headlights
- Heated Power Door Mirrors with Turn Indicators
- Tire Sealant and Inflator Kit (in place of spare tire)
- Keyless Access System with Smart Entry

*** TECH PACKAGE ***
- Acura Navigation System with Voice Recognition
- AcuraLink Communication System
- Acura ELS Studio Premium Audio System
- HD Radio
- Remote Engine Start
- Blind Spot Information
- Front and Rear Parking Sensors
- Rain Sensing Wipers
- LED Puddle Lights
- Rear Cross Traffic Monitor

*** ACURAWATCH FEATURES ***
- Adaptive Cruise Control
- Collision Mitigation Braking
- Forward Collision Warning
- Lane Departure Warning
- Lane Keeping Assist System
- Road Departure Mitigation

Manufacturer's Suggested Retail Price	**$52,800.00**

MSRP Includes:
-6YR/70K Mile Powertrain Warranty
-4YR/50K Mile Ltd Vehicle Warranty
-Full Tank of Fuel

- SiriusXM Includes:
Free Activation and 3 Months Free Service (excl. AK & HI)

Premium Exterior Color	400.00
Destination and Handling	995.00
TOTAL VEHICLE PRICE (includes Pre-Delivery Service)	**$54,195.00**

License and title fees, state and local taxes and dealer options and accessories are not included in the manufacturer's suggested retail price

MCGRATH ACURA OF WESTMONT
400 E. OGDEN AVENUE
WESTMONT, IL 60559

VIN: 5J8YD7H54KL000411

PORT OF ENTRY: EAST LIBERTY
DELIVERY POINT: CHICAGO
SHIP#:
ROW/SPACE: 620-002
TRANS.METHOD: TRUCK

ORIG. DLR: 251430
REF.NO: 40832
HN CODE: AL-7210
EMISSION: 50 STATE
CONTROL NO: 123875
DEALER: 251430

EPA DOT Fuel Economy and Environment — Gasoline Vehicle

Fuel Economy

27 MPG combined city/hwy — 26 city — 27 highway

3.7 gallons per100 miles

Small SUVs range from 18 to 37 MPG.
The best vehicle rates 136 MPGe.

You **spend** **$1,250** **in fuel costs over 5 years** compared to the average new vehicle.

Annual fuel cost **$1,650**

Fuel Economy & Greenhouse Gas Rating (tailpipe only): 6 (1 — 10 Best)

Smog Rating (tailpipe only): 3 (1 — 10 Best)

This vehicle emits 330 grams CO_2 per mile. The best emits 0 grams per mile (tailpipe only). Producing and distributing fuel also create emissions; learn more at fueleconomy.gov.

Actual results will vary for many reasons, including driving conditions and how you drive and maintain your vehicle. The average new vehicle gets 27 MPG and costs $7,000 to fuel over 5 years. Cost estimates are based on 15,000 miles per year at $3.00 per gallon. MPGe is miles per gasoline gallon equivalent. Vehicle emissions are a significant cause of climate change and smog.

fueleconomy.gov
Calculate personalized estimates and compare vehicles

Smartphone QR Code ™

PARTS CONTENT INFORMATION

FOR VEHICLES IN THIS CARLINE
U.S./Canadian Parts Content: **65 %**

NOTE: Parts content does not include final assembly, distribution or other non-parts costs.

FOR THIS VEHICLE
Final Assembly Point:
EAST LIBERTY, OHIO USA
Country of Origin: Engine:
JAPAN
Transmission:
JAPAN

GOVERNMENT 5-STAR SAFETY RATING

Overall Vehicle Score ★★★★★
Based on the combined ratings of frontal, side and rollover.
Should ONLY be compared to other vehicles of similar size and weight.

Frontal Crash — Driver ★★★★★ / Passenger ★★★★★
Based on the risk of injury in a frontal impact.
Should ONLY be compared to other vehicles of similar size and weight.

Side Crash — Front seat ★★★★★ / Rear seat ★★★★★
Based on the risk of injury in a side impact.

Rollover ★★★★
Based on the risk of rollover in a single vehicle crash.

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

Appendix B: Subset of Vehicles Used for Comparative Analysis

Model Year	Represented Test Veh Make	Represented Test Veh Model	Test Vehicle ID	Test Veh Displacement (L)	Vehicle Type	Rated Horsepower	# of Cylinders and Rotors	Tested Transmission Type Code	Tested Transmission Type	# of Gears	Drive System Description	Transmission Overdrive Code	Equivalent Test Weight (lbs.)	Test Number	Test Originator	Test Procedure Description	Test Fuel Type Cd	Test Fuel Type Description	RND_ADJ_FE	FE_UNIT	FE Bag 1	FE Bag 2	FE Bag 3	FE Bag 4	Target Coef A (lbf)	Target Coef B (lbf/mph)	Target Coef C (lbf/mph**2)
2019	ACURA	MDX AWD A-spec	EKBN1A	3.500	Car	290	6	SA	Semi-Automatic	9	2-Wheel Drive, Front	2	4500	KHNX10053154	MFR	Federal fuel 2-day exhaust (w/can load)	61	Tier 2 Cert Gasoline	24.2	MPG	23.3000000	23.3000000	26.9000000		29.960	0.5017	0.02494
2019	ACURA	MDX AWD A-spec	EKBN1A	3.500	Car	290	6	SA	Semi-Automatic	9	2-Wheel Drive, Front	2	4500	KHNX10053155	MFR	HWFE	61	Tier 2 Cert Gasoline	34.7	MPG					29.960	0.5017	0.02494
2019	HONDA	MDX AWD	EHJ61A	3.500	Car	290	6	SA	Semi-Automatic	9	2-Wheel Drive, Front	2	4500	HHNX10040716	MFR	Federal fuel 2-day exhaust (w/can load)	61	Tier 2 Cert Gasoline	24.4	MPG	24.0000000	23.3000000	27.0000000		26.780	0.48500	0.023700
2019	HONDA	MDX AWD	EHJ61A	3.500	Car	290	6	SA	Semi-Automatic	9	2-Wheel Drive, Front	2	4500	HHNX10041909	MFR	HWFE	61	Tier 2 Cert Gasoline	37.6	MPG					26.780	0.48500	0.023700
2019	HONDA	MDX FWD	EHJ62A	3.500	Car	290	6	SA	Semi-Automatic	9	2-Wheel Drive, Front	2	4250	HHNX91003104	EPA	HWFE	61	Tier 2 Cert Gasoline	41.0	MPG					23.810	0.31980	0.025210
2019	HONDA	MDX FWD	EHJ62A	3.500	Car	290	6	SA	Semi-Automatic	9	2-Wheel Drive, Front	2	4250	HHNX91003105	EPA	Federal fuel 2-day exhaust (w/can load)	61	Tier 2 Cert Gasoline	26.0	MPG	25.1874340	24.7772965	29.3777674		23.810	0.31980	0.025210
2019	HONDA	MDX HYBRID	EHWS1D	3.000	Car	321	6	AMS	Automated Manual-Selectable (e.g. Automated Manual with paddles)	7	All Wheel Drive	2	4750	HHNX10043908	MFR	Federal fuel 2-day exhaust (w/can load)	61	Tier 2 Cert Gasoline	34.3	MPG	24.8000000	46.0000000	29.3000000	44.4000000	32.990	0.27560	0.024890
2019	HONDA	MDX HYBRID	EHWS1D	3.000	Car	321	6	AMS	Automated Manual-Selectable (e.g. Automated Manual with paddles)	7	All Wheel Drive	2	4750	HHNX10043909	MFR	HWFE	61	Tier 2 Cert Gasoline	38.6	MPG					32.990	0.27560	0.024890
2019	HONDA	MDX HYBRID	EHWS1D	3.000	Car	321	6	AMS	Automated Manual-Selectable (e.g. Automated Manual with paddles)	7	All Wheel Drive	2	4750	HHNX10044439	MFR	Federal fuel 2-day exhaust (w/can load)	61	Tier 2 Cert Gasoline	35.0	MPG	25.4000000	44.2000000	30.7000000	45.6000000	34.350	0.25100	0.024900
2019	HONDA	MDX HYBRID	EHWS1D	3.000	Car	321	6	AMS	Automated Manual-Selectable (e.g. Automated Manual with paddles)	7	All Wheel Drive	2	4750	HHNX10044440	MFR	HWFE	61	Tier 2 Cert Gasoline	38.5	MPG					34.350	0.25100	0.024900
2019	BMW	X5 xDrive40i	LB12150	3.000	Both	335		SA	Semi-Automatic	8	All Wheel Drive	2	5250	KBMX10055030	MFR	Federal fuel 3-day exhaust	61	Tier 2 Cert Gasoline	25.0	MPG	22.5000000	25.1000000	27.1000000		61.900	-0.3500	0.03111
2019	BMW	X5 xDrive40i	LB12150	3.000	Both	335		SA	Semi-Automatic	8	All Wheel Drive	2	5250	KBMX10055031	MFR	HWFE	61	Tier 2 Cert Gasoline	37.0	MPG					61.900	-0.3500	0.03111
2019	BMW	X5 xDrive40i	LB12150	3.000	Both	335		SA	Semi-Automatic	8	All Wheel Drive	2	5250	KBMX10054811	MFR	HWFE	61	Tier 2 Cert Gasoline	35.2	MPG					62.500	-0.3460	0.03272
2019	BMW	X5 xDrive40i	LB12150	3.000	Both	335		SA	Semi-Automatic	8	All Wheel Drive	2	5250	KBMX10054812	MFR	Federal fuel 3-day exhaust	61	Tier 2 Cert Gasoline	25.3	MPG	22.9000000	25.8000000	26.3000000		62.500	-0.3460	0.03272
2019	BMW	X5 xDrive40i	LB12150	3.000	Both	335		SA	Semi-Automatic	8	All Wheel Drive	2	5250	KBMX10054809	MFR	HWFE	61	Tier 2 Cert Gasoline	35.9	MPG					61.100	-0.3490	0.03272
2019	BMW	X5 xDrive40i	LB12150	3.000	Both	335		SA	Semi-Automatic	8	All Wheel Drive	2	5250	KBMX10054810	MFR	Federal fuel 3-day exhaust	61	Tier 2 Cert Gasoline	25.3	MPG	23.3000000	26.5000000	24.7000000		61.100	-0.3490	0.03272
2019	BMW	X5 xDrive40i	LB12150	3.000	Both	335		SA	Semi-Automatic	8	All Wheel Drive	2	5250	KBMX10055029	MFR	Federal fuel 3-day exhaust	61	Tier 2 Cert Gasoline	25.7	MPG	23.5000000	25.7000000	27.4000000		60.600	-0.3540	0.03111
2019	BMW	X5 xDrive40i	LB12150	3.000	Both	335		SA	Semi-Automatic	8	All Wheel Drive	2	5250	KBMX10055032	MFR	HWFE	61	Tier 2 Cert Gasoline	37.1	MPG					60.600	-0.3540	0.03111
2019	Land Rover	Discovery 340PS	3DHTT006	3.000	Truck	340	6	SA	Semi-Automatic	8	4-Wheel Drive	2	5500	HJLX10045188	MFR	Federal fuel 2-day exhaust (w/can load)	61	Tier 2 Cert Gasoline	19.7	MPG	18.8153000	18.8772000	22.2464000		68.640	0.09490	0.033600
2019	Land Rover	Discovery 340PS	3DHTT006	3.000	Truck	340	6	SA	Semi-Automatic	8	4-Wheel Drive	2	5500	HJLX10045215	MFR	HWFE	61	Tier 2 Cert Gasoline	28.6	MPG					68.640	0.09490	0.033600
2019	Land Rover	Discovery 258PS	3DHTT007	3.000	Truck	258	6	SA	Semi-Automatic	8	4-Wheel Drive	2	5500	HJLX10045027	MFR	CVS 75 and later (w/o can. load)	19	Federal Cert Diesel 7-15 PPM Sulfur	26.3	MPG	21.7858000	27.4268000	28.5264000		68.640	0.09490	0.033600
2019	Land Rover	Discovery 258PS	3DHTT007	3.000	Truck	258	6	SA	Semi-Automatic	8	4-Wheel Drive	2	5500	HJLX10045027	MFR	CVS 75 and later (w/o can. load)	19	Federal Cert Diesel 7-15 PPM Sulfur	26.3	MPG	21.7858000	27.4268000	28.5264000		68.640	0.09490	0.033600
2019	Land Rover	Discovery 258PS	3DHTT007	3.000	Truck	258	6	SA	Semi-Automatic	8	4-Wheel Drive	2	5500	HJLX10045027	MFR	CVS 75 and later (w/o can. load)	19	Federal Cert Diesel 7-15 PPM Sulfur	26.3	MPG	21.7858000	27.4268000	28.5264000		68.640	0.09490	0.033600
2019	Land Rover	Discovery 258PS	3DHTT007	3.000	Truck	258	6	SA	Semi-Automatic	8	4-Wheel Drive	2	5500	HJLX10045028	MFR	HWFE	19	Federal Cert Diesel 7-15 PPM Sulfur	36.1	MPG					68.640	0.09490	0.033600
2019	Land Rover	Discovery 258PS	3DHTT007	3.000	Truck	258	6	SA	Semi-Automatic	8	4-Wheel Drive	2	5500	HJLX10045028	MFR	HWFE	19	Federal Cert Diesel 7-15 PPM Sulfur	36.1	MPG					68.640	0.09490	0.033600
2019	Land Rover	Discovery 258PS	3DHTT007	3.000	Truck	258	6	SA	Semi-Automatic	8	4-Wheel Drive	2	5500	HJLX10045028	MFR	HWFE	19	Federal Cert Diesel 7-15 PPM Sulfur	36.1	MPG					68.640	0.09490	0.033600

Model Year	Represented Test Veh Make	Represented Test Veh Model	Test Vehicle ID	Test Veh Displacement (L)	Vehicle Type	Rated Horsepower	# of Cylinders and Rotors	Tested Transmission Type Code	Tested Transmission Type	# of Gears	Drive System Description	Transmission Overdrive Code	Equivalent Test Weight (lbs.)	Test Number	Test Originator	Test Procedure Description	Test Fuel Type Cd	Test Fuel Type Description	RND_ADJ_FE	FE_UNIT	FE Bag 1	FE Bag 2	FE Bag 3	FE Bag 4	Target Coef A (lbf)	Target Coef B (lbf/mph)	Target Coef C (lbf/mph**2)
2019	Land Rover	Discovery Sport 250PS	LHITT006	2.000	Truck	250	4	SA	Semi-Automatic	9	All Wheel Drive	2	4500	JJLX10050860	MFR	Federal fuel 2-day exhaust (w/can load)	61	Tier 2 Cert Gasoline	26.1	MPG	24.3400000	26.2250000	27.3250000		39.460	0.57063	0.023790
2019	Land Rover	Discovery Sport 250PS	LHITT006	2.000	Truck	250	4	SA	Semi-Automatic	9	All Wheel Drive	2	4500	JJLX10050861	MFR	HWFE	61	Tier 2 Cert Gasoline	35.5	MPG					39.460	0.57063	0.023790
2019	Land Rover	Discovery Sport 300PS	3AITT057	2.000	Truck	300	4	SA	Semi-Automatic	9	All Wheel Drive	2	4500	JJLX10050908	MFR	Federal fuel 2-day exhaust (w/can load)	61	Tier 2 Cert Gasoline	25.4	MPG	23.8920000	25.1380000	27.1090000		39.460	0.57063	0.023790
2019	Land Rover	Discovery Sport 300PS	3AITT057	2.000	Truck	300	4	SA	Semi-Automatic	9	All Wheel Drive	2	4500	JJLX10050909	MFR	HWFE	61	Tier 2 Cert Gasoline	35.5	MPG					39.460	0.57063	0.023790
2019	Mercedes-Benz	GLE 400 4MATIC	W166E30DETC-Z6011-1	2.996	Truck	329	6	A	Automatic	9	All Wheel Drive	2	5500	JMBX10055589	MFR	Federal fuel 2-day exhaust (w/can load)	61	Tier 2 Cert Gasoline	21.8	MPG	20.7458900	21.2004100	23.7540100		48.602	0.28887	0.025401
2019	Mercedes-Benz	GLE 400 4MATIC	W166E30DETC-Z6011-1	2.996	Truck	329	6	A	Automatic	9	All Wheel Drive	2	5500	JMBX10055590	MFR	HWFE	61	Tier 2 Cert Gasoline	31.9	MPG					48.602	0.28887	0.025401
2019	INFINITI	QX60 AWD	GJB474	3.500	Truck	295	6	CVT	Continuously Variable	1	2-Wheel Drive, Front	2	4750	HNSX91003181	EPA	HWFE	61	Tier 2 Cert Gasoline	36.8000000	MPG					40.280	0.40470	0.020280
2019	INFINITI	QX60 AWD	GJB474	3.500	Truck	295	6	CVT	Continuously Variable	1	2-Wheel Drive, Front	2	4750	HNSX91003182	EPA	Federal fuel 2-day exhaust (w/can load)	61	Tier 2 Cert Gasoline	23.5000000	MPG	22.8134798	22.4540790	26.3681778		40.280	0.40470	0.020280
2019	INFINITI	QX60 AWD	GJB474	3.500	Truck	295	6	CVT	Continuously Variable	1	2-Wheel Drive, Front	2	4750	HNSX10043689	MFR	Federal fuel 2-day exhaust (w/can load)	61	Tier 2 Cert Gasoline	24.3000000	MPG					40.280	0.40470	0.020280
2019	INFINITI	QX60 AWD	GJB474	3.500	Truck	295	6	CVT	Continuously Variable	1	2-Wheel Drive, Front	2	4750	HNSX10043690	MFR	HWFE	61	Tier 2 Cert Gasoline	37.3000000	MPG					40.280	0.40470	0.020280
2019	INFINITI	QX60 AWD	GJB474	3.500	Truck	295	6	CVT	Continuously Variable	1	2-Wheel Drive, Front	2	4750	HNSX10045580	MFR	Federal fuel 2-day exhaust (w/can load)	61	Tier 2 Cert Gasoline	24.0000000	MPG					40.960	0.41150	0.021140
2019	INFINITI	QX60 AWD	GJB474	3.500	Truck	295	6	CVT	Continuously Variable	1	2-Wheel Drive, Front	2	4750	HNSX10045581	MFR	HWFE	61	Tier 2 Cert Gasoline	36.7000000	MPG					40.960	0.41150	0.021140
2019	INFINITI	QX60 AWD	GJB474	3.500	Truck	295	6	CVT	Continuously Variable	1	2-Wheel Drive, Front	2	4750	HNSX10045725	MFR	Federal fuel 2-day exhaust (w/can load)	61	Tier 2 Cert Gasoline	24.1000000	MPG					40.960	0.41150	0.021140
2019	INFINITI	QX60 AWD	GJB474	3.500	Truck	295	6	CVT	Continuously Variable	1	2-Wheel Drive, Front	2	4750	HNSX10045726	MFR	HWFE	61	Tier 2 Cert Gasoline	36.8000000	MPG					40.960	0.41150	0.021140
2019	INFINITI	QX60 FWD	GJB475	3.500	Truck	295	6	CVT	Continuously Variable	1	2-Wheel Drive, Front	2	4750	HNSX91003183	EPA	HWFE	61	Tier 2 Cert Gasoline	37.2000000	MPG					38.780	0.25530	0.021800
2019	INFINITI	QX60 FWD	GJB475	3.500	Truck	295	6	CVT	Continuously Variable	1	2-Wheel Drive, Front	2	4750	HNSX91003184	EPA	Federal fuel 2-day exhaust (w/can load)	61	Tier 2 Cert Gasoline	24.3000000	MPG	23.7242820	23.3878497	26.8045219		38.780	0.25530	0.021800
2019	INFINITI	QX60 FWD	GJB475	3.500	Truck	295	6	CVT	Continuously Variable	1	2-Wheel Drive, Front	2	4750	HNSX10043697	MFR	Federal fuel 2-day exhaust (w/can load)	61	Tier 2 Cert Gasoline	25.3000000	MPG					38.780	0.25530	0.021800
2019	INFINITI	QX60 FWD	GJB475	3.500	Truck	295	6	CVT	Continuously Variable	1	2-Wheel Drive, Front	2	4750	HNSX10043698	MFR	HWFE	61	Tier 2 Cert Gasoline	38.4000000	MPG					38.780	0.25530	0.021800
2019	AUDI	Q7 2.0L	HAAC-Q7A	1.984	Both	252	4	SA	Semi-Automatic	8	All Wheel Drive	2	5000	HVGA10040461	MFR	SC03	61	Tier 2 Cert Gasoline	22.7000000	MPG					46.311	0.25682	0.025317
2019	AUDI	Q7 2.0L	HAAC-Q7A	1.984	Both	252	4	SA	Semi-Automatic	8	All Wheel Drive	2	5000	HVGA10040463	MFR	US06	61	Tier 2 Cert Gasoline	21.9000000	MPG	14.3000000	25.9000000			46.311	0.25682	0.025317
2019	AUDI	Q7 2.0L	HAAC-Q7A	1.984	Both	252	4	SA	Semi-Automatic	8	All Wheel Drive	2	5000	HVGA10040589	MFR	HWFE	61	Tier 2 Cert Gasoline	37.3000000	MPG					46.311	0.25682	0.025317
2019	AUDI	Q7 2.0L	HAAC-Q7A	1.984	Both	252	4	SA	Semi-Automatic	8	All Wheel Drive	2	5000	JVGA10048565	MFR	Federal fuel 2-day exhaust (w/can load)	61	Tier 2 Cert Gasoline	24.5000000	MPG	22.5000000	25.0000000	24.5000000		46.311	0.25682	0.025317
2019	AUDI	Q7 2.0L	HAAC-Q7A	1.984	Both	252	4	SA	Semi-Automatic	8	All Wheel Drive	2	5000	JVGA10048566	MFR	Cold CO	27	Cold CO Premium (Tier 2)	18.9000000	MPG	15.9000000	19.5000000	20.8000000		50.942	0.28250	0.027849
2019	AUDI	Q7 3.0L	HAUT-Q7A	3.000	Truck	333	6	SA	Semi-Automatic	8	2-Wheel Drive, Front	2	5250	HVGA10038865	MFR	HWFE	61	Tier 2 Cert Gasoline	35.2000000	MPG					48.559	0.25682	0.025317
2019	AUDI	Q7 3.0L	HAUT-Q7A	3.000	Truck	333	6	SA	Semi-Automatic	8	2-Wheel Drive, Front	2	5250	HVGA10038866	MFR	Federal fuel 3-day exhaust	61	Tier 2 Cert Gasoline	23.5000000	MPG	21.6000000	23.9000000	24.3000000		48.559	0.25682	0.025317
2019	Volvo	XC90 T5 FWD	201904	1.969	Both	250	4	SA	Semi-Automatic	8	2-Wheel Drive, Front	2	4500	KVVX10053556	MFR	Federal fuel 3-day exhaust	61	Tier 2 Cert Gasoline	27.3000000	MPG	27.0588000	26.1145000	30.0906000		28.300	0.15645	0.028046
2019	Volvo	XC90 T5 FWD	201904	1.969	Both	250	4	SA	Semi-Automatic	8	2-Wheel Drive, Front	2	4500	KVVX10053557	MFR	HWFE	61	Tier 2 Cert Gasoline	40.9000000	MPG					28.300	0.15645	0.028046
2019	Volvo	XC90 T6 AWD	201915	1.969	Both	316	4	SA	Semi-Automatic	8	All Wheel Drive	2	5000	KVVX10053705	MFR	Federal fuel 3-day exhaust	61	Tier 2 Cert Gasoline	24.4000000	MPG	24.0388000	23.6608000	26.1854000		44.442	0.17963	0.027462
2019	Volvo	XC90 T6 AWD	201915	1.969	Both	316	4	SA	Semi-Automatic	8	All Wheel Drive	2	5000	KVVX10053706	MFR	HWFE	61	Tier 2 Cert Gasoline	37.3000000	MPG					44.442	0.17963	0.027462
2019	Volvo	XC90 T8 AWD	201901	1.969	Both	313	4	SA	Semi-Automatic	8	All Wheel Drive	2	5500	KVVX10053615	MFR	Federal fuel 2-day exhaust (w/can load)	61	Tier 2 Cert Gasoline	30.9000000	MPG	25.2851000	36.6100000	28.6225000	34.6056000	36.312	0.35403	0.025058
2019	Volvo	XC90 T8 AWD	201901	1.969	Both	313	4	SA	Semi-Automatic	8	All Wheel Drive	2	5500	KVVX10053618	MFR	HWFE	61	Tier 2 Cert Gasoline	38.4000000	MPG					36.312	0.35403	0.025058
2019	Volvo	XC90 T8 AWD	201901	1.969	Both	313	4	SA	Semi-Automatic	8	All Wheel Drive	2	5500	KVVX10053625	MFR	Charge Depleting UDDS	62	Electricity	0	MPG					36.312	0.35403	0.025058
2019	Volvo	XC90 T8 AWD	201901	1.969	Both	313	4	SA	Semi-Automatic	8	All Wheel Drive	2	5500	KVVX10053630	MFR	Charge Depleting Highway	62	Electricity	0	MPG					36.312	0.35403	0.025058

Appendix C: 2019 Acura MDX SH Test Signals

The following signals were collected at 10Hz for each test. Note that the signal sampling rate for CAN and diagnostic messages depends on the vehicle, and the actual transmission rate may be faster or slower than the 10Hz sample rate.

Table 21. Facility and vehicle signal list

Facility, dyno and cell data	Analog data from vehicle	Modal tailpipe emissions
DAQ_Time[s]	DAQ_Time[s]_RawVehicleDAQ	AMA_Dilute_THC[mg/s]
Time[s]_RawFacilities	Time[s]_RawVehicleDAQ	AMA_Dilute_CH4[mg/s]
Dyno_Spd[mph]	Engine_Oil_Dipstick_Temp__C	AMA_Dilute_NOx[mg/s]
Dyno_TractiveForce[N]	Radiator_Air_Outlet_Temp__C	AMA_Dilute_COlow[mg/s]
Dyno_LoadCell[N]	Engine_Bay_Temp__C	AMA_Dilute_COmid[mg/s]
Distance[mi]	Cabin_Temp__C	AMA_Dilute_CO2[mg/s]
Dyno_Spd_Front[mph]	Cabin_Upper_Vent_Temp__C	AMA_Dilute_HFID[mg/s]
Dyno_TractiveForce_Front[N]	Cabin_Lower_Vent_Temp__C	AMA_Dilute_NMHC[mg/s]
Dyno_LoadCell_Front[N]	Cabin_Defrost_Temp__C	AMA_Dilute_Fuel[g/s]
Dyno_Spd_Rear[mph]	Eng_FuelFlow_Direct2__gps	
Dyno_LoadCell_Rear[N]	HVBatt_Volt_Hioki_U1__V	
Dyno_TractiveForce_Rear[N]	HVBatt_Curr_Hioki_I1__A	
DilAir_RH[%]	HVBatt_Power_Hioki_P1__kW	
Tailpipe_Press[inH2O]	DCDC_Out_Curr_Hioki_I3__A	
Cell_Temp[C]	DCDC_Out_Power_Hioki_P3__W	
Cell_RH[%]	HVAC_Comp_Curr_Hioki_I2__A	
Cell_Press[inHg]	12VBatt_Curr_Hioki_I4__A	
Tire_Front_Temp[C]	12VBatt_Volt_Hioki_U4__V	
Tire_Rear_Temp[C]	Eng_FuelFlow_Direct__ccps	
Drive_Schedule_Time[s]	Eng_Fuel_Temp_Direct__C	
Drive_Trace_Schedule[mph]		
Exhaust_Bag		

Table 22. CAN signal list

Vehicle input signals	Engine related messages	High-voltage battery signals
Pedal_Accel_Pos_CAN2__per	Eng_airfuel_lambda_bank1_PGM	HVBatt_cell_voltage_X_EPIMA__mV (ch 1 to 72)
Pedal_Accel_State_CAN2	Eng_airfuel_lambda_bank2_PGM	HVBatt_current_CAN5__A
Pedal_Brake_State_CAN2	Eng_coolant_temp_2_PGM__degC	HVBatt_DCDC_converter_elec_cons_CAN5__W
Veh_speed_CAN2__mph	Eng_coolant_temp_CAN5__C	HVBatt_DCDC_converter_temp_EPIMA__degC
Brake_master_cylinder_pressure_CAN2__MPa	Eng_DFCO_CAN5__rpm	HVBatt_fan1_speed_EPIMA__rpm
Regen_Braking_Pressure_CAN2	Eng_EGR_L_command_PGM__mm	HVBatt_SOC_CAN5__per
Brake_VSA_fluid_pressure_sensor_CAN4__MPa	Eng_fuel_injector_duration_PGM__ms	HVBatt_temp_sensor_X_EPIMA__degC (Sen 1 to 6)
Brake_master_cylinder_pressure_CAN4__Mpa	Eng_intakeair_temp_1_PGM__degC	HVBatt_veh_inside_air_temp_EPIMA__degC
Veh_total_mileage_CAN4__km	Eng_knock_control_PGM	HVBatt_veh_outside_air_temp_EPIMA__degC
	Eng_knock_retard_PGM__deg	HVBatt_voltage_CAN5__V
	Eng_MAF_sensor_flowrate_PGM__gs	
	Eng_MAP_sensor_press_PGM__kPa	
	Eng_spark_advance_PGM__deg	
	Eng_speed_CAN5__rpm	
	Eng_throttle_pos_sensor_relative_AT__per	
	Eng_throttle_valve_PGM__deg	
	Eng_torque_target_crank_end_PGMFI__Nm	
	Exhaust_catalyst_temp_bank1__degC	
	Exhaust_catalyst_temp_bank2__degC	

Front motor signals	Transmission signals	Climate control signals
Motor_power_CAN5__W	Trans_actual_gear_even_shaft_CAN5	HVAC_AC_Demand_State_CAN2
Motor_speed_CAN5__rpm	Trans_actual_gear_odd_shaft_CAN5	HVAC_AC_pwr_consumption_CAN2__W
Motor_torque_CAN5__Nm	Trans_ATF_temp_CAN5__C	HVAC_driver_seat_heater_BCAN
	Trans_even_clutch_target_torque_CAN5__Nm	HVAC_fan_setting_BCAN
Rear motor signals	Trans_even_shaft_speed_AT__rpm	
TMU_L_power_CAN5__W	Trans_gear_engaged_CAN2	
TMU_L_speed_CAN5__rpm	Trans_odd_clutch_target_torque_CAN5__Nm	
TMU_L_torque_CAN5__Nm	Trans_odd_shaft_speed_AT__rpm	
TMU_R_power_CAN5__W	Trans_out_shaft_speed_AT__rpm	
TMU_R_speed_CAN5__rpm		
TMU_R_torque_CAN5__Nm		

Appendix D: Cert Fuel Specifications

Table 23. Certificate of Analysis for Tier 3, Low Octane, test fuel used in tests 61904015-61904038

haltermannsolutions

Telephone: (800) 969-2542

Certificate of Analysis

FAX: (281) 457-1469

PRODUCT: EPA Tier 3 EEE Emission Certification Fuel, General Testing - Regular

Batch No.: GH1621LT10

Specification No.: HF2021

Tank No.: Drums

Date: 8/18/2018

TEST	METHOD	UNITS	SPECIFICATIONS MIN	SPECIFICATIONS TARGET	SPECIFICATIONS MAX	RESULTS
Distillation - IBP	ASTM D86[2]	°F				96.0
5%		°F				120.0
10%		°F	120		140	128.2
20%		°F				138.7
30%		°F				147.0
40%		°F				154.4
50%		°F	190		210	198.1
60%		°F				231.7
70%		°F				254.2
80%		°F				282.4
90%		°F	315		335	320.9
95%		°F				343.0
Distillation - EP		°F	380		420	384.9
Recovery		%		Report		97.3
Residue		ml			2.0	1.2
Loss		%		Report		1.4
Gravity @ 60° F	ASTM D4052[2]	°API		Report		58.13
Density @ 15.56° C	ASTM D4052[2]	kg/l		Report		0.7454
Reid Vapor Pressure EPA Equation	ASTM D5191[2]	psi	8.7		9.2	9.1
Carbon	ASTM D5291[2]	wt fraction		Report		0.8252
Hydrogen	ASTM D5291[2]	wt fraction		Report		0.1384
Hydrogen/Carbon ratio	ASTM D5291[2]	mole/mole		Report		1.999
Oxygen	ASTM D4815[2]	wt %		Report		3.64
Ethanol content	ASTM D5599-00[2]	vol %	9.6		10.0	9.7
Total oxygentates other than ethanol	ASTM D4815[2]	vol %			0.1	None Detected
Sulfur	ASTM D5453[2]	mg/kg	8.0		11.0	8.8
Phosphorus	ASTM D3231[2]	g/l			0.0013	None Detected
Lead	ASTM D3237[2]	g/l			0.0026	None Detected
Composition, aromatics	ASTM D5769[1]	vol %	21.0		25.0	23.2
C6 aromatics (benzene)	ASTM D5769[1]	vol %	0.5		0.7	0.5
C7 aromatics (toluene)	ASTM D5769[1]	vol %	5.2		6.4	6.0
C8 aromatics	ASTM D5769[1]	vol %	5.2		6.4	5.9
C9 aromatics	ASTM D5769[1]	vol %	5.2		6.4	5.7
C10+ aromatics	ASTM D5769[1]	vol %	4.4		5.6	5.1
Composition, olefins	ASTM D6550[2]	wt %	4.0		10.0	7.6
Oxidation Stability	ASTM D525[2]	minutes	1000			1000+
Copper Corrosion	ASTM D130[2]				1	1a
Existent gum, washed	ASTM D381[2]	mg/100mls			3.0	<0.5
Existent gum, unwashed	ASTM D381[2]	mg/100mls		Report		1.5
Research Octane Number	ASTM D2699[2]			Report		92.0
Motor Octane Number	ASTM D2700[2]			Report		84.3
R+M/2	D2699/2700[2]		87.0		88.4	88.2
Sensitivity	D2699/2700[2]		7.5			7.7
Net Heat of Combustion	ASTM D240[2]	BTU/lb		Report		17994

Quality Assurance Technician

[1] Haltermann Solutions is accredited to ISO/IEC 17025 by ANAB for the tests referred to with this footnote.
[2] Tested by ISO/IEC 17025 accredited subcontractor.

Gasoline and diesel specialty fuels from Haltermann Solutions shall remain within specifications for a minimum of 3 years from the date on the COA so long as the drums are sealed and unopened in their original container and stored in a warehouse at ambient conditions. Specialty fuels that have been intentionally modified for aggressive or corrosive properties are excluded.

Table 24. Certificate of Analysis for Tier 3, Low Octane, test fuel used in tests 61904039-61905008

haltermannsolutions

Certificate of Analysis

Telephone: (800) 969-2542 **FAX: (281) 457-1469**

PRODUCT: EPA Tier 3 EEE Emission Certification Fuel, General Testing - Regular

Batch No.: GH2321LT10

Specification No.: HF2021

Tank No.: Drums

Date: 8/28/2018

TEST	METHOD	UNITS	SPECIFICATIONS			RESULTS
			MIN	TARGET	MAX	
Distillation - IBP	ASTM D86[2]	°F				99.2
5%		°F				121.6
10%		°F	120		140	129.4
20%		°F				139.4
30%		°F				147.6
40%		°F				154.0
50%		°F	190		210	200.4
60%		°F				232.7
70%		°F				257.3
80%		°F				282.8
90%		°F	315		335	320.7
95%		°F				342.3
Distillation - EP		°F	380		420	386.3
Recovery		%		Report		97.2
Residue		ml			2.0	1.1
Loss		%		Report		1.7
Gravity @ 60° F	ASTM D4052[2]	°API		Report		57.92
Density @ 15.56° C	ASTM D4052[2]	kg/l		Report		0.7463
Reid Vapor Pressure EPA Equation	ASTM D5191[2]	psi	8.7		9.2	8.9
Carbon	ASTM D5291[2]	wt fraction		Report		0.825
Hydrogen	ASTM D5291[2]	wt fraction		Report		0.1384
Hydrogen/Carbon ratio	ASTM D5291[2]	mole/mole		Report		1.999
Oxygen	ASTM D4815[2]	wt %		Report		3.64
Ethanol content	ASTM D5599-00[2]	vol %	9.6		10.0	9.7
Total oxygentates other than ethanol	ASTM D4815[2]	vol %			0.1	None Detected
Sulfur	ASTM D5453[2]	mg/kg	8.0		11.0	8.8
Phosphorus	ASTM D3231[2]	g/l			0.0013	None Detected
Lead	ASTM D3237[2]	g/l			0.0026	None Detected
Composition, aromatics	ASTM D5769[1]	vol %	21.0		25.0	23.2
C6 aromatics (benzene)	ASTM D5769[1]	vol %	0.5		0.7	0.5
C7 aromatics (toluene)	ASTM D5769[1]	vol %	5.2		6.4	6.0
C8 aromatics	ASTM D5769[1]	vol %	5.2		6.4	5.9
C9 aromatics	ASTM D5769[1]	vol %	5.2		6.4	5.7
C10+ aromatics	ASTM D5769[1]	vol %	4.4		5.6	5.1
Composition, olefins	ASTM D6550[2]	wt %	4.0		10.0	7.6
Oxidation Stability	ASTM D525[2]	minutes	1000			1000+
Copper Corrosion	ASTM D130[2]				1	1a
Existent gum, washed	ASTM D381[2]	mg/100mls			3.0	<0.5
Existent gum, unwashed	ASTM D381[2]	mg/100mls		Report		1.5
Research Octane Number	ASTM D2699[2]			Report		92.0
Motor Octane Number	ASTM D2700[2]			Report		84.3
R+M/2	D2699/2700[2]		87.0		88.4	88.2
Sensitivity	D2699/2700[2]		7.5			7.7
Net Heat of Combustion	ASTM D240[2]	BTU/lb		Report		17994

Quality Assurance Technician

[1] Haltermann Solutions is accredited to ISO/IEC 17025 by ANAB for the tests referred to with this footnote.
[2] Tested by ISO/IEC 17025 accredited subcontractor.

Gasoline and diesel specialty fuels from Haltermann Solutions shall remain within specifications for a minimum of 3 years from the date on the COA so long as the drums are sealed and unopened in their original container and stored in a warehouse at ambient conditions. Specialty fuels that have been intentionally modified for aggressive or corrosive properties are excluded.

Main Lab, 15600 West Hardy Rd., Houston, TX 77060 USA

Table 25. Certificate of Analysis for Tier 2, High Octane, test fuel used in tests 61905009-61905029

APRF REC'D 3 DRUMS (6TOTAL)
7/30/18

haltermannsolutions
Telephone: (800) 969-2542

Certificate of Analysis

FAX: (281) 457-1469

PRODUCT: EPA TIER II EEE FEDERAL REGISTER

PRODUCT CODE: HF0437

Batch No.: GE3121GP10

Tank No.: Drums

Date: 6/26/2018

TEST	METHOD	UNITS	HALTERMANN Specs MIN	TARGET	MAX	RESULTS
Distillation - IBP	ASTM D86[2]	°F	75		95	87
5%		°F				110
10%		°F	120		135	123
20%		°F				140
30%		°F				160
40%		°F				187
50%		°F	200		230	216
60%		°F				231
70%		°F				242
80%		°F				259
90%		°F	305		325	316
95%		°F				340
Distillation - EP		°F			415	400
Recovery		vol %		Report		97.5
Residue		vol %		Report		0.7
Loss		vol %		Report		1.8
Gravity	ASTM D4052[2]	°API	58.7		61.2	58.9
Density	ASTM D4052[2]	kg/l	0.734		0.744	0.743
Reid Vapor Pressure	ASTM D5191[2]	psi	8.7		9.2	8.9
Carbon	ASTM D3343[1]	wt fraction		Report		0.8665
Carbon	ASTM D5291[2]	wt fraction		Report		0.8663
Hydrogen	ASTM D5291[2]	wt fraction		Report		0.1337
Hydrogen/Carbon ratio	ASTM D5291[2]	mole/mole		Report		1.839
Stoichiometric Air/Fuel Ratio				Report		14.567
Oxygen	ASTM D4815[2]	wt %			0.05	None Detected
Sulfur	ASTM D5453[2]	wt %	0.0025		0.0035	0.0032
Lead	ASTM D3237[2]	g/gal			0.01	None Detected
Phosphorus	ASTM D3231[2]	g/gal			0.005	None Detected
Silicon	ASTM 5184[2]	mg/kg			4	None Detected
Composition, aromatics	ASTM D1319[2]	vol %			35	31
Composition, olefins	ASTM D1319[2]	vol %			10	1
Composition, saturates	ASTM D1319[2]	vol %		Report		69
Particulate matter	ASTM D5452[2]	mg/l			1	0
Oxidation Stability	ASTM D525[2]	minutes	240			1000+
Copper Corrosion	ASTM D130[2]				1	1a
Gum content, washed	ASTM D381[2]	mg/100mls			5	<0.5
Fuel Economy Numerator/C Density	ASTM D5291[1]		2401		2441	2432
C Factor	ASTM D5291[1]			Report		0.9987
Research Octane Number	ASTM D2699[2]		96.0			97.3
Motor Octane Number	ASTM D2700[2]			Report		88.6
Sensitivity	D2699/2700[2]		7.5			8.7
Net Heating Value, btu/lb	ASTM D3338[1]	btu/lb		Report		18441
Net Heating Value, btu/lb	ASTM D240[2]	btu/lb		Report		18623
Color	VISUAL			Report		Undyed

Quality Assurance Technician

[1] Haltermann Solutions is accredited to ISO/IEC 17025 by ANAB for the tests referred to with this footnote.
[2] Tested by ISO/IEC 17025 accredited subcontractor.

Gasoline and diesel specialty fuels from Haltermann Solutions shall remain within specifications for a minimum of 3 years from the date on the COA so long as the drums are sealed and unopened in their original container and stored in a warehouse at ambient conditions. Specialty fuels that have been intentionally modified for aggressive or corrosive properties are excluded.

Main Lab, 15600 West Hardy Rd., Houston, TX 77060 USA

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Appendix E: Test Summary

Test ID [#]	Cycle	Test Time	Start Comments	End Comments	Test Cell Temp [C]	Test weight [lb]	Dyno Target A:	Dyno Target B:	Dyno Target C:	Cycle Distance [mi]	APCtime	ASCR	ASC_d	ASC_t	CE_d	CE_t	EER	ER	IWR	Cycle Fuel Consumed [gal] (Emiss Bag)	Cycle Fuel economy [mpg] (Emiss Bag)	Fuel Consumption Bag [l/100km]	Fuel used modal [gal]	Fuel Economy Modal [mpg]	Fuel Consumption Modal [l/100km]	HV Batt Δ [Wh]	HV Batt Average Power P1 [W]	HV Batt Energy consumption [Wh/mi]	DCDC Out Δ WP2 [Wh]	DCDC Out Average Power P2 [W]	DCDC Out Δ WP2 [Wh/mi]	12V Neg Out Δ WP2 [Wh]	12V Neg Out Average Power P2 [W]	12V Neg Out Δ WP2 [Wh/mi]	SOC init	SOC end	Delta SOC
Day 0+ - Channel Checkout / prep																																					
Day 1 - 72F Testing / Standard Cycles / Tier III LO																																					
61904015	UDDS x2	04/12/19, 08:31:28 AM	UDDSx2, 4 bag, cold start (FTP), using ANL ABS bypass method (NO HANDYMAN), hood down with speed match fan	ok	24	4750	34.35	0.251	0.0249	3.60	2703.884058	1.47283713	2079.076821	2048.899863	3.70334136	3.67343301	0.45816089	0.81417968	0.58535394	0.151	23.8	9.89	0.151	23.9	9.85	-201.000	-1492.117	-55.777	74.289	530.499	20.615	-1.929	-14.294	-0.535	46.2	82.4	36.2
61904015	UDDS x2	04/12/19, 08:31:28 AM	UDDSx2, 4 bag, cold start (FTP), using ANL ABS bypass method (NO HANDYMAN), hood down with speed match fan	ok	21	4750	34.35	0.251	0.0249	3.89	1643.883377	1.26382486	3459.541832	3416.364963	3.38115105	3.36816468	-0.32280124	0.38556235	0.71576032	0.093	41.9	5.61	0.092	42.4	5.55	164.000	628.767	42.188	114.311	473.276	29.406	-0.661	-2.618	-0.170	82.4	44.8	(37.6)
61904015	UDDSx2 1+2	04/12/19, 08:31:28 AM	UDDSx2, 4 bag, cold start (FTP), using ANL ABS bypass method (NO HANDYMAN), hood down with speed match fan	ok	22					7.49										0.244	30.68	7.67	0.243	30.86	7.62	-37.000	-431.675	-4.939	188.600	501.888	25.2	-2.590	-8.456	-0.3			(1.4)
61904015	UDDS x2	04/12/19, 08:31:28 AM	UDDSx2, 4 bag, cold start (FTP), using ANL ABS bypass method (NO HANDYMAN), hood down with speed match fan	ok	24	4750	34.35	0.251	0.0249	3.61	2702.529417	1.74777068	2084.695244	2048.885425	3.71775444	3.6733962	0.66786697	1.20755399	0.58535141	0.127	28.4	8.28	0.126	28.8	8.18	-199.000	-1532.952	-55.123	76.507	545.536	21.192	-7.016	-49.936	-1.943	44.8	78.1	33.3
61904015	UDDS x2	04/12/19, 08:31:28 AM	UDDSx2, 4 bag, cold start (FTP), using ANL ABS bypass method (NO HANDYMAN), hood down with speed match fan	ok	21	4750	34.35	0.251	0.0249	3.89	1643.716291	2.13356411	3489.217752	3416.3282	3.39557864	3.3680971	0.08578629	0.81593663	0.71576389	0.093	42.0	5.61	0.091	42.5	5.54	142.000	624.029	36.522	114.847	475.746	29.538	-0.882	-3.626	-0.227	78.1	46.0	(32.1)
61904015	UDDSx2 3+4	04/12/19, 08:31:28 AM	UDDSx2, 4 bag, cold start (FTP), using ANL ABS bypass method (NO HANDYMAN), hood down with speed match fan	ok	23					7.50										0.220	34.13	6.89	0.217	34.55	6.81	-57.000	-454.462	-7.602	191.354	510.641	25.5	-7.898	-26.781	-1.1			1.3
61904016	UDDS x2	04/12/19, 09:49:22 AM	UDDS #3, 2 bag, warm start, using ANL ABS bypass method (NO HANDYMAN), hood down with speed match fan	ok	24	4750	34.35	0.251	0.0249	3.57	2716.494622	-1.61459333	2015.787233	2048.868122	3.64633658	3.67331593	-0.26623642	-0.73446875	0.58535811	0.128	28.0	8.40	0.126	28.3	8.30	-195.752	-1396.145	-54.769	79.680	569.010	22.294	-9.638	-68.741	-2.697	46.0	78.3	32.3
61904016	UDDS x2	04/12/19, 09:49:22 AM	UDDS #3, 2 bag, warm start, using ANL ABS bypass method (NO HANDYMAN), hood down with speed match fan	ok	21	4750	34.35	0.251	0.0249	3.84	1657.397006	0.72972792	3441.229248	3416.299556	3.313775	3.36799875	-1.14015243	-1.60996921	0.71577643	0.087	44.0	5.35	0.086	44.6	5.27	161.110	672.016	41.944	114.904	476.390	29.915	-1.493	-6.221	-0.389	78.3	43.4	(34.9)
61904016	UDDSx2 1+2	04/12/19, 09:49:22 AM	UDDS #3, 2 bag, warm start, using ANL ABS bypass method (NO HANDYMAN), hood down with speed match fan	ok	23					7.42										0.215	34.49	6.82	0.212	34.94	6.73	-34.642	-362.064	-4.672	194.584	522.700	26.2	-11.130	-37.481	-1.5			(2.6)
61904017	HWYx2	04/12/19, 10:26:40 AM	HWYx2, 2 bag, warm start, using ANL ABS bypass method (NO HANDYMAN), hood down with speed match fan	ok	26	4750	34.35	0.251	0.0249	10.28	2184.08291	1.80847195	1330.449216	1306.815818	9.19530661	9.16650428	0.12565545	0.31421282	0.27652988	0.324	31.7	7.42	0.324	31.7	7.43	-265.000	-1247.383	-25.788	119.413	561.920	11.621	-6.590	-31.094	-0.641	43.7	88.5	44.8
61904017	HWYx2	04/12/19, 10:26:40 AM	HWYx2, 2 bag, warm start, using ANL ABS bypass method (NO HANDYMAN), hood down with speed match fan	ok	25	4750	34.35	0.251	0.0249	10.28	2184.470671	3.39854127	1351.219507	1306.807128	9.24328286	9.16647129	0.63213745	0.83796226	0.2765289	0.293	35.0	6.71	0.293	35.1	6.70	2.000	3.868	0.195	113.643	534.722	11.058	-0.760	-3.483	-0.074	88.2	88.6	0.4
61904018	US06x2	04/12/19, 11:08:56 AM	US06x2,4 bag, warm start, using ANL ABS bypass method (NO HANDYMAN), hood down with speed match fan	ok	21	4750	34.35	0.251	0.0249	1.78	6271.935053	-0.36800327	2450.533866	2459.58522	3.64154008	3.60449759	0.44402354	1.02767409	0.81050249	0.110	16.3	14.46	0.109	16.3	14.40	-61.000	-938.964	-34.224	41.357	639.285	23.203	-4.543	-70.348	-2.549	88.3	86.9	8.1
61904018	US06x2	04/12/19, 11:08:56 AM	US06x2,4 bag, warm start, using ANL ABS bypass method (NO HANDYMAN), hood down with speed match fan	ok	26	4750	34.35	0.251	0.0249	6.24	13341.53433	11.74071856	1273.122681	1139.354299	8.18882605	8.18426453	-0.07475436	0.05573533	0.3379619	0.248	25.2	9.34	0.247	25.3	9.31	35.000	345.349	5.606	56.936	559.465	9.120	-2.380	-23.398	-0.381	79.2	69.7	(9.6)
61904018	US06x2 1+2	04/12/19, 11:08:56 AM	US06x2,4 bag, warm start, using ANL ABS bypass method (NO HANDYMAN), hood down with speed match fan	ok	23					8.03										0.358	22.45	10.48	0.356	22.54	10.44	-26.000	-296.807	-3.240	98.293	599.375	12.2	-6.923	-46.873	-0.9			(1.5)
61904018	US06x2	04/12/19, 11:08:56 AM	US06x2,4 bag, warm start, using ANL ABS bypass method (NO HANDYMAN), hood down with speed match fan	ok	22	4750	34.35	0.251	0.0249	1.78	6245.388936	0.8844743	2481.3459	2459.591445	3.65837447	3.60453307	0.77870956	1.49371361	0.81049866	0.114	15.7	15.02	0.114	15.6	15.07	-103.631	-1582.556	-58.070	37.354	575.246	20.931	-0.250	-3.806	-0.140	82.5	86.6	15.2
61904018	US06x2	04/12/19, 11:08:56 AM	US06x2,4 bag, warm start, using ANL ABS bypass method (NO HANDYMAN), hood down with speed match fan	ok	26	4750	34.35	0.251	0.0249	6.25	13345.02548	3.4749312	1178.877707	1139.288225	8.15496723	8.18415663	-0.5568381	-0.35665748	0.3379411	0.239	26.2	8.99	0.239	26.2	8.98	47.000	475.357	7.523	54.486	536.573	8.722	-0.370	-3.547	-0.059	80.7	69.6	(11.2)
61904018	US06x2 3+4	04/12/19, 11:08:56 AM	US06x2,4 bag, warm start, using ANL ABS bypass method (NO HANDYMAN), hood down with speed match fan	ok	24					8.03										0.353	22.77	10.33	0.353	22.76	10.34	-56.631	-553.600	-7.051	91.839	555.909	11.4	-0.620	-3.677	-0.1			4.1
61904019	UDDS x2	04/12/19, 01:20:40 PM	UDDS prep, 1 bag, warm start, using ANL ABS bypass method (NO HANDYMAN), hood down with speed match fan	OK	22	4750	34.35	0.251	0.0249	7.50	2047.764026	2.01318559	5575.193587	5465.16958	7.11354946	7.04130584	0.38797308	1.02599746	0.64774174	0.199	37.7	6.24	0.198	37.9	6.20	171.000	449.455	22.806	186.094	487.796	24.819	-3.234	-8.396	-0.431	86.5	48.6	(37.9)
Day 2- 72F Testing / Standard Cycles / Tier III LO																																					
61904020	UDDS x2	04/16/19, 10:12:12 AM	UDDSx2, 4 bag, cold start (FTP), using ANL ABS bypass	ok	23	4750	34.35	0.251	0.0249	3.60	2703.989563	1.07677734	2070.985227	2048.922889	3.69907896	3.67345651	0.33191893	0.69750247	0.58535916	0.154	23.5	10.03	0.153	23.5	10.01	-171.000	-1223.553	-47.447	76.238	543.239	21.153	-2.580	-18.384	-0.716	48.6	79.8	31.2
61904020	UDDS x2	04/16/19, 10:12:12 AM	UDDSx2, 4 bag, cold start (FTP), using ANL ABS bypass	ok	20	4750	34.35	0.251	0.0249	3.88	1643.962228	1.48780905	3467.192277	3416.363314	3.40326274	3.36816398	0.50982837	1.04207404	0.71575962	0.092	42.2	5.57	0.091	42.5	5.53	147.000	616.043	37.884	114.010	472.728	29.382	-0.170	-0.751	-0.044	79.8	45.0	(34.9)
61904020	UDDSx2 1+2	04/16/19, 10:12:12 AM	UDDSx2, 4 bag, cold start (FTP), using ANL ABS bypass	ok	22					7.48										0.246	30.48	7.72	0.245	30.59	7.69	-24.000	-303.755	-3.207	190.248	507.983	25.4	-2.751	-9.568	-0.4			(3.7)
61904020	UDDS x2	04/16/19, 10:12:12 AM	UDDSx2, 4 bag, cold start (FTP), using ANL ABS bypass	ok	24	4750	34.35	0.251	0.0249	3.60	2702.540587	-0.27620173	2043.227382	2048.886442	3.68267894	3.67340714	-0.04924479	0.25240336	0.58535054	0.132	27.3	8.63	0.131	27.5	8.54	-203.000	-1443.208	-56.360	76.379	544.709	21.205	-6.489	-46.110	-1.802	45.0	80.3	35.4
61904020	UDDS x2	04/16/19, 10:12:12 AM	UDDSx2, 4 bag, cold start (FTP), using ANL ABS bypass	ok	21	4750	34.35	0.251	0.0249	3.89	1643.685185	2.76527926	3510.807346	3416.336112	3.42109268	3.36810642	0.80594544	1.57317671	0.71576409	0.090	43.0	5.47	0.090	43.4	5.42	165.000	691.512	42.427	114.481	474.338	29.437	-0.080	-0.353	-0.021	80.3	43.1	(37.2)
61904020	UDDSx2 3+4	04/16/19, 10:12:12 AM	UDDSx2, 4 bag, cold start (FTP), using ANL ABS bypass	ok	23					7.49										0.223	33.66	6.99	0.220	33.98	6.92	-38.000	-375.848	-5.073	190.860	509.524	25.5	-6.569	-23.232	-0.9			(1.8)
61904021	UDDS x2	04/16/19, 11:30:02 AM	UDDS, 2 bag, warm start,, using ANL ABS bypass	OK	24	4750	34.35	0.251	0.0249	3.58	2716.40968	0.7884266	2065.017797	2048.864008	3.68900358	3.67330636	0.73989241	0.42733216	0.58535764	0.127	28.3	8.32	0.125	28.5	8.24	-166.000	-1184.870	-46.373	80.218	573.385	22.409	-9.768	-69.695	-2.729	43.1	71.9	28.8
61904021	UDDS x2	04/16/19, 11:30:02 AM	UDDS, 2 bag, warm start,, using ANL ABS bypass	OK	21	4750	34.35	0.251	0.0249	3.85	1657.35003	1.40846004	3464.421427	3416.304149	3.33463231	3.3679922	-0.77579347	-0.99049784	0.71577848	0.091	42.4	5.55	0.090	43.0	5.47	115.000	470.019	29.860	114.942	476.089	29.845	-0.893	-3.659	-0.232	71.9	44.2	(27.7)
61904021	UDDSx2 1+2	04/16/19, 11:30:02 AM	UDDS, 2 bag, warm start,, using ANL ABS bypass	OK	23					7.43										0.217	34.18	6.88	0.215	34.55	6.81	-51.000	-357.426	-6.863	195.160	524.737	26.3	-10.661	-36.677	-1.4			1.1
61904022	HWYx2	04/16/19, 01:23:22 PM	Hwyx2, 2 bag, warm start,, using ANL ABS bypass	ok	26	4750	34.35	0.251	0.0249	10.23	2184.408796	1.37675571	1324.814316	1306.822562	9.16766166	9.16652682	0.27485992	0.01238026	0.27653079	0.323	31.6	7.43	0.324	31.6	7.45	-239.000	-1118.881	-23.363	114.724	540.574	11.215	-0.310	-1.606	-0.030	45.8	87.4	41.5
61904022	HWYx2	04/16/19, 01:23:22 PM	Hwyx2, 2 bag, warm start,, using ANL ABS bypass	ok	25	4750	34.35	0.251	0.0249	10.22	2184.722004	0.79246403	1317.17402	1306.817957	9.09510523	9.1664984	-0.38703338	-0.77884891	0.2765305	0.285	35.8	6.56	0.285	35.8	6.57	-25.000	-117.725	-2.447	111.030	522.467	10.868	-0.260	-1.248	-0.025	87.0	86.8	(0.2)
61904023	US06x2	04/16/19, 02:05:00 PM	US06x2, 4 bag, warm start,, using ANL ABS bypass	ok	21	4750	34.35	0.251	0.0249	1.79	6275.18421	-0.29940978	2452.275002	2459.639403	3.65185986	3.60460183	0.4471322	1.31104698	0.8105002	0.110	16.3	14.45	0.110	16.2	14.49	-73.000	-1164.983	-40.843	40.880	631.269	22.872	-3.986	-61.576	-2.230	87.3	88.0	10.6
61904023	US06x2	04/16/19, 02:05:00 PM	US06x2, 4 bag, warm start,, using ANL ABS bypass	ok	25	4750	34.35	0.251	0.0249	6.24	13347.29298	4.04799743	1185.594207	1139.46855	8.19896452	8.18442172	0.10146145	0.17768874	0.33799928	0.244	25.5	9.21	0.244	25.6	9.18	33.000	338.912	5.289	55.820	549.831	8.946	-1.200	-11.833	-0.192	79.5	69.7	(9.9)
61904023	US06x2 1+2	04/16/19, 02:05:00 PM	US06x2, 4 bag, warm start,, using ANL ABS bypass	ok	23					8.03										0.354	22.67	10.37	0.354	22.70	10.36	-40.000	-413.035	-4.983	96.700	590.550	12.0	-5.186	-36.705	-0.6			0.7
61904023	US06x2	04/16/19, 02:05:00 PM	US06x2, 4 bag, warm start,, using ANL ABS bypass	ok	22	4750	34.35	0.251	0.0249	1.79	6247.182241	-0.05769627	2458.199142	2459.618249	3.6506187	3.60457964	0.35597005	1.27723793	0.81049561	0.113	15.8	14.86	0.113	15.8	14.89	-106.000	-1644.297	-59.272	37.426	574.789	20.928	-0.080	-0.904	-0.045	84.1	87.7	14.7
61904023	US06x2	04/16/19, 02:05:00 PM	US06x2, 4 bag, warm start,, using ANL ABS bypass	ok	26	4750	34.35	0.251	0.0249	6.24	13352.32234	5.33075735	1200.177357	1139.436749	8.18957731	8.18440539	-0.00923563	0.06319242	0.33798825	0.241	25.9	9.10	0.241	25.9	9.10	45.000	469.556	7.212	54.790	538.956	8.781	-0.110	-1.038	-0.018	80.4	69.3	(11.1)
61904023	US06x2 3+4	04/16/19, 02:05:00 PM	US06x2, 4 bag, warm start,, using ANL ABS bypass	ok	24					8.03										0.354	22.66	10.38	0.355	22.64	10.39	-61.000	-587.370	-7.599	92.216	556.872	11.5	-0.190	-0.971	0.0			3.6
61904024	UDDS Prep	04/16/19, 02:48:09 PM	UDDS prep, 1 bag, warm start,, using ANL ABS bypass	ok	22	4750	34.35	0.251	0.0249	7.51	2049.163776	1.72946552	5559.838666	5465.317878	7.11165169	7.04152963	0.26086276	0.99583559	0.647745	0.199	37.8	6.23	0.198	38.0	6.19	162.000	418.316	21.584	191.352	501.661	25.495	-6.623	-17.344	-0.882	87.4	52.5	(35.0)
Day 3 - 72F Testing / Standard Cycles / Tier III LO																																					
61904025	UDDS x2	04/17/19, 07:46:00 AM	UDDSx2, 4 bag, cold start (FTP), using ANL ABS bypass	ok	24	4750	34.35	0.251	0.0249	3.59	2703.59332	0.6913097	2063.078128	2048.913788	3.69703724	3.67344212	0.60579958	0.64231643	0.5853571	0.151	23.8	9.86	0.150	23.9	9.84	-195.578	-1394.236	-54.445	75.306	537.475	20.964	-2.446	-17.464	-0.681	52.7	84.9	32.2
61904025	UDDS x2	04/17/19, 07:46:00 AM	UDDSx2, 4 bag, cold start (FTP), using ANL ABS bypass	ok	20	4750	34.35	0.251	0.0249	3.84	1643.80431	0.55641851	3435.360529	3416.351318	3.3341216	3.3681466	-0.57121861	-1.01019946	0.71576063	0.086	44.6	5.27	0.086	44.8	5.26	161.000	659.925	41.897	113.470	470.038	29.528	-0.270	-1.113	-0.070	84.9	50.3	(34.6)
61904025	UDDSx2 1+2	04/17/19, 07:46:00 AM	UDDSx2, 4 bag, cold start (FTP), using ANL ABS bypass	ok	22					7.43										0.237	31.40	7.49	0.236	31.48	7.47	-34.578	-367.155	-4.651	188.775	503.756	25.4	-2.716	-9.288	-0.4			(2.5)
61904025	UDDS x2	04/17/19, 07:46:00 AM	UDDSx2, 4 bag, cold start (FTP), using ANL ABS bypass	ok	24	4750	34.35	0.251	0.0249	3.61	2702.110039	2.01974512	2090.252869	2048.870899	3.72431273	3.67337886	0.87185765	1.38656741	0.58534937	0.127	28.3	8.30	0.126	28.6	8.22	-174.000	-1245.266	-48.212	76.564	545.510	21.215	-6.519	-46.281	-1.806	50.3	80.0	29.8
61904025	UDDS x2	04/17/19, 07:46:00 AM	UDDSx2, 4 bag, cold start (FTP), using ANL ABS bypass	ok	22	4750	34.35	0.251	0.0249	3.89	1643.499493	1.66004825	3473.035776	3416.323163	3.40793091	3.36808047	0.30940431	1.18317935	0.71576642	0.090	43.1	5.46	0.090	43.4	5.42	145.000	602.107	37.242	114.536	474.821	29.417	-0.160	-0.723	-0.041	80.0	47.3	(32.8)
61904025	UDDSx2 3+4	04/17/19, 07:46:00 AM	UDDSx2, 4 bag, cold start (FTP), using ANL ABS bypass	ok	23					7.50										0.218	34.44	6.83	0.216	34.75	6.77	-29.000	-321.579	-3.865	191.100	510.166	25.5	-6.679	-23.502	-0.9			(3.0)
61904026	UDDS x2	04/17/19, 09:02:29 AM	UDDS #3, 2 bag, warm start, using ANL ABS bypass	ok	24	4750	34.35	0.251	0.0249	3.58	2717.111129	0.44073181	2057.927952	2048.897807	3.66561669	3.67335678	0.05596369	-0.21070887	0.58536379	0.127	28.3	8.31	0.125	28.6	8.22	-179.000	-1287.452	-49.980	80.083	571.934	22.360	-9.543	-68.262	-2.665	47.8	77.8	30.0
61904026	UDDS x2	04/17/19, 09:02:29 AM	UDDS #3, 2 bag, warm start, using ANL ABS bypass	ok	22	4750	34.35	0.251	0.0249	3.85	1658.056959	0.37991392	3429.333362	3416.354157	3.32141767	3.36807714	-1.05001071	-1.38534426	0.71577545	0.084	45.9	5.13	0.084	46.0	5.11	162.000	675.308	42.117	114.240	473.491	29.700	-0.640	-2.659	-0.166	77.8	41.5	(36.4)
61904026	UDDSx2 1+2	04/17/19, 09:02:29 AM	UDDS #3, 2 bag, warm start, using ANL ABS bypass	ok	23					7.43										0.210	35.29	6.67	0.209	35.57	6.61	-17.000	-306.072	-2.289	194.322	522.713	26.2	-10.183	-35.460	-1.4			(6.4)
61904028	HWYx2	04/17/19, 10:08:44 AM	Hwyx2, 2 bag, warm start, using ANL ABS bypass, repeat	ok	25	4750	34.35	0.251	0.0249	10.27	2183.511931	2.96955169	1345.608043	1306.801885	9.21884303	9.16646928	0.45490942	0.57136223	0.27652757	0.289	35.5	6.62	0.289	35.5	6.62	-20.000	-91.765	-1.948	117.949	554.938	11.487	-5.928	-27.908	-0.577	89.5	89.2	(0.3)
61904028	HWYx2	04/17/19, 10:08:44 AM	Hwyx2, 2 bag, warm start, using ANL ABS bypass, repeat	ok	25	4750	34.35	0.251	0.0249	10.28	2183.819603	4.48673755	1365.425412	1306.793038	9.21973969	9.16645466	0.3646581	0.5813046	0.27652586	0.285	36.1	6.52	0.284	36.2	6.51	-36.000	-163.155	-3.502	109.680	516.165	10.671	-0.210	-0.964	-0.020	88.9	91.3	2.5
61904029	US06x3	04/17/19, 10:51:48 AM	US06x3, 3 bag, warm start, using ANL ABS bypass, repeat, PREP/STANDARD mode/SPORT mode	ok	24	4750	34.35	0.251	0.0249	8.03	10611.2507	1.6453296	3658.308807	3599.091883	11.84127465	11.78904187	0.20547415	0.44306212	0.48246583	0.353	22.7	10.35	0.353	22.7	10.34	-11.000	-62.938	-1.371	104.037	626.242	12.963	-12.459	-75.030	-1.552	91.2	86.2	(5.0)
61904029	US06x3	04/17/19, 10:51:48 AM	US06x3, 3 bag, warm start, using ANL ABS bypass, repeat, PREP/STANDARD mode/SPORT mode	ok	24	4750	34.35	0.251	0.0249	8.04	10609.33628	1.90650014	3667.653147	3599.037492	11.90344361	11.78894561	0.54236708	0.97123189	0.482462	0.355	22.6	10.38	0.355	22.7	10.38	-47.000	-283.311	-5.845	91.940	552.097	11.434	-0.240	-1.447	-0.030	84.0	84.9	0.9
61904029	US06x3	04/17/19, 10:51:48 AM	US06x3, 3 bag, warm start, using ANL ABS bypass, repeat, PREP/STANDARD mode/SPORT mode	ok	24	4750	34.35	0.251	0.0249	8.03	10610.37614	1.14259309	3640.065216	3598.943931	11.81661847	11.78880994	-0.04344702	0.23588916	0.48244562	0.349	23.0	10.22	0.348	23.0	10.21	-52.000	-359.921	-6.476	90.260	542.897	11.241	-0.220	-1.233	-0.027	82.3	86.1	3.8
61904030	SSS 55mph	04/17/19, 12:51:01 PM	SSS 55MPH, 1 bag, warm start, using ANL ABS bypass, warm up for SSS testing	ok	26	4750	34.35	0.251	0.0249	9.18	8808.58236	5.77432985	520.1389206	491.744	8.7547102	8.767332	-0.08722133	-0.14396397	0.07539688	0.268	34.3	6.86	0.269	34.1	6.90	-3.000	-19.247	-0.327	89.269	536.047	9.729	-0.310	-1.982	-0.034	77.0	77.0	0.0
61904031	SSS 30mph	04/17/19, 01:21:01 PM	SSS 30MPH, 1 bag, warm start, using ANL ABS bypass,	ok	20	4750	34.35	0.251	0.0249	5.02	2621.555288	39.95065189	375.3812365	268.224	2.50960962	2.49913666	0.21053234	0.41906302	0.07869515	0.082	60.9	3.86	0.082	61.4	3.83	156.000	940.102	31.089	89.319	535.426	17.800	-12.404	-74.361	-2.472	66.5	35.9	(30.6)
61904032	SSS 45mph	04/17/19, 01:41:17 PM	SSS 45MPH, 1 bag, warm start, using ANL ABS bypass, BAGS OFF	ok	25	4750	34.35	0.251	0.0249	7.51	5896.742021	20.25409937	483.8255332	402.336	5.60200999	5.60285343	-0.00573327	-0.01505374	0.07897893				0.190	39.5	5.96	-33.574	-201.904	-4.470	82.869	496.408	11.034	-0.740	-4.400	-0.099	25.8	26.5	0.7
61904033	SSS 60mph	04/17/19, 01:57:32 PM	SSS 60MPH, 1 bag, warm start, using ANL ABS bypass, BAGS OFF	OK	26	4750	34.35	0.251	0.0249	10.04	10483.15205	3.91706034	557.4609919	536.448	10.79479051	10.74503752	0.25521595	0.46303229	0.07321331				0.317	31.7	7.43	-69.642	-420.767	-6.939	88.882	533.489	8.857	-0.538	-3.243	-0.054	38.9	50.9	12.0
Day 4 - 72F Testing / WLTP / Tier III LO																																					
61904035	WLTP	04/18/19, 08:05:00 AM	WLTP, 4 bag, cold start, using ANL ABS bypass,	ok	22	4750	34.35	0.251	0.0249	1.93	1227.849138	1.24087524	2023.901794	1999.095512	1.80499286	1.78155942	0.68152285	1.31533293	0.79293551	0.089	21.7	10.82	0.088	21.9	10.75	7.000	53.001	3.634	85.816	525.256	44.550	-1.357	-8.176	-0.704	71.3	68.1	(3.2)
61904035	WLTP	04/18/19, 08:05:00 AM	WLTP, 4 bag, cold start, using ANL ABS bypass,	ok	22	4750	34.35	0.251	0.0249	2.95	2415.663557	2.04194888	1895.846276	1857.90873	3.00081587	3.02232699	-0.93550432	-0.71174036	0.68273762	0.093	31.7	7.42	0.093	31.8	7.39	-99.000	-814.200	-33.506	59.976	499.008	20.298	-0.080	-0.667	-0.027	68.1	82.9	14.8
61904035	WLTP	04/18/19, 08:05:00 AM	WLTP, 4 bag, cold start, using ANL ABS bypass,	ok	24	4750	34.35	0.251	0.0249	4.40	2128.053528	1.27005008	1647.979777	1627.312098	4.35775739	4.37166052	-0.54180337	-0.31802864	0.48891059	0.129	34.2	6.88	0.128	34.3	6.85	-14.000	-127.394	-3.184	64.055	506.444	14.567	-0.080	-0.685	-0.018	82.9	82.9	0.0
61904035	WLTP	04/18/19, 08:05:00 AM	WLTP, 4 bag, cold start, using ANL ABS bypass,	ok	26	4750	34.35	0.251	0.0249	5.13	1874.390803	3.05204283	1023.707829	993.389166	6.86506462	6.86688009	-0.0308748	-0.02643805	0.32898236	0.187	27.4	8.57	0.188	27.3	8.61	48.000	537.264	9.358	45.856	512.909	8.940	-0.060	-0.536	-0.012	82.9	70.5	(12.4)
61904036	WLTP Hot Start	04/18/19, 08:59:07 AM	WLTP, 4 bag, warm start, using ANL ABS bypass,	ok	20	4750	34.35	0.251	0.0249	1.91	1228.83739	2.25465198	2044.185296	1999.112272	1.80168902	1.78158274	1.15559622	1.12856268	0.79293351	0.036	53.3	4.42	0.035	54.8	4.29	191.000	1182.661	99.813	96.617	591.478	50.490	-18.965	-116.193	-9.911	70.8	32.3	(38.5)
61904036	WLTP Hot Start	04/18/19, 08:59:07 AM	WLTP, 4 bag, warm start, using ANL ABS bypass,	ok	23	4750	34.35	0.251	0.0249	2.94	2416.666301	1.37228026	1883.453121	1857.956747	3.03663677	3.02238268	0.71294492	0.47161762	0.68273953	0.102	28.7	8.19	0.103	28.6	8.22	-237.000	-1999.404	-80.582	62.005	515.832	21.082	-1.060	-8.746	-0.360	32.3	73.9	41.6
61904036	WLTP Hot Start	04/18/19, 08:59:07 AM	WLTP, 4 bag, warm start, using ANL ABS bypass,	ok	25	4750	34.35	0.251	0.0249	4.37	2128.903162	2.39745996	1666.355815	1627.340967	4.32321685	4.37169881	-0.76487024	-1.10899593	0.48891429	0.132	33.2	7.08	0.131	33.4	7.05	-66.565	-524.624	-15.225	65.100	514.458	14.890	-0.160	-1.335	-0.037	73.8	83.2	9.4
61904036	WLTP Hot Start	04/18/19, 08:59:07 AM	WLTP, 4 bag, warm start, using ANL ABS bypass,	ok	25	4750	34.35	0.251	0.0249	5.11	1874.789915	3.25366306	1025.715575	993.3938854	6.83088198	6.86688993	-0.24290615	-0.52437057	0.32898396	0.185	27.7	8.49	0.184	27.7	8.48	40.000	457.390	7.821	46.820	523.866	9.155	-0.060	-0.564	-0.012	83.2	72.4	(10.8)
61904037	SSS 15mph	04/18/19, 09:48:24 AM	SSS 15MPH, 1 bag,warm start, using ANL ABS bypass, BAGS OFF	ok, stopped test after 4 full SOC swings	20	4750	34.35	0.251	0.0249	4.06	395.8004378	82.63154315	244.9308152	134.112	1.32536393	1.34892313	0.60565655	-1.74651929	0.03644943				0.056	72.2	3.26	188.000	691.009	46.336	126.542	465.566	31.189	-5.690	-20.609	-1.402	77.1	40.3	(36.8)
61904038	SSS 75mph	04/18/19, 10:12:08 AM	SSS 75MPH, 1 bag,warm start, using ANL ABS bypass, BAGS OFF	ok, returbn fan went into alarm and shut down	33	4750	34.35	0.251	0.0249	12.51	16381.99832	13.54998793	761.420799	670.56	18.51073296	18.52745029	-0.05406453	-0.09023007	0.06634411				0.506	24.7	9.51	-156.000	-936.907	-12.466	89.887	537.349	7.183	-1.600	-9.436	-0.128	22.1	50.5	28.4
Day 5 - 72F Testing / Performance / Tier III LO																																					
61904039	WOTS following 55mph warmup	04/19/19, 08:00:53 AM	WOTSx5 after 55mph warmup for 10 minutes, 2 bag,warm start, using ANL ABS bypass, BAGS OFF	ok, fuel scale signals were saturated	26	4750	34.35	0.251	0.0249	9.20	8805.655921	7.43026843	528.2818992	491.744	8.80562783	8.76733086	0.25531214	0.43681456	0.07539689				0.280	32.8	7.16	-3.000	-17.089	-0.326	87.341	523.898	9.497	-0.130	-1.008	-0.014	77.1	77.0	(0.2)
61904040	Passing Maneuvers 0%	04/19/19, 08:33:22 AM	Tip-ins, 0% grade, 1 bag, warm start, using ANL ABS bypass, BAGS OFF	ok	23	4750	34.35	0.251	0.0249	3.35	18673.59864	20.1882153	1343.223494	1117.6	5.24224868	5.38448593	-0.66443245	-2.64161257	0.45758078				0.172	19.5	12.09	-120.000	-1735.072	-35.819	42.000	615.360	12.537	-4.833	-70.969	-1.443	63.6	77.5	13.8
61904041	Passing Maneuvers 3%	04/19/19, 08:45:37 AM	Tip-ins, 3% grade, 1 bag, warm start, using ANL ABS bypass, BAGS OFF	ok	23	4750	34.35	0.251	0.0249	3.36	18684.19268	17.4966562	1313.14263	1117.6	5.38129823	5.38453438	1.69349543	-0.06010086	0.45757666				0.237	14.2	16.59	121.000	1773.111	36.029	42.363	620.013	12.614	-4.323	-63.219	-1.287	80.1	51.2	(28.9)
61904042	Passing Maneuvers 6%	04/19/19, 09:04:08 AM	Tip-ins, 6% grade, 1 bag, warm start, using ANL ABS bypass, BAGS OFF	ok, drove at 55 MPH to cool engine after cycle	24	4750	34.35	0.251	0.0249	3.44	18678.79676	35.54592874	1514.8613	1117.6	5.7743401	5.38452609	6.24239628	7.23952303	0.45757737				0.303	11.4	20.72	-83.853	-1153.066	-24.397	43.765	640.522	12.733	-4.979	-72.915	-1.449	52.4	60.4	8.0
61904043	25% grade test	04/19/19, 10:00:44 AM	25% grade accel from stop, 1 bag, warm start, using ANL ABS bypass, BAGS OFF	ok, ended 25% after battery deplete and vehicle decelerating, drove 60 MPH at 0% grade to recharge, stabilize and cool powertrain	27	4750	34.35	0.251	0.0249	5.46	0	Inf	699.6876143	0	5.46974196	0	NaN	Inf	NaN				0.414	13.2	17.84	-6.000	-51.248	-1.098	65.671	563.608	12.021	-6.086	-42.526	-1.114	73.6	67.7	(5.9)
61904044	SSS 15, 30, 45, 60, 75 3% grade	04/19/19, 10:53:51 AM	SSS 15, 30, 45, 60 and 75 MPH @3% grade until SOC swing 1 bag, warm start, using ANL ABS bypass, BAGS OFF	ok, 60 MPH SS did not stabilize battery current will need to run	25	4750	34.35	0.251	0.0249	5.73	656.3789247	397.2199219	666.8315817	134.112	4.62463114	0.83211203	58.81148359	455.7702516	0.05908758				0.323	17.7	13.26	-96.252	-572.407	-16.796	92.409	554.209	16.126	-6.440	-38.682	-1.124	50.8	63.6	12.8
61904045	SSS 60 & 75mph 3% grade	04/19/19, 11:12:54 AM	SSS 60 and 75 MPH @3% grade until SOC stabilized 1 bag, warm start, using ANL ABS bypass, BAGS OFF	ok, powertrain tries to use pack as efficiently as possible at grade. when it transitions from depleting to charging and you attempt to maintain speed the powertrain reacts the opposite way and you end up chasing the target speed	26	4750	34.35	0.251	0.0249	8.66	0	Inf	802.4306302	0	10.7186976	0	NaN	Inf	NaN				0.517	16.7	14.05	129.783	898.044	14.983	80.436	564.800	9.286	-3.898	-26.921	-0.450	74.1	46.9	(27.2)
61904046	55mph warmup	04/19/19, 12:45:34 PM	SSS 55 MPH warmup for 5 minutes 1 bag, warm start, using ANL ABS bypass, BAGS OFF	ok	26	4750	34.35	0.251	0.0249	4.60	17564.62844	15.2583038	566.7757935	491.744	4.72436132	4.71548605	0.10524347	0.18821533	0.14018269				0.153	30.0	7.84	-175.000	-2103.569	-38.036	44.769	535.530	9.731	-0.140	-1.527	-0.030	47.0	76.9	30.0
61904047	SSS 15, 30, 45, 60, 75 6% grade	04/19/19, 01:08:16 PM	SSS 15_13_45_60_75 at 6% grade, High SOC start, 1 bag, warm start, using ANL ABS bypass, BAGS OFF	ok	23	4750	34.35	0.251	0.0249	4.55	1069.284642	15.8578881	776.8966545	670.56	5.15412688	5.10873163	0.73304192	0.88858169	0.24060514				0.381	11.9	19.69	194.000	1811.608	42.652	61.984	579.442	13.627	-4.563	-42.652	-1.003	94.1	56.6	(37.5)
61904048	UDDS Prep	04/19/19, 01:26:53 PM	UDDS prep for hot testing with HVAC set to AUTO 72°F, 1 bag, warm start, using ANL ABS bypass,	ok	21	4750	34.35	0.251	0.0249	7.41	2047.230242	2.00978104	5574.976899	5465.13956	7.13694149	7.04125418	1.91676713	1.35895266	0.64773995	0.224	33.1	7.11	0.224	33.0	7.12	16.160	36.244	2.182	234.532	615.076	31.662	-6.203	-16.340	-0.837	56.0	43.8	(12.2)

Test ID [#]	Cycle	Test Time	Start Comments	End Comments	Test Cell Temp [C]	Test weight [lb]	Dyno Target A:	Dyno Target B:	Dyno Target C:	Cycle Distance [mi]	APCtime	ASCR	ASC_d	ASC_t	CE_d	CE_t	EER	ER	IWR	Cycle Fuel Consumed [gal] (Emiss Bag)	Cycle Fuel economy [mpg] (Emiss Bag)	Fuel Consumption Bag [l/100km]	Fuel used modal [gal]	Fuel Economy Modal [mpg]	Fuel Consumption Modal [l/100km]	HV Batt Δ [Wh]	HV Batt Average Power P1 [W]	HV Batt Energy consumption [Wh/mi]	DCDC Out Δ WP2 [Wh]	DCDC Out Average Power P2 [W]	DCDC Out Δ WP2 [Wh/mi]	12V Neg Out Δ WP2 [Wh]	12V Neg Out Average Power P2 [W]	12V Neg Out Δ WP2 [Wh/mi]	SOC init	SOC end	Delta SOC
Day 6 - 95F with solar/ Standard Cycles / Tier III LO																																					
61904049	UDDS x2	04/23/19, 07:47:48 AM	UDDSx2, 2 bag, cold start in HOT (soaked) test cell @95°F, with solar load 850W/m^2, solar load on 30 minute soak prior to first test. HVAC on AUTO 72°F (rear OFF)	ok	36	4750	34.35	0.251	0.0249	3.58	2704.001835	-0.01628924	2048.580561	2048.914314	3.6607199	3.67344536	0.05657715	-0.34641763	0.58535638	0.159	22.4	10.48	0.159	22.5	10.45	-183.000	-1303.971	-51.167	90.370	644.238	25.267	2.314	16.812	0.647	45.3	76.7	31.4
61904049	UDDS x2	04/23/19, 07:47:48 AM	UDDSx2, 2 bag, cold start in HOT (soaked) test cell @95°F, with solar load 850W/m^2, solar load on 30 minute soak prior to first test. HVAC on AUTO 72°F (rear OFF)	ok	34	4750	34.35	0.251	0.0249	3.85	1643.949537	1.17205406	3456.386528	3416.345116	3.34981611	3.36815765	-0.24177612	-0.54455697	0.71575758	0.115	33.5	7.03	0.115	33.5	7.02	137.000	577.321	35.601	132.950	550.775	34.549	-2.685	-11.147	-0.698	76.7	45.5	(31.2)
61904049	UDDSx2 1+2	04/23/19, 07:47:48 AM	UDDSx2, 2 bag, cold start in HOT (soaked) test cell @95°F, with solar load 850W/m^2, solar load on 30 minute soak prior to first test. HVAC on AUTO 72°F (rear OFF)	ok	35					7.42										0.274	27.06	8.69	0.274	27.13	8.67	-46.000	-363.325	-6.196	223.320	597.507	30.1	-0.371	2.832	0.0			0.2
61904049	UDDS x2	04/23/19, 07:47:48 AM	UDDSx2, 2 bag, cold start in HOT (soaked) test cell @95°F, with solar load 850W/m^2, solar load on 30 minute soak prior to first test. HVAC on AUTO 72°F (rear OFF)	ok	37	4750	34.35	0.251	0.0249	3.59	2702.62483	-0.31512112	2042.440376	2048.896883	3.66920535	3.67340422	0.02214597	-0.1143046	0.58535597	0.138	26.1	9.02	0.136	26.3	8.93	-128.000	-908.230	-35.693	90.540	645.424	25.247	-6.836	-48.573	-1.906	45.4	68.1	22.7
61904049	UDDS x2	04/23/19, 07:47:48 AM	UDDSx2, 2 bag, cold start in HOT (soaked) test cell @95°F, with solar load 850W/m^2, solar load on 30 minute soak prior to first test. HVAC on AUTO 72°F (rear OFF)	ok	34	4750	34.35	0.251	0.0249	3.87	1643.721093	1.06577379	3452.745803	3416.335396	3.37609409	3.36811159	-0.13917222	0.23700225	0.71576387	0.123	31.6	7.44	0.122	31.8	7.40	75.000	307.208	19.358	135.500	561.639	34.973	-1.861	-7.819	-0.480	68.1	47.9	(20.2)
61904049	UDDSx2 3+4	04/23/19, 07:47:48 AM	UDDSx2, 2 bag, cold start in HOT (soaked) test cell @95°F, with solar load 850W/m^2, solar load on 30 minute soak prior to first test. HVAC on AUTO 72°F (rear OFF)	ok	36					7.46										0.260	28.68	8.20	0.258	28.91	8.14	-53.000	-300.511	-7.104	226.040	603.531	30.3	-8.696	-28.196	-1.2			2.5
61904050	SC03x3	04/23/19, 09:06:02 AM	SC03x3, 3 bag, hot start in HOT (soaked) test cell @95°F, with solar load 850W/m^2, HVAC on AUTO 72°F (rear OFF), HVAC control per cycle: AUTO-AUTO-OFF	ok	37	4750	34.35	0.251	0.0249	3.59	2640.703002	0.06793462	2533.252805	2531.533017	3.74642783	3.72313577	0.23220827	0.62560343	0.68856614	0.137	26.2	8.96	0.136	26.5	8.89	64.000	389.537	17.810	117.760	706.748	32.770	-5.644	-33.812	-1.571	47.8	32.3	(15.5)
61904050	SC03x3	04/23/19, 09:06:02 AM	SC03x3, 3 bag, hot start in HOT (soaked) test cell @95°F, with solar load 850W/m^2, HVAC on AUTO 72°F (rear OFF), HVAC control per cycle: AUTO-AUTO-OFF	ok	36	4750	34.35	0.251	0.0249	3.59	2631.322972	-0.04429289	2530.388903	2531.510182	3.71469301	3.72311712	-0.49726745	-0.22626478	0.68856201	0.159	22.5	10.45	0.159	22.6	10.40	-189.000	-1128.528	-52.659	117.720	703.530	32.799	-6.264	-37.364	-1.745	32.1	66.6	34.5
61904050	SC03x3	04/23/19, 09:06:02 AM	SC03x3, 3 bag, hot start in HOT (soaked) test cell @95°F, with solar load 850W/m^2, HVAC on AUTO 72°F (rear OFF), HVAC control per cycle: AUTO-AUTO-OFF	ok	36	4750	34.35	0.251	0.0249	3.57	2636.01533	1.76419884	2576.119	2531.459029	3.75716979	3.72305195	1.21818556	0.9163944	0.68855606	0.136	26.3	8.96	0.135	26.4	8.91	-49.000	-281.074	-13.732	69.912	419.411	19.593	0.427	2.685	0.120	66.5	72.1	5.7
61904051	HWYx2	04/23/19, 10:13:27 AM	HWYx2, 2 bag, hot start in HOT (soaked) test cell @95°F, with solar load 850W/m^2, HVAC on AUTO 72°F (rear OFF)	ok	39	4750	34.35	0.251	0.0249	10.27	2184.007509	2.70841194	1342.202034	1306.808283	9.24775517	9.16649699	0.76786306	0.88646926	0.27652834	0.333	30.8	7.63	0.334	30.8	7.64	-90.000	-423.072	-8.765	166.593	784.742	16.224	-10.986	-51.846	-1.070	70.0	86.2	16.2
61904051	HWYx2	04/23/19, 10:13:27 AM	HWYx2, 2 bag, hot start in HOT (soaked) test cell @95°F, with solar load 850W/m^2, HVAC on AUTO 72°F (rear OFF)	ok	38	4750	34.35	0.251	0.0249	10.28	2184.243757	3.86284875	1357.286074	1306.80613	9.23958158	9.16648436	0.59757932	0.79744007	0.27652816	0.303	33.9	6.94	0.303	33.9	6.95	-32.000	-146.699	-3.114	127.800	600.954	12.436	-1.780	-8.194	-0.173	85.2	89.2	4.1
61904052	US06x3	04/23/19, 10:57:49 AM	US06x3, 3 bag, hot start in HOT (soaked) test cell @95°F, with solar load 850W/m^2, HVAC on AUTO 72°F (rear OFF), modes for cycles: NORMAL/NORMAL/SPORT	ok	39	4750	34.35	0.251	0.0249	7.93	10606.43193	-1.53494683	3543.656631	3598.897798	11.5081351	11.78875563	-1.39606644	-2.38040837	0.48243557	0.356	22.3	10.56	0.355	22.3	10.54	26.000	169.111	3.281	122.669	737.555	15.478	-5.720	-34.947	-0.722	87.1	76.9	(10.2)
61904052	US06x3	04/23/19, 10:57:49 AM	US06x3, 3 bag, hot start in HOT (soaked) test cell @95°F, with solar load 850W/m^2, HVAC on AUTO 72°F (rear OFF), modes for cycles: NORMAL/NORMAL/SPORT	ok	39	4750	34.35	0.251	0.0249	8.00	10605.19225	1.09790204	3638.393607	3598.881415	11.74803696	11.7887186	-0.23884239	-0.34508959	0.48243411	0.364	22.0	10.69	0.361	22.1	10.63	-34.000	-198.785	-4.251	108.789	654.690	13.601	-0.500	-3.239	-0.063	77.2	76.7	(0.4)
61904052	US06x3	04/23/19, 10:57:49 AM	US06x3, 3 bag, hot start in HOT (soaked) test cell @95°F, with solar load 850W/m^2, HVAC on AUTO 72°F (rear OFF), modes for cycles: NORMAL/NORMAL/SPORT	ok	39	4750	34.35	0.251	0.0249	8.00	10605.85205	1.65757579	3658.406872	3598.754784	11.74742674	11.78857698	-0.21158653	-0.34906875	0.48241195	0.360	22.2	10.60	0.360	22.2	10.60	-39.000	-233.902	-4.877	105.449	633.834	13.188	-0.520	-3.225	-0.065	77.2	77.4	0.3
61904053	SSS 55mph warmup	04/23/19, 01:04:31 PM	55MPS SS 10 minute warmup to stabilize HVAC, 1 bag, hot start in HOT (soaked) test cell @95°F, with solar load 850W/m^2, HVAC on AUTO 72°F (rear OFF),	ok	39	4750	34.35	0.251	0.0249	9.19	8808.58236	11.84444232	549.9883344	491.744	8.78284604	8.76733012	0.10267811	0.17697436	0.0753969				0.287	32.0	7.34	-67.000	-401.840	-7.293	107.134	643.164	11.661	-0.250	-1.736	-0.027	64.6	76.9	12.3
61904054	SSS 15mph warmup	04/23/19, 01:21:54 PM	15MPS SS 20 minute hold, 1 bag, hot start in HOT (soaked) test cell @95°F, with solar load 850W/m^2, HVAC on AUTO 72°F (rear OFF),	ok	32	4750	34.35	0.251	0.0249	2.40	639.8976784	79.56586108	240.8193676	134.112	0.81431123	0.85233231	2.30020991	-4.4608283	0.05768582				0.058	41.2	5.71	18.000	153.905	7.508	96.876	568.742	40.409	-6.960	-32.163	-2.903	40.9	37.1	(3.9)
61904055	SSS 30mph warmup	04/23/19, 01:37:05 PM	30MPH SS 10 minute hold, 1 bag, hot start in HOT (soaked) test cell @95°F, with solar load 850W/m^2, HVAC on AUTO 72°F (rear OFF),	ok	37	4750	34.35	0.251	0.0249	5.02	2621.555288	53.66066699	412.1547874	268.224	2.51137938	2.49913592	0.21340743	0.48990779	0.07869517				0.113	44.3	5.31	-48.000	-286.374	-9.559	78.624	470.685	15.658	-1.040	-6.138	-0.207	26.5	32.9	6.4
61904056	SSS 45mph warmup	04/23/19, 01:54:06 PM	45MPH SS 10 minute hold, 1 bag, hot start in HOT (soaked) test cell @95°F, with solar load 850W/m^2, HVAC on AUTO 72°F (rear OFF),	ok	38	4750	34.35	0.251	0.0249	7.51	5896.742021	22.32828799	492.1707408	402.336	5.60813378	5.60285509	0.10095531	0.09421436	0.07897891				0.196	38.2	6.15	-15.000	-90.675	-1.997	89.135	533.958	11.868	-0.370	-2.146	-0.049	33.9	32.7	(1.2)
61904057	SSS 60mph warmup	04/23/19, 02:10:17 PM	60MPH SS 10 minute hold, 1 bag, hot start in HOT (soaked) test cell @95°F, with solar load 850W/m^2, HVAC on AUTO 72°F (rear OFF),	ok, 45 MPH SStest was not changed but ran as a 60 MPH SS	40	4750	34.35	0.251	0.0249	10.03	5896.742021	37.22612318	552.1100949	402.336	10.76441576	5.60285359	30.53070715	92.12380959	0.07897893				0.321	31.3	7.52	-116.000	-692.022	-11.571	94.674	568.497	9.444	-1.050	-6.431	-0.105	29.1	50.8	21.7
61904058	SSS 75mph warmup	04/23/19, 02:27:50 PM	75MPH SS 10 minute hold, 1 bag, hot start in HOT (soaked) test cell @95°F, with solar load 850W/m^2, HVAC on AUTO 72°F (rear OFF),	ok	40	4750	34.35	0.251	0.0249	12.51	16381.99832	16.95252353	784.2368418	670.56	18.47357005	18.52745281	-0.18654248	-0.29082659	0.0663441				0.503	24.9	9.46	-145.502	-869.794	-11.635	106.414	637.517	8.509	-10.470	-62.762	-0.837	24.2	50.4	26.2
Day 7 - 20F / Standard Cycles / Tier III LO																																					
61904059	Idle Warm up	04/24/19, 09:06:07 AM	Idle warmup test, 1 bag, BAGS off	ok	22	4750	34.35	0.251	0.0249	0.00	0	NaN	0	0	0	0	NaN	NaN	NaN							-16.000	-42.408	-1024983.985	144.534	371.997	##########	-1.255	-3.224	-80367.008	0.0	77.0	77.0
61904060	HWYx2	04/24/19, 09:45:16 AM	HWYx2, 2 bag with 2X Vehicle On coastdown to verify vehicle losses have not changed	ok, Vehicle On coastdown within spec of 2# or 2%	26	4750	34.35	0.251	0.0249	10.28	2184.314469	4.21212824	1361.86723	1306.822203	9.20712094	9.16652531	0.20048081	0.44286822	0.27653074	0.314	32.7	7.19	0.314	32.8	7.18	-84.000	-398.778	-8.170	116.492	547.988	11.330	-4.697	-22.078	-0.457	77.5	93.0	15.5
61904060	HWYx2	04/24/19, 09:45:16 AM	HWYx2, 2 bag with 2X Vehicle On coastdown to verify vehicle losses have not changed	ok, Vehicle On coastdown within spec of 2# or 2%	25	4750	34.35	0.251	0.0249	10.28	2184.656468	2.28131451	1336.625448	1306.812935	9.17761184	9.16650268	-0.08764452	0.12119303	0.27652928	0.288	35.6	6.60	0.288	35.7	6.59	-25.000	-133.525	-2.432	107.700	507.316	10.479	-0.120	-0.646	-0.012	67.7	86.1	18.4
61904061	UDDS prep	04/24/19, 02:30:03 PM	UDDS prep, 1 bag, cold test cell 20°F, HVAC on AUTO 72°F	ok, switched AUTO heated seats to OFF	-7	4750	34.35	0.251	0.0249	7.40	2048.026674	1.14609956	5527.84534	5465.208608	7.02268386	7.04137014	0.38787002	-0.26537845	0.64774165	0.281	26.3	8.94	0.281	26.4	8.93	32.000	79.759	4.323	285.902	749.847	38.623	-2.479	-6.550	-0.335	76.0	67.4	(8.6)
61904063	UDDS x2	04/25/19, 08:51:00 AM	UDDSx2, 4 bag, warm start in cold test cell (20°F), HVAC AUTO 72°F, Rear HVAC OFF,	ok	-6	4750	34.35	0.251	0.0249	3.60	2702.246092	1.33625314	2076.274573	2048.896134	3.68989202	3.67340232	0.11079053	0.44889441	0.58535669	0.136	26.5	8.89	0.134	26.9	8.74	4.403	31.288	1.222	117.259	836.401	32.544	-4.210	-30.013	-1.168	86.1	81.9	(4.1)
61904063	UDDS x2	04/25/19, 08:51:00 AM	UDDSx2, 4 bag, warm start in cold test cell (20°F), HVAC AUTO 72°F, Rear HVAC OFF,	ok	-7	4750	34.35	0.251	0.0249	3.89	1643.73009	2.43361042	3499.498506	3416.35767	3.4023762	3.36814514	0.15466966	1.0163176	0.71576085	0.115	33.8	6.97	0.115	33.8	6.96	171.000	710.587	43.924	156.569	648.743	40.217	-2.655	-11.021	-0.682	82.0	40.3	(41.7)
61904063	UDDSx2 1+2	04/25/19, 08:51:00 AM	UDDSx2, 4 bag, warm start in cold test cell (20°F), HVAC AUTO 72°F, Rear HVAC OFF,	ok	-6					7.50										0.251	29.81	7.89	0.249	30.09	7.82	175.403	370.937	23.399	273.828	742.572	36.5	-6.865	-20.517	-0.9			(45.8)
61904063	UDDS x2	04/25/19, 08:51:00 AM	UDDSx2, 4 bag, warm start in cold test cell (20°F), HVAC AUTO 72°F, Rear HVAC OFF,	ok	-6	4750	34.35	0.251	0.0249	3.60	2701.999113	1.44165462	2078.411731	2048.874044	3.7116515	3.6733806	0.67542185	1.04184425	0.58535001	0.154	23.4	10.05	0.153	23.6	9.95	-210.000	-1491.651	-58.270	108.589	774.391	30.131	-3.585	-25.422	-0.995	40.2	76.9	36.7
61904063	UDDS x2	04/25/19, 08:51:00 AM	UDDSx2, 4 bag, warm start in cold test cell (20°F), HVAC AUTO 72°F, Rear HVAC OFF,	ok	-7	4750	34.35	0.251	0.0249	3.89	1643.363549	2.92539776	3516.242749	3416.302317	3.3849459	3.36806807	-0.27145032	0.50111307	0.71576434	0.116	33.6	7.00	0.116	33.4	7.04	109.000	443.648	28.022	145.621	603.176	37.437	-1.440	-5.979	-0.370	76.9	49.1	(27.8)
61904063	UDDSx2 3+4	04/25/19, 08:51:00 AM	UDDSx2, 4 bag, warm start in cold test cell (20°F), HVAC AUTO 72°F, Rear HVAC OFF,	ok	-6					7.49										0.270	27.79	8.46	0.269	27.87	8.44	-101.000	-524.002	-13.478	254.210	688.783	33.9	-5.025	-15.701	-0.7			8.9
61904064	HWYx3	04/25/19, 10:07:50 AM	HWYx3, 3 bag, warm start in cold test cell (20°F), HVAC AUTO 72°F, Rear HVAC OFF,	ok	-4	4750	34.35	0.251	0.0249	10.27	2184.256667	-1.06703443	1292.867669	1306.811801	9.17231957	9.16649959	-0.04973083	0.06349183	0.276529	0.366	28.1	8.38	0.365	28.1	8.37	-244.000	-1143.164	-23.762	160.708	756.123	15.651	-4.220	-19.832	-0.411	49.8	90.2	40.4
61904064	HWYx3	04/25/19, 10:07:50 AM	HWYx3, 3 bag, warm start in cold test cell (20°F), HVAC AUTO 72°F, Rear HVAC OFF,	ok	-5	4750	34.35	0.251	0.0249	10.27	2180.878761	5.24748198	1375.378067	1306.803775	9.23134271	9.16646946	0.61608709	0.70772349	0.27652821	0.326	31.5	7.46	0.325	31.6	7.45	-25.264	-137.903	-2.461	130.559	613.699	12.718	-0.980	-4.566	-0.095	89.7	89.2	(0.6)
61904064	HWYx3	04/25/19, 10:07:50 AM	HWYx3, 3 bag, warm start in cold test cell (20°F), HVAC AUTO 72°F, Rear HVAC OFF,	ok	-5	4750	34.35	0.251	0.0249	10.28	2220.725388	6.64308849	1393.617913	1306.805657	9.23839659	9.17057776	0.63530289	0.73952621	0.27640467	0.328	31.3	7.50	0.326	31.5	7.46	-29.000	-136.853	-2.822	130.149	610.443	12.663	-0.510	-2.446	-0.050	88.8	91.2	2.4
61904065	US06x2	04/25/19, 11:04:38 AM	US06x2, 4 bag, warm start in cold test cell (20°F), HVAC AUTO 72°F, Rear HVAC OFF,	ok	-5	4750	34.35	0.251	0.0249	1.78	6269.657148	0.29074096	2466.681151	2459.530289	3.61494535	3.60447607	-0.09694676	0.29045218	0.81048679	0.115	15.4	15.25	0.115	15.4	15.23	-36.000	-527.723	-20.236	53.280	823.578	29.949	-1.548	-23.875	-0.870	89.6	86.1	4.3
61904065	US06x2	04/25/19, 11:04:38 AM	US06x2, 4 bag, warm start in cold test cell (20°F), HVAC AUTO 72°F, Rear HVAC OFF,	ok	0	4750	34.35	0.251	0.0249	6.22	13331.44232	6.12714636	1208.942483	1139.145378	8.17555341	8.18399176	0.05603441	-0.10310802	0.33789186	0.267	23.3	10.09	0.266	23.4	10.04	17.000	157.073	2.731	79.407	780.441	12.756	-1.940	-18.919	-0.312	76.4	68.6	(7.8)
61904065	US06x2 1+2	04/25/19, 11:04:38 AM	US06x2, 4 bag, warm start in cold test cell (20°F), HVAC AUTO 72°F, Rear HVAC OFF,	ok	-2					8.00										0.382	20.94	11.23	0.381	21.01	11.20	-19.000	-185.325	-2.374	132.687	802.009	16.6	-3.488	-21.397	-0.4			(3.5)
61904065	US06x2	04/25/19, 11:04:38 AM	US06x2, 4 bag, warm start in cold test cell (20°F), HVAC AUTO 72°F, Rear HVAC OFF,	ok	-6	4750	34.35	0.251	0.0249	1.77	6241.944124	1.69718543	2501.259189	2459.516631	3.6447282	3.60445776	1.31285604	1.11723998	0.81048815	0.118	15.0	15.64	0.117	15.2	15.50	-93.000	-1426.171	-52.590	43.838	674.856	24.790	-0.428	-6.646	-0.242	83.2	87.5	14.1
61904065	US06x2	04/25/19, 11:04:38 AM	US06x2, 4 bag, warm start in cold test cell (20°F), HVAC AUTO 72°F, Rear HVAC OFF,	ok	-1	4750	34.35	0.251	0.0249	6.22	13337.77885	5.49653009	1201.732647	1139.120544	8.18507859	8.18393307	0.22126869	0.01399712	0.33788427	0.259	24.1	9.78	0.257	24.2	9.71	27.000	272.591	4.339	65.752	647.603	10.568	-0.590	-5.757	-0.095	78.2	68.4	(9.8)
61904065	US06x2 3+4	04/25/19, 11:04:38 AM	US06x2, 4 bag, warm start in cold test cell (20°F), HVAC AUTO 72°F, Rear HVAC OFF,	ok	-3					7.99										0.376	21.24	11.08	0.373	21.40	10.99	-66.000	-576.790	-8.260	109.589	661.229	13.7	-1.018	-6.202	-0.1			4.3
61904066	SSS 55mph	04/25/19, 12:46:42 PM	55MPH SSS, 10 minute hold to warm up and stabilize temps for SSS tests, warm start in cold test cell (20°F), HVAC AUTO 72°F, Rear HVAC OFF, Bags OFF	ok	-3	4750	34.35	0.251	0.0249	9.18	8808.58236	10.08425528	541.3327203	491.744	8.77731564	8.76733269	0.06522054	0.11386523	0.07539688				0.315	29.2	8.06	-9.000	-52.700	-0.980	131.912	789.275	14.362	-0.300	-1.587	-0.033	77.0	77.0	0.0
61904067	SSS 15mph	04/25/19, 01:02:01 PM	15MPH SSS, 20 minute hold, warm start in cold test cell (20°F), HVAC AUTO 72°F, Rear HVAC OFF, Bags OFF	ok	-9	0	0	0	0	4.98	0	191.3464617	390.7305667	134.112	0	0	NaN	NaN	NaN				0.129	38.5	6.11	-60.000	-179.447	-12.047	201.183	603.456	40.395	-0.260	-0.811	-0.052	65.4	72.0	6.5
61904068	SSS 30mph	04/25/19, 01:28:04 PM	30MPH SSS, 10 minute hold, warm start in cold test cell (20°F), HVAC AUTO 72°F, Rear HVAC OFF, Bags OFF	ok	-6	4750	34.35	0.251	0.0249	5.02	2621.555288	43.30496914	384.3783204	268.224	2.51527206	2.49913647	0.35285822	0.6456467	0.07869516				0.112	44.8	5.25	89.000	533.648	17.722	94.648	567.089	18.847	-0.080	-0.477	-0.016	63.9	39.7	(24.1)
61904069	SSS 45mph	04/25/19, 01:42:45 PM	45MPH SSS, 10 minute hold, warm start in cold test cell (20°F), HVAC AUTO 72°F, Rear HVAC OFF, Bags OFF	ok	-6	4750	34.35	0.251	0.0249	7.51	5896.742021	17.60160602	473.1535976	402.336	5.59921346	5.60285602	-0.04311388	-0.06501259	0.07897889				0.228	32.9	7.14	-172.000	-1025.901	-22.904	98.178	588.042	13.074	-0.060	-0.382	-0.008	42.0	63.7	21.7
61904070	SSS 60mph	04/25/19, 01:57:46 PM	60MPH SSS, 10 minute hold, warm start in cold test cell (20°F), HVAC AUTO 72°F, Rear HVAC OFF, Bags OFF	ok	-1	0	0	0	0	10.02	0	3.56371863	555.5654973	536.448	0	0	NaN	NaN	NaN				0.343	29.2	8.06	82.000	487.318	8.181	99.129	594.017	9.890	-0.040	-0.410	-0.004	66.6	50.5	(16.0)
61904071	SSS 75mph	04/25/19, 02:12:23 PM	75MPH SSS, 10 minute hold, warm start in cold test cell (20°F), HVAC AUTO 72°F, Rear HVAC OFF, Bags OFF	ok	1	4750	34.35	0.251	0.0249	12.51	16381.99832	17.36410264	786.9967266	670.56	18.50565944	18.52745012	-0.07418579	-0.11761291	0.06634411				0.535	23.4	10.07	-16.000	-94.229	-1.279	95.752	574.313	7.652	-0.040	-0.421	-0.003	50.9	50.2	(0.6)
61904072	UDDS Prep	04/25/19, 02:39:08 PM	UDDS prep for cold start, warm start in cold test cell (20°F), HVAC AUTO 72°F, Rear HVAC OFF,	ok	-7	4750	34.35	0.251	0.0249	7.51	2049.432136	1.93701262	5571.196182	5465.332011	7.13183903	7.0415654	0.48688602	1.28201085	0.64774465	0.229	32.7	7.19	0.228	32.9	7.15	108.000	278.074	14.381	250.976	657.140	33.420	-7.050	-18.398	-0.939	72.6	48.0	(24.6)
Day 8 - 20F / Standard Cycles / Tier III LO																																					
61904073	UDDS x2	04/26/19, 02:07:32 PM	UDDSx2, 4 bag (FTP), cold start in cold test cell (20°F), after force cool for 6 hours, HVAC AUTO 72°F, Rear HVAC OFF,	ok	-6	4750	34.35	0.251	0.0249	3.58	2702.822616	1.76637904	2085.074728	2048.883676	3.68136433	3.67340246	0.63935931	0.21674379	0.58535118	0.214	16.7	14.08	0.215	16.6	14.16	-234.000	-1672.815	-65.440	123.614	881.244	34.570	-5.598	-39.923	-1.566	49.1	84.8	35.7
61904073	UDDS x2	04/26/19, 02:07:32 PM	UDDSx2, 4 bag (FTP), cold start in cold test cell (20°F), after force cool for 6 hours, HVAC AUTO 72°F, Rear HVAC OFF,	ok	-7	4750	34.35	0.251	0.0249	3.85	1643.475301	1.95549417	3483.123949	3416.318048	3.36774358	3.36810466	0.33907125	-0.01072064	0.71576066	0.161	23.9	9.82	0.159	24.2	9.70	-16.000	-66.753	-4.160	188.106	779.812	48.904	-1.070	-4.481	-0.278	84.8	77.5	(7.2)
61904073	UDDSx2 1+2	04/26/19, 02:07:32 PM	UDDSx2, 4 bag (FTP), cold start in cold test cell (20°F), after force cool for 6 hours, HVAC AUTO 72°F, Rear HVAC OFF,	ok	-6					7.42										0.375	19.81	11.87	0.374	19.85	11.85	-250.000	-869.784	-33.683	311.720	830.528	42.0	-6.668	-22.202	-0.9			28.4
61904073	UDDS x2	04/26/19, 02:07:32 PM	UDDSx2, 4 bag (FTP), cold start in cold test cell (20°F), after force cool for 6 hours, HVAC AUTO 72°F, Rear HVAC OFF,	ok	-6	4750	34.35	0.251	0.0249	3.58	2701.856927	1.06229847	2070.625123	2048.860113	3.68593051	3.67336902	0.65406482	0.34196115	0.5853464	0.137	26.0	9.03	0.136	26.2	8.96	-19.000	-137.968	-5.308	119.394	851.677	33.353	-3.264	-23.266	-0.912	77.5	77.5	0.0
61904073	UDDS x2	04/26/19, 02:07:32 PM	UDDSx2, 4 bag (FTP), cold start in cold test cell (20°F), after force cool for 6 hours, HVAC AUTO 72°F, Rear HVAC OFF,	ok	-7	4750	34.35	0.251	0.0249	3.85	1643.254593	2.54586034	3503.263522	3416.289561	3.37771944	3.36804488	0.53799189	0.28724546	0.71576543	0.123	31.3	7.52	0.122	31.6	7.44	67.000	274.312	17.402	160.152	663.075	41.596	-1.020	-4.184	-0.265	77.5	56.3	(21.2)
61904073	UDDSx2 3+4	04/26/19, 02:07:32 PM	UDDSx2, 4 bag (FTP), cold start in cold test cell (20°F), after force cool for 6 hours, HVAC AUTO 72°F, Rear HVAC OFF,	ok	-6					7.43										0.261	28.51	8.25	0.258	28.78	8.17	48.000	68.172	6.460	279.546	757.376	37.6	-4.284	-13.725	-0.6			(21.2)
Day 9 - 72F Testing / Standard Cycles with hood up and CSF/ Tier III LO																																					
61904074	LA92x2	04/29/19, 12:46:39 PM	LA92x2, 2 bag, cold start (prep) and hot start	ok	24	4750	34.35	0.251	0.0249	9.80	4148.873368	2.57895605	7468.845745	7281.070146	12.21580341	12.10664607	1.02240009	0.90163151	0.63597845	0.434	22.6	10.42	0.432	22.7	10.37	-181.000	-450.740	-18.463	210.220	529.078	21.444	-2.320	-5.866	-0.237	56.7	80.8	24.1
61904074	LA92x2	04/29/19, 12:46:39 PM	LA92x2, 2 bag, cold start (prep) and hot start	ok	21	4750	34.35	0.251	0.0249	9.85	4091.060063	0.54966075	7320.973769	7280.953227	12.13426944	12.10641637	-0.10767825	0.23006866	0.6359806	0.374	26.3	8.93	0.369	26.7	8.82	-41.000	-107.011	-4.163	203.151	504.125	20.626	0.369	0.907	0.037	80.5	78.5	(2.0)
61904075	JC08x2	04/29/19, 01:50:29 PM	JC08x2, 2 bag, prep and hot start	ok	23	4750	34.35	0.251	0.0249	5.10	1488.415383	1.69281022	3722.717128	3660.747618	4.65316726	4.62751642	-0.08359533	0.55431131	0.67490945	0.148	34.5	6.82	0.148	34.4	6.84	55.000	163.013	10.779	171.056	511.090	33.524	-7.998	-23.840	-1.568	78.5	62.5	(16.0)
61904076	UDDS x2	04/29/19, 02:49:46 PM	UDDS, 2 bag, prep for cold start CERT style with hood up and fan at 6MPH (5300 CFM)	ok	22	4750	34.35	0.251	0.0249	3.61	2718.091014	2.27689844	2095.56801	2048.916267	3.73859135	3.67338226	1.34486778	1.77517855	0.58536804	0.125	28.9	8.14	0.124	29.2	8.06	-127.000	-907.559	-35.223	82.790	591.911	22.961	-11.347	-81.098	-3.147	67.7	88.1	20.5
61904076	UDDS x2	04/29/19, 02:49:46 PM	UDDS, 2 bag, prep for cold start CERT style with hood up and fan at 6MPH (5300 CFM)	ok	23	4750	34.35	0.251	0.0249	3.90	1658.367278	3.18264189	3525.106933	3416.375922	3.41666817	3.3681117	0.3536602	1.44165259	0.71577452	0.087	44.9	5.24	0.087	45.1	5.22	182.000	751.943	46.646	116.530	482.763	29.866	-0.440	-1.771	-0.113	88.1	48.6	(39.5)
61904076	UDDSx2 1+2	04/29/19, 02:49:46 PM	UDDS, 2 bag, prep for cold start CERT style with hood up and fan at 6MPH (5300 CFM)	ok	23					7.51										0.212	35.48	6.63	0.210	35.73	6.58	55.000	-77.808	7.326	199.320	537.337	26.6	-11.787	-41.434	-1.6			(19.1)
61904077	UDDS x2	04/30/19, 08:10:56 AM	UDDSx2, 4 bag (FTP), cold start, CERT style with hood up and fan at 6MPH (5300 CFM)	ok	21	4750	34.35	0.251	0.0249	3.62	2704.193287	1.04177408	2070.26138	2048.916301	3.73761747	3.6734519	1.05111474	1.74673782	0.58535612	0.154	23.5	10.01	0.155	23.4	10.07	-228.000	-1618.563	-63.065	74.145	528.629	20.509	-1.300	-9.239	-0.360	0.0	88.2	88.2
61904077	UDDS x2	04/30/19, 08:10:56 AM	UDDSx2, 4 bag (FTP), cold start, CERT style with hood up and fan at 6MPH (5300 CFM)	ok	23	4750	34.35	0.251	0.0249	3.89	1644.068345	2.53675968	3503.031843	3416.366827	3.40124878	3.36816598	0.25971447	0.9822199	0.71575994	0.087	44.9	5.24	0.086	45.4	5.18	201.000	837.865	51.702	113.035	468.342	29.075	0.005	0.006	0.001	88.2	44.6	(43.6)
61904077	UDDSx2 1+2	04/30/19, 08:10:56 AM	UDDSx2, 4 bag (FTP), cold start, CERT style with hood up and fan at 6MPH (5300 CFM)	ok	22					7.50										0.240	31.20	7.54	0.240	31.21	7.54	-27.000	-390.349	-3.599	187.180	498.486	24.9	-1.295	-4.616	-0.2			44.6
61904077	UDDS x2	04/30/19, 08:10:56 AM	UDDSx2, 4 bag (FTP), cold start, CERT style with hood up and fan at 6MPH (5300 CFM)	ok	22	4750	34.35	0.251	0.0249	3.60	2702.736554	1.43694115	2078.33468	2048.893289	3.70648015	3.67341313	0.53469366	0.90017168	0.58535305	0.133	27.1	8.66	0.132	27.3	8.62	-159.000	-1130.093	-44.118	76.894	548.383	21.336	-6.415	-45.650	-1.780	44.6	72.4	27.8
61904077	UDDS x2	04/30/19, 08:10:56 AM	UDDSx2, 4 bag (FTP), cold start, CERT style with hood up and fan at 6MPH (5300 CFM)	ok	21	4750	34.35	0.251	0.0249	3.90	1643.825917	2.44964477	3500.036511	3416.348118	3.42629424	3.36811974	0.63550205	1.72721013	0.71576547	0.096	40.5	5.80	0.096	40.7	5.77	114.000	469.956	29.219	115.681	479.402	29.649	0.000	-0.030	0.000	72.4	44.4	(28.0)
61904077	UDDSx2 3+4	04/30/19, 08:10:56 AM	UDDSx2, 4 bag (FTP), cold start, CERT style with hood up and fan at 6MPH (5300 CFM)	ok	22					7.51										0.229	32.77	7.18	0.228	32.94	7.14	-45.000	-330.069	-5.996	192.576	513.892	25.7	-6.415	-22.840	-0.9			(0.1)
61904078	HWYx2	04/30/19, 09:28:17 AM	HWYx2x2, 2 bag, warm start, CERT style with hood up and fan at 6MPH (5300 CFM)	ok, forgot to remove combine phases from host processing list	23	4750	34.35	0.251	0.0249	10.27	2184.61738	3.10111161	1347.352142	1306.826009	9.19960717	9.16652995	0.21804195	0.36084779	0.27653151	0.333	30.8	7.64	0.332	30.9	7.61	-279.000	-1317.511	-27.163	130.442	613.643	12.700	-9.346	-43.922	-0.910	44.8	90.3	45.5
61904078	HWYx2	04/30/19, 09:28:17 AM	HWYx2x2, 2 bag, warm start, CERT style with hood up and fan at 6MPH (5300 CFM)	ok, forgot to remove combine phases from host processing list	22	4750	34.35	0.251	0.0249	10.27	2184.988305	2.57838559	1340.51444	1306.819592	9.16240982	9.16651087	-0.18459773	-0.04473953	0.27653061	0.290	35.4	6.64	0.290	35.5	6.63	-6.000	-34.303	-0.584	120.697	568.411	11.751	-0.207	-1.039	-0.020	90.0	86.0	(4.0)
61904079	Tip Ins- Sport Mode	04/30/19, 10:28:11 AM	SPORT MODE SS tip-ins with extended SS, 0% grade, 1 bag, BAGS OFF	ok	26	4750	34.35	0.251	0.0249	5.02	11480.91325	13.12513949	1163.143634	1028.192	6.44550848	6.53554358	-0.70891486	-1.37762233	0.35024165			#DIV/0!	0.203	24.7	9.51	-8.000	-87.110	-1.593	63.182	621.822	12.579	-10.075	-99.198	-2.006	85.0	78.4	(6.7)
Day 10 - 72F Testing / Performance / Tier III LO																																					
61905001	Constant pedal tip ins 5-100%	05/01/19, 08:57:11 AM	55MPH SS warmup with constant pedal tip ins 5-50%x5%, 60-100%x10%	ok	26	4750	34.35	0.251	0.0249	9.25	8805.655921	11.08629213	546.2601764	491.744	8.91774923	8.76732954	0.96118245	1.71568429	0.07539691	0.280	33.0	7.12	0.283	32.7	7.20	4.000	25.726	0.433	110.263	660.765	11.923	-23.157	-138.826	-2.504	77.0	77.0	(0.0)
61905002	Dyno Accleration Ramps	05/01/19, 01:32:43 PM	55MPH SS warmup for constant pedal acceleration ramps	ok	26	4750	34.35	0.251	0.0249	9.20	8805.655921	10.09595662	541.3902609	491.744	8.80784839	8.7673309	0.26165801	0.46214163	0.07539689				0.276	33.3	7.06	8.000	49.409	0.870	87.161	523.427	9.475	-0.280	-1.843	-0.030	78.6	76.9	(1.7)
61905003	Onroad Cycle	05/02/19, 09:06:06 AM	Onroad cycle for vehicle warmup, robot driver, 1 bag, cold start, bags OFF	ok	25	4750	34.35	0.251	0.0249	31.09	7379.206597	0.30303729	7799.242738	7775.67953	39.72086062	38.93895406	1.7621979	2.00803173	0.3758489				1.203	25.8	9.10	-39.000	-66.452	-1.255	350.118	549.241	11.263	-10.436	-16.334	-0.336	89.7	80.1	(9.6)
61905004	Power Cycles	05/02/19, 09:57:08 AM	Power cycles, mirrored, hot start, 2 bag, bags OFF	ok	25	4750	34.35	0.251	0.0249	7.75	1938.286215	-0.98011094	5168.597241	5219.756647	11.08179935	11.04752371	0.08841412	0.3102564	0.67617631				0.294	26.3	8.93	24.000	84.230	3.097	130.786	554.387	16.877	-7.397	-31.267	-0.954	78.5	68.6	(9.9)
61905005	Min/Max SOC test	05/02/19, 10:35:23 AM	Blank bag max/min SOC swing	ok	23	4750	34.35	0.251	0.0249	17.19	0	Inf	1000.028434	0	11.28853822	0	NaN	Inf	NaN				0.543	31.7	7.42	130.000	296.543	7.560	322.188	679.686	18.738	-4.010	-8.282	-0.233	93.0	52.6	(40.4)
61905006	Engine Mapping 1	05/02/19, 01:26:03 PM	Blank bag engine mapping	ok	21	4750	34.35	0.251	0.0249	7.02	0	Inf	1101.58262	0	3.42387957	0	NaN	Inf	NaN				0.406	17.3	13.62	102.000	267.192	14.528	199.201	521.826	28.372	-0.480	-0.049	-0.068	94.7	74.4	(20.3)
61905007	Engine Mapping 2	05/03/19, 08:30:01 AM	Blank bag engine mapping with 55MPH SS 10 minute warmup	ok	26	4750	34.35	0.251	0.0249	9.20	8805.655921	11.6043639	548.8077632	491.744	8.80827337	8.76732897	0.26548811	0.46701109	0.07539691				0.281	32.8	7.17	-3.000	-16.087	-0.326	87.340	523.937	9.495	-0.200	-1.298	-0.022	77.0	77.0	(0.1)
61905008	Engine Mapping 3	05/03/19, 10:42:36 AM	Blank bag engine mapping	ok	24	4750	34.35	0.251	0.0249	14.91	0	Inf	884.2924772	0	10.58868935	0	NaN	Inf	NaN				1.002	14.9	15.81	-124.000	-219.619	-8.319	316.656	560.906	21.243	-4.838	-8.325	-0.325	74.9	92.4	17.6

Test ID [#]	Cycle	Test Time	Start Comments	End Comments	Test Cell Temp [C]	Test weight [lb]	Dyno Target A:	Dyno Target B:	Dyno Target C:	Cycle Distance [mi]	APCtime	ASCR	ASC_d	ASC_t	CE_d	CE_t	EER	ER	IWR	Cycle Fuel Consumed [gal] (Emiss Bag)	Cycle Fuel economy [mpg] (Emiss Bag)	Fuel Consumption Bag [l/100km]	Fuel used modal [gal]	Fuel Economy Modal [mpg]	Fuel Consumption Modal [l/100km]	HV Batt Δ [Wh]	HV Batt Average Power P1 [W]	HV Batt Energy consumption [Wh/mi]	DCDC Out Δ WP2 [Wh]	DCDC Out Average Power P2 [W]	DCDC Out Δ WP2 [Wh/mi]	12V Neg Out Δ WP2 [Wh]	12V Neg Out Average Power P2 [W]	12V Neg Out Δ WP2 [Wh/mi]	SOC init	SOC end	Delta SOC
Day 11- FUEL SWAP / - 72F Testing / Standard cycles/ Tier II HO																																					
61905009	Octane Adjustment Cycle																																				
61905010	UDDS x2	05/06/19, 07:52:32 AM	UDDSx2, 4 bag (FTP), cold start, with EPA Tier 2 EEE 92 Octance CERT fuel	ok	24	4750	34.35	0.251	0.0249	3.59	2704.370147	0.97395922	2068.884179	2048.928451	3.65967928	3.67345598	-0.21058984	-0.37503377	0.58536027	0.156	23.0	10.23	0.156	23.0	10.24	-205.000	-1462.206	-57.182	76.434	545.326	21.320	-2.894	-20.510	-0.807	46.1	80.7	34.6
61905010	UDDS x2	05/06/19, 07:52:32 AM	UDDSx2, 4 bag (FTP), cold start, with EPA Tier 2 EEE 92 Octance CERT fuel	ok	22	4750	34.35	0.251	0.0249	3.85	1644.18434	1.45311384	3466.030845	3416.386855	3.34974417	3.36819206	-0.24200344	-0.54770891	0.7157606	0.089	43.0	5.46	0.090	42.8	5.50	149.000	608.240	38.721	114.066	472.577	29.642	-0.206	-0.842	-0.054	80.7	46.2	(34.5)
61905010	UDDSx2 1+2	05/06/19, 07:52:32 AM	UDDSx2, 4 bag (FTP), cold start, with EPA Tier 2 EEE 92 Octance CERT fuel	ok	23					7.43										0.245	30.29	7.76	0.246	30.21	7.79	-56.000	-426.983	-7.534	190.499	508.952	25.6	-3.100	-10.676	-0.4			0.2
61905010	UDDS x2	05/06/19, 07:52:32 AM	UDDSx2, 4 bag (FTP), cold start, with EPA Tier 2 EEE 92 Octance CERT fuel	ok	23	4750	34.35	0.251	0.0249	3.61	2703.025835	1.89204953	2087.667578	2048.90135	3.74759587	3.67341199	1.50752007	2.01948163	0.58535723	0.137	26.4	8.93	0.136	26.5	8.88	-214.000	-1524.894	-59.308	77.965	555.657	21.607	-6.393	-45.446	-1.772	46.2	84.0	37.8
61905010	UDDS x2	05/06/19, 07:52:32 AM	UDDSx2, 4 bag (FTP), cold start, with EPA Tier 2 EEE 92 Octance CERT fuel	ok	22	4750	34.35	0.251	0.0249	3.90	1643.965773	1.81321517	3478.293047	3416.347319	3.41835358	3.36812458	0.35923917	1.49130451	0.7157646	0.088	44.4	5.30	0.087	44.6	5.27	161.000	663.254	41.246	113.747	471.695	29.141	-0.078	-0.392	-0.020	84.0	48.3	(35.7)
61905010	UDDSx2 3+4	05/06/19, 07:52:32 AM	UDDSx2, 4 bag (FTP), cold start, with EPA Tier 2 EEE 92 Octance CERT fuel	ok	23					7.51										0.225	33.41	7.04	0.224	33.58	7.01	-53.000	-430.820	-7.056	191.712	513.676	25.5	-6.471	-22.919	-0.9			2.1
61905011	UDDS #3 HS	05/06/19, 09:10:08 AM	UDDS #3, 2bag, warm start, with EPA Tier 2 EEE 92 Octane CERT fuel	ok	22	4750	34.35	0.251	0.0249	3.90	1657.31414	1.04280607	3451.933881	3416.30841	3.38176281	3.36800581	-0.57830065	0.40846119	0.71577621	0.086	45.3	5.20	0.085	45.8	5.13	162.000	674.122	41.559	114.538	474.627	29.383	-0.570	-2.416	-0.146	80.1	44.1	(36.0)
61905011	UDDS #3 HS	05/06/19, 09:10:08 AM	UDDS #3, 2bag, warm start, with EPA Tier 2 EEE 92 Octane CERT fuel	ok	23					7.51										0.212	35.48	6.63	0.208	36.06	6.52	-23.000	-327.464	-3.063	194.377	522.557	25.9	-10.052	-35.063	-1.3			(4.2)
61905012	HWYx2	05/06/19, 10:32:25 AM	HWYx2 with VEHICLE ON coastdown x2, 2bag, warm start, with EPA Tier 2 EEE 92 Octane CERT fuel, coastdowns to verify no changes in vehicle losses over duration of testing	ok, 1 bin(60MPH) of both coastdowns slightly out of spec	25	4750	34.35	0.251	0.0249	10.28	2184.227586	2.72282569	1342.401476	1306.81907	9.24122377	9.16651551	0.61659845	0.81501274	0.27653026	0.327	31.5	7.48	0.325	31.6	7.44	-251.000	-1182.850	-24.425	113.920	536.780	11.085	-0.310	-1.475	-0.030	44.4	88.4	44.1
61905012	HWYx2	05/06/19, 10:32:25 AM	HWYx2 with VEHICLE ON coastdown x2, 2bag, warm start, with EPA Tier 2 EEE 92 Octane CERT fuel, coastdowns to verify no changes in vehicle losses over duration of testing	ok, 1 bin(60MPH) of both coastdowns slightly out of spec	25	4750	34.35	0.251	0.0249	10.27	2184.546696	2.18004664	1335.301332	1306.812216	9.17586777	9.16649143	-0.02751661	0.10228936	0.27652939	0.287	35.8	6.56	0.285	36.1	6.52	-14.000	-66.089	-1.363	112.619	529.938	10.966	-0.240	-1.140	-0.023	88.1	89.0	0.9
61905013	US06x2	05/06/19, 12:40:29 PM	US06x2, 4 bag, warm start, with EPA Tier 2 EEE 92 Octane CERT fuel	ok	23	4750	34.35	0.251	0.0249	1.79	6273.537628	0.74185529	2477.848117	2459.601434	3.67934924	3.60456579	1.16648584	2.07468681	0.81049512	0.119	15.0	15.64	0.118	15.1	15.56	-134.000	-2080.269	-74.953	37.230	576.154	20.824	-0.543	-8.479	-0.304	76.6	88.5	21.8
61905013	US06x2	05/06/19, 12:40:29 PM	US06x2, 4 bag, warm start, with EPA Tier 2 EEE 92 Octane CERT fuel	ok	27	4750	34.35	0.251	0.0249	6.25	13345.56169	6.03979805	1208.23653	1139.417985	8.19226781	8.18438148	-0.17466309	0.09635826	0.3379818	0.241	26.0	9.05	0.240	26.1	9.01	33.000	320.262	5.279	54.346	535.166	8.693	-0.160	-1.710	-0.026	79.7	69.8	(9.9)
61905013	US06x2 1+2	05/06/19, 12:40:29 PM	US06x2, 4 bag, warm start, with EPA Tier 2 EEE 92 Octane CERT fuel	ok	25					8.04										0.359	22.37	10.51	0.358	22.47	10.47	-101.000	-880.003	-12.563	91.576	555.660	11.4	-0.703	-5.095	-0.1			11.9
61905013	US06x2	05/06/19, 12:40:29 PM	US06x2, 4 bag, warm start, with EPA Tier 2 EEE 92 Octane CERT fuel	ok	23	4750	34.35	0.251	0.0249	1.79	6245.936859	1.15634515	2488.022794	2459.581543	3.68180619	3.60454938	1.32525744	2.14331414	0.81049162	0.110	16.2	14.54	0.111	16.1	14.61	-67.444	-1028.810	-37.760	37.212	572.217	20.834	-0.110	-1.555	-0.062	86.4	85.6	8.8
61905013	US06x2	05/06/19, 12:40:29 PM	US06x2, 4 bag, warm start, with EPA Tier 2 EEE 92 Octane CERT fuel	ok	27	4750	34.35	0.251	0.0249	6.25	13349.9974	-1.92478342	1117.444871	1139.375379	8.2109959	8.18430532	0.08821297	0.32611915	0.33796879	0.236	26.5	8.88	0.236	26.5	8.87	36.444	325.236	5.831	54.624	536.171	8.740	-0.160	-1.348	-0.026	79.0	69.3	(9.7)
61905013	US06x2 3+4	05/06/19, 12:40:29 PM	US06x2, 4 bag, warm start, with EPA Tier 2 EEE 92 Octane CERT fuel	ok	25					8.04										0.346	23.21	10.14	0.347	23.19	10.14	-31.000	-351.787	-3.858	91.836	554.194	11.4	-0.270	-1.451	0.0			(0.9)
61905014	SSS 15mph	05/06/19, 01:28:16 PM	15MPH SSS, 20 minute hold, 1 bag, bags OFF, with EPA Tier 2 EEE 92 Octane CERT fuel	ok, stopped early due to plenty of SOC cycles	22	4750	34.35	0.251	0.0249	3.82	421.9278326	85.26918854	248.4682141	134.112	1.25959818	1.26831028	1.33917493	-0.6869063	0.03876613				0.043	88.0	2.67	187.000	726.911	48.972	115.774	453.646	30.319	-2.554	-9.802	-0.669	75.3	39.0	(36.3)
61905015	SSS 30mph	05/06/19, 01:49:21 PM	30MPH SSS, 10 minute hold, 1 bag, bags OFF, with EPA Tier 2 EEE 92 Octane CERT fuel	ok	24	4750	34.35	0.251	0.0249	5.02	2621.555288	37.99163856	370.1266926	268.224	2.50723772	2.4991355	0.10193451	0.32420091	0.07869519				0.104	48.3	4.87	-83.267	-499.170	-16.592	78.797	472.271	15.701	-0.880	-5.330	-0.175	28.3	39.8	11.5
61905016	SSS 45mph	05/06/19, 02:04:37 PM	45MPH SSS, 10 minute hold, 1 bag, bags OFF, with EPA Tier 2 EEE 92 Octane CERT fuel	ok	25	4750	34.35	0.251	0.0249	7.51	5896.742021	23.86501606	498.353551	402.336	5.59439343	5.60285615	-0.12982464	-0.15104302	0.07897889				0.185	40.6	5.80	-51.461	-304.094	-6.853	82.934	496.841	11.044	-0.840	-5.009	-0.112	30.9	33.4	2.5
61905017	SSS 60mph	05/06/19, 02:20:21 PM	60MPH SSS, 10 minute hold, 1 bag, bags OFF, with EPA Tier 2 EEE 92 Octane CERT fuel	ok	26	4750	34.35	0.251	0.0249	10.03	10483.15205	4.70551935	561.6906645	536.448	10.77602033	10.74503355	0.16220658	0.28838228	0.07321334				0.310	32.3	7.28	-36.000	-214.506	-3.590	89.053	532.297	8.881	-0.800	-4.635	-0.080	44.2	50.8	6.6
61905018	SSS 75mph	05/06/19, 02:38:38 PM	75MPH SSS, 10 minute hold, 1 bag, bags OFF, with EPA Tier 2 EEE 92 Octane CERT fuel	ok	27	4750	34.35	0.251	0.0249	12.51	16381.99832	18.58771841	795.2018046	670.56	18.51230738	18.52745147	-0.02329629	-0.08173861	0.0663441				0.489	25.6	9.20	-9.000	-49.351	-0.719	88.983	534.518	7.112	-1.060	-6.527	-0.085	50.5	50.5	0.1
61905019	UDDS Prep	05/06/19, 03:00:24 PM	UDDS prep, 1 bag, for CERT style testing with EPA Tier 2 EEE 92 Octane CERT fuel, hood up, fan at 6 MPH (5300CFM)	ok	19	4750	34.35	0.251	0.0249	7.51	2048.738436	1.56062873	5550.577699	5465.284893	7.13551092	7.04147797	0.48832816	1.33541498	0.64774449	0.191	39.4	5.97	0.190	39.6	5.95	127.000	344.632	16.903	193.403	507.144	25.741	-6.833	-17.883	-0.909	76.2	46.7	(29.4)
Day 12 - 72F Testing / Standard and performance cycles/ Tier II HO																																					
61905020	UDDS x2	05/07/19, 07:49:12 AM	UDDSx2, 2 bag (FTP), cold start, CERT style testing with EPA Tier 2 EEE 92 Octane CERT fuel, hood up, fan at 6 MPH (5300CFM)	ok	21	4750	34.35	0.251	0.0249	3.58	2701.420484	1.29613877	2075.426748	2048.870542	3.69110801	3.67337544	0.75855405	0.48273219	0.58534922	0.152	23.6	9.98	0.153	23.5	10.02	-241.000	-1726.565	-67.300	77.109	549.578	21.533	-4.439	-31.553	-1.240	47.4	88.8	41.4
61905020	UDDS x2	05/07/19, 07:49:12 AM	UDDSx2, 2 bag (FTP), cold start, CERT style testing with EPA Tier 2 EEE 92 Octane CERT fuel, hood up, fan at 6 MPH (5300CFM)	ok	22	4750	34.35	0.251	0.0249	3.84	1643.11405	2.28708186	3494.441706	3416.307947	3.38054941	3.36806619	0.8423552	0.37063443	0.71576428	0.083	46.3	5.08	0.083	46.5	5.05	220.000	910.710	57.268	113.340	469.581	29.503	-0.180	-0.772	-0.047	88.8	41.5	(47.3)
61905020	UDDSx2 1+2	05/07/19, 07:49:12 AM	UDDSx2, 2 bag (FTP), cold start, CERT style testing with EPA Tier 2 EEE 92 Octane CERT fuel, hood up, fan at 6 MPH (5300CFM)	ok	21					7.42										0.235	31.60	7.44	0.235	31.57	7.45	-21.000	-407.928	-2.829	190.448	509.580	25.7	-4.619	-16.162	-0.6			(5.9)
61905020	UDDS x2	05/07/19, 07:49:12 AM	UDDSx2, 2 bag (FTP), cold start, CERT style testing with EPA Tier 2 EEE 92 Octane CERT fuel, hood up, fan at 6 MPH (5300CFM)	ok	23	4750	34.35	0.251	0.0249	3.61	2701.147301	1.62564338	2082.145976	2048.839158	3.73078363	3.67333645	0.8944841	1.56389632	0.58534227	0.134	27.0	8.71	0.132	27.3	8.61	-100.000	-716.404	-27.666	77.498	552.314	21.441	-6.448	-45.887	-1.784	41.5	58.9	17.4
61905020	UDDS x2	05/07/19, 07:49:12 AM	UDDSx2, 2 bag (FTP), cold start, CERT style testing with EPA Tier 2 EEE 92 Octane CERT fuel, hood up, fan at 6 MPH (5300CFM)	ok	22	4750	34.35	0.251	0.0249	3.89	1642.921185	2.60687483	3505.330685	3416.272731	3.41723259	3.36800339	0.60381435	1.46167307	0.7157676	0.116	33.4	7.04	0.116	33.5	7.03	43.000	168.478	11.046	118.532	491.504	30.450	-0.220	-0.942	-0.057	58.9	45.2	(13.7)
61905020	UDDSx2 3+4	05/07/19, 07:49:12 AM	UDDSx2, 2 bag (FTP), cold start, CERT style testing with EPA Tier 2 EEE 92 Octane CERT fuel, hood up, fan at 6 MPH (5300CFM)	ok	22					7.51										0.250	29.99	7.84	0.249	30.19	7.79	-57.000	-273.963	-7.593	196.030	521.909	26.1	-6.668	-23.415	-0.9			3.7
61905021	HWYx2	05/07/19, 09:23:29 AM	HWYx2, 2bag, warm start, CERT style testing with EPA Tier 2 EEE 92 Octane CERT fuel, hood up, fan at 6 MPH (5300CFM)	ok	23	4750	34.35	0.251	0.0249	10.28	2183.819499	3.18101279	1348.374581	1306.804948	9.29410458	9.16649129	1.17384251	1.39217157	0.27652768	0.321	32.0	7.35	0.320	32.1	7.32	-250.000	-1185.729	-24.325	133.503	628.131	12.990	-10.744	-50.462	-1.045	44.9	87.5	42.5
61905021	HWYx2	05/07/19, 09:23:29 AM	HWYx2, 2bag, warm start, CERT style testing with EPA Tier 2 EEE 92 Octane CERT fuel, hood up, fan at 6 MPH (5300CFM)	ok	23	4750	34.35	0.251	0.0249	10.28	2184.082823	3.5816939	1353.608463	1306.802787	9.24761702	9.16646771	0.63337326	0.88528447	0.2765278	0.280	36.7	6.42	0.279	36.9	6.38	-11.000	-72.866	-1.070	120.575	567.670	11.727	-0.380	-1.842	-0.037	87.2	83.9	(3.2)
61905022	WOTs	05/07/19, 10:11:02 AM	Blank bag 5 WOTS, testing with EPA Tier 2 EEE 92 Octane CERT fuel, bags OFF	ok	25	4750	34.35	0.251	0.0249	3.99	0	Inf	3644.131737	0	8.31954261	0	NaN	Inf	NaN				0.276	14.5	16.26	-61.000	-577.737	-15.287	62.814	645.533	15.742	-4.925	-49.055	-1.234	84.2	93.9	9.6
61905023	Accessory Load Test	05/07/19, 11:02:54 AM	Blank bag accessory load test	ok, anl bypass used to keep vehicle stop/start functional	22	4750	34.35	0.251	0.0249	0.21	0	Inf	341.6250575	0	0.2614971	0	NaN	Inf	NaN							207.000	318.877	987.708	165.050	254.053	787.542	8.860	13.679	42.276	88.9	50.2	(38.6)
61905024	Passing Maneuvers	05/07/19, 01:16:54 PM	Passing Manuevers with 55MPH warmup, 4 bag, bags OFF using EPA Tier 2 EEE 92 Octane CERT Fuel, 0%, 3%, and 6%	ok	23	4750	34.35	0.251	0.0249	5.01	424.4706021	4.07988862	511.8066075	491.744	4.80893055	4.79861784	0.09608218	0.21490993	0.13775415				0.180	27.9	8.44	-247.000	-2465.956	-49.307	55.009	549.548	10.981	-1.130	-11.463	-0.226	50.8	92.5	41.7
61905025	UDDS x2	05/07/19, 02:04:19 PM	UDDSx2, 4 bag, prep for cold start FTP using EPA Tier 2 EEE 92 Octane CERT Fuel,	ok	20	4750	34.35	0.251	0.0249	3.61	2702.78307	1.11411754	2071.714577	2048.887561	3.72409102	3.67341525	0.73572179	1.37952752	0.58534964	0.117	30.8	7.64	0.117	30.9	7.60	-97.000	-684.162	-26.842	80.929	577.133	22.395	-9.240	-65.810	-2.557	61.2	80.1	18.9
61905025	UDDS x2	05/07/19, 02:04:19 PM	UDDSx2, 4 bag, prep for cold start FTP using EPA Tier 2 EEE 92 Octane CERT Fuel,	ok	22	4750	34.35	0.251	0.0249	3.89	1643.455925	1.5275234	3468.51397	3416.328749	3.40224751	3.3681078	0.16868219	1.01361665	0.71576134	0.090	43.3	5.43	0.090	43.3	5.44	129.000	532.214	33.141	116.650	483.155	29.968	-1.290	-5.349	-0.331	80.1	50.7	(29.4)
61905025	UDDSx2 1+2	05/07/19, 02:04:19 PM	UDDSx2, 4 bag, prep for cold start FTP using EPA Tier 2 EEE 92 Octane CERT Fuel,	ok	21					7.51										0.207	36.23	6.49	0.207	36.31	6.48	32.000	-75.974	4.263	197.580	530.144	26.3	-10.530	-35.580	-1.4			(10.5)
61905025	UDDS x2	05/07/19, 02:04:19 PM	UDDSx2, 4 bag, prep for cold start FTP using EPA Tier 2 EEE 92 Octane CERT Fuel,	ok	23	4750	34.35	0.251	0.0249	3.61	2701.736889	1.35182806	2076.559862	2048.862761	3.72124955	3.67336204	0.88024947	1.30364253	0.58534788	0.122	29.7	7.93	0.120	30.0	7.83	-158.000	-1137.035	-43.818	79.138	564.524	21.947	-6.039	-43.031	-1.675	50.6	78.0	27.4
61905025	UDDS x2	05/07/19, 02:04:19 PM	UDDSx2, 4 bag, prep for cold start FTP using EPA Tier 2 EEE 92 Octane CERT Fuel,	ok	22	4750	34.35	0.251	0.0249	3.89	1643.186545	1.39213734	3463.849101	3416.289658	3.40343373	3.3680359	0.15054543	1.05099315	0.71576566	0.089	43.9	5.36	0.089	43.7	5.39	148.000	613.671	38.001	119.812	496.285	30.763	-1.162	-4.858	-0.298	78.0	44.9	(33.1)
61905025	UDDSx2 3+4	05/07/19, 02:04:19 PM	UDDSx2, 4 bag, prep for cold start FTP using EPA Tier 2 EEE 92 Octane CERT Fuel,	ok	22					7.50										0.210	35.67	6.59	0.209	35.84	6.56	-10.000	-261.682	-1.333	198.950	530.405	26.5	-7.201	-23.944	-1.0			(5.7)
Day 13 - 72F Testing / Standard Cycles with hood up and CSF/ Tier II HO																																					
61905026	UDDS x2	05/08/19, 08:45:22 AM	UDDSx2, 4 bag (FTP) cold start using EPA Tier 2 EEE 92 Octane CERT Fuel,	ok	22	4750	34.35	0.251	0.0249	3.61	2700.55682	0.98443798	2068.997204	2048.827765	3.70338149	3.67332518	0.34858518	0.81823165	0.58533936	0.153	23.6	9.97	0.153	23.5	10.00	-235.000	-1669.772	-65.137	74.232	529.890	20.576	-2.132	-15.346	-0.591	0.0	85.6	85.6
61905026	UDDS x2	05/08/19, 08:45:22 AM	UDDSx2, 4 bag (FTP) cold start using EPA Tier 2 EEE 92 Octane CERT Fuel,	ok	23	4750	34.35	0.251	0.0249	3.89	1642.472848	1.89980889	3481.154939	3416.252667	3.42192532	3.36798917	0.71983469	1.60143459	0.71576512	0.085	45.7	5.15	0.085	45.8	5.14	192.000	782.584	49.313	112.878	467.504	28.992	-0.919	-3.749	-0.236	85.6	44.2	(41.4)
61905026	UDDSx2 1+2	05/08/19, 08:45:22 AM	UDDSx2, 4 bag (FTP) cold start using EPA Tier 2 EEE 92 Octane CERT Fuel,	ok	22					7.50										0.238	31.49	7.47	0.238	31.46	7.48	-43.000	-443.594	-5.732	187.110	498.697	24.9	-3.051	-9.548	-0.4			44.2
61905026	UDDS x2	05/08/19, 08:45:22 AM	UDDSx2, 4 bag (FTP) cold start using EPA Tier 2 EEE 92 Octane CERT Fuel,	ok	22	4750	34.35	0.251	0.0249	3.58	2700.233175	2.95333712	2109.314443	2048.806286	3.72724062	3.67329491	1.86897483	1.46859175	0.58533454	0.125	28.6	8.22	0.123	29.0	8.11	-194.000	-1374.472	-54.256	78.007	556.637	21.816	-7.607	-54.345	-2.127	44.6	77.6	33.0
61905026	UDDS x2	05/08/19, 08:45:22 AM	UDDSx2, 4 bag (FTP) cold start using EPA Tier 2 EEE 92 Octane CERT Fuel,	ok	21	4750	34.35	0.251	0.0249	3.84	1642.277515	0.38444738	3429.346584	3416.213042	3.34292969	3.36792634	-0.16786578	-0.74219686	0.71576767	0.082	47.0	5.01	0.082	47.0	5.00	170.000	700.689	44.298	114.689	474.801	29.885	-1.049	-4.277	-0.273	77.6	39.7	(37.9)
61905026	UDDSx2 3+4	05/08/19, 08:45:22 AM	UDDSx2, 4 bag (FTP) cold start using EPA Tier 2 EEE 92 Octane CERT Fuel,	ok	22					7.41										0.207	35.87	6.56	0.205	36.17	6.50	-24.000	-336.892	-3.237	192.696	515.719	26.0	-8.656	-29.311	-1.2			(4.9)
61905027	UDDS x2	05/08/19, 10:14:06 AM	UDDS, 2 bag, warm start using EPA Tier 2 EEE 92 Octane CERT Fuel, ANL Bypass	OK	21	4750	34.35	0.251	0.0249	3.61	2716.164349	-0.21636544	2044.428505	2048.861533	3.70536222	3.67329374	0.27239271	0.87301697	0.58535956	0.129	28.1	8.38	0.128	28.2	8.35	-235.000	-1671.467	-65.052	92.069	658.020	25.486	-20.990	-149.940	-5.810	40.1	81.1	41.0
61905027	UDDS x2	05/08/19, 10:14:06 AM	UDDS, 2 bag, warm start using EPA Tier 2 EEE 92 Octane CERT Fuel, ANL Bypass	OK	22	4750	34.35	0.251	0.0249	3.89	1657.247014	1.47294118	3466.618316	3416.298252	3.41064685	3.3679959	0.4779504	1.26635993	0.71577646	0.085	45.5	5.16	0.086	45.5	5.17	169.000	709.504	43.444	117.270	486.371	30.146	-2.700	-11.240	-0.694	81.1	44.1	(37.0)
61905027	UDDSx2 1+2	05/08/19, 10:14:06 AM	UDDS, 2 bag, warm start using EPA Tier 2 EEE 92 Octane CERT Fuel, ANL Bypass	OK	21					7.50										0.214	35.03	6.71	0.214	35.11	6.70	-66.000	-480.982	-8.797	209.339	572.196	27.9	-23.690	-80.590	-3.2			4.0
61905028	UDDS x2	05/08/19, 11:05:45 AM	UDDS, 2 bag, warm start using EPA Tier 2 EEE 92 Octane CERT Fuel, Honda Handyman Dyno Mode	ok	21	4750	34.35	0.251	0.0249	3.61	2717.713379	1.21308919	2073.752886	2048.897927	3.71165787	3.67336847	0.47211597	1.04235114	0.58536376	0.130	27.7	8.48	0.129	28.0	8.39	-172.000	-1236.115	-47.628	149.280	1066.977	41.337	-78.122	-558.285	-21.633	44.3	73.6	29.3
61905028	UDDS x2	05/08/19, 11:05:45 AM	UDDS, 2 bag, warm start using EPA Tier 2 EEE 92 Octane CERT Fuel, Honda Handyman Dyno Mode	ok	22	4750	34.35	0.251	0.0249	3.89	1658.03591	1.6852131	3473.936665	3416.363657	3.39864555	3.36808836	0.18985761	0.9072563	0.71577464	0.095	40.9	5.75	0.095	41.1	5.73	120.000	496.430	30.868	133.659	553.464	34.382	-17.762	-73.554	-4.569	73.6	45.5	(28.1)
61905028	UDDSx2 1+2	05/08/19, 11:05:45 AM	UDDS, 2 bag, warm start using EPA Tier 2 EEE 92 Octane CERT Fuel, Honda Handyman Dyno Mode	ok	21					7.50										0.225	33.30	7.06	0.223	33.57	7.01	-52.000	-369.843	-6.934	282.939	810.221	37.7	-95.884	-315.920	-12.8			1.2
61905029	UDDS x2	05/08/19, 11:47:14 AM	UDDS, 2 bag, warm start using EPA Tier 2 EEE 92 Octane CERT Fuel, Honda Handyman Dyno Mode	Test ok	22	4750	34.35	0.251	0.0249	3.60	2717.62255	2.25492024	2095.1127	2048.911383	3.7144702	3.67337659	0.89427002	1.11868769	0.58536653	0.125	28.9	8.14	0.123	29.2	8.05	-217.000	-1547.277	-60.299	77.624	554.422	21.570	-5.957	-42.524	-1.655	0.0	83.3	83.2
61905029	UDDS x2	05/08/19, 11:47:14 AM	UDDS, 2 bag, warm start using EPA Tier 2 EEE 92 Octane CERT Fuel, Honda Handyman Dyno Mode	Test ok	21	4750	34.35	0.251	0.0249	3.87	1658.231217	2.19952253	3491.500315	3416.356778	3.41519099	3.36809724	1.01252843	1.39823023	0.71577232	0.086	44.8	5.25	0.086	45.3	5.20	158.000	671.604	40.782	116.949	484.571	30.186	-1.570	-6.517	-0.405	83.3	49.0	(34.3)
61905029	UDDSx2 1+2	05/08/19, 11:47:14 AM	UDDS, 2 bag, warm start using EPA Tier 2 EEE 92 Octane CERT Fuel, Honda Handyman Dyno Mode	Test ok	22					7.47										0.211	35.42	6.64	0.209	35.79	6.57	-59.000	-437.836	-7.895	194.573	519.496	26.0	-7.527	-24.521	-1.0			48.9
End of Test																																					

																Liquid Fuel usage						Electric consumption [Wh/mi]								SOC		
Test ID [#]	Cycle	Test Cell Temp [C]	Test weight [lb]	Dyno Target A:	Dyno Target B:	Dyno Target C:	Cycle Distance [mi]	APCtime	ASCR	ASC_d	ASC_t	CE_d	CE_t	EER	ER	IWR	Cycle Fuel Consumed [gal] (Emiss Bag)	Cycle Fuel economy [mpg] (Emiss Bag)	Fuel Consumption Bag [l/100km]	Fuel used modal [gal]	Fuel Economy Modal [mpg]	Fuel Consumption Modal [l/100km]	HV Batt Δ [Wh]	HV Batt Average Power P1 [W]	HV Batt Energy consumption [Wh/mi]	DCDC Out Δ WP2 [Wh]	DCDC Out Average Power P2 [W]	DCDC Out Δ WP2 [Wh/mi]	12V Neg Out Δ WP2 [Wh]	12V Neg Out Average Power P2 [W]	12V Neg Out Δ WP2 [Wh/mi]	SOC init	SOC end	Delta SOC
Day 0+ - Channel Checkout / prep																																	
Day 1 - 72F Testing / Standard Cycles / Tier III LO																																	
61904015	**UDDS x2**	24	4750	34.35	0.251	0.0249	3.60	2703.884	1.472837	2079.077	2048.9	3.703341	3.673433	0.458161	0.81418	0.585354	0.151	23.8	9.89	0.151	23.9	9.85	-201.000	-1492.117	-55.777	74.289	530.499	20.615	-1.929	-14.294	-0.535	46.2	82.4	36.2
61904015	**UDDS x2**	21	4750	34.35	0.251	0.0249	3.89	1643.883	1.263825	3459.542	3416.365	3.381151	3.368165	-0.322801	0.385562	0.71576	0.093	41.9	5.61	0.092	42.4	5.55	164.000	628.767	42.188	114.311	473.276	29.406	-0.661	-2.618	-0.170	82.4	44.8	(37.6)
61904015	**UDDSx2 1+2**	**22**					**7.49**										**0.244**	**30.68**	**7.67**	**0.243**	**30.86**	**7.62**	**-37.000**	-431.675	**-4.939**	**188.600**	501.888	**25.2**	**-2.590**	-8.456	**-0.3**			(1.4)
61904015	**UDDS x2**	24	4750	34.35	0.251	0.0249	3.61	2702.529	1.747771	2084.695	2048.885	3.717754	3.673396	0.667867	1.207554	0.585351	0.127	28.4	8.28	0.126	28.8	8.18	-199.000	-1532.952	-55.123	76.507	545.536	21.192	-7.016	-49.936	-1.943	44.8	78.1	33.3
61904015	**UDDS x2**	21	4750	34.35	0.251	0.0249	3.89	1643.716	2.133564	3489.218	3416.328	3.395579	3.368097	0.085786	0.815937	0.715764	0.093	42.0	5.61	0.091	42.5	5.54	142.000	624.029	36.522	114.847	475.746	29.538	-0.882	-3.626	-0.227	78.1	46.0	(32.1)
61904015	**UDDSx2 3+4**	**23**					**7.50**										**0.220**	**34.13**	**6.89**	**0.217**	**34.55**	**6.81**	**-57.000**	-454.462	**-7.602**	**191.354**	510.641	**25.5**	**-7.898**	-26.781	**-1.1**			1.3
61904016	**UDDS x2**	24	4750	34.35	0.251	0.0249	3.57	2716.495	-1.614593	2015.787	2048.868	3.646337	3.673316	-0.266236	-0.734469	0.585358	0.128	28.0	8.40	0.126	28.3	8.30	-195.752	-1396.145	-54.769	79.680	569.010	22.294	-9.638	-68.741	-2.697	46.0	78.3	32.3
61904016	**UDDS x2**	21	4750	34.35	0.251	0.0249	3.84	1657.397	0.729728	3441.229	3416.3	3.313775	3.367999	-1.140152	-1.609969	0.715776	0.087	44.0	5.35	0.086	44.6	5.27	161.110	672.016	41.944	114.904	476.390	29.915	-1.493	-6.221	-0.389	78.3	43.4	(34.9)
61904016	**UDDSx2 1+2**	**23**					**7.42**										**0.215**	**34.49**	**6.82**	**0.212**	**34.94**	**6.73**	**-34.642**	-362.064	**-4.672**	**194.584**	522.700	**26.2**	**-11.130**	-37.481	**-1.5**			(2.6)
61904017	**HWYx2**	26	4750	34.35	0.251	0.0249	10.28	2184.083	1.808472	1330.449	1306.816	9.195307	9.166504	0.125655	0.314213	0.27653	0.324	31.7	7.42	0.324	31.7	7.43	-265.000	-1247.383	-25.788	119.413	561.920	11.621	-6.590	-31.094	-0.641	43.7	88.5	44.8
61904017	**HWYx2**	25	4750	34.35	0.251	0.0249	10.28	2184.471	3.398541	1351.22	1306.807	9.243283	9.166471	0.632137	0.837962	0.276529	0.293	35.0	6.71	0.293	35.1	6.70	2.000	3.868	0.195	113.643	534.722	11.058	-0.760	-3.483	-0.074	88.2	88.6	0.4
61904018	**US06x2**	21	4750	34.35	0.251	0.0249	1.78	6271.935	-0.368003	2450.534	2459.585	3.64154	3.604498	0.444024	1.027674	0.810502	0.110	16.3	14.46	0.109	16.3	14.40	-61.000	-938.964	-34.224	41.357	639.285	23.203	-4.543	-70.348	-2.549	88.3	86.9	8.1
61904018	**US06x2**	26	4750	34.35	0.251	0.0249	6.24	13341.53	11.74072	1273.123	1139.354	8.188826	8.184265	-0.074754	0.055735	0.337962	0.248	25.2	9.34	0.247	25.3	9.31	35.000	345.349	5.606	56.936	559.465	9.120	-2.380	-23.398	-0.381	79.2	69.7	(9.6)
61904018	**US06x2 1+2**	**23**					**8.03**										**0.358**	**22.45**	**10.48**	**0.356**	**22.54**	**10.44**	**-26.000**	-296.807	**-3.240**	**98.293**	599.375	**12.2**	**-6.923**	-46.873	**-0.9**			(1.5)
61904018	**US06x2**	22	4750	34.35	0.251	0.0249	1.78	6245.389	0.884474	2481.346	2459.591	3.658374	3.604533	0.77871	1.493714	0.810499	0.114	15.7	15.02	0.114	15.6	15.07	-103.631	-1582.556	-58.070	37.354	575.246	20.931	-0.250	-3.806	-0.140	82.5	86.6	15.2
61904018	**US06x2**	26	4750	34.35	0.251	0.0249	6.25	13345.03	3.474931	1178.878	1139.288	8.154967	8.184157	-0.556838	-0.356657	0.337941	0.239	26.2	8.99	0.239	26.2	8.98	47.000	475.357	7.523	54.486	536.573	8.722	-0.370	-3.547	-0.059	80.7	69.6	(11.2)
61904018	**US06x2 3+4**	**24**					**8.03**										**0.353**	**22.77**	**10.33**	**0.353**	**22.76**	**10.34**	**-56.631**	-553.600	**-7.051**	**91.839**	555.909	**11.4**	**-0.620**	-3.677	**-0.1**			4.1
61904019	**UDDS x2**	22	4750	34.35	0.251	0.0249	7.50	2047.764	2.013186	5575.194	5465.17	7.113549	7.041306	0.387973	1.025997	0.647742	0.199	37.7	6.24	0.198	37.9	6.20	171.000	449.455	22.806	186.094	487.796	24.819	-3.234	-8.396	-0.431	86.5	48.6	(37.9)
Day 2- 72F Testing / Standard Cycles / Tier III LO																																	
61904020	**UDDS x2**	23	4750	34.35	0.251	0.0249	3.60	2703.99	1.076777	2070.985	2048.923	3.699079	3.673457	0.331919	0.697502	0.585359	0.154	23.5	10.03	0.153	23.5	10.01	-171.000	-1223.553	-47.447	76.238	543.239	21.153	-2.580	-18.384	-0.716	48.6	79.8	31.2
61904020	**UDDS x2**	20	4750	34.35	0.251	0.0249	3.88	1643.962	1.487809	3467.192	3416.363	3.403263	3.368164	0.509828	1.042074	0.71576	0.092	42.2	5.57	0.091	42.5	5.53	147.000	616.043	37.884	114.010	472.728	29.382	-0.170	-0.751	-0.044	79.8	45.0	(34.9)
61904020	**UDDSx2 1+2**	**22**					**7.48**										**0.246**	**30.48**	**7.72**	**0.245**	**30.59**	**7.69**	**-24.000**	-303.755	**-3.207**	**190.248**	507.983	**25.4**	**-2.751**	-9.568	**-0.4**			(3.7)
61904020	**UDDS x2**	24	4750	34.35	0.251	0.0249	3.60	2702.541	-0.276202	2043.227	2048.886	3.682679	3.673407	-0.049245	0.252403	0.585351	0.132	27.3	8.63	0.131	27.5	8.54	-203.000	-1443.208	-56.360	76.379	544.709	21.205	-6.489	-46.110	-1.802	45.0	80.3	35.4
61904020	**UDDS x2**	21	4750	34.35	0.251	0.0249	3.89	1643.685	2.765279	3510.807	3416.336	3.421093	3.368106	0.805945	1.573177	0.715764	0.090	43.0	5.47	0.090	43.4	5.42	165.000	691.512	42.427	114.481	474.338	29.437	-0.080	-0.353	-0.021	80.3	43.1	(37.2)
61904020	**UDDSx2 3+4**	**23**					**7.49**										**0.223**	**33.66**	**6.99**	**0.220**	**33.98**	**6.92**	**-38.000**	-375.848	**-5.073**	**190.860**	509.524	**25.5**	**-6.569**	-23.232	**-0.9**			(1.8)
61904021	**UDDS x2**	24	4750	34.35	0.251	0.0249	3.58	2716.41	0.788427	2065.018	2048.864	3.689004	3.673306	0.739892	0.427332	0.585358	0.127	28.3	8.32	0.125	28.5	8.24	-166.000	-1184.870	-46.373	80.218	573.385	22.409	-9.768	-69.695	-2.729	43.1	71.9	28.8
61904021	**UDDS x2**	21	4750	34.35	0.251	0.0249	3.85	1657.35	1.40846	3464.421	3416.304	3.334632	3.367992	-0.775793	-0.990498	0.715778	0.091	42.4	5.55	0.090	43.0	5.47	115.000	470.019	29.860	114.942	476.089	29.845	-0.893	-3.659	-0.232	71.9	44.2	(27.7)
61904021	**UDDSx2 1+2**	**23**					**7.43**										**0.217**	**34.18**	**6.88**	**0.215**	**34.55**	**6.81**	**-51.000**	-357.426	**-6.863**	**195.160**	524.737	**26.3**	**-10.661**	-36.677	**-1.4**			1.1
61904022	**HWYx2**	26	4750	34.35	0.251	0.0249	10.23	2184.409	1.376756	1324.814	1306.823	9.167662	9.166527	0.27486	0.01238	0.276531	0.323	31.6	7.43	0.324	31.6	7.45	-239.000	-1118.881	-23.363	114.724	540.574	11.215	-0.310	-1.606	-0.030	45.8	87.4	41.5
61904022	**HWYx2**	25	4750	34.35	0.251	0.0249	10.22	2184.722	0.792464	1317.174	1306.818	9.095105	9.166498	-0.387033	-0.778849	0.276531	0.285	35.8	6.56	0.285	35.8	6.57	-25.000	-117.725	-2.447	111.030	522.467	10.868	-0.260	-1.248	-0.025	87.0	86.8	(0.2)
61904023	**US06x2**	21	4750	34.35	0.251	0.0249	1.79	6275.184	-0.29941	2452.275	2459.639	3.65186	3.604602	0.447132	1.311047	0.8105	0.110	16.3	14.45	0.110	16.2	14.49	-73.000	-1164.983	-40.843	40.880	631.269	22.872	-3.986	-61.576	-2.230	87.3	88.0	10.6
61904023	**US06x2**	25	4750	34.35	0.251	0.0249	6.24	13347.29	4.047997	1185.594	1139.469	8.198965	8.184422	0.101461	0.177689	0.337999	0.244	25.5	9.21	0.244	25.6	9.18	33.000	338.912	5.289	55.820	549.831	8.946	-1.200	-11.833	-0.192	79.5	69.7	(9.9)
61904023	**US06x2 1+2**	**23**					**8.03**										**0.354**	**22.67**	**10.37**	**0.354**	**22.70**	**10.36**	**-40.000**	-413.035	**-4.983**	**96.700**	590.550	**12.0**	**-5.186**	-36.705	**-0.6**			0.7
61904023	**US06x2**	22	4750	34.35	0.251	0.0249	1.79	6247.182	-0.057696	2458.199	2459.618	3.650619	3.60458	0.35597	1.277238	0.810496	0.113	15.8	14.86	0.113	15.8	14.89	-106.000	-1644.297	-59.272	37.426	574.789	20.928	-0.080	-0.904	-0.045	84.1	87.7	14.7
61904023	**US06x2**	26	4750	34.35	0.251	0.0249	6.24	13352.32	5.330757	1200.177	1139.437	8.189577	8.184405	-0.009236	0.063192	0.337988	0.241	25.9	9.10	0.241	25.9	9.10	45.000	469.556	7.212	54.790	538.956	8.781	-0.110	-1.038	-0.018	80.4	69.3	(11.1)
61904023	**US06x2 3+4**	**24**					**8.03**										**0.354**	**22.66**	**10.38**	**0.355**	**22.64**	**10.39**	**-61.000**	-587.370	**-7.599**	**92.216**	556.872	**11.5**	**-0.190**	-0.971	**0.0**			3.6
61904024	**UDDS Prep**	22	4750	34.35	0.251	0.0249	7.51	2049.164	1.729466	5559.839	5465.318	7.111652	7.04153	0.260863	0.995836	0.647745	0.199	37.8	6.23	0.198	38.0	6.19	162.000	418.316	21.584	191.352	501.661	25.495	-6.623	-17.344	-0.882	87.4	52.5	(35.0)

																Liquid Fuel usage						Electric consumption [Wh/mi]								SOC		
Test ID [#]	Cycle	Test Cell Temp [C]	Test weight [lb]	Dyno Target A:	Dyno Target B:	Dyno Target C:	Cycle Distance [mi]	APCtime	ASCR	ASC_d	ASC_t	CE_d	CE_t	EER	ER	IWR	Cycle Fuel Consumed [gal] (Emiss Bag)	Cycle Fuel economy [mpg] (Emiss Bag)	Fuel Consumption Bag [l/100km]	Fuel used modal [gal]	Fuel Economy Modal [mpg]	Fuel Consumption Modal [l/100km]	HV Batt Δ [Wh]	HV Batt Average Power P1 [W]	HV Batt Energy consumption [Wh/mi]	DCDC Out Δ WP2 [Wh]	DCDC Out Average Power P2 [W]	DCDC Out Δ WP2 [Wh/mi]	12V Neg Out Δ WP2 [Wh]	12V Neg Out Average Power P2 [W]	12V Neg Out Δ WP2 [Wh/mi]	SOC init	SOC end	Delta SOC
Day 3 - 72F Testing / Standard Cycles / Tier III LO																																
61904025	**UDDS x2**	24	4750	34.35	0.251	0.0249	3.59	2703.593	0.69131	2063.078	2048.914	3.697037	3.673442	0.6058	0.642316	0.585357	0.151	23.8	9.86	0.150	23.9	9.84	-195.578	-1394.236	-54.445	75.306	537.475	20.964	-2.446	-17.464	-0.681	52.7	84.9	32.2
61904025	**UDDS x2**	20	4750	34.35	0.251	0.0249	3.84	1643.804	0.556419	3435.361	3416.351	3.334122	3.368147	-0.571219	-1.010199	0.715761	0.086	44.6	5.27	0.086	44.8	5.26	161.000	659.925	41.897	113.470	470.038	29.528	-0.270	-1.113	-0.070	84.9	50.3	(34.6)
61904025	**UDDSx2 1+2**	**22**					**7.43**										**0.237**	**31.40**	**7.49**	**0.236**	**31.48**	**7.47**	**-34.578**	-367.155	**-4.651**	**188.775**	503.756	**25.4**	**-2.716**	-9.288	**-0.4**			(2.5)
61904025	**UDDS x2**	24	4750	34.35	0.251	0.0249	3.61	2702.11	2.019745	2090.253	2048.871	3.724313	3.673379	0.871858	1.386567	0.585349	0.127	28.3	8.30	0.126	28.6	8.22	-174.000	-1245.266	-48.212	76.564	545.510	21.215	-6.519	-46.281	-1.806	50.3	80.0	29.8
61904025	**UDDS x2**	22	4750	34.35	0.251	0.0249	3.89	1643.499	1.660048	3473.036	3416.323	3.407931	3.36808	0.309404	1.183179	0.715766	0.090	43.1	5.46	0.090	43.4	5.42	145.000	602.107	37.242	114.536	474.821	29.417	-0.160	-0.723	-0.041	80.0	47.3	(32.8)
61904025	**UDDSx2 3+4**	**23**					**7.50**										**0.218**	**34.44**	**6.83**	**0.216**	**34.75**	**6.77**	**-29.000**	-321.579	**-3.865**	**191.100**	510.166	**25.5**	**-6.679**	-23.502	**-0.9**			(3.0)
61904026	**UDDS x2**	24	4750	34.35	0.251	0.0249	3.58	2717.111	0.440732	2057.928	2048.898	3.665617	3.673357	0.055964	-0.210709	0.585364	0.127	28.3	8.31	0.125	28.6	8.22	-179.000	-1287.452	-49.980	80.083	571.934	22.360	-9.543	-68.262	-2.665	47.8	77.8	30.0
61904026	**UDDS x2**	22	4750	34.35	0.251	0.0249	3.85	1658.057	0.379914	3429.333	3416.354	3.321418	3.368077	-1.050011	-1.385344	0.715775	0.084	45.9	5.13	0.084	46.0	5.11	162.000	675.308	42.117	114.240	473.491	29.700	-0.640	-2.659	-0.166	77.8	41.5	(36.4)
61904026	**UDDSx2 1+2**	**23**					**7.43**										**0.210**	**35.29**	**6.67**	**0.209**	**35.57**	**6.61**	**-17.000**	-306.072	**-2.289**	**194.322**	522.713	**26.2**	**-10.183**	-35.460	**-1.4**			(6.4)
61904028	**HWYx2**	25	4750	34.35	0.251	0.0249	10.27	2183.512	2.969552	1345.608	1306.802	9.218843	9.166469	0.454909	0.571362	0.276528	0.289	35.5	6.62	0.289	35.5	6.62	-20.000	-91.765	-1.948	117.949	554.938	11.487	-5.928	-27.908	-0.577	89.5	89.2	(0.3)
61904028	**HWYx2**	25	4750	34.35	0.251	0.0249	10.28	2183.82	4.486738	1365.425	1306.793	9.21974	9.166455	0.364658	0.581305	0.276526	0.285	36.1	6.52	0.284	36.2	6.51	-36.000	-163.155	-3.502	109.680	516.165	10.671	-0.210	-0.964	-0.020	88.9	91.3	2.5
61904029	**US06x3**	24	4750	34.35	0.251	0.0249	8.03	10611.25	1.64533	3658.309	3599.092	11.84127	11.78904	0.205474	0.443062	0.482466	0.353	22.7	10.35	0.353	22.7	10.34	-11.000	-62.938	-1.371	104.037	626.242	12.963	-12.459	-75.030	-1.552	91.2	86.2	(5.0)
61904029	**US06x3**	24	4750	34.35	0.251	0.0249	8.04	10609.34	1.9065	3667.653	3599.037	11.90344	11.78895	0.542367	0.971232	0.482462	0.355	22.6	10.38	0.355	22.7	10.38	-47.000	-283.311	-5.845	91.940	552.097	11.434	-0.240	-1.447	-0.030	84.0	84.9	0.9
61904029	**US06x3**	24	4750	34.35	0.251	0.0249	8.03	10610.38	1.142593	3640.065	3598.944	11.81662	11.78881	-0.043447	0.235889	0.482446	0.349	23.0	10.22	0.348	23.0	10.21	-52.000	-359.921	-6.476	90.260	542.897	11.241	-0.220	-1.233	-0.027	82.3	86.1	3.8
61904030	**SSS 55mph**	26	4750	34.35	0.251	0.0249	9.18	8808.582	5.77433	520.1389	491.744	8.75471	8.767332	-0.087221	-0.143964	0.075397	0.268	34.3	6.86	0.269	34.1	6.90	-3.000	-19.247	-0.327	89.269	536.047	9.729	-0.310	-1.982	-0.034	77.0	77.0	0.0
61904031	**SSS 30mph**	20	4750	34.35	0.251	0.0249	5.02	2621.555	39.95065	375.3812	268.224	2.50961	2.499137	0.210532	0.419063	0.078695	0.082	60.9	3.86	0.082	61.4	3.83	156.000	940.102	31.089	89.319	535.426	17.800	-12.404	-74.361	-2.472	66.5	35.9	(30.6)
61904032	**SSS 45mph**	25	4750	34.35	0.251	0.0249	7.51	5896.742	20.2541	483.8255	402.336	5.60201	5.602853	-0.005733	-0.015054	0.078979				0.190	39.5	5.96	-33.574	-201.904	-4.470	82.869	496.408	11.034	-0.740	-4.400	-0.099	25.8	26.5	0.7
61904033	**SSS 60mph**	26	4750	34.35	0.251	0.0249	10.04	10483.15	3.91706	557.461	536.448	10.79479	10.74504	0.255216	0.463032	0.073213				0.317	31.7	7.43	-69.642	-420.767	-6.939	88.882	533.489	8.857	-0.538	-3.243	-0.054	38.9	50.9	12.0
Day 4 - 72F Testing / WLTP / Tier III LO																																
61904035	**WLTP**	22	4750	34.35	0.251	0.0249	1.93	1227.849	1.240875	2023.902	1999.096	1.804993	1.781559	0.681523	1.315333	0.792936	0.089	21.7	10.82	0.088	21.9	10.75	7.000	53.001	3.634	85.816	525.256	44.550	-1.357	-8.176	-0.704	71.3	68.1	(3.2)
61904035	**WLTP**	22	4750	34.35	0.251	0.0249	2.95	2415.664	2.041949	1895.846	1857.909	3.000816	3.022327	-0.935504	-0.71174	0.682738	0.093	31.7	7.42	0.093	31.8	7.39	-99.000	-814.200	-33.506	59.976	499.008	20.298	-0.080	-0.667	-0.027	68.1	82.9	14.8
61904035	**WLTP**	24	4750	34.35	0.251	0.0249	4.40	2128.054	1.27005	1647.98	1627.312	4.357757	4.371661	-0.541803	-0.318029	0.488911	0.129	34.2	6.88	0.128	34.3	6.85	-14.000	-127.394	-3.184	64.055	506.444	14.567	-0.080	-0.685	-0.018	82.9	82.9	0.0
61904035	**WLTP**	26	4750	34.35	0.251	0.0249	5.13	1874.391	3.052043	1023.708	993.3892	6.865065	6.86688	-0.030875	-0.026438	0.328982	0.187	27.4	8.57	0.188	27.3	8.61	48.000	537.264	9.358	45.856	512.909	8.940	-0.060	-0.536	-0.012	82.9	70.5	(12.4)
61904036	**WLTP Hot Start**	20	4750	34.35	0.251	0.0249	1.91	1228.837	2.254652	2044.185	1999.112	1.801689	1.781583	1.155596	1.128563	0.792934	0.036	53.3	4.42	0.035	54.8	4.29	191.000	1182.661	99.813	96.617	591.478	50.490	-18.965	-116.193	-9.911	70.8	32.3	(38.5)
61904036	**WLTP Hot Start**	23	4750	34.35	0.251	0.0249	2.94	2416.666	1.37228	1883.453	1857.957	3.036637	3.022383	0.712945	0.471618	0.68274	0.102	28.7	8.19	0.103	28.6	8.22	-237.000	-1999.404	-80.582	62.005	515.832	21.082	-1.060	-8.746	-0.360	32.3	73.9	41.6
61904036	**WLTP Hot Start**	25	4750	34.35	0.251	0.0249	4.37	2128.903	2.39746	1666.356	1627.341	4.323217	4.371699	-0.76487	-1.108996	0.488914	0.132	33.2	7.08	0.131	33.4	7.05	-66.565	-524.624	-15.225	65.100	514.458	14.890	-0.160	-1.335	-0.037	73.8	83.2	9.4
61904036	**WLTP Hot Start**	25	4750	34.35	0.251	0.0249	5.11	1874.79	3.253663	1025.716	993.3939	6.830882	6.86689	-0.242906	-0.524371	0.328984	0.185	27.7	8.49	0.184	27.7	8.48	40.000	457.390	7.821	46.820	523.866	9.155	-0.060	-0.564	-0.012	83.2	72.4	(10.8)
61904037	**SSS 15mph**	20	4750	34.35	0.251	0.0249	4.06	395.8004	82.63154	244.9308	134.112	1.325364	1.348923	0.605657	-1.746519	0.036449				0.056	72.2	3.26	188.000	691.009	46.336	126.542	465.566	31.189	-5.690	-20.609	-1.402	77.1	40.3	(36.8)
61904038	**SSS 75mph**	33	4750	34.35	0.251	0.0249	12.51	16382	13.54999	761.4208	670.56	18.51073	18.52745	-0.054065	-0.09023	0.066344				0.506	24.7	9.51	-156.000	-936.907	-12.466	89.887	537.349	7.183	-1.600	-9.436	-0.128	22.1	50.5	28.4
Day 5 - 72F Testing / Performance / Tier III LO																																
61904039	**WOTS following 55mph warmup**	26	4750	34.35	0.251	0.0249	9.20	8805.656	7.430268	528.2819	491.744	8.805628	8.767331	0.255312	0.436815	0.075397				0.280	32.8	7.16	-3.000	-17.089	-0.326	87.341	523.898	9.497	-0.130	-1.008	-0.014	77.1	77.0	(0.2)
61904040	**Passing Maneuvers 0%**	23	4750	34.35	0.251	0.0249	3.35	18673.6	20.18822	1343.223	1117.6	5.242249	5.384486	-0.664432	-2.641613	0.457581				0.172	19.5	12.09	-120.000	-1735.072	-35.819	42.000	615.360	12.537	-4.833	-70.969	-1.443	63.6	77.5	13.8
61904041	**Passing Maneuvers 3%**	23	4750	34.35	0.251	0.0249	3.36	18684.19	17.49666	1313.143	1117.6	5.381298	5.384534	1.693495	-0.060101	0.457577				0.237	14.2	16.59	121.000	1773.111	36.029	42.363	620.013	12.614	-4.323	-63.219	-1.287	80.1	51.2	(28.9)
61904042	**Passing Maneuvers 6%**	24	4750	34.35	0.251	0.0249	3.44	18678.8	35.54593	1514.861	1117.6	5.77434	5.384526	6.242396	7.239523	0.457577				0.303	11.4	20.72	-83.853	-1153.066	-24.397	43.765	640.522	12.733	-4.979	-72.915	-1.449	52.4	60.4	8.0
61904043	**25% grade test**	27	4750	34.35	0.251	0.0249	5.46	0	Inf	699.6876	0	5.469742	0	NaN	Inf	NaN				0.414	13.2	17.84	-6.000	-51.248	-1.098	65.671	563.608	12.021	-6.086	-42.526	-1.114	73.6	67.7	(5.9)
61904044	**SSS 15, 30, 45, 60, 75 3% grade**	25	4750	34.35	0.251	0.0249	5.73	656.3789	397.2199	666.8316	134.112	4.624631	0.832112	58.81148	455.7703	0.059088				0.323	17.7	13.26	-96.252	-572.407	-16.796	92.409	554.209	16.126	-6.440	-38.682	-1.124	50.8	63.6	12.8
61904045	**SSS 60 & 75mph 3% grade**	26	4750	34.35	0.251	0.0249	8.66	0	Inf	802.4306	0	10.7187	0	NaN	Inf	NaN				0.517	16.7	14.05	129.783	898.044	14.983	80.436	564.800	9.286	-3.898	-26.921	-0.450	74.1	46.9	(27.2)
61904046	**55mph warmup**	26	4750	34.35	0.251	0.0249	4.60	17564.63	15.2583	566.7758	491.744	4.724361	4.715486	0.105243	0.188215	0.140183				0.153	30.0	7.84	-175.000	-2103.569	-38.036	44.769	535.530	9.731	-0.140	-1.527	-0.030	47.0	76.9	30.0
61904047	**SSS 15, 30, 45, 60, 75 6% grade**	23	4750	34.35	0.251	0.0249	4.55	1069.285	15.85789	776.8967	670.56	5.154127	5.108732	0.733042	0.888582	0.240605				0.381	11.9	19.69	194.000	1811.608	42.652	61.984	579.442	13.627	-4.563	-42.652	-1.003	94.1	56.6	(37.5)
61904048	**UDDS Prep**	21	4750	34.35	0.251	0.0249	7.41	2047.23	2.009781	5574.977	5465.14	7.136941	7.041254	1.916767	1.358953	0.64774	0.224	33.1	7.11	0.224	33.0	7.12	16.160	36.244	2.182	234.532	615.076	31.662	-6.203	-16.340	-0.837	56.0	43.8	(12.2)

																Liquid Fuel usage						Electric consumption [Wh/mi]								SOC		
Test ID [#]	Cycle	Test Cell Temp [C]	Test weight [lb]	Dyno Target A:	Dyno Target B:	Dyno Target C:	Cycle Distance [mi]	APCtime	ASCR	ASC_d	ASC_t	CE_d	CE_t	EER	ER	IWR	Cycle Fuel Consumed [gal] (Emiss Bag)	Cycle Fuel economy [mpg] (Emiss Bag)	Fuel Consumption Bag [l/100km]	Fuel used modal [gal]	Fuel Economy Modal [mpg]	Fuel Consumption Modal [l/100km]	HV Batt Δ [Wh]	HV Batt Average Power P1 [W]	HV Batt Energy consumption [Wh/mi]	DCDC Out Δ WP2 [Wh]	DCDC Out Average Power P2 [W]	DCDC Out Δ WP2 [Wh/mi]	12V Neg Out Δ WP2 [Wh]	12V Neg Out Average Power P2 [W]	12V Neg Out Δ WP2 [Wh/mi]	SOC init	SOC end	Delta SOC
Day 6 - 95F with solar/ Standard Cycles / Tier III LO																																
61904049	**UDDS x2**	36	4750	34.35	0.251	0.0249	3.58	2704.002	-0.016289	2048.581	2048.914	3.66072	3.673445	0.056577	-0.346418	0.585356	0.159	22.4	10.48	0.159	22.5	10.45	-183.000	-1303.971	-51.167	90.370	644.238	25.267	2.314	16.812	0.647	45.3	76.7	31.4
61904049	**UDDS x2**	34	4750	34.35	0.251	0.0249	3.85	1643.95	1.172054	3456.387	3416.345	3.349816	3.368158	-0.241776	-0.544557	0.715758	0.115	33.5	7.03	0.115	33.5	7.02	137.000	577.321	35.601	132.950	550.775	34.549	-2.685	-11.147	-0.698	76.7	45.5	(31.2)
61904049	**UDDSx2 1+2**	**35**					**7.42**										**0.274**	**27.06**	**8.69**	**0.274**	**27.13**	**8.67**	**-46.000**	-363.325	**-6.196**	**223.320**	597.507	**30.1**	**-0.371**	2.832	**0.0**			0.2
61904049	**UDDS x2**	37	4750	34.35	0.251	0.0249	3.59	2702.625	-0.315121	2042.44	2048.897	3.669205	3.673404	0.022146	-0.114305	0.585356	0.138	26.1	9.02	0.136	26.3	8.93	-128.000	-908.230	-35.693	90.540	645.424	25.247	-6.836	-48.573	-1.906	45.4	68.1	22.7
61904049	**UDDS x2**	34	4750	34.35	0.251	0.0249	3.87	1643.721	1.065774	3452.746	3416.335	3.376094	3.368112	-0.139172	0.237002	0.715764	0.123	31.6	7.44	0.122	31.8	7.40	75.000	307.208	19.358	135.500	561.639	34.973	-1.861	-7.819	-0.480	68.1	47.9	(20.2)
61904049	**UDDSx2 3+4**	**36**					**7.46**										**0.260**	**28.68**	**8.20**	**0.258**	**28.91**	**8.14**	**-53.000**	-300.511	**-7.104**	**226.040**	603.531	**30.3**	**-8.696**	-28.196	**-1.2**			2.5
61904050	**SC03x3**	37	4750	34.35	0.251	0.0249	3.59	2640.703	0.067935	2533.253	2531.533	3.746428	3.723136	0.232208	0.625603	0.688566	0.137	26.2	8.96	0.136	26.5	8.89	64.000	389.537	17.810	117.760	706.748	32.770	-5.644	-33.812	-1.571	47.8	32.3	(15.5)
61904050	**SC03x3**	36	4750	34.35	0.251	0.0249	3.59	2631.323	-0.044293	2530.389	2531.51	3.714693	3.723117	-0.497267	-0.226265	0.688562	0.159	22.5	10.45	0.159	22.6	10.40	-189.000	-1128.528	-52.659	117.720	703.530	32.799	-6.264	-37.364	-1.745	32.1	66.6	34.5
61904050	**SC03x3**	36	4750	34.35	0.251	0.0249	3.57	2636.015	1.764199	2576.119	2531.459	3.75717	3.723052	1.218186	0.916394	0.688556	0.136	26.3	8.96	0.135	26.4	8.91	-49.000	-281.074	-13.732	69.912	419.411	19.593	0.427	2.685	0.120	66.5	72.1	5.7
61904051	**HWYx2**	39	4750	34.35	0.251	0.0249	10.27	2184.008	2.708412	1342.202	1306.808	9.247755	9.166497	0.767863	0.886469	0.276528	0.333	30.8	7.63	0.334	30.8	7.64	-90.000	-423.072	-8.765	166.593	784.742	16.224	-10.986	-51.846	-1.070	70.0	86.2	16.2
61904051	**HWYx2**	38	4750	34.35	0.251	0.0249	10.28	2184.244	3.862849	1357.286	1306.806	9.239582	9.166484	0.597579	0.79744	0.276528	0.303	33.9	6.94	0.303	33.9	6.95	-32.000	-146.699	-3.114	127.800	600.954	12.436	-1.780	-8.194	-0.173	85.2	89.2	4.1
61904052	**US06x3**	39	4750	34.35	0.251	0.0249	7.93	10606.43	-1.534947	3543.657	3598.898	11.50814	11.78876	-1.396066	-2.380408	0.482436	0.356	22.3	10.56	0.355	22.3	10.54	26.000	169.111	3.281	122.669	737.555	15.478	-5.720	-34.947	-0.722	87.1	76.9	(10.2)
61904052	**US06x3**	39	4750	34.35	0.251	0.0249	8.00	10605.19	1.097902	3638.394	3598.881	11.74804	11.78872	-0.238842	-0.34509	0.482434	0.364	22.0	10.69	0.361	22.1	10.63	-34.000	-198.785	-4.251	108.789	654.690	13.601	-0.500	-3.239	-0.063	77.2	76.7	(0.4)
61904052	**US06x3**	39	4750	34.35	0.251	0.0249	8.00	10605.85	1.657576	3658.407	3598.755	11.74743	11.78858	-0.211587	-0.349069	0.482412	0.360	22.2	10.60	0.360	22.2	10.60	-39.000	-233.902	-4.877	105.449	633.834	13.188	-0.520	-3.225	-0.065	77.2	77.4	0.3
61904053	**SSS 55mph warmup**	39	4750	34.35	0.251	0.0249	9.19	8808.582	11.84444	549.9883	491.744	8.782846	8.76733	0.102678	0.176974	0.075397				0.287	32.0	7.34	-67.000	-401.840	-7.293	107.134	643.164	11.661	-0.250	-1.736	-0.027	64.6	76.9	12.3
61904054	**SSS 15mph warmup**	32	4750	34.35	0.251	0.0249	2.40	639.8977	79.56586	240.8194	134.112	0.814311	0.852332	2.30021	-4.460828	0.057686				0.058	41.2	5.71	18.000	153.905	7.508	96.876	568.742	40.409	-6.960	-32.163	-2.903	40.9	37.1	(3.9)
61904055	**SSS 30mph warmup**	37	4750	34.35	0.251	0.0249	5.02	2621.555	53.66067	412.1548	268.224	2.511379	2.499136	0.213407	0.489908	0.078695				0.113	44.3	5.31	-48.000	-286.374	-9.559	78.624	470.685	15.658	-1.040	-6.138	-0.207	26.5	32.9	6.4
61904056	**SSS 45mph warmup**	38	4750	34.35	0.251	0.0249	7.51	5896.742	22.32829	492.1707	402.336	5.608134	5.602855	0.100955	0.094214	0.078979				0.196	38.2	6.15	-15.000	-90.675	-1.997	89.135	533.958	11.868	-0.370	-2.146	-0.049	33.9	32.7	(1.2)
61904057	**SSS 60mph warmup**	40	4750	34.35	0.251	0.0249	10.03	5896.742	37.22612	552.1101	402.336	10.76442	5.602854	30.53071	92.12381	0.078979				0.321	31.3	7.52	-116.000	-692.022	-11.571	94.674	568.497	9.444	-1.050	-6.431	-0.105	29.1	50.8	21.7
61904058	**SSS 75mph warmup**	40	4750	34.35	0.251	0.0249	12.51	16382	16.95252	784.2368	670.56	18.47357	18.52745	-0.186542	-0.290827	0.066344				0.503	24.9	9.46	-145.502	-869.794	-11.635	106.414	637.517	8.509	-10.470	-62.762	-0.837	24.2	50.4	26.2
Day 7 - 20F / Standard Cycles / Tier III LO																																
61904059	**Idle Warm up**	22	4750	34.35	0.251	0.0249	0.00	0	NaN	0	0	0	0	NaN	NaN	NaN							-16.000	-42.408	-1024983.985	144.534	371.997	#########	-1.255	-3.224	#########	0.0	77.0	77.0
61904060	**HWYx2**	26	4750	34.35	0.251	0.0249	10.28	2184.314	4.212128	1361.867	1306.822	9.207121	9.166525	0.200481	0.442868	0.276531	0.314	32.7	7.19	0.314	32.8	7.18	-84.000	-398.778	-8.170	116.492	547.988	11.330	-4.697	-22.078	-0.457	77.5	93.0	15.5
61904060	**HWYx2**	25	4750	34.35	0.251	0.0249	10.28	2184.656	2.281315	1336.625	1306.813	9.177612	9.166503	-0.087645	0.121193	0.276529	0.288	35.6	6.60	0.288	35.7	6.59	-25.000	-133.525	-2.432	107.700	507.316	10.479	-0.120	-0.646	-0.012	67.7	86.1	18.4
61904061	**UDDS prep**	-7	4750	34.35	0.251	0.0249	7.40	2048.027	1.1461	5527.845	5465.209	7.022684	7.04137	0.38787	-0.265378	0.647742	0.281	26.3	8.94	0.281	26.4	8.93	32.000	79.759	4.323	285.902	749.847	38.623	-2.479	-6.550	-0.335	76.0	67.4	(8.6)
61904063	**UDDS x2**	-6	4750	34.35	0.251	0.0249	3.60	2702.246	1.336253	2076.275	2048.896	3.689892	3.673402	0.110791	0.448894	0.585357	0.136	26.5	8.89	0.134	26.9	8.74	4.403	31.288	1.222	117.259	836.401	32.544	-4.210	-30.013	-1.168	86.1	81.9	(4.1)
61904063	**UDDS x2**	-7	4750	34.35	0.251	0.0249	3.89	1643.73	2.43361	3499.499	3416.358	3.402376	3.368145	0.15467	1.016318	0.715761	0.115	33.8	6.97	0.115	33.8	6.96	171.000	710.587	43.924	156.569	648.743	40.217	-2.655	-11.021	-0.682	82.0	40.3	(41.7)
61904063	**UDDSx2 1+2**	**-6**					**7.50**										**0.251**	**29.81**	**7.89**	**0.249**	**30.09**	**7.82**	**175.403**	370.937	**23.399**	**273.828**	742.572	**36.5**	**-6.865**	-20.517	**-0.9**			(45.8)
61904063	**UDDS x2**	-6	4750	34.35	0.251	0.0249	3.60	2701.999	1.441655	2078.412	2048.874	3.711652	3.673381	0.675422	1.041844	0.58535	0.154	23.4	10.05	0.153	23.6	9.95	-210.000	-1491.651	-58.270	108.589	774.391	30.131	-3.585	-25.422	-0.995	40.2	76.9	36.7
61904063	**UDDS x2**	-7	4750	34.35	0.251	0.0249	3.89	1643.364	2.925398	3516.243	3416.302	3.384946	3.368068	-0.27145	0.501113	0.715764	0.116	33.6	7.00	0.116	33.4	7.04	109.000	443.648	28.022	145.621	603.176	37.437	-1.440	-5.979	-0.370	76.9	49.1	(27.8)
61904063	**UDDSx2 3+4**	**-6**					**7.49**										**0.270**	**27.79**	**8.46**	**0.269**	**27.87**	**8.44**	**-101.000**	-524.002	**-13.478**	**254.210**	688.783	**33.9**	**-5.025**	-15.701	**-0.7**			8.9
61904064	**HWYx3**	-4	4750	34.35	0.251	0.0249	10.27	2184.257	-1.067034	1292.868	1306.812	9.17232	9.1665	-0.049731	0.063492	0.276529	0.366	28.1	8.38	0.365	28.1	8.37	-244.000	-1143.164	-23.762	160.708	756.123	15.651	-4.220	-19.832	-0.411	49.8	90.2	40.4
61904064	**HWYx3**	-5	4750	34.35	0.251	0.0249	10.27	2180.879	5.247482	1375.378	1306.804	9.231343	9.166469	0.616087	0.707723	0.276528	0.326	31.5	7.46	0.325	31.6	7.45	-25.264	-137.903	-2.461	130.559	613.699	12.718	-0.980	-4.566	-0.095	89.7	89.2	(0.6)
61904064	**HWYx3**	-5	4750	34.35	0.251	0.0249	10.28	2220.725	6.643088	1393.618	1306.806	9.238397	9.170578	0.635303	0.739526	0.276405	0.328	31.3	7.50	0.326	31.5	7.46	-29.000	-136.853	-2.822	130.149	610.443	12.663	-0.510	-2.446	-0.050	88.8	91.2	2.4
61904065	**US06x2**	-5	4750	34.35	0.251	0.0249	1.78	6269.657	0.290741	2466.681	2459.53	3.614945	3.604476	-0.096947	0.290452	0.810487	0.115	15.4	15.25	0.115	15.4	15.23	-36.000	-527.723	-20.236	53.280	823.578	29.949	-1.548	-23.875	-0.870	89.6	86.1	4.3
61904065	**US06x2**	0	4750	34.35	0.251	0.0249	6.22	13331.44	6.127146	1208.942	1139.145	8.175553	8.183992	0.056034	-0.103108	0.337892	0.267	23.3	10.09	0.266	23.4	10.04	17.000	157.073	2.731	79.407	780.441	12.756	-1.940	-18.919	-0.312	76.4	68.6	(7.8)
61904065	**US06x2 1+2**	**-2**					**8.00**										**0.382**	**20.94**	**11.23**	**0.381**	**21.01**	**11.20**	**-19.000**	-185.325	**-2.374**	**132.687**	802.009	**16.6**	**-3.488**	-21.397	**-0.4**			(3.5)
61904065	**US06x2**	-6	4750	34.35	0.251	0.0249	1.77	6241.944	1.697185	2501.259	2459.517	3.644728	3.604458	1.312856	1.11724	0.810488	0.118	15.0	15.64	0.117	15.2	15.50	-93.000	-1426.171	-52.590	43.838	674.856	24.790	-0.428	-6.646	-0.242	83.2	87.5	14.1
61904065	**US06x2**	-1	4750	34.35	0.251	0.0249	6.22	13337.78	5.49653	1201.733	1139.121	8.185079	8.183933	0.221269	0.013997	0.337884	0.259	24.1	9.78	0.257	24.2	9.71	27.000	272.591	4.339	65.752	647.603	10.568	-0.590	-5.757	-0.095	78.2	68.4	(9.8)
61904065	**US06x2 3+4**	**-3**					**7.99**										**0.376**	**21.24**	**11.08**	**0.373**	**21.40**	**10.99**	**-66.000**	-576.790	**-8.260**	**109.589**	661.229	**13.7**	**-1.018**	-6.202	**-0.1**			4.3
61904066	**SSS 55mph**	-3	4750	34.35	0.251	0.0249	9.18	8808.582	10.08426	541.3327	491.744	8.777316	8.767333	0.065221	0.113865	0.075397				0.315	29.2	8.06	-9.000	-52.700	-0.980	131.912	789.275	14.362	-0.300	-1.587	-0.033	77.0	77.0	0.0
61904067	**SSS 15mph**	-9	0	0	0	0	4.98	0	191.3465	390.7306	134.112	0	0	NaN	NaN	NaN				0.129	38.5	6.11	-60.000	-179.447	-12.047	201.183	603.456	40.395	-0.260	-0.811	-0.052	65.4	72.0	6.5
61904068	**SSS 30mph**	-6	4750	34.35	0.251	0.0249	5.02	2621.555	43.30497	384.3783	268.224	2.515272	2.499136	0.352858	0.645647	0.078695				0.112	44.8	5.25	89.000	533.648	17.722	94.648	567.089	18.847	-0.080	-0.477	-0.016	63.9	39.7	(24.1)
61904069	**SSS 45mph**	-6	4750	34.35	0.251	0.0249	7.51	5896.742	17.60161	473.1536	402.336	5.599213	5.602856	-0.043114	-0.065013	0.078979				0.228	32.9	7.14	-172.000	-1025.901	-22.904	98.178	588.042	13.074	-0.060	-0.382	-0.008	42.0	63.7	21.7
61904070	**SSS 60mph**	-1	0	0	0	0	10.02	0	3.563719	555.5655	536.448	0	0	NaN	NaN	NaN				0.343	29.2	8.06	82.000	487.318	8.181	99.129	594.017	9.890	-0.040	-0.410	-0.004	66.6	50.5	(16.0)
61904071	**SSS 75mph**	1	4750	34.35	0.251	0.0249	12.51	16382	17.3641	786.9967	670.56	18.50566	18.52745	-0.074186	-0.117613	0.066344				0.535	23.4	10.07	-16.000	-94.229	-1.279	95.752	574.313	7.652	-0.040	-0.421	-0.003	50.9	50.2	(0.6)
61904072	**UDDS Prep**	-7	4750	34.35	0.251	0.0249	7.51	2049.432	1.937013	5571.196	5465.332	7.131839	7.041565	0.486886	1.282011	0.647745	0.229	32.7	7.19	0.228	32.9	7.15	108.000	278.074	14.381	250.976	657.140	33.420	-7.050	-18.398	-0.939	72.6	48.0	(24.6)

																	Liquid Fuel usage						Electric consumption [Wh/mi]								SOC		
Test ID [#]	Cycle	Test Cell Temp [C]	Test weight [lb]	Dyno Target A:	Dyno Target B:	Dyno Target C:	Cycle Distance [mi]	APCtime	ASCR	ASC_d	ASC_t	CE_d	CE_t	EER	ER	IWR	Cycle Fuel Consumed [gal] (Emiss Bag)	Cycle Fuel economy [mpg] (Emiss Bag)	Fuel Consumption Bag [l/100km]	Fuel used modal [gal]	Fuel Economy Modal [mpg]	Fuel Consumption Modal [l/100km]	HV Batt Δ [Wh]	HV Batt Average Power P1 [W]	HV Batt Energy consumption [Wh/mi]	DCDC Out Δ WP2 [Wh]	DCDC Out Average Power P2 [W]	DCDC Out Δ WP2 [Wh/mi]	12V Neg Out Δ WP2 [Wh]	12V Neg Out Average Power P2 [W]	12V Neg Out Δ WP2 [Wh/mi]	SOC init	SOC end	Delta SOC
Day 8 - 20F / Standard Cycles / Tier III LO																																	
61904073	**UDDS x2**	-6	4750	34.35	0.251	0.0249	3.58	2702.823	1.766379	2085.075	2048.884	3.681364	3.673402	0.639359	0.216744	0.585351	0.214	16.7	14.08	0.215	16.6	14.16	-234.000	-1672.815	-65.440	123.614	881.244	34.570	-5.598	-39.923	-1.566	49.1	84.8	35.7
61904073	**UDDS x2**	-7	4750	34.35	0.251	0.0249	3.85	1643.475	1.955494	3483.124	3416.318	3.367744	3.368105	0.339071	-0.010721	0.715761	0.161	23.9	9.82	0.159	24.2	9.70	-16.000	-66.753	-4.160	188.106	779.812	48.904	-1.070	-4.481	-0.278	84.8	77.5	(7.2)
61904073	**UDDSx2 1+2**	**-6**					**7.42**										**0.375**	**19.81**	**11.87**	**0.374**	**19.85**	**11.85**	**-250.000**	-869.784	**-33.683**	**311.720**	830.528	**42.0**	**-6.668**	-22.202	**-0.9**			28.4
61904073	**UDDS x2**	-6	4750	34.35	0.251	0.0249	3.58	2701.857	1.062298	2070.625	2048.86	3.685931	3.673369	0.654065	0.341961	0.585346	0.137	26.0	9.03	0.136	26.2	8.96	-19.000	-137.968	-5.308	119.394	851.677	33.353	-3.264	-23.266	-0.912	77.5	77.5	0.0
61904073	**UDDS x2**	-7	4750	34.35	0.251	0.0249	3.85	1643.255	2.54586	3503.264	3416.29	3.377719	3.368045	0.537992	0.287245	0.715765	0.123	31.3	7.52	0.122	31.6	7.44	67.000	274.312	17.402	160.152	663.075	41.596	-1.020	-4.184	-0.265	77.5	56.3	(21.2)
61904073	**UDDSx2 3+4**	**-6**					**7.43**										**0.261**	**28.51**	**8.25**	**0.258**	**28.78**	**8.17**	**48.000**	68.172	**6.460**	**279.546**	757.376	**37.6**	**-4.284**	-13.725	**-0.6**			(21.2)
Day 9 - 72F Testing / Standard Cycles with hood up and CSF/ Tier III LO																																	
61904074	**LA92x2**	24	4750	34.35	0.251	0.0249	9.80	4148.873	2.578956	7468.846	7281.07	12.2158	12.10665	1.0224	0.901632	0.635978	0.434	22.6	10.42	0.432	22.7	10.37	-181.000	-450.740	-18.463	210.220	529.078	21.444	-2.320	-5.866	-0.237	56.7	80.8	24.1
61904074	**LA92x2**	21	4750	34.35	0.251	0.0249	9.85	4091.06	0.549661	7320.974	7280.953	12.13427	12.10642	-0.107678	0.230069	0.635981	0.374	26.3	8.93	0.369	26.7	8.82	-41.000	-107.011	-4.163	203.151	504.125	20.626	0.369	0.907	0.037	80.5	78.5	(2.0)
61904075	**JC08x2**	23	4750	34.35	0.251	0.0249	5.10	1488.415	1.69281	3722.717	3660.748	4.653167	4.627516	-0.083595	0.554311	0.674909	0.148	34.5	6.82	0.148	34.4	6.84	55.000	163.013	10.779	171.056	511.090	33.524	-7.998	-23.840	-1.568	78.5	62.5	(16.0)
61904076	**UDDS x2**	22	4750	34.35	0.251	0.0249	3.61	2718.091	2.276898	2095.568	2048.916	3.738591	3.673382	1.344868	1.775179	0.585368	0.125	28.9	8.14	0.124	29.2	8.06	-127.000	-907.559	-35.223	82.790	591.911	22.961	-11.347	-81.098	-3.147	67.7	88.1	20.5
61904076	**UDDS x2**	23	4750	34.35	0.251	0.0249	3.90	1658.367	3.182642	3525.107	3416.376	3.416668	3.368112	0.35366	1.441653	0.715775	0.087	44.9	5.24	0.087	45.1	5.22	182.000	751.943	46.646	116.530	482.763	29.866	-0.440	-1.771	-0.113	88.1	48.6	(39.5)
61904076	**UDDSx2 1+2**	**23**					**7.51**										**0.212**	**35.48**	**6.63**	**0.210**	**35.73**	**6.58**	**55.000**	-77.808	**7.326**	**199.320**	537.337	**26.6**	**-11.787**	-41.434	**-1.6**			(19.1)
61904077	**UDDS x2**	21	4750	34.35	0.251	0.0249	3.62	2704.193	1.041774	2070.261	2048.916	3.737617	3.673452	1.051115	1.746738	0.585356	0.154	23.5	10.01	0.155	23.4	10.07	-228.000	-1618.563	-63.065	74.145	528.629	20.509	-1.300	-9.239	-0.360	0.0	88.2	88.2
61904077	**UDDS x2**	23	4750	34.35	0.251	0.0249	3.89	1644.068	2.53676	3503.032	3416.367	3.401249	3.368166	0.259714	0.98222	0.71576	0.087	44.9	5.24	0.086	45.4	5.18	201.000	837.865	51.702	113.035	468.342	29.075	0.005	0.006	0.001	88.2	44.6	(43.6)
61904077	**UDDSx2 1+2**	**22**					**7.50**										**0.240**	**31.20**	**7.54**	**0.240**	**31.21**	**7.54**	**-27.000**	-390.349	**-3.599**	**187.180**	498.486	**24.9**	**-1.295**	-4.616	**-0.2**			44.6
61904077	**UDDS x2**	22	4750	34.35	0.251	0.0249	3.60	2702.737	1.436941	2078.335	2048.893	3.70648	3.673413	0.534694	0.900172	0.585353	0.133	27.1	8.66	0.132	27.3	8.62	-159.000	-1130.093	-44.118	76.894	548.383	21.336	-6.415	-45.650	-1.780	44.6	72.4	27.8
61904077	**UDDS x2**	21	4750	34.35	0.251	0.0249	3.90	1643.826	2.449645	3500.037	3416.348	3.426294	3.36812	0.635502	1.72721	0.715765	0.096	40.5	5.80	0.096	40.7	5.77	114.000	469.956	29.219	115.681	479.402	29.649	0.000	-0.030	0.000	72.4	44.4	(28.0)
61904077	**UDDSx2 3+4**	**22**					**7.51**										**0.229**	**32.77**	**7.18**	**0.228**	**32.94**	**7.14**	**-45.000**	-330.069	**-5.996**	**192.576**	513.892	**25.7**	**-6.415**	-22.840	**-0.9**			(0.1)
61904078	**HWYx2**	23	4750	34.35	0.251	0.0249	10.27	2184.617	3.101112	1347.352	1306.826	9.199607	9.16653	0.218042	0.360848	0.276532	0.333	30.8	7.64	0.332	30.9	7.61	-279.000	-1317.511	-27.163	130.442	613.643	12.700	-9.346	-43.922	-0.910	44.8	90.3	45.5
61904078	**HWYx2**	22	4750	34.35	0.251	0.0249	10.27	2184.988	2.578386	1340.514	1306.82	9.16241	9.166511	-0.184598	-0.04474	0.276531	0.290	35.4	6.64	0.290	35.5	6.63	-6.000	-34.303	-0.584	120.697	568.411	11.751	-0.207	-1.039	-0.020	90.0	86.0	(4.0)
61904079	**Tip Ins- Sport Mode**	26	4750	34.35	0.251	0.0249	5.02	11480.91	13.12514	1163.144	1028.192	6.445508	6.535544	-0.708915	-1.377622	0.350242			#DIV/0!	0.203	24.7	9.51	-8.000	-87.110	-1.593	63.182	621.822	12.579	-10.075	-99.198	-2.006	85.0	78.4	(6.7)
Day 10 - 72F Testing / Performance / Tier III LO																																	
61905001	**Constant pedal tip ins 5-100%**	26	4750	34.35	0.251	0.0249	9.25	8805.656	11.08629	546.2602	491.744	8.917749	8.76733	0.961182	1.715684	0.075397	0.280	33.0	7.12	0.283	32.7	7.20	4.000	25.726	0.433	110.263	660.765	11.923	-23.157	-138.826	-2.504	77.0	77.0	(0.0)
61905002	**Dyno Accleration Ramps**	26	4750	34.35	0.251	0.0249	9.20	8805.656	10.09596	541.3903	491.744	8.807848	8.767331	0.261658	0.462142	0.075397				0.276	33.3	7.06	8.000	49.409	0.870	87.161	523.427	9.475	-0.280	-1.843	-0.030	78.6	76.9	(1.7)
61905003	**Onroad Cycle**	25	4750	34.35	0.251	0.0249	31.09	7379.207	0.303037	7799.243	7775.68	39.72086	38.93895	1.762198	2.008032	0.375849				1.203	25.8	9.10	-39.000	-66.452	-1.255	350.118	549.241	11.263	-10.436	-16.334	-0.336	89.7	80.1	(9.6)
61905004	**Power Cycles**	25	4750	34.35	0.251	0.0249	7.75	1938.286	-0.980111	5168.597	5219.757	11.0818	11.04752	0.088414	0.310256	0.676176				0.294	26.3	8.93	24.000	84.230	3.097	130.786	554.387	16.877	-7.397	-31.267	-0.954	78.5	68.6	(9.9)
61905005	**Min/Max SOC test**	23	4750	34.35	0.251	0.0249	17.19	0	Inf	1000.028	0	11.28854	0	NaN	Inf	NaN				0.543	31.7	7.42	130.000	296.543	7.560	322.188	679.686	18.738	-4.010	-8.282	-0.233	93.0	52.6	(40.4)
61905006	**Engine Mapping 1**	21	4750	34.35	0.251	0.0249	7.02	0	Inf	1101.583	0	3.42388	0	NaN	Inf	NaN				0.406	17.3	13.62	102.000	267.192	14.528	199.201	521.826	28.372	-0.480	-0.049	-0.068	94.7	74.4	(20.3)
61905007	**Engine Mapping 2**	26	4750	34.35	0.251	0.0249	9.20	8805.656	11.60436	548.8078	491.744	8.808273	8.767329	0.265488	0.467011	0.075397				0.281	32.8	7.17	-3.000	-16.087	-0.326	87.340	523.937	9.495	-0.200	-1.298	-0.022	77.0	77.0	(0.1)
61905008	**Engine Mapping 3**	24	4750	34.35	0.251	0.0249	14.91	0	Inf	884.2925	0	10.58869	0	NaN	Inf	NaN				1.002	14.9	15.81	-124.000	-219.619	-8.319	316.656	560.906	21.243	-4.838	-8.325	-0.325	74.9	92.4	17.6

																Liquid Fuel usage						Electric consumption [Wh/mi]								SOC		
Test ID [#]	Cycle	Test Cell Temp [C]	Test weight [lb]	Dyno Target A:	Dyno Target B:	Dyno Target C:	Cycle Distance [mi]	APCtime	ASCR	ASC_d	ASC_t	CE_d	CE_t	EER	ER	IWR	Cycle Fuel Consumed [gal] (Emiss Bag)	Cycle Fuel economy [mpg] (Emiss Bag)	Fuel Consumption Bag [l/100km]	Fuel used modal [gal]	Fuel Economy Modal [mpg]	Fuel Consumption Modal [l/100km]	HV Batt Δ [Wh]	HV Batt Average Power P1 [W]	HV Batt Energy consumption [Wh/mi]	DCDC Out Δ WP2 [Wh]	DCDC Out Average Power P2 [W]	DCDC Out Δ WP2 [Wh/mi]	12V Neg Out Δ WP2 [Wh]	12V Neg Out Average Power P2 [W]	12V Neg Out Δ WP2 [Wh/mi]	SOC init	SOC end	Delta SOC
Day 11- FUEL SWAP / - 72F Testing / Standard cycles/ Tier II HO																																
61905009	**Octane Adjustment Cycle**																															
61905010	**UDDS x2**	24	4750	34.35	0.251	0.0249	3.59	2704.37	0.973959	2068.884	2048.928	3.659679	3.673456	-0.21059	-0.375034	0.58536	0.156	23.0	10.23	0.156	23.0	10.24	-205.000	-1462.206	-57.182	76.434	545.326	21.320	-2.894	-20.510	-0.807	46.1	80.7	34.6
61905010	**UDDS x2**	22	4750	34.35	0.251	0.0249	3.85	1644.184	1.453114	3466.031	3416.387	3.349744	3.368192	-0.242003	-0.547709	0.715761	0.089	43.0	5.46	0.090	42.8	5.50	149.000	608.240	38.721	114.066	472.577	29.642	-0.206	-0.842	-0.054	80.7	46.2	(34.5)
61905010	**UDDSx2 1+2**	**23**					**7.43**										**0.245**	**30.29**	**7.76**	**0.246**	**30.21**	**7.79**	**-56.000**	-426.983	**-7.534**	**190.499**	508.952	**25.6**	**-3.100**	-10.676	**-0.4**			0.2
61905010	**UDDS x2**	23	4750	34.35	0.251	0.0249	3.61	2703.026	1.89205	2087.668	2048.901	3.747596	3.673412	1.50752	2.019482	0.585357	0.137	26.4	8.93	0.136	26.5	8.88	-214.000	-1524.894	-59.308	77.965	555.657	21.607	-6.393	-45.446	-1.772	46.2	84.0	37.8
61905010	**UDDS x2**	22	4750	34.35	0.251	0.0249	3.90	1643.966	1.813215	3478.293	3416.347	3.418354	3.368125	0.359239	1.491305	0.715765	0.088	44.4	5.30	0.087	44.6	5.27	161.000	663.254	41.246	113.747	471.695	29.141	-0.078	-0.392	-0.020	84.0	48.3	(35.7)
61905010	**UDDSx2 3+4**	**23**					**7.51**										**0.225**	**33.41**	**7.04**	**0.224**	**33.58**	**7.01**	**-53.000**	-430.820	**-7.056**	**191.712**	513.676	**25.5**	**-6.471**	-22.919	**-0.9**			2.1
61905011	**UDDS #3 HS**	22	4750	34.35	0.251	0.0249	3.90	1657.314	1.042806	3451.934	3416.308	3.381763	3.368006	-0.578301	0.408461	0.715776	0.086	45.3	5.20	0.085	45.8	5.13	162.000	674.122	41.559	114.538	474.627	29.383	-0.570	-2.416	-0.146	80.1	44.1	(36.0)
61905011	**UDDS #3 HS**	**23**					**7.51**										**0.212**	**35.48**	**6.63**	**0.208**	**36.06**	**6.52**	**-23.000**	-327.464	**-3.063**	**194.377**	522.557	**25.9**	**-10.052**	-35.063	**-1.3**			(4.2)
61905012	**HWYx2**	25	4750	34.35	0.251	0.0249	10.28	2184.228	2.722826	1342.401	1306.819	9.241224	9.166516	0.616598	0.815013	0.27653	0.327	31.5	7.48	0.325	31.6	7.44	-251.000	-1182.850	-24.425	113.920	536.780	11.085	-0.310	-1.475	-0.030	44.4	88.4	44.1
61905012	**HWYx2**	25	4750	34.35	0.251	0.0249	10.27	2184.547	2.180047	1335.301	1306.812	9.175868	9.166491	-0.027517	0.102289	0.276529	0.287	35.8	6.56	0.285	36.1	6.52	-14.000	-66.089	-1.363	112.619	529.938	10.966	-0.240	-1.140	-0.023	88.1	89.0	0.9
61905013	**US06x2**	23	4750	34.35	0.251	0.0249	1.79	6273.538	0.741855	2477.848	2459.601	3.679349	3.604566	1.166486	2.074687	0.810495	0.119	15.0	15.64	0.118	15.1	15.56	-134.000	-2080.269	-74.953	37.230	576.154	20.824	-0.543	-8.479	-0.304	76.6	88.5	21.8
61905013	**US06x2**	27	4750	34.35	0.251	0.0249	6.25	13345.56	6.039798	1208.237	1139.418	8.192268	8.184381	-0.174663	0.096358	0.337982	0.241	26.0	9.05	0.240	26.1	9.01	33.000	320.262	5.279	54.346	535.166	8.693	-0.160	-1.710	-0.026	79.7	69.8	(9.9)
61905013	**US06x2 1+2**	**25**					**8.04**										**0.359**	**22.37**	**10.51**	**0.358**	**22.47**	**10.47**	**-101.000**	-880.003	**-12.563**	**91.576**	555.660	**11.4**	**-0.703**	-5.095	**-0.1**			11.9
61905013	**US06x2**	23	4750	34.35	0.251	0.0249	1.79	6245.937	1.156345	2488.023	2459.582	3.681806	3.604549	1.325257	2.143314	0.810492	0.110	16.2	14.54	0.111	16.1	14.61	-67.444	-1028.810	-37.760	37.212	572.217	20.834	-0.110	-1.555	-0.062	86.4	85.6	8.8
61905013	**US06x2**	27	4750	34.35	0.251	0.0249	6.25	13350	-1.924783	1117.445	1139.375	8.210996	8.184305	0.088213	0.326119	0.337969	0.236	26.5	8.88	0.236	26.5	8.87	36.444	325.236	5.831	54.624	536.171	8.740	-0.160	-1.348	-0.026	79.0	69.3	(9.7)
61905013	**US06x2 3+4**	**25**					**8.04**										**0.346**	**23.21**	**10.14**	**0.347**	**23.19**	**10.14**	**-31.000**	-351.787	**-3.858**	**91.836**	554.194	**11.4**	**-0.270**	-1.451	**0.0**			(0.9)
61905014	**SSS 15mph**	22	4750	34.35	0.251	0.0249	3.82	421.9278	85.26919	248.4682	134.112	1.259598	1.26831	1.339175	-0.686906	0.038766				0.043	88.0	2.67	187.000	726.911	48.972	115.774	453.646	30.319	-2.554	-9.802	-0.669	75.3	39.0	(36.3)
61905015	**SSS 30mph**	24	4750	34.35	0.251	0.0249	5.02	2621.555	37.99164	370.1267	268.224	2.507238	2.499136	0.101935	0.324201	0.078695				0.104	48.3	4.87	-83.267	-499.170	-16.592	78.797	472.271	15.701	-0.880	-5.330	-0.175	28.3	39.8	11.5
61905016	**SSS 45mph**	25	4750	34.35	0.251	0.0249	7.51	5896.742	23.86502	498.3536	402.336	5.594393	5.602856	-0.129825	-0.151043	0.078979				0.185	40.6	5.80	-51.461	-304.094	-6.853	82.934	496.841	11.044	-0.840	-5.009	-0.112	30.9	33.4	2.5
61905017	**SSS 60mph**	26	4750	34.35	0.251	0.0249	10.03	10483.15	4.705519	561.6907	536.448	10.77602	10.74503	0.162207	0.288382	0.073213				0.310	32.3	7.28	-36.000	-214.506	-3.590	89.053	532.297	8.881	-0.800	-4.635	-0.080	44.2	50.8	6.6
61905018	**SSS 75mph**	27	4750	34.35	0.251	0.0249	12.51	16382	18.58772	795.2018	670.56	18.51231	18.52745	-0.023296	-0.081739	0.066344				0.489	25.6	9.20	-9.000	-49.351	-0.719	88.983	534.518	7.112	-1.060	-6.527	-0.085	50.5	50.5	0.1
61905019	**UDDS Prep**	19	4750	34.35	0.251	0.0249	7.51	2048.738	1.560629	5550.578	5465.285	7.135511	7.041478	0.488328	1.335415	0.647744	0.191	39.4	5.97	0.190	39.6	5.95	127.000	344.632	16.903	193.403	507.144	25.741	-6.833	-17.883	-0.909	76.2	46.7	(29.4)
Day 12 - 72F Testing / Standard and performance cycles/ Tier II HO																																
61905020	**UDDS x2**	21	4750	34.35	0.251	0.0249	3.58	2701.42	1.296139	2075.427	2048.871	3.691108	3.673375	0.758554	0.482732	0.585349	0.152	23.6	9.98	0.153	23.5	10.02	-241.000	-1726.565	-67.300	77.109	549.578	21.533	-4.439	-31.553	-1.240	47.4	88.8	41.4
61905020	**UDDS x2**	22	4750	34.35	0.251	0.0249	3.84	1643.114	2.287082	3494.442	3416.308	3.380549	3.368066	0.842355	0.370634	0.715764	0.083	46.3	5.08	0.083	46.5	5.05	220.000	910.710	57.268	113.340	469.581	29.503	-0.180	-0.772	-0.047	88.8	41.5	(47.3)
61905020	**UDDSx2 1+2**	**21**					**7.42**										**0.235**	**31.60**	**7.44**	**0.235**	**31.57**	**7.45**	**-21.000**	-407.928	**-2.829**	**190.448**	509.580	**25.7**	**-4.619**	-16.162	**-0.6**			(5.9)
61905020	**UDDS x2**	23	4750	34.35	0.251	0.0249	3.61	2701.147	1.625643	2082.146	2048.839	3.730784	3.673336	0.894484	1.563896	0.585342	0.134	27.0	8.71	0.132	27.3	8.61	-100.000	-716.404	-27.666	77.498	552.314	21.441	-6.448	-45.887	-1.784	41.5	58.9	17.4
61905020	**UDDS x2**	22	4750	34.35	0.251	0.0249	3.89	1642.921	2.606875	3505.331	3416.273	3.417233	3.368003	0.603814	1.461673	0.715768	0.116	33.4	7.04	0.116	33.5	7.03	43.000	168.478	11.046	118.532	491.504	30.450	-0.220	-0.942	-0.057	58.9	45.2	(13.7)
61905020	**UDDSx2 3+4**	**22**					**7.51**										**0.250**	**29.99**	**7.84**	**0.249**	**30.19**	**7.79**	**-57.000**	-273.963	**-7.593**	**196.030**	521.909	**26.1**	**-6.668**	-23.415	**-0.9**			3.7
61905021	**HWYx2**	23	4750	34.35	0.251	0.0249	10.28	2183.819	3.181013	1348.375	1306.805	9.294105	9.166491	1.173843	1.392172	0.276528	0.321	32.0	7.35	0.320	32.1	7.32	-250.000	-1185.729	-24.325	133.503	628.131	12.990	-10.744	-50.462	-1.045	44.9	87.5	42.5
61905021	**HWYx2**	23	4750	34.35	0.251	0.0249	10.28	2184.083	3.581694	1353.608	1306.803	9.247617	9.166468	0.633373	0.885284	0.276528	0.280	36.7	6.42	0.279	36.9	6.38	-11.000	-72.866	-1.070	120.575	567.670	11.727	-0.380	-1.842	-0.037	87.2	83.9	(3.2)
61905022	**WOTs**	25	4750	34.35	0.251	0.0249	3.99	0	Inf	3644.132	0	8.319543	0	NaN	Inf	NaN				0.276	14.5	16.26	-61.000	-577.737	-15.287	62.814	645.533	15.742	-4.925	-49.055	-1.234	84.2	93.9	9.6
61905023	**Accessory Load Test**	22	4750	34.35	0.251	0.0249	0.21	0	Inf	341.6251	0	0.261497	0	NaN	Inf	NaN							207.000	318.877	987.708	165.050	254.053	787.542	8.860	13.679	42.276	88.9	50.2	(38.6)
61905024	**Passing Maneuvers**	23	4750	34.35	0.251	0.0249	5.01	424.4706	4.079889	511.8066	491.744	4.808931	4.798618	0.096082	0.21491	0.137754				0.180	27.9	8.44	-247.000	-2465.956	-49.307	55.009	549.548	10.981	-1.130	-11.463	-0.226	50.8	92.5	41.7
61905025	**UDDS x2**	20	4750	34.35	0.251	0.0249	3.61	2702.783	1.114118	2071.715	2048.888	3.724091	3.673415	0.735722	1.379528	0.58535	0.117	30.8	7.64	0.117	30.9	7.60	-97.000	-684.162	-26.842	80.929	577.133	22.395	-9.240	-65.810	-2.557	61.2	80.1	18.9
61905025	**UDDS x2**	22	4750	34.35	0.251	0.0249	3.89	1643.456	1.527523	3468.514	3416.329	3.402248	3.368108	0.168682	1.013617	0.715761	0.090	43.3	5.43	0.090	43.3	5.44	129.000	532.214	33.141	116.650	483.155	29.968	-1.290	-5.349	-0.331	80.1	50.7	(29.4)
61905025	**UDDSx2 1+2**	**21**					**7.51**										**0.207**	**36.23**	**6.49**	**0.207**	**36.31**	**6.48**	**32.000**	-75.974	**4.263**	**197.580**	530.144	**26.3**	**-10.530**	-35.580	**-1.4**			(10.5)
61905025	**UDDS x2**	23	4750	34.35	0.251	0.0249	3.61	2701.737	1.351828	2076.56	2048.863	3.72125	3.673362	0.880249	1.303643	0.585348	0.122	29.7	7.93	0.120	30.0	7.83	-158.000	-1137.035	-43.818	79.138	564.524	21.947	-6.039	-43.031	-1.675	50.6	78.0	27.4
61905025	**UDDS x2**	22	4750	34.35	0.251	0.0249	3.89	1643.187	1.392137	3463.849	3416.29	3.403434	3.368036	0.150545	1.050993	0.715766	0.089	43.9	5.36	0.089	43.7	5.39	148.000	613.671	38.001	119.812	496.285	30.763	-1.162	-4.858	-0.298	78.0	44.9	(33.1)
61905025	**UDDSx2 3+4**	**22**					**7.50**										**0.210**	**35.67**	**6.59**	**0.209**	**35.84**	**6.56**	**-10.000**	-261.682	**-1.333**	**198.950**	530.405	**26.5**	**-7.201**	-23.944	**-1.0**			(5.7)

																Liquid Fuel usage						Electric consumption [Wh/mi]								SOC		
Test ID [#]	Cycle	Test Cell Temp [C]	Test weight [lb]	Dyno Target A:	Dyno Target B:	Dyno Target C:	Cycle Distance [mi]	APCtime	ASCR	ASC_d	ASC_t	CE_d	CE_t	EER	ER	IWR	Cycle Fuel Consumed [gal] (Emiss Bag)	Cycle Fuel economy [mpg] (Emiss Bag)	Fuel Consumption Bag [l/100km]	Fuel used modal [gal]	Fuel Economy Modal [mpg]	Fuel Consumption Modal [l/100km]	HV Batt Δ [Wh]	HV Batt Average Power P1 [W]	HV Batt Energy consumption [Wh/mi]	DCDC Out Δ WP2 [Wh]	DCDC Out Average Power P2 [W]	DCDC Out Δ WP2 [Wh/mi]	12V Neg Out Δ WP2 [Wh]	12V Neg Out Average Power P2 [W]	12V Neg Out Δ WP2 [Wh/mi]	SOC init	SOC end	Delta SOC
Day 13 - 72F Testing / Standard Cycles with hood up and CSF/ Tier II HO																																
61905026	**UDDS x2**	22	4750	34.35	0.251	0.0249	3.61	2700.557	0.984438	2068.997	2048.828	3.703381	3.673325	0.348585	0.818232	0.585339	0.153	23.6	9.97	0.153	23.5	10.00	-235.000	-1669.772	-65.137	74.232	529.890	20.576	-2.132	-15.346	-0.591	0.0	85.6	85.6
61905026	**UDDS x2**	23	4750	34.35	0.251	0.0249	3.89	1642.473	1.899809	3481.155	3416.253	3.421925	3.367989	0.719835	1.601435	0.715765	0.085	45.7	5.15	0.085	45.8	5.14	192.000	782.584	49.313	112.878	467.504	28.992	-0.919	-3.749	-0.236	85.6	44.2	(41.4)
61905026	**UDDSx2 1+2**	**22**					**7.50**										**0.238**	**31.49**	**7.47**	**0.238**	**31.46**	**7.48**	**-43.000**	-443.594	**-5.732**	**187.110**	498.697	**24.9**	**-3.051**	-9.548	**-0.4**			44.2
61905026	**UDDS x2**	22	4750	34.35	0.251	0.0249	3.58	2700.233	2.953337	2109.314	2048.806	3.727241	3.673295	1.868975	1.468592	0.585335	0.125	28.6	8.22	0.123	29.0	8.11	-194.000	-1374.472	-54.256	78.007	556.637	21.816	-7.607	-54.345	-2.127	44.6	77.6	33.0
61905026	**UDDS x2**	21	4750	34.35	0.251	0.0249	3.84	1642.278	0.384447	3429.347	3416.213	3.34293	3.367926	-0.167866	-0.742197	0.715768	0.082	47.0	5.01	0.082	47.0	5.00	170.000	700.689	44.298	114.689	474.801	29.885	-1.049	-4.277	-0.273	77.6	39.7	(37.9)
61905026	**UDDSx2 3+4**	**22**					**7.41**										**0.207**	**35.87**	**6.56**	**0.205**	**36.17**	**6.50**	**-24.000**	-336.892	**-3.237**	**192.696**	515.719	**26.0**	**-8.656**	-29.311	**-1.2**			(4.9)
61905027	**UDDS x2**	21	4750	34.35	0.251	0.0249	3.61	2716.164	-0.216365	2044.429	2048.862	3.705362	3.673294	0.272393	0.873017	0.58536	0.129	28.1	8.38	0.128	28.2	8.35	-235.000	-1671.467	-65.052	92.069	658.020	25.486	-20.990	-149.940	-5.810	40.1	81.1	41.0
61905027	**UDDS x2**	22	4750	34.35	0.251	0.0249	3.89	1657.247	1.472941	3466.618	3416.298	3.410647	3.367996	0.47795	1.26636	0.715776	0.085	45.5	5.16	0.086	45.5	5.17	169.000	709.504	43.444	117.270	486.371	30.146	-2.700	-11.240	-0.694	81.1	44.1	(37.0)
61905027	**UDDSx2 1+2**	**21**					**7.50**										**0.214**	**35.03**	**6.71**	**0.214**	**35.11**	**6.70**	**-66.000**	-480.982	**-8.797**	**209.339**	572.196	**27.9**	**-23.690**	-80.590	**-3.2**			4.0
61905028	**UDDS x2**	21	4750	34.35	0.251	0.0249	3.61	2717.713	1.213089	2073.753	2048.898	3.711658	3.673368	0.472116	1.042351	0.585364	0.130	27.7	8.48	0.129	28.0	8.39	-172.000	-1236.115	-47.628	149.280	1066.977	41.337	-78.122	-558.285	-21.633	44.3	73.6	29.3
61905028	**UDDS x2**	22	4750	34.35	0.251	0.0249	3.89	1658.036	1.685213	3473.937	3416.364	3.398646	3.368088	0.189858	0.907256	0.715775	0.095	40.9	5.75	0.095	41.1	5.73	120.000	496.430	30.868	133.659	553.464	34.382	-17.762	-73.554	-4.569	73.6	45.5	(28.1)
61905028	**UDDSx2 1+2**	**21**					**7.50**										**0.225**	**33.30**	**7.06**	**0.223**	**33.57**	**7.01**	**-52.000**	-369.843	**-6.934**	**282.939**	810.221	**37.7**	**-95.884**	-315.920	**-12.8**			1.2
61905029	**UDDS x2**	22	4750	34.35	0.251	0.0249	3.60	2717.623	2.25492	2095.113	2048.911	3.71447	3.673377	0.89427	1.118688	0.585367	0.125	28.9	8.14	0.123	29.2	8.05	-217.000	-1547.277	-60.299	77.624	554.422	21.570	-5.957	-42.524	-1.655	0.0	83.3	83.2
61905029	**UDDS x2**	21	4750	34.35	0.251	0.0249	3.87	1658.231	2.199523	3491.5	3416.357	3.415191	3.368097	1.012528	1.39823	0.715772	0.086	44.8	5.25	0.086	45.3	5.20	158.000	671.604	40.782	116.949	484.571	30.186	-1.570	-6.517	-0.405	83.3	49.0	(34.3)
61905029	**UDDSx2 1+2**	**22**					**7.47**										**0.211**	**35.42**	**6.64**	**0.209**	**35.79**	**6.57**	**-59.000**	-437.836	**-7.895**	**194.573**	519.496	**26.0**	**-7.527**	-24.521	**-1.0**			48.9
End of Test																																

Appendix F: Test ID to Figure Matrix

This appendix specifies which test IDs were used to make the figures in the report.

Figure #	**Test IDs**
Figure 1: 2019 Acura MDX Sport Hybrid powertrain architecture	Not applicable
Figure 2: Distribution of horsepower and equivalent test weight among comparable vehicles in test group	Not applicable
Figure 3: Distribution of unadjusted FTP fuel economy for comparison vehicles	Not applicable
Figure 4: Distribution of unadjusted HWFET fuel economy for comparison vehicles	Not applicable
Figure 5: Vehicle mounted for full testing inside the AMTL 4WD chassis dynamometer.	Not applicable
Figure 6: Overview of general instrumentation for a hybrid vehicle	Not applicable
Figure 8: Wiring of Hioki power analyzer measurement on the Acura MDX Sport Hybrid	Not applicable
Figure 9: CAN breakout on the 2019 Acura MDX Sport Hybrid	Not applicable
Figure 10: Overview of steady state drive cycle with preparation	61904044
Figure 11: Vehicle acceleration with varying constant pedal inputs	61905001
Figure 12: Constant acceleration ramp cycles with varying accelerator pedal inputs	61905002
Figure 13: Example of engine mapping operation with fixed engine speed and varying pedal inputs	61905006
Figure 14: Acura MDX Sport Hybrid test vehicle mounted to the chassis dynamometer	Not applicable
Figure 15: Overview of 2019 Acura MDX Sport Hybrid powertrain operation	61904015
Figure 16: Daily drive cycle test sequence executed in the morning	61904015. 61904016, 61904017, 61904018
Figure 17: Raw fuel economy results: UDDS and HWFET certification cycles	Tier 2 – 93 AKI: • TS#1: 61905010, 61905011, 61905012, 61905013 • TS#2: 61905020, 61905021 (EPA style testing) Tier 3 – 88 AKI: • TS#1: 61904015. 61904016, 61904017, 61904018 • TS#2: 61904020, 61904021, 61904022, 61904023 • TS#3: 61904025, 61904026, 61904028, 61904029
Figure 18: Raw fuel economy results for certification cycles across different temperature conditions	72F avg: • TS#1: 61904015. 61904016, 61904017, 61904018 • TS#2: 61904020, 61904021, 61904022, 61904023

Figure #	Test IDs
	• TS#3: 61904025, 61904026, 61904028, 61904029 20F: • 61904073, 61904063, 61904064, 61904065 95F: • 61904049, 61904050 (SC03 instead of UDDS#3), 61904051, 61904052
Figure 19: Engine operation on the UDDS across different temperatures	• 20F: 61904073 • 72F: 61904015 • 95F: 61904049
Figure 20: Powertrain and cabin temperature profiles across different temperature	• 20F: 61904073, 61904063, 61904064, 61904065 • 72F: 61904015. 61904016, 61904017, 61904018 • 95F: 61904049, 61904050 (SC03 instead of UDDS#3), 61904051, 61904052
Figure 21: Steady state speed operation at 23°C °C and 0% grade, Tier 3 low-octane fuel	61904030, 61904031, 61904032, 61904033, 61904037, 61904038
Figure 22: Steady state speed operation at 23 °C and 0% grade, Tier 2 high-octane fuel	61905014 61905015 61905016 61905017 61905018
Figure 23: Powertrain operation during the 55 mph to 80 mph passing maneuver	61904040
Figure 24: Powertrain operation during maximum acceleration	61904039
Figure 25: Acura MDX continuous power test on simulated 25% grade	61904043
Figure 26: Fuel energy consumption as a function of battery net energy change	Tier 2 – 93 AKI: • TS#1: 61905010, 61905011, 61905012, 61905013 Tier 3 – 88 AKI: • TS#1: 61904015. 61904016, 61904017, 61904018 • TS#2: 61904020, 61904021, 61904022, 61904023 TS#3: 61904025, 61904026, 61904028, 61904029
Figure 27: Spark advance comparison of Tier 2 and Tier 3 fuels	All tests split into Tier 2 and Tier 3 batches
Figure 28 Schematic of the vehicle configuration	AUTONOMIE
Figure 29: Calculation of missing signals for component	AUTONOMIE

Figure #	Test IDs
Figure 30: Engine speed and gear numbers observed during the tests	AUTONOMIE
Figure 31: Overview of hybrid operating modes	AUTONOMIE
Figure 32: Engine fuel rate map of engine speed vs torque	AUTONOMIE
Figure 33: Engine ON instances and their dependence on vehicle operating conditions	AUTONOMIE
Figure 34. Engine ON/OFF and fuel cutoff instances from test data	AUTONOMIE
Figure 35: Battery characteristics observed from test data	AUTONOMIE
Figure 36: Power split between the two electric machines	AUTONOMIE
Figure 37: Engine load adjustments with electric machines	AUTONOMIE
Figure 38: Overview of a rule-based control algorithm for Acura MDX hybrid powertrain	AUTONOMIE
Figure 39: Validation process for 2019 Acura MDX in Autonomie	
Figure 40: Simulation results and test data for UDDS cycle	AUTONOMIE
Figure 41: Simulation results and test data for HWFET cycle	AUTONOMIE

Appendix G: Comments From External Reviewers

This document contains the comments from external reviewers on the vehicle testing and validation reports for the following 4 vehicles

- Infiniti QX50, 2L Turbo VCR, CVT
- 2019 Acura MDX Sport Hybrid, 3L V6 VTEC, 7 spd DCT
- Toyota Camry, 2.5L I4, 8 spd AT
- Honda Accord, 1.5L turbo VTEC, CVT

Reviewer 1

Prof. Giorgio Rizzoni

Ford Motor Company Chair in ElectroMechanical Systems, is a Professor of Mechanical and Aerospace Engineering and of Electrical and Computer Engineering at Ohio State University (OSU).

Argonne National Lab (ANL) has operated the Advanced Mobility Technology Laboratory (AMTL, formerly Advanced Powertrain Research Facility, APRF) for over 20 years. This reviewer is quite familiar with the operation and characteristics of the AMTL, having served as an Associate Technical Team Member of the Vehicle Systems Analysis Technical Team of the U.S. DRIVE Partnership between 2013 and 2016. During this time, I had the opportunity to participate in numerous program reviews of the work done by ANL-APRF in characterizing and evaluating the fuel economy, energy efficiency and emissions of a number of vehicles, mostly with focus on alternative fuels and powertrains. During the course of these reviews, it became apparent that the test capabilities and instrumentation of the AMTL are of the highest quality, and far exceed the minimum requirements for certification testing. The four-wheel-drive chassis dynamometer is operated in an environmental chamber capable of low- and high-temperature testing, and the available instrumentation permits both non-intrusive and intrusive testing to evaluate not only the fuel economy and emissions of the vehicle, but also to perform distinct and specific tests to evaluate the energy efficiency and power consumption of specific subsystems and components in the vehicle. In addition, the APRF team has developed considerable software analysis capabilities that allow the team to present results in comprehensive and carefully thought-out graphical and tabular forms. In my 35-year career as an automotive researcher, I have not come across a public-domain test facility of this kind that matches the capabilities of the AMTL. The work presented in this report is of the highest quality.

The test plan is quite comprehensive, designed to address specific questions related to the fuel economy impact of the operation of various automotive subsystems, and far exceeds the minimum requirements of certification testing. I have no suggestions for further improvement.

The tests conducted in the study were comprehensive and evaluated vehicle fuel economy under different environmental conditions (72, 20, and 95 °F, the last with solar radiation emulation), and with fuels with different octane ratings (regular and premium). In addition to performing fuel economy tests following regulatory driving cycles (UDDS, HWFET, US06, and SC03, LA92 and JCo8), the testing included steady speed tests at different grades, tests during passing maneuvers, and wide-open throttle and idle fuel consumption tests. The test program is as comprehensive as one could expect to implement in a chassis dynamometer test cell. The comparison with EPA CAFE test results is very valuable.

The graphical and tabular summary of the test results give a clear and concise representation of the results. I made some recommendations on minor improvements that I believe will be incorporated in the final report. The only item that is important to note is the lack of consistency

in the units used throughout the report. This is an industry-wide problem, wherein SI and English units are both used and not always both shown next to one another.

The energy analysis, including both fuel economy and overall efficiency, is comprehensive and includes consideration of thermal environment (both ambient temperature as well as cold and hot start conditions), and of different vehicle modes of operation (accel/decel, cruise, stop). The visual presentation of these results is excellent and gives the reader the opportunity to understand the results of complex tests.

As part of the peer review process, I took the time to carefully review the report, and made a number of editorial suggestions that, in my opinion, further enhanced the already excellent quality of the report. I believe that the final product is a well-organized, readable, clear and accurate report.

Vehicle specific comments:

Infinity QX50:

This report provides testing results for a 2019 Infiniti QX50 equipped with a turbocharged 2.0 liter in-line four-cylinder Variable Compression Ratio (VCR) Atkinson cycle-capable engine with dual fuel injection, coupled to the driveline by a CVT. The combination of features in this powertrain is novel, to best of this reviewer's knowledge, and is a very appropriate choice for testing and analysis at Argonne.

The additional analysis presented in the report on: details of VCR engine operation; dual fuel injection strategies; transmission operating strategy; torque converter lock-up strategies; vehicle performance (acceleration and passing maneuvers); fuel cut-off strategies; cycle thermal test conditions; comparison of fuels with different AKI ratings; and accessory load operation further enhances the quality and completeness of the report. The Autonomie Model Validation section is a valuable addition to the testing results and is very well executed.

Acura MDXSH

This report provides testing results for a 2019 Acura MDX Sport Hybrid equipped with a 3.0 V6 Variable Valve Timing and Lift Electronic Control (VTEC) engine coupled through a 7-speed dual clutch transmission (DTC) and a three-motor hybrid system. The 2019 Acura MDX sport hybrid "super-handling" all-wheel drive (SH-AWD) system includes a 143-kW engine coupled to a 7-speed dual clutch transmission (DCT) and a 35-kW electric motor in the front and two 27-kW electric motors on the rear axle, capable of driving each wheel independently, thus replacing the rear differential. The 3.0L V6 engine is port fuel injected and can perform cylinder deactivation for each bank to achieve higher low-load efficiencies. The configuration of the rea electric machines permits the implementation of torque-vectoring strategies and enable superior vehicle handling. This choice of this vehicle is appropriate as it represents a trend towards achieving improved fuel economy while also providing improved performance.

Camry:

The vehicle tested in this report is equipped with a 2.5 L in-line four-cylinder engine coupled to an 8-speed automatic transmission. The engine is a high expansion ratio Atkinson cycle engine with very high peak thermal efficiency (40%), dual variable valve timing, cooled EGR. The 8-speed transmission is a new development that replaces the previously employed 6-speed transmission. The vehicle is claimed to offer outstanding fuel economy while delivering

impressive performance. The results presented in the report clearly support these statements and suggest that the technologies embodied in this vehicle are representative of future trends for conventional (i.e.: non-hybrid) powertrains in mid-size sedans.

Accord

The vehicle tested in this report is equipped with a best-in-class powertrain, featuring a turbocharged 1.5 L in-line four-cylinder engine with variable valve timing and lift electronic control (VTEC) paired with a direct injection system and a continuously variable transmission. The Honda's VTEC turbo technology is marketed as part of the powertrain technologies marketed by Honda as "Earth Dreams Technology." The vehicle is claimed to offer outstanding fuel economy while delivering impressive performance. The results presented in the report clearly support these statements and suggest that the technologies embodied in this vehicle are representative of future trends for conventional (i.e.: non-hybrid) powertrains in mid-size sedans.

The additional analysis presented in the report on: transmission and torque converter operating strategy (including different transmission operating modes); vehicle performance (acceleration and passing maneuvers); start-stop operation; vehicle fuel injection strategies; fuel cut-off strategies; cycle thermal test conditions; comparison of fuels with different AKI ratings; and accessory load operation further enhances the quality and completeness of the report. The Autonomie Model Validation section is a valuable addition to the testing results, and is very well executed.

Reviewer 2

Prof. David Foster

Phil and Jean Myers Professor Emeritus,
Department of Mechanical Engineering, University of Wisconsin-Madison

The experimental protocols and quality of the data taken is very good. It was also nice to see the extra dyno test runs that were developed to probe the vehicle control systems and performance for a more extensive range of operating conditions than the standardized certification tests. The use of this data to fit the Autonomie simulation was impressive as were the correlations between the simulation predictions and the certification cycle test data. Very nice work.

I have made many comments throughout the four reports. Some were generic to the descriptions of the experimental procedure and simulation tuning. Relative to these comments, I sometimes repeated them in the individual reports and other times merely said I had made a comment on the item being described in one of the reports previously reviewed. I hope that the individual teams will share the generic comments about operating procedure, etc. with each other.

Finally, I also had suggestions which I thought would increase the impact of this work. I think that the detail of the operating characteristics of the specific components of each vehicles powertrain contained in Autonomie puts you are in a position to quantify the incremental improvement each of the advanced powertrain technologies makes in the vehicles' fuel economy and performance relative to previous model vehicles as well as competitor vehicles. This is what I expected as part of the discussion on the insights gained from vehicle testing. I inferred this from reading the contract statement: "The focus of the evaluation was to understand the use of critical powertrain components and their impact on the vehicle efficiency," given in the introduction and/or conclusion of each report. In conclusion of each report I made an extended comment further detailing this thought – usually with specific reference to the technologies used in the vehicle reported on in the report.

Below is a copy of my conclusive comment from the Acura Performance Report:

"This is a similar comment to that made in the reports I have previously reviewed.

This is very good work. The experimental protocol, procedures and data taking techniques are of high quality. The component data extracted from the tests were used to tune Autonomie which was then used to simulate the vehicle with excellent results.

The reporting of the data in this report was pretty much just that; here is the data we got; we can see the different aspect of the powertrain engaging and disengaging; here are the results for the two different octane fuels that were tested, etc. However, there was very little discussion of, or attempts to quantify, the impact on fuel economy and performance improvement of the individual advanced technologies used in the vehicle. Also, to me it was disconcerting that when the testing showed no difference between the manufacturer's recommended high-octane fuel and the less expensive low octane fuel almost no discussion ensued. To me this was a significant finding.

I think you are well situated to make these assessments. The Autonomie simulation has energy flows and performance evaluation criteria for most, if not all, of the components and subsystems of the vehicle. I thought it would be possible to use the simulation, which reproduces the data well, to partition the energy flow from the fuel to the wheels for the various driving conditions tested and quantify the impact of the different technologies on fuel economy and performance.

By doing this for the different vehicles tested you would be able to offer a look-up type categorization of the potential benefits of different technologies, used either separately or synergistically, on overall vehicle performance.

Such an analysis would be a tremendous contribution to the technical and regulatory community, and it is what I inferred what the NHTSA was interested in. It is why I offer this comment on the highlighted phrase."

The testing of the impact of the fuels octane number was particularly surprising. In general the octane number did not make a significance difference in the vehicles performance. In fact in the Acura, where the manufacturer recommends high octane gasoline, the low octane gasoline showed better performance. This is a significant finding which I do not understand. It was not discussed in any detail in the report.

There is no reason to discount the data in your tests. However, if this is true, why would the manufacturers recommend high octane gasoline when better performance could be obtained with a less expensive fuel? I made comments of this nature in the different vehicle reports because I think this is a significant finding. It is also one that your laboratory should make absolutely sure that nothing is strange with the data. I even suggested asking Honda about this. To that end, I think one needs to be sure that there are no caveats to this data before it is disseminated more widely in the public arena. This result is significant!

For more detail on this I am also including the extended comment I made in the fuels testing section of the Acura Performance report:

"Considering these tests relative to the fuel test results given in the Infinity makes me more confused. It seems to me that the most important test to perform for this evaluation is the one using the manufacturer's recommended octane rating fuel – which should to be the focus of your results.

If the manufacturer recommends the lower octane fuel isn't it safe to assume that they have optimized the engine for the lower-octane fuel, and have not included technologies that would optimize for higher octane? For example, the range of spark advance might be limited, the chosen compression ratio might not be optimal if a higher-octane fuel were used, …. In other words, using a high-octane fuel could very well result in significant knock margin being 'left on the table' because of this non optimal operation. In which case it would be easy to interpret results of such tests out of context and come to a more general conclusion that higher octane is not worth very much.

I commented in the Infinity testing that an opportunity may have been missed by not running a lower octane fuel in the vehicle which specifies high-octane. It might more clearly inform us on the magnitude of performance improvements that are available through the use of a high-octane fuel in a vehicle which has been optimized of that fuel. Or conversely, it could inform us of the performance degradation that will be experienced from using a low octane fuel in a vehicle designed for high octane fuel.

For this vehicle it appears that you are doing what I suggested in the Infinity report. (Although because of confusion in how the fuel specifications are given in Appendix D, I got confused trying to interpret the results.) I was hoping your data, when combined with the fuel testing data from the other vehicle performance evaluations, would show the performance detriments that may occur when an engine optimized for higher octane fuel is run on low octane fuel. It could

also give information about using a lower octane fuel in an engine optimized for high octane relative to the performance of an engine/vehicle optimized for a lower octane number fuel using the low octane fuel. And finally, it could assess if there is any benefit to using a high-octane fuel in an engine optimized for low octane.

Partitioning these efficiency contributions of both engine technology and fuel specifications would be a significant contribution to the larger technical community, regulatory agencies, and the public in general."

Perhaps the level of energy flow partitioning I was hoping for is outside of the scope of the contract with NHTSA. If it is, fine, but I still think these data and the subsequent Autonomie simulation capabilities give ANL and unique opportunity to offer some quantification of the efficiency improvement potential for a wide array of advanced technology components that are being incorporated into new vehicles.

Reviewer 3

Prof. Douglas Nelson

Department of Mechanical Engineering, Virginia Tech

Comments on Toyota Camry report:

The ANL report documents vehicle testing and model development for the 2018 Toyota Camry XLE 2.5L

PFI/DI engine coupled to an eight-speed automatic transmission. This vehicle was selected to evaluate these technologies and to develop models in support of NHTSA's CAFE work. Overall, the report is of high quality and achieves the objectives set out in the report. The following comments are intended to help improve the report.

The report should add an Executive Summary that clearly states the results of the report. The Conclusions should also be revised and extended to include what is significant about the results; does the work provide new and better data, models, and control? Does this engine have improved efficiency beyond previous versions of direct and port fuel injection engines? Does the Atkinson cycle used in a conventional vehicle rather than a hybrid have any issues with operation of the engine?

The given reference [8] does not seem to be available (yet?) to the public. The data provided in the report is of very high quality and high value, but the errors and uncertainty are not adequately addressed. The excellent repeatability of some data has been shown. Even if the details are provided in [8] a brief summary of the overall testing data quality/uncertainty should be included in the report.

Comments on Infiniti QX50 report

The ANL report documents vehicle testing and model development for the 2019 Infinity QX50 2.0L variable compression ratio (VCR) turbocharged engine coupled to a continuously variable transmission (CVT). This vehicle was selected to evaluate these technologies and to develop models in support of NHTSA's CAFÉ work. Overall, the report is of high quality and achieves the objectives set out in the report. The following comments are intended to help improve the report.

The Executive Summary should clearly state the results of the modeling and validation sections of the report. The Conclusions should also be revised and extended to include what is significant about the results; does the work provide new and better data, models, and control? Does this engine have improved efficiency beyond previous versions of direct and port fuel injection engines? Does the Atkinson cycle used in this conventional vehicle rather than a hybrid have any issues with operation of the engine? What are the advantages of VCR for efficiency vs performance? The given reference [4] does not seem to be available (yet?) to the public. The data provided in the report is of very high quality and high value, but the errors and uncertainty are not adequately addressed. The excellent repeatability of some data has been shown. Even if the details are provided in [4] a brief summary of the overall testing data quality/uncertainty should be included in the report.

Overall, the testing sections have good documentation and presentation of the complex interactions of VCR, boost, DI and ignition timing. The following comments are provided in the order of the report, and are not in any order of significance. In several places in the vehicle

comparison, the term “adjusted” fuel economy is used. The fuel economy results available from the EPA test car list (tcl) data (as referenced) are broadly understood to be unadjusted values that correspond to specific dive cycles and phases, while the label fuel economy available from fueleconomy.gov are adjusted. CAFE is based on unadjusted fuel economy directly available from the EPA test car list data. That tcl data does have a header that says RND_ADJ_FE, but that ADJ is not in the same context. If you use the term adjusted with respect to the tcl data, please very specifically define what the adjustment means in this context. Is it the weighting of the cold start and hot start phases 1 and 3 of the UDDS test results to get the FTP? Then why are HwFET results also (sometimes) referenced as adjusted? Please just be very clear about this term as there is a lot of confusion about CAFÉ vs Label fuel economy.

The mix of using superscripted numbers for both footnotes and references is a bit confusing – suggest using references in [#] format as in the other reports.

Comments on the Accord report

The ANL report documents vehicle testing and model development for the 2018 Honda Accord LX 1.5L turbocharged engine coupled to a continuously variable transmission (CVT). This vehicle was selected to evaluate these technologies and to develop models in support of NHTSA’s CAFE work. Overall, the report is of high quality and achieves the objectives set out in the report. The following comments are intended to help improve the report.

The report should add an Executive Summary that clearly states the results of the report. The conclusions should also be revised and extended to include what is significant about the results; does the work provide new and better data, models, and control? Does this engine have improved efficiency beyond previous versions of turbocharged four-cylinder engines? Does the CVT have reduced losses in addition to improving the operation of the engine?

The given reference [8] does not seem to be available (yet?) to the public. The data provided in the report is of very high quality and high value, but the errors and uncertainty are not adequately addressed. The excellent repeatability of some data has been shown. Even if the details are provided in [8] a brief summary of the overall testing data quality/uncertainty should be included in the report.

Comments on Acura MDXSH

The ANL report documents vehicle testing and model development for the 2019 Acura MDX SH 3.0L VTEC engine coupled to a 7-speed dual clutch transmission and a 3-motor hybrid electric system. This AWD hybrid vehicle was selected to evaluate these technologies and to develop models in support of NHTSA’s CAFE work. Overall, the report is of high quality and achieves the objectives set out in the report. The following comments are intended to help improve the report.

The Executive Summary should clearly state the results of the modeling and validation sections of the report. The Conclusions should also be revised and extended to include what is significant about the results; does the work provide new and better data, models, and control? Does this hybrid vehicle have improved engine efficiency beyond previous hybrids? Does the DCT with integrated motor have significant fuel consumption benefits? What are the advantages of rear motors for efficiency vs performance?

The given reference [4] does not seem to be available (yet?) to the public. The data provided in the report is of very high quality and high value, but the accuracy and uncertainty are not

adequately addressed. The excellent repeatability of some data has been shown. Even if the details are provided in [4] a brief summary of the overall testing data quality/uncertainty should be included in the report.

Overall, the testing sections have good documentation and presentation of the complex interactions of hybrid strategy and components.

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