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Vehicle Technology Assessment, Model Development and Validation of a 2018 Toyota Camry XLE With a 2.5L I4 And 8-Speed Automatic Transmission

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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. In 2019 NHTSA funded a project at Argonne to benchmark a 2018 Toyota Camry sedan, resulting in an extensive dataset for analysis, model development, and validation with Argonne's Autonomie to assess the fuel-saving technologies of this advanced powertrain. The Camry was equipped with the 2.5L I4 "Dynamic Force" engine coupled to a newly introduced 8-speed automatic transmission acclaimed for providing favorable fuel economy results while delivering significant vehicle performance.

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Definitions and Abbreviations

Acronyms	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
r_t	radius of tire
$R_{xy}(\tau)$	cross-correlation over the range of lags (τ) 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
$T_{wheel,brake}$	brake torque 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_{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 is an agency within the U.S. Department of Transportation (DOT), which sets Corporate Average Fuel Economy (CAFE) standards for passenger cars, light trucks and medium-duty passenger vehicles. NHTSA contracted with Argonne National Laboratory (Argonne) to conduct full vehicle simulations using its Autonomie software (https://www.autonomie.net/) and provide input into the CAFE model for determining optimum average fuel economy based on numerous technological and economic factors. Autonomie relies on vehicle and component data for model development and validation. Argonne's Advanced Mobility Technology Laboratory (AMTL) provides the laboratory test data used in Autonomie. In 2019 NHTSA funded a project at Argonne to benchmark a 2018 Toyota Camry sedan, resulting in an extensive dataset for 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 2018 Toyota Camry equipped with the 2.5L I4 "Dynamic Force" engine coupled to a newly introduced 8-speed automatic transmission. This powertrain is acclaimed for providing favorable fuel economy results while delivering significant vehicle performance [1]. The focus of the evaluation is 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. Furthermore, focused testing was performed to characterize different powertrain components' performance. Note that this provided a vehicle system focus and does not result in component specific results such as engine fuel maps, which may be best developed from focused testing efforts on the components rather than vehicle system level experimentation.

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, and the impact of high-level changes such as test temperature, test methodology, and test fuel. Finally, model development and validation are discussed.

2. Introduction and Background

Argonne National Laboratory performed a technology assessment of a 2018 Toyota Camry based on a joint vehicle evaluation, modeling, and simulation effort. The vehicle evaluation focused on developing an understanding of 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). In addition, this dataset will be made publicly available through the Advanced Mobility Technology Laboratory's Downloadable Driving Database (D3) at www.anl.gov/d3.

3. Test Vehicle Description

3.1. Vehicle Specifications

In 2018, Toyota began offering a new powertrain lineup, with an engine technology marketed as "Dynamic Force." This powertrain technology was described as providing many improvements over previous generations of engine technology. The engine redesign includes new technologies that are said to allow it to produce ample torque at all speeds, including high-speed combustion stated to increase the engine thermal efficiency by 15 percent while reducing the fuel consumption, a variable control system that allows precise control of the fuel injection to reduce emissions, and an improved thermal management system [1][3]. In addition, the Camry features an updated 8-speed automatic transmission with a wider gear range stated to increase responsiveness and efficiency and to provide a more compact design compared to the previous generation 6-speed transmission [2][3]. An overview of the vehicle's technical specifications can be found in Table 1.

Table 1. Technical specifications of the model year (MY) 2018 Toyota Camry test vehicle (Toyota Motor Sales, USA Inc., n.d.)

Test vehicle	2018 Toyota Camry XLE/2.5L I4 Dynamic Force (A25A-FKS) w/ 8-speed automatic transmission
Vehicle identification number	4T1B11HK2JU057338
Engine	2.5-liter, I4, DOHC 16V, 151 kW (206 hp) @ 6,600 rpm, 250 Nm (186 ft*lbf) @ 5,000 rpm Compression ratio 13.0:1 D-4S= Port-fuel Injection and direct injection
Transmission	8-speed UB80E "Direct 8AT" automatic transmission 1st 5.250 2nd 3.028 3rd 1.950 4th 1.456 5th 1.220 6th 1.000 7th 0.808 8th 0.673 Differential gear ratio = 2.802 235/45 R18 tires
Climate control	Dual-zone automatic climate control Belt-driven air conditioning compressor R1234-yf refrigerant
EPA label fuel economy (mpg) [a]	28 City/39 Highway (HWFET)/32 Combined, regular gasoline

[a] Data from fueleconomy.gov.

The full vehicle build details can be found in the test vehicle's Monroney label, or window sticker, in Appendix A: Vehicle Build Sheet.

3.2. Key Technology Features

The 2018 Toyota Camry was produced with a new generation of Toyota internal combustion engine called a Dynamic Force engine in the Toyota New Global Architecture (TNGA). As stated by the manufacturer, the engine was redesigned from the basic structure of the prior generation resulting in efficiency improvements throughout the powertrain, high-speed combustion, and an advanced variable valve control system [1]. The engine is a naturally aspirated, in-line, 4-cylinder, 2.5L, 16-valve, dual overhead cam (DOHC) engine referred to as the A25A-FKS. The engine operates on a high- expansion-ratio Atkinson cycle to provide improved engine performance; noise, vibration, and harshness (NVH); and fuel economy, with a peak thermal efficiency of 40 percent, and expanded operational areas of higher overall thermal efficiency [1]. The following technologies, referenced from Toyota press releases [1] and service documentation [3], are used.

- Atkinson cycle, high-tumble-ratio, high-efficiency intake port design with a stroke-to-bore ratio of 1.2, enabling high-speed combustion.
- Widened angle between intake and exhaust ports, with a straightened intake port runner
- Dual VVT-iE: Dual variable valve yiming – Intelligent
  - Adjustment of intake camshaft timing through an electrically operated actuator with a range of 70 degrees
  - Adjustment of exhaust camshaft timing through a hydraulic actuator with a range of 41 degrees
- D-4S: Direct injection (DI) 4-stroke gasoline engine: Superior version
  - Blending of direct and port fuel injection (PFI)
- DIS: Direct ignition system
- ETCS-i: Electronic throttle control system – Intelligent
- EGR: Exhaust gas recirculation with a high-volume/high-efficiency cooler
  - Cylinder heads have built-in EGR cooler functionality
- Continuously variable capacity oil pump
  - Engine oil flow rate control under any running condition

In addition to the Dynamic Force engine, as part of the TNGA, Toyota developed two new automatic transmissions—the 8-speed transmission Direct Shift-8AT and a 10-speed Direct Shift-10AT [2]. Several transmission-specific enhancements were noted for both transmissions to improve efficiency and reduce energy loss. These transmission enhancements, summarized from Toyota press releases [2] and service documentation [3], include the following.

- Reduced friction between gears during engagement from new gear tooth surface processing techniques.
- Clutch friction material configuration change to reduce clutch torque loss by a stated 50% (compared to prior 6-speed transmission) during rotation by improving fluid drag force.
- Widened gearing and newly developed torque converter for broader lockup range and quicker response.

Note, in vehicles with the A25A–FKS engine, such as the test vehicle, the powertrain was equipped with the UB80E 8-speed automatic transaxle known as the Direct Shift-8AT.

3.3. Comparison Vehicles and Preliminary Analysis

This section will provide a brief comparison of the 2018 Toyota Camry with historical trends in this category and other vehicles released in the midsize non-luxury vehicle category for the 2018 model year (MY). The 2018 Toyota Camry was offered in five trim levels: L, LE, SE, XLE, and XSE. All trim levels are equipped with a 2.5L engine as standard, while the XLE and XSE are offered with an optional 3.5L V6. Following a joint review of possible powertrain configurations with project sponsors, the 2018 Toyota Camry XLE with a 2.5L engine and 8-speed UB80E transmission was chosen for this research.

This 2018 Toyota Camry XLE test vehicle has a curb weight of 3,351 lbs, with a gross vehicle and equivalent test weight (ETW) of 3,625 lbs. To provide insight into trends for similar vehicles in this category, the test vehicle was compared with cars of a similar weight. To this end, the 2017 U.S. Environmental Protection Agency (EPA) fuel economy trends report [4] provides a glimpse into the historical trends from 1975 to 2020 for similar cars within the weight class of 3,500–4,000 lbs. The trend of average fuel economy rates, with the specific test vehicle combined results for the 2018 Toyota Camry indicated by a star, are shown in Figure 1.

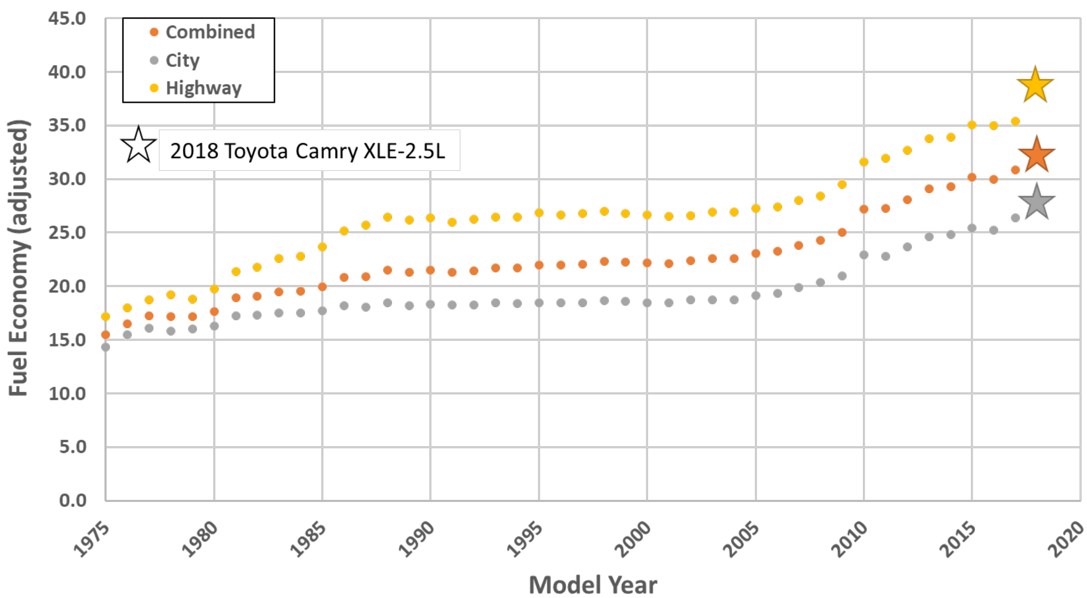

Figure 1. Fuel economy trends: cars in the 3,500-lb weight class

Combined fuel economy for mid-sized passenger cars has been steadily increasing from 25.3 mpg since 2009 to 30.2 in 2017 (EPA, 2019). The Camry 2.5L XLE, offered the first year of a new generation of Toyota powertrains, provides insight into how this trend will likely continue to increase. Improvements are found in both the test vehicle's city and highway fuel economy rates, with the highway cycle fuel economy results demonstrating the greatest increase over the historical trend.

Beyond historical trends of vehicles in a similar weight category, there are benefits in comparing the test vehicle with other vehicles in the MY2018 midsize category. For this comparison, vehicles of similar test weight, with a starting manufacturer suggested retail price (MSRP) below $25,000 were considered. Following vehicle selection based on these broad criteria, all trim levels were then considered based on data available in the EPA vehicle test car list database[5]. A subset of selected vehicles used for this comparison can be found in Appendix B: Subset of Midsize Cars for Comparative Analysis. The resulting list of comparable midsize sedans from the 2018 model year is summarized in the list below.

- Buick Regal
- Chevrolet Malibu
- Ford Fusion
- Kia Optima
- Honda Accord
- Hyundai Sonata
- Mazda 6
- Nissan Altima
- Subaru Legacy
- Toyota Camry
- Volkswagen Passat

Vehicle weights in those reviewed varied considerably, as optional powertrains (with the exception of hybrids) and trim levels were also considered. Figure 2 shows the distributions of weight and horsepower available of the vehicles reviewed.

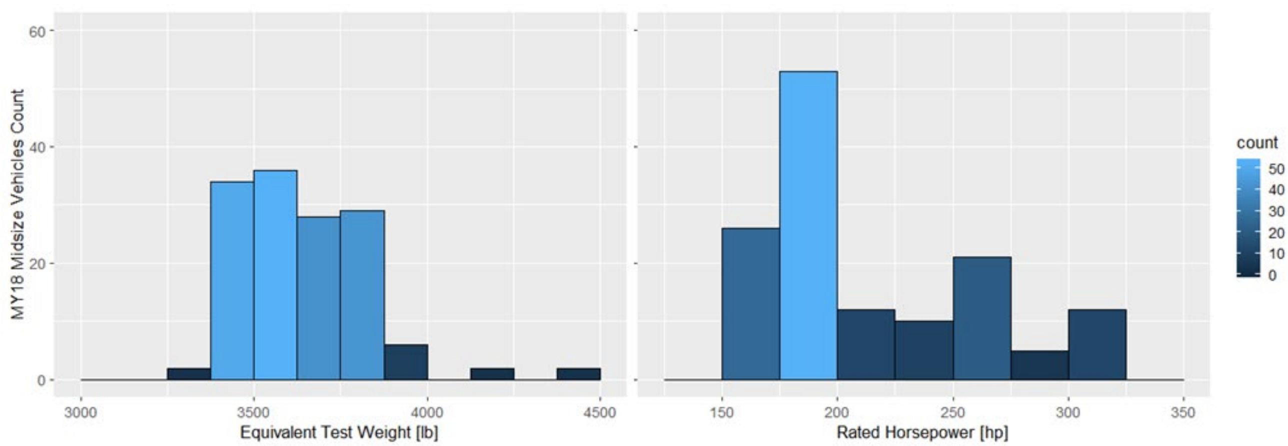

Figure 2. Summary distributions of weight and horsepower of the midsize cars included in the review

The 2018 Camry 2.5L XLE test vehicle weight is near the mean of the category based on its equivalent test weight of 3,625 lbs. Note that ETW is the test weight used for chassis dynamometer testing based on the inertia weight classes. The inertia weight class is defined by Table 1 in 40 CFR § 1066.805 [6].

In addition, the test car's rated engine power of 151kW (203 hp) is also near the mean of 159kW (213.2 hp) for its category. Fuel economy in this category varies considerably based on powertrain and trim selection. The fuel economy values published by manufacturers is termed as adjusted fuel economy values, as the observed (unadjusted) fuel economy from vehicle dynamometer is adjusted downward based on EPA's established procedure. A comparison of the unadjusted fuel economy, separated by induction category, is shown on the Federal test procedure (FTP) cycle in Figure 3: FTP fuel economy of 2018 midsize vehicles.

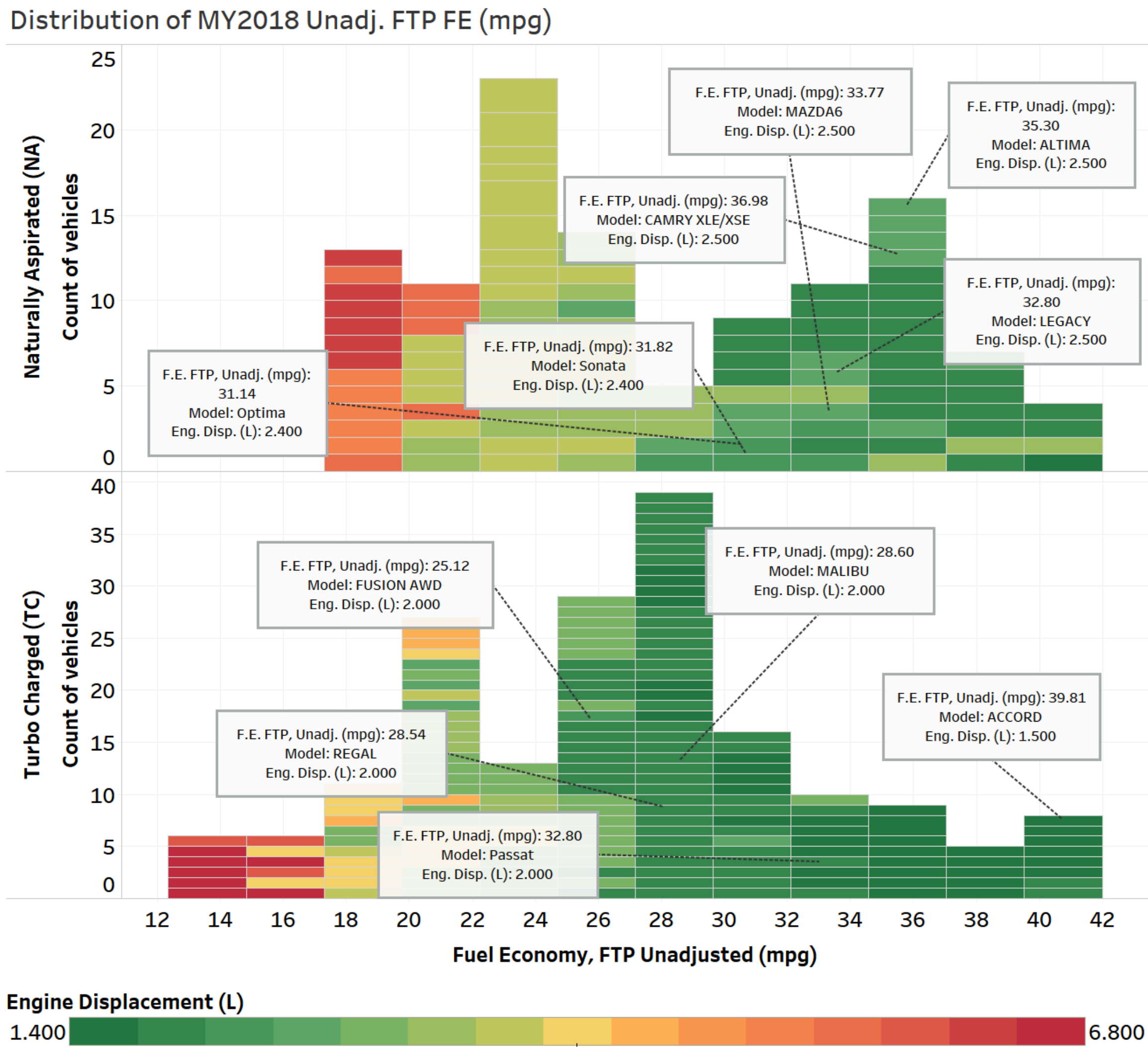

Figure 3. FTP fuel economy of 2018 midsize vehicles

The adjusted fuel economy on the FTP cycle of the 2018 Toyota Camry XLE is within the highest of the sample set. Only alternative trim levels of the Toyota Camry with the 2.5L engine and the recently revised Honda Accord 1.5L powertrain offered higher fuel economy above 37 mpg. Figure 4 displays the fuel economy of the vehicles in the sample set by transmission type and gear count.

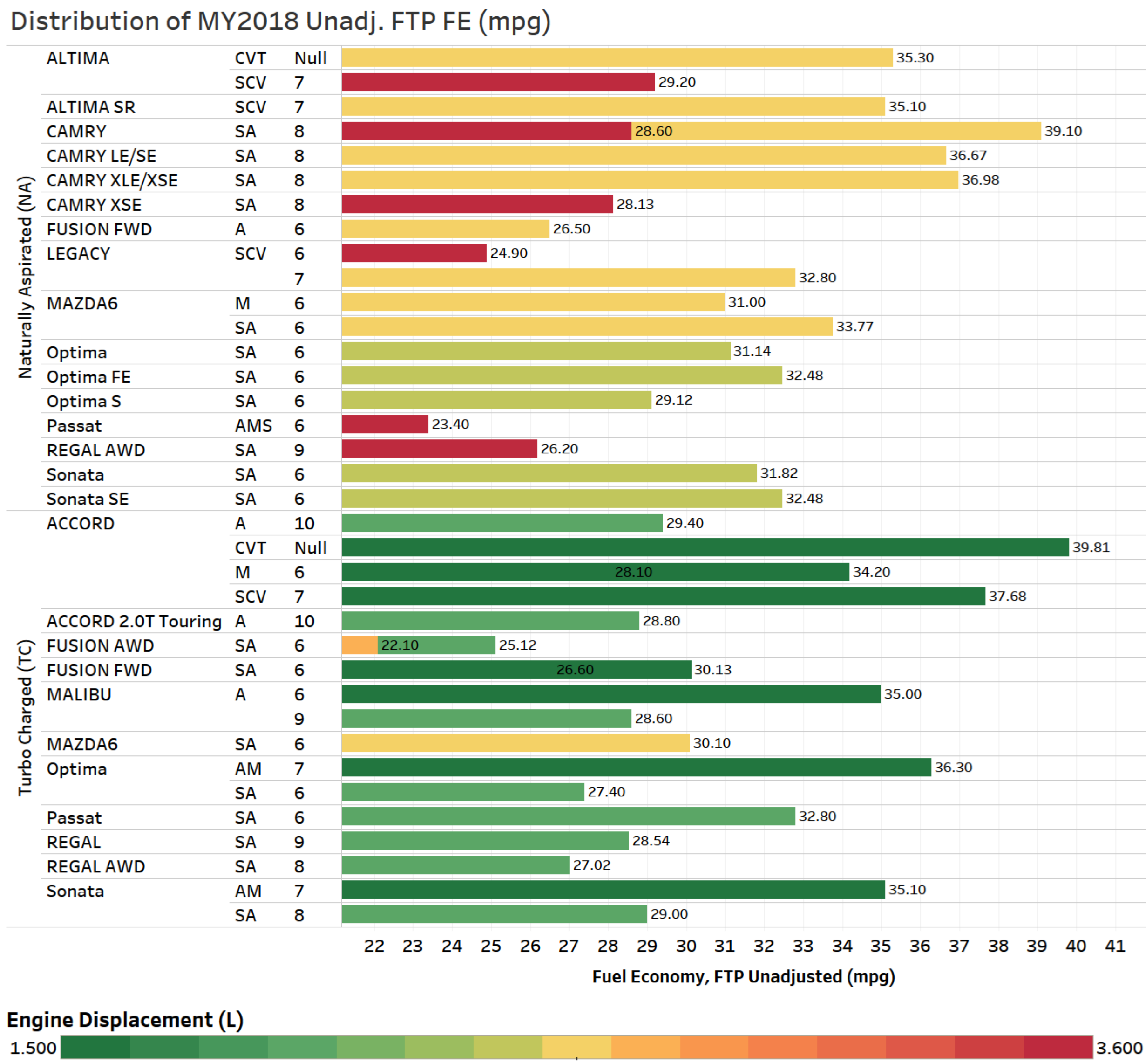

Figure 4. FTP fuel economy of 2018 midsize vehicles by vehicle

The fuel economy results for the 2018 Toyota Camry were similarly high on the reported Highway Fuel Economy Test (HWFET) cycle. Of the vehicles compared, the five test vehicles with the highest reported fuel economy were all varying trim levels of the 2.5L Toyota Camry. Overviews of the 2018 Toyota Camry HWFET fuel economy can be found are in Figure 5 and Figure 6.

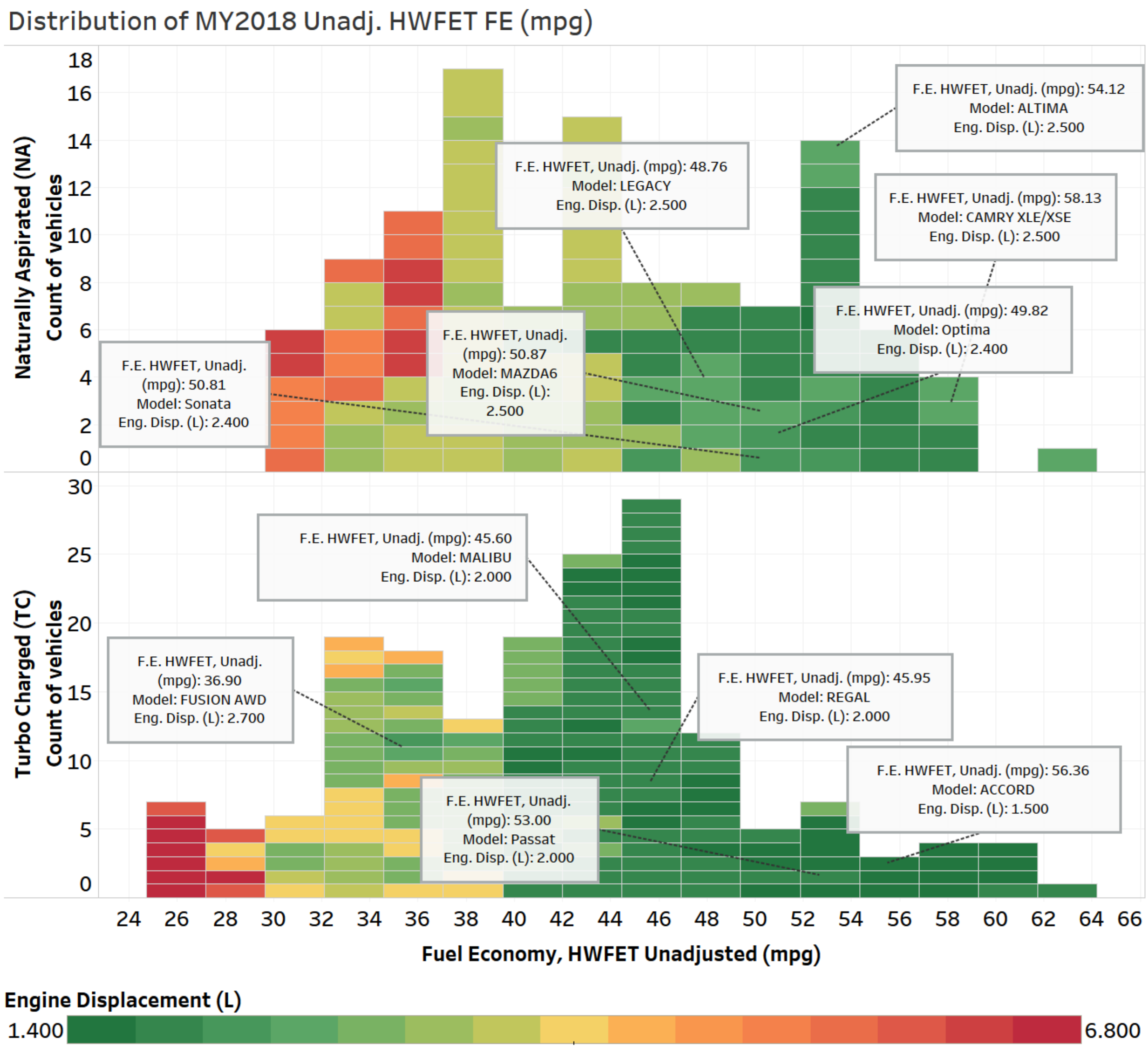

Figure 5. HWFET fuel economy of 2018 midsize vehicle

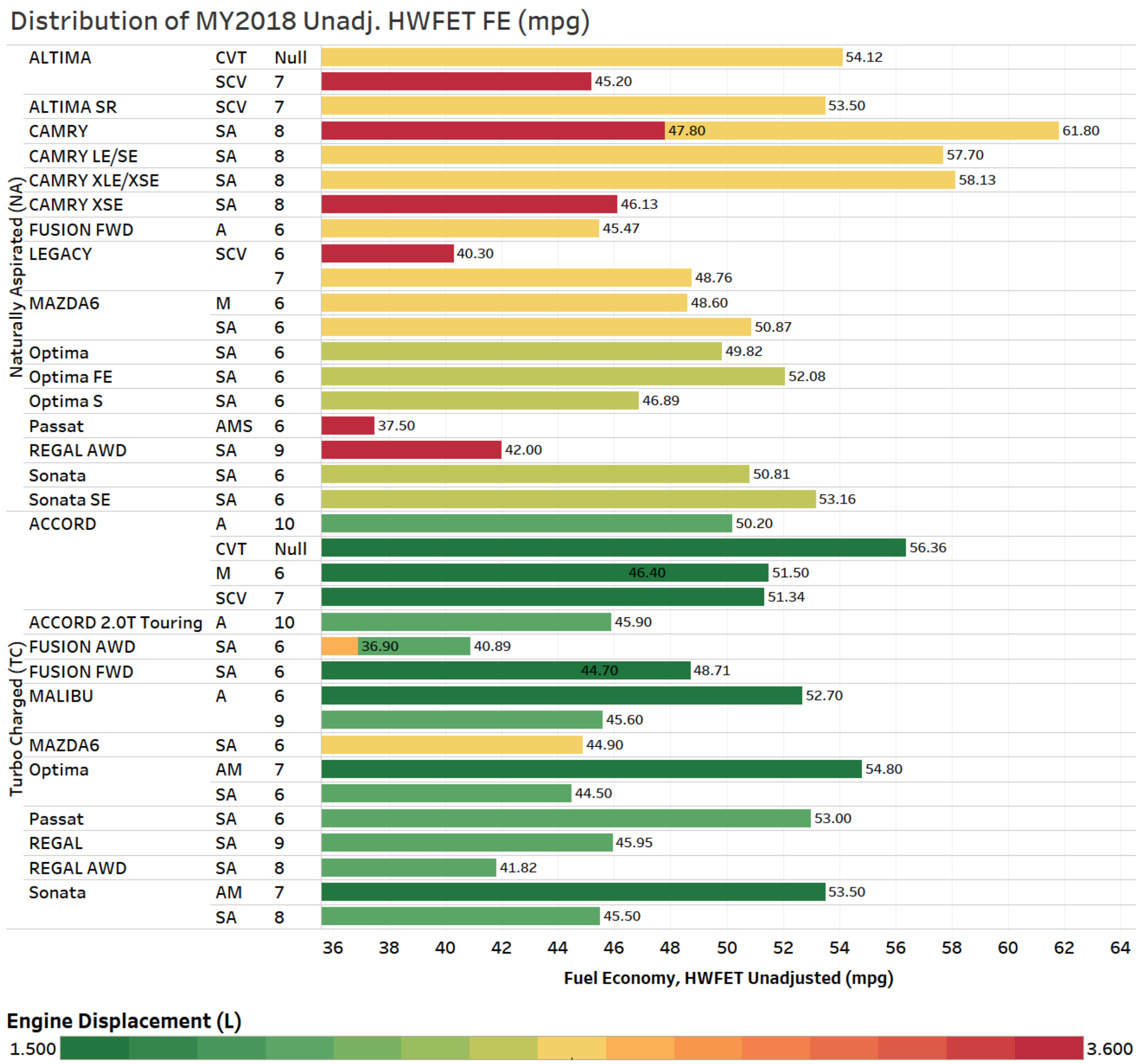

Figure 6. HWFET fuel economy of 2018 midsize vehicles by vehicle selected

4. Testing Overview

4.1. General Testing Overview

4.1.1. Vehicle Procurement and Break In

Vehicle trim level selection followed an extensive review of available vehicle options that could affect vehicle energy use. As testing was performed at above and below a 23 °C ambient temperature, automatic climate control offers insights into the climate control system operation, which affects vehicle energy consumption. At above ambient (hot) temperatures, the air conditioning (AC) system provides a load on the powertrain, which can be affected by controlled cabin temperature, controlled airflow, and AC compressor operation. At low temperatures, the climate control system affects the rate at which fluid temperatures rise as coolant flow is routed to the passenger cabin, reducing the waste heat that is available for the powertrain.

After a review of the 2018 Toyota Camry trim levels found that the XLE trim level provided all desired features, it was chosen to be the test vehicle. The test vehicle was purchased new from a Toyota dealership, providing a known (near zero mile) starting point of vehicle maintenance and operation history.

A new vehicle must be "broken in" for stability and consistent vehicle losses of tires and of moving and rotating components and to ensure catalyst "degreening." An industry standard with a duration of 4,000 miles is established for proper vehicle break-in [7][8]. On the test vehicle, these preliminary 4,000 miles 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. On-road mileage accumulation of 2,000 miles ensured proper break-in of vehicle tires and other rotating components, in addition to collecting data of on-road vehicle operation. The remaining 2,000 miles were completed on a chassis dynamometer to expedite the vehicle evaluation.

A key component of an effective break-in is variations in powertrain speed and loading. Break-in miles accumulated on-road inherently provide this variability, whereas variability in operation on a chassis dynamometer depends on the driving cycle completed. To ensure variability while accumulating miles on the dynamometer, several custom drive cycles were created based on collected on-road data with varying acceleration rates and speeds. An example of a custom drive trace is shown in Figure 7.

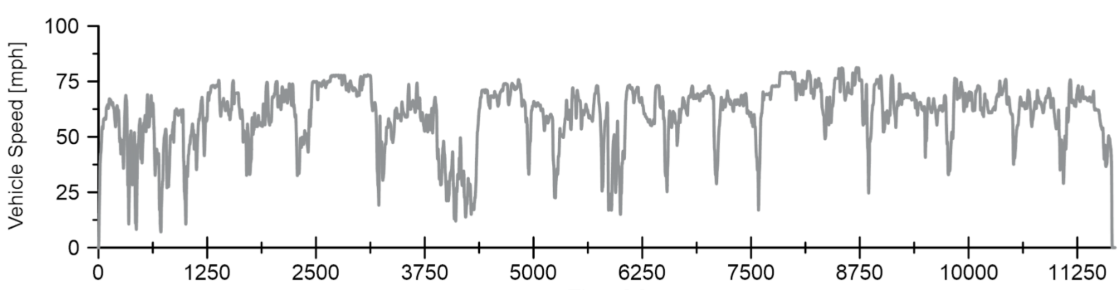

Figure 7. Drive cycle developed from on-road data for on dyno mileage accumulation

Vehicle operation on dynamometer mileage accumulation was provided by a custom-built robot driver, allowing for consistent mileage accumulation while reducing project burden. Figure 8 shows the test vehicle during mileage accumulation.

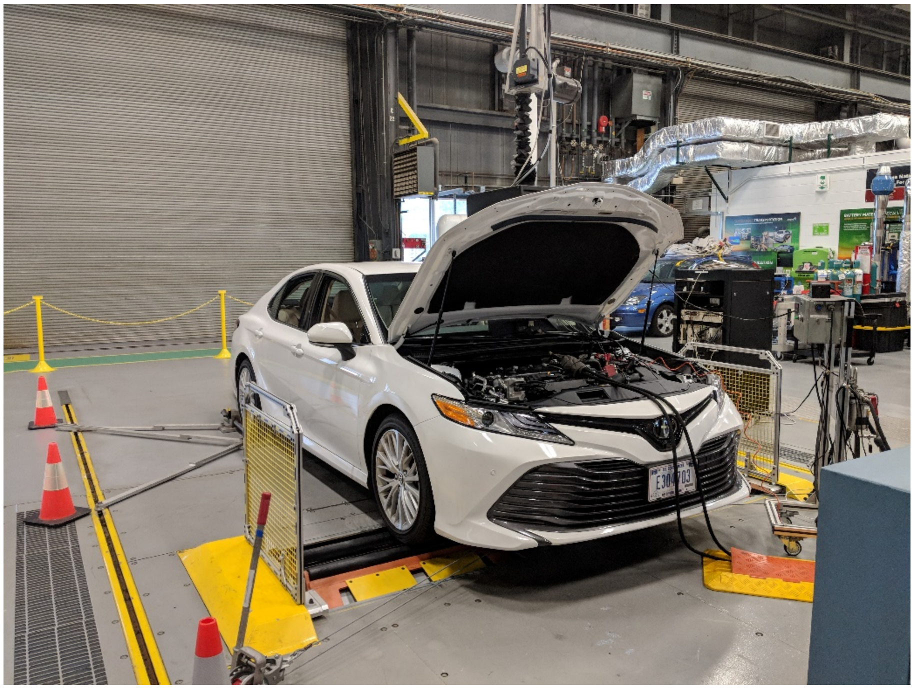

Figure 8. Vehicle mounted for mileage accumulation on the AMTL two-wheel drive (2WD) chassis dynamometer

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. For further information regarding the methods of vehicle testing, please review the AMTL Testing Methodologies Report [9]. Figure 9 shows the test vehicle located in the 4-wheel drive (4WD) chassis dynamometer during testing at the AMTL.

Figure 9. Figure 9: Vehicle mounted for full testing inside the AMTL 4WD chassis dynamometer.

4.2.1.2. Instrumentation

Vehicle instrumentation was developed to be sufficiently comprehensive to provide overall insight into vehicle operation and to supply modeling and simulation with enough detail to develop models, calibrate control strategies, and validate simulation results. This section describes the vehicle-specific instrumentation installed, in addition to the generic facility instrumentation listed in Table 2.

Table 2. 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]	

Additional analog signals include a thermocouple measuring the air temperature behind the radiator and a thermocouple measuring the engine bay temperature.

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 (several signals)
  - Brake pedal (several signals)
  - Mode selection (Comfort/Normal/Sport)
  - Transmission Park-Reverse-Neutral-Drive-Low (PRNDL) selection
- Engine:
  - Engine load
  - Engine speed

  - Intake air temperature
  - Exhaust and intake cam angle
  - Knock feedback
  - Spark adjustment
  - Equivalence ratio
  - Engine DI to PFI operational mode
  - Fuel rail pressure (low pressure)
- Cooling system
  - Engine cylinder head temperature
  - Engine cooling fan speed
- Transmission
  - Transmission temperature
  - Gear number
  - Transmission turbine shaft speed
  - Transmission output speed
  - Torque converter lockup operation

The list above is only a subset of the signals collected. The complete list for the test vehicle can be found in Appendix C: 2018 Toyota Camry XLE Test Signals.

4.2.1.3. Fuel Flow Measurements (PFI, DI, Total- Coriolis, Modal, Bag)

The 2.5L I4 Dynamic Force engine has two fuel injection systems: a direct injection (DI) system, and a port fuel injection (PFI) system. The total fuel flow was measured using a Coriolis fuel flow meter supplied from the engine bay connection by the low-pressure fuel pump, and the junction that splits the fuel between the DI and PFI systems. At the output of the Coriolis meter, the fuel flow was split and routed to two independent positive displacement fuel scales, allowing for direct measurement of DI and PFI flow. Each system was then routed to the respective fuel rail for the high-pressure fuel pump inlet. It should be noted that the addition of hosing, although required for DI/PFI analysis, results in some delay due to fuel storage. In addition, following the vehicle's remounting to the chassis dynamometer for additional testing as noted in Appendix D: Test Summary, the fuel flow instrumentation was modified to capture only total fuel flow rather than separating out fuel flowing to the direct and port fuel injection systems. Figure 10 and Figure 11 illustrate the fuel system instrumentation of the test vehicle.

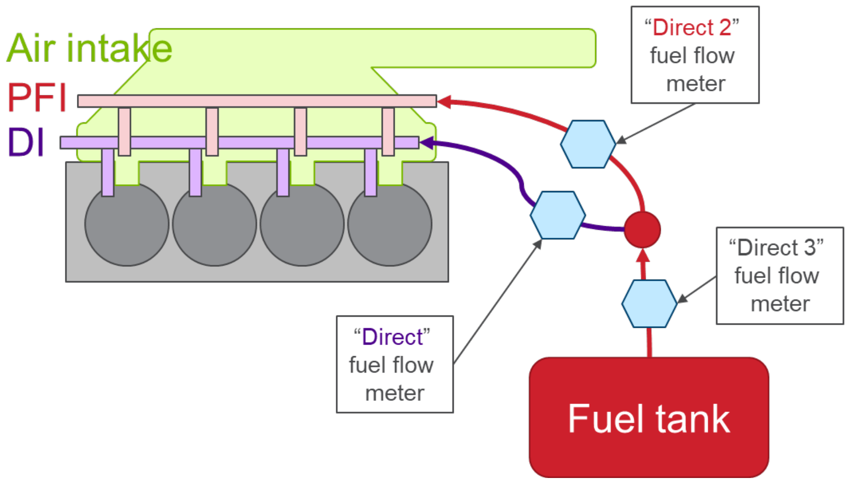

Figure 10. Instrumentation of port and direct fuel injection systems (61808001–61808051)

In should be noted that on tests 61811001–61811014, only total fuel flow was measured prior to the DI/PFI junction at the "Direct 3" location.

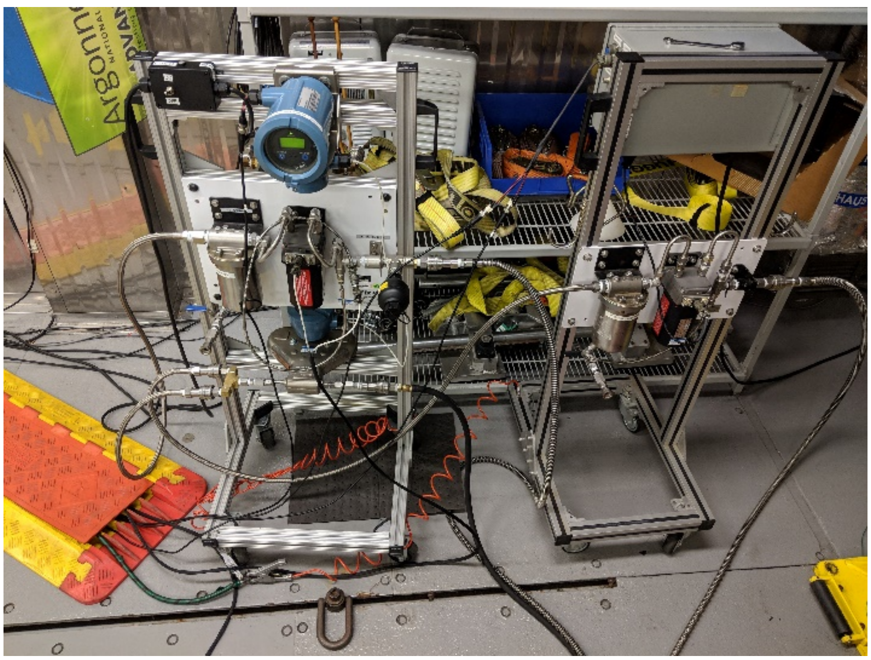

Figure 11. Direct fuel flow measurements via fuel scale and Coriolis flow meters

4.2.1.4. Hioki Setup

Vehicle electrical systems measurements were captured with a 4-channel Hioki 3390-10 power analyzer. Three channels were instrumented, each with a direct measurement of current with Hioki CT6843 200A current probes. Voltage for each channel was measured across the 12V battery, which was then bridged to act as the source for all three channels. From the measured current and voltage channels, power and energy use were calculated in the analyzer. An overview of vehicle 12V system instrumentation is shown in Figure 12.

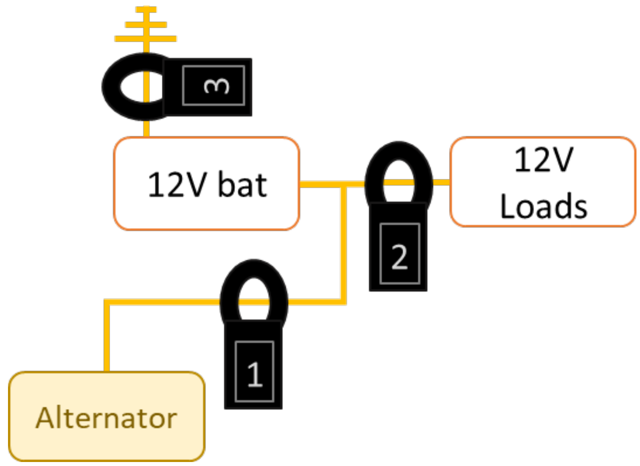

Figure 12. Wiring of the Hioki Power Analyzer on the 2018 Toyota Camry test vehicle

4.2.1.5. CAN Signals

A core capability of the AMTL staff is the ability to decode the vehicle and powertrain internal communication messages (i.e., the CAN). Over the last few years, AMTL staff have developed powerful tools and expertise that enable the decoding of both broadcast and diagnostic CAN messages. These tools rely on the understanding of CAN messaging structure, the correlation of changes in CAN messages to known instrumentation signals, and the ability to use the chassis dynamometer environment to safely control planned scenarios to enable the decoding of specific 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 for the vehicle, which are detailed in Appendix C: 2018 Toyota Camry XLE Test Signals. This instrumentation included the determination and probing of eight separate CAN networks across the vehicle that were joined to a single measurement location for data collection, as shown in Figure 13.

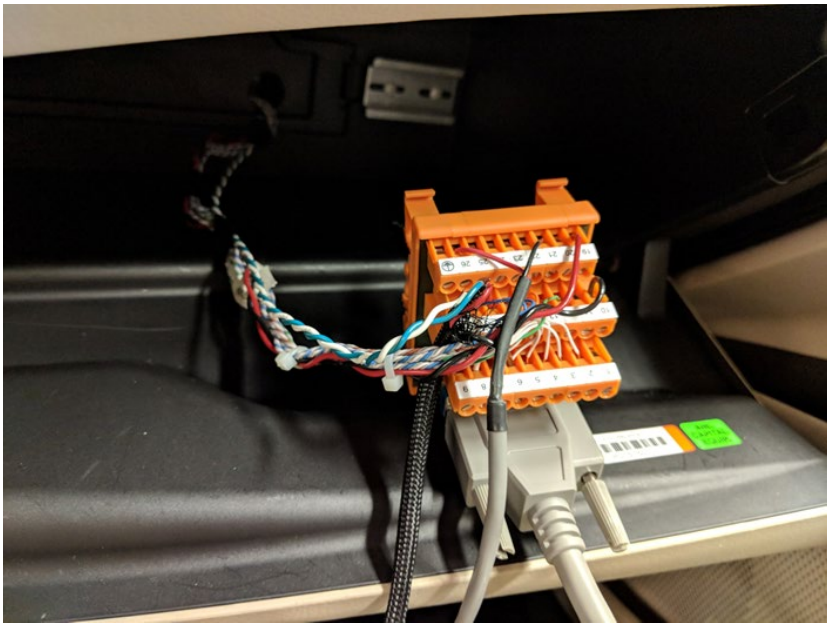

Figure 13. CAN breakout on the 2018 Toyota Camry XLE

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

4.2.2. Test Plan Execution

4.2.2.1. Overview of Testing Matrix

Table 3 provides a summary of the tests that were executed as part of the general test plan. A test sequence, depicted in Figure 20, is repeated three times at 23 °C, while testing at -7 °C and 35 °C did not include any repeat testing. In addition to this initial testing which occurred on a high-octane certification fuel, additional testing using a low-octane certification fuel provided data for a comparison study of the effects of octane which will be discussed in a later section.

Table 3. Summary of the executed general test plan

Test Cycle/Test Conditions	23 °C	35 °C + 850W/m^2	-7 °C	23 °C Tier 3 Fuel
UDDSx3 (including cold start)[a]	3x	UDDSx2	1x	3x
HWFETx2	3x	2x	HWFETx3	3x
US06x2 (4bag)	3x	2x	1x	3x
SC03x2	N/A	2x	N/A	N/A
Steady-state speed testing 0%, 3%, 6% grade	1x	1x		1x
Passing 0%, 3%, 6% grade	1x			1x
WOT'sx3	1x			1x

[a] SC03 = air conditioning test; UDDS = urban dynamometer driving schedule; US06 = US06 dynamometer driving schedule

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 US06
- Transmission mapping through:
    - Constant accelerator tip-ins tests
    - Accelerator tip-ins with vehicle locked at constant speed
- High load engine and transmission mapping

The table in Appendix D: Test Summary summarizes the final tests performed in this effort.

4.2.2.2. Driver Selection (Human vs. Robotic)

Argonne has experienced dynamometer drivers who have driven test cycles on chassis rolls for decades. Vehicle operation on all drive cycles was completed with these trained human drivers unless otherwise noted. To supplement their efforts and provide greater control for specific tests such as mapping or steady-state speeds, Argonne also uses a robot driver. These focused tests perform best when step-change inputs can be executed and subsequently held constant on braking or accelerator inputs — an operation that is more easily performed by an actuator. The driver used to perform each specific test is identified in the test plan located in Appendix D: Test Summary.

4.2.2.3. 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 in standard vehicle and test setup is discussed in separate documentation, which can be found in the AMTL Testing Methodologies report [9]. For specific details on how a test was performed, please consult Appendix D: Test Summary.

All testing on both the 2WD and 4WD chassis dynamometers was conducted with the Forward Collision Warning and Pre-collision Braking systems disabled through the driver control interface. Analysts reviewed and confirmed test data to ensure consistent vehicle operation with these systems disabled with the vehicle operating on the chassis dynamometer.

4.2.3. 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 2018 Toyota Camry. Additional operational testing discussion can be found in a supplemental report [9].

4.2.3.1. Steady State Speeds

Steady-state speed tests determine vehicle operation while the vehicle is driven at a constant speed and load point. These cycles are conducted by following a constructed driving schedule and are completed with a minimum of 30 seconds spent at each speed until stability is determined. Vehicle speed is increased in 10-mph increments up to 80 mph, held for the set period of time, and then reduced to a stop in 10-mph increments (Figure 14). Holding each speed following both the increases and decreases in speed captures variability in powertrain operation, as well as the starting thermal state. These cycles may be repeated at varying grades to capture variations in vehicle loading at a steady state.

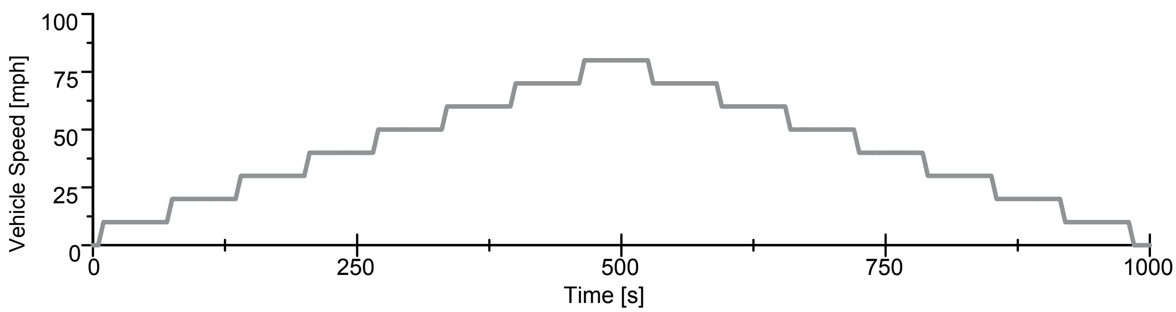

Figure 14. Overview of steady state drive cycle with preparation

Prior to each steady-state speed cycle, the vehicle is warmed to an engine oil temperature of above 80 °C, or similar to that observed on transient drive cycles. On the 2018 Toyota Camry, steady-state speed cycles were performed at the test temperatures of 23 °C (0% grade, both fuels), and 35 °C (0%, 3%, and 6% grades), as contained in Appendix D: Test Summary.

4.2.3.2. Powertrain Mapping Cycles

Limitations and operation of the vehicle powertrain are not common during operation on transient drive cycles. To properly map powertrain operation, custom cycles are used to control vehicle operation and effectively map component operation. For mapping powertrain operation of the 2018 Toyota Camry, Argonne used a combination of custom drive cycles, a robotic driver, and feedback from focused instrumentation. Mapping was performed using a series of tests. The first method consisted of the dynamometer being placed in the road load simulation mode, and accelerating with fixed accelerator pedal inputs, as shown in Figure 15. It should be noted that a max dynamometer speed of 85mph limited the vehicle speed, which can be seen at about 3,500s in the following test cycle.

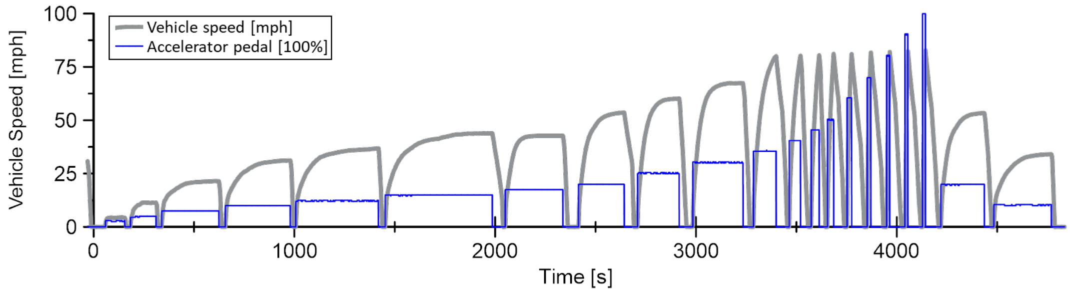

Figure 15. Vehicle acceleration with varying constant pedal inputs

This method provides a map of load demand and upshift strategy for the full range of powertrain operation. Accelerator pedal inputs were held in 2.5% increments to a position of 20%, then increased by 5% bins to 50%, and then by 10% up until full accelerator pedal input.

Additional mapping is required to capture transmission operation during deceleration. For this testing the dynamometer is placed into a mode that provides ramps of constant acceleration and a deceleration rate of 2 mph/s. This acceleration rate was chosen to provide an acceleration rate low enough to have a low change in vehicle speed during the shift event but is high enough to avoid component overheating. During ramp cycles, the accelerator pedal input was held constant while vehicle speed varied. An overview of the cycle is shown in Figure 16.

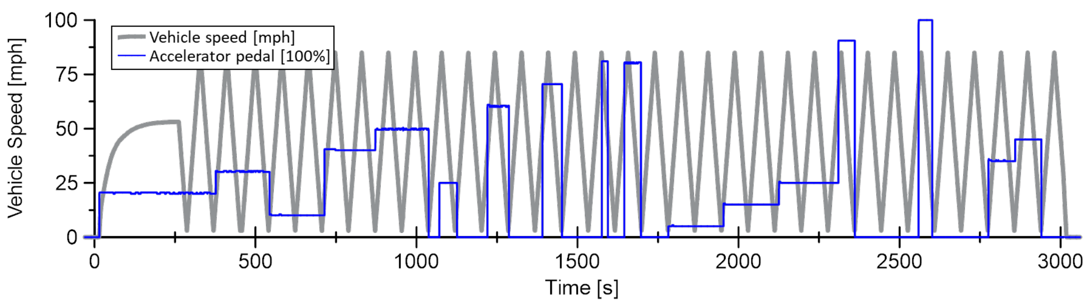

Figure 16. Constant acceleration ramp cycles with varying accelerator pedal inputs

One additional method of powertrain mapping focused on engine mapping, in which the goal is to develop a map of varying engine speed vs. load. Engine mapping on a chassis dynamometer is inherently challenging when compared to an engine dynamometer due to transmission operation, which can lead to “holes” in the map caused by the torque converter operation, and transmission shift commands. To avoid these “holes,” the AMTL staff decoded communication messages that control the demanded transmission gear and used this method of control to effectively lock the torque converter and lock the transmission into a desired gear.

Once control over vehicle gear was established, testing was conducted by setting the chassis dynamometer to a vehicle speed that provided a desired engine speed under the vehicle-selected gear. The vehicle speeds of 20 mph to 85 mph were used to match specific engine speed and load points, with higher vehicle speeds enabling reduced wheel slip on the chassis dynamometer. Once the desired engine speed point was reached, the vehicle control was overridden, and the transmission locked into gear and the robotic driver used to increase accelerator pedal position, varying engine load and mapping out each engine speed point. Figure 17 shows a summary of this cycle.

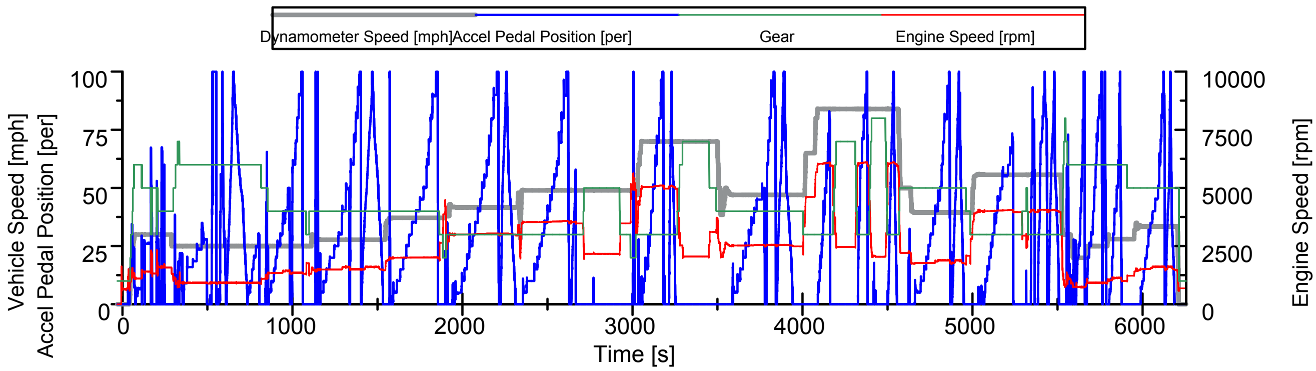

Figure 17. Engine mapping operation under fixed engine speed and varying pedal inputs

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

One important factor in the fuel economy observed during chassis dynamometer testing is the test fuel that is used. Test fuels vary in many ways including energy content, octane, and others. The 2018 Toyota Camry is listed as requiring an octane rating of 87 (research octane number [RON] 91) or higher. Manufacturer certification testing provided by EPA [5] was performed on a high-octane (RON 93) Tier 2 fuel. As a low-octane fuel is likely to be used by consumers, and prior dynamometer testing was conducted on a high-octane fuel, the use of both fuels was evaluated to capture data on the impacts of each fuel on vehicle operation.

The low-octane fuel chosen was EPA Tier 3 EEE certification fuel with an octane rating of 88 anti-knock index (AKI) and 10% ethanol content. The fuel was procured through Haltermann Solutions under the product code of HF2021. Table 4 provides the major specifications of the low octane Tier 3 certification fuel used. The complete fuel specifications for each fuel can be found in Appendix E: Cert Fuel Specifications.

Table 4. Main specifications of the low-octane Tier 3 EEE fuel for test for Test IDs 61807001–61808040

Fuel Name:	**HF2021 EEE Tier 3**
Ethanol content	10%
Carbon weight fraction	0.827
Density	0.744 [g/ml]
Net heating value	17958 [BTU/lbm]
RON	91.9
Motor octane number (MON)	83.3
R+M/2	87.6
Sensitivity	8.6

Additional testing was performed using a high-octane Tier 2 certification fuel. This fuel was procured through Haltermann Solutions under the product code of HF0437. Table 5 provides the major specifications for the Tier 2 certification fuel that we used.

Table 5. Main specifications of the high-octane Tier 2 EEE fuel (Test IDs 61808041–61808050)

Fuel Name:	**HF0437 EEE Tier 2**
Ethanol content	0%
Carbon weight fraction	0.8658
Density	0.743 [g/ml]
Net heating value	18627 [BTU/lbm]
RON	96.8
MON	89.1
R+M/2	93.0
Sensitivity	7.7

The high-octane Tier 2 fuel has a 3.7% higher energy content by mass compared to the low-octane Tier 3 fuel. This was accounted for in post processing for all fuel economy calculations. In addition, vehicle efficiency calculations use the actual fuel energy content and density, considering fuel variability.

Additional follow-on testing that explored the impact of varying vehicle setups, such as variable speed fan speed, hood position, and dynamometer mode, took place after a period where the vehicle was removed from the dynamometer. This testing was also conducted using the high-octane Tier 2 certification fuel to provide a comparison with EPA-listed dynamometer testing with the vehicle in 2WD mode. The specifications for this high-octane, Tier 2 test fuel are listed in Table 6.

Table 6. Main specifications of the EPA Tier 2 EEE fuel (Test IDs 61811001–61811014)

Fuel Name:	**HF0437 EEE Tier 2**
Ethanol content	0%
Carbon weight fraction	0.8665
Density	0.743 [g/ml]
Net heating value	18623 [BTU/lbm]
RON	97.3
MON	88.6
R+M/2	93.0
Sensitivity	8.7

It should be noted that the majority of the testing was performed using a low-octane certification fuel, though Appendix E: Cert Fuel Specifications provides a reference for the specific fuel used for each test.

4.2.5. Vehicle Setup

Argonne referenced manufacturer supplied certification data published by the EPA [5], to determine the test weight and road load coefficients. The vehicle was tested in 4WD mode using both the front and the rear rolls in the test cell, and it was restrained on the chassis dynamometer using chains linked to towers at each corner of the vehicle. The team performed the vehicle coast down and vehicle loss determination before testing started. The bulk of the test was completed in 4WD mode (i.e., with all four wheels spinning). In addition, the team explored different testing setups including some 2WD modes as discussed in Section 5.8.

Table 7 provides the chassis dynamometer setup parameters for the Toyota Camry, referenced from the manufacturer certification documentation and the EPA Test Car List Database [5]. Figure 18 shows the test vehicle mounted to the chassis dynamometer.

Table 7. Chassis dynamometer target parameters for the 2018 Toyota Camry XLE test vehicle

Test weight	**3,625 [lb]**	
Chassis dyno setup	4WD on rolls with dyno mode	
	Target	**Set**
Road load A term	26.51 [lb]	-13.27 [lb]
Road load B term	0.1985 [lb/mph]	0.3003 [lb/mph]
Road load C term	0.0165 [lb/mph^{a}]	0.0142 [lb/mph^{a}]

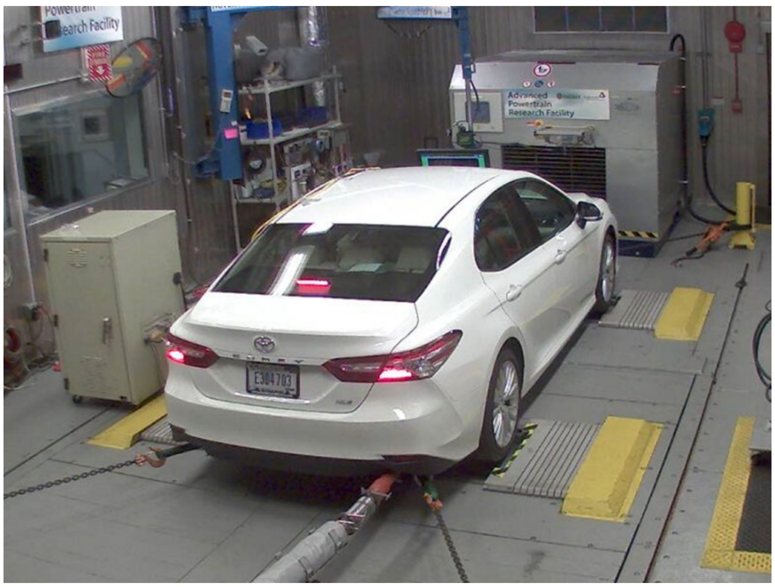

Figure 18. Toyota Camry test vehicle mounted to the chassis dynamometer inside of the test cell

Appendix D: Test Summary contains further details on the vehicle dynamometer coefficients used for specific tests.

5. Vehicle Testing Analysis

5.1. Vehicle Operation Overview

To provide an overview of the highlights of vehicle operation, Figure 19 displays an example of general vehicle operation on a section of the UDDS cycle. As the test vehicle was not equipped with an engine idle stop feature, the vehicle enters accelerations with the engine at idle. When the vehicle accelerates, it shifts quickly through the gears to maintain a low engine speed. At the relative low speed of 35 mph and low accelerator pedal position, the transmission is already in seventh gear. During deceleration, the fuel to the engine is cut off while the engine is motored through the transmission and locked torque converter using the kinetic energy of the vehicle. The engine resumes fueling again before the vehicle comes to a full stop. Figure 19 provides an overview of this powertrain operation.

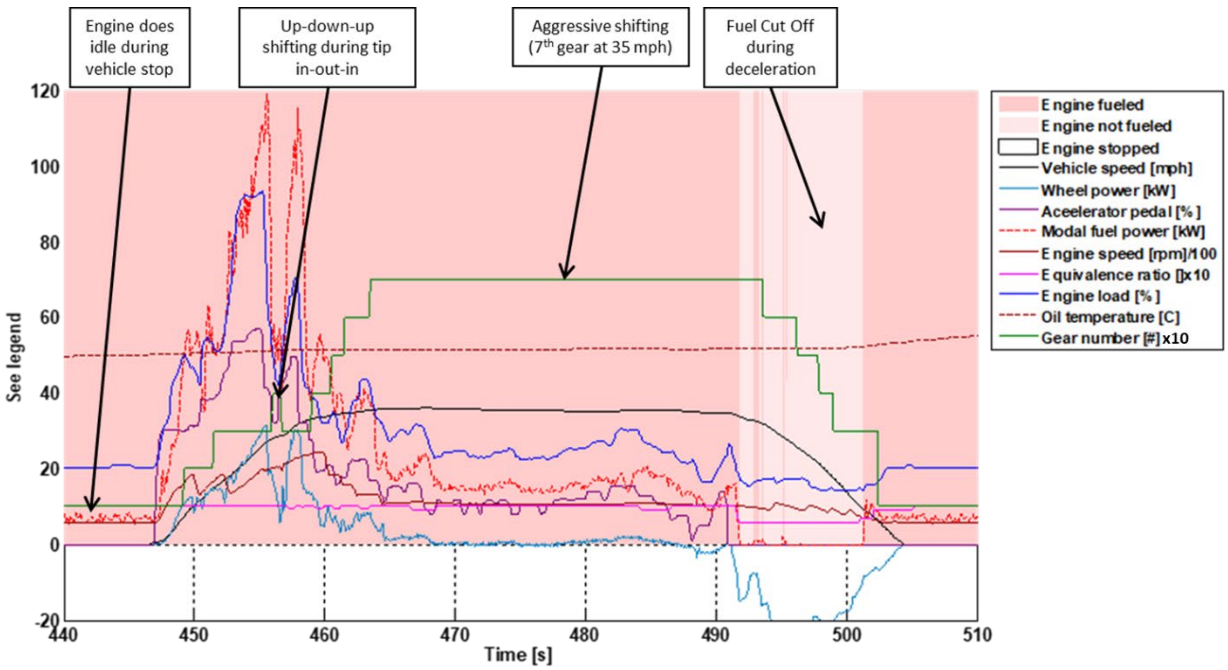

Figure 19. Toyota Camry powertrain operation on cold start UDDS

5.2. Transient Cycle Results

5.2.1. Fuel Economy

5.2.1.1. Standard Fuel Economy Test Sequence Overview

The fuel economy testing focus for this work is on the UDDS, the Highway (HWFET), and the US06 drive cycles at the 23 °C ambient temperature. The test sequence includes a cold-start UDDS, a hot-start UDDS, a third UDDS, a HWFET (highway) pair, and a US06 pair. The preparation for the cold-start test consists of completing a UDDS cycle at 23 °C and leaving the vehicle to soak thermally at 23 °C for more than 12 hours. The overnight soak is performed on the chassis dynamometer in the test cell as the vehicle remains mounted on the rolls for the duration of the testing. The graph in Figure 20 shows the sequence of drive cycles executed, which was repeated three times to capture test-to-test variability on the low-octane fuel. Note that a 10-minute soak period is held between the UDDS cycles as noted in the figure. The fuel economy numbers in this report are based on the test phases highlighted by the pink boxes. The phases for the US06 drive cycle are the split city and HWFET (highway) phases needed to calculate the EPA 5-cycle fuel economy label.

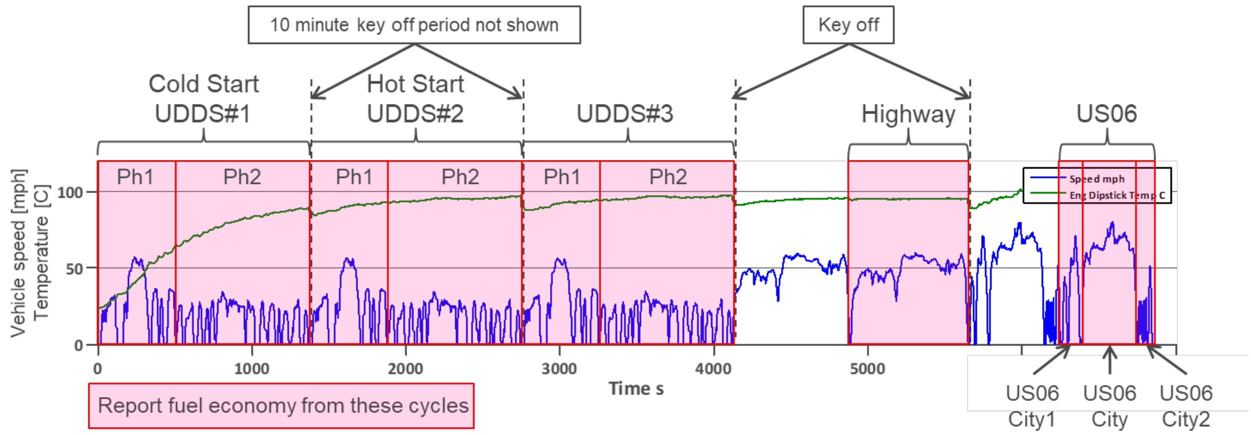

Figure 20. Daily drive cycle test sequence executed in the morning

5.2.1.2. Corporate Average Fuel Economy (CAFE) Certification Cycle Fuel Economy Results

Figure 21 and Table 8 compare the three test sequences completed at the AMTL. These tests were performed on the low octane Tier 3 fuel. The test results on the Tier 3 fuel show good repeatability, with the highest deviation of any phase to the average fuel economy being less than 0.5%.

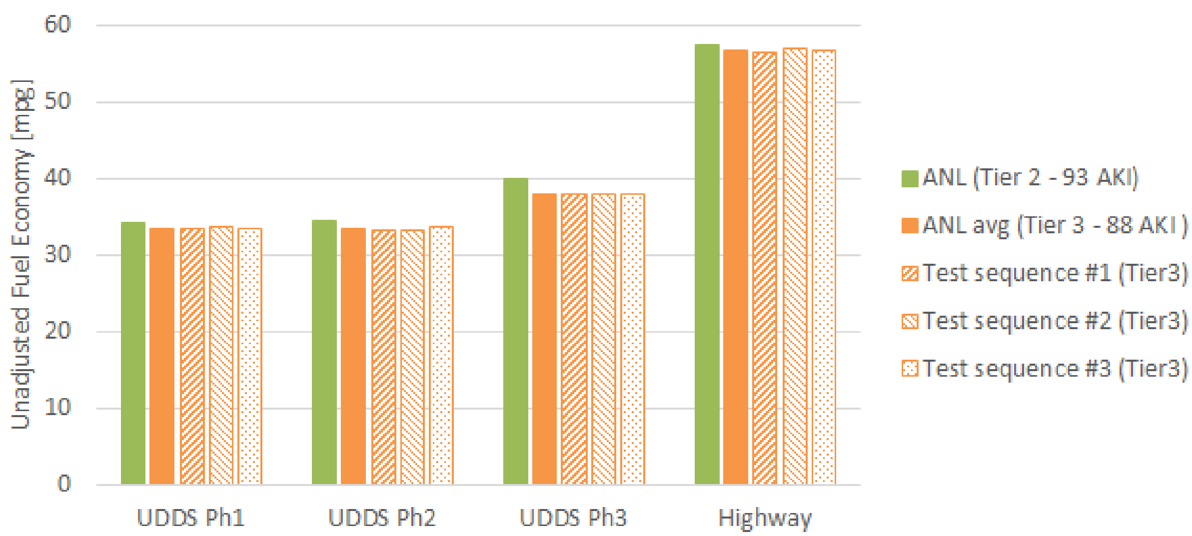

Figure 21. Raw fuel economy results: UDDS and HWFET certification cycles from Argonne

Table 8. Raw fuel economy results (mpg): UDDS and HWFET certification cycles from Argonne

	Argonne (Tier 2) 93 AKI	Argonne avg. (Tier 3) 88 AKI	Repeat #1 (Tier 3) 88 AKI	Repeat #2 (Tier 3) 88 AKI	Repeat #3 (Tier 3) 88 AKI
UDDS Phase 1	34.3	33.5	33.5	33.6	33.4
UDDS Phase 2	34.5	33.4	33.3	33.3	33.6
UDDS Phase 3	40.0	37.9	37.9	37.9	37.9
HWFET	57.4	56.6	56.4	56.9	56.7

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 9. The drive cycles include the cold-start UDDS (Phases 1 and 2), the hot-start UDDS (Phases 3 and 4), a third UDDS cycle, the HWFET cycle, and the US06 cycle. The third UDDS cycle is not part of the certification testing, however, it is performed to capture the fuel economy and operational changes as the powertrain temperature reaches higher operating temperatures as shown in Figure 20. Both the HWFET and US06 drive cycles were tested in phases, and the fuel economy presented here is from the second cycle as described in Figure 20.

Table 9. Raw Tier 3 – 88 AKI Unadjusted fuel economy results for drive cycle results

	Fuel Economy (mpg)
UDDS #1 cold start	33.4
UDDS#1 Phase 1	33.5
UDDS#1 Phase 2	33.4
UDD S#2 hot start	35.7
UDDS#2 Phase 1	37.9
UDDS#2 Phase 2	33.9
UDDS #3	35.9
UDDS#3 Phase 1	38.2
UDDS#3 Phase 2	34.0
HWFET	56.6
US06	32.7
US06 City	20.2
US06 Highway	39.1

5.2.2. Vehicle Efficiency based on Low Octane Fuel Testing

The vehicle efficiency is calculated by dividing the positive driven cycle energy (CEd) by the fuel energy used over the drive cycle as is discussed in the SAE J2951 standard [10]. Table 10 provides the calculated vehicle efficiencies for the drive cycles in each test sequence.

Table 10. Powertrain efficiencies (percentage) based on J2951 positive cycle energy

	Test Sequence #1 (%)	Test Sequence #2 (%)	Test Sequence #3 (%)	Average (%)
UDDS #1 cold start	21.7	21.4	21.5	21.5
UDDS #2 hot start	22.9	22.9	22.9	22.9
UDDS #3	23.0	23.0	22.8	22.9
HWFET	32.4	32.4	32.3	32.4
US06	30.1	30.8	31.4	30.8

The lowest average vehicle efficiency occurs on the UDDS cycle, which is typical for conventional vehicles. The UDDS cycle is a stop-and-go drive cycle with very mild power requirements. On the UDDS cycle, the engine operates at low load with a relatively low throttle opening, which increases the pumping losses. The powertrain efficiency increases by 1.5% from the cold-start cycle to the third cycle where the powertrain has reached its operating temperature.

The average powertrain efficiency is the highest on the HWFET drive cycle. The powertrain can take full advantage of the 8-speed automatic transmission on the HWFET cycle. The eighth gear is engaged about 70% of the time, and the seventh and eighth gears combined are engaged more than 88% of the time, which results in median speeds of between 1,200 rpm to 1,500 rpm on the HWFET cycle. The engine down speeding coupled with the Atkinson cycle engine enables the vehicle to achieve a vehicle efficiency as calculated by SAE J2951[10] of above 30% on the HWFET cycle.

The average powertrain efficiency on the US06 drive cycle is also over 30%. This drive cycle requires high engine loads. These high loads, along with the flexibility in operation from the 8-speed automatic transmission and the Atkinson cycle engine, enable the high vehicle efficiencies.

5.2.3. Thermal 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 5-cycle fuel economy label. Figure 22 provides the test results for these conditions and drive cycles.

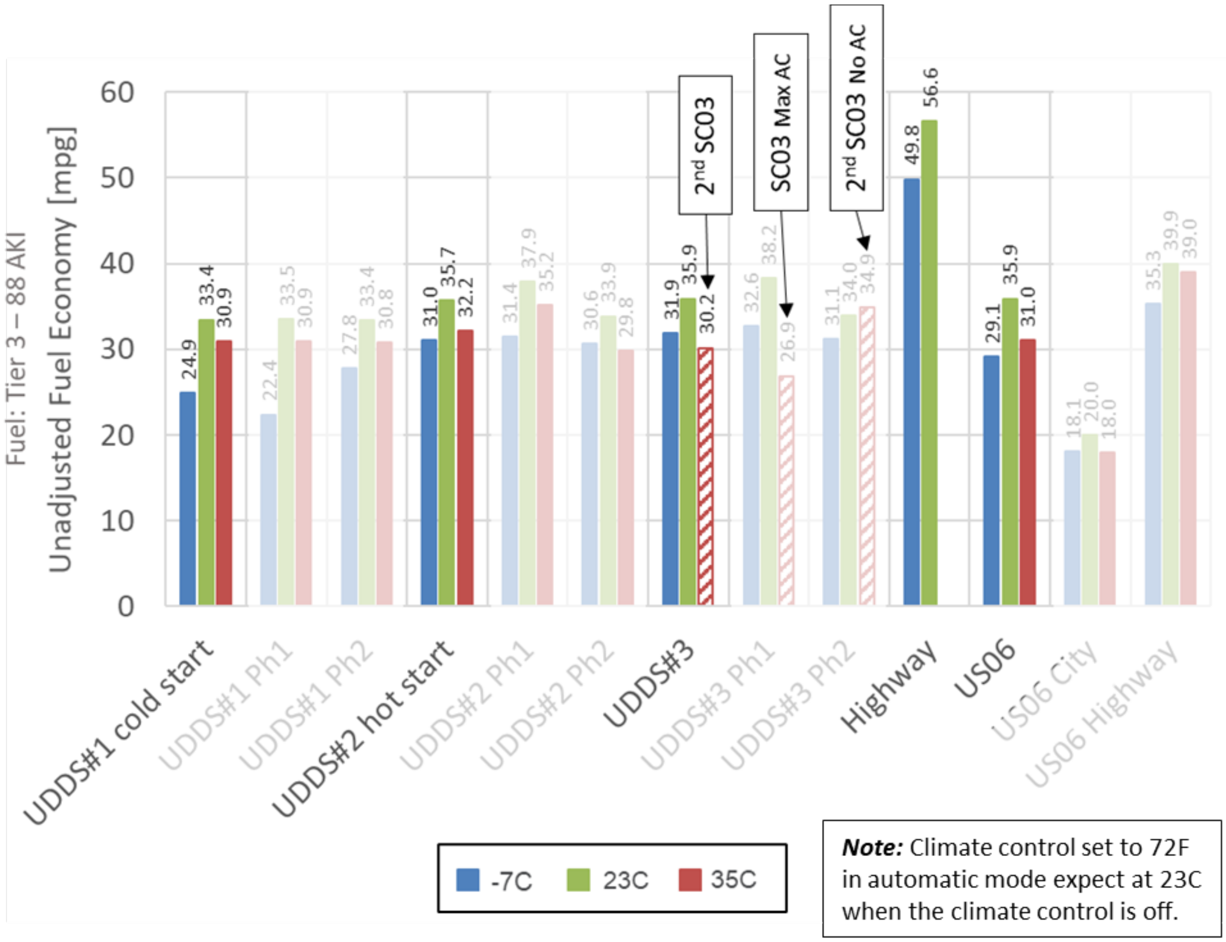

Figure 22. Raw fuel economy results for certification cycles across different temperature conditions

The fuel economy for the cold-start UDDS at -7 °C is decreased by 26% compared to the same test at 23 °C, yet the fuel economy for the second urban cycle at -7 °C is only 13% lower compared to the same test at 23 °C. The powertrain must overcome significantly increased friction losses throughout the drive train on the cold start at -7 °C; however, once the powertrain reaches a steady operating temperature, those friction losses become less significant. The fuel economy penalty at -7 °C compared to 23 °C become smaller as the powertrain temperature increases.

The fuel economy at the 35 °C test condition is also reduced compared to the 23 °C test condition. At 35 °C, the fuel economy decreases by 8% and 10% for the cold-start UDDS and the hot-start UDDS, respectively, compared to the 23 °C test condition. The fuel economy reduction is driven by the additional power required to operate the air conditioning system to cool down the cabin. The deceleration fuel cut-off (DFCO) is reduced (13.8% DFCO UDDS cold start at 23 °C compared to 11.9% at 35 °C) as the engine restarts fueling sooner to provide power to the AC compressor when the kinetic energy of the vehicle is no longer high enough. Note that for the 35 °C testing, the third UDDS was replaced by SC03 drive cycles.

Table 11 provides 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 AC compressor at 35 °C is also apparent in this table. It is noteworthy that the efficiency impact of the AC compressor is lower on the high-power US06 drive cycle as the ratio between the AC power to the average wheel power is lower compared to the same ratio for the lower-power UDDS cycle.

Table 11. Powertrain efficiencies across different ambient test conditions based on Tier 3 fuel

	-7 °C Vehicle Eff (%)	**23 °C Vehicle Eff (%)**	**35 °C Vehicle Eff (%)**
UDDS #1 cold start	16.0	21.5	19.8
UDDS #2 hot start	19.8	22.9	20.8
UDDS #3	20.2	22.9	21.2
HWFET	28.4	32.4	N/A
US06	27.5	30.8	29.3

Figure 23 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 case. At -7 °C, the engine operation is slightly shifted to higher speeds and higher loads. At 35 °C, the average absolute engine load shifted upwards slightly. The overall absolute engine load envelop is increased, which also results from the additional power required for the AC compressor.

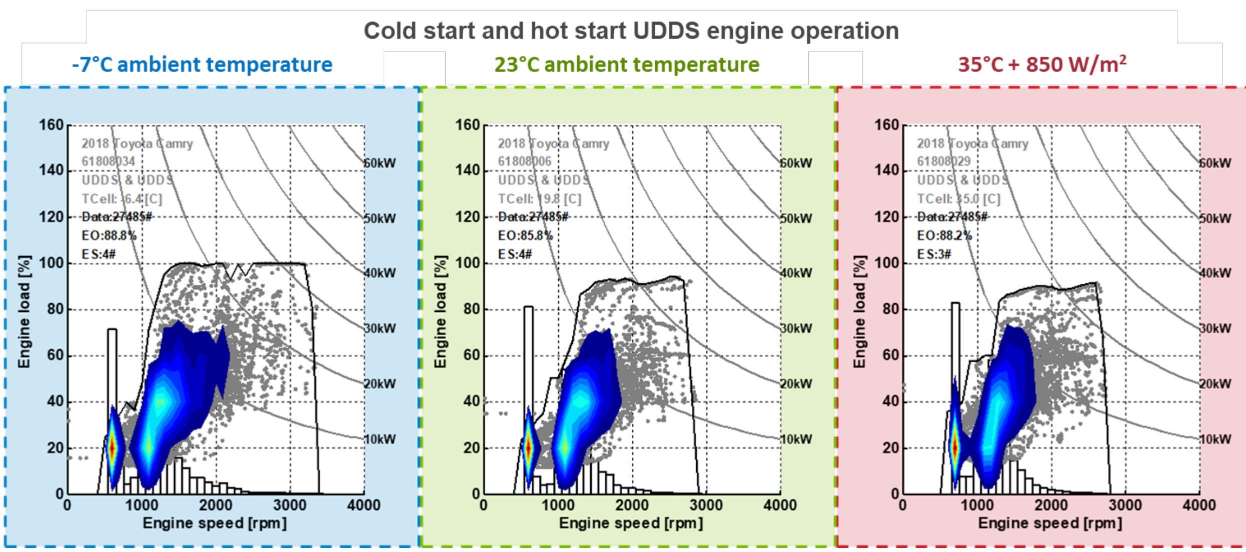

Figure 23. Cold-start engine operation on the UDDS across different temperatures

Figure 24 shows some relevant powertrain and ambient temperature profiles over the completion of the test sequence. To obtain a thermally stable result, three HWFET drive cycles were tested at -7 °C. The SC03 is a critical test at 35 °C, which replaced the HWFET cycle during this testing series. 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 condition.

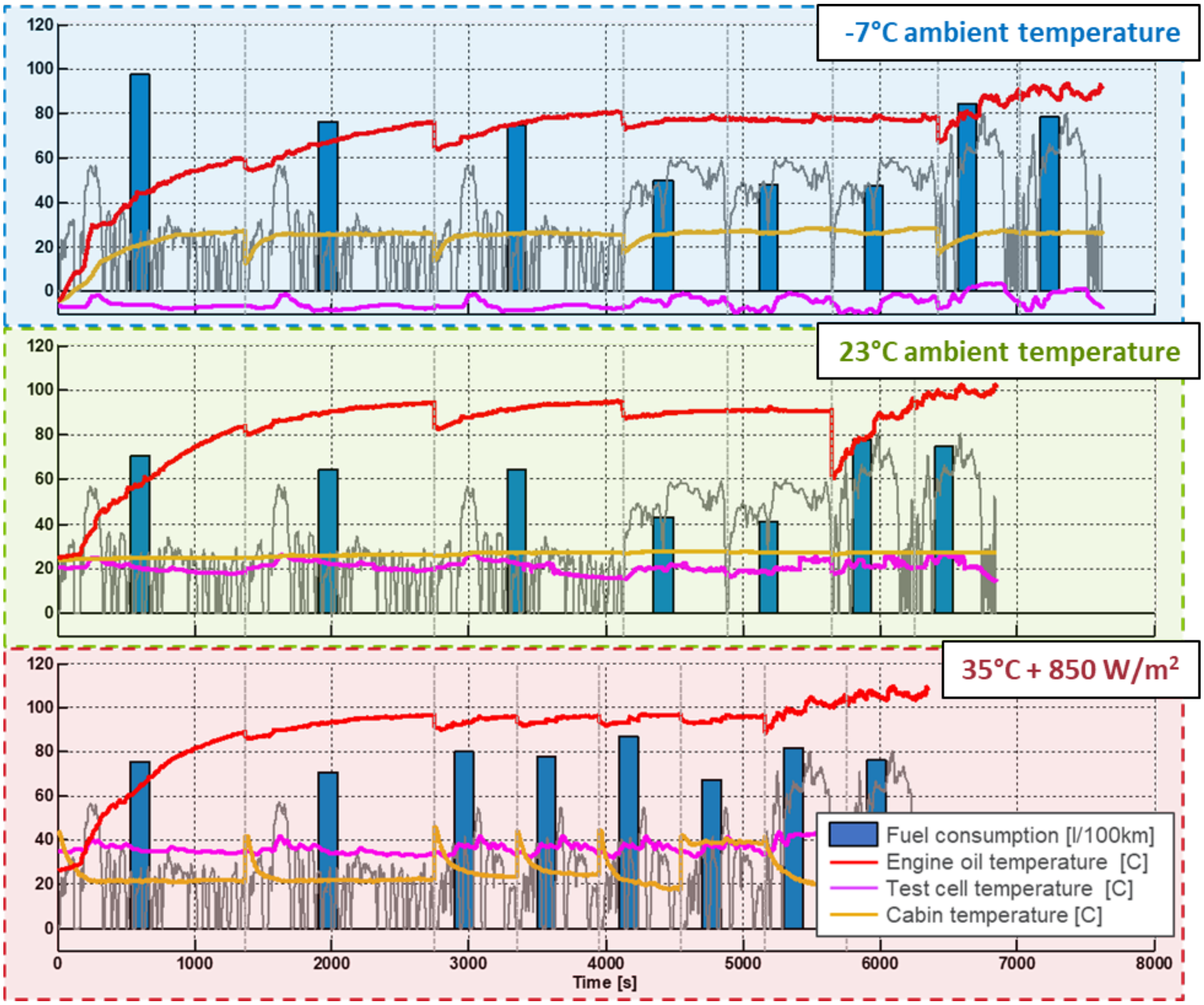

Figure 24. Powertrain and cabin temperature profiles across varying ambient temperatures

The engine oil temperature is representative of the powertrain temperature. For all three ambient temperature conditions, the final engine oil temperature for the US06 is around 90 °C to 105 °C.

5.3. Steady-State Speed Fuel Economy and Efficiency

One characterization test run is the steady-state speed drive cycle, which holds vehicle speed for a duration of 1 minute at speeds from 10 mph to 80 mph in increments of 10 mph. On this cycle, the vehicle is first accelerated, then decelerated, through the speed set points to capture effects that may be seen in gear selection. The fuel economy results as well as some vehicle characterization parameters are presented in Figure 25. Note, the hood remained closed during testing with the variable speed fan matching the driven vehicle speed. For each steady-state speed, the vehicle efficiency, power required at the wheel, and engine speed are calculated.

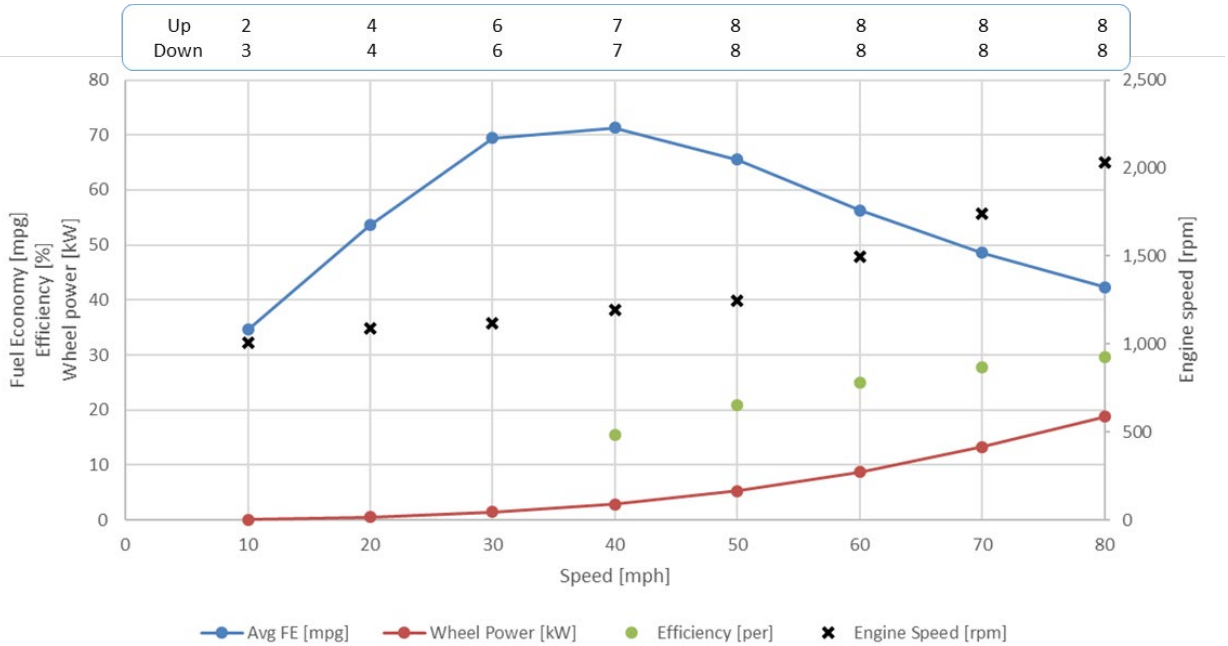

Figure 25. Steady-state speed operation at 72 °F and 0% grade – Tier 3 low-octane fuel

The highest fuel economy was displayed at a vehicle speed of 40mph. Below 40mph, a low resulting vehicle efficiency results in reduced fuel economy, although required wheel power remains low. Although vehicle efficiency increases as vehicle speed increases, the additional wheel power required offsets any improvements in efficiency, thus reducing overall fuel economy. Peak vehicle efficiency is just below 30% at 80 mph. Engine speed remains between 1,000 and 1,250 rotations per minute (RPM) until the highest gear, the eighth gear, is engaged at 50 mph. Following this shift to eighth gear, engine speed increases in relation to vehicle speed with a resulting speed of about 2,000 rpm at 80mph.

As discussed in Section 5.7, additional testing was performed using a high-octane Tier 2 fuel. Testing on both fuels was conducted with the dynamometer in 4WD mode and with the vehicle remaining mounted to the dynamometer through the fuel swap. Figure 26 demonstrates vehicle operation with the high-octane fuel. Fuel economy, vehicle efficiency, and general vehicle operation all remained in that expected for test-to-test variability between the two fuels.

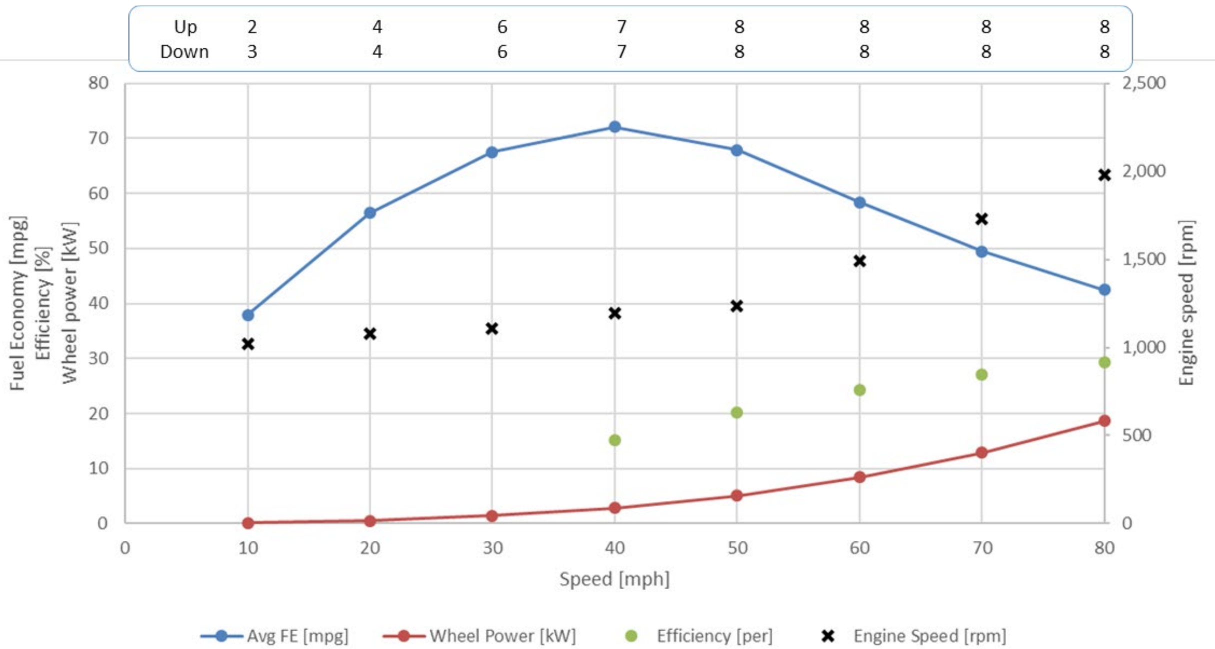

Figure 26. Steady state speed operation at 72 °F and 0% grade - Tier 2 high-octane fuel

Additional steady-state testing was completed at the elevated temperature of 35 °C with solar emulation, at varying grades of 0%, 3%, and 6%. The results of the test performed at 0% grade are displayed in Figure 27.

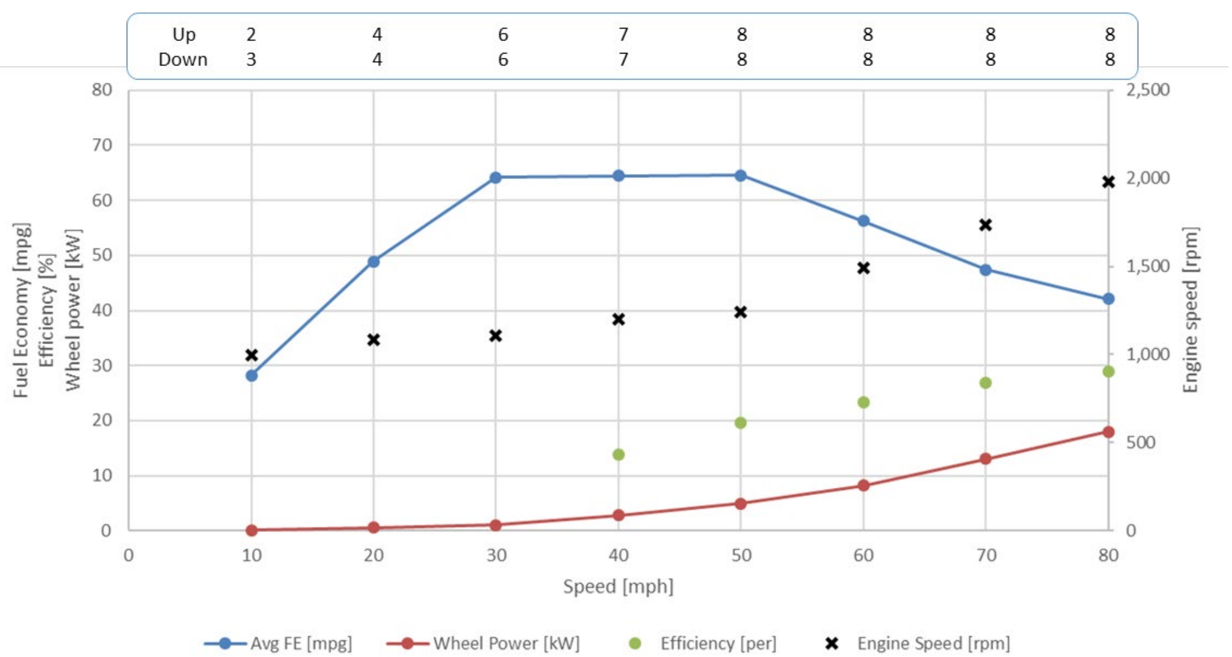

Figure 27. Steady-state speed operation at 95 °F and 0% grade

At this elevated test temperature, transmission operation remained the same at each set speed. Peak fuel economy was reduced to approximately 64 mpg and remained at this level from 30 to 50 mph. Vehicle efficiency is reduced by several percentage points at lower speeds due to heating, ventilation, and Air Conditioning (HVAC) operation. It should be noted that the vehicle cabin conditioned to a steady state prior to the start of this test, so that no impact of a "pulldown" of cabin temperature affected the results.

Vehicle gear selection remained consistent with prior tests and engine speed remained consistent as well. An additional point of note is the reduced impact on fuel economy at higher speeds compared to lower speeds. As vehicle load increases with vehicle speed increases, the overall proportional impact of HVAC loads is reduced. In addition, increases in powertrain temperatures, which are enabled by the electronic thermostat and the electric water pump, reduce losses, further improving vehicle efficiency. At a speed of 80 mph, both vehicle efficiency and fuel economy between the 23 °C and elevated 35 °C testing are in test-to-test variability.

5.4. Passing Maneuver Results and General Operation

To develop an understanding of vehicle performance when a vehicle is overtaking 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 12 summarizes the time it took the Camry to complete each passing maneuver on both high- and low-octane fuels.

Table 12. Time duration for acceleration events

Passing Manuever Time [s]				
		0% grade	**3% grade**	**6% grade**
Low octane	**35–55**	4.3	4.7	5.0
	55–65	3.6	3.8	4.4
	35–70	7.9	9.0	10.1
	55–80	7.4	8.4	10.2
High octane	**35–55**	4.4	4.6	4.9
	55–65	3.7	3.5	4.3
	35–70	7.9	8.7	9.9
	55–80	7.4	7.9	9.8

A plot of the powertrain details for the passing maneuver from 55 mph to 80 mph is shown in Figure 28. In this case, the powertrain required slightly more than one-tenth of a second after 100% application of the accelerator pedal to downshift from eighth gear to fifth gear. An additional shift from fifth to third gear occurred about 1 second after 100% pedal application. Immediately upon 100% pedal application, the torque converter unlocks and remains unlocked for about 2.5 seconds, or until the vehicle reaches 60 mph. Fuel injection mode switches from “either,” a mixture of PFI and DI injection, to DI only for the remainder of the acceleration. Fuel enrichment to a ratio of 0.86 begins approximately 0.4 seconds after 100% pedal application.

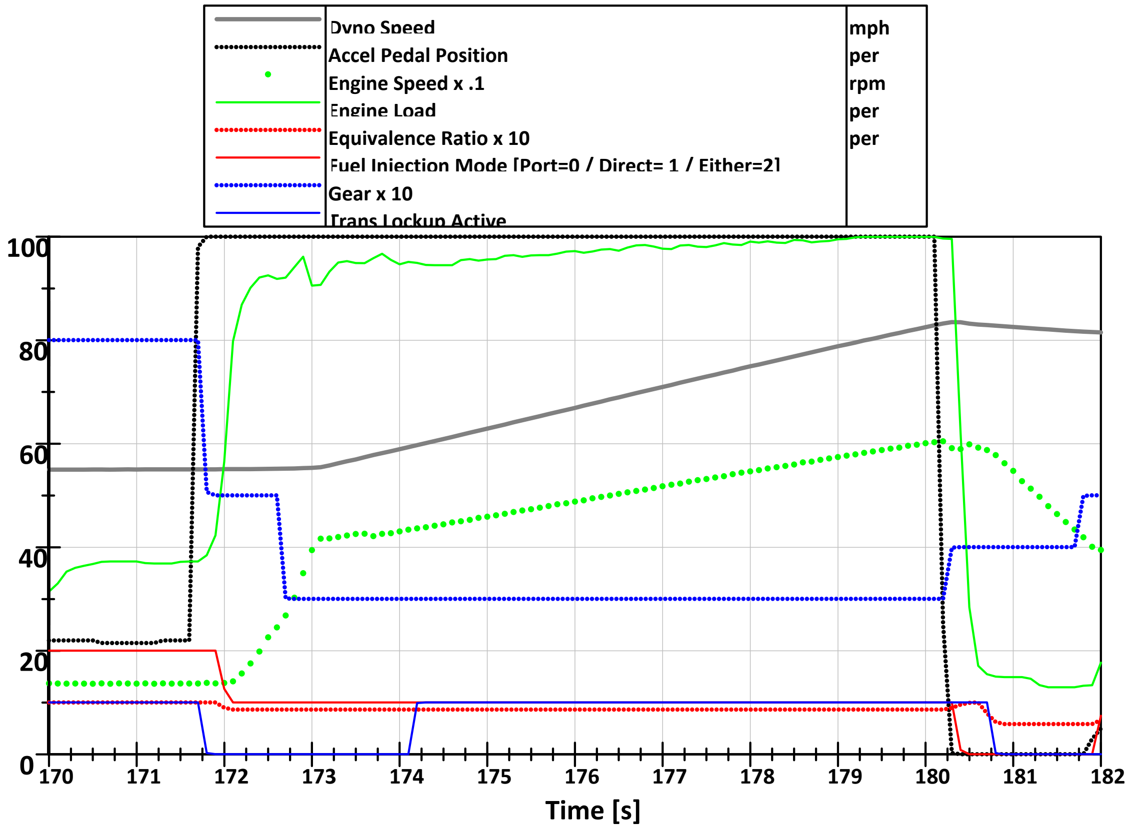

Figure 28. Powertrain operation during the 55-mph to 80-mph passing maneuver on low-octane Tier 3 fuel

5.5. Operation During Maximum Acceleration (Tier 3 – 88 AKI)

Maximum acceleration performance tests were performed on the chassis dynamometer. The test is performed from a rolling start to alleviate the traction issues of the tire on a steel roll. Figure 29 shows the details of the powertrain operation during the maximum acceleration test. The DI fuel system is used during the acceleration phase. The equivalence ratio remains stoichiometric with small deviations during shift phases. The transmission shifts from first to second at approximately 25 mph and from second to third at 60 mph. The engine speed reaches 6,700 rpm at the shift points. The torque converter slips from launch through first and second gear and then locks in third gear. The maximum power at the wheel during these accelerations is about 112 kW at 80 mph.

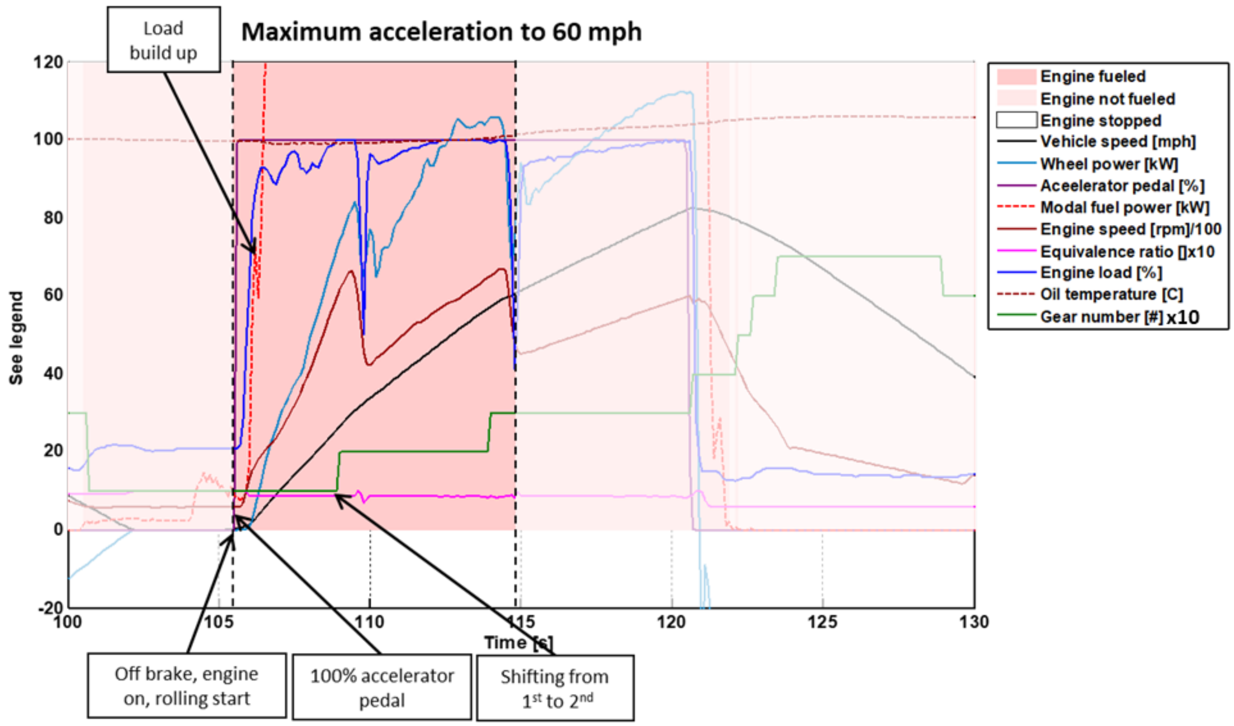

Figure 29. Powertrain operation during maximum acceleration

Repeat testing of the maximum acceleration were performed and are shown in Figure 30. The acceleration and the power delivery values were found to be consistent of this duration of tests.

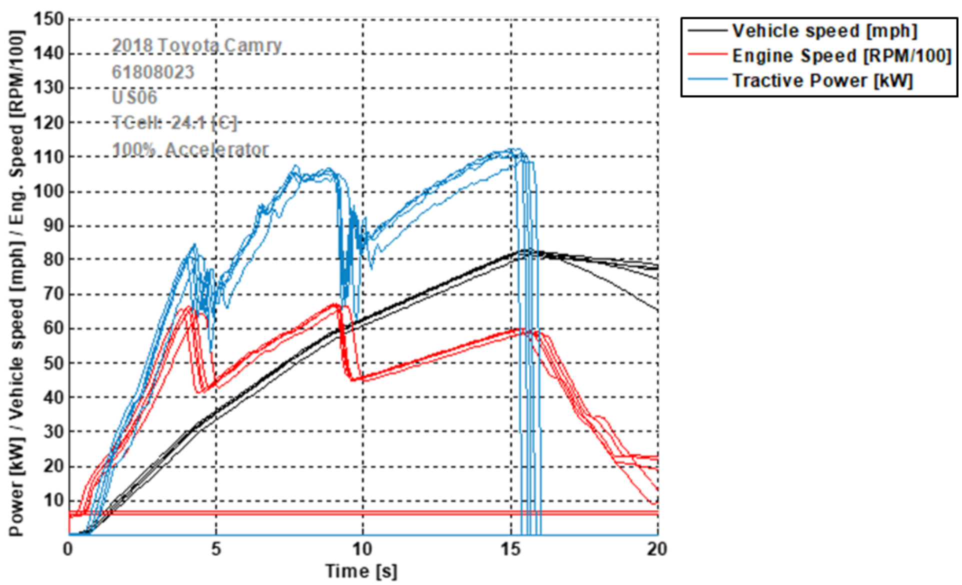

Figure 30. Repeat maximum acceleration runs overlaid

5.6. Idle Fuel Flow Rate Test Results

A 30-minute engine idle test in cold-start conditions is performed with the transmission in park, following an overnight soak at the test temperature of 23 °C. This test is designed to characterize engine behavior and fuel flow rate as the powertrain warms up at idle in Park.

Figure 31 shows the first 120 seconds of the cold start engine idle test. The engine is started at 3.5 seconds into the test to ensure that all measurements are properly captured following the start of test. By 5 seconds, engine speed is increased to more than 1,850 rpm before settling to 1,450 rpm. The ignition is retarded to help with the warm-up of the exhaust aftertreatment system. At approximately 25 seconds, the vehicle transitions to closed-loop operation. During this transition, ignition timing advances; and engine load, fuel power, and engine speed all decrease. At this transition, catalyst temperature from diagnostics (vehicle calculated) is reported at 280 °C. Approximately 85 seconds into the test, the vehicle transitions from DI to PFI. A slight dwell time is evident between the transition from DI to PFI due to the damping effect from fuel lines used for the measurement equipment. It should be noted that the catalyst temperature, a CAN reported signal has a default value of 675 °C prior to the engine start where it resets to the correct value.

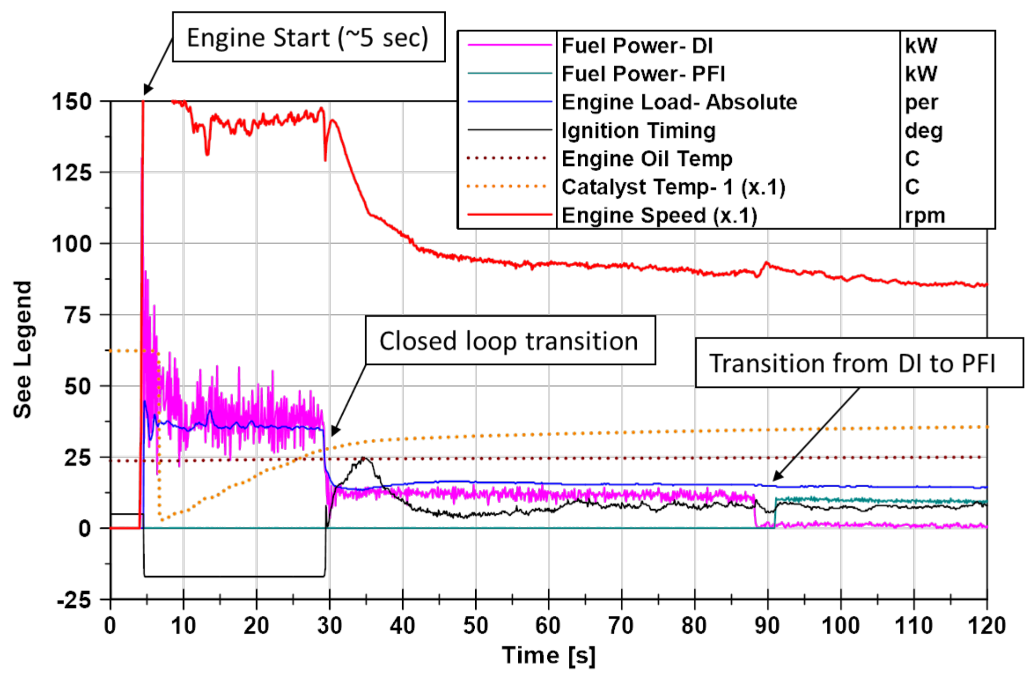

Figure 31. Initial 120 s of the idle fuel flow test

Figure 32 shows the full 30-minute duration of the idle fuel flow test. Engine oil temperature continues to increase over the duration of the test, ending slightly over 75 °C. At 525 seconds after the engine start, the catalyst temperature reaches a steady state of 405 °C.

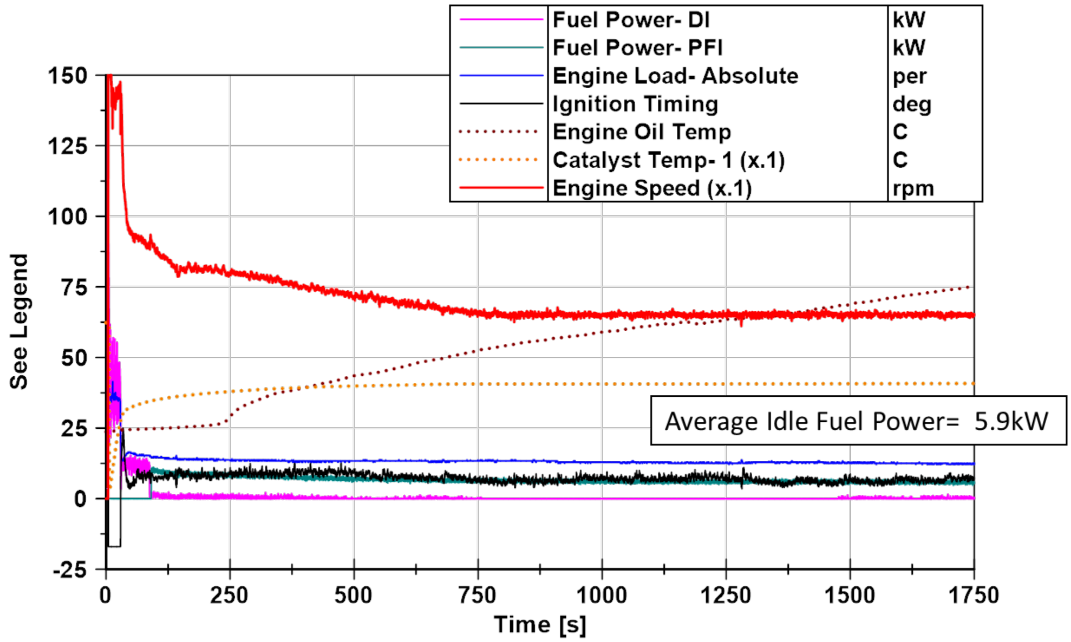

Figure 32. Idle fuel flow test – full duration

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

Fuels with octane ratings of 87 (RON 91) and higher are recommended for use in the 2018 Toyota Camry. Because of its lower price, the lower-octane fuel is expected to be the dominant fuel used by consumers for the Toyota Camry. Argonne tested the vehicle with both low and high octane certification fuels to capture data on the impact of octane rating on fuel economy and performance. The Tier 2 certification fuel has an octane rating of 93 AKI, and the Tier 3 certification fuel has an octane rating of 88 AKI. The Tier 2 fuel represents the premium fuel, and the Tier 3 fuel represents the regular fuel in this investigation.

The specifications for the fuels are in Table 5 and Table 6, with full fuel specification sheets in Appendix E: Cert Fuel Specifications. Although 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 it 3.7% lower compared to the Tier 2 – 93 AKI.

All testing for this octane comparison was performed with the dynamometer operating in 4WD mode, with a closed hood and a vehicle speed-match fan at an ambient test temperature of 23 °C. The initial testing of the Camry was performed on Tier 3 – 88 AKI. The majority of testing occurred on the low octane fuel, after which the fuel was drained and switched to Tier 2 – 93 AKI. Fuel exchange took place while the vehicle remained on the chassis dynamometer to reduce variability inherent in removing and remounting a vehicle for testing. Following the fuel change, a series of steady-state speed and transient (some aggressive) drive cycles were used to acclimate the vehicle to the new fuel. Once acclimated, a test sequence identical to that on the low-octane fuel was completed for comparison. A full review of the test order and the tests performed are provided in Appendix D: Test Summary.

The fuel economy results are shown in Table 13. At first glance, it appears that the higher-octane fuel (Tier 2 – 93 AKI) results in higher fuel economy; yet it is important to remember the 3.7%

difference in energy content between the fuels. Thus, Table 13 also includes the energy-adjusted fuel economy for the Tier 2 fuel. The energy adjustment calculation determined the ratio of the volumetric energy content of the Tier 2 and Tier 3 fuel to obtain an energy-equivalent gallon with the Tier 3 fuel as the reference. On the energy-adjusted basis, it appears that the Tier 2 fuel economy is slightly lower as compared to the Tier 3.

Table 13. Octane impact on fuel economy (mpg) on standard drive cycles at 23 °C

	Tier 3 – 88 AKI Avg. Fuel Economy (mpg)	**Tier 2 – 93 AKI Fuel Economy (mpg)**	**Difference based on mpg (%)**	**Tier 2 – 93 AKI Energy-Adj Fuel Economy (mpge)**	**Difference based on mpge (%)**
UDDS #1 cold start	33.4	34.4	2.8	33.1	-1.0
UDDS #2 hot start	35.7	37.1	3.8	35.7	0.0
UDDS #3	35.9	36.8	2.5	35.4	-1.3
Highway	56.6	57.4	1.3	55.3	-2.4
US06	32.7	33.7	3.1	32.4	-0.7

The vehicle efficiency based on the SAE J2951 [10] calculations are shown in Table 14. The vehicle efficiencies for the Tier 2 – 93 AKI fuel are lower than for the Tier 3 – 88 AKI fuel. It is not possible to determine the reasons (octane, energy content, other fuel specifications) for the shift without further testing. Additionally, focused testing with increased instrumentation would quantify test to test variability, and where it arises from.

Table 14. Octane Impact on vehicle efficiency

Vehicle Efficiency	**Tier 3 – 88 AKI (%)**	**Tier 2 – 93 AKI (%)**
UDDS #1 cold start	21.5	20.2
UDDS #2 hot start	22.9	21.7
UDDS #3	22.9	21.6
Highway	32.4	30.3
US06	30.8	29.4

Figure 33 shows the value of knock feedback correction on a pair of UDDS cycles (a cold-start followed by hit-start UDDS) for the series of tests for both fuels. The knock feedback correction is an ignition adjustment the engine controller establishes based on the knock sensor readings at high loads in response to aggressive engine loading. The correction value on the Tier 2 – 93 AKI fuel is consistently higher than the Tier 3 – 88 AKI fuel by 2 degrees crank angle. An additional item of note is the adjustment to the knock feedback value, which occurs at approximately 2,150 seconds on an acceleration at high speed. As knock is more likely to occur at high load points, additional tests were reviewed for adjustment between fuels.

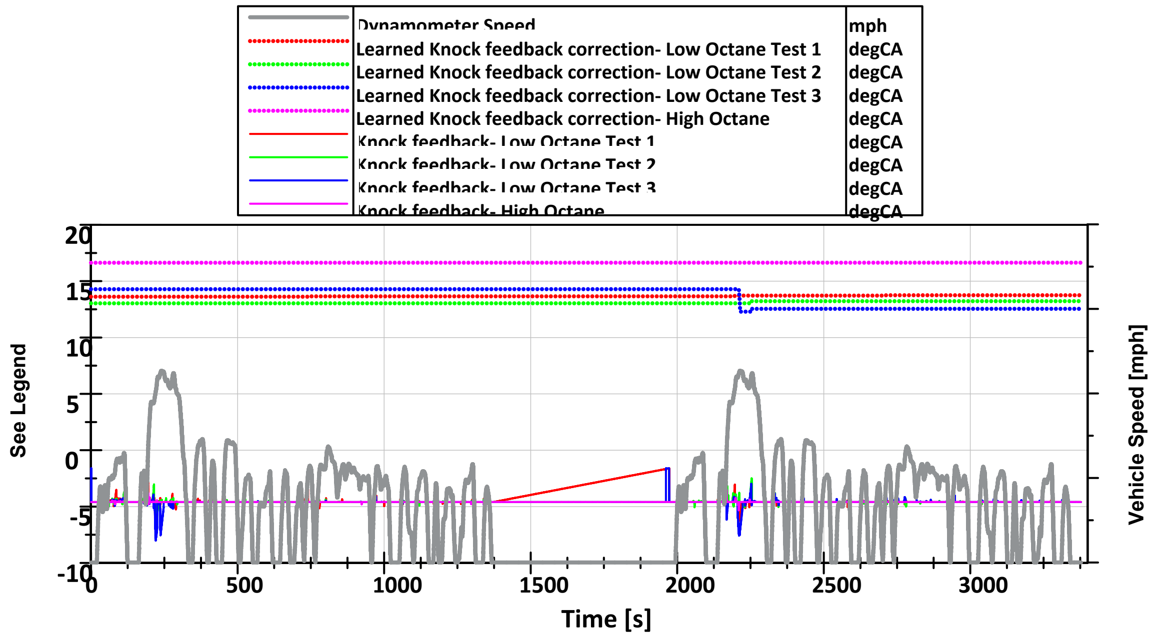

Figure 33. Knock feedback signals on UDDSx2 cold-start cycles

Figure 34 shows the ignition timing for both fuels for the UDDS, HWFET, and US06 cycles, as well as the passing maneuver test and the maximum acceleration test. The maximum absolute load limit appears to be the same for both fuels (note that this is not absolute engine brake torque). For the lower-octane fuel, the spark ignition timing is retarded by a few degrees at these higher loads to prevent engine knock from occurring.

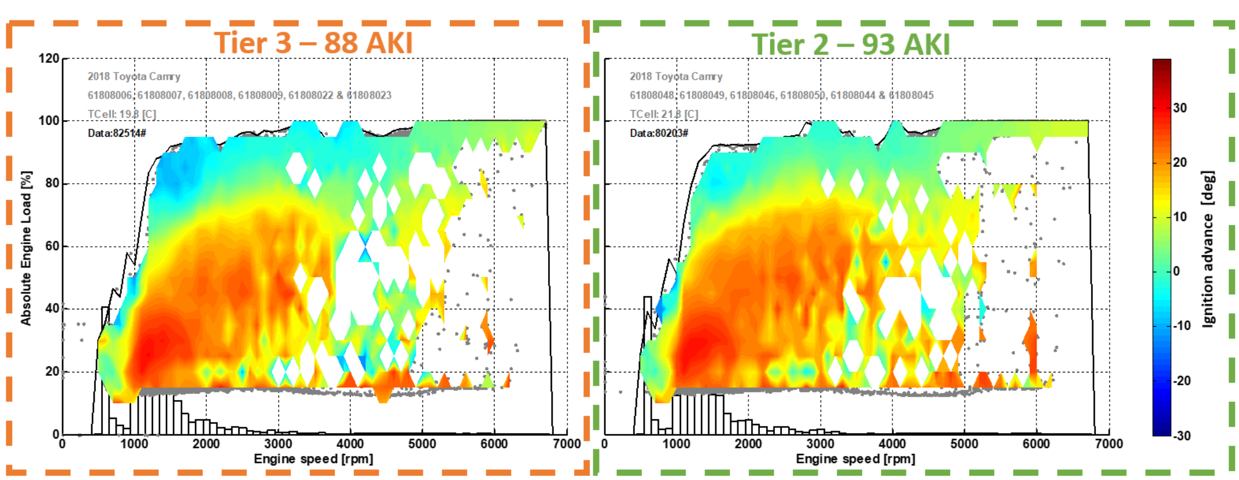

Figure 34. Spark advance comparison between Tier 2 and Tier 3 fuels

Additionally, vehicle performance on these acceleration tests was found is improved on the 93 AKI fuel when compared to the 88 AKI fuel. Vehicle acceleration to 80 mph was 1 second faster under maximum acceleration with the 93 AKI fuel. The performance tests suggest that the engine torque is increased with the higher-octane fuel due to effects of spark advance.

5.8. Analysis on Impact of Different Test Dynamometer and Cooling Setups

As mentioned in the vehicle and test cell setup section, the Argonne testing deviates from certification testing as Argonne's goal is research fidelity rather than regulatory compliance. To quantify the differences, the AMTL executed additional testing to probe the impact of different vehicle and test cell setups. The major differences center around the cooling setup with changes around the test cell fan speed control and a test setup in 4WD vs. 2WD on the chassis dynamometer.

The multiple setups under which the vehicle has been tested are described in Table 15. The AMTL performed the majority of the testing in Setup 1. Setup 2 has the same setup as Setup 1, though it occurred after the vehicle was removed from the chassis dynamometer and driven on the road for 600 miles for on-road testing. At the beginning of Setup 1, the vehicle loss was determined in the 4WD mode on the chassis dynamometer using the target road load coefficients from Table 7, which were published by the EPA. The fuel economy of the Highway drive cycle was 57.4 mpg and 53.8 mpg on Tier 2 fuel for Setup 1 and 2, respectively. This difference represents the variability in fuel economy when taking the vehicle off the dynamometer between tests, even though coast down testing was performed to redetermine vehicle losses.

Table 15. Varying vehicle modes during comparative HWFET cycle testing

	Setup 1	**Setup 2**	**Setup 3**	**Setup 4**	**Setup 5**
Test IDs	61808046	61811006	61811008	61811009	61811013
Test setup:					
Fuel	Tier 2 fuel				
Vehicle fan state	Variable	Variable	Constant 5250 CFM	Constant 5250 CFM	Constant 5250 CFM
Hood position	Closed	Closed	Open	Open	Open
Dyno mode	4WD	4WD	4WD	2WD	2WD
Dyno sets A [lb] B [lb/mph] C [lb/mph^2]	4WD determined A = -13.27 B = 0.3003 C = 0.0142	Initial coefficients A = -13.27 B = 0.3003 C = 0.0142	Initial coefficients A = -13.27 B = 0.3003 C = 0.0142	EPA listed A = 8.992 B = 0.0187 C = 0.0178	2WD determined A = 6.1244 B = 0.1732 C = 0.0160
Note	Majority of testing	Vehicle remounted after 600 miles of on-road testing	EPA cooling	2WD setup – Traction control off EPA cooling	2WD setup – Traction control off EPA cooling
Results					
Fuel economy Tier 2 (mpg)	57.4	53.8	53.7	54.0	55.0
Fuel energy [MJ]	21.74	23.23	23.25	23.15	22.70

	Setup 1	Setup 2	Setup 3	Setup 4	Setup 5
CEd (J2951)	6.58	6.69	6.67	6.67	6.60
Veff (J2951)	30.3%	28.8%	28.7%	28.8%	29.1%
Alternator load [Wh]	47.2	52.4	86.4	81.6	84.0

The difference between Setups 2 and 3 is the cooling. The use of a constant fan speed with the vehicle hood open, impacts the vehicle thermal state, which makes a difference on the HWFET cycle. The fuel economy for Setups 2 and 3 at 53.8 mpg and 53.7 mpg, respectively, was similar; yet the cooling system in the car operates differently, as shown in Figure 35. The engine and transmission operate at a higher temperature in Setup 3, and the vehicle cooling fan turns on.

Comparing Setup 3 to Setup 5 shows the difference between 4WD and 2WD testing. The difference appears minimal. Comparing Setups 4 and 5 highlights the difference between using the EPA road load set coefficients vs. the Argonne-determined 2WD road load set coefficients; again, the difference is minimal.

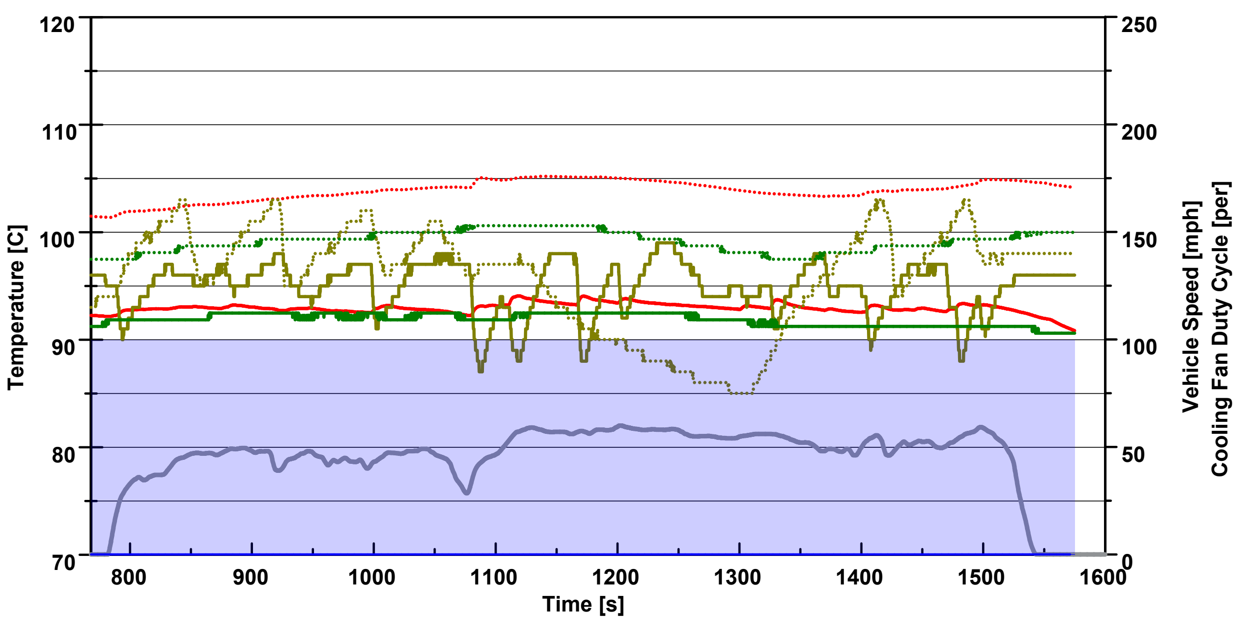

Figure 35. Powertrain thermal and cooling information between different testing setups.

5.9. CAFE Fuel Economy Results With Certification Testing Comparison

The fuel economy results from the testing at Argonne compare closely to the fuel economy results published by EPA for manufacturer certification under the data on cars used for testing fuel economy[6]. Data was published on the unadjusted fuel economy results from the manufacturer for phases 1, 2, and 3 of the UDDS, as well as the HWFET cycle. Figure 36 and Table 16 compare the published fuel economy results to the low-octane three-test sequences and one high-octane test completed at the AMTL. Note: The vehicle setup at Argonne for several tests varies from the certification testing as described in Table 15.

The test results on the Tier 3 fuel show a good repeatability, the highest deviation of any phase to the average fuel economy is less than 0.5%.

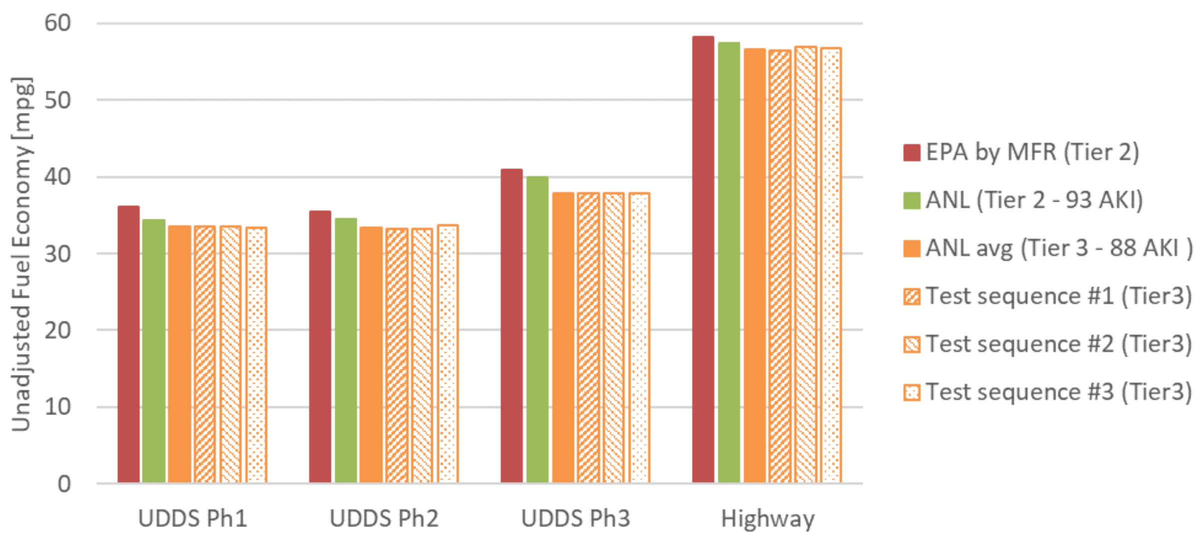

Figure 36. Raw fuel economy results: UDDS and HWFET certification cycles from EPA and Argonne

Table 16. Raw fuel economy results: UDDS and HWFET certification cycles from EPA and Argonne

	EPA by MFR (Tier 2)	Argonne (Tier 2 – 93 AKI)	Argonne avg. (Tier 3 – 88 AKI)	Repeat #1 (Tier 3)	Repeat #2 (Tier 3)	Repeat #3 (Tier 3)
UDDS Phase 1	36.1	34.3	33.5	33.5	33.6	33.4
UDDS Phase 2	35.5	34.5	33.4	33.3	33.3	33.6
UDDS Phase 3	40.9	40.0	37.9	37.9	37.9	37.9
HWFET	58.2	57.4	56.6	56.4	56.9	56.7

6. Component and Control Analysis

This section describes the vehicle component controls, including transmission shifting, torque converter lockup, engine fuel cutoff, and detailed component control concepts. Models and control calibrations developed through this analysis have been implemented in Autonomie.

6.1. Signal Calculations for Control Analysis

The vehicle component control analysis is conducted using Autonomie "Import Test Data" process. 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 37.

In Figure 37 the signals labeled in black, blue and green are obtained directly from the test. At energy management strategy level, the signals used to calculate the engine power and the signals to calculate the 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 prior published work [11]. Techniques used in the process will be described in the following section.

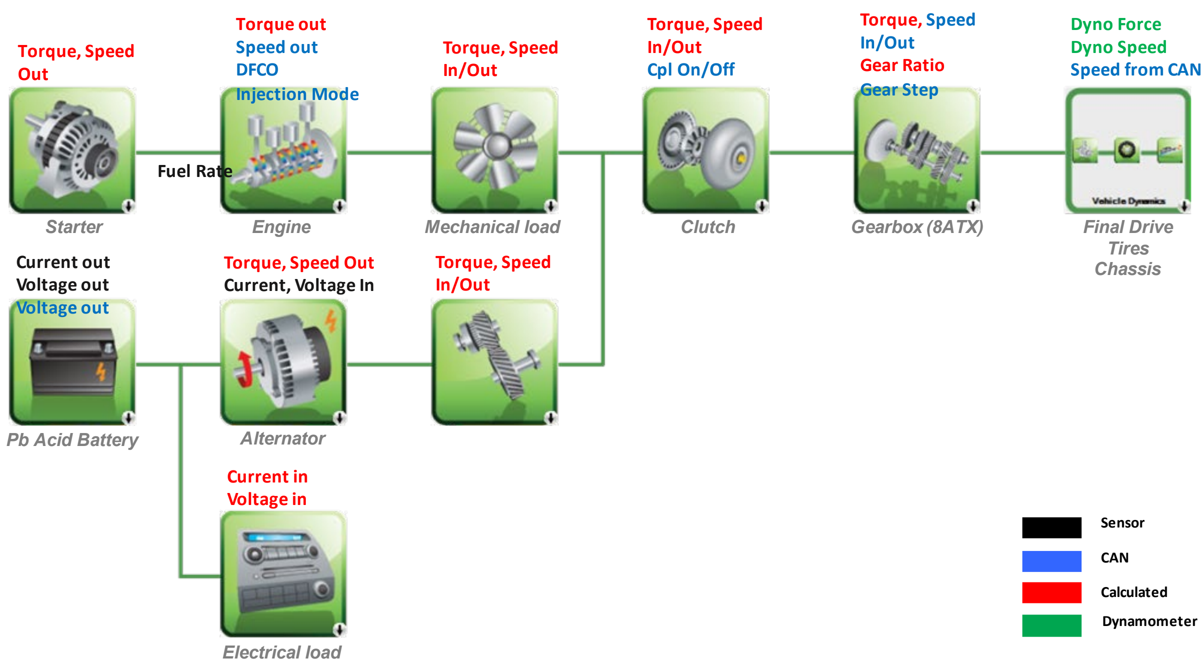

Figure 37. Schematic of the vehicle configuration

Since not all signals can be recorded, additional one are calculated based on measured ones and additional information obtained by external sources [5]. First, the time based rotating speed of each component is calculated as shown in Figure 38.

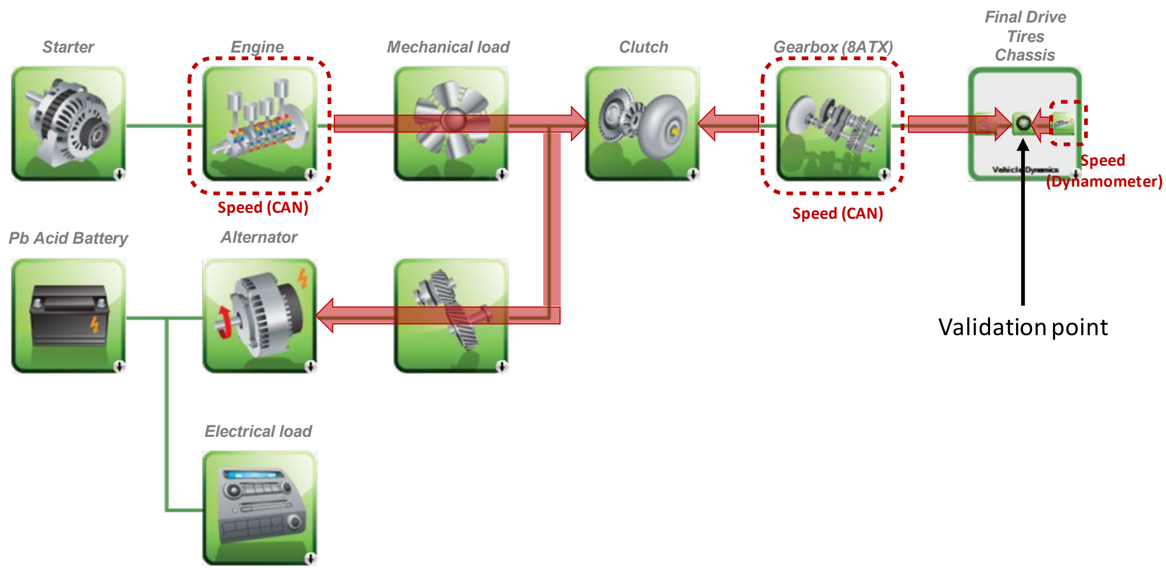

Figure 38. Calculation of missing signals for component speed

The wheel speed can be calculated from the speed signal that is obtained from the dynamometer.

$$w_{wheel} = \frac{1}{r_t} v_{chassis}$$

Equation 1

where r_t is the radius of the tire. Because the tire under driving condition is known, the speeds can be validated by comparing the two values of w_{wheel} 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 39 shows the flow of the calculation for torque signals. Because an accurate transmission efficiency map is not available, the torque calculation process is divided into two parts: from the transmission output to the wheel and from the engine to the transmission input.

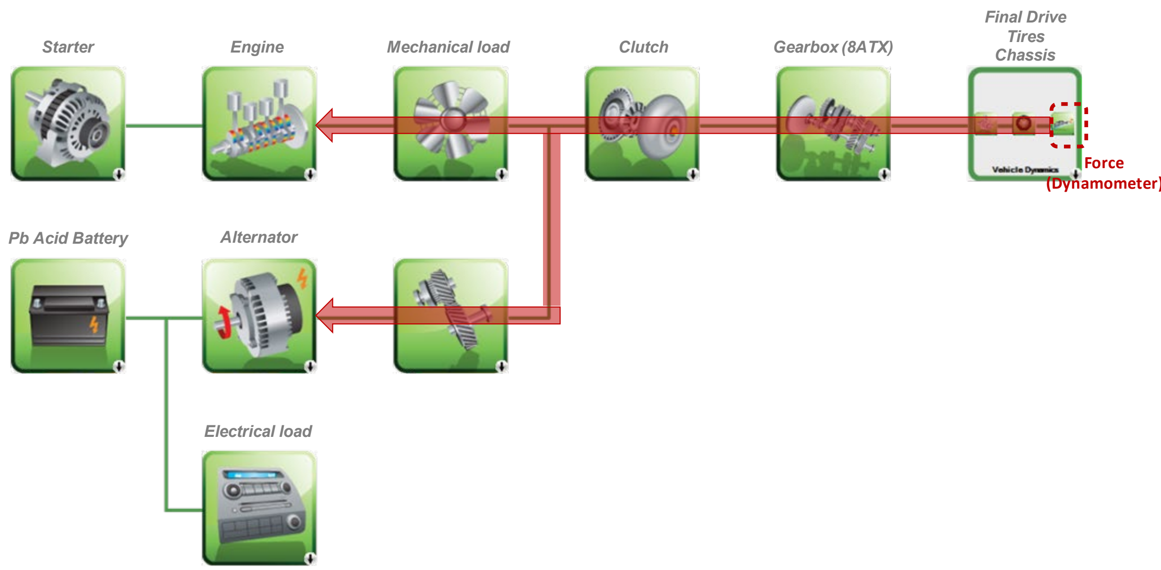

Figure 39. Calculation of missing signals for component torque

The output torque of the final drive is calculated from the force obtained from the dynamometer.

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

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, which are generic values and will be applied to the following calculations in this report.

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

Equation 4

The torque input of torque converter is calculated from the gearbox torque and the torque converter characteristics.

$$T_{TC,in} = \frac{T_{gb,in}}{T_{ratio}(= f(\omega_{ratio}))} + \dot{\omega}_{TC} \cdot J_{TC}$$

Equation 5

where T_{ratio} is the torque ratio of torque converter, and ω_{ratio} is the speed ratio of turbine speed to impeller speed for torque converter.

The torque of engine is calculated from the torque of torque converter and accessory load torque.

$$T_{eng} = T_{TC,in} - T_{acc_{mech}}$$

Equation 6

All the equations for torque calculation are based on static equilibrium. The parameter values used in the calculations are listed in Table 17.

Table 17. Parameter values used for calculating additional signals

Parameters	Values
Tire radius, r_t	0.323m
Gear ratio of the transmission	5.250/ 3.028/ 1.950/ 1.456/ 1.220/ 1.000/ 0.808/ 0.673
Gear ratio of the final drive, γ_{fd}	2.802
Vehicle test weight	1,644 kg

In addition, we also calculate the signal for the actual gear number. There is a gear number signal in the CAN signal, but it is a request signal for control, and the actual gear number can be calculated as follows. In Figure 40 the speed ratio (yellow) is obtained from the CAN, and speed ratio (green dot) is calculated on the basis of measured turbine speed and vehicle speed. Compared to the request signal from CAN, the actual gear ratio is delayed due to the shifting time. The elements of actual speed ratio can be rounded to the nearest value of gear ratio that we already know.

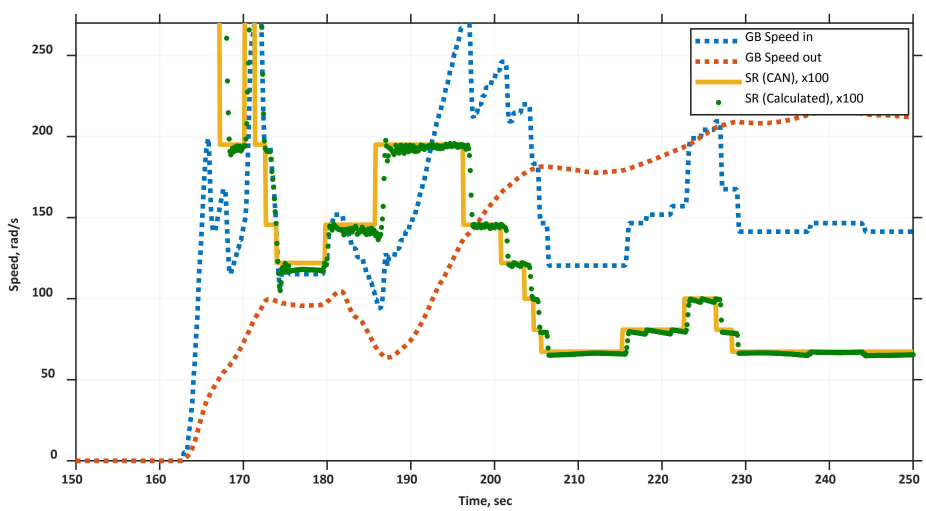

Figure 40. Calculation of missing signals for component speed

Besides the signals introduced in this section, other signals representing efforts and flows are calculated based on reasonable assumptions. However, the signals introduced in this section are important signals to analyze the control behavior of the vehicle.

6.2. Transmission Operation

The 2018 Toyota Camry has an 8-speed automatic transmission. The transmission operation was analyzed to estimate those control parameters used in Autonomie. The details of such analysis are explained in the subsequent sections.

6.2.1. Cert Cycle Duration in Each Gear

Figure 41 shows the comparison of time spent in each gear number for each gear.

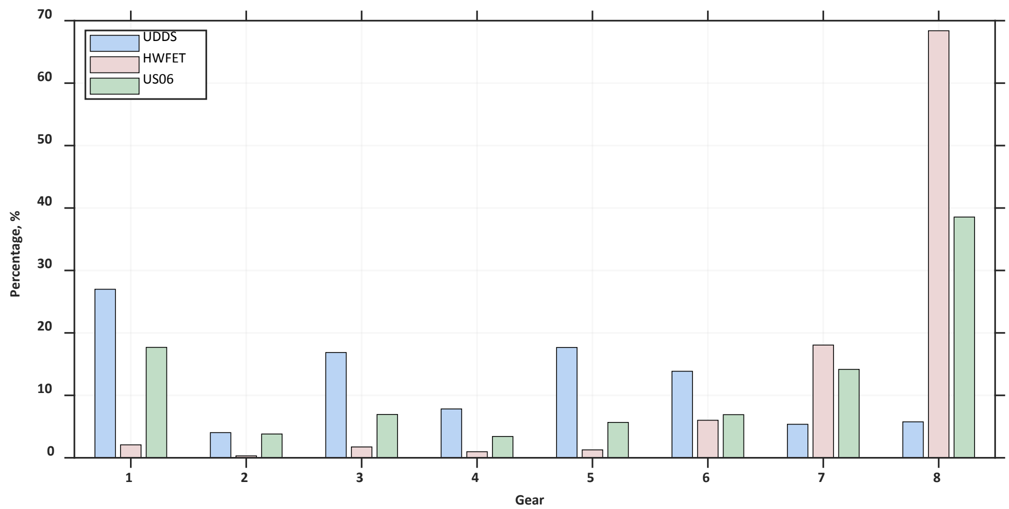

Figure 41. Time spent in each gear number for the UDDS/HWFET/US06 cycles

In the case of urban driving it is found that the lower gears are used more frequently, but in high-speed driving the transmission is operating in the eighth gear approximately 70% of the time.

6.2.2. Shift Mapping

Once all the test data were imported, the analysis functions developed in this study were used to generate shifting maps using the integrated test data. Using these functions, plots could be generated to implement upshifting and downshifting maps. In Figure 42 and Figure 43, the transmission operation points of the 8-speed automatic transmission for the 2018 Toyota Camry's overall driving cycles (under normal ambient temperature) are shown with respect to either vehicle speed and accelerator pedal position, or vehicle speed and wheel torque. In Figure 44 and Figure 45, the shifting points are also plotted with respect to vehicle speed and accelerator pedal position for both upshift and downshift.

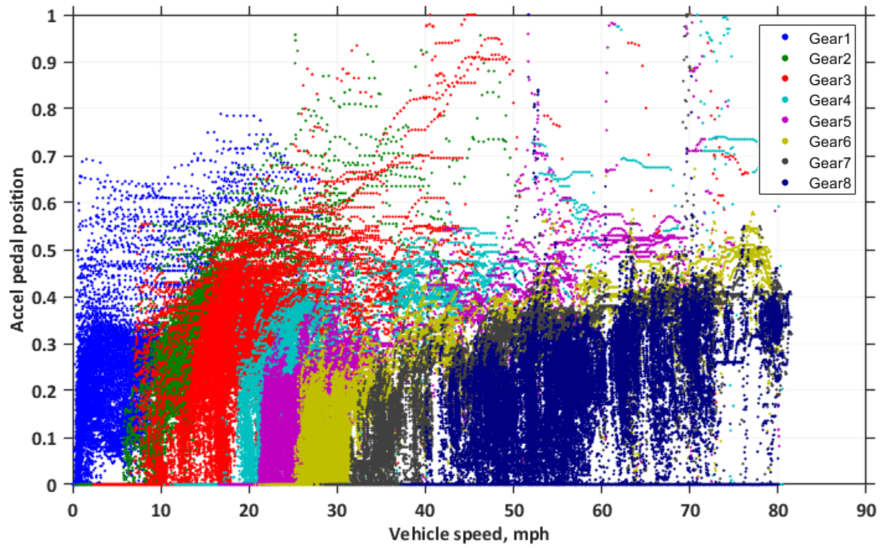

Figure 42. All operating points according to gear number – vehicle speed vs accelerator

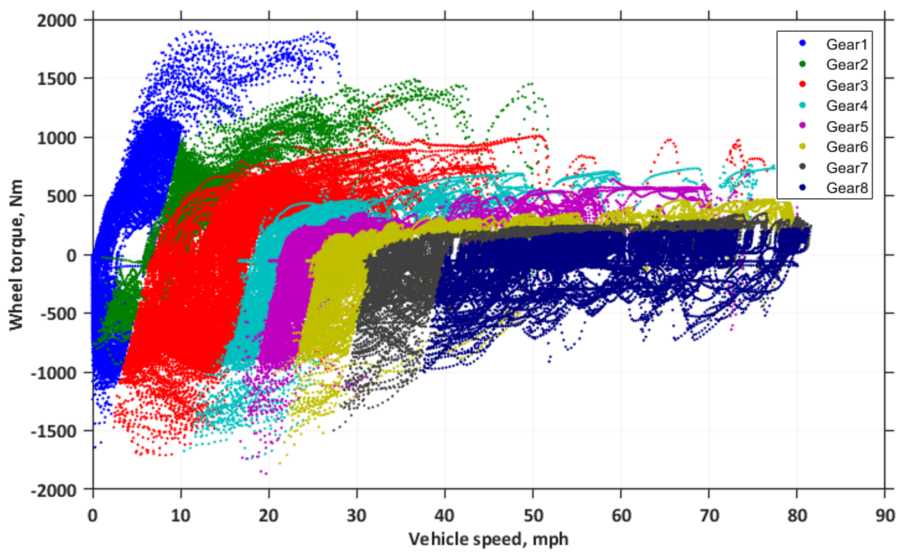

Figure 43. All operating points according to gear number – vehicle speed vs. wheel torque

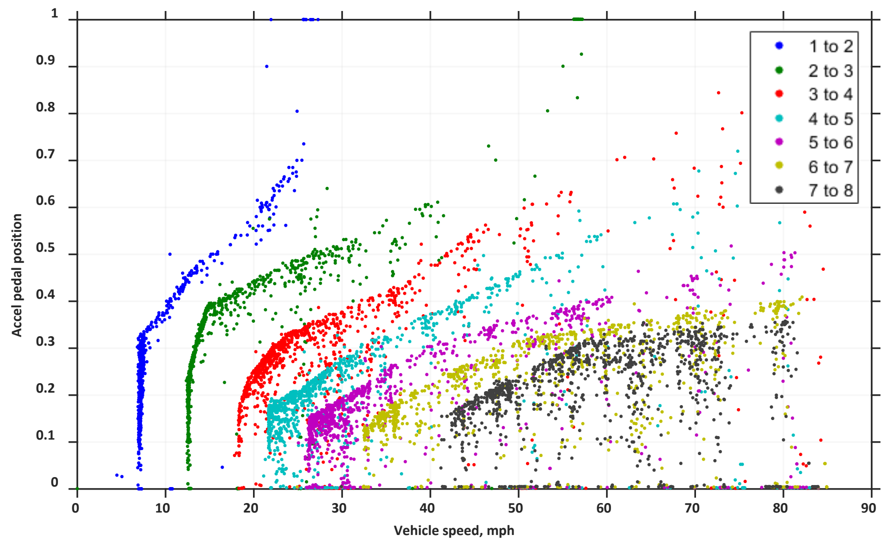

Figure 44. Transmission shifting points – upshifting

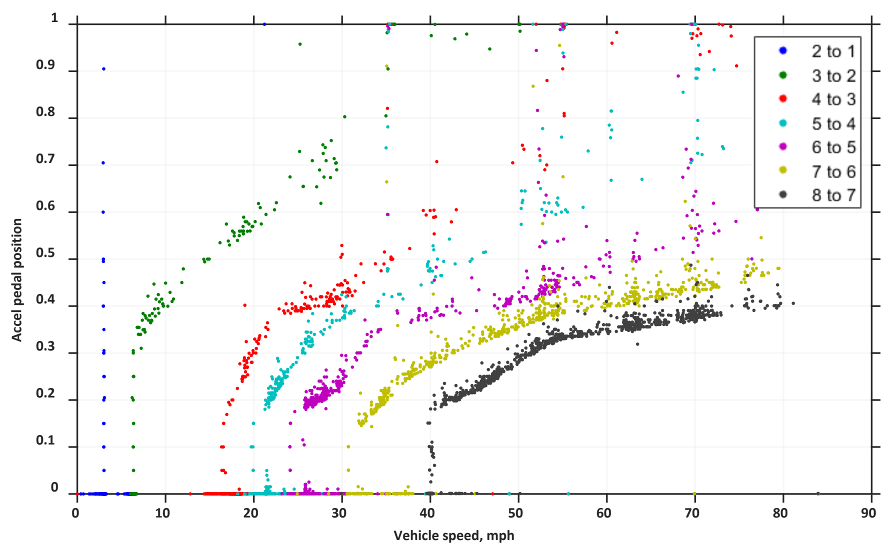

Figure 45. Transmission shifting points – downshifting

6.2.3. Torque Converter Lockup Status

In order to see the overall behavior of the torque converter lockup status, all operating points of the vehicle from all test data are shown in Figure 46 and Figure 47. These graphs show that the clutch is locked above a certain speed or above a certain torque. Figure 47 shows that the clutch is locked when the wheel torque is mostly positive, and the vehicle speed is about 13 mph or higher. In particular, in the high-torque region of low vehicle speed, the torque converter is unlocked to utilize the torque multiplying effect.

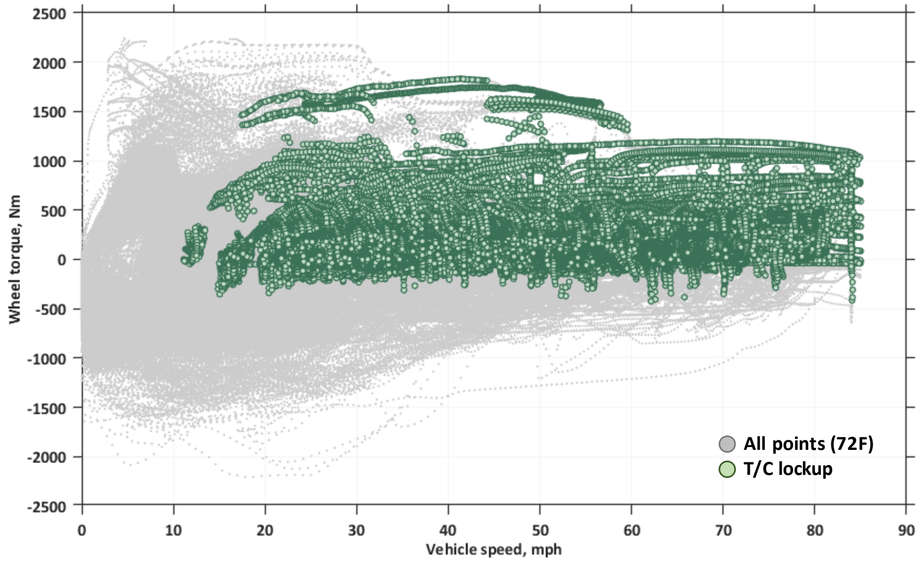

Figure 46. Torque converter lockup operation – wheel torque vs. vehicle speed

In Figure 47, the torque converter locks up above 1,000 rpm for gears greater than or equal to the second gear of transmission. It is also evident that when the engine speed is high by each gear, the torque converter is released.

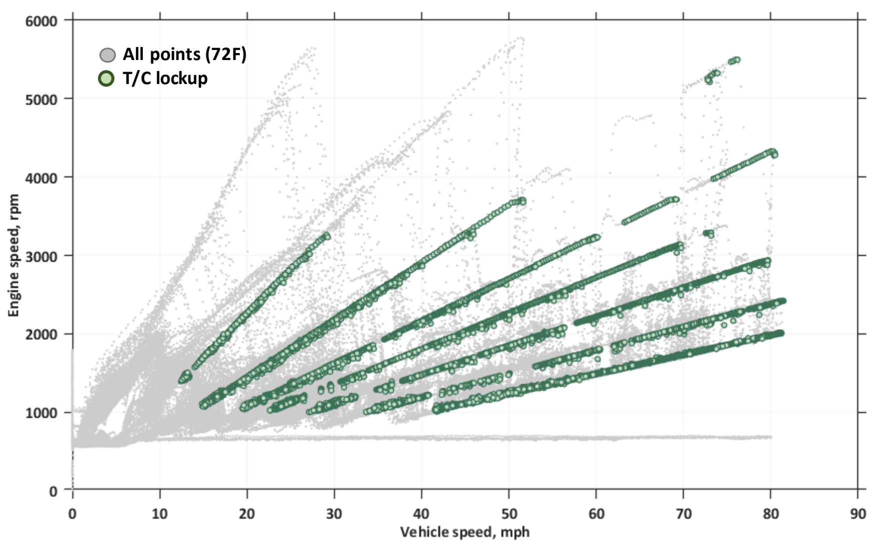

Figure 47. Torque converter lockup operation – engine speed vs. vehicle speed

The percentage of torque converter lockup per cycle is summarized in Table 18. While driving in the urban cycle, the torque converter is locked approximately 20 percent of the time, but it is locked up more than 50 percent of the time during high-speed driving.

Table 18. Percentage time of torque converter locked per each cycle

Test Cycle	UDDS	HWFET	US06	WLTP[a]	NEDC[a]	LA92[a]
%	15.48	55.56	36.70	22.85	21.64	15.15

[a] LA92 = also called the Unified LA-92; NEDC = New European driving cycle; and WLTP = world harmonized light-duty vehicles test procedure.

6.2.4. Lockup Variability per Gear

To analyze how torque converter lockup is controlled for each gear, we plot the points at which the clutch is engaging and the points at which the clutch is disengaging. In Figure 48 and Figure 49, the points at which the torque converter clutch is engaging are indicated by green points, and the points at which the clutch is disengaging by red points in the domain of engine speed and acceleration pedal position.

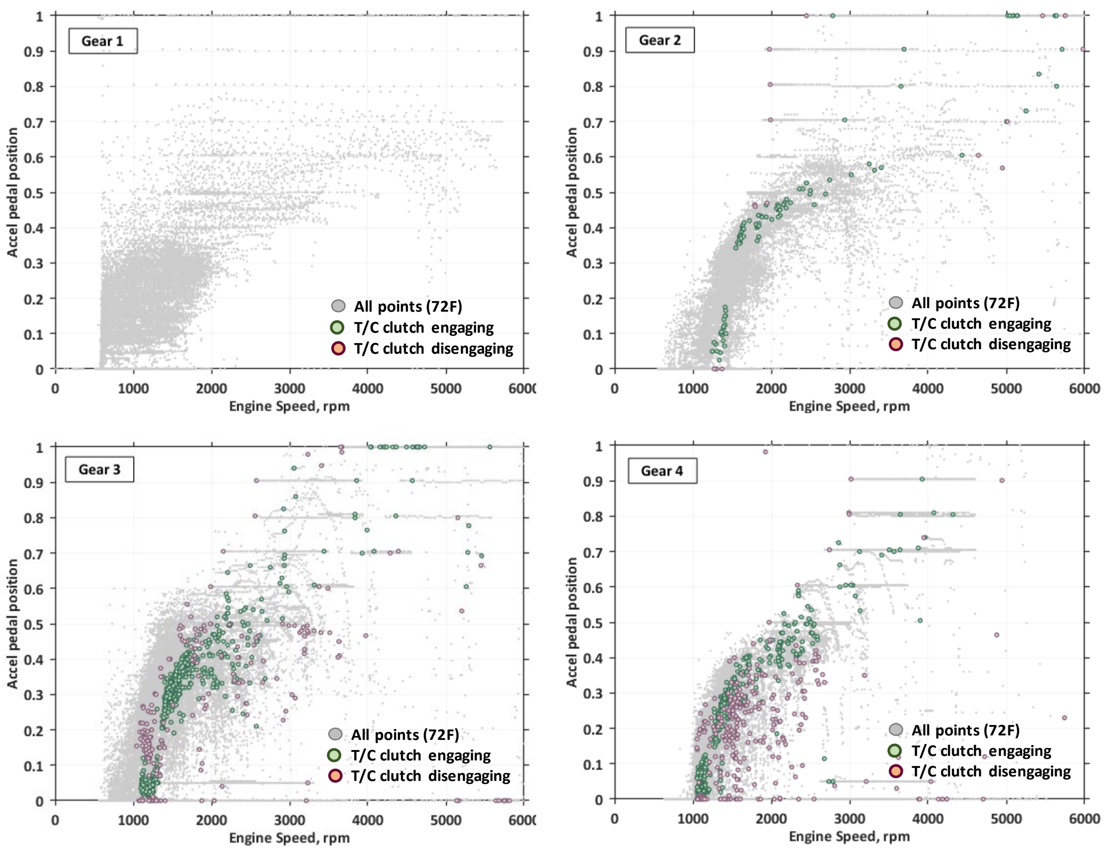

Figure 48. Torque converter operation points for lockup vs. non-lockup for each gear (1 to 4)

As noted in Section 6.3.2, the torque converter clutch is not engaged in the first gear. The points at which the clutch of the torque converter is engaged are clearly visible in the form of lines, whereas the points that are released are relatively distributed in many places. Our analysis of these findings is that if the engine speed is increased, the clutch is released to shift to the high gear. Further, if the acceleration pedal position increases, the clutch is again released in order to shift to a lower gear or requires a torque multiplying effect of torque converter.

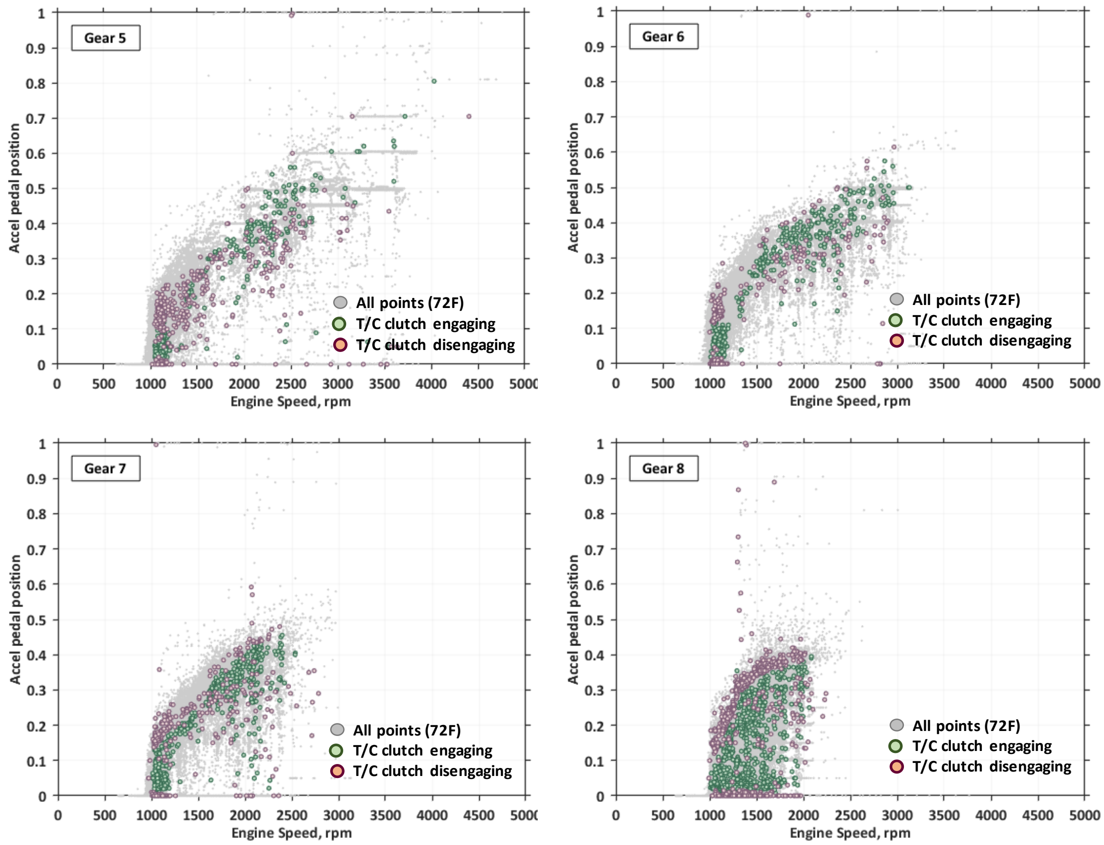

Figure 49. Torque converter operation points for lockup vs. non-lockup for each gear (5 to 8)

In Figure 50 the torque converter lockup is shown for various engine speeds. Difference between the torque converter turbine converter turbine speed and the torque converter impeller speed help in identifying the lockup conditions. The points at which the torque converter clutch is engaged are indicated by the green points. It is evident that the torque converter is engaged when the difference is smaller than about 60 rpm. When engine speed is less than 1,000 rpm, the torque converter remains open.

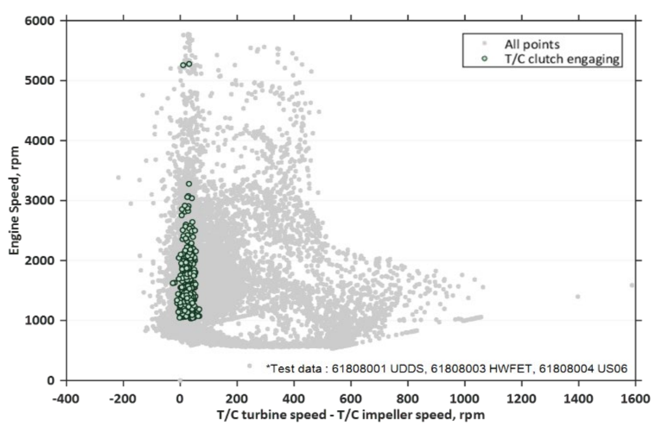

Figure 50. Torque converter operation points for lockup

6.3. Deceleration Fuel Cutoff

Deceleration fuel cutoff (DFCO) is a feature that many current electronic control units (ECUs) support; it detects whether the vehicle is coasting downhill and then cuts fuel to the engine and allows the wheels to keep the engine running. To analyze when DFCO works, we first plot the operating points on the graph of the wheel torque and vehicle speed axes. In Figure 51 the DFCO is active only when the wheel torque is negative, especially when the vehicle speed is above about 1 mph.

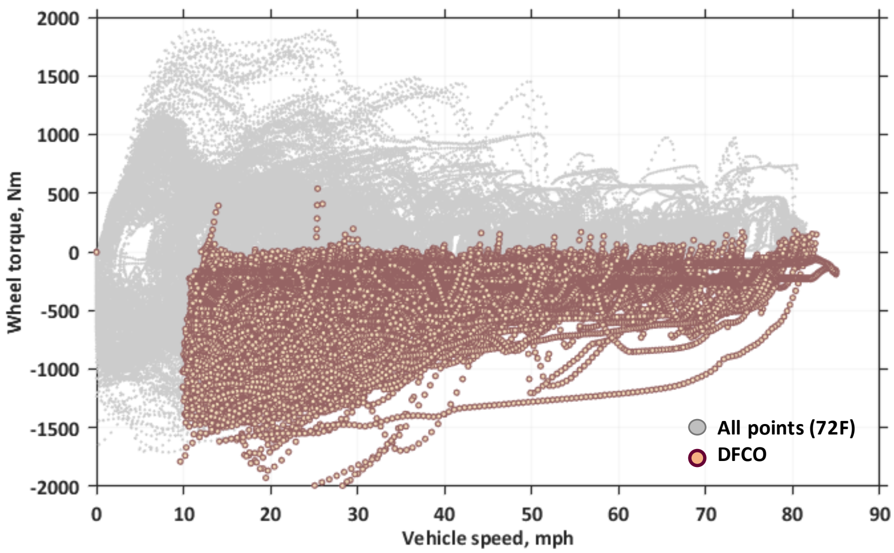

Figure 51. Operation of the DFCO when the braking is active

In Figure 52 DFCO operation points are shown in plot engine speed and vehicle speed. It is evident that DFCO does not activate in the first and second gears.

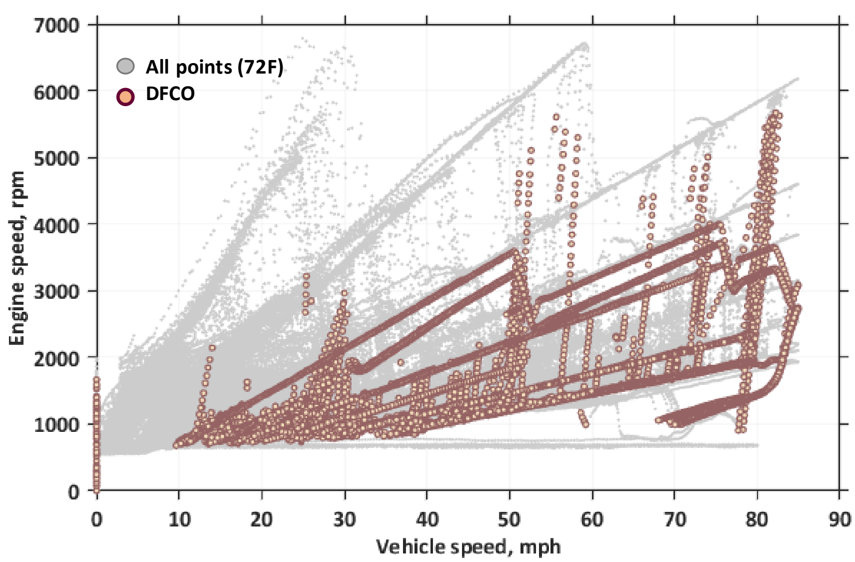

Figure 52. Operation of the DFCO for each gear

6.4. PFI vs. DI Operation

The 2018 Toyota Camry is equipped with an entirely new combustion technology engine that has adopted a new multi-hole type of direct fuel injector (DFI) with improved engine power and fuel economy and reduced exhaust emissions. The engine implemented a new D-4S system that allows transition to multi injection mode (i.e., direct injection, or DI and port fuel injection, or PFI) by control of the multi-hole fuel injector. To analyze how the injection mode of the engine is determined, we first checked the engine power points by engine coolant temperature. Figure 53 and Figure 54 show that fuel injection mode is controlled differently depending on engine coolant temperature for all driving cycles at normal ambient temperature. When the initial engine is started cold as shown in Figure 55, only the DI mode is used until the coolant temperature becomes warm (about 35 °C). When the engine coolant temperature is between 35 °C and 60 °C, the fuel is injected in PFI mode for the initial low-power section, and only DI mode is performed in the higher power range. When the engine coolant is above 60 °C, the fuel is injected by DI mode only in the high-power operating range.

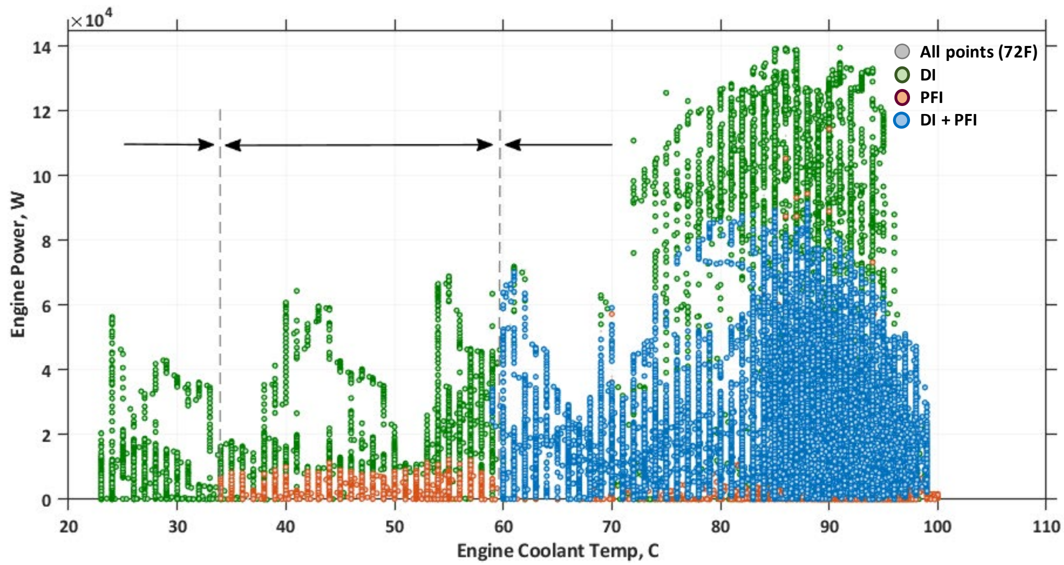

Figure 53. Operating behavior of the fuel injection mode

In Figure 54 we plotted the injection mode of the engine in the axis of engine torque and speed when the engine coolant temperature is between 35 °C and 60 °C. In order to obtain the control boundary, we selected only the engine operating points when the engine speed stays steady in range, such as +/-140rpm for 2 seconds—we only tune the thresholds to get a better trend, as shown in the right plot of Figure 54.

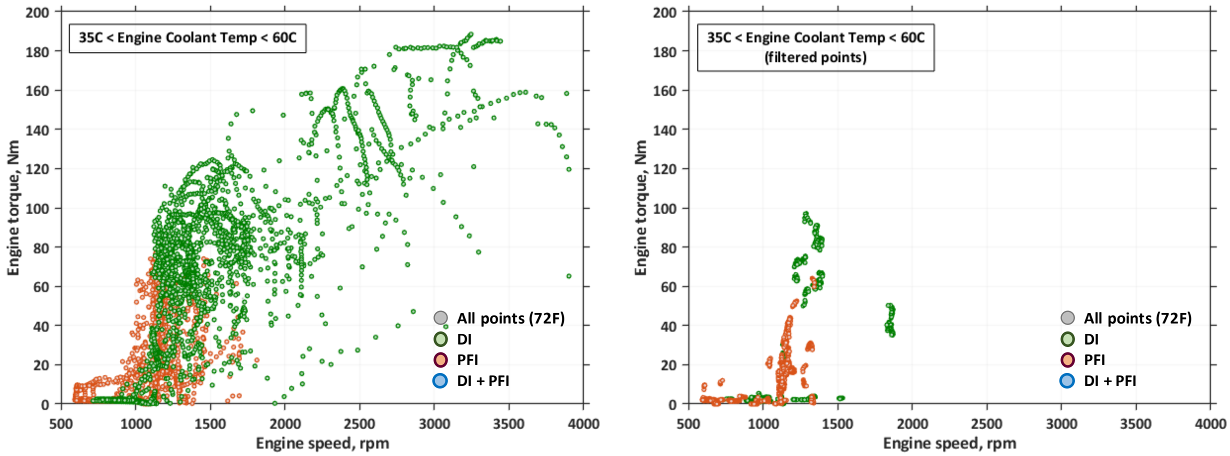

Figure 54. Operating behavior of the fuel injection mode (when the engine coolant temperature is between 35 °C and 60 °C)

By using the filtering techniques for engine mapping test data, we obtained the operating boundary as shown in the right plot of Figure 55. The engine operates in PFI mode at initial start-up or at low power demand, and uses both modes simultaneously in most engine operating ranges. However, it is evident that only the DI mode is used in the region of high torque or high speed of engine.

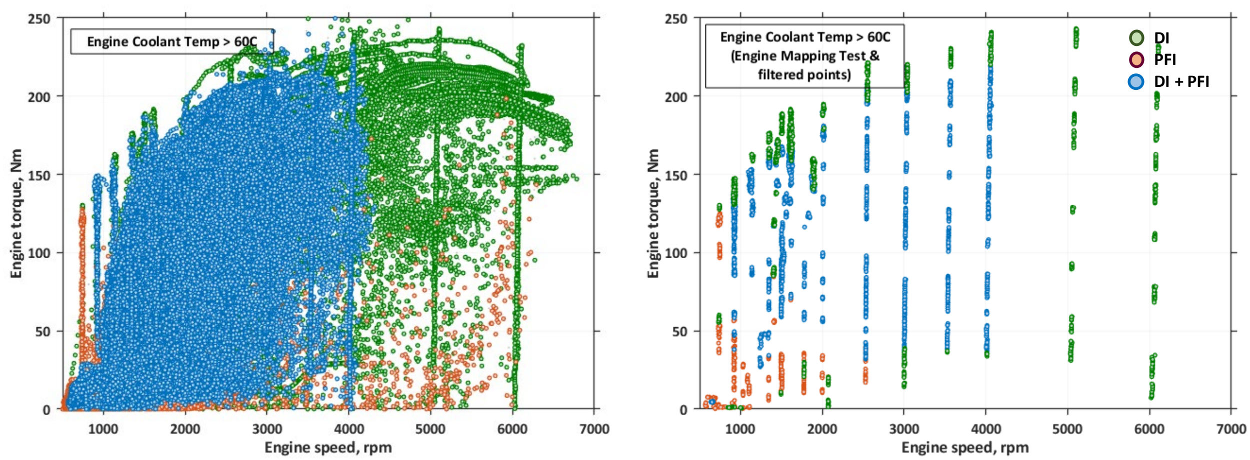

Figure 55. Operating behavior of the fuel injection mode (when the engine coolant temperature is above 60 °C)

6.5. Engine Operation

6.5.1. Fuel Rate Map

To validate the vehicle model with the test data, the engine model is the most important component to be precise. The engine fuel rate map is imported from the engine mapping test data as in Figure 56. Till the engine warms up to a stable operating temperature, it would have a relatively higher fuel consumption. However, the engine model is assumed to be in the warmup state for validation purpose, so the fuel map is generated from test data where engine coolant temperature is above 60 °C. In the figure the only points that remain are when the time derivative of the acceleration pedal is below 0.1/s, by which it is assumed that the points are obtained under relatively steady operating conditions.

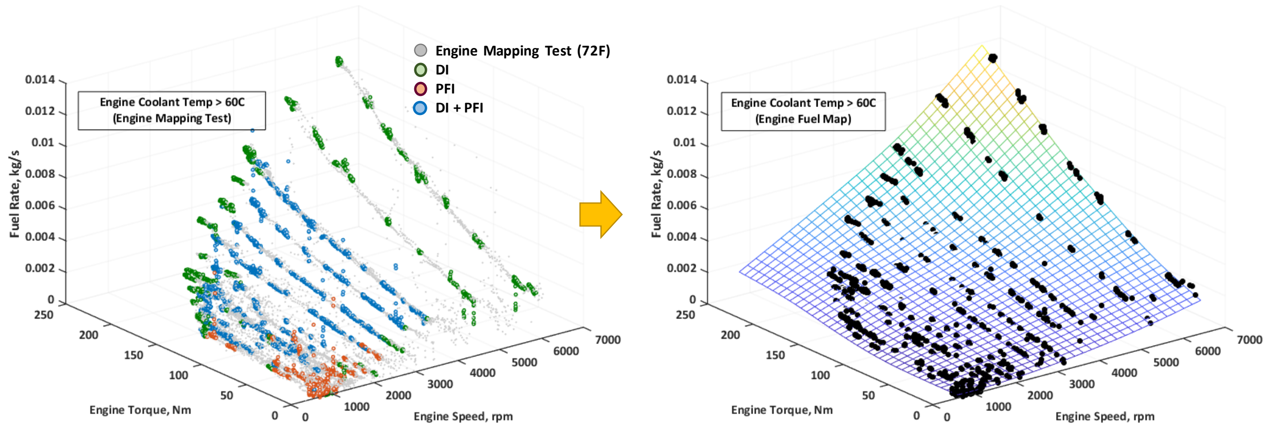

Figure 56. Engine fuel rate map according to engine speed and torque

6.5.2. Torque Pedal Map

The accelerator pedal is not a simple way of directly moving the throttles on the engine, because the ECU replaced the traditional Bowden cable between the pedal and throttle with a pedal position sensor and a map. Such torque pedal maps are restricted to each gear, vehicle speed, and transmission mode of operation, etc. To analyze the torque pedal maps according to the engine speed and the accelerator pedal for each gear, we plot the engine throttle position as shown in Figure 57 and Figure 58. For each gear stage, the correlation between the accelerator pedal and the engine throttle position appears to be slightly different. When the engine speed or vehicle speed is high, it is evident that the engine throttle responds even more sensitively when the driver steps on the same accelerator pedal.

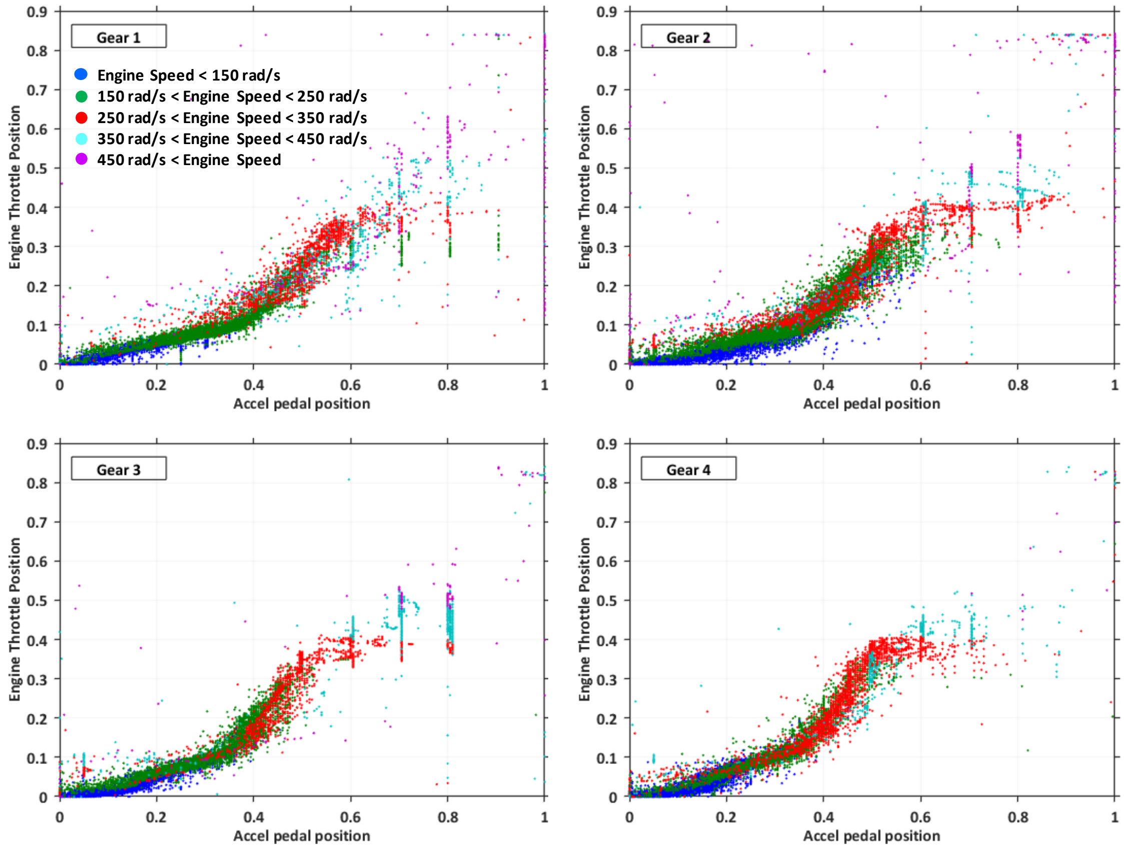

Figure 57. Torque pedal map for each gear (1 to 4)

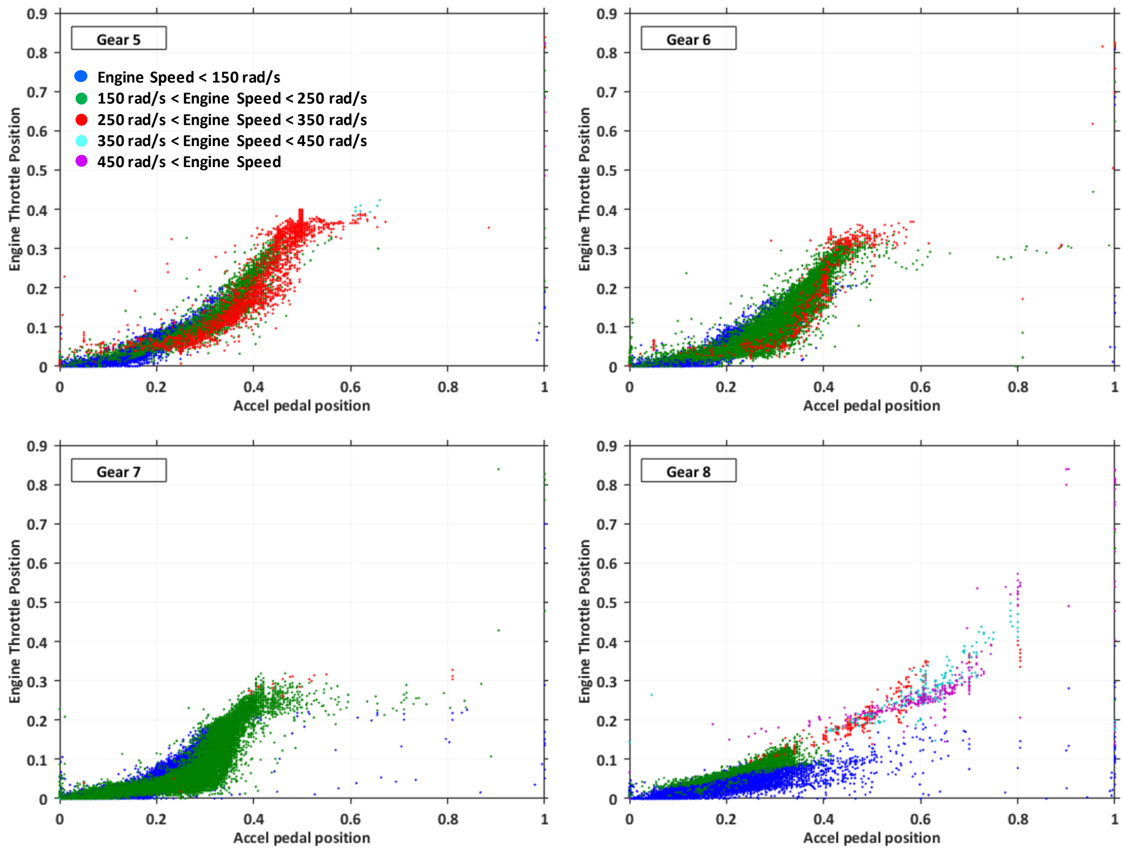

Figure 58. Torque pedal map for each gear (5 to 8)

6.6. Impact of Thermal Management Technologies on Vehicle Controls

We have introduced the analysis results about the thermal control of the vehicle. In this chapter, additional control behaviors observed in our analysis will be introduced especially for thermal condition. These controls are not very essential to determining the operations of the components if the vehicle is driving under normal conditions. However, the thermal impacts on control and performance become more important issues even in conventional vehicles. The thermal impacts that affect control behavior will be vigorously discussed first, followed by the performance analysis under different thermal conditions.

6.6.1. Engine Operation Under Cold Conditions

Although the thermal management system for the engine is designed to heat it up as quickly as possible with advanced techniques [6], it is impossible to completely avoid operating the engine in low temperature because the engine is never hot enough at vehicle start when the vehicle has not been operated for a long time. After startup and while engine is still idling, the coolant temperature is still low and more fuel than normal is needed until the engine warms up to operating temperatures—the engine does not have an electrical heater that keeps the engine itself warm.

Figure 59 shows three different control behaviors under different engine coolant temperatures.

- The engine is operated normally if the coolant temperature is hot enough (hot-start).
- If the coolant temperature is in the medium range — that is, between 35 °C and 80 °C – the engine stays on higher speed than on normal idle speed (about 600 rpm) even if there is no power demand. This is a specific control behavior at vehicle start because the engine operates as if it is in a hot condition once the coolant temperature is medium after the initial period.
- When the engine coolant is very low (below 0 °C) under cold ambient temperature. Under this situation, the engine is forced to be turned on and the engine operates at a higher speed until the engine coolant reaches a medium temperature.

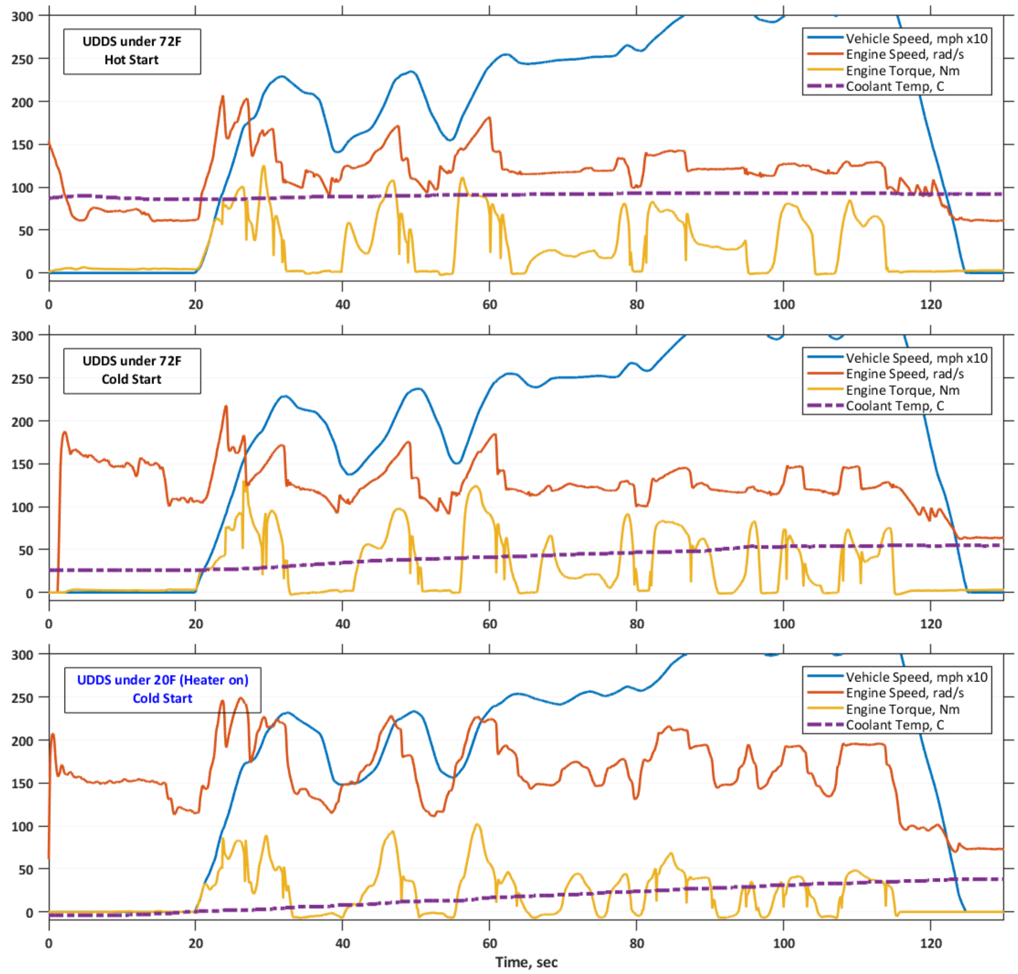

Figure 59. Engine operation at the launch of the vehicle differs according to the engine coolant temperature

We have identified the engine speed when the engine is in an idle state under the cold condition, which is shown in Figure 60. We collected all operating points when the engine is turned on because of the cold conditions but there is no power demand from the driver. The plot shows that the engine speed is controlled according to the engine coolant temperature, which means that the idle speed has a strong correlation with the engine coolant temperature under the cold condition.

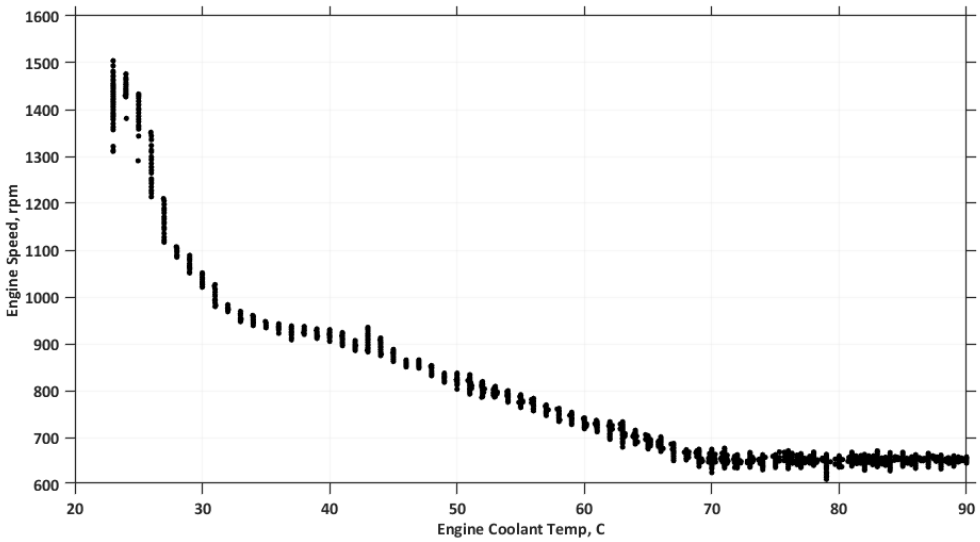

Figure 60. Engine idle speed is controlled according to the coolant temperature

In contrast, Figure 61 shows the comparative results of the coolant temperatures according to driving conditions. The coolant temperature cannot easily reach a hot temperature when the engine is operated with the heater on under cold ambient temperature.

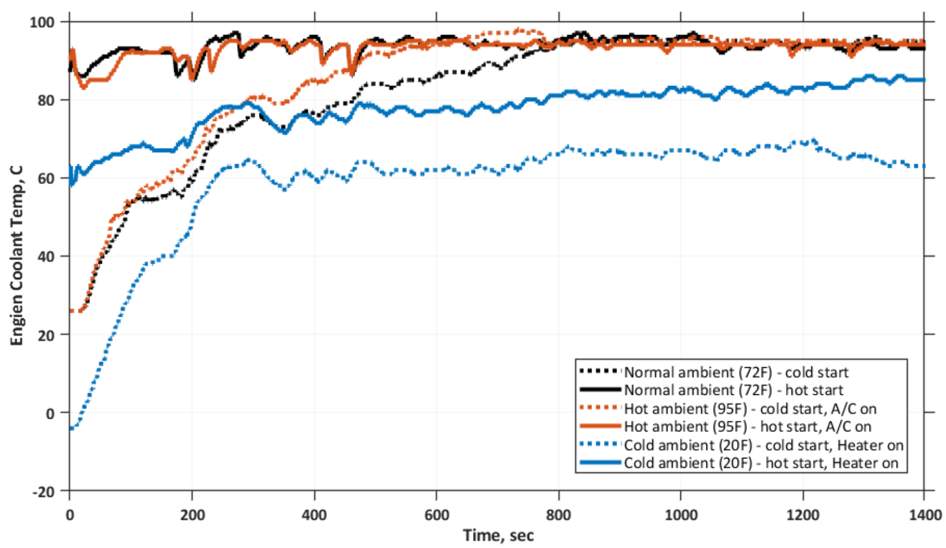

Figure 61. Behaviors of engine coolant temperatures on UDDS under different test conditions

6.6.2. Engine Injection Under Cold Conditions

To prevent operation of the engine when the engine is cold, the engine is controlled in different ways if the engine coolant temperature is low. Further, the cold condition can also affect the control behavior of the injection system. We turn now to introducing these control behaviors.

Figure 62 shows that fuel injection mode is controlled differently depending on engine coolant temperature for driving cycles at cold ambient temperature (20 °F). When ambient conditions are very cold at initial engine start, the figure shows that the fuel is injected in only the DI mode —

which is the same result as with the test data under normal ambient temperatures. However, unlike when ambient temperatures are normal, the PFI mode starts to operate immediately after the engine coolant temperature reaches more than 20 °C.

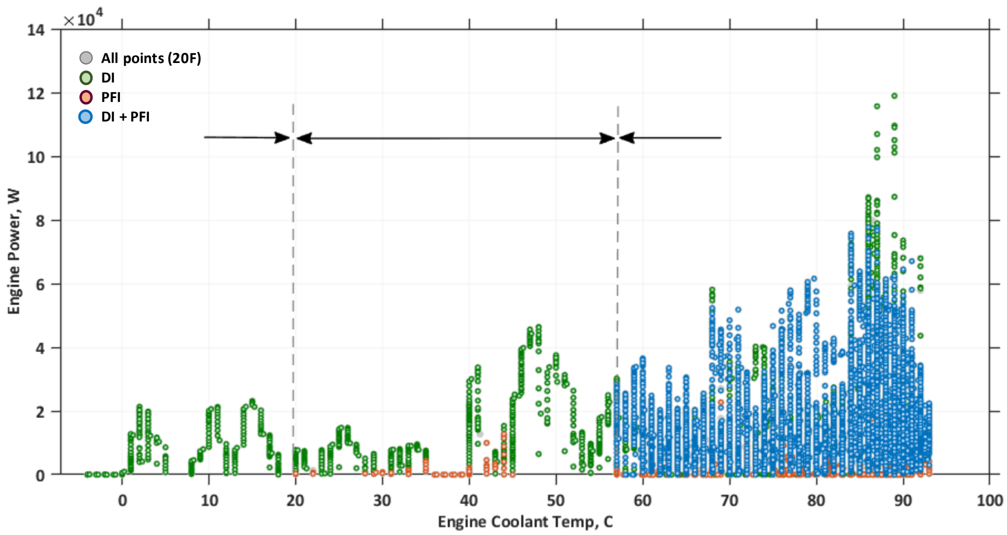

Figure 62. Operating behavior of the fuel injection mode under cold ambient temperature

Figure 63 shows two control behaviors under different ambient temperatures. We found that the initial PFI mode appears to operate after the initial approximately 50 seconds, regardless of engine coolant temperature. Then, it seems that both the DI and PFI modes start to operate at the same time after the engine coolant temperature reaches about 60 °C.

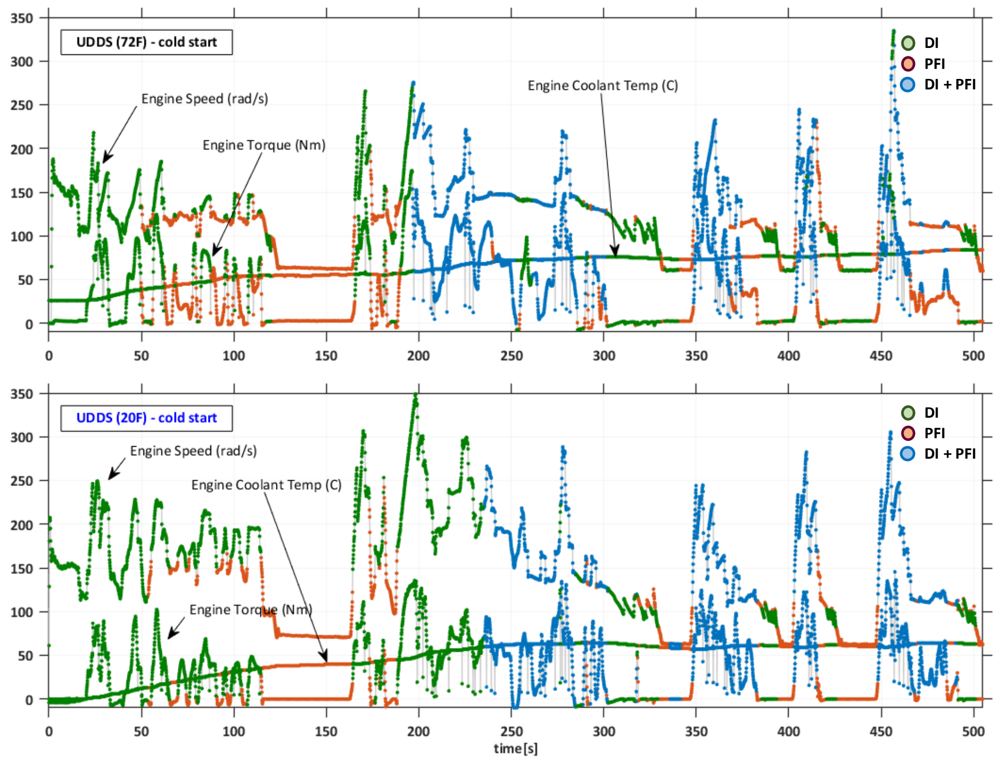

Figure 63. Fuel system operation at vehicle start under different ambient temperatures

6.6.3. Engine Performances

The thermal conditions affect not only the control of the components but also their performance. The performance of the engine noticeably deteriorates under very cold conditions. Unfortunately, because we do not have test data for each component under the different thermal conditions, we also do not have detailed enough results in several cases in this section to show the degradation; however, we trust that readers will still have useful information for understanding the performance degradation caused by the thermal conditions.

The engine generates a lot of heat. Approximately one-third of the input power is converted to mechanical work, and another third is exhausted as emission gas, so the last third of the input power contributes to heating the engine block. Therefore, the engine temperature increases very quickly as long as the engine is turned on; however, the coolant temperature is not sustained on high temperature if the ambient temperature is very cold. Although we could not provide an entire fuel map according to the engine temperature, Figure 64 shows that the fuel consumption rate is affected significantly by the thermal condition.

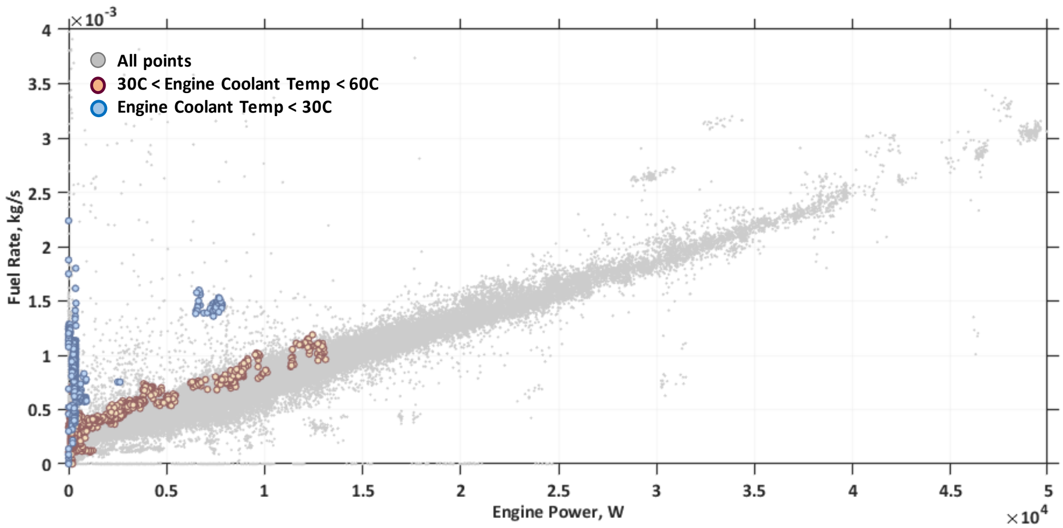

Figure 64. Fuel rate of engine according to engine power for different coolant temperatures

The figure shows the fuel rate according to the engine output power, and the operating points are grouped by the engine coolant temperature range. First of all, the fuel rate shows meaningful trends, as a function of the engine coolant temperature. Although cylinder temperature might have a stronger correlation with the efficiency than the coolant temperature, it is not available, and the coolant temperature can be considered a closest "proxy" temperature to the heat source in that the coolant temperature is one of the highest temperature signals that we have from the test.

The results in Figure 65 state that the engine consumes two times more fuel than normal if the engine coolant temperature is low, even when the engine is at the same throttle position. If the coolant temperature is very low, it seems that more fuel is injected in the same throttle. We must note that the additional fuel consumption can be caused by lower engine efficiency under cold conditions, or it might result because the engine choses far different operating points compared to what it selects under normal conditions.

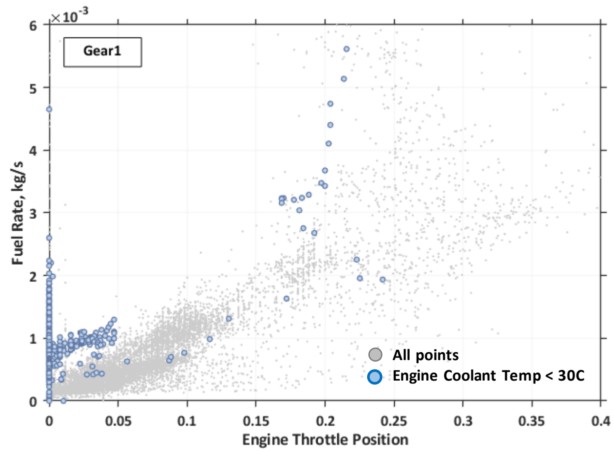

Figure 65. Fuel rate of engine according to engine throttle position for cold coolant temperature

6.6.4. Fuel Consumption Analysis

The changes in performance finally affect the vehicle's fuel consumption, and the thermal impact on the fuel consumption can be explained by the performance levels of the components. Figure 66 shows the fuel consumption of several tests that were performed on the UDDS cycle but under different test conditions.

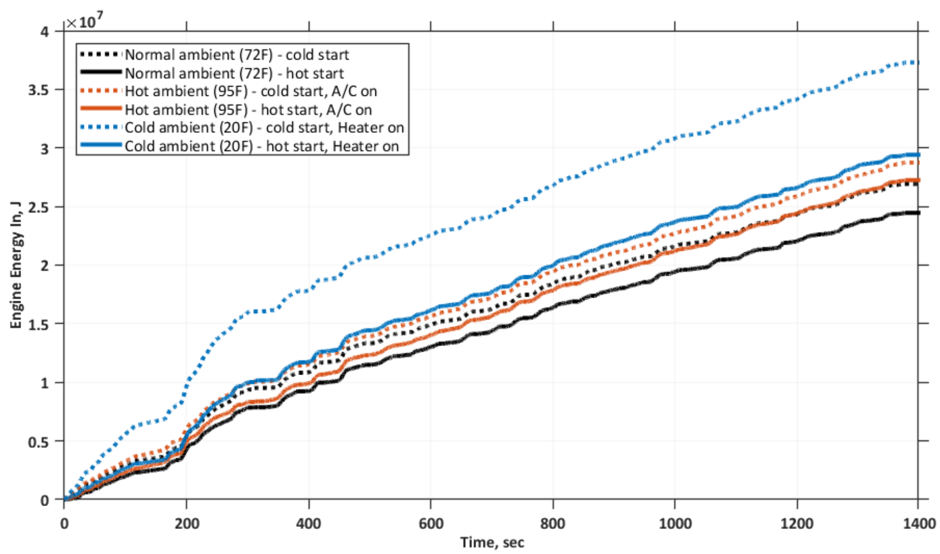

Figure 66. Accumulated fuel consumption trajectories on UDDS under different test conditions

Although we have used distinct colors for thermal conditions, the colors indicate the ambient temperatures. Further, the dotted line indicates that the engine starts at cold temperature. In the results, the test conducted in normal ambient temperatures with the HVAC off shows the best fuel economy; however, fuel economy decreases when the AC system is operating — there are variations according to the initial state of the components, such as the engine temperature or the transmission temperature. On the other hand, although the test is performed under cold conditions, the vehicle consumes about only 20% more fuel than it does if the engine starts in hot conditions. However, the fuel consumption is dramatically increased if the engine starts at a cold temperature and the cabin heater is turned on, because the engine cannot use all the waste heat to increase the engine temperature. Therefore, because the engine temperature is not well maintained, the engine consumes more fuel then than it does under the other conditions, which is worse for fuel economy (Appendix D: Test Summary).

6.7. Accessory Load

There is no electrical heater for the cabin in the 2018 Toyota Camry, so the most significant impact on the electrical accessory load is caused by the air conditioning system under hot ambient conditions. We obtained current signals for the electrical accessory load from our test data. Figure 67 shows the accessory power while the vehicle is at a full stop, and the operating points are grouped according to operating conditions.

First, the black points are the accessory power when the AC or heater is not turned on —the HVAC system is off. The power required without any demand by the HVAC system is about 330 W regardless of the thermal conditions. Second, the battery power increases by about 100 W to 110 W if the AC system in the passenger compartment is turned on in hot conditions, which is assumed to be caused by the ventilating system blowing hot air from the engine into the cabin, the power required for heating is relatively small compared to that for the AC system.

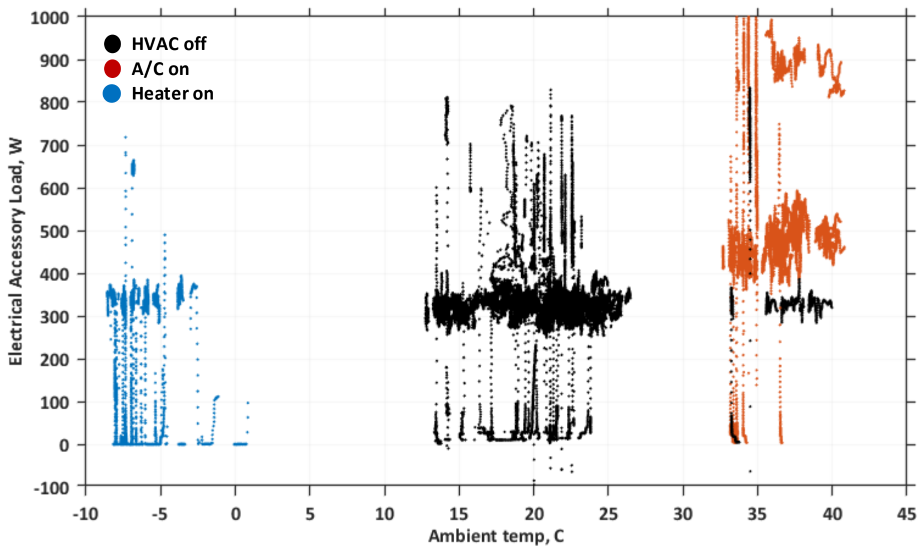

Figure 67. Electrical consumption when the vehicle is fully stopped

6.8. Energy Balance Diagram

In Section 6.1.2, the additional signals were calculated based on other signals or based on additional information provided by external sources [5]. Based on the signals calculated in section 6.1 for each component, the total amounts of energy going in and out can be computed by post-processing in Autonomie. The "Input" and "Output" names are confusing because their roles can be exchanged. Therefore, each port means the one power flow, and all components have two ports in Autonomie. For example, Figure 68 shows the energy in and out for two ports, and the efficiency values for the component of final drive.

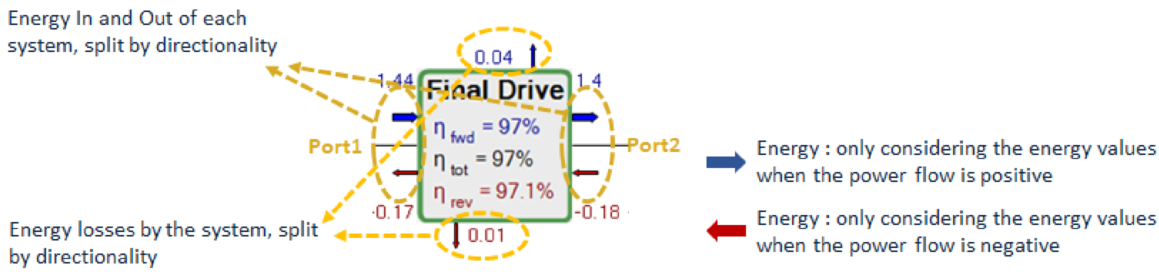

Figure 68. Example of energy calculation for one component on Autonomie

In the figure, the total efficiency can be computed on each port in different ways, and the following show the definitions of efficiency values.

- η_{fwd}: Total efficiency when the power on port 1 and 2 is positive (positive positive).
- η_{tot}: Total aggregate efficiency.
- η_{rev}: Total efficiency when the power on port 1 and 2 is negative (negative negative).

For each component, the total energy consumption and efficiency are calculated based on test data and our assumptions. Figure 69 and Figure 70 shows the final diagrams from the Autonomie graphical user interface after post-processing for the energy balance on the UDDS and HWFET cycles. It should be noted that the efficiency of some components (transmission, alternator, reduction gear, torque converter) is taken into account in our assumptions.

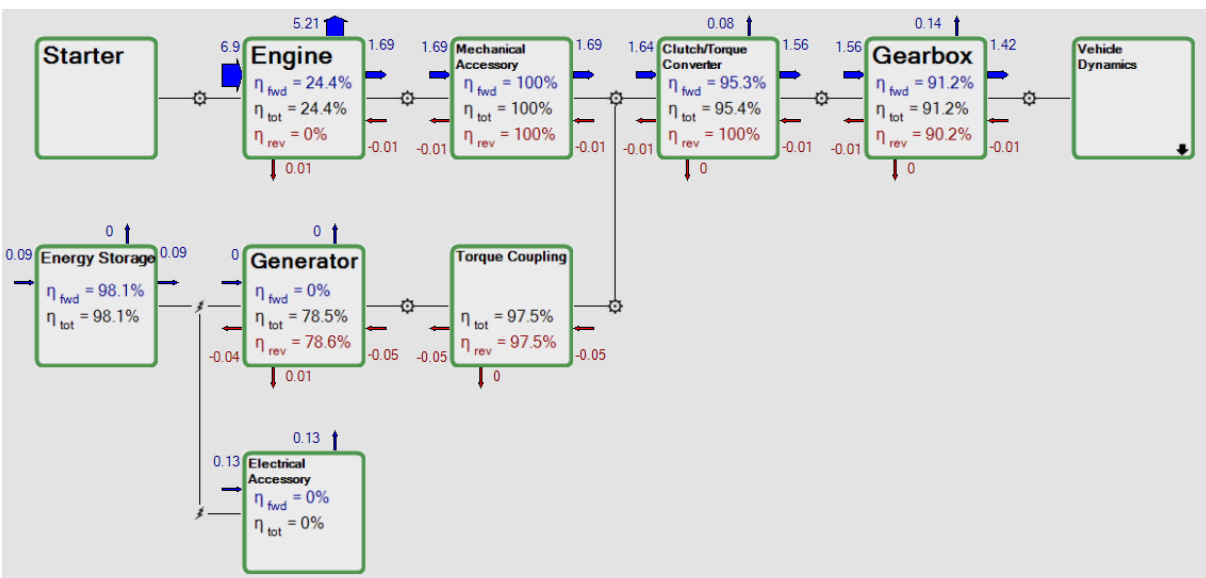

Figure 69. Energy balance diagram on UDDS in Autonomie

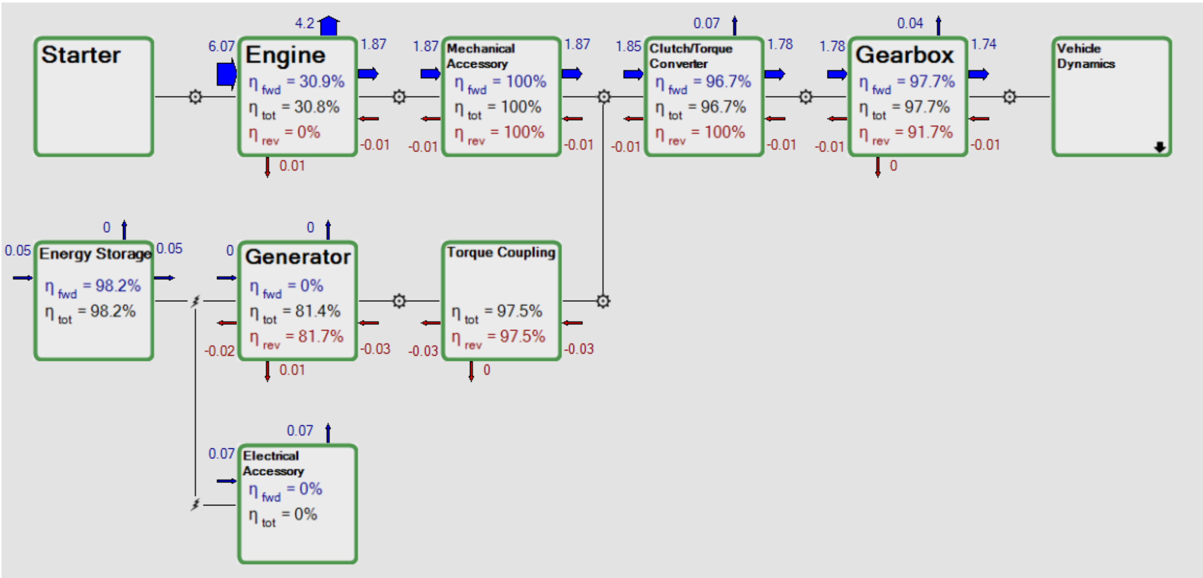

Figure 70. Energy balance diagram on HWFET in Autonomie

7. Autonomie Model Validation

Analysis of vehicle-level control from vehicle test data was performed to merge the separately developed vehicle component models into a vehicle simulation model. Component control functions include: transmission shifting, torque converter lockup, engine fuel cutoff, and transient control. The analyzed component models including the control model are implemented and integrated in Autonomie to a vehicle simulation model for the 2018 Toyota Camry. However, the vehicle model is simulated only during the vehicle warm-up phase (i.e., for a hot start). Because all of 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 71.

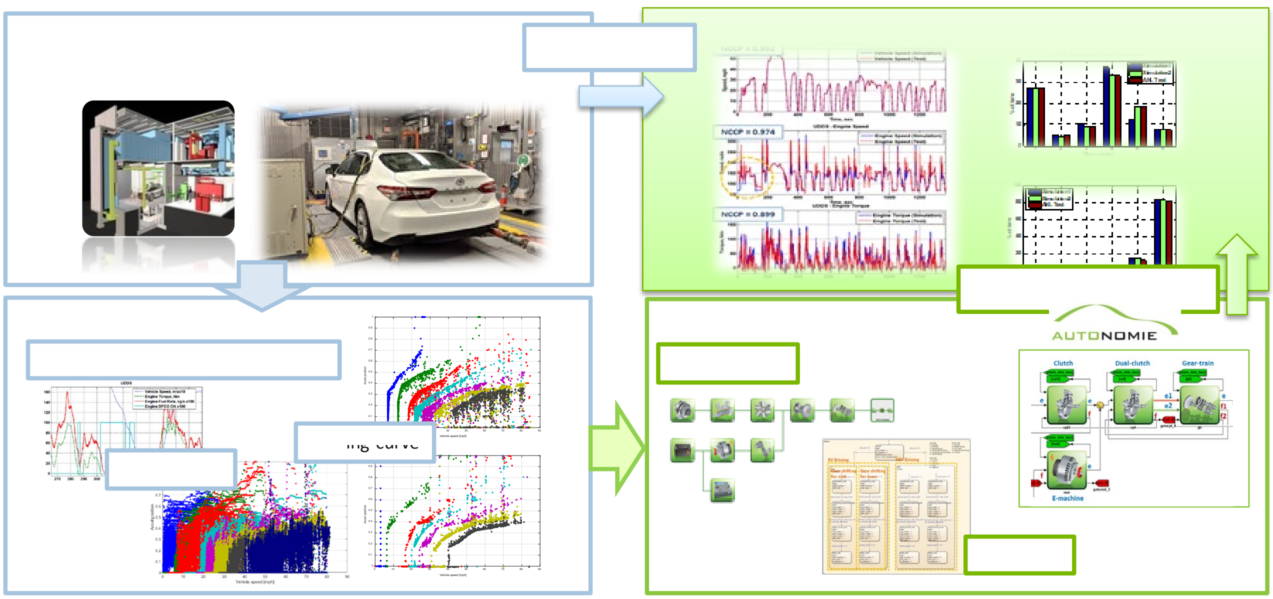

Figure 71. Validation process for the 2018 Toyota Camry in Autonomie

The simulation was conducted in the UDDS, HWFET, and US06 cycles. Figure 72, Figure 73, and Figure 74 show the vehicle speed, engine speed, engine torque, wheel power, gear number, cumulative fuel consumption, and accelerator pedal position of both simulation results and test data, which aligned well for each cycle.

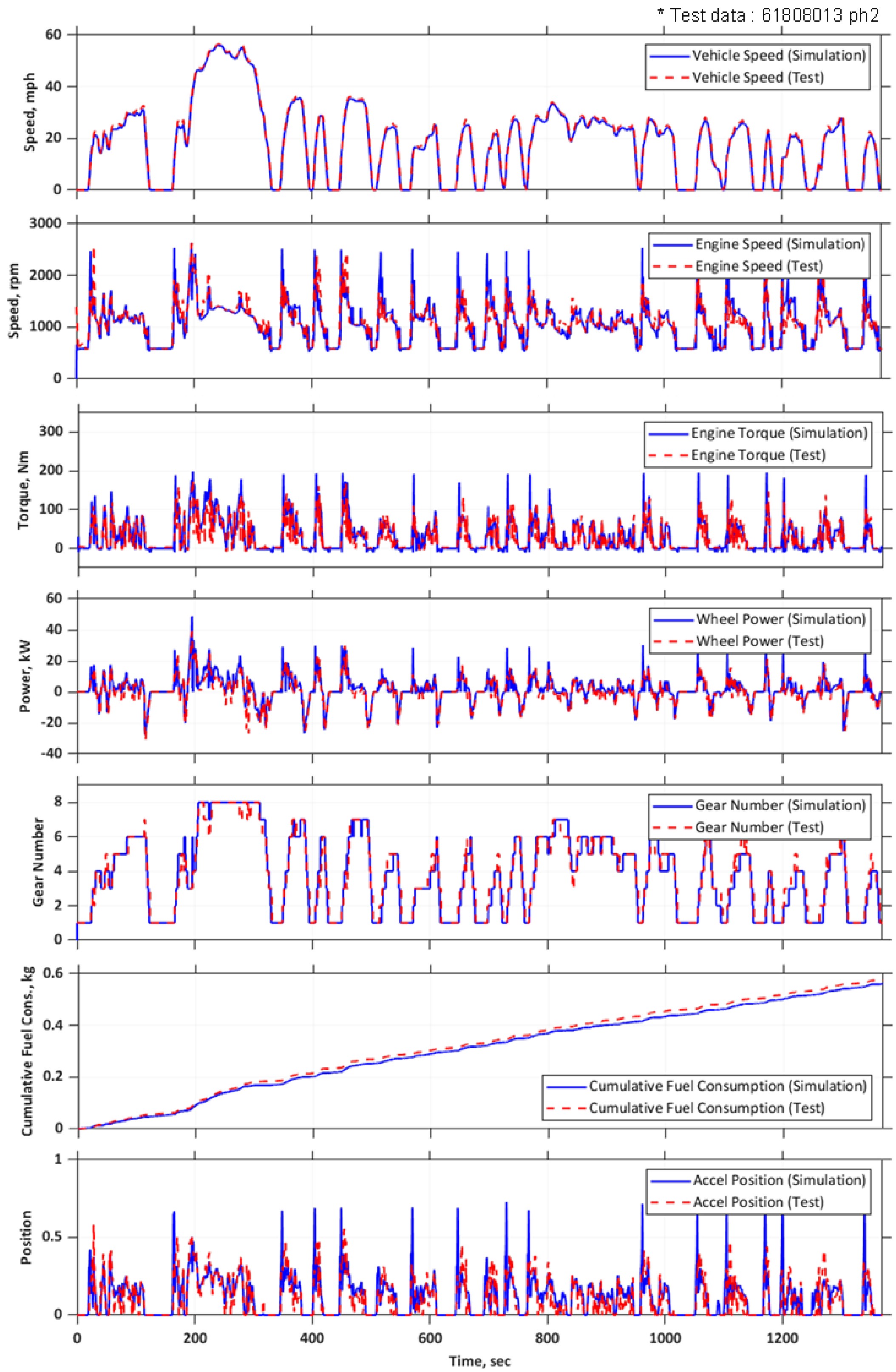

Figure 72. Simulation results and test data for the UDDS cycle

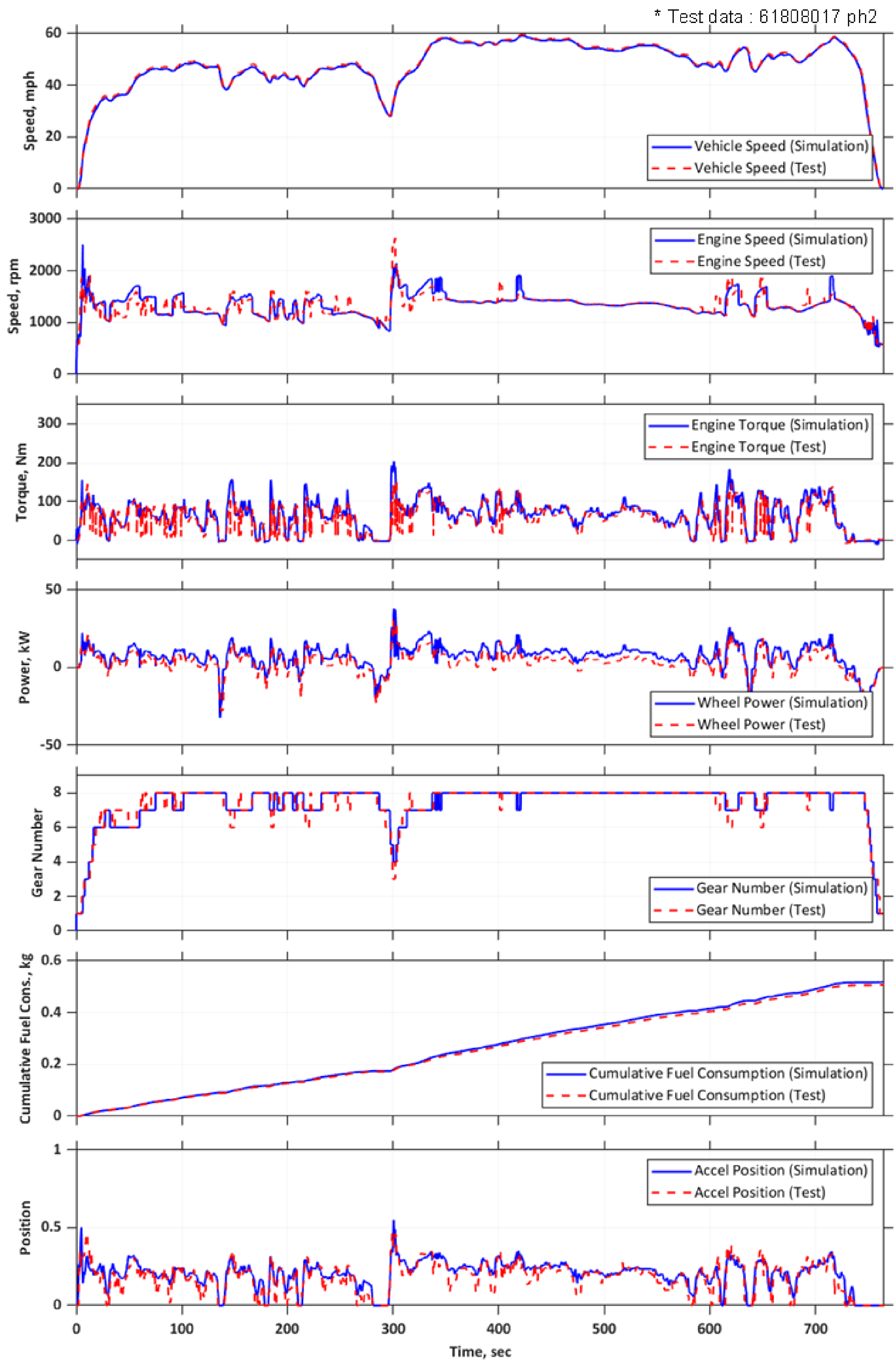

Figure 73. Simulation results and test data for the HWFET cycle

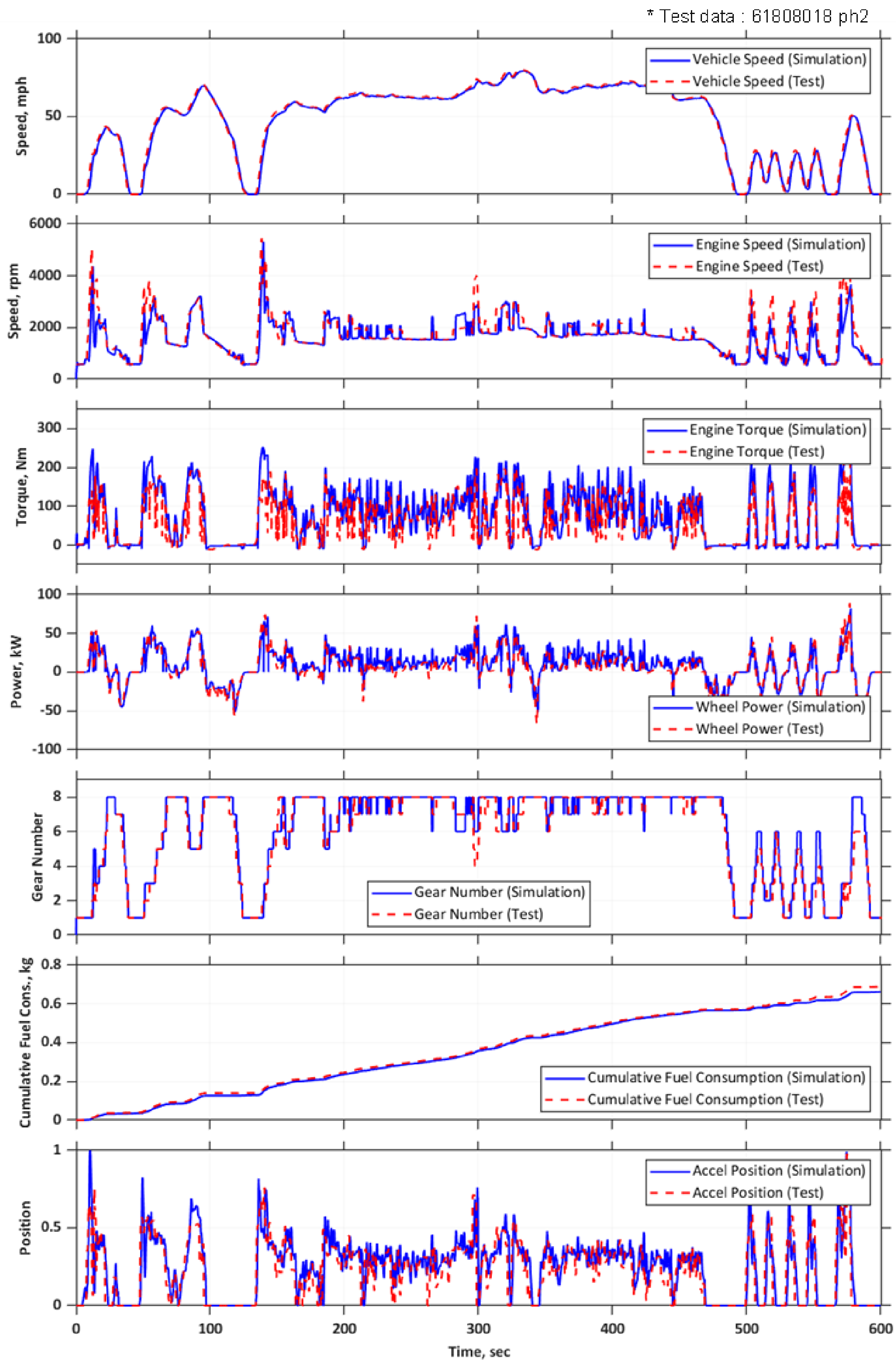

Figure 74. Simulation results and test data for the US06 cycle

To compare second-by-second time varying signal traces between test and simulation, the normalized cross correlation power (NCCP) is used [7]. The NCCP is calculated using Equations (8) and (9) where, x and y represent two distinct signals. When applied to a test signal and a simulation signal of the same quantity, a value of NCCP equal to or greater than 0.9 indicates a high level of correlation. Conversely, lower values indicate a relatively poor correlation.

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

Equation 7

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

Equation 8

In Table 19 the NCCP values of simulation results were represented for the UDDS, HWFET, and US06 cycles. It is evident that the values for the vehicle speed, gear number, and engine speed, which exceeded 0.9, indicate the highest levels of correlation, whereas there was relatively lower correlation in the engine torque.

Table 19. The NCCP values for UDDS, HWFET, and US06 cycles

	UDDS (Test data: 61808013 Ph. 2)	**HWFET** (Test data: 61808017 Ph. 2)	**US06** (Test data: 61808018 Ph. 2)
Vehicle speed	0.972	0.989	0.987
Gear number	0.983	0.997	0.967
Engine speed	0.978	0.983	0.873
Engine torque	0.850	0.892	0.805

Figure 75 and Figure 76 show the vehicle speed where the torque converter was locked. In addition, the torque converter lockup status was compared according to vehicle speed and engine speed between the simulation results and test data for the UDDS (test data: 61808013 Ph. 2), HWFET (test data: 61808017 Ph. 2), and US06 cycles (test data: 61808018 Ph. 2) in Figure 75. The figure shows that operation of the torque converter in simulation was similar to that of the test data. In Figure 77, the engine fuel cutoff status was compared with the test data for the UDDS (test data: 61808013 Ph. 2), HWFET (test data: 61808017 Ph. 2), and US06 cycles (test data: 61808018 Ph. 2). The engine fuel cut-off in simulation showed a similar tendency compared to the test data.

The percentages of times for torque converter lockup and engine fuel cut-off were represented in Table 20.

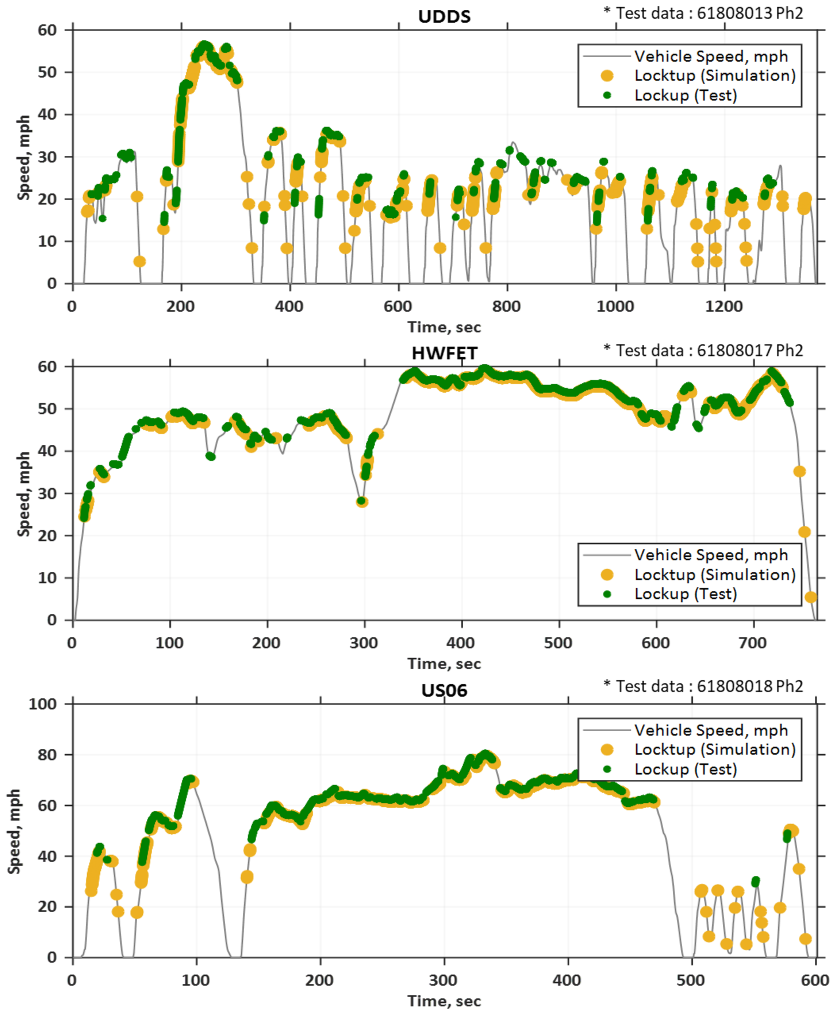

Figure 75. Torque converter locked vehicle speed

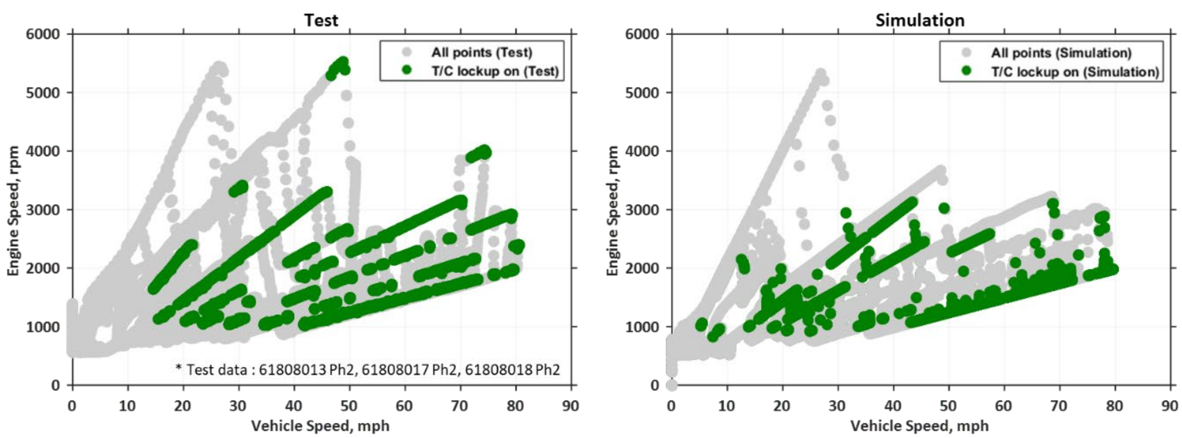

Figure 76. Comparison of torque converter lockup status

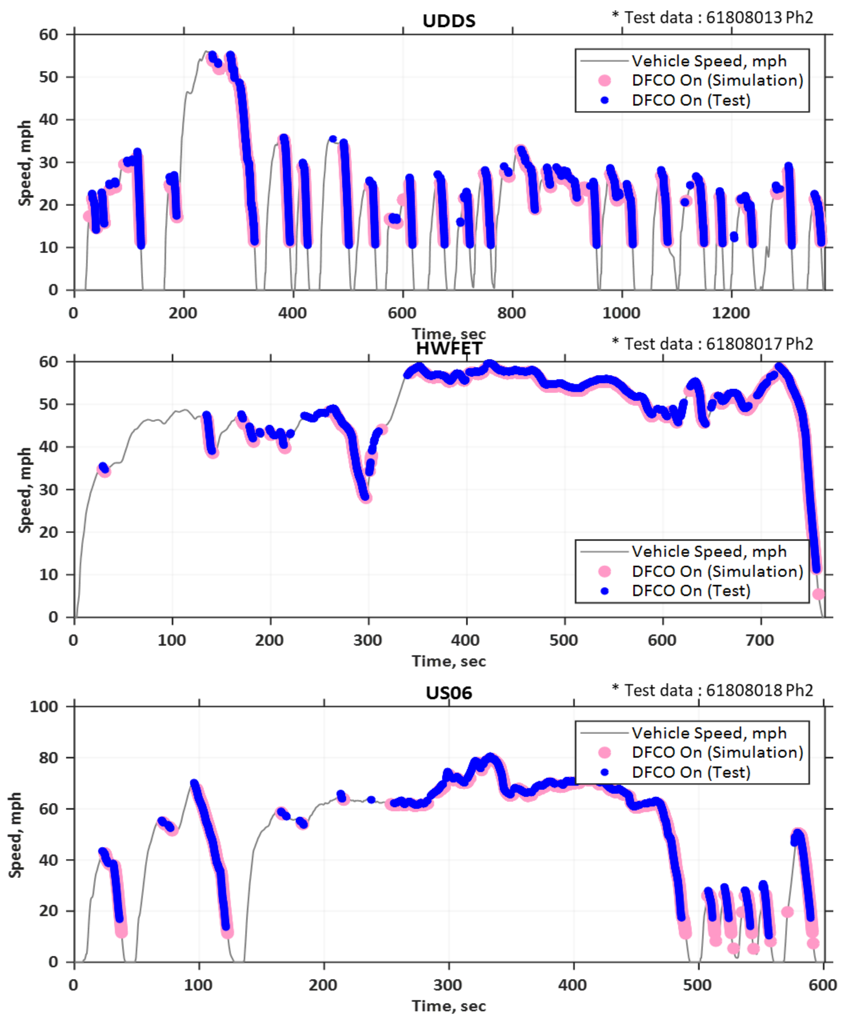

Figure 77. Engine fuel cut-off vehicle speed

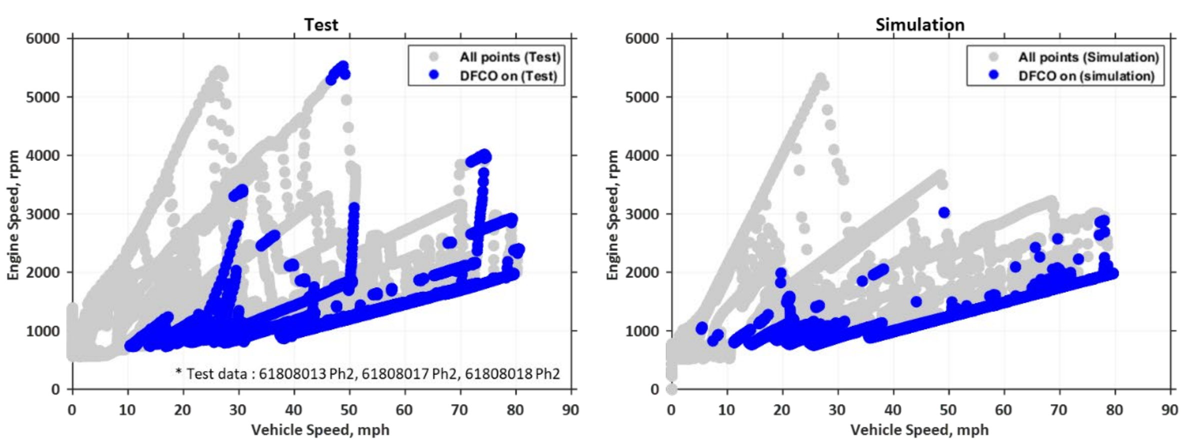

Figure 78. Comparison of engine fuel cut-off status

Table 20. Percentage of times for torque converter lockup and DFCO on

		UDDS (Test data: 61808013 Ph. 2)	**HWFET** (Test data: 61808017 Ph. 2)	**US06** (Test data: 61808018 Ph. 2)
T/C lockup (%)	Test	17.66	56.13	40.80
	Simulation	15.29	57.98	43.48
DFCO on (%)	Test	17.48	9.86	16.33
	Simulation	20.30	11.32	15.81

Engine operating areas were compared with particular test data on the UDDS, HWFET, and US06 cycles in Figure 79: Comparison of engine operating points on the UDDS cycle, Figure 80, and Figure 81, respectively. In the simulation results, the engine operated in similar levels of engine speed and torque as compared to the test data.

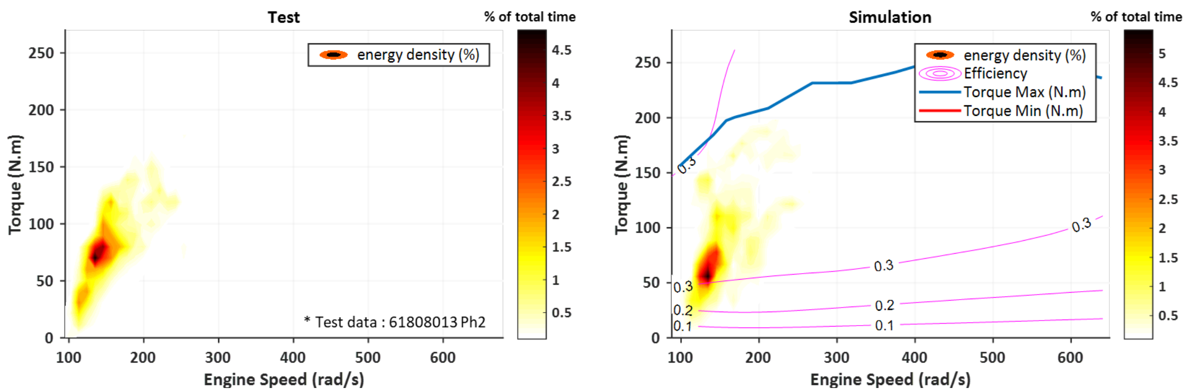

Figure 79. Comparison of engine operating points on the UDDS cycle

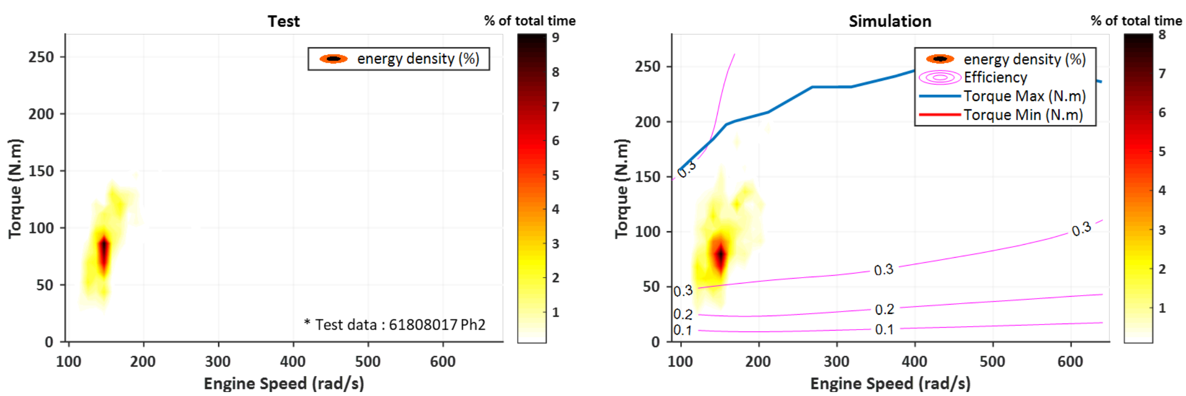

Figure 80. Comparison of engine operating points on the HWFET cycle

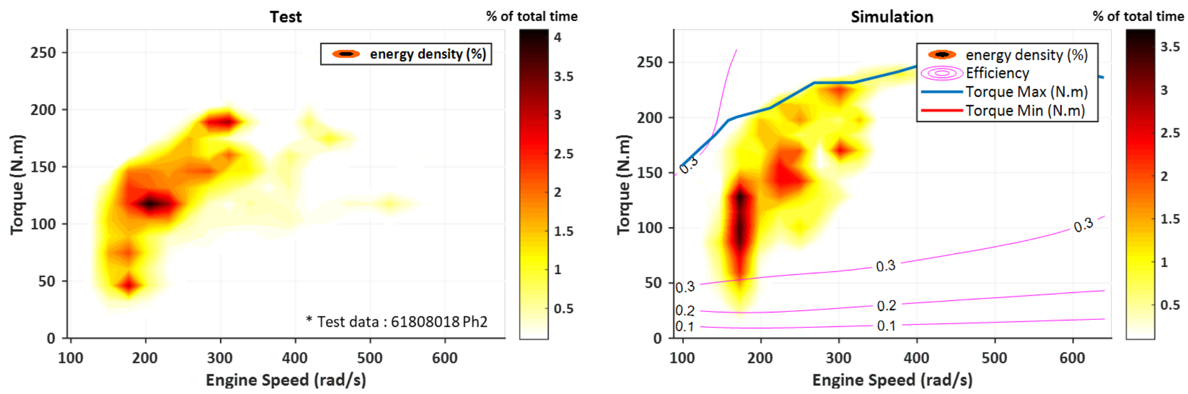

Figure 81. Comparison of engine operating points on the US06 cycle

The fuel consumption simulation results are compared to the average fuel consumption of the test data to validate the simulation performance in Figure 82. The average fuel consumption was obtained from the test data, which was captured from a hot-start condition. The results show that the simulation's fuel consumption results for the three drive cycles are 6.54 L/100km, 4.30 L/100km, and 7.04 L/100km (Table 21), which differed from the test data by 1.50%, 0.20%, and -4.60%, respectively.

Table 21. Fuel consumption comparison of test data and Autonomie simulation results

Fuel consumption [L/100km]	**UDDS**[a]	**HWFET**[b]	**US06**[c]
Test average	6.45	4.29	7.38
Simulation (error)	6.54 (1.50 %)	4.30 (0.20 %)	7.04 (-4.60 %)

[a] Test data for UDDS: 61808001 Ph. 2, 61808002, 61808005, 61808006 Ph. 2, 61808012, 61808013 Ph. 2, and 61808014.
[b] Test data for HWFET: 61808003 Ph. 1, 61808003 Ph. 2, 61808008 Ph. 1, 61808008 Ph. 2, 61808017 Ph.1, and 61808017.
[c] Test data for US06: 61808004 Ph. 2, 61808009 Ph. 2, 61808018 Ph. 2, 61808026 Ph. 2

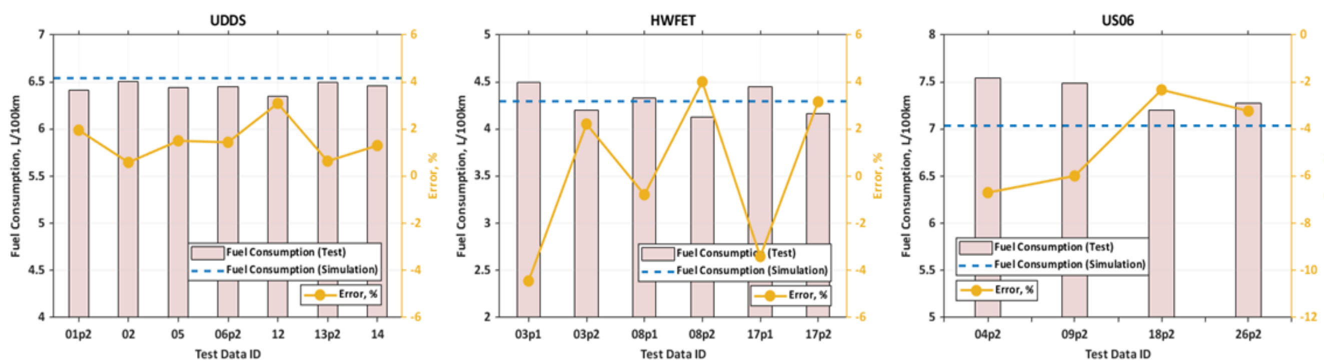

Figure 82. Fuel consumption and error between test data and simulation result

8. Conclusions

NHTSA sets CAFE standards for passenger cars, light trucks, and medium-duty passenger vehicles. NHTSA contracted with Argonne to conduct full vehicle simulation using Autonomie (https://www.autonomie.net/) software to provide input into the CAFE model to determine optimum average fuel economy based on numerous technological and economic factors. Autonomie relies on vehicle technology assumptions for model development and validation. Argonne's Advanced Mobility Technology Laboratory provides the laboratory test data that inform the technology assumptions in Autonomie. NHTSA funded Argonne's AMTL to perform a benchmark of a 2018 Toyota Camry XLE midsize passenger car and to provide data to Autonomie and assess the fuel saving technologies of that powertrain.

The vehicle benchmarked in this report is a 2018 Toyota Camry XLE with the 2.5-liter I4 Dynamic Force engine coupled to a newly introduced 8-speed automatic transmission. This particular powertrain configuration provides favorable fuel economy results while providing significant vehicle performance. The focus of the benchmark is to understand the usage of the critical powertrain components and their impact on 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. The vehicle is tested on a chassis dynamometer in the controlled laboratory environment across a range of certification tests. Further tests were performed to map the different powertrain components.

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Appendix A: Vehicle Build Sheet

TOYOTA
Let's Go Places

DESC.:	CAMRY	4-DOOR XLE SEDAN
VIN:	4T1B11HK2JU057338	
YR/MDL:	2018/2540E	
CLR:	SUPER WHITE/LA40	(0040/40)
FINAL ASSEMBLY POINT:	GEORGETOWN, KENTUCKY, U.S.A.	

GOVERNMENT 5-STAR SAFETY RATINGS

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

STANDARD EQUIPMENT

MECHANICAL & PERFORMANCE
- 2.5L Dynamic Force 4-Cyl DOHC 16V D-4S Dual Injection w/ Dual VVT-i Engine
- 206 hp @ 6600 rpm / 186 lb-ft @ 5000 rpm
- Direct Shift 8-Speed ECT-i Transmission w/ Sequential Shift Mode
- Pwr-Assist Front/Solid Rear Disc Brakes

SAFETY & CONVENIENCE
- Toyota Safety Sense-P: Pre-Collision Sys w/Pedestrian Detection, Dynamic Radar Cruise Control, Lane Departure Alert w/ Steering Assist, Automatic High Beams
- Star Safety System: Enhanced Vehicle Stability Control, Traction Control, Anti-Lock Brakes, Electronic Brake Force Distribution, Brake Assist and Smart Stop Technology
- LATCH-Lower Anchor & Tether for Children
- Whiplash-Injury-Lessening Front Seats
- Ten Airbags
- Blind Spot Monitor w/ Rear Cross Traffic Alert

EXTERIOR
- 18" Chrome Machined-Finish Alloy Wheels with P235/45R18 Tires
- LED Headlights w/ Integrated LED DRLs w/ Auto On/Off
- Single Exhaust with Chrome Finisher
- Color-Keyed Heated Power Outside Mirrors

INTERIOR
- Entune 3.0 Audio w/ Connected Nav Scout GPS Link App & App Suite 7" Tch Screen 6 Spkrs, Bluetooth, USB, AUX
- Leather-Trimmed Heated Front Seats w/ 8-Way Power Driver & Passenger Seats
- Leather-Trimmed Steering Wheel w/ Audio Bluetooth Phone & Voice Command Cntrls
- Backup Camera w/ Dynamic Gridlines
- 7" TFT Multi-Information Display
- Tire Pressure Monitor System
- Smart Key System w/ Push Button Start
- Dual-Zone Auto Climate Control

Full Tank of Gas

MANUFACTURER'S SUGGESTED RETAIL PRICE		$28,450.00
OPTIONAL EQUIPMENT		
FE	50 State Emissions	
2T	All Weather Floor Liners/Cargo Tray	254.00
DELIVERY PROCESSING AND HANDLING FEE		895.00
TOTAL		$29,599.00

EPA DOT Fuel Economy and Environment

Gasoline Vehicle

Fuel Economy

32 MPG combined city/hwy

28 city **39** highway

3.1 gallons per 100 miles

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

Annual fuel **cost** **$ 1,100**

Fuel Economy & Greenhouse Gas Rating (tailpipe only): 7 (1–10 Best)

Smog Rating (tailpipe only): 7 (1–10 Best)

This vehicle emits 274 grams CO2 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 $6,750 to fuel over 5 years. Cost estimates are based on 15,000 miles per year at $2.40 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™

The New Vehicle Limited Warranty provides 3-year/36,000 mile basic coverage, 5-year/60,000 mile powertrain coverage, plus 5-year/unlimited mile corrosion perforation coverage. See Warranty and Maintenance Guide for details. An extended service contract may be available for the vehicle. Ask dealer for details.
Manufacturer's suggested retail price includes manufacturer's recommended pre-delivery service. Gasoline, license and title fees, applicable federal, state and local taxes and dealer and distributor installed options and accessories are not included in the manufacturer's suggested retail price.

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

Delivered by Truck to: 12015
CONTINENTAL TOYOTA
6701 S. LAGRANGE ROAD
HODGKINS IL60525

Appendix B: Subset of Midsize Cars for Comparative Analysis

Model Year	Represented Test Veh Make	Represented Test Veh Model	Make Model Description, Disp,	Test Veh Displacement (L)	Vehicle Type	Rated Horsepower	# of Cylinders and Rotors	nt Test Wei	Test Number	Test Originator	Test Procedure Description	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)
2018	BUICK	REGAL	BUICK REGAL: 2L, 3875	2	Car	260	4	3875	JGMX91003633	EPA	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	27.9	MPG	26.6178391	26.8490274	31.5612281		29.28	0.443	0.01583
2018	BUICK	REGAL	BUICK REGAL: 2L, 3875	2	Car	260	4	3875	JGMX91003634	EPA	HWFE	Tier 2 Cert Gasoline	45.8	MPG					29.28	0.443	0.01583
2018	BUICK	REGAL	BUICK REGAL: 2L, 3750	2	Car	260	4	3750	JGMX10049714	MFR	Federal fuel 3-day exhaust	Tier 2 Cert Gasoline	29.7	MPG	28	28.3	32.8		25.43	0.4243	0.01583
2018	BUICK	REGAL	BUICK REGAL: 2L, 3750	2	Car	260	4	3750	JGMX10049715	MFR	HWFE	Tier 2 Cert Gasoline	46.2	MPG					25.43	0.4243	0.01583
2018	BUICK	REGAL AWD	BUICK REGAL AWD: 2L, 4000	2	Car	260	4	4000	JGMX10049870	MFR	Federal fuel 3-day exhaust	Tier 2 Cert Gasoline	27.2	MPG	25.8	26.1	30		37.19	0.3482	0.01763
2018	BUICK	REGAL AWD	BUICK REGAL AWD: 2L, 4000	2	Car	260	4	4000	JGMX10049871	MFR	HWFE	Tier 2 Cert Gasoline	42	MPG					37.19	0.3482	0.01763
2018	BUICK	REGAL TOURX AWD	BUICK REGAL TOURX AWD: 2L, 4250	2	Car	260	4	4250	JGMX10049724	MFR	Federal fuel 3-day exhaust	Tier 2 Cert Gasoline	27	MPG	25.2	26	29.8		38.37	0.3661	0.0178
2018	BUICK	REGAL TOURX AWD	BUICK REGAL TOURX AWD: 2L, 4250	2	Car	260	4	4250	JGMX10049725	MFR	HWFE	Tier 2 Cert Gasoline	41.8	MPG					38.37	0.3661	0.0178
2018	Ford	Fusion	Ford Fusion: 1.5L, 3750	1.5	Car	169	4	3750	HFMX10049588	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	30.2	MPG	30.1	28.9	33.2		24.48	0.1365	0.01826
2018	Ford	Fusion	Ford Fusion: 1.5L, 3750	1.5	Car	169	4	3750	HFMX10049589	MFR	HWFE	Tier 2 Cert Gasoline	49.1	MPG					24.48	0.1365	0.01826
2018	Ford	Fusion	Ford Fusion: 1.5L, 3750	1.5	Car	169	4	3750	HFMX10049594	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	30.4	MPG	30.3	29.1	33.4		24.48	0.1365	0.01826
2018	Ford	Fusion	Ford Fusion: 1.5L, 3750	1.5	Car	169	4	3750	HFMX10049595	MFR	HWFE	Tier 2 Cert Gasoline	49.8	MPG					24.48	0.1365	0.01826
2018	Ford	Fusion	Ford Fusion: 2L, 4000	2	Car	240	4	4000	HFMX10049678	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	25.3	MPG	24.3	24.1	28.9		35.1	0.2652	0.01889
2018	Ford	Fusion	Ford Fusion: 2L, 4000	2	Car	240	4	4000	HFMX10049681	MFR	HWFE	Tier 2 Cert Gasoline	41.2	MPG					35.1	0.2652	0.01889
2018	Ford	Fusion	Ford Fusion: 1.5L, 3750	1.5	Car	169	4	3750	HFMX10049590	MFR	HWFE	Tier 2 Cert Gasoline	48	MPG					24.48	0.1365	0.01826
2018	Ford	Fusion	Ford Fusion: 1.5L, 3750	1.5	Car	169	4	3750	HFMX10049591	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	29.9	MPG	29.1	28.6	33.9		24.48	0.1365	0.01826
2018	Ford	Fusion	Ford Fusion: 1.5L, 3750	1.5	Car	169	4	3750	HFMX10049592	MFR	HWFE	Tier 2 Cert Gasoline	48.7	MPG					24.48	0.1365	0.01826
2018	Ford	Fusion	Ford Fusion: 1.5L, 3750	1.5	Car	169	4	3750	HFMX10049593	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	30.1	MPG	29.3	28.8	34.1		24.48	0.1365	0.01826
2018	Ford	Fusion	Ford Fusion: 2L, 3875	2	Car	240	4	3875	HFMX10040612	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	26.6	MPG	26.5739027	25.0704292	30.1756432		29.4	0.1681	0.01803
2018	Ford	Fusion	Ford Fusion: 2L, 3875	2	Car	240	4	3875	HFMX10040779	MFR	HWFE	Tier 2 Cert Gasoline	44.7	MPG					29.4	0.1681	0.01803
2018	Ford	Fusion	Ford Fusion: 2.7L, 4500	2.7	Car	325	6	4500	HFMX10049586	MFR	HWFE	Tier 2 Cert Gasoline	36.9	MPG					36.58	0.5648	0.01842
2018	Ford	Fusion	Ford Fusion: 2.7L, 4500	2.7	Car	325	6	4500	HFMX10049587	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	22.1	MPG	22	20.7	25.1		36.58	0.5648	0.01842
2018	Ford	Fusion FWD	Ford Fusion FWD: 1.5L, 3750	1.5	Car	169	4	3750	HFMX10049582	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	29.3	MPG	28.8	28.1	32.4		34.93	0.1712	0.01793
2018	Ford	Fusion FWD	Ford Fusion FWD: 1.5L, 3750	1.5	Car	169	4	3750	HFMX10049583	MFR	HWFE	Tier 2 Cert Gasoline	46.3	MPG					34.93	0.1712	0.01793
2018	Ford	FUSION FWD	Ford FUSION FWD: 2.5L, 3750	2.5	Car	173	4	3750	HFMX10049584	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	26.5	MPG	26.4	24.8	30.3		34.96	0.1714	0.01826
2018	Ford	FUSION FWD	Ford FUSION FWD: 2.5L, 3750	2.5	Car	173	4	3750	HFMX10049585	MFR	HWFE	Tier 2 Cert Gasoline	43.7	MPG					34.96	0.1714	0.01826
2018	Ford	FUSION FWD	Ford FUSION FWD: 2.5L, 3750	2.5	Car	173	4	3750	HFMX10049601	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	26.8	MPG	26.5	24.7	30.4		24.5	0.1367	0.01859
2018	Ford	FUSION FWD	Ford FUSION FWD: 2.5L, 3750	2.5	Car	173	4	3750	HFMX10049602	MFR	HWFE	Tier 2 Cert Gasoline	46.6	MPG					24.5	0.1367	0.01859
2018	Ford	FUSION FWD	Ford FUSION FWD: 2.5L, 3750	2.5	Car	173	4	3750	HFMX10049603	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	26.8	MPG	26.5	24.7	30.4		24.5	0.1367	0.01859
2018	CHEVROLET	MALIBU	CHEVROLET MALIBU: 1.5L, 3375	1.5	Car	160	4	3375	JGMX10047813	MFR	Federal fuel 3-day exhaust	Tier 2 Cert Gasoline	35	MPG	33.5	34.4	37.5		26.28	0.1589	0.01722
2018	CHEVROLET	MALIBU	CHEVROLET MALIBU: 1.5L, 3375	1.5	Car	160	4	3375	JGMX10047814	MFR	HWFE	Tier 2 Cert Gasoline	52.6	MPG					26.28	0.1589	0.01722
2018	CHEVROLET	MALIBU	CHEVROLET MALIBU: 2L, 3625	2	Car	260	4	3625	JGMX10047786	MFR	Federal fuel 3-day exhaust	Tier 2 Cert Gasoline	28.6	MPG	27.5	27.2	32.5		29.73	0.4356	0.01501
2018	CHEVROLET	MALIBU	CHEVROLET MALIBU: 2L, 3625	2	Car	260	4	3625	JGMX10047817	MFR	HWFE	Tier 2 Cert Gasoline	45.6	MPG					29.73	0.4356	0.01501
2018	HONDA	ACCORD	HONDA ACCORD: 1.5L, 3625	1.5	Car	193	4	3625	JHNX10050345	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	37.6	MPG	37.3	36.8	39.4		49.55	-0.596	0.02744
2018	HONDA	ACCORD	HONDA ACCORD: 1.5L, 3625	1.5	Car	193	4	3625	JHNX10050346	MFR	HWFE	Tier 2 Cert Gasoline	50.5	MPG					49.55	-0.596	0.02744
2018	HONDA	ACCORD	HONDA ACCORD: 1.5L, 3500	1.5	Car	193	4	3500	JHNX10050353	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	37.7	MPG	37.9	36.6	40.2		48.77	-0.598	0.02761
2018	HONDA	ACCORD	HONDA ACCORD: 1.5L, 3500	1.5	Car	193	4	3500	JHNX10050354	MFR	HWFE	Tier 2 Cert Gasoline	51.6	MPG					48.77	-0.598	0.02761
2018	HONDA	ACCORD	HONDA ACCORD: 1.5L, 3500	1.5	Car	192	4	3500	JHNX10050359	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	34.2	MPG	37.6	31.5	37.8		24.86	0.3191	0.01773
2018	HONDA	ACCORD	HONDA ACCORD: 1.5L, 3500	1.5	Car	192	4	3500	JHNX10050360	MFR	HWFE	Tier 2 Cert Gasoline	51.5	MPG					24.86	0.3191	0.01773
2018	HONDA	ACCORD	HONDA ACCORD: 1.5L, 3500	1.5	Car	193	4	3500	JHNX10050355	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	39.9	MPG	41	38.2	42.6		43.75	-0.6042	0.02619
2018	HONDA	ACCORD	HONDA ACCORD: 1.5L, 3500	1.5	Car	193	4	3500	JHNX10050356	MFR	HWFE	Tier 2 Cert Gasoline	55.9	MPG					43.75	-0.6042	0.02619
2018	HONDA	ACCORD	HONDA ACCORD: 1.5L, 3500	1.5	Car	193	4	3500	JHNX91003607	EPA	HWFE	Tier 2 Cert Gasoline	57	MPG					43.75	-0.6042	0.02669
2018	HONDA	ACCORD	HONDA ACCORD: 1.5L, 3500	1.5	Car	193	4	3500	JHNX91003609	EPA	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	39.7	MPG	38.1430979	39.1298744	42.464714		43.75	-0.6042	0.02669
2018	HONDA	ACCORD	HONDA ACCORD: 2L, 3750	2	Car	252	4	3750	JHNX10050436	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	28.8	MPG	28.9	27.3	31.9		25.66	0.361	0.01802
2018	HONDA	ACCORD	HONDA ACCORD: 2L, 3750	2	Car	252	4	3750	JHNX10050437	MFR	HWFE	Tier 2 Cert Gasoline	45.9	MPG					25.66	0.361	0.01802
2018	HONDA	ACCORD	HONDA ACCORD: 2L, 3625	2	Car	252	4	3625	JHNX10049832	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	28.1	MPG	29.4	26.1	31.7		25.78	0.3414	0.01729
2018	HONDA	ACCORD	HONDA ACCORD: 2L, 3625	2	Car	252	4	3625	JHNX10050438	MFR	HWFE	Tier 2 Cert Gasoline	46.4	MPG					25.78	0.3414	0.01729
2018	HONDA	ACCORD	HONDA ACCORD: 2L, 3625	2	Car	252	4	3625	JHNX10050599	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	29.9	MPG	28.5	28	33.3		28.73	0.0246	0.01935
2018	HONDA	ACCORD	HONDA ACCORD: 2L, 3625	2	Car	252	4	3625	JHNX10050600	MFR	HWFE	Tier 2 Cert Gasoline	51	MPG					28.73	0.0246	0.01935
2018	HYUNDAI	Sonata	HYUNDAI Sonata: 2.4L, 3625	2.4	Car	185	4	3625	GHYX10035939	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	31	MPG	29.9397	29.4786	35.2751		32.262	0.16063	0.018298
2018	HYUNDAI	Sonata	HYUNDAI Sonata: 2.4L, 3625	2.4	Car	185	4	3625	GHYX10035940	MFR	HWFE	Tier 2 Cert Gasoline	49.1	MPG					32.262	0.16063	0.018298
2018	HYUNDAI	Sonata	HYUNDAI Sonata: 2.4L, 3500	2.4	Car	185	4	3500	GHYX10035941	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	31.9	MPG					27.526	0.13932	0.017723
2018	HYUNDAI	Sonata	HYUNDAI Sonata: 2.4L, 3500	2.4	Car	185	4	3500	GHYX10035942	MFR	HWFE	Tier 2 Cert Gasoline	51.9	MPG					27.526	0.13932	0.017723
2018	HYUNDAI	Sonata	HYUNDAI Sonata: 2.4L, 3625	2.4	Car	185	4	3625	GHYX10035947	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	32.2	MPG					32.262	0.16063	0.018298
2018	HYUNDAI	Sonata	HYUNDAI Sonata: 2.4L, 3625	2.4	Car	185	4	3625	GHYX10035948	MFR	HWFE	Tier 2 Cert Gasoline	51.9	MPG					32.262	0.16063	0.018298
2018	HYUNDAI	Sonata	HYUNDAI Sonata: 2.4L, 3625	2.4	Car	185	4	3625	GHYX10035949	MFR	HWFE	Tier 2 Cert Gasoline	51.3	MPG					32.262	0.16063	0.018298
2018	HYUNDAI	Sonata	HYUNDAI Sonata: 2.4L, 3500	2.4	Car	185	4	3500	GHYX10035950	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	32.9	MPG					27.526	0.13932	0.017723
2018	HYUNDAI	Sonata	HYUNDAI Sonata: 2.4L, 3500	2.4	Car	185	4	3500	GHYX10035951	MFR	HWFE	Tier 2 Cert Gasoline	54.1	MPG					27.526	0.13932	0.017723
2018	Hyundai	Sonata	Hyundai Sonata: 2L, 3875	2	Car	248	4	3875	JHYX10046478	MFR	HWFE	Tier 2 Cert Gasoline	45.5	MPG					32.822	0.33462	0.015902
2018	Hyundai	Sonata	Hyundai Sonata: 2L, 3875	2	Car	248	4	3875	JHYX10046479	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	29	MPG	27.23	28.2764	31.9375		32.822	0.33462	0.015902
2018	Hyundai	Sonata	Hyundai Sonata: 1.6L, 3500	1.6	Car	178	4	3500	JHYX10045750	MFR	US06	Tier 2 Cert Gasoline	33	MPG	20.6896	39.613			32.44	-0.03278	0.019661
2018	Hyundai	Sonata	Hyundai Sonata: 1.6L, 3500	1.6	Car	178	4	3500	JHYX10045751	MFR	SC03	Tier 2 Cert Gasoline	27.8	MPG					32.44	-0.03278	0.019661
2018	Hyundai	Sonata	Hyundai Sonata: 1.6L, 3500	1.6	Car	178	4	3500	JHYX10045752	MFR	Cold CO	Cold CO Regular (Tier 2)	30.8	MPG	27.891	29.9862	35.5561		35.684	-0.03606	0.021627
2018	Hyundai	Sonata	Hyundai Sonata: 1.6L, 3500	1.6	Car	178	4	3500	JHYX10046468	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	35.1	MPG	34.5446	33.7834	38.1408		32.44	-0.03278	0.019661
2018	Hyundai	Sonata	Hyundai Sonata: 1.6L, 3500	1.6	Car	178	4	3500	JHYX10046469	MFR	HWFE	Tier 2 Cert Gasoline	53.5	MPG					32.44	-0.03278	0.019661

Model Year	Represented Test Veh Make	Represented Test Veh Model	Make Model Description, Disp,	Test Veh Displacement (L)	Vehicle Type	Rated Horsepower	# of Cylinders and Rotors	nt Test Wei	Test Number	Test Originator	Test Procedure Description	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)
2018	KIA	Optima	KIA Optima: 2L, 3875	2	Car	245	4	3875	GHYX10037887	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	27.4	MPG					34.56	0.39395	0.015464
2018	KIA	Optima	KIA Optima: 2L, 3875	2	Car	245	4	3875	GHYX10037888	MFR	HWFE	Tier 2 Cert Gasoline	44.5	MPG					34.56	0.39395	0.015464
2018	KIA	Optima	KIA Optima: 2.4L, 3625	2.4	Car	185	4	3625	GHYX10037875	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	31.6	MPG					29.099	0.33773	0.015751
2018	KIA	Optima	KIA Optima: 2.4L, 3625	2.4	Car	185	4	3625	GHYX10037876	MFR	HWFE	Tier 2 Cert Gasoline	50.1	MPG					29.099	0.33773	0.015751
2018	KIA	Optima	KIA Optima: 2.4L, 3625	2.4	Car	185	4	3625	GHYX10037873	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	30.3	MPG					29.099	0.33773	0.015751
2018	KIA	Optima	KIA Optima: 2.4L, 3625	2.4	Car	185	4	3625	GHYX10037874	MFR	HWFE	Tier 2 Cert Gasoline	49.3	MPG					29.099	0.33773	0.015751
2018	KIA	Optima	KIA Optima: 1.6L, 3500	1.6	Car	178	4	3500	GHYX10037314	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	36.3	MPG					27.883	0.1882	0.017448
2018	KIA	Optima	KIA Optima: 1.6L, 3500	1.6	Car	178	4	3500	GHYX10037315	MFR	HWFE	Tier 2 Cert Gasoline	54.8	MPG					27.883	0.1882	0.017448
2018	Kia	Optima	Kia Optima: 2.4L, 3625	2.4	Car	185	4	3625	JHYX10050820	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	29.4	MPG	29.0381	27.6773	33.0827		31.669	0.29442	0.01701
2018	Kia	Optima	Kia Optima: 2.4L, 3625	2.4	Car	185	4	3625	JHYX10050821	MFR	HWFE	Tier 2 Cert Gasoline	47.1	MPG					31.669	0.29442	0.01701
2018	Kia	Optima	Kia Optima: 2.4L, 3625	2.4	Car	185	4	3625	JHYX10049716	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	28.5	MPG	28.3755	26.9348	32.4824		31.669	0.29442	0.01701
2018	Kia	Optima	Kia Optima: 2.4L, 3625	2.4	Car	185	4	3625	JHYX10050819	MFR	HWFE	Tier 2 Cert Gasoline	46.4	MPG					31.669	0.29442	0.01701
2018	KIA	Optima Fe	KIA Optima Fe: 2.4L, 3500	2.4	Car	185	4	3500	GHYX10038244	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	32.9	MPG					30.932	0.16628	0.016555
2018	KIA	Optima Fe	KIA Optima Fe: 2.4L, 3500	2.4	Car	185	4	3500	GHYX10038245	MFR	HWFE	Tier 2 Cert Gasoline	52.5	MPG					30.932	0.16628	0.016555
2018	KIA	Optima FE	KIA Optima FE: 2.4L, 3500	2.4	Car	185	4	3500	GHYX10038254	MFR	HWFE	Tier 2 Cert Gasoline	51.3	MPG					30.932	0.16628	0.016555
2018	KIA	Optima FE	KIA Optima FE: 2.4L, 3500	2.4	Car	185	4	3500	GHYX10038258	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	31.7	MPG					30.932	0.16628	0.016555
2018	MAZDA	Mazda6	MAZDA Mazda6: 2.5L, 3875	2.5	Car	227	4	3875	JTKX10051196	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	30.1	MPG	27.967	29.382	33.6266		34.981	0.15271	0.018864
2018	MAZDA	Mazda6	MAZDA Mazda6: 2.5L, 3875	2.5	Car	227	4	3875	JTKX10051197	MFR	HWFE	Tier 2 Cert Gasoline	44.9	MPG					34.981	0.15271	0.018864
2018	MAZDA	Mazda6	MAZDA Mazda6: 2.5L, 3625	2.5	Car	187	4	3625	JTKX10051156	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	31	MPG	30.7055	29.2862	35.2337		26.069	0.28718	0.017201
2018	MAZDA	Mazda6	MAZDA Mazda6: 2.5L, 3625	2.5	Car	187	4	3625	JTKX10051157	MFR	HWFE	Tier 2 Cert Gasoline	48.6	MPG					26.069	0.28718	0.017201
2018	MAZDA	Mazda6	MAZDA Mazda6: 2.5L, 3750	2.5	Car	187	4	3750	JTKX10051258	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	33.7	MPG	31.3671	33.1252	36.9972		33.516	0.06647	0.01894
2018	MAZDA	Mazda6	MAZDA Mazda6: 2.5L, 3750	2.5	Car	187	4	3750	JTKX10051259	MFR	HWFE	Tier 2 Cert Gasoline	50.8	MPG					33.516	0.06647	0.01894
2018	MAZDA	Mazda6	MAZDA Mazda6: 2.5L, 3750	2.5	Car	187	4	3750	JTKX91003738	EPA	HWFE	Tier 2 Cert Gasoline	50.9	MPG					32.773	0.16507	0.018005
2018	MAZDA	Mazda6	MAZDA Mazda6: 2.5L, 3750	2.5	Car	187	4	3750	JTKX91003739	EPA	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	33.8	MPG	31.6849443	33.3107154	37.0755168		32.773	0.16507	0.018005
2018	NISSAN	ALTIMA	NISSAN ALTIMA: 2.5L, 3500	2.5	Car	179	4	3500	JNSX10048404	MFR	US06	Tier 2 Cert Gasoline	33.6	MPG	21.8	40			31.04	-0.2831	0.02171
2018	NISSAN	ALTIMA	NISSAN ALTIMA: 2.5L, 3500	2.5	Car	179	4	3500	JNSX10049260	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	35.5	MPG	34.6	33.8	40.1		31.04	-0.2831	0.02171
2018	NISSAN	ALTIMA	NISSAN ALTIMA: 2.5L, 3500	2.5	Car	179	4	3500	JNSX10049261	MFR	HWFE	Tier 2 Cert Gasoline	55	MPG					31.04	-0.2831	0.02171
2018	NISSAN	ALTIMA SR	NISSAN ALTIMA SR: 2.5L, 3500	2.5	Car	179	4	3500	JNSX10048401	MFR	US06	Tier 2 Cert Gasoline	34.3	MPG	21.8	41.1			37.46	-0.182	0.01917
2018	NISSAN	ALTIMA SR	NISSAN ALTIMA SR: 2.5L, 3500	2.5	Car	179	4	3500	JNSX10049258	MFR	HWFE	Tier 2 Cert Gasoline	53.7	MPG					37.46	-0.182	0.01917
2018	NISSAN	ALTIMA SR	NISSAN ALTIMA SR: 2.5L, 3500	2.5	Car	179	4	3500	JNSX10049264	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	35.2	MPG	34.5	33.6	39.3		37.46	-0.182	0.01917
2018	NISSAN	ALTIMA SR	NISSAN ALTIMA SR: 2.5L, 3500	2.5	Car	179	4	3500	JNSX10049366	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	35.1	MPG	34.4	33.5	39.2		37.46	-0.182	0.01917
2018	NISSAN	ALTIMA SR	NISSAN ALTIMA SR: 2.5L, 3500	2.5	Car	179	4	3500	JNSX10049368	MFR	HWFE	Tier 2 Cert Gasoline	53.5	MPG					37.46	-0.182	0.01917
2018	NISSAN	ALTIMA SR	NISSAN ALTIMA SR: 2.5L, 3500	2.5	Car	179	4	3500	JNSX10049371	MFR	US06	Tier 2 Cert Gasoline	34.1	MPG	21.8	40.9			37.46	-0.182	0.01917
2018	NISSAN	NISSAN ALTIMA SL	NISSAN NISSAN ALTIMA SL: 3.5L, 3750	3.5	Car	270	6	3750	FNSX10029853	MFR	US06	Tier 2 Cert Gasoline	29.6	MPG	19.2	35			33.4	0.0834	0.01834
2018	NISSAN	NISSAN ALTIMA SL	NISSAN NISSAN ALTIMA SL: 3.5L, 3750	3.5	Car	270	6	3750	FNSX10031313	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	29.2	MPG	28.1	27.6	33.6		33.4	0.0834	0.01834
2018	NISSAN	NISSAN ALTIMA SL	NISSAN NISSAN ALTIMA SL: 3.5L, 3750	3.5	Car	270	6	3750	FNSX10031314	MFR	HWFE	Tier 2 Cert Gasoline	45.2	MPG					33.4	0.0834	0.01834
2018	SUBARU	LEGACY	SUBARU LEGACY: 2.5L, 3875	2.5	Both	175	4	3875	FFJX10030669	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	33.6	MPG					35.55	0.0273	0.02036
2018	SUBARU	LEGACY	SUBARU LEGACY: 2.5L, 3875	2.5	Both	175	4	3875	FFJX10030670	MFR	HWFE	Tier 2 Cert Gasoline	50.7	MPG					35.55	0.0273	0.02036
2018	SUBARU	LEGACY	SUBARU LEGACY: 3.6L, 4000	3.6	Both	256	6	4000	FFJX10029253	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	24.9	MPG					32.07	-0.0128	0.02181
2018	SUBARU	LEGACY	SUBARU LEGACY: 3.6L, 4000	3.6	Both	256	6	4000	FFJX10030687	MFR	HWFE	Tier 2 Cert Gasoline	40.3	MPG					32.07	-0.0128	0.02181
2018	SUBARU	LEGACY	SUBARU LEGACY: 2.5L, 3875	2.5	Both	175	4	3875	HFJX10041935	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	32.3	MPG	31.579865	31.34863	34.737767		38.35	0.054	0.02003
2018	SUBARU	LEGACY	SUBARU LEGACY: 2.5L, 3875	2.5	Both	175	4	3875	HFJX10041936	MFR	HWFE	Tier 2 Cert Gasoline	47.6	MPG					38.35	0.054	0.02003
2018	TOYOTA	CAMRY	TOYOTA CAMRY: 2.5L, 3500	2.5	Car	203	4	3500	JTYX10046387	MFR	HWFE	Tier 2 Cert Gasoline	61.8	MPG					21.006	0.17604	0.016028
2018	TOYOTA	CAMRY	TOYOTA CAMRY: 2.5L, 3500	2.5	Car	203	4	3500	JTYX10046391	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	39.1	MPG	38.2894671	37.4672085	43.1249854		21.006	0.17604	0.016028
2018	TOYOTA	CAMRY	TOYOTA CAMRY: 3.5L, 3875	3.5	Car	301	6	3875	JTYX10046635	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	28.6	MPG	29.2528576	26.7151098	32.3691975		24.843	0.40298	0.015068
2018	TOYOTA	CAMRY	TOYOTA CAMRY: 3.5L, 3875	3.5	Car	301	6	3875	JTYX10046636	MFR	HWFE	Tier 2 Cert Gasoline	47.8	MPG					24.843	0.40298	0.015068
2018	TOYOTA	CAMRY LE/SE	TOYOTA CAMRY LE/SE: 2.5L, 3625	2.5	Car	203	4	3625	JTYX91003439	EPA	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	36.2	MPG	34.9059193	35.1032922	39.8964643		25.587	0.19688	0.016371
2018	TOYOTA	CAMRY LE/SE	TOYOTA CAMRY LE/SE: 2.5L, 3625	2.5	Car	203	4	3625	JTYX91003440	EPA	HWFE	Tier 2 Cert Gasoline	57.1	MPG					25.587	0.19688	0.016371
2018	TOYOTA	CAMRY LE/SE	TOYOTA CAMRY LE/SE: 2.5L, 3625	2.5	Car	203	4	3625	JTYX10046386	MFR	HWFE	Tier 2 Cert Gasoline	61.4	MPG					21.662	0.17941	0.016016
2018	TOYOTA	CAMRY LE/SE	TOYOTA CAMRY LE/SE: 2.5L, 3625	2.5	Car	203	4	3625	JTYX10046390	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	38.9	MPG	37.8274752	37.4672085	43.125651		21.662	0.17941	0.016016
2018	TOYOTA	CAMRY LE/SE	TOYOTA CAMRY LE/SE: 2.5L, 3625	2.5	Car	203	4	3625	JTYX10046388	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	38.1	MPG	36.8364492	36.6899619	41.8959113		24.047	0.1891	0.016418
2018	TOYOTA	CAMRY LE/SE	TOYOTA CAMRY LE/SE: 2.5L, 3625	2.5	Car	203	4	3625	JTYX10046389	MFR	HWFE	Tier 2 Cert Gasoline	59.3	MPG					24.047	0.1891	0.016418
2018	TOYOTA	CAMRY XLE/XSE	TOYOTA CAMRY XLE/XSE: 2.5L, 3750	2.5	Car	206	4	3750	JTYX10046557	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	35.6	MPG	34.26003	34.4059859	39.116687		32.527	0.22484	0.017128
2018	TOYOTA	CAMRY XLE/XSE	TOYOTA CAMRY XLE/XSE: 2.5L, 3750	2.5	Car	206	4	3750	JTYX10046558	MFR	HWFE	Tier 2 Cert Gasoline	54.2	MPG					32.527	0.22484	0.017128
2018	TOYOTA	CAMRY XLE/XSE	TOYOTA CAMRY XLE/XSE: 2.5L, 3625	2.5	Car	203	4	3625	JTYX10046442	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	37	MPG	36.0594713	35.5121899	40.9258593		26.509	0.19851	0.016476
2018	TOYOTA	CAMRY XLE/XSE	TOYOTA CAMRY XLE/XSE: 2.5L, 3625	2.5	Car	203	4	3625	JTYX10046443	MFR	HWFE	Tier 2 Cert Gasoline	58.2	MPG					26.509	0.19851	0.016476
2018	TOYOTA	CAMRY XSE	TOYOTA CAMRY XSE: 3.5L, 3875	3.5	Car	301	6	3875	JTYX10046633	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	29.1	MPG	29.7438903	27.1248271	32.9912194		24.032	0.41181	0.014567
2018	TOYOTA	CAMRY XSE	TOYOTA CAMRY XSE: 3.5L, 3875	3.5	Car	301	6	3875	JTYX10046639	MFR	HWFE	Tier 2 Cert Gasoline	48.6	MPG					24.032	0.41181	0.014567
2018	TOYOTA	CAMRY XSE	TOYOTA CAMRY XSE: 3.5L, 3875	3.5	Car	301	6	3875	JTYX10046632	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	29.2	MPG	29.6451155	27.291988	33.3646383		22.382	0.40349	0.014614
2018	TOYOTA	CAMRY XSE	TOYOTA CAMRY XSE: 3.5L, 3875	3.5	Car	301	6	3875	JTYX10046634	MFR	HWFE	Tier 2 Cert Gasoline	49.4	MPG					22.382	0.40349	0.014614
2018	TOYOTA	CAMRY XSE	TOYOTA CAMRY XSE: 3.5L, 3875	3.5	Car	301	6	3875	JTYX10046640	MFR	HWFE	Tier 2 Cert Gasoline	46.1	MPG					27.975	0.41014	0.016383
2018	TOYOTA	CAMRY XSE	TOYOTA CAMRY XSE: 3.5L, 3875	3.5	Car	301	6	3875	JTYX10046641	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	28.2	MPG	28.4923177	26.5546678	31.9187687		27.975	0.41014	0.016383
2018	TOYOTA	CAMRY XSE	TOYOTA CAMRY XSE: 3.5L, 3875	3.5	Car	301	6	3875	JTYX10046637	MFR	HWFE	Tier 2 Cert Gasoline	46.1	MPG					27.415	0.40732	0.016401
2018	TOYOTA	CAMRY XSE	TOYOTA CAMRY XSE: 3.5L, 3875	3.5	Car	301	6	3875	JTYX10046638	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	28.1	MPG	28.5855949	26.3178338	31.6882198		27.415	0.40732	0.016401
2018	VOLKSWAGEN	Passat	VOLKSWAGEN Passat: 2L, 3625	2	Car	174	4	3625	JVGA10047228	MFR	US06	Tier 2 Cert Gasoline	31.7	MPG	19.2	38.7			30.394	0.18194	0.01746
2018	VOLKSWAGEN	Passat	VOLKSWAGEN Passat: 2L, 3625	2	Car	174	4	3625	JVGA10047230	MFR	SC03	Tier 2 Cert Gasoline	26.7	MPG					30.394	0.18194	0.01746
2018	VOLKSWAGEN	Passat	VOLKSWAGEN Passat: 2L, 3625	2	Car	174	4	3625	JVGA10047232	MFR	Cold CO	Cold CO Premium (Tier 2)	26.9	MPG	22.1	26.8	32.3		33.434	0.20014	0.019206
2018	VOLKSWAGEN	Passat	VOLKSWAGEN Passat: 2L, 3625	2	Car	174	4	3625	JVGA10047597	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	32.8	MPG	32.2	30.8	37.3		30.394	0.18194	0.01746
2018	VOLKSWAGEN	Passat	VOLKSWAGEN Passat: 2L, 3625	2	Car	174	4	3625	JVGA10047598	MFR	HWFE	Tier 2 Cert Gasoline	53	MPG					30.394	0.18194	0.01746
2018	VOLKSWAGEN	Passat	VOLKSWAGEN Passat: 3.6L, 3875	3.6	Car	280	6	3875	JVGA10049350	MFR	Federal fuel 2-day exhaust (w/can load)	Tier 2 Cert Gasoline	23.4	MPG	23.5	21.8	27.1		31.451	0.26297	0.01845
2018	VOLKSWAGEN	Passat	VOLKSWAGEN Passat: 3.6L, 3875	3.6	Car	280	6	3875	JVGA10049351	MFR	HWFE	Tier 2 Cert Gasoline	37.5	MPG					31.451	0.26297	0.01845
2018	VOLKSWAGEN	Passat	VOLKSWAGEN Passat: 3.6L, 3875	3.6	Car	280	6	3875	JVGA10049352	MFR	US06	Tier 2 Cert Gasoline	25.5	MPG	17	29.8			31.451	0.26297	0.01845
2018	VOLKSWAGEN	Passat	VOLKSWAGEN Passat: 3.6L, 3875	3.6	Car	280	6	3875	JVGA10049353	MFR	SC03	Tier 2 Cert Gasoline	20.7	MPG					31.451	0.26297	0.01845
2018	VOLKSWAGEN	Passat	VOLKSWAGEN Passat: 3.6L, 3875	3.6	Car	280	6	3875	JVGA10049354	MFR	Cold CO	Cold CO Premium (Tier 2)	21.3	MPG	19.5	20.3	25.2		34.596	0.28927	0.020294

Appendix C: 2018 Toyota Camry XLE Test Signals

The signals shown in Tables 22 and 23 were collected at 10 Hz for each test. Note that the signal sampling rate for the CAN and diagnostic messages is dependent on the vehicle, and the actual transmission rate may be faster or slower than the 10-Hz sample rate.

Table 22. 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]	Solar_Array_Ind_Temp[°C]	AMA_Dilute_Fuel[g/s]
Dyno_Spd_Rear[mph]	Eng_FuelFlow_Direct2[gps]	
Dyno_LoadCell_Rear[N]	12VBatt_Volt_Hioki_U1[V]	
Dyno_TractiveForce_Rear[N]	12VBatt_Curr_Hioki_I1[A]	
DilAir_RH(%)	12VBatt_Power_Hioki_P1[W]	
Tailpipe_Press[inH2O]	Alternator_Curr_Hioki_I2[A]	
Cell_Temp[°C]	Alternator_Power_Hioki_P2[W]	
Cell_RH(%)	12VBatt_Curr_Hi_Hioki_I3[A]	
Cell_Press[inHg]	12VBatt_Power_Hi_Hioki_P3[W]	
Tire_Front_Temp[°C]	Eng_FuelFlow_Direct[ccps]	
Tire_Rear_Temp[°C]	Eng_Fuel_Temp_Direct[°C]	
Drive_Schedule_Time[s]		
Drive_Trace_Schedule[mph]		
Exhaust_Bag		

Table 23. CAN Signal List

CAN Stream	**Scantool Stream**
Trans_turbine_spd_CAN2__rpm	Brake_master_cylinder_control_torque_ECM__Nm
Trans_gear_CAN2	Eng_cat_temp_1_1_ECM__C
Veh_wheel_speed_FR_CAN2__kph	Eng_cat_temp_1_2_ECM__C
Veh_wheel_speed_FL_CAN2__kph	Eng_coolant_temp_ECM__C
Veh_wheel_speed_RR_CAN2__kph	Eng_cooling_fan_duty_ECM__per
Veh_wheel_speed_RL_CAN2__kph	Eng_equiv_ratio_commanded_ECM
Eng_spd_CAN2__rpm	Eng_fuel_cut_DFCO_ECM
Pedal_accel_pos_CAN2__per	Eng_injection_mode_ECM
Veh_PRNDL_pos_CAN2	Eng_intakeair_temp_ECM__C
Trans_turbine_spd_CAN2__rpm	Eng_knock_feedback_ECM__degCA
Trans_gear_CAN2	Eng_load_absolute_ECM__per
Brake_switch_light_CAN4	Eng_load_calculated_ECM__per
	Eng_spd_ECM__rpm
	Eng_throttle_position_ECM__per
	Eng_timing_advance_cyl_1_ECM__deg
	Eng_water_pump_speed_ECM__rpm
	HVAC_AC_on_setting_BCAN
	HVAC_ambient_temp_HVAC__C
	HVAC_blower_motor_spd_HVAC
	HVAC_recirc_setting_BCAN
	HVAC_refrigerant_pressure_HVAC__kPag
	HVAC_room_temp_HVAC__C
	HVAC_solar_sensor_d_side_HVAC
	HVAC_solar_sensor_P_side_HVAC
	Trans_gear_manual_set_CAN4
	Trans_oil_temp_TCU__C
	Trans_output_axis_speed_ECM__rpm

Appendix D: 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]	Cycle Fuel Consumed [gal] (Emiss Bag)	Cycle Fuel Economy [mpg] (Emiss Bag)	Fuel used modal [gal]	Fuel Economy Modal [mpg]	Alternator Out (200A) Δ [Wh]	Alternator Out (200A) Energy consumption [Wh/mi]	12V Batt (Pos) Δ WP2 [Wh]	12V Batt (Pos) Δ WP2 [Wh/mi]	12V Batt (Neg) (200A) Δ [Wh]	12V Batt (Neg) (200A) Average Power P1 [W]	12V Batt (Neg) (200A) Energy consumption [Wh/mi]	APCtime	ASCR	ASC_d	ASC_t	CE_d	CE_t	DR	D_d	D_t	EER	ER	IWR
Day 0 Coastdowns, Channel Check and Prep																																	
Day 1, Cert cycles in 4WD																																	
61808001	UDDS cold start Ph 1	08/01/18, 09:54:40 AM	UDDSx2, 4 bag (FTP), cold start, split fuel flow measurement,	ok	24	3625	26.509	0.19851	0.016476	3.60	0.107	33.5	0.109	33.2	39.560	10.981	-9.208	-2.556	-18.666	-132.180	-5.181	2050.070758	3.0974694	2112.494	2049.026	2.789522	2.724714	0.32189	3.602544	3.590985	2.00885	2.378521	0.602314
61808001	UDDS cold start Ph 2	08/01/18, 09:54:40 AM	UDDSx2, 4 bag (FTP), cold start, split fuel flow measurement,	ok	22	3625	26.509	0.19851	0.016476	3.90	0.117	33.3	0.115	33.8	53.216	13.645	-3.917	-1.004	-23.114	-95.809	-5.927	1250.64796	4.9654506	3586.189	3416.542	2.693175	2.550559	1.039447	3.89996	3.859839	4.311038	5.591538	0.72139
61808001	**UDDS cold start Ph 1+2**	08/01/18, 09:54:40 AM	**UDDSx2, 4 bag (FTP), cold start, split fuel flow measurement,**	**ok**	**23**					**7.50**	**0.225**	**33.39**	**0.224**	**33.51**	**92.776**	**12.366**	**-13.125**	**-1.7**	**-41.780**	**-113.995**	**-5.6**		**4.2651498**	**5698.683**	**5465.568**	**5.482697**	**5.275274**	**0.693615**	**7.502505**	**7.450825**	**3.115863**	**3.931993**	**0.659886**
61808001	UDDS hot start Ph 1	08/01/18, 09:54:40 AM	UDDSx2, 4 bag (FTP), cold start, split fuel flow measurement,	ok	23	3625	26.509	0.19851	0.016476	3.59	0.095	37.88	0.095	37.63	39.198	10.927	-5.031	-1.4	-17.095	-121.684	-4.8	2050.439724	2.3996898	2098.177	2049.008	2.788318	2.724691	-0.10273	3.587297	3.590986	2.382317	2.335219	0.602312
61808001	UDDS hot start Ph 2	08/01/18, 09:54:40 AM	UDDSx2, 4 bag (FTP), cold start, split fuel flow measurement,	ok	22	3625	26.509	0.19851	0.016476	3.85	0.113	33.94	0.111	34.52	57.643	14.989	-2.800	-0.7	-24.521	-101.767	-6.4	1250.788829	1.7941442	3477.839	3416.542	2.580419	2.550556	-0.3669	3.84568	3.859841	1.519944	1.170845	0.721391
61808001	**UDDS hot start Ph 1+2**	08/01/18, 09:54:40 AM	**UDDSx2, 4 bag (FTP), cold start, split fuel flow measurement,**	**ok**	**22**					**7.43**	**0.208**	**35.73**	**0.207**	**35.96**	**96.841**	**13.028**	**-7.831**	**-1.1**	**-41.616**	**-111.725**	**-5.6**		**2.0211603**	**5576.017**	**5465.549**	**5.368737**	**5.275247**	**-0.23958**	**7.432976**	**7.450827**	**1.976795**	**1.77225**	**0.659886**
61808002	UDDS hot start #2 Ph 1	08/01/18, 11:15:27 AM	UDDS, 2 bag, cold start, split fuel flow measurement,	ok	22	3625	26.509	0.19851	0.016476	3.61	0.095	37.88	0.096	37.75	42.084	11.669	-8.200	-2.3	-19.381	-136.606	-5.4	2050.081443	2.0936647	2091.905	2049.026	2.788193	2.724703	0.436183	3.606648	3.590985	1.850859	2.33017	0.602308
61808002	UDDS hot start #2 Ph 2	08/01/18, 11:15:27 AM	UDDS, 2 bag, cold start, split fuel flow measurement,	ok	15	3625	26.509	0.19851	0.016476	3.88	0.115	33.76	0.113	34.36	57.854	14.907	-2.641	-0.7	-24.501	-101.715	-6.3	1250.876248	3.1211608	3523.161	3416.526	2.639583	2.550557	0.542627	3.880784	3.859839	2.848385	3.490433	0.721387
61808002	**UDDS hot start #2 Ph 1+2**	08/01/18, 11:15:27 AM	**UDDS, 2 bag, cold start, split fuel flow measurement,**	**ok**	**19**					**7.49**	**0.210**	**35.63**	**0.208**	**35.91**	**99.938**	**13.347**	**-10.840**	**-1.4**	**-43.882**	**-119.160**	**-5.9**		**2.7359566**	**5615.067**	**5465.532**	**5.427776**	**5.27526**	**0.491325**	**7.487432**	**7.450824**	**2.332392**	**2.89115**	**0.659882**
61808003	HWY #1 & coastdown check	08/01/18, 01:32:56 PM	Hwyx2, 2 bag, split fuel flow measurement, with Vehicle On coastdown to verify vehicle losses	ok, coastdown ok	23	3625	26.509	0.19851	0.016476	10.27	0.191	53.70	0.191	53.79	70.469	6.859	-24.161	-2.4	-36.466	-171.831	-3.5	1648.532128	3.7276477	1355.577	1306.862	6.584267	6.59102	0.161104	10.2732	10.25668	-0.26384	-0.10247	0.293512
61808003	HWY #2 & coastdown check	08/01/18, 01:32:56 PM	Hwyx2, 2 bag, split fuel flow measurement, with Vehicle On coastdown to verify vehicle losses	ok, coastdown ok	24	3625	26.509	0.19851	0.016476	10.29	0.182	56.38	0.181	56.76	51.090	4.967	-3.481	-0.3	-21.733	-102.166	-2.1	1648.844697	8.0161195	1411.621	1306.862	6.645573	6.59101	0.294414	10.28688	10.25668	0.529048	0.827842	0.293512
61808004	US06x2 Ph 1	08/01/18, 02:37:12 PM	US06x2, 4 (split) bag, split fuel flow measurement,	ok	22	3625	26.509	0.19851	0.016476	1.78	0.091	19.6	0.092	19.3	24.832	13.989	-5.253	-2.959	-9.671	-149.811	-5.448	4754.168106	0.7450035	2478.068	2459.743	2.732568	2.713096	0.174184	1.775192	1.772105	0.539632	0.717689	0.821824
61808004	US06x2 Ph 2	08/01/18, 02:37:12 PM	US06x2, 4 (split) bag, split fuel flow measurement,	ok	24	3625	26.509	0.19851	0.016476	6.24	0.161	38.8	0.162	38.6	31.702	5.081	-4.329	-0.694	-11.984	-117.650	-1.921	10055.31923	-1.2556584	1125.658	1139.972	5.809709	5.839877	0.067069	6.239041	6.234859	-0.5867	-0.5166	0.361715
61808004	US06x2 Ph 1+2	08/01/18, 02:37:12 PM	US06x2, 4 (split) bag, split fuel flow measurement,	ok	**23**					**8.01**	**0.251**	**31.88**	**0.254**	**31.59**	**56.534**	**7.054**	**-9.582**	**-1.2**	**-21.655**	-133.731	**-2.7**												
61808004	US06x2 Ph 3	08/01/18, 02:37:12 PM	US06x2, 4 (split) bag, split fuel flow measurement,	ok	23	3625	26.509	0.19851	0.016476	1.77	0.090	19.7	0.093	19.0	19.916	11.262	-0.654	-0.370	-6.082	-93.791	-3.439	4741.425222	-0.3578738	2450.931	2459.734	2.682295	2.713082	-0.21315	1.768328	1.772106	-0.93216	-1.13474	0.821828
61808004	US06x2 Ph 4	08/01/18, 02:37:12 PM	US06x2, 4 (split) bag, split fuel flow measurement,	ok	26	3625	26.509	0.19851	0.016476	6.23	0.159	39.1	0.159	39.0	28.428	4.566	-1.076	-0.173	-9.654	-95.386	-1.551	10053.87448	-0.5345491	1133.824	1139.918	5.743679	5.839809	-0.14574	6.225772	6.234858	-1.52548	-1.64611	0.361697
61808004	US06x2 Ph 3+4	08/01/18, 02:37:12 PM	US06x2, 4 (split) bag, split fuel flow measurement,	ok	**24**					**7.99**	**0.249**	**32.12**	**0.253**	**31.63**	**48.344**	**6.047**	**-1.730**	**-0.2**	**-15.736**	-94.589	**-2.0**												
61808005	UDDS Prep	08/01/18, 03:16:45 PM	UDDS prep, 1 bag, split fuel flow measurement,	ok	15	3625	26.509	0.19851	0.016476	7.43	0.209	35.5	0.203	36.6	104.140	14.019	-12.505	-1.683	-45.493	-119.144	-6.124	1556.815099	0.6434657	5500.752	5465.583	5.313551	5.275193	-0.29833	7.428585	7.450813	1.018086	0.727155	0.659899
Day 2, Cert cycles in 4WD																																	
61808006	UDDS cold start Ph 1	08/02/18, 09:09:30 AM	UDDSx2, 4 bag (FTP), cold start, split fuel flow measurement,	ok	22	3625	26.509	0.19851	0.016476	3.59	0.107	33.6	0.107	33.5	34.165	9.512	-3.793	-1.056	-14.858	-105.553	-4.136	2049.270568	1.6390208	2082.603	2049.02	2.76309	2.724704	0.026822	3.591949	3.590986	1.362783	1.408804	0.602313
61808006	UDDS cold start Ph 2	08/02/18, 09:09:30 AM	UDDSx2, 4 bag (FTP), cold start, split fuel flow measurement,	ok	19	3625	26.509	0.19851	0.016476	3.86	0.116	33.3	0.113	34.1	51.367	13.325	-2.120	-0.550	-21.713	-90.101	-5.632	1250.806206	1.743072	3476.089	3416.537	2.592142	2.550567	-0.12521	3.855006	3.859838	1.727074	1.630012	0.721386
61808006	**UDDS cold start Ph 1+2**	08/02/18, 09:09:30 AM	UDDSx2, 4 bag (FTP), cold start, split fuel flow measurement,	ok	**21**					**7.45**	**0.223**	**33.44**	**0.220**	**33.78**	**85.533**	**11.486**	**-5.913**	**-0.8**	**-36.571**	-97.827	**-4.9**					3.382093							
61808006	UDDS hot start Ph 1	08/02/18, 09:09:30 AM	UDDSx2, 4 bag (FTP), cold start, split fuel flow measurement,	ok	23	3625	26.509	0.19851	0.016476	3.60	0.095	37.9	0.095	37.8	39.551	10.988	-5.835	-1.621	-17.427	-124.736	-4.841	2050.472959	1.7520249	2084.916	2049.017	2.776146	2.724693	0.239611	3.59959	3.590986	1.618216	1.888386	0.602315
61808006	UDDS hot start Ph 2	08/02/18, 09:09:30 AM	UDDSx2, 4 bag (FTP), cold start, split fuel flow measurement,	ok	21	3625	26.509	0.19851	0.016476	3.88	0.114	34.0	0.112	34.7	57.185	14.754	-2.190	-0.565	-24.184	-100.515	-6.240	1250.72055	1.6245107	3472.04	3416.538	2.60591	2.550554	0.413426	3.875798	3.859841	1.719639	2.170367	0.72139
61808006	**UDDS hot start Ph 1+2**	08/02/18, 09:09:30 AM	UDDSx2, 4 bag (FTP), cold start, split fuel flow measurement,	ok	**22**					**7.48**	**0.209**	**35.76**	**0.207**	**36.14**	**96.736**	**12.940**	**-8.025**	**-1.1**	**-41.611**	-112.626	**-5.6**					3.376536							
61808007	UDDS hot start #2 Ph 1	08/02/18, 10:31:16 AM	UDDS #3, 2 bag, warm start, split fuel flow measurement,	ok	23	3625	26.509	0.19851	0.016476	3.59	0.093	38.8	0.093	38.5	41.570	11.564	-7.765	-2.160	-18.987	-136.390	-5.282	2060.679082	1.1743155	2073.076	2049.014	2.741613	2.724643	0.105048	3.594753	3.590986	0.51458	0.622834	0.602324
61808007	UDDS hot start #2 Ph 2	08/02/18, 10:31:16 AM	UDDS #3, 2 bag, warm start, split fuel flow measurement,	ok	19	3625	26.509	0.19851	0.016476	3.87	0.113	34.2	0.111	34.9	57.524	14.856	-2.370	-0.612	-24.334	-100.726	-6.284	1261.645322	1.322188	3461.701	3416.528	2.594705	2.550514	0.315671	3.872015	3.859831	1.392839	1.732642	0.721398
61808007	**UDDS hot start #2 Ph 1+2**	08/02/18, 10:31:16 AM	UDDS #3, 2 bag, warm start, split fuel flow measurement,	ok		3625	26.509	0.19851	0.016476	7.47	0.206	36.3																					
61808008	HWY #1	08/02/18, 11:09:25 AM	Hwyx2, 2 bag, warm start, split fuel flow measurement,	ok	20	3625	26.509	0.19851	0.016476	10.24	0.186	55.1	0.185	55.3	60.338	5.894	-5.890	-0.575	-25.236	-118.688	-2.465	1648.502778	1.7532903	1329.775	1306.861	6.567129	6.591019	-0.19765	10.23641	10.25668	-0.16541	-0.36246	0.293512
61808008	HWY #2	08/02/18, 11:09:25 AM	Hwyx2, 2 bag, warm start, split fuel flow measurement,	ok	21	3625	26.509	0.19851	0.016476	10.25	0.180	56.9	0.180	57.0	50.260	4.904	-1.672	-0.163	-20.910	-98.486	-2.040	1648.778316	1.559807	1327.244	1306.86	6.568538	6.591005	-0.07248	10.24925	10.25668	-0.26931	-0.34087	0.293512
61808009	US06x2 Ph 1	08/02/18, 01:06:22 PM	US06x2, 4 (split) bag, warm start, split fuel flow measurement,	ok	21	3625	26.509	0.19851	0.016476	1.78	0.091	19.5	0.092	19.4	19.560	11.018	-0.560	-0.315	-5.967	-92.327	-3.361	4753.715039	-0.2693565	2453.115	2459.74	2.703071	2.713095	0.180189	1.775298	1.772105	-0.55171	-0.36948	0.82182
61808009	US06x2 Ph 2	08/02/18, 01:06:22 PM	US06x2, 4 (split) bag, warm start, split fuel flow measurement,	ok	23	3625	26.509	0.19851	0.016476	6.22	0.161	38.8	0.161	38.7	28.008	4.499	-0.861	-0.138	-9.457	-93.321	-1.519	10053.32682	0.8103489	1149.166	1139.929	5.807279	5.839868	-0.16157	6.224784	6.234858	-0.39869	-0.55803	0.361698
61808009	US06x2 Ph 1+2	08/02/18, 01:06:22 PM	US06x2, 4 (split) bag, warm start, split fuel flow measurement,	ok	**22**					**8.00**	**0.252**	**31.77**	**0.253**	**31.67**	**47.568**	**5.946**	**-1.421**	**-0.2**	**-15.423**	-92.824	**-1.9**												
61808009	US06x2 Ph 3	08/02/18, 01:06:22 PM	US06x2, 4 (split) bag, warm start, split fuel flow measurement,	ok	20	3625	26.509	0.19851	0.016476	1.78	0.088	20.2	0.088	20.2	19.429	10.928	-0.510	-0.287	-5.850	-90.190	-3.290	4740.903042	0.8031648	2479.487	2459.731	2.747914	2.713073	0.325907	1.77788	1.772105	0.946142	1.284199	0.821832
61808009	US06x2 Ph 4	08/02/18, 01:06:22 PM	US06x2, 4 (split) bag, warm start, split fuel flow measurement,	ok	23	3625	26.509	0.19851	0.016476	6.23	0.159	39.1	0.159	39.1	27.889	4.476	-0.810	-0.130	-9.343	-92.485	-1.500	10053.47517	-0.6518194	1132.508	1139.938	5.830414	5.83986	-0.06317	6.23092	6.234859	-0.09874	-0.16176	0.361702
61808009	US06x2 Ph 3+4	08/02/18, 01:06:22 PM	US06x2, 4 (split) bag, warm start, split fuel flow measurement,	ok	**22**					**8.01**	**0.248**	**32.35**	**0.247**	**32.41**	**47.318**	**5.908**	**-1.320**	**-0.2**	**-15.193**	-91.337	**-1.9**												
61808010	SSS 0-80-0	08/02/18, 02:06:59 PM	SSS stairs, 0-80-0, 1 minute hold warm start, split fuel flow measurement,	ok, need to run a bag in test to get modal fuel data	NaN	3625	26.509	0.19851	0.016476																								
61808011	SSS 0-80-1	08/02/18, 02:31:06 PM	SSS stairs, 0-80-0, 1 bag, bags OFF, 1 minute hold warm start, split fuel flow measurement,	ok	20	3625	26.509	0.19851	0.016476	11.58			0.241	48.0	74.202	6.409	-5.567	-0.481	-30.103	-110.575	-2.600	612.3838649	48.593794	1062.838	715.264	8.27255	8.253209	0.192211	11.57774	11.55553	0.042026	0.234336	0.12932
61808012	UDDS Prep	08/02/18, 03:02:20 PM	UDDS prep, 1 bag, warm start, split fuel flow measurement,	ok	21	3625	26.509	0.19851	0.016476	7.48	0.207	36.2	0.203	36.8	96.680	12.929	-7.464	-0.998	-41.411	-108.600	-5.538	1556.621574	1.1392811	5527.816	5465.548	5.348681	5.275169	0.36437	7.477962	7.450813	1.015032	1.393547	0.659895
Day 3, Cert cycles in 4WD																																	
61808013	UDDSx2, cold start Ph 1	08/03/18, 01:27:52 PM	UDDSx2, 4 bag (FTP), cold start, split fuel flow measurement, VSpy DAQ clock enabled (CAN 0)	ok	24	3625	26.509	0.19851	0.016476	3.60	0.108	33.4	0.109	33.1	33.713	9.372	-3.412	-0.949	-14.600	-104.326	-4.058	2049.263334	1.9100444	2088.156	2049.019	2.758051	2.724709	0.176399	3.597319	3.590985	1.034626	1.223686	0.602312
61808013	UDDS cold start Ph 2	08/03/18, 01:27:52 PM	UDDSx2, 4 bag (FTP), cold start, split fuel flow measurement, VSpy DAQ clock enabled (CAN 0)	ok	22	3625	26.509	0.19851	0.016476	3.88	0.115	33.6	0.114	33.9	51.298	13.212	-2.025	-0.522	-21.724	-90.110	-5.595	1250.9411	2.5081467	3502.248	3416.555	2.631758	2.550569	0.589576	3.882596	3.85984	2.513581	3.183168	0.72139
61808013	**UDDS cold start Ph 1+2**	08/03/18, 01:27:52 PM	UDDSx2, 4 bag (FTP), cold start, split fuel flow measurement, VSpy DAQ clock enabled (CAN 0)	ok	**23**					**7.48**	**0.223**	**33.50**	**0.223**	**33.52**	**85.011**	**11.365**	**-5.437**	**-0.7**	**-36.324**	-97.218	**-4.9**												
61808013	UDDS hot start Ph 3	08/03/18, 01:27:52 PM	UDDSx2, 4 bag (FTP), cold start, split fuel flow measurement, VSpy DAQ clock enabled (CAN 0)	ok	23	3625	26.509	0.19851	0.016476	3.59	**0.095**	37.9	0.096	37.5	39.006	10.856	-4.980	-1.386	-17.131	-122.591	-4.768	2050.49253	1.9719073	2089.384	2048.98	2.787938	2.724671	0.058765	3.593097	3.590987	2.211888	2.322014	0.602306
61808013	UDDS hot start Ph 4	08/03/18, 01:27:52 PM	UDDSx2, 4 bag (FTP), cold start, split fuel flow measurement, VSpy DAQ clock enabled (CAN 0)	ok	21	3625	26.509	0.19851	0.016476	3.86	0.115	33.6	0.113	34.0	57.145	14.812	-2.087	-0.541	-24.082	-99.724	-6.242	1250.715031	2.6690044	3507.72	3416.533	2.604648	2.550559	-0.04501	3.858103	3.859841	2.120724	2.120683	0.721389
61808013	**UDDS hot start Ph 3+4**	08/03/18, 01:27:52 PM	UDDSx2, 4 bag (FTP), cold start, split fuel flow measurement, VSpy DAQ clock enabled (CAN 0)	ok	**22**					**7.45**	**0.209**	**35.57**	**0.209**	**35.62**	**96.151**	**12.904**	**-7.067**	**-0.9**	**-41.213**	-111.157	**-5.5**												
61808014	UDDS hot start #2 Ph 1	08/03/18, 02:47:15 PM	UDDS #3, 2 bag, warm start, split fuel flow measurement, VSpy DAQ clock enabled (CAN 0)	ok	25	3625	26.509	0.19851	0.016476	3.60	0.094	38.1	0.095	38.0	41.170	11.432	-7.314	-2.031	-18.850	-134.524	-5.234	2061.539645	0.6786522	2062.925	2049.02	2.743638	2.724651	0.287211	3.601295	3.590982	0.406811	0.696857	0.602325
61808014	UDDS hot start #2 Ph 2	08/03/18, 02:47:15 PM	UDDS #3, 2 bag, warm start, split fuel flow measurement, VSpy DAQ clock enabled (CAN 0)	ok	20	3625	26.509	0.19851	0.016476	3.87	0.114	33.9	0.113	34.4	57.584	14.886	-2.469	-0.638	-24.424	-101.323	-6.314	1261.675082	1.5485914	3469.449	3416.54	2.597956	2.55052	0.220643	3.868348	3.859832	1.609273	1.859846	0.721401
61808014	**UDDS hot start #2 Ph 1+2**	08/03/18, 02:47:15 PM	UDDS #3, 2 bag, warm start, split fuel flow measurement, VSpy DAQ clock enabled (CAN 0)	ok	**22**					**7.47**	**0.209**	**35.82**	**0.207**	**36.06**	**98.754**	**13.221**	**-9.783**	**-1.3**	**-43.273**	-117.923	**-5.8**												
Day 4: Additional Cycles																																	
61808015	WLTP, ph 1	08/06/18, 09:57:28 AM	WLTP, 4 bag, cold start, split fuel flow measurement	ok	22	3625	26.509	0.19851	0.016476	1.93	0.081	23.8	0.081	23.9	44.350	22.950	-10.673	-5.523	-21.578	-132.284	-11.166	937.6408937	2.895037	2057.073	1999.196	1.404645	1.353408	0.949625	1.93249	1.914311	2.732706	3.785785	0.796616
61808015	WLTP, ph 2	08/06/18, 09:57:28 AM	WLTP, 4 bag, cold start, split fuel flow measurement	ok	23	3625	26.509	0.19851	0.016476	2.95	0.080	37.0	0.081	36.6	30.602	10.374	-4.938	-1.674	-13.708	-113.947	-4.647	1834.386893	0.6952298	1871.015	1858.097	2.268673	2.270956	0.054349	2.949921	2.948318	-0.15506	-0.10056	0.693486
61808015	WLTP, ph 3	08/06/18, 09:57:28 AM	WLTP, 4 bag, cold start, split fuel flow measurement	ok	24	3625	26.509	0.19851	0.016476	4.39	0.099	44.4	0.099	44.2	31.714	7.216	-3.818	-0.869	-13.624	-107.984	-3.100	1616.882211	2.8396669	1673.694	1627.479	3.230393	3.200391	0.164925	4.394848	4.387612	0.765327	0.937427	0.509716
61808015	WLTP, ph 4	08/06/18, 09:57:28 AM	WLTP, 4 bag, cold start, split fuel flow measurement	ok	25	3625	26.509	0.19851	0.016476	5.13	0.125	41.1	0.126	40.8	25.923	5.052	-1.918	-0.374	-9.190	-102.451	-1.791	1404.580238	3.9957011	1033.1	993.4063	4.878589	4.886903	0.039065	5.130837	5.128833	-0.20956	-0.17014	0.352795
61808016	WLTP, ph 1	08/06/18, 10:46:50 AM	WLTP, 4 bag, hot start, split fuel flow measurement	ok	18	3625	26.509	0.19851	0.016476	1.91	0.070	27.4	0.071	26.8	46.331	24.240	-8.613	-4.506	-21.688	-132.750	-11.347	937.9713582	2.3799871	2046.795	1999.214	1.388044	1.353422	-0.15596	1.911325	1.914311	2.646358	2.558089	0.796616
61808016	WLTP, ph 2	08/06/18, 10:46:50 AM	WLTP, 4 bag, hot start, split fuel flow measurement	ok	22	3625	26.509	0.19851	0.016476	2.93	0.077	37.9	0.080	36.6	30.986	10.560	-2.471	-0.842	-13.094	-108.880	-4.462	1835.700416	0.0374036	1858.813	1858.118	2.267112	2.270976	-0.47843	2.934213	2.948319	0.308806	-0.17014	0.693486
61808016	WLTP, ph 3	08/06/18, 10:46:50 AM	WLTP, 4 bag, hot start, split fuel flow measurement	ok	24	3625	26.509	0.19851	0.016476	4.37	0.094	46.4	0.097	45.1	32.427	7.420	-1.700	-0.389	-13.357	-105.731	-3.056	1616.294661	1.9096003	1658.563	1627.484	3.193278	3.200395	-0.39116	4.370449	4.387612	0.169162	-0.22237	0.509717
61808016	WLTP, ph 4	08/06/18, 10:46:50 AM	WLTP, 4 bag, hot start, split fuel flow measurement	ok	24	3625	26.509	0.19851	0.016476	5.11	0.122	41.9	0.124	41.4	25.986	5.083	-0.920	-0.180	-8.994	-100.876	-1.759	1406.365658	3.6862337	1030.043	993.4233	4.841275	4.886946	-0.31928	5.112458	5.128834	-0.62107	-0.93455	0.3528
61808017	Hwyx2, ph 1	08/06/18, 12:51:25 PM	Hwyx2, 2 bag, cool start, split fuel flow measurement	ok	24	3625	26.509	0.19851	0.016476	10.23	0.189	54.1	0.189	54.2	66.668	6.517	-20.248	-1.979	-33.791	-159.026	-3.303	1648.406524	1.7869267	1330.214	1306.862	6.55757	6.591012	-0.25991	10.23002	10.25668	-0.24874	-0.50739	0.293512
61808017	Hwyx2, ph 2	08/06/18, 12:51:25 PM	Hwyx2, 2 bag, cool start, split fuel flow measurement	ok	25	3625	26.509	0.19851	0.016476	10.23	0.180	56.7	0.180	56.8	51.559	5.039	-3.708	-0.362	-22.184	-104.492	-2.168	1648.813159	4.0306146	1359.534	1306.859	6.554984	6.591004	-0.24227	10.23183	10.25668	-0.3059	-0.5465	0.293512
61808018	US06x2, ph 1	08/06/18, 01:31:54 PM	US06x2, 4 (split) bag, hot start, split fuel flow measurement	ok	22	3625	26.509	0.19851	0.016476	1.78	0.089	19.9	0.091	19.5	24.150	13.562	-4.586	-2.575	-9.255	-143.279	-5.197	4754.370074	-0.9536651	2436.309	2459.767	2.690972	2.71312	0.4855	1.780709	1.772105	-1.31255	-0.81633	0.821826
61808018	US06x2, ph 2	08/06/18, 01:31:54 PM	US06x2, 4 (split) bag, hot start, split fuel flow measurement	ok	26	3625	26.509	0.19851	0.016476	6.24	0.159	39.1	0.160	39.0	32.120	5.146	-3.889	-0.623	-11.835	-116.811	-1.896	10056.45189	1.2978632	1154.787	1139.991	5.795925	5.839918	0.101958	6.241215	6.234858	-0.86177	-0.75332	0.361721
61808018	US06x2, ph 1+2	08/06/18, 01:31:54 PM	US06x2, 4 (split) bag, hot start, split fuel flow measurement	ok	**24**					**8.02**	**0.249**	**32.24**	**0.251**	**31.93**	**56.270**	**7.015**	**-8.475**	**-1.1**	**-21.089**	-130.045	**-2.6**												
61808018	US06x2, ph 3	08/06/18, 01:31:54 PM	US06x2, 4 (split) bag, hot start, split fuel flow measurement	ok	22	3625	26.509	0.19851	0.016476	1.78	0.088	20.2	0.090	19.8	19.909	11.203	-0.643	-0.362	-6.147	-94.633	-3.459	4741.926811	-0.0451922	2458.644	2459.756	2.707665	2.713108	0.286181	1.777177	1.772106	-0.48778	-0.20062	0.821825
61808018	US06x2, ph 4	08/06/18, 01:31:54 PM	US06x2, 4 (split) bag, hot start, split fuel flow measurement	ok	25	3625	26.509	0.19851	0.016476	6.24	0.151	41.4	0.152	41.2	27.899	4.471	-1.017	-0.163	-9.727	-95.806	-1.559	10055.89269	-2.1884859	1115.038	1139.987	5.72843	5.839922	0.07372	6.239455	6.234859	-2.02145	-1.90914	0.36172
61808018	US06x2, ph 3+4	08/06/18, 01:31:54 PM	US06x2, 4 (split) bag, hot start, split fuel flow measurement	ok	**24**					**8.02**	**0.239**	**33.57**	**0.241**	**33.25**	**47.808**	**5.964**	**-1.661**	**-0.2**	**-15.874**	-95.220	**-2.0**												
61808019	NEDCx2, ph 1	08/06/18, 02:14:22 PM	NEDCx2, 4 bag, hot start, split fuel flow measurement	ok	18	3625	26.509	0.19851	0.016476	2.55	0.086	29.7	0.084	30.4	63.026	24.701	-12.093	-4.740	-29.512	-136.355	-11.567	361.8785227	5.2589714	2268.802	2155.448	1.548389	1.526956	0.97518	2.551461	2.52682	0.422513	1.403624	0.632322
61808019	NEDCx2, ph 2	08/06/18, 02:14:22 PM	NEDCx2, 4 bag, hot start, split fuel flow measurement	ok	24	3625	26.509	0.19851	0.016476	4.33	0.090	48.2	0.090	48.1	27.990	6.463	-1.030	-0.238	-11.584	-104.414	-2.675	395.7516234	5.8220007	823.0414	777.7602	3.216471	3.215793	0.204222	4.331015	4.322188	-0.1831	0.021087	0.336361
61808019	NEDCx2, ph 1+2	08/06/18, 02:14:22 PM	NEDCx2, 4 bag, hot start, split fuel flow measurement	ok	**21**					**6.88**	**0.176**	**39.14**	**0.174**	**39.54**	**91.016**	**13.224**	**-13.123**	**-1.9**	**-41.096**	-120.384	**-6.0**												
61808019	NEDCx2, ph 3	08/06/18, 02:14:22 PM	NEDCx2, 4 bag, hot start, split fuel flow measurement	ok	20	3625	26.509	0.19851	0.016476	2.55	0.084	30.3	0.082	31.0	51.416	20.146	-1.756	-0.688	-21.564	-99.824	-8.449	362.0561194	6.9848062	2306.002	2155.448	1.561263	1.526953	1.003792	2.552184	2.52682	1.215871	2.246983	0.632324
61808019	NEDCx2, ph 4	08/06/18, 02:14:22 PM	NEDCx2, 4 bag, hot start, split fuel flow measurement	ok	22	3625	26.509	0.19851	0.016476	4.33	0.090	48.3	0.090	48.3	28.290	6.534	-0.912	-0.211	-11.584	-104.314	-2.676	395.7509048	6.5004913	828.3184	777.7602	3.210425	3.215791	0.168195	4.329458	4.322188	-0.33561	-0.16686	0.336361
61808019	NEDCx2, ph 3+4	08/06/18, 02:14:22 PM	NEDCx2, 4 bag, hot start, split fuel flow measurement	ok	**21**					**6.88**	**0.174**	**39.60**	**0.172**	**40.02**	**79.705**	**11.582**	**-2.668**	**-0.4**	**-33.148**	-102.069	**-4.8**												

											Liquid Fuel usage											SAE J2951 Metrics											
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]	Cycle Fuel Consumed [gal] (Emiss Bag)	Cycle Fuel Economy [mpg] (Emiss Bag)	Fuel used modal [gal]	Fuel Economy Modal [mpg]	Alternator Out (200A) Δ [Wh]	Alternator Out (200A) Energy consumption [Wh/mi]	12V Batt (Pos) Δ WP2 [Wh]	12V Batt (Pos) Δ WP2 [Wh/mi]	12V Batt (Neg) (200A) Δ [Wh]	12V Batt (Neg) (200A) Average Power P1 [W]	12V Batt (Neg) (200A) Energy consumption [Wh/mi]	APCtime	ASCR	ASC_d	ASC_t	CE_d	CE_t	DR	D_d	D_t	EER	ER	IWR
Day 5, Alternate Cycles and Transmission Mapping																																	
61808020	LA92x2	08/07/18, 08:13:26 AM	LA92x2, 2 bag, hot start, split fuel flow measurement	ok	20	3625	26.509	0.19851	0.016476	9.80	0.324	30.3	0.323	30.4	93.695	9.564	-4.594	-0.469	-36.852	-92.587	-3.762	3131.356468	1.3892873	7383.334	7282.164	9.035962	8.997608	-0.20201	9.796159	9.815988	0.625604	0.426265	0.653176
61808020	LA92x2	08/07/18, 08:13:26 AM	LA92x2, 2 bag, hot start, split fuel flow measurement	ok	16	3625	26.509	0.19851	0.016476	9.83	0.308	31.9	0.305	32.2	98.577	10.030	-2.917	-0.297	-38.006	-93.442	-3.867	3067.263277	0.8249944	7342.21	7282.133	9.040727	8.997508	0.119776	9.827745	9.815988	0.358842	0.480342	0.653183
61808021	JC08x2	08/07/18, 09:20:49 AM	JC08x2, 2 bag, hot start, split fuel flow measurement	ok	22	3625	26.509	0.19851	0.016476	5.05	0.155	32.7	0.151	33.4	89.985	17.814	-12.039	-2.383	-40.567	-121.179	-8.031	1129.881107	1.4000266	3712.457	3661.199	3.50153	3.479829	-0.37022	5.051219	5.069989	0.987683	0.623623	0.685034
61808021	JC08x2	08/07/18, 09:20:49 AM	JC08x2, 2 bag, hot start, split fuel flow measurement	ok	21	3625	26.509	0.19851	0.016476	5.04	0.153	32.9	0.150	33.7	80.666	16.003	-2.616	-0.519	-33.417	-99.414	-6.629	1129.99021	0.9476986	3695.866	3661.169	3.48203	3.479817	-0.57765	5.040701	5.069988	0.640864	0.063617	0.685032
61808022	Passing Manuevers @ 0, 3 & 6% grade	08/07/18, 10:20:03 AM	Passing Manuevers, hot start, split fuel flow measurement, bags OFF	ok	25	3625	26.509	0.19851	0.016476	10.01			0.528	19.0	75.538	7.545	-5.613	-0.561	-24.122	-107.456	-2.409	13160.92593	13.925761	3819.703	3352.8	11.55239	11.76804	-2.36969	10.01199	10.255	0.547241	-1.83247	0.47934
61808023	WOTs x5	08/07/18, 11:04:45 AM	WOTsx5, hot start, split fuel flow measurement, bags OFF	ok	23	3625	26.509	0.19851	0.016476	7.96			0.255	31.2	49.495	6.218	-6.740	-0.847	-19.319	-117.895	-2.427												
61808024	25% grade test,	08/07/18, 11:20:39 AM	25% Grade, max MPH, hot start, split fuel flow measurement, bags OFF	ok	18	3625	26.509	0.19851	0.016476	2.35			0.220	10.7	21.098	8.965	-1.429	-0.607	-6.672	-100.829	-2.835												
61808025	Transmission mapping, constant pedal tip ins	08/07/18, 01:54:06 PM	Transmission shift mapping at constant pedal tip in, split fuel flow measurement, bags OFF	ok, disregard bags	-63	3625	26.509	0.19851	0.016476	45.75	0.166	275.0	1.036	44.2	336.655	7.359	-31.073	-0.679	-141.092	295.866	-3.084												
Day 6, More Mapping																																	
61808026	US06x2, ph 1	08/08/18, 08:24:32 AM	US06 cold start as warmup, split fuel flow measurement, bags OFF	ok	24	3625	26.509	0.19851	0.016476	8.06			0.264	30.5	49.390	6.124	-5.091	-0.631	-17.702	-106.733	-2.195	7992.307249	-0.0344518	3598.764	3600.004	8.643535	8.555464	0.710744	8.06487	8.007954	0.315426	1.029417	0.507623
61808026	US06x2, ph 2	08/08/18, 08:24:32 AM	US06 cold start as warmup, split fuel flow measurement, bags OFF	ok	24	3625	26.509	0.19851	0.016476	8.07			0.246	32.8	45.728	5.670	-1.423	-0.176	-14.839	-89.025	-1.840	7981.442732	0.1993883	3607.169	3599.991	8.66259	8.55543	0.716929	8.065364	8.007952	0.528991	1.252546	0.507622
61808027	Transmission mapping with ramps	08/08/18, 09:14:30 AM	Transmission shift mapping with ramps	ok, 5-50% X5%, 50-100% x 10%, varying	24	3625	26.509	0.19851	0.016476	36.63			1.306	28.0	233.262	6.368	-7.611	-0.208	-76.425	-89.463	-2.086												
61808028	CAVs cycles, ph 1	08/08/18, 01:02:26 PM	CAVs ACC cycles, 3 bag	ok	25	3625	26.509	0.19851	0.016476	20.93	0.396	52.9	0.401	52.2	106.958	5.109	-17.240	-0.824	-47.145	-117.255	-2.252	1743.268954	13.799084	2846.128	2501.012	14.37644	13.80772	0.7377	20.93371	20.78042	3.247404	4.11886	0.304474
61808028	CAVs cycles, ph 2	08/08/18, 01:02:26 PM	CAVs ACC cycles, 3 bag	ok	24	3625	26.509	0.19851	0.016476	20.93	0.381	54.9	0.387	54.1	97.054	4.636	-3.230	-0.154	-38.548	-95.979	-1.841	1744.292894	14.058462	2852.62	2501.016	14.39294	13.80772	0.737705	20.93372	20.78042	3.35827	4.238308	0.304475
61808028	CAVs cycles, ph 3	08/08/18, 01:02:26 PM	CAVs ACC cycles, 3 bag	ok	25	3625	26.509	0.19851	0.016476	20.93	0.385	54.4	0.387	54.1	97.038	4.636	-3.130	-0.150	-38.479	-95.843	-1.838	1744.294986	13.973204	2850.489	2501.017	14.38815	13.80772	0.73581	20.93332	20.78042	3.327903	4.203605	0.304475
Day 7, Hot Testing 95F with Solar																																	
61808029	UDDSx2, cold start Ph 1	08/09/18, 08:31:23 AM	UDDSx2, 4 bag (FTP), cold start in hot (95°F) test cell, HVAC-AUTO-72°F, solar load 850W/m^2 at base of windshield, Solar on 30 minutes prior to first cycle	ok	37	3625	26.509	0.19851	0.016476	3.59	0.116	30.9	0.117	30.8	44.231	12.329	-2.549	-0.710	-17.785	-126.856	-4.958	2049.847141	0.8275351	2065.97	2049.014	2.749081	2.724702	-0.09999	3.587395	3.590986	0.985897	0.894724	0.602312
61808029	UDDSx2 cold start Ph 2	08/09/18, 08:31:23 AM	UDDSx2, 4 bag (FTP), cold start in hot (95°F) test cell, HVAC-AUTO-72°F, solar load 850W/m^2 at base of windshield, Solar on 30 minutes prior to first cycle	ok	35	3625	26.509	0.19851	0.016476	3.85	0.125	30.8	0.129	30.0	66.769	17.324	-2.155	-0.559	-26.887	-110.934	-6.976	1250.633028	1.7911989	3477.735	3416.538	2.610123	2.550559	-0.14993	3.854052	3.859839	2.428561	2.335346	0.721389
61808029	**UDDSx2 cold start Ph 1+2**	08/09/18, 08:31:23 AM	UDDSx2, 4 bag (FTP), cold start in hot (95°F) test cell, HVAC-AUTO-72°F, solar load 850W/m^2 at base of windshield, Solar on 30 minutes prior to first cycle	ok	**36**					**7.44**	**0.241**	**30.86**	**0.245**	**30.34**	**110.999**	**14.916**	**-4.704**	**-0.6**	**-44.673**	-118.895	**-6.0**												
61808029	UDDSx2 hot start Ph 3	08/09/18, 08:31:23 AM	UDDSx2, 4 bag (FTP), cold start in hot (95°F) test cell, HVAC-AUTO-72°F, solar load 850W/m^2 at base of windshield, Solar on 30 minutes prior to first cycle	ok	37	3625	26.509	0.19851	0.016476	3.62	0.103	35.2	0.103	35.0	50.332	13.902	-3.370	-0.931	-19.522	-139.242	-5.392	2050.277585	2.8219267	2106.833	2049.011	2.785249	2.724691	0.824951	3.620609	3.590985	1.367217	2.222555	0.602313
61808029	UDDSx2 hot start Ph 4	08/09/18, 08:31:23 AM	UDDSx2, 4 bag (FTP), cold start in hot (95°F) test cell, HVAC-AUTO-72°F, solar load 850W/m^2 at base of windshield, Solar on 30 minutes prior to first cycle	ok	34	3625	26.509	0.19851	0.016476	3.90	0.131	29.8	0.129	30.4	70.509	18.068	-2.130	-0.546	-28.412	-117.758	-7.280	1250.735359	3.3488181	3530.959	3416.545	2.683159	2.550557	1.103825	3.902447	3.859841	3.89273	5.198936	0.721391
61808029	**UDDSx2 hot start Ph 3+4**	08/09/18, 08:31:23 AM	UDDSx2, 4 bag (FTP), cold start in hot (95°F) test cell, HVAC-AUTO-72°F, solar load 850W/m^2 at base of windshield, Solar on 30 minutes prior to first cycle	ok	**35**					**7.52**	**0.234**	**32.15**	**0.232**	**32.43**	**120.841**	**16.063**	**-5.500**	**-0.7**	**-47.934**	-128.500	**-6.4**												
61808031	SC03x2 ph 1	08/09/18, 10:35:16 AM	SC03x4, 4 bag, hot start in hot (95°F) test cell, HVAC-AUTO-72°F, solar load 850W/m^2 at base of windshield, HVAC; AUTO 72, AUTO 72, MAX_OFF	ok	36	3625	26.509	0.19851	0.016476	3.57	0.121	29.4	0.122	29.2	70.036	19.637	-4.395	-1.232	-27.199	-162.723	-7.626	2004.255129	0.4026709	2542.073	2531.878	2.795636	2.79544	-0.35962	3.566603	3.579476	0.366602	0.007012	0.699975
61808031	SC03x2 ph 2	08/09/18, 10:35:16 AM	SC03x4, 4 bag, hot start in hot (95°F) test cell, HVAC-AUTO-72°F, solar load 850W/m^2 at base of windshield, HVAC; AUTO 72, AUTO 72, MAX_OFF	ok	36	3625	26.509	0.19851	0.016476	3.60	0.119	30.2	0.120	29.9	66.977	18.625	-3.982	-1.107	-25.599	-153.365	-7.119	1999.605417	0.6468195	2548.243	2531.867	2.840029	2.795434	0.460355	3.595954	3.579476	1.117095	1.595271	0.699975
61808031	SC03x2 ph 3	08/09/18, 10:35:16 AM	SC03x4, 4 bag, hot start in hot (95°F) test cell, HVAC-AUTO-72°F, solar load 850W/m^2 at base of windshield, HVAC; AUTO 72, AUTO 72, MAX_OFF	ok	36	3625	26.509	0.19851	0.016476	3.60	0.134	26.9	0.134	26.8	114.113	31.722	-3.755	-1.044	-44.650	-265.590	-12.412	2003.675441	1.271145	2564.057	2531.873	2.851458	2.795426	0.49671	3.597255	3.579475	1.478094	2.004432	0.69998
61808031	SC03x2 ph 4	08/09/18, 10:35:16 AM	SC03x4, 4 bag, hot start in hot (95°F) test cell, HVAC-AUTO-72°F, solar load 850W/m^2 at base of windshield, HVAC; AUTO 72, AUTO 72, MAX_OFF	ok	36	3625	26.509	0.19851	0.016476	3.60	0.103	34.9	0.104	34.7	50.890	14.143	-4.072	-1.132	-19.377	-114.731	-5.385	1997.164512	1.8362292	2578.368	2531.877	2.846196	2.795408	0.524793	3.59826	3.579475	1.268997	1.816845	0.699985
61808032	US06x2, ph 1	08/09/18, 12:07:36 PM	US06x2, 2 bag, hot start in hot (95°F) test cell, HVAC-AUTO-72°F, solar load 850W/m^2 at base of windshield	ok	40	3625	26.509	0.19851	0.016476	7.99	0.274	29.2	0.274	29.2	93.006	11.638	-5.052	-0.632	-33.804	-203.214	-4.230	7992.194989	-0.6337477	3577.201	3600.016	8.470327	8.555478	-0.20613	7.991443	8.00795	-0.79709	-0.99528	0.507626
61808032	US06x2, ph 2	08/09/18, 12:07:36 PM	US06x2, 2 bag, hot start in hot (95°F) test cell, HVAC-AUTO-72°F, solar load 850W/m^2 at base of windshield	ok	40	3625	26.509	0.19851	0.016476	8.00	0.258	31.0	0.259	31.0	64.582	8.068	-1.783	-0.223	-21.657	-130.076	-2.706	7981.725449	-0.0081563	3599.712	3600.006	8.547593	8.555422	-0.04186	8.004601	8.007953	-0.04969	-0.0915	0.507626
61808033	UDDS prep for cold	08/09/18, 02:46:34 PM	UDDS, 1 bag prep for Cold testing at 20°F test cell	ok	24	3625	26.509	0.19851	0.016476	7.44	0.216	34.5	0.211	35.2	98.066	13.184	-15.808	-2.125	-43.867	-114.803	-5.898	1556.556207	1.3440756	5539	5465.539	5.361041	5.275154	-0.17233	7.437973	7.450812	1.771624	1.62814	0.659897
Day 8, Cold Testing 20F																																	
61808034	UDDS cold start Ph 1	08/10/18, 07:53:56 AM	UDDSx2, 4 bag (FTP/Cold CO), Cold testing at 20°F test cell, HVAC-AUTO-72°F	ok	-5	3625	26.509	0.19851	0.016476	3.59	0.160	22.4	0.161	22.3	0.210	0.058	-0.030	-0.008	-0.076	-0.848	-0.021	2049.982845	1.7361554	2084.59	2049.016	2.751157	2.724707	-0.024	3.590124	3.590986	0.985192	0.970759	0.602311
61808034	UDDS cold start Ph 2	08/10/18, 07:53:56 AM	UDDSx2, 4 bag (FTP/Cold CO), Cold testing at 20°F test cell, HVAC-AUTO-72°F	ok	-7	3625	26.509	0.19851	0.016476	3.86	0.139	27.8	0.136	28.3	0.030	0.008	0.000	0.000	-0.010	-0.032	-0.003	1250.546956	2.8236575	3512.997	3416.526	2.626056	2.550549	-0.09274	3.856259	3.859839	2.965347	2.960389	0.721389
61808034	**UDDS cold start Ph 1+2**	08/10/18, 07:53:56 AM	UDDSx2, 4 bag (FTP/Cold CO), Cold testing at 20°F test cell, HVAC-AUTO-72°F	ok	**-6**					**7.45**	**0.299**	**24.90**	**0.297**	**25.05**	**0.240**	**0.032**	**-0.030**	**0.0**	**-0.086**	-0.440	**0.0**												
61808034	UDDS hot start Ph 1	08/10/18, 07:53:56 AM	UDDSx2, 4 bag (FTP/Cold CO), Cold testing at 20°F test cell, HVAC-AUTO-72°F	ok	-6	3625	26.509	0.19851	0.016476	3.61	0.115	31.4	0.116	31.0	2.288	0.634	-0.140	-0.039	-0.845	-5.844	-0.234	2050.461914	2.1953068	2094.001	2049.019	2.759625	2.7247	0.458159	3.607438	3.590986	0.813213	1.281795	0.602313
61808034	UDDS hot start Ph 2	08/10/18, 07:53:56 AM	UDDSx2, 4 bag (FTP/Cold CO), Cold testing at 20°F test cell, HVAC-AUTO-72°F	ok	-7	3625	26.509	0.19851	0.016476	3.89	0.127	30.6	0.124	31.3	24.991	6.417	-0.990	-0.254	-9.296	-38.320	-2.387	1250.724615	2.8380296	3513.49	3416.528	2.61988	2.550548	0.895344	3.8944	3.859841	1.774721	2.718307	0.72139
61808034	**UDDS hot start Ph 1+2**	08/10/18, 07:53:56 AM	UDDSx2, 4 bag (FTP/Cold CO), Cold testing at 20°F test cell, HVAC-AUTO-72°F	ok	**-6**					**7.50**	**0.242**	**31.01**	**0.241**	**31.15**	**27.278**	**3.636**	**-1.130**	**-0.2**	**-10.141**	-22.082	**-1.4**												
61808035	UDDS hot start #2 Ph 1	08/10/18, 09:11:45 AM	UDDS #3, warm start, Cold testing at 20°F test cell, HVAC-AUTO-72°F	ok	-6	3625	26.509	0.19851	0.016476	3.61	0.110	32.6	0.111	32.6	27.583	7.650	-1.860	-0.516	-9.471	-67.139	-2.627	2061.611655	1.4446879	2078.613	2049.011	2.748509	2.724648	0.405653	3.605548	3.590981	0.466005	0.875739	0.602322
61808035	UDDS hot start #2 Ph 2	08/10/18, 09:11:45 AM	UDDS #3, warm start, Cold testing at 20°F test cell, HVAC-AUTO-72°F	ok	-7	3625	26.509	0.19851	0.016476	3.88	0.125	31.1	0.122	31.8	60.953	15.699	-2.710	-0.698	-22.763	-94.157	-5.863	1261.656797	2.2467964	3493.289	3416.536	2.583379	2.550509	0.591684	3.882669	3.859831	0.688204	1.288757	0.721402
61808035	**UDDS hot start #2 Ph 1+2**	08/10/18, 09:11:45 AM	UDDS #3, warm start, Cold testing at 20°F test cell, HVAC-AUTO-72°F	ok						7.49	0.235	31.9	0.233	32.2									1.9460892	5571.912	5465.547	5.331888	5.275157	0.502024	7.488217	7.450812	0.567305	1.075431	0.659896
61808036	HWY #1	08/10/18, 09:48:02 AM	Hwyx3, 3 bag, warm start, Cold testing at 20°F test cell, HVAC-AUTO-72°F	ok	-4	3625	26.509	0.19851	0.016476	10.25	0.210	48.8	0.210	48.7	55.452	5.412	-3.940	-0.385	-21.355	-100.190	-2.084	1647.742027	3.116431	1347.589	1306.861	6.590541	6.591012	-0.10716	10.24569	10.25668	0.100029	-0.00714	0.293512
61808036	HWY #2	08/10/18, 09:48:02 AM	Hwyx3, 3 bag, warm start, Cold testing at 20°F test cell, HVAC-AUTO-72°F	ok	-5	3625	26.509	0.19851	0.016476	10.24	0.207	49.4	0.205	49.8	50.788	4.962	-1.878	-0.183	-18.816	-88.178	-1.838	1646.631683	2.633948	1341.281	1306.859	6.571174	6.591011	-0.19824	10.23635	10.25668	-0.10304	-0.30097	0.293511
61808036	HWY #3	08/10/18, 09:48:02 AM	Hwyx3, 3 bag, warm start, Cold testing at 20°F test cell, HVAC-AUTO-72°F	ok	-5	3625	26.509	0.19851	0.016476	10.25	0.206	49.8	0.204	50.2	33.528	3.270	-1.130	-0.110	-12.462	-58.095	-1.215	1676.741821	4.132859	1360.869	1306.858	6.569042	6.594079	-0.14917	10.25249	10.26781	-0.23139	-0.37968	0.293375
61808037	US06x2 Ph 1	08/10/18, 10:46:48 AM	US06x2, 4 bag, warm start, Cold testing at 20°F test cell, HVAC-AUTO-72°F	ok	-4	3625	26.509	0.19851	0.016476	1.78	0.099	18.1	0.099	18.0	1.464	0.821	-0.160	-0.090	-0.548	-7.865	-0.307	4753.675825	0.0737487	2461.564	2459.75	2.723193	2.713104	0.625599	1.783191	1.772105	-0.25282	0.37184	0.821825
61808037	US06x2 Ph 2	08/10/18, 10:46:48 AM	US06x2, 4 bag, warm start, Cold testing at 20°F test cell, HVAC-AUTO-72°F	ok	2	3625	26.509	0.19851	0.016476	6.25	0.177	35.3	0.177	35.3	5.886	0.942	-0.440	-0.070	-2.082	-19.217	-0.333	10053.43111	-1.2479493	1125.683	1139.908	5.805953	5.839826	0.165824	6.245197	6.234859	-0.7502	-0.58003	0.361692
61808037	US06x2 Ph 1+2	08/10/18, 10:46:48 AM	US06x2, 4 bag, warm start, Cold testing at 20°F test cell, HVAC-AUTO-72°F	ok	**-1**					**8.03**	**0.276**	**29.12**	**0.276**	**29.10**	**7.350**	**0.916**	**-0.600**	**-0.1**	**-2.630**	-13.541	**-0.3**												
61808037	US06x2 Ph 3	08/10/18, 10:46:48 AM	US06x2, 4 bag, warm start, Cold testing at 20°F test cell, HVAC-AUTO-72°F	ok	-5	3625	26.509	0.19851	0.016476	1.78	0.090	19.7	0.090	19.7	1.150	0.646	-0.080	-0.045	-0.410	-6.308	-0.230	4741.104321	0.6523554	2475.783	2459.737	2.731573	2.713101	0.401629	1.779223	1.772105	0.277336	0.680853	0.821825
61808037	US06x2 Ph 4	08/10/18, 10:46:48 AM	US06x2, 4 bag, warm start, Cold testing at 20°F test cell, HVAC-AUTO-72°F	ok	-1	3625	26.509	0.19851	0.016476	6.24	0.169	37.0	0.168	37.1	6.540	1.048	-0.200	-0.032	-2.230	-22.863	-0.357	10053.62852	-1.1105827	1127.262	1139.922	5.781908	5.839836	0.127168	6.242787	6.234858	-1.13033	-0.99195	0.361697
61808037	US06x2 Ph 3+4	08/10/18, 10:46:48 AM	US06x2, 4 bag, warm start, Cold testing at 20°F test cell, HVAC-AUTO-72°F	ok	**-3**					**8.02**	**0.259**	**30.94**	**0.259**	**31.00**	**7.690**	**0.959**	**-0.280**	**0.0**	**-2.640**	-14.586	**-0.3**												
Day 9, Performance Testing																																	
61808038	30 minute idle test	08/13/18, 09:28:38 AM	30 minute idle warmup test	ok	21	3625	26.509	0.19851	0.016476	0.00	0.089	0.0	0.106	0.0																			
61808039	Engine Mapping	08/13/18, 02:00:13 PM	Engine mapping	ok	-526	3625	26.509	0.19851	0.016476	76.00			3.038	25.0	544.960	7.171	-20.244	-0.266	-147.934	1776.840	-1.947												
Day 10, Steady State Speeds, fuel swap																																	
61808040	Steady State Speeds at 95F 55mph warmup	08/14/18, 09:21:15 AM	SSS, 0-80-0, 30 second hold at 0, 3 & 6% grade, 95°F test cell with HVAC ON AUTO 72°F, with 10 min 55MPH warmup for HVAC stabilization, Bag collection OFF	ok	39	3625	26.509	0.19851	0.016476	9.47			0.203	46.6	91.714	9.688	-3.192	-0.337	-35.663	-198.757	-3.767	179.062885	11.879864	550.8679	492.3745	6.282896	6.293046	-0.05285	9.467227	9.472234	-0.1086	-0.16128	0.080163
61808040	Steady State Speeds at 95F 0% Grade	08/14/18, 09:21:15 AM	SSS, 0-80-0, 30 second hold at 0, 3 & 6% grade, 95°F test cell with HVAC ON AUTO 72°F, with 10 min 55MPH warmup for HVAC stabilization, Bag collection OFF	ok	38	3625	26.509	0.19851	0.016476	6.23			0.148	42.2	43.735	7.016	-1.428	-0.229	-15.754	-106.955	-2.527	1130.162544	19.663962	855.9132	715.264	4.769255	4.788858	0.187146	6.233838	6.222193	-0.59894	-0.40934	0.222873
61808040	Steady State Speeds at 95F 3% Grade	08/14/18, 09:21:15 AM	SSS, 0-80-0, 30 second hold at 0, 3 & 6% grade, 95°F test cell with HVAC ON AUTO 72°F, with 10 min 55MPH warmup for HVAC stabilization, Bag collection OFF	ok	38	3625	26.509	0.19851	0.016476	6.22			0.246	25.3	51.232	8.231	-1.410	-0.227	-16.210	-110.056	-2.605	1130.551308	14.105498	816.1555	715.264	4.77101	4.788859	0.027611	6.223911	6.222193	-0.40183	-0.37272	0.222873
61808040	Steady State Speeds at 95F 6% Grade	08/14/18, 09:21:15 AM	SSS, 0-80-0, 30 second hold at 0, 3 & 6% grade, 95°F test cell with HVAC ON AUTO 72°F, with 10 min 55MPH warmup for HVAC stabilization, Bag collection OFF	ok	38	3625	26.509	0.19851	0.016476	6.22			0.357	17.4	61.675	9.912	-1.362	-0.219	-16.822	-113.854	-2.703	1130.550784	22.023871	872.7928	715.264	4.826615	4.788858	0.004222	6.222456	6.222193	0.778086	0.788443	0.222873
Swap to High Octane Fuel (EPA Tier II EEE HF0437)																																	
61808041	Octane Adjuster Cycle	08/14/18, 02:49:16 PM	Switch to HF0437, EEE, Tier II, 92 Octane Fuel, Octane adjuster cycle, no fuel scales	ok, no bag data, no fuel scales	27	3625	26.509	0.19851	0.016476	14.33			0.437	32.8	99.549	6.945	-19.979	-1.394	-38.967	-125.396	-2.718	5307.941382	0.6718565	6017.704	5977.544	14.66282	14.67826	0.161739	14.33452	14.31138	-0.26724	-0.10522	0.457219
Day 11, High Octane fuel testing																																	
61808042	Octane Adjuster Cycle 2	08/16/18, 08:34:31 AM	SSS 60 MPH, 1 hour for fuel scale de-aerate and vehicle warmup	ok, fuel scales look good, vehicle warm	21	3625	26.509	0.19851	0.016476	25.51			0.576	44.3	111.650	4.376	-3.870	-0.152	-38.690	-72.822	-1.516	2522.738526	788.53543	4766.531	536.448	21.22415	22.83508	-19.739	25.51149	31.78567	13.64713	-7.05462	0.026291
61808043	Steady State Speeds 0-80-0 1 min hold	08/16/18, 09:23:40 AM	HF0437 Fuel Testing, SSS, 0-80-0, 1 minute hold, warm start, 1 bag, bags OFF, modal ON	ok	25	3625	26.509	0.19851	0.016476	11.56			0.232	49.8	72.295	6.251	-4.659	-0.403	-27.666	-101.534	-2.392	612.3900193	21.766353	870.9509	715.264	8.200808	8.253193	0.078271	11.56458	11.55553	-0.71755	-0.63472	0.129321
61808044	WOTs x 5	08/16/18, 09:49:00 AM	HF0437 Fuel Testing, WOTsx5, warm start, 1 bag, bags OFF, modal ON	ok	24	3625	26.509	0.19851	0.016476	3.17			0.229	13.8	25.930	8.181	-1.605	-0.506	-8.408	-81.313	-2.653	0	Inf	3754.677	0	6.682831	0	Inf	3.169629	0	NaN	Inf	NaN
61808045	Passing Manuevers @ 0, 3 &6% grade	08/16/18, 10:13:30 AM	HF0437 Fuel Testing, Passing Manuevers at 0, 3, & 6% grade, warm start, 1 bag, bags OFF, modal ON	ok	26	3625	26.509	0.19851	0.016476	10.02			0.496	20.2	75.471	7.529	-4.120	-0.411	-22.493	-100.391	-2.244	13162.6773	13.964979	3821.018	3352.8	11.56846	11.76809	-2.24722	10.02455	10.255	0.56036	-1.69637	0.479338
61808046	HWY #1	08/16/18, 12:59:17 PM	HF0437 Fuel Testing, Hwyx2, 2 bag with VEHICLE ON coastdown to verify vehicle losses	ok, coastdowns within spec	26	3625	26.509	0.19851	0.016476	10.24	0.189	54.3	0.189	54.3	61.153	5.973	-12.485	-1.219	-26.610	-125.323	-2.599	1648.484329	2.0230969	1333.299	1306.86	6.572966	6.591022	-0.17805	10.23842	10.25668	-0.09615	-0.27394	0.293511
61808046	HWY #2	08/16/18, 12:59:17 PM	HF0437 Fuel Testing, Hwyx2, 2 bag with VEHICLE ON coastdown to verify vehicle losses	ok, coastdowns within spec	26	3625	26.509	0.19851	0.016476	10.24	0.178	57.4	0.179	57.3	47.158	4.605	-1.560	-0.152	-18.594	-87.597	-1.816	1648.872191	2.9125798	1344.928	1306.865	6.582217	6.591015	-0.16283	10.23998	10.25668	0.02938	-0.13349	0.293513
61808047	UDDS prep	08/16/18, 02:11:22 PM	HF0437 Fuel Testing, UDDS prep, 1 bag	ok	23	3625	26.509	0.19851	0.016476	7.49	0.202	37.0	0.205	36.6	92.257	12.313	-6.942	-0.927	-37.164	-97.732	-4.960	1556.679049	2.5148779	5603.014	5465.562	5.410692	5.275167	0.557158	7.492326	7.450813	1.961561	2.569114	0.659898

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]	Liquid Fuel usage: Cycle Fuel Consumed [gal] (Emiss Bag)	Cycle Fuel Economy [mpg] (Emiss Bag)	Fuel used modal [gal]	Fuel Economy Modal [mpg]	Alternator Out (200A) Δ [Wh]	Alternator Out (200A) Energy consumption [Wh/mi]	12V Batt (Pos) Δ WP2 [Wh]	12V Batt (Pos) Δ WP2 [Wh/mi]	12V Batt (Neg) (200A) Δ [Wh]	12V Batt (Neg) (200A) Average Power P1 [W]	12V Batt (Neg) (200A) Energy consumption [Wh/mi]
Day 12, High Octane fuel testing cert testing																					
61808048	UDDS cold start Ph 1	08/17/18, 08:34:44 AM	HF0437 Fuel Testing, UDDSx2, 4 bag (FTP), cold start	ok	25	3625	26.509	0.19851	0.016476	3.60	0.105	34.3	0.105	34.2	26.532	7.369	-2.790	-0.775	-10.994	-78.781	-3.053
61808048	UDDS cold start Ph 2	08/17/18, 08:34:44 AM	HF0437 Fuel Testing, UDDSx2, 4 bag (FTP), cold start	ok	21	3625	26.509	0.19851	0.016476	3.87	0.112	34.5	0.111	34.8	46.568	12.019	-2.142	-0.553	-18.825	-78.015	-4.859
61808048	**UDDS cold start Ph 1+2**	08/17/18, 08:34:44 AM	HF0437 Fuel Testing, UDDSx2, 4 bag (FTP), cold start	ok	**23**					**7.48**	**0.217**	**34.37**	**0.217**	**34.50**	**73.100**	**9.779**	**-4.932**	**-0.7**	**-29.819**	-78.398	**-4.0**
61808048	UDDS hot start Ph 1	08/17/18, 08:34:44 AM	HF0437 Fuel Testing, UDDSx2, 4 bag (FTP), cold start	ok	24	3625	26.509	0.19851	0.016476	3.60	0.090	40.0	0.091	39.6	29.422	8.163	-2.454	-0.681	-12.312	-86.801	-3.416
61808048	UDDS hot start Ph 2	08/17/18, 08:34:44 AM	HF0437 Fuel Testing, UDDSx2, 4 bag (FTP), cold start	ok	22	3625	26.509	0.19851	0.016476	3.88	0.112	34.7	0.110	35.2	47.915	12.342	-1.730	-0.446	-19.325	-80.175	-4.978
61808048	**UDDS hot start Ph 1+2**	08/17/18, 08:34:44 AM	HF0437 Fuel Testing, UDDSx2, 4 bag (FTP), cold start	ok	**23**					**7.49**	**0.202**	**37.06**	**0.201**	**37.23**	**77.336**	**10.330**	**-4.184**	**-0.6**	**-31.638**	-83.488	**-4.2**
61808049	UDDS hot start #2 Ph 1	08/17/18, 09:52:02 AM	HF0437 Fuel Testing, UDDS #3, 2 bag, hot start	ok	24	3625	26.509	0.19851	0.016476	3.60	0.091	39.3	0.092	39.0	36.369	10.116	-3.967	-1.103	-15.231	-108.678	-4.237
61808049	UDDS hot start #2 Ph 2	08/17/18, 09:52:02 AM	HF0437 Fuel Testing, UDDS #3, 2 bag, hot start	ok	22	3625	26.509	0.19851	0.016476	3.86	0.111	34.7	0.110	35.2	55.548	14.407	-1.716	-0.445	-22.336	-92.168	-5.793
61808049	**UDDS hot start #2 Ph 1+2**	08/17/18, 09:52:02 AM	HF0437 Fuel Testing, UDDS #3, 2 bag, hot start	ok		3625	26.509	0.19851	0.016476	7.45	0.202	36.8	0.202	36.9							
61808050	US06x2 Ph 1	08/17/18, 10:30:11 AM	HF0437 Fuel Testing, US06x2, 4 bag (split), hot start	ok	24	3625	26.509	0.19851	0.016476	1.78	0.087	20.4	0.087	20.4	19.777	11.130	-2.070	-1.165	-6.678	-102.264	-3.758
61808050	US06x2 Ph 2	08/17/18, 10:30:11 AM	HF0437 Fuel Testing, US06x2, 4 bag (split), hot start	ok	29	3625	26.509	0.19851	0.016476	6.24	0.158	39.5	0.158	39.5	28.806	4.614	-1.038	-0.166	-9.474	-93.293	-1.518
61808050	US06x2 Ph 1+2	08/17/18, 10:30:11 AM	HF0437 Fuel Testing, US06x2, 4 bag (split), hot start	ok	**26**					**8.02**	**0.245**	**32.70**	**0.245**	**32.76**	**48.583**	**6.058**	**-3.108**	**-0.4**	**-16.152**	-97.778	**-2.0**
61808050	US06x2 Ph 3	08/17/18, 10:30:11 AM	HF0437 Fuel Testing, US06x2, 4 bag (split), hot start	ok	24	3625	26.509	0.19851	0.016476	1.78	0.086	20.7	0.086	20.7	15.310	8.583	-0.440	-0.247	-4.810	-74.752	-2.697
61808050	US06x2 Ph 4	08/17/18, 10:30:11 AM	HF0437 Fuel Testing, US06x2, 4 bag (split), hot start	ok	27	3625	26.509	0.19851	0.016476	6.25	0.152	41.1	0.151	41.3	27.148	4.346	-0.730	-0.117	-8.904	-87.570	-1.426
61808050	US06x2 Ph 3+4	08/17/18, 10:30:11 AM	HF0437 Fuel Testing, US06x2, 4 bag (split), hot start	ok	**26**					**8.03**	**0.238**	**33.70**	**0.237**	**33.83**	**42.458**	**5.288**	**-1.170**	**-0.1**	**-13.714**	-81.161	**-1.7**
61808051	Accessory Load Test	08/17/18, 01:24:36 PM	Accessory load test	ok	NaN	3625	26.509	0.19851	0.016476						0.030	#VALUE!	-51.050	#VALUE!	-17.130	NaN	#VALUE!
Certification Style testing- Swap to High Octane Fuel (EPA Tier II EEE HF0437)																					
Day 13, Certification testing prep																					
61811001	HWYx3 w/ coastdowns ph 1	11/14/18, 01:33:38 PM	Hwyx3, 3 bag with coastdown time to re-establish 4WD vehicle losses	ok, Axis camera fault, coastdowns OK except a little less loss than expected based on EOT costdowns	25	3625	26.509	0.19851	0.016476	10.25	0.205	49.9	0.206	49.7	86.628	8.455	0.000	0.000	-36.962	-172.112	-3.608
61811001	HWYx3 w/ coastdowns ph 2	11/14/18, 01:33:38 PM	Hwyx3, 3 bag with coastdown time to re-establish 4WD vehicle losses	ok, Axis camera fault, coastdowns OK except a little less loss than expected based on EOT costdowns	25	3625	26.509	0.19851	0.016476	10.26	0.194	52.9	0.192	53.4	69.963	6.822	0.000	0.000	-20.145	-93.796	-1.964
61811001	HWYx3 w/ coastdowns ph 3	11/14/18, 01:33:38 PM	Hwyx3, 3 bag with coastdown time to re-establish 4WD vehicle losses	ok, Axis camera fault, coastdowns OK except a little less loss than expected based on EOT costdowns	25	3625	26.509	0.19851	0.016476	10.24	0.197	52.1	0.195	52.5	66.755	6.519	0.000	0.000	-14.297	-66.019	-1.396
61811003	UDDS Prep	11/14/18, 03:20:31 PM	UDDS prep, 1 bag, retry after turning pre-collision OFF	ok	21	3625	26.509	0.19851	0.016476	7.48	0.209	35.7	0.211	35.4	118.475	15.841	0.000	0.000	-24.878	-65.396	-3.326
Day 14, Verfication following remount																					
61811004	UDDS cold start Ph 1	11/15/18, 07:48:44 AM	UDDSx2, 2 bag (FTP), cold start, hood down with speed match fan, 4WD mode	ok	23	3625	26.509	0.19851	0.016476	3.58	0.106	33.7	0.107	33.6	36.909	10.297	0.000	0.000	-4.827	-35.075	-1.347
61811004	UDDS cold start Ph 2	11/15/18, 07:48:44 AM	UDDSx2, 2 bag (FTP), cold start, hood down with speed match fan, 4WD mode	ok	21	3625	26.509	0.19851	0.016476	3.86	0.115	33.7	0.113	34.0	54.369	14.098	0.000	0.000	-2.361	-9.519	-0.612
61811004	**UDDS cold start Ph 1+2**	11/15/18, 07:48:44 AM	UDDSx2, 2 bag (FTP), cold start, hood down with speed match fan, 4WD mode	ok	**22**					**7.44**	**0.221**	**33.68**	**0.220**	**33.80**	**91.277**	**12.267**	**0.000**	**0.0**	**-7.188**	-22.297	**-1.0**
61811004	UDDS hot start Ph 1	11/15/18, 07:48:44 AM	UDDSx2, 2 bag (FTP), cold start, hood down with speed match fan, 4WD mode	ok	24	3625	26.509	0.19851	0.016476	3.60	0.092	39.0	0.092	39.0	38.571	10.716	0.000	0.000	-3.164	-22.210	-0.879
61811004	UDDS hot start Ph 2	11/15/18, 07:48:44 AM	UDDSx2, 2 bag (FTP), cold start, hood down with speed match fan, 4WD mode	ok	21	3625	26.509	0.19851	0.016476	3.87	0.114	34.1	0.111	34.8	59.338	15.330	0.000	0.000	-0.810	-3.011	-0.209
61811004	**UDDS hot start Ph 1+2**	11/15/18, 07:48:44 AM	UDDSx2, 2 bag (FTP), cold start, hood down with speed match fan, 4WD mode	ok	**23**					**7.47**	**0.206**	**36.26**	**0.203**	**36.73**	**97.909**	**13.107**	**0.000**	**0.0**	**-3.974**	-12.611	**-0.5**
61811005	UDDS hot start #2 Ph 1	11/15/18, 09:06:50 AM	UDDS, 2 bag, warm start, hood down with speed match fan, 4WD mode	ok	24	3625	26.509	0.19851	0.016476	3.59	0.098	36.5	0.098	36.6	41.791	11.631	0.000	0.000	-5.148	-36.893	-1.433
61811005	UDDS hot start #2 Ph 2	11/15/18, 09:06:50 AM	UDDS, 2 bag, warm start, hood down with speed match fan, 4WD mode	ok	21	3625	26.509	0.19851	0.016476	3.86	0.118	32.7	0.115	33.5	59.906	15.537	0.000	0.000	-1.250	-5.392	-0.324
61811005	**UDDS hot start #2 Ph 1+2**	11/15/18, 09:06:50 AM	UDDS, 2 bag, warm start, hood down with speed match fan, 4WD mode	ok		3625	26.509	0.19851	0.016476	7.45	0.216	34.4	0.213	34.9	**101.697**	**13.653**	**0.000**	**0.0**	**-6.398**	-21.142	**-0.9**
61811006	HWY #1	11/15/18, 09:43:58 AM	Hwyx2, 2 bag, warm start, hood down with speed match fan, 4WD mode	ok	26	3625	26.509	0.19851	0.016476	10.25	0.196	52.2	0.195	52.5	63.477	6.194	0.000	0.000	-5.118	-24.146	-0.499
61811006	HWY #2	11/15/18, 09:43:58 AM	Hwyx2, 2 bag, warm start, hood down with speed match fan, 4WD mode	ok	25	3625	26.509	0.19851	0.016476	10.26	0.191	53.8	0.190	54.0	52.356	5.102	0.000	0.000	-0.330	-1.546	-0.032
61811007	US06x2 Ph 1	11/15/18, 10:28:13 AM	US06x2, 4 bag, warm start, hood down with speed match fan, 4WD mode	ok	22	3625	26.509	0.19851	0.016476	1.78	0.088	20.2	0.088	20.3	24.542	13.798	0.000	0.000	-3.699	-55.460	-2.080
61811007	US06x2 Ph 2	11/15/18, 10:28:13 AM	US06x2, 4 bag, warm start, hood down with speed match fan, 4WD mode	ok	26	3625	26.509	0.19851	0.016476	6.24	0.159	39.3	0.158	39.6	33.511	5.374	0.000	0.000	-3.853	-37.835	-0.618
61811007	US06x2 Ph 1+2	11/15/18, 10:28:13 AM	US06x2, 4 bag, warm start, hood down with speed match fan, 4WD mode	ok	**24**					**8.01**	**0.247**	**32.47**	**0.245**	**32.66**	**58.053**	**7.243**	**0.000**	**0.0**	**-7.553**	-46.648	**-0.9**
61811007	US06x2 Ph 3	11/15/18, 10:28:13 AM	US06x2, 4 bag, warm start, hood down with speed match fan, 4WD mode	ok	22	3625	26.509	0.19851	0.016476	1.78	0.087	20.3	0.087	20.4	20.433	11.502	0.000	0.000	-0.230	-3.956	-0.129
61811007	US06x2 Ph 4	11/15/18, 10:28:13 AM	US06x2, 4 bag, warm start, hood down with speed match fan, 4WD mode	ok	26	3625	26.509	0.19851	0.016476	6.24	0.157	39.7	0.156	39.9	29.223	4.686	0.000	0.000	-0.240	-2.431	-0.038
61811007	US06x2 Ph 3+4	11/15/18, 10:28:13 AM	US06x2, 4 bag, warm start, hood down with speed match fan, 4WD mode	ok	**24**					**8.01**	**0.244**	**32.80**	**0.243**	**32.93**	**49.656**	**6.197**	**0.000**	**0.0**	**-0.470**	-3.194	**-0.1**
61811009	HWY #1	11/15/18, 01:49:50 PM	HWYx2, 2 bag w coast down, hood up with C speed fan, 2WD mode to establish losses for 2WD EPA style test comparison, Dyno sets changed during first Hwy from ANL 4WD to EPA-2WD of A=8.992 / B=.01874 / C=.017762	ok	23	3625	26.509	0.19851	0.016476	10.14	0.188	54.0	0.188	53.9	79.954	7.882	0.000	0.000	-5.808	-27.345	-0.573
61811009	HWY #2	11/15/18, 01:49:50 PM	HWYx2, 2 bag w coast down, hood up with C speed fan, 2WD mode to establish losses for 2WD EPA style test comparison, Dyno sets changed during first Hwy from ANL 4WD to EPA-2WD of A=8.992 / B=.01874 / C=.017762	ok	22	3625	26.509	0.19851	0.016476	10.27	0.190	54.0	0.189	54.4	81.606	7.948	0.000	0.000	-0.810	-4.042	-0.079
61811010	UDDS Prep	11/15/18, 02:43:29 PM	UDDS prep, 1 bag, hood up with C speed fan, 2WD mode using new dyno sets from previous coastdown (EPA Cert Style)		23	3625	26.509	0.19851	0.016476	7.48	0.203	36.8	0.206	36.4	120.451	16.093	0.000	0.000	-6.920	-18.159	-0.925
Day 15, Certification style testing																					
61811011	UDDS cold start Ph 1	11/16/18, 07:51:48 AM	UDDSx2, 4 bag, cold start (FTP), hood up with C speed fan, 2WD mode using new dyno sets from previous coastdown (EPA Cert Style)	ok	22	3625	26.509	0.19851	0.016476	3.58	0.104	34.5	0.104	34.4	34.764	9.700	0.000	0.000	-2.690	-19.266	-0.751
61811011	UDDS cold start Ph 2	11/16/18, 07:51:48 AM	UDDSx2, 4 bag, cold start (FTP), hood up with C speed fan, 2WD mode using new dyno sets from previous coastdown (EPA Cert Style)	ok	22	3625	26.509	0.19851	0.016476	3.84	0.112	34.3	0.112	34.5	52.089	13.548	0.000	0.000	-0.002	-0.023	0.000
61811011	**UDDS cold start Ph 1+2**	11/16/18, 07:51:48 AM	UDDSx2, 4 bag, cold start (FTP), hood up with C speed fan, 2WD mode using new dyno sets from previous coastdown (EPA Cert Style)	ok	**22**					**7.43**	**0.216**	**34.37**	**0.216**	**34.41**	**86.853**	**11.692**	**0.000**	**0.0**	**-2.691**	-9.645	**-0.4**
61811011	UDDS hot start Ph 1	11/16/18, 07:51:48 AM	UDDSx2, 4 bag, cold start (FTP), hood up with C speed fan, 2WD mode using new dyno sets from previous coastdown (EPA Cert Style)	ok	22	3625	26.509	0.19851	0.016476	3.61	0.092	39.4	0.092	39.2	44.804	12.413	0.000	0.000	-3.150	-22.207	-0.873
61811011	UDDS hot start Ph 2	11/16/18, 07:51:48 AM	UDDSx2, 4 bag, cold start (FTP), hood up with C speed fan, 2WD mode using new dyno sets from previous coastdown (EPA Cert Style)	ok	23	3625	26.509	0.19851	0.016476	3.89	0.115	33.9	0.113	34.3	70.571	18.123	0.000	0.000	-0.394	-1.552	-0.101
61811011	**UDDS hot start Ph 1+2**	11/16/18, 07:51:48 AM	UDDSx2, 4 bag, cold start (FTP), hood up with C speed fan, 2WD mode using new dyno sets from previous coastdown (EPA Cert Style)	ok	**23**					**7.50**	**0.206**	**36.38**	**0.205**	**36.52**	**115.375**	**15.376**	**0.000**	**0.0**	**-3.543**	-11.880	**-0.5**
61811012	UDDS hot start #2 Ph 1	11/16/18, 09:11:55 AM	UDDS, 2 bag, warm start, hood up with C speed fan, 2WD mode using new dyno sets from previous coastdown (EPA Cert Style)	ok	21	3625	26.509	0.19851	0.016476	3.60	0.093	38.9	0.093	38.9	41.032	11.383	0.000	0.000	-4.299	-32.359	-1.193
61811012	UDDS hot start #2 Ph 2	11/16/18, 09:11:55 AM	UDDS, 2 bag, warm start, hood up with C speed fan, 2WD mode using new dyno sets from previous coastdown (EPA Cert Style)	ok	23	3625	26.509	0.19851	0.016476	3.88	0.115	33.8	0.113	34.2	70.894	18.278	0.000	0.000	-1.670	-7.103	-0.431
61811012	**UDDS hot start #2 Ph 1+2**	11/16/18, 09:11:55 AM	UDDS, 2 bag, warm start, hood up with C speed fan, 2WD mode using new dyno sets from previous coastdown (EPA Cert Style)	ok		3625	26.509	0.19851	0.016476	7.48	0.207	36.1	0.206	36.3	**111.926**	**14.957**	**0.000**	**0.0**	**-5.969**	-19.731	**-0.8**
61811013	HWY #1	11/16/18, 09:51:17 AM	Hwyx2, 2 bag, warm start, hood up with C speed fan, 2WD mode using new dyno sets from previous coastdown (EPA Cert Style)	ok	21	3625	26.509	0.19851	0.016476	10.26	0.189	54.4	0.189	54.4	76.674	7.474	0.000	0.000	-3.248	-15.033	-0.317
61811013	HWY #2	11/16/18, 09:51:17 AM	Hwyx2, 2 bag, warm start, hood up with C speed fan, 2WD mode using new dyno sets from previous coastdown (EPA Cert Style)	ok	23	3625	26.509	0.19851	0.016476	10.26	0.186	55.0	0.185	55.4	84.024	8.193	0.000	0.000	-0.328	-1.652	-0.032
61811014	US06x2 Ph 1	11/16/18, 10:40:13 AM	US06x2, 4 bag (split) bag, warm start, hood up with C speed fan, 2WD mode using new dyno sets from previous coastdown (EPA Cert Style), 16MPH fixed fan	ok	21	3625	26.509	0.19851	0.016476	1.78	0.086	20.7	0.086	20.6	24.175	13.600	0.000	0.000	-2.090	-32.999	-1.176
61811014	US06x2 Ph 2	11/16/18, 10:40:13 AM	US06x2, 4 bag (split) bag, warm start, hood up with C speed fan, 2WD mode using new dyno sets from previous coastdown (EPA Cert Style), 16MPH fixed fan	ok	20	3625	26.509	0.19851	0.016476	6.24	0.153	40.8	0.153	40.9	33.581	5.380	0.000	0.000	-2.575	-25.521	-0.413
61811014	US06x2 Ph 1+2	11/16/18, 10:40:13 AM	US06x2, 4 bag (split) bag, warm start, hood up with C speed fan, 2WD mode using new dyno sets from previous coastdown (EPA Cert Style), 16MPH fixed fan	ok	**21**					**8.02**	**0.239**	**33.56**	**0.239**	**33.55**	**57.756**	**7.202**	**0.000**	**0.0**	**-4.665**	-29.260	**-0.6**
61811014	US06x2 Ph 3	11/16/18, 10:40:13 AM	US06x2, 4 bag (split) bag, warm start, hood up with C speed fan, 2WD mode using new dyno sets from previous coastdown (EPA Cert Style), 16MPH fixed fan	ok	22	3625	26.509	0.19851	0.016476	1.78	0.086	20.8	0.086	20.8	23.314	13.084	0.000	0.000	-0.430	-7.036	-0.241
61811014	US06x2 Ph 4	11/16/18, 10:40:13 AM	US06x2, 4 bag (split) bag, warm start, hood up with C speed fan, 2WD mode using new dyno sets from previous coastdown (EPA Cert Style), 16MPH fixed fan	ok	23	3625	26.509	0.19851	0.016476	6.24	0.153	40.7	0.154	40.6	49.052	7.863	0.000	0.000	-0.540	-5.399	-0.087
61811014	US06x2 Ph 3+4	11/16/18, 10:40:13 AM	US06x2, 4 bag (split) bag, warm start, hood up with C speed fan, 2WD mode using new dyno sets from previous coastdown (EPA Cert Style), 16MPH fixed fan	ok	**23**					**8.02**	**0.239**	**33.59**	**0.239**	**33.51**	**72.366**	**9.023**	**0.000**	**0.0**	**-0.970**	-6.217	**-0.1**
End of Testing																					

SAE J2951 Metrics

Test ID [#]	Cycle	APCtime	ASCR	ASC_d	ASC_t	CE_d	CE_t	DR	D_d	D_t	EER	ER	IWR
61808048	UDDS cold start Ph 1	2049.46555	0.7067363	2063.509	2049.027	2.74838	2.724719	0.26822	3.600618	3.590986	0.595004	0.868391	0.602313
61808048	UDDS cold start Ph 2	1250.979591	1.8684497	3480.386	3416.549	2.599983	2.550574	0.381541	3.874566	3.859839	1.526064	1.937168	0.721387
61808048	UDDS cold start Ph 1+2												
61808048	UDDS hot start Ph 1	2050.685714	0.2763711	2054.694	2049.031	2.748566	2.724708	0.365065	3.604095	3.590985	0.506096	0.875592	0.602317
61808048	UDDS hot start Ph 2	1250.791965	1.2398657	3458.897	3416.537	2.604622	2.550562	0.579553	3.882209	3.859839	1.508007	2.119523	0.721389
61808048	UDDS hot start Ph 1+2												
61808049	UDDS hot start #2 Ph 1	2062.00494	1.949429	2088.98	2049.035	2.761198	2.72467	0.113373	3.595052	3.590981	1.211036	1.340645	0.602328
61808049	UDDS hot start #2 Ph 2	1261.718015	1.2415779	3458.964	3416.545	2.575393	2.550514	-0.11046	3.855568	3.859831	1.075427	0.975462	0.721404
61808049	UDDS hot start #2 Ph 1+2		1.5069499	5547.944	5465.58	5.336592	5.275184	-0.00258	7.45062	7.450812	1.153236	1.164082	0.6599
61808050	US06x2 Ph 1	4754.377434	0.2161601	2465.07	2459.753	2.723621	2.713115	0.272411	1.776933	1.772106	0.11439	0.387243	0.821826
61808050	US06x2 Ph 2	10055.66871	-1.6200842	1121.501	1139.969	5.826476	5.839893	0.128609	6.242877	6.234859	-0.35919	-0.22976	0.361714
61808050	US06x2 Ph 1+2												
61808050	US06x2 Ph 3	4741.673713	0.3549855	2468.469	2459.737	2.75091	2.713098	0.65132	1.783647	1.772105	0.732149	1.393673	0.821825
61808050	US06x2 Ph 4	10055.3117	-2.9683345	1106.132	1139.97	5.782547	5.839891	0.17985	6.246072	6.234858	-1.17331	-0.98194	0.361713
61808050	US06x2 Ph 3+4												
61808051	Accessory Load Test												
61811001	HWYx3 w/ coastdowns ph 1	1655.968828	9.6817359	1433.345	1306.822	6.713894	6.584657	0.065246	10.24574	10.23906	1.860937	1.962707	0.293785
61811001	HWYx3 w/ coastdowns ph 2	1653.378992	9.4755916	1430.65	1306.821	6.682253	6.584656	0.163871	10.25584	10.23906	1.299072	1.482197	0.293785
61811001	HWYx3 w/ coastdowns ph 3	1656.266433	13.945737	1489.208	1306.945	6.689165	6.584994	0.003661	10.23944	10.23906	1.553705	1.581945	0.293803
61811003	UDDS Prep	1554.10902	2.1378506	5582.055	5465.217	5.364146	5.274799	0.376506	7.478865	7.450812	1.295395	1.693843	0.659885
61811004	UDDS cold start Ph 1	2047.888351	1.5043206	2079.709	2048.887	2.742943	2.724592	-0.18659	3.584285	3.590985	0.85436	0.67352	0.602275
61811004	UDDS cold start Ph 2	1248.577584	1.3731602	3463.223	3416.312	2.579094	2.55031	-0.0885	3.85642	3.859836	1.203567	1.128654	0.721397
61811004	UDDS cold start Ph 1+2												
61811004	UDDS hot start Ph 1	2047.638939	1.1014965	2071.466	2048.898	2.750416	2.724564	0.231481	3.599297	3.590985	0.710613	0.948836	0.602292
61811004	UDDS hot start Ph 2	1248.573888	0.880131	3446.385	3416.317	2.581866	2.550293	0.280301	3.870659	3.85984	0.945984	1.237996	0.721404
61811004	UDDS hot start Ph 1+2												
61811005	UDDS hot start #2 Ph 1	2058.566689	3.3243393	2117.017	2048.905	2.784393	2.724506	0.057359	3.593041	3.590981	2.094685	2.198087	0.602306
61811005	UDDS hot start #2 Ph 2	1259.454713	4.1188577	3557.048	3416.334	2.629877	2.550272	-0.11001	3.855581	3.859827	3.133626	3.121432	0.721407
61811005	UDDS hot start #2 Ph 1+2		3.8209947	5674.065	5465.239	5.41427	5.274778	-0.02934	7.448622	7.450808	2.604965	2.64451	0.65989
61811006	HWY #1	1646.849586	9.6491248	1432.914	1306.817	6.69181	6.590913	-0.07934	10.24854	10.25668	1.585911	1.530848	0.293505
61811006	HWY #2	1647.014538	13.406909	1482.026	1306.822	6.693164	6.590903	0.044114	10.26121	10.25668	1.484395	1.551541	0.293506
61811007	US06x2 Ph 1	4757.06109	0.1818003	2464.122	2459.651	2.712284	2.713017	0.367025	1.778608	1.772104	-0.39417	-0.02703	0.82181
61811007	US06x2 Ph 2	10037.26766	-0.733142	1131.241	1139.596	5.792675	5.839448	0.019465	6.236073	6.23486	-0.82707	-0.80098	0.361588
61811007	US06x2 Ph 1+2												
61811007	US06x2 Ph 3	4737.505858	1.1867209	2488.829	2459.64	2.742536	2.713015	0.249266	1.776522	1.772105	0.829821	1.088117	0.821816
61811007	US06x2 Ph 4	10039.97775	0.0598454	1140.175	1139.493	5.778406	5.839259	0.018919	6.236037	6.234858	-1.07222	-1.04213	0.361552
61811007	US06x2 Ph 3+4												
61811009	HWY #1	1646.896336	8.3806372	1416.336	1306.816	6.629326	6.590898	-1.10585	10.14326	10.25668	1.67911	0.583046	0.293505
61811009	HWY #2	1647.201616	9.5626555	1431.782	1306.815	6.672075	6.590913	0.102403	10.26718	10.25668	1.115293	1.23143	0.293504
61811010	UDDS Prep	1554.75484	2.3825081	5595.533	5465.322	5.399125	5.274905	0.450559	7.484381	7.450811	1.86055	2.354923	0.659889
61811011	UDDS cold start Ph 1	2048.918115	0.4428693	2057.998	2048.923	2.725898	2.724599	-0.20195	3.583733	3.590985	0.249517	0.047682	0.602299
61811011	UDDS cold start Ph 2	1249.07867	1.4191408	3464.837	3416.354	2.577209	2.550356	-0.39332	3.844656	3.859837	1.43115	1.052896	0.721392
61811011	UDDS cold start Ph 1+2												
61811011	UDDS hot start Ph 1	2047.892959	1.1926902	2073.333	2048.896	2.766391	2.724569	0.517198	3.609559	3.590987	1.002388	1.534973	0.602289
61811011	UDDS hot start Ph 2	1248.918491	1.9899403	3484.343	3416.36	2.609913	2.550346	0.881212	3.893853	3.85984	1.421208	2.335614	0.721398
61811011	UDDS hot start Ph 1+2												
61811012	UDDS hot start #2 Ph 1	2059.193555	1.1197739	2071.822	2048.879	2.753562	2.72452	0.380964	3.60466	3.59098	0.677764	1.065953	0.602293
61811012	UDDS hot start #2 Ph 2	1259.802061	1.7663513	3476.69	3416.345	2.60838	2.550296	0.483596	3.878498	3.859832	1.753981	2.277525	0.72141
61811012	UDDS hot start #2 Ph 1+2	NaN	1.5239534	5548.512	5465.224	5.361941	5.274816	0.434132	7.483158	7.450812	1.197813	1.65173	0.659884
61811013	HWY #1	1646.448064	1.0196834	1320.124	1306.799	6.599793	6.590865	0.02407	10.25915	10.25668	0.111244	0.135465	0.293502
61811013	HWY #2	1646.421435	4.3151089	1363.177	1306.788	6.596835	6.590854	-0.01057	10.2556	10.25668	0.101228	0.090751	0.2935
61811014	US06x2 Ph 1	4753.862367	0.1957055	2464.404	2459.59	2.730328	2.71295	0.308712	1.777575	1.772104	0.329756	0.640581	0.821821
61811014	US06x2 Ph 2	10025.70955	-3.9978971	1093.696	1139.242	5.762262	5.839087	0.11481	6.242018	6.23486	-1.44959	-1.31571	0.361463
61811014	US06x2 Ph 1+2												
61811014	US06x2 Ph 3	4705.814768	0.1037979	2461.15	2458.598	2.716896	2.712855	0.551305	1.781839	1.772069	-0.40176	0.148951	0.821118
61811014	US06x2 Ph 4	10027.85053	-3.1514713	1103.279	1139.18	5.774726	5.838975	0.052475	6.23813	6.234859	-1.16564	-1.10034	0.361442
61811014	US06x2 Ph 3+4												

Appendix E: Cert Fuel Specifications

Tables 24, 25, and 26 show the Certificates of Analysis for the Tier 2 and Tier 3 test fuels.

Table 24. Certificate of Analysis for Tier 3 test fuel used in tests 61807001–61808040

REC'D 2 DRUMS 2-6-2018

haltermannsolutions

Certificate of Analysis

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

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

Specification No.: HF2021

Batch No.: FH3021HW10
Tank No.: DRUMS
Date: 7/24/2017

TEST	METHOD	UNITS	SPECIFICATIONS MIN	TARGET	MAX	RESULTS
Distillation - IBP	ASTM D86[2]	°F				100.5
5%		°F				124.1
10%		°F	120		140	130.4
20%		°F				138.8
30%		°F				147.1
40%		°F				154.5
50%		°F	190		210	203.9
60%		°F				236.4
70%		°F				258.5
80%		°F				283.3
90%		°F	315		335	321.1
95%		°F				339.8
Distillation - EP		°F	380		420	383.6
Recovery		%		Report		97.8
Residue		ml			2.0	1.1
Loss		%		Report		1.1
Gravity @ 60°F	ASTM D4052[2]	°API		Report		58.50
Density @ 15.56°C	ASTM D4052[2]	kg/l		Report		0.7440
Reid Vapor Pressure EPA Equation	ASTM D5191[2]	psi	8.7		9.2	8.9
Carbon	ASTM D5291[2]	wt fraction		Report		0.827
Hydrogen	ASTM D5291[2]	wt fraction		Report		0.138
Hydrogen/Carbon ratio	ASTM D5291[2]	mole/mole		Report		1.989
Oxygen	ASTM D4815[2]	wt %		Report		3.85
Ethanol content	ASTM D5599-00[2]	vol %	9.6		10.0	10.0
Total oxygentates other than ethanol	ASTM D4815[2]	vol %			0.1	None Detected
Sulfur	ASTM D5453[2]	mg/kg	8.0		11.0	8.2
Phosphorus	ASTM D3231[2]	g/l			0.0013	None Detected
Lead	ASTM D3237[2]	g/l			0.0026	None Detected
Composition, aromatics	ASTM D5769[2]	vol %	21.0		25.0	23.8
C6 aromatics (benzene)	ASTM D5769[2]	vol %	0.5		0.7	0.5
C7 aromatics (toluene)	ASTM D5769[2]	vol %	5.2		6.4	6.2
C8 aromatics	ASTM D5769[2]	vol %	5.2		6.4	6.1
C9 aromatics	ASTM D5769[2]	vol %	5.2		6.4	5.6
C10+ aromatics	ASTM D5769[2]	vol %	4.4		5.6	5.5
Composition, olefins	ASTM D6550[2]	wt %	4.0		10.0	5.5
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		91.9
Motor Octane Number	ASTM D2700[2]			Report		83.3
R+M/2	D2699/2700[2]		87.0		88.4	87.6
Sensitivity	D2699/2700[2]		7.5			8.6
Net Heat of Combustion	ASTM D240[2]	BTU/lb		Report		17958

Quality Assurance Technician

[1] Haltermann Solutions is accredited to ISO/IEC 17025 by A2LA 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.

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Table 25. Certificate of Analysis for Tier 2 test fuel used in tests 61808041–61808051

haltermannsolutions

Telephone: (800) 969-2542

Certificate of Analysis

FAX: (281) 457-1469

REC'D 5 DRUMS 8-18-17 3-APRF 2-SUPERTRUCK

PRODUCT: EPA TIER II EEE FEDERAL REGISTER

PRODUCT CODE: HF0437

Batch No.: FC2421BE10

Tank No.: Drums

Date: 6/23/2017

TEST	METHOD	UNITS	HALTERMANN Specs MIN	TARGET	MAX	RESULTS
Distillation - IBP	ASTM D86[2]	°F	75		95	87
5%		°F				111
10%		°F	120		135	125
20%		°F				145
30%		°F				167
40%		°F				195
50%		°F	200		230	218
60%		°F				231
70%		°F				240
80%		°F				258
90%		°F	305		325	312
95%		°F				339
Distillation - EP		°F			415	393
Recovery		vol %		Report		97.2
Residue		vol %		Report		1.1
Loss		vol %		Report		1.7
Gravity	ASTM D4052[1]	°API	58.7		61.2	58.9
Density	ASTM D4052[1]	kg/l	0.734		0.744	0.743
Reid Vapor Pressure	ASTM D5191[1]	psi	8.7		9.2	9.0
Carbon	ASTM D3343[2]	wt fraction		Report		0.8658
Carbon	ASTM D5291[2]	wt fraction		Report		0.8678
Hydrogen	ASTM D5291[2]	wt fraction		Report		0.1322
Hydrogen/Carbon ratio	ASTM D5291[2]	mole/mole		Report		1.815
Stoichiometric Air/Fuel Ratio				Report		14.533
Oxygen	ASTM D4815[2]	wt %			0.05	None Detected
Sulfur	ASTM D5453[2]	wt %	0.0025		0.0035	0.0028
Lead	ASTM D3237[2]	g/gal			0.01	None Detected
Phosphorous	ASTM D3231[2]	g/gal			0.005	None Detected
Silicon	ASTM 5184	mg/kg			4	None Detected
Composition, aromatics	ASTM D1319[2]	vol %			35	29
Composition, olefins	ASTM D1319[2]	vol %			10	1
Composition, saturates	ASTM D1319[2]	vol %		Report		70
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[2]		2401		2441	2436
C Factor	ASTM D5291[2]			Report		1.0004
Research Octane Number	ASTM D2699[2]		96.0			96.8
Motor Octane Number	ASTM D2700[2]			Report		89.1
Sensitivity	D2699/2700[2]		7.5			7.7
Net Heating Value, btu/lb	ASTM D3338[1]	btu/lb		Report		18460
Net Heating Value, btu/lb	ASTM D240[2]	btu/lb		Report		18627
Color	VISUAL			Report		Undyed

APPROVED BY: [signature]

[1] Haltermann Solutions is accredited to ISO/IEC 17025 by A2LA 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.

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Table 26. Certificate of Analysis for Tier 2 test fuel used in tests 61811001–61811014

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

Batch No.: GE3121GP10

PRODUCT CODE: HF0437

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 ______ [signature]

[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 F: Test IDs to Figures Matrix

In this appendix, Table 27 specifies which test IDs were used to make the figures in the report.

Table 27. Test IDs to Figures Matrix

Figure	**Test IDs**
Figure 1: Fuel economy trends: cars in the 3,500-lb weight class	Not applicable
Figure 2: Summary distributions of weight and horsepower of the midsize cars included in the review.	Not applicable
Figure 3: FTP fuel economy of 2018 midsize vehicles	Not applicable
Figure 4: FTP fuel economy of 2018 midsize vehicles by vehicle	Not applicable
Figure 5: HWFET fuel economy of 2018 midsize vehicles	Not applicable
Figure 6: HWFET fuel economy of 2018 midsize vehicles by vehicle selected	Not applicable
Figure 7: Drive cycle developed from on-road data for on dyno mileage accumulation	Not applicable
Figure 8: Vehicle mounted for mileage accumulation on the AMTL two-wheel drive (2WD) chassis dynamometer	Not applicable
Figure 9: Vehicle mounted for full testing inside the AMTL 4WD chassis dynamometer.	Not applicable
Figure 10: Instrumentation of port and direct fuel injection systems (61808001–61808051)	Not applicable
Figure 11: Direct fuel flow measurements via fuel scale and Coriolis flow meters	Not applicable
Figure 12: Wiring of the Hioki Power Analyzer on the 2018 Toyota Camry test vehicle	Not applicable
Figure 13: CAN breakout on the 2018 Toyota Camry XLE	Not applicable
Figure 14: Overview of steady state drive cycle with preparation	61808010
Figure 15: Vehicle acceleration with varying constant pedal inputs	61808025
Figure 16: Constant acceleration ramp cycles with varying accelerator pedal inputs	61808027
Figure 17: Engine mapping operation under fixed engine speed and varying pedal inputs	61808039
Figure 18: Toyota Camry test vehicle mounted to the chassis dynamometer inside of the test cell	Not applicable
Figure 19: Toyota Camry powertrain operation on cold start UDDS	61808006
Figure 20: Daily drive cycle test sequence executed in the morning	61808006, 61808007, 61808008, 61808009
Figure 21: Raw fuel economy results: UDDS and HWFET certification cycles from Argonne	Tier 2 – 93 AKI: 61808048 Tier 3 – 88 AKI: 61808001, 61808003, 61808006, 61808008, 61808013, 61808015
Figure 22: Raw fuel economy results for certification cycles across different temperature conditions	23°C avg.: • TS#1: 61808001, 61808002, 61808003, 61808004 • TS#2: 61808006, 61808007, 61808008, 61808009 • TS#3: 61808013, 61808014, 61808017, 618080118 -7°C:

Figure	Test IDs
	• 61808034, 61808035, 61808036, 61808037 35 °C: • 61808029, 61808031 (SC03), 61808032 (US06)
Figure 23: Cold-start engine operation on the UDDS across different temperatures	61808034, 61808006, 61808029
Figure 24: Powertrain and cabin temperature profiles across varying ambient temperatures	• -7 °C: 61808034, 61808035, 61808036, 61808037 • 23 °C: 61808001, 61808002, 61808003, 61808004 • 35 °C: 61808029, 61808031 (SC03), 61808032 (US06)
Figure 25: Steady-state speed operation at 72 °F and 0% grade – Tier 3 low-octane fuel	61808011
Figure 26: Steady state speed operation at 72 °F and 0% grade - Tier 2 high-octane fuel	61808043
Figure 27: Steady-state speed operation at 95 °F and 0% grade	61808040
Figure 28: Powertrain operation during the 55-mph to 80-mph passing maneuver on low-octane Tier 3 fuel.	61808022
Figure 29: Powertrain operation during maximum acceleration	61808023
Figure 30: Repeat maximum acceleration runs overlaid	61808023
Figure 31: Initial 120 s of the idle fuel flow test	61808038
Figure 32: Idle fuel flow test – full duration	61808038
Figure 33: Knock feedback signals on UDDSx2 cold-start cycles	61808048
Figure 34: Spark advance comparison between Tier 2 and Tier 3 fuels	Tier 3 – 88 AKI: 61808006, 61808007, 61808008, 61808009, 618008022, 61808023 Tier 2 – 93 AKI: 61808048, 61808049, 61808046, 61808050, 61808044, 61808045
Figure 35: Powertrain thermal and cooling information between different testing setups.	61811006, 61811013
Figure 36: Raw fuel economy results: UDDS and HWFET certification cycles from EPA and Argonne	EPA test car data list Tier 2 – 93 AKI: 61808048 Tier 3 – 88 AKI: 61808001, 61808003, 61808006, 61808008, 61808013, 61808015
Figure 37: Schematic of the vehicle configuration	Not applicable
Figure 38: Calculation of missing signals for component speed	Not applicable
Figure 39: Calculation of missing signals for component torque	Not applicable
Figure 40: Calculation of missing signals for component speed	Autonomie
Figure 41: Time spent in each gear number for the UDDS/HWFET/US06 cycles	Autonomie
Figure 42: All operating points according to gear number – vehicle speed vs accelerator pedal position	Autonomie
Figure 43: All operating points according to gear number – vehicle speed vs. wheel torque	Autonomie

Figure	Test IDs
Figure 44: Transmission shifting points – upshifting	Autonomie
Figure 45: Transmission shifting points – downshifting	Autonomie
Figure 46: Torque converter lockup operation – wheel torque vs. vehicle speed	Autonomie
Figure 47: Torque converter lockup operation – engine speed vs. vehicle speed	Autonomie
Figure 48: Torque converter operation points for lockup vs. non-lockup for each gear (1 to 4)	Autonomie
Figure 49: Torque converter operation points for lockup vs. non-lockup for each gear (5 to 8)	Autonomie
Figure 50: Torque converter operation points for lockup	Autonomie
Figure 51: Operation of the DFCO when the braking is active	Autonomie
Figure 52: Operation of the DFCO for each gear	Autonomie
Figure 53: Operating behavior of the fuel injection mode	Autonomie
Figure 54: Operating behavior of the fuel injection mode (when the engine coolant temperature is between 35 °C and 60 °C)	Autonomie
Figure 55: Operating behavior of the fuel injection mode (when the engine coolant temperature is above 60 °C)	Autonomie
Figure 56: Engine fuel rate map according to engine speed and torque	Autonomie
Figure 57: Torque pedal map for each gear (1 to 4)	Autonomie
Figure 58: Torque pedal map for each gear (5 to 8)	Autonomie
Figure 59: Engine operation at the launch of the vehicle differs according to the engine coolant temperature	Autonomie
Figure 60: Engine idle speed is controlled according to the coolant temperature	Autonomie
Figure 61: Behaviors of engine coolant temperatures on UDDS under different test conditions	Autonomie
Figure 62: Operating behavior of the fuel injection mode under cold ambient temperature	Autonomie
Figure 63: Fuel system operation at vehicle start under different ambient temperatures	Autonomie
Figure 64: Fuel rate of engine according to engine power for different coolant temperatures	Autonomie
Figure 65: Fuel rate of engine according to engine throttle position for cold coolant temperature	Autonomie
Figure 66: Accumulated fuel consumption trajectories on UDDS under different test conditions	Autonomie
Figure 67: Electrical consumption when the vehicle is fully stopped	Autonomie
Figure 68: Example of energy calculation for one component on Autonomie	Not applicable
Figure 69: Energy balance diagram on UDDS in Autonomie	Autonomie
Figure 70: Energy balance diagram on HWFET in Autonomie	Autonomie
Figure 71: Validation process for the 2018 Toyota Camry in Autonomie	Not applicable
Figure 72: Simulation results and test data for the UDDS cycle	Autonomie
Figure 73: Simulation results and test data for the HWFET cycle	Autonomie

Figure	**Test IDs**
Figure 74: Simulation results and test data for the US06 cycle	Autonomie
Figure 75: Torque converter locked vehicle speed	Autonomie
Figure 76: Comparison of torque converter lockup status	Autonomie
Figure 77: Engine fuel cutoff vehicle speed	Autonomie
Figure 78: Comparison of engine fuel cutoff status	Autonomie
Figure 79: Comparison of engine operating points on the UDDS cycle	Autonomie
Figure 80: Comparison of engine operating points on the HWFET cycle	Autonomie
Figure 81: Comparison of engine operating points on the US06 cycle	Autonomie
Figure 82: Fuel consumption and error between test data and simulation result	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 four vehicles.

1. Infiniti QX50, 2L Turbo VCR, CVT
2. 2019 Acura MDX Sport Hybrid, 3L V6 VTEC, 7 spd DCT
3. Toyota Camry, 2.5L I4, 8 spd AT
4. 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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National Highway
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