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Vehicle Technology Assessment, Model Development, and Validation of a 2018 Honda Accord LX With a 1.5L I4 and Continuously Variable 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. The vehicle benchmarked in this report is a 2018 Honda Accord equipped with the 1.5 liter, inline, 4-cylinder "Earth Dreams" engine with a continuously variable automatic transmission acclaimed for providing favorable fuel economy while still providing capable vehicle performance. The evaluation focuses on use of critical powertrain components and their impact on vehicle energy use and efficiency. The Honda was instrumented to characterize the operating conditions of critical components as well as understand the overall control strategy. Standardized tests were performed on a chassis dynamometer in a controlled laboratory environment across a range of certification tests, and other testing conditions relevant for model development and validation. Additional testing focused on characterization of different powertrain components performance and control.

17. Key Words
CAFE, Honda Accord, Argonne, Autonomie, continuously variable transmission, Earth Dreams

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Definitions and Abbreviations

Acronyms	**Description**
°C or C	degrees Celsius
°F or F	degrees Fahrenheit
2WD	two-wheel drive
4WD	four-wheel drive
AC	air conditioning
AKI	anti-knock index
AMTL	Advanced Mobility Technology Laboratory (Argonne)
Autonomie	Argonne full vehicle simulation software https://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
cc	cubic centimeter
ccps	cubic centimeters per second
CEd	positive driven cycle energy
CFR	Code for Federal Regulation
cm	centimeter
CO	carbon monoxide
CO_2	carbon dioxide
D3	Downloadable Dynamometer Database (www.anl.gov/d3)
DAQ	data acquisition system
deg	degree
DFCO	deceleration fuel cutoff
DFI	direct fuel injected
DI	direct Injection
DOHC	double overhead cam
DOT	U.S. Department of Transportation
DR	distance rating
EGR	exhaust gas recirculation system
EPA	U.S. Environmental Protection Agency
ER	energy rating
EER	energy economy rating
FTP	Federal test procedure (EPA defined)
gps	grams per second
HC	hydrocarbon
HEV	hybrid electric vehicle
hp	horsepower
Highway or HWFET	EPA certification testing: Highway dynamometer driving cycle

Acronyms	**Description**
Hz	hertz
inH20	inches of water
inHg	inches of mercury
kPa	kilopascal
kph	kilometer per hour
kW	kilowatt
L	liter
LA92	California unified driving schedule
lb/lbs	pound(s)
lb-ft	Foot pounds
lbm	pound-mass
LHV	lower heating value
m	meter
MBT	maximum brake torque
mg	milligrams
mpg	mile(s) per gallon
mph	miles per hour
N	newton
NA	naturally aspirated
Nm	newton-meters (torque)
NOx	oxides of nitrogen
PFI	port fuel injected
RMS	root mean squared
rpm	rotations per minute
RWD	Rear wheel drive
s	second
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
V	volts

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

1. Introduction

The U.S. Department of Transportation's National Highway Traffic Safety Administration sets Corporate Average Fuel Economy (CAFE) standards for passenger cars, light trucks, and medium-duty vehicles. NHTSA has contracted Argonne National Laboratory to conduct full vehicle simulations using Argonne's Autonomie software (www.autonomie.net/), to provide input into the CAFE model to determine the contribution of vehicle technologies on fuel economy. To model and simulate the new technologies employed in vehicles, it is critical to consistently update and validate Autonomie using vehicle and component test data. For the past 20 years Argonne's Advanced Mobility Technology Laboratory (AMTL) has been providing the laboratory vehicle test data to support Autonomie modelling and validation.

The vehicle benchmarked in this report is a 2018 Honda Accord equipped with the 1.5 liter, inline four cylinder "Earth Dreams" engine coupled to a continuously variable automatic transmission. This powertrain configuration is acclaimed for providing favorable fuel economy results while still providing capable vehicle performance [1]. The focus of the evaluation is to understand the use of critical powertrain components and their impact on vehicle energy use and efficiency. The test vehicle was instrumented to characterize the operating conditions of critical components as well as understand the overall control strategy. Standardized tests were performed on a chassis dynamometer in a controlled laboratory environment across a range of certification tests, and other testing conditions relevant for model development and validation. Furthermore, additional testing focused on characterization of different powertrain components performance and control (e.g., shifting).

The analysis in this report is separated into several sections:

- Vehicle instrumentation and setup.
- Vehicle energy consumption and efficiency testing results across a wide range of standard (e.g., U.S. certification, acceleration, steady-state) and specialized (e.g., constant pedal position) driving cycles across different thermal conditions
- System and component control analysis
- Autonomie model development and validation.

In addition to this report, the dataset will be made publicly available through the Advanced Mobility Technology Laboratory's Downloadable Driving Database (D3) at www.anl.gov/d3.

2. Test Vehicle Description

2.1. Vehicle Specifications

The 2018 Honda Accord, the tenth generation of the Accord model, is constructed on a refined modular platform and features a turbocharged, 1.5 L, in-line four-cylinder engine with variable valve timing and lift electronic control (VTEC) paired with a continuously variable transmission [1]. The Honda's VTEC turbo technology is marketed as part of the cluster of new generation of powertrain technologies known as "Earth Dreams Technology." The manufacturer states that the engine achieves the fuel economy benefits of a small engine while maintaining drivability by combining the turbo charger with a direct injection system and variable valve timing mechanism [2]. Dual valve timing control (VTC) and stable combustion further reduce pumping losses and yield lower fuel consumption across a wider load range [2]. An overview of the test vehicle's technical specifications is shown in Table 1.

Table 1: Technical specifications of the MY2018 Honda Accord LX test vehicle [1]

Test vehicle	2018 Honda Accord sedan LX/1.5 L I4 with continuously variable transmission
VIN	1HGCV1F14JA056668
Engine	1.5 liter, I4, single-scroll turbocharger, DOHC VTEC ® 16V 143 kW (192 hp) @ 5,500 rpm, 260 Nm (192 lb-ft) @ 1,600-5,000 rpm Redline- 6,500 rpm Compression ratio 10.3 :1 Direct injection
Transmission	CVT with overdrive Ratio range: 2.645-0.405 Differential gear ratio: 5.36 225/50 R17 tires
Climate control	Dual-zone automatic climate control Belt-driven air conditioning compressor R-1234yf refrigerant
EPA label fuel economy (mpg) [1]	30 city/38 hwy/33 combined

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

2.2. Key Technology Features

The 2018 Honda Accord was produced with a new generation of Honda internal combustion engines part of "Earth Dream Technology:" a direct-injection in-line 4-cylinder, 1.5 liter, 16-valve, dual overhead cam engine (Honda Motor Company, n.d.). Development objectives with this downsized, turbocharged engine were set to ensure a balance of high power and high torque while lowering fuel consumption and emissions to the top level of the vehicle class (Nakano et

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[1] Data from fueleconomy.gov

al., 2016). The engine uses the following technologies (Honda Motor Company, n.d.), (Nakano et al., 2016).

- Direct injection technology
    - In-cylinder direct injection with high-pressure multi-hole injector between intake valves
    - Reduced friction for increased efficiency and response at high torque
- Rapid combustion technology
    - Optimized cylinder port shape for more stable combustion
    - High tumble intake port to strengthen air flow
    - Strong tumble flow during cold starts
    - Higher compression ratio and optimized ignition timing to raise thermal efficiency even under high load
- Turbocharger with electronic wastegate
    - Increased responsiveness
    - Increased fuel economy under low-load conditions
- Dual VTC technology
    - Low engine speed/high load range: Valve overlap is increased to leverage the scavenging effect, raise charging efficiency, and suppress knock, while as the same time the scavenging effect increases turbine speed.
    - Medium engine speed range: The valve overlap limits are reduced, and the electric wastegate is controlled to raise the turbocharged pressure
    - Low engine speed/low load range, and high engine speed/all load: Valve overlap is reduced to increase combustion stability by reducing the internal EGR amount, lower exhaust resistance
    - High engine speed/all load: Valve overlap is reduced to increase combustion stability by reducing the internal EGR amount, lower exhaust resistance and heighten knock resistance
- Water-cooled exhaust manifold built into cylinder head
    - Reduced high-load exhaust gas temperature, increasing fuel economy

In addition the 2018 Honda Accord is equipped with a continuously variable transmission (CVT) that features the following technologies.

- Overview of design [1]:
    - Pump, turbine and stator assembly in a single unit
    - Four parallel shafts: input shaft, drive pulley shaft, driven pulley shaft, and final drive shaft
        - Input shaft connects to the torque converter turbine and integrates the forward clutch, connecting the drive pulley shaft end
        - Drive pulley shaft includes CVT drive pulley, a moveable and fixed-face pulley
        - Driven pulley shaft includes CVT driven pulley, a moveable and fixed-face pulley

- Six-position shift lever with multiple modes
  - Park/Reverse/Neutral/Drive/Sport/Low
    - Sport mode: non-stage speeds (standard stepped transmission behavior not emulated), transmission keeps engine at higher rpm than in drive mode
    - Low mode: engine braking and power for climbing, transmission shifts to lowest pulley ratio
  - Transmission lock-up: operates in drive, sport, and low positions
  - Step-shift mode: while accelerator pedal is depressed deeply, engine speed reaches maximum, and vehicle speed is high, CVT switches to an automatic transmission like multistage gear shift
- Engine driven transmission fluid pump

- Operation highlights of Honda continuously variable transmissions [3], [4]:
  - Expanded ratio range over prior generation CVTs providing:
    - Increased fuel efficiency performance (high ratio locked)
    - Guaranteed driving force (low ratio locked)
  - Advanced control vane-type oil pump with half-feed switching and expansion of half-feed operation
  - Transmission fluid with high metal friction coefficient (HCF2)
    - Increased transmission capacity
    - Reduced fuel consumption and increased fuel efficiency
  - Optimization of pulley V-surface properties
  - Protective control technologies
    - Engine speed control (restricted to max transmission fluid temperature)
    - Engine torque cooperative control
    - CVTF temperature control

2.3. Comparison Vehicles and Preliminary Analysis

The Honda Accord is a top-selling model in the mid-sized vehicle category. This section provides a brief comparison of the 2018 Honda Accord with historical trends in this category and other vehicles released in the midsized non-luxury vehicle category for the 2018 model year. The non-hybrid 2018 Honda Accord was offered in four trim levels: LX, EX-L, Sport, and Touring. All trim levels are equipped with a 1.5 L turbocharged engine, with the EX-L, Sport, and Touring levels offering an optional turbocharged 2.0 L I4. Following a joint review of possible powertrain configurations with the project sponsors, the 2018 Honda Accord LX with the turbocharged 1.5 L engine and continuously variable transmission was selected for this research.

This 2018 Honda Accord LX test vehicle has a curb weight of 3131 lbs, with a gross vehicle and equivalent test weight of 3,500 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 EPA fuel economy trends report [5] provides a glimpse into the historical trends from 1975 until 2020 for similar cars within the weight class of 3,500-4,000 lbs. The trend of average fuel economy, with the specific test vehicle shown as a star, can be seen in Figure 1.

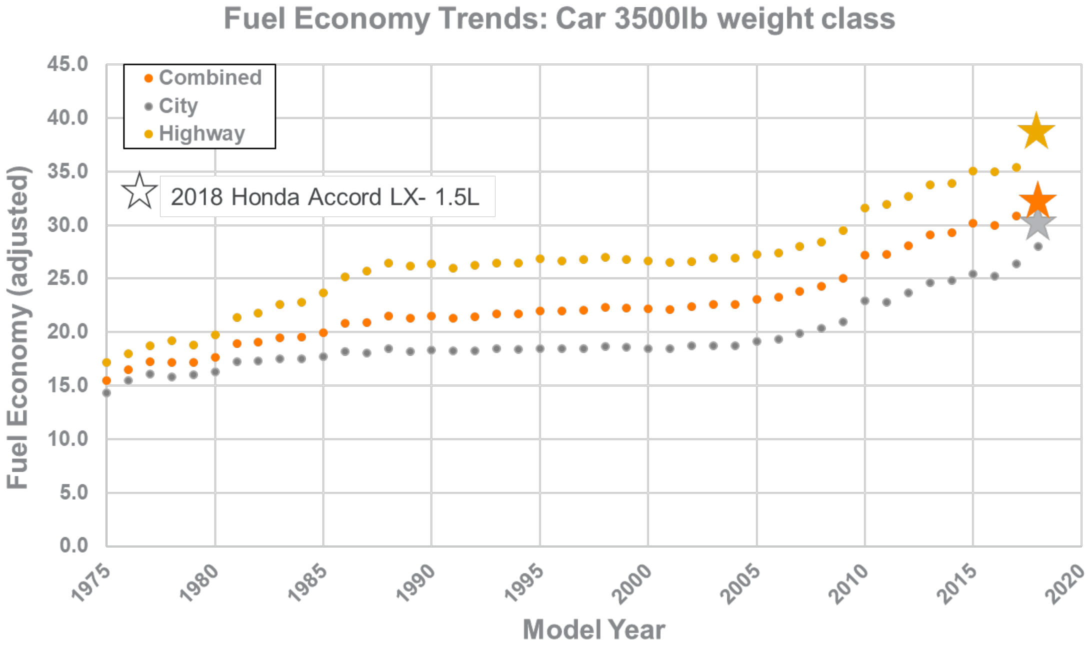


Figure 1: Fuel economy trends: car 3,500 lb weight class

Combined fuel economy for midsized passenger cars has been steadily increasing from 25 mpg since 2009. The 2018 Honda Accord 1.5 L, as the first year of a new generation of Honda powertrains, provides insight into how this trend will likely continue. Improvements were found in both city and highway fuel economy, 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 within the model year (MY) 2018 midsize category. For this comparison, vehicles of similar vehicle class, with a starting manufacturer's suggested retail price (MSRP) below $25,000, were considered. With vehicles selected based on these broad criteria, all trim levels were then considered based on data available in the EPA vehicle test car list database [6]. (A subset of selected vehicles used for this comparison can be found in Appendix B: Subset of Midsized 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

The vehicle weights varied considerably, as optional powertrains (with the exception of hybrids) and trim levels were also considered. The distribution of weight and available power for the vehicles reviewed is shown in Figure 2.

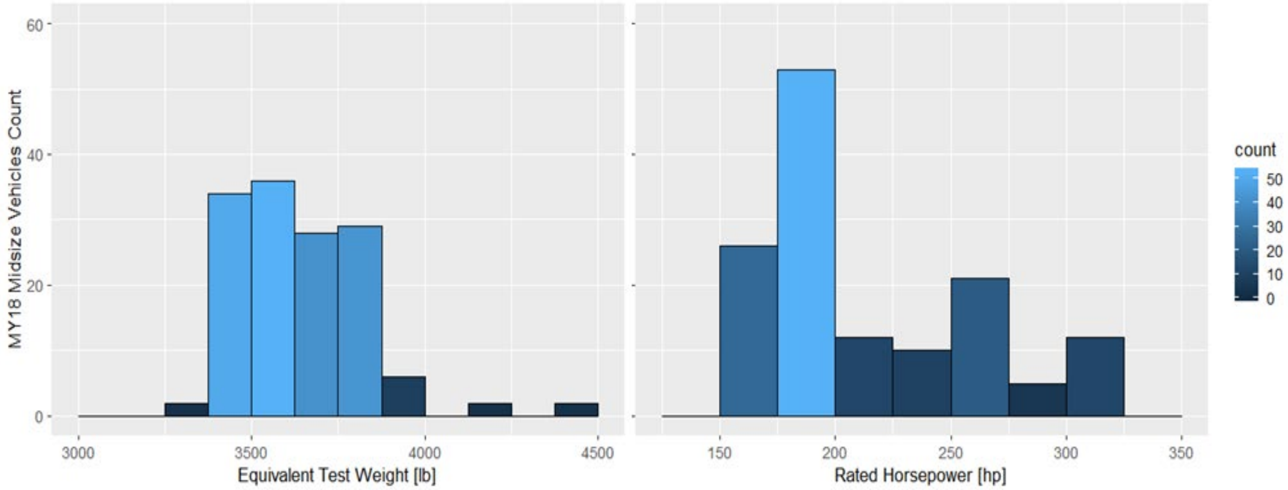


Figure 2: Summary distributions of weight and horsepower of mid-size cars reviewed

The 2018 Accord 1.5 L LX test vehicle weight was near the mean of the category, with an equivalent test weight of 3,500 lbs, and at 192 hp (143 kW), the power available was slightly below the mean of 213.2 hp (159 kW). Fuel economy in this category varies considerably by powertrain and trim selection. The fuel economy values published by manufacturer are termed "adjusted fuel economy values", as the observed (unadjusted) fuel economy from vehicle dynamometer is adjusted downward based on established procedures [6]. A comparison of the unadjusted fuel economy (FE), separated by air induction system category, can be seen on the fuel test procedure (FTP) cycle in Figure 3.

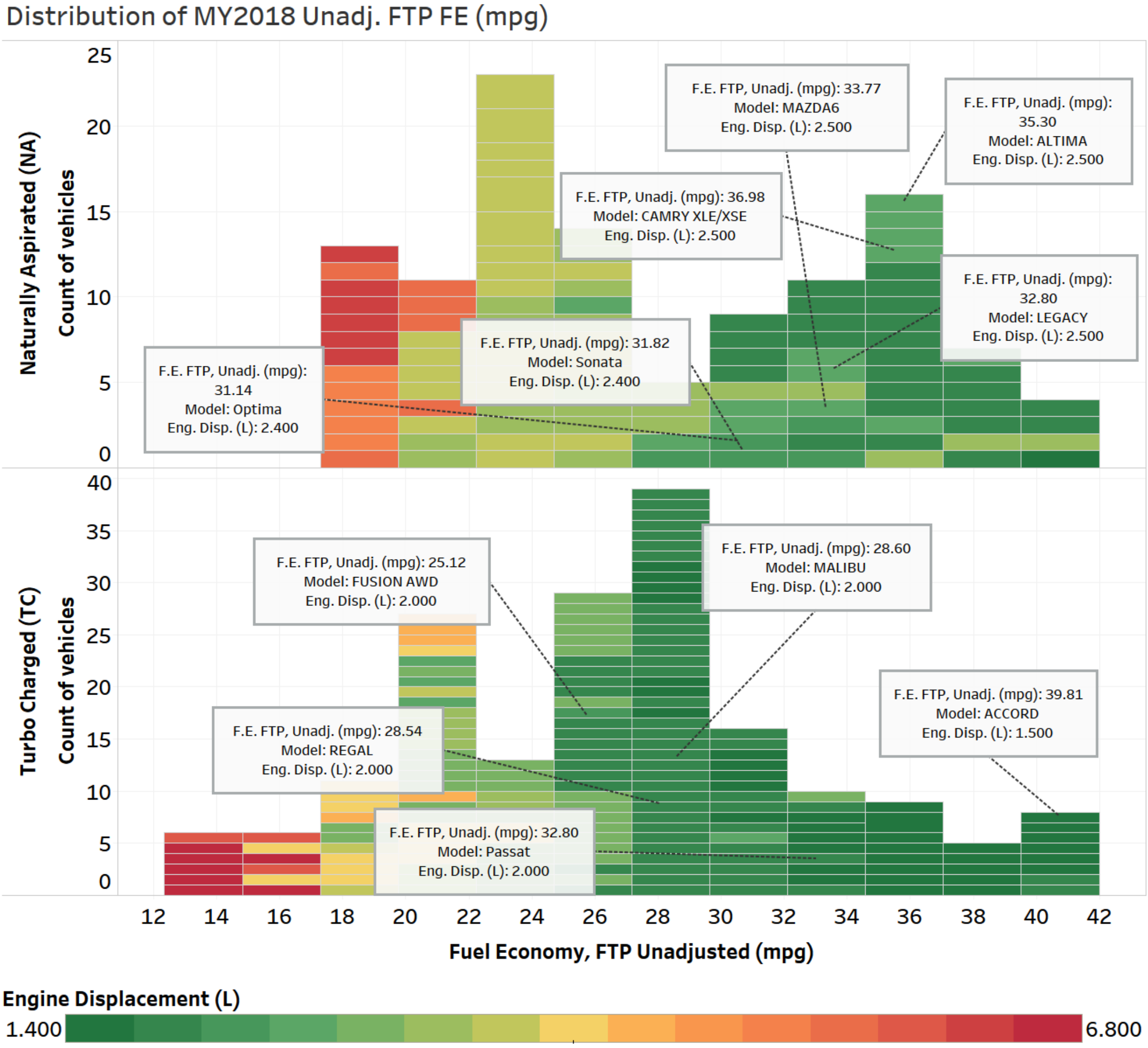


Figure 3: FTP unadjusted fuel economy (FE) of 2018 midsize vehicles

As shown in Figure 4 the 2018 Honda Accord LX with CVT is amongst the most fuel efficient vehicles in its class both on the FTP and HWFET cycles.

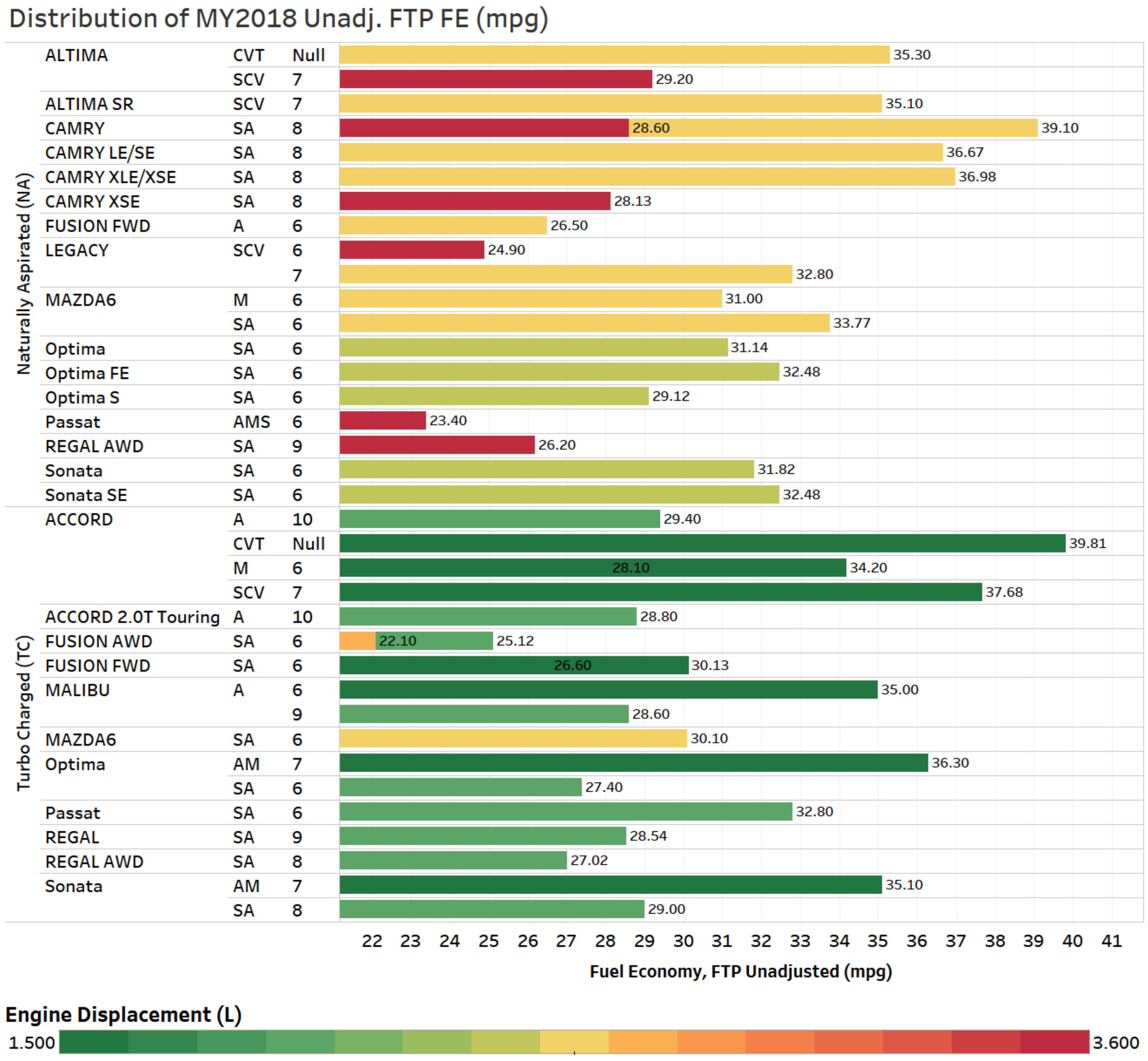


Figure 4: FTP unadjusted fuel economy of 2018 midsize vehicles by vehicle

The 2018 Honda Accord unadjusted fuel economy is also on the upper end of the sample set on the reported highway fuel economy driving (HWFET) cycle, as shown in Figure 5 and Figure 6.

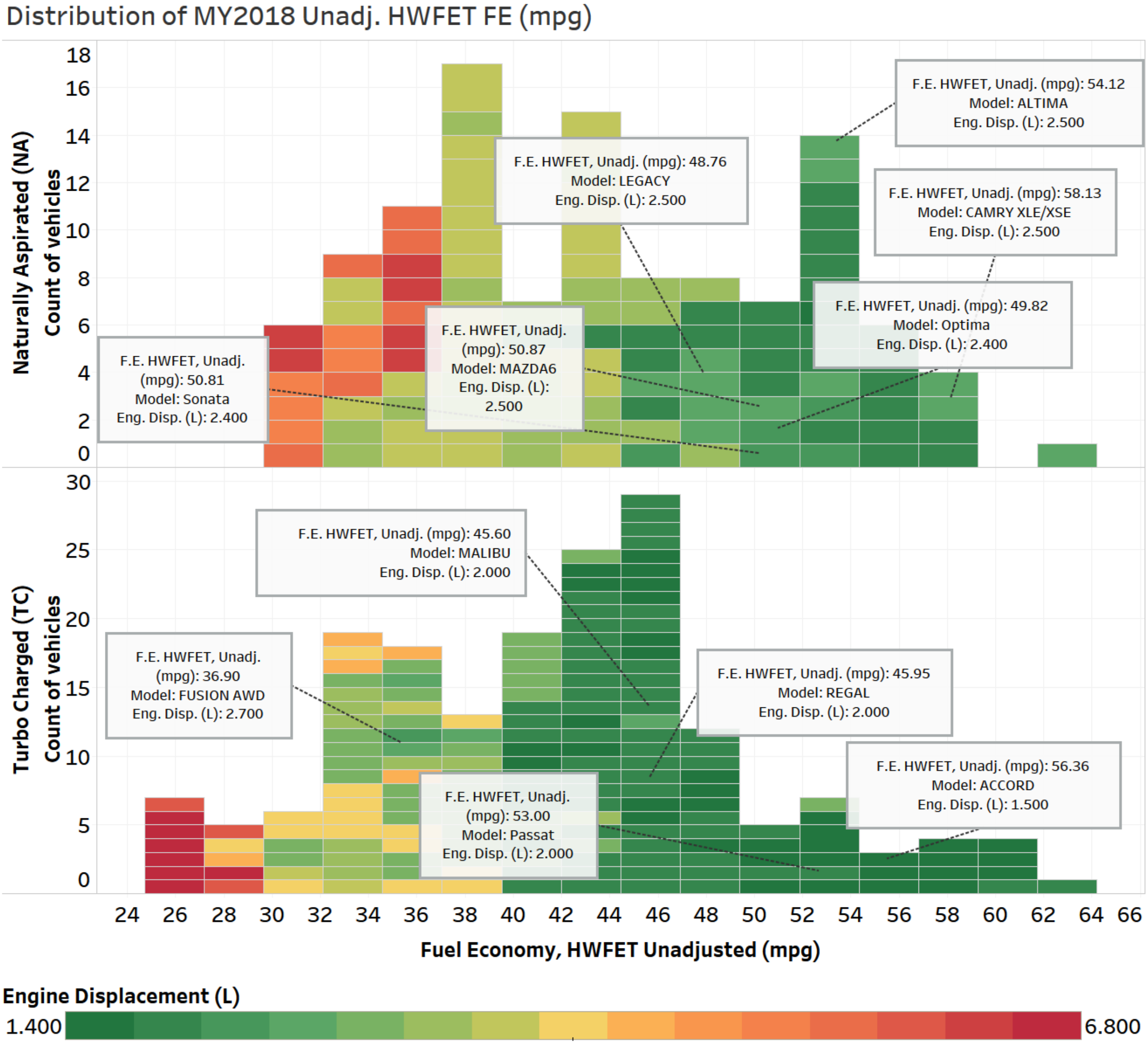


Figure 5: Highway unadjusted fuel economy of 2018 midsize vehicles

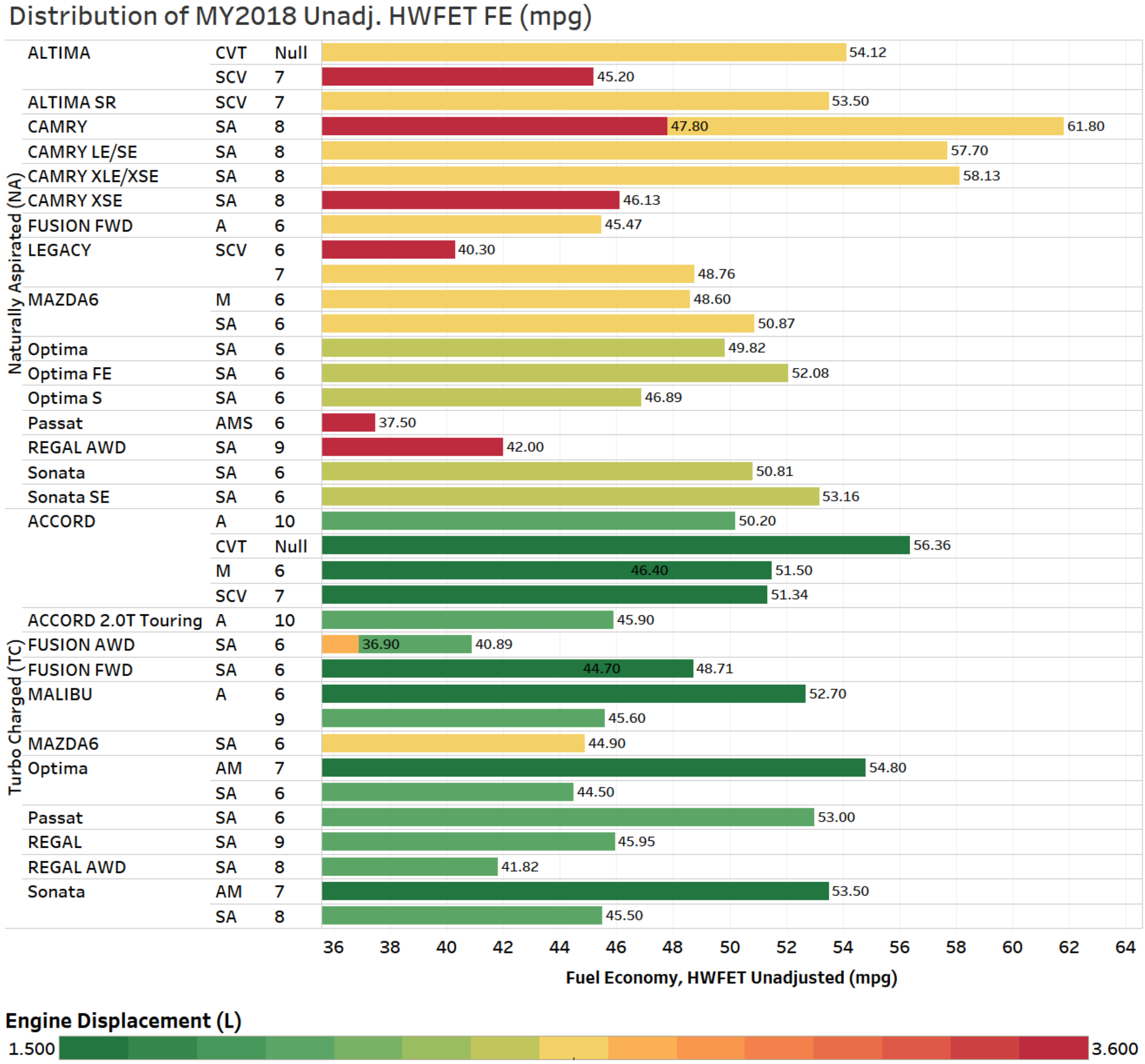


Figure 6: Highway unadjusted fuel economy of 2018 midsize vehicles by vehicle selected

When compared to other vehicles in the market, the 2018 Honda Accord demonstrates high fuel economy on both the HWFET and FTP cycles with the vehicle weight and engine power slightly lower than the mean of the vehicles compared in the category. The following sections describe the vehicle and component operating conditions that led to those vehicle fuel economy values.

3. Testing Overview

3.1. Vehicle Break-In

A new vehicle must be "broken in" for stability, for consistent vehicle losses to tires and moving and rotating components, and to ensure catalyst "degreening." An established industry standard for proper vehicle break-in is 4,000 miles, as required in the Code for Federal Regulations, Title 40, Part 86 [7][8]. On the test vehicle, this 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. The preliminary vehicle mileage accumulation up to 2,500 miles was completed on transient drive cycles on a chassis dynamometer, in order to expedite the vehicle evaluation. Following this, on-road mileage accumulation of 1,500 miles ensured proper break-in of vehicle tires and other rotating components, in addition to collecting on-road data on vehicle operation.

A key component of an effective break-in is variation in powertrain speed and loading. Break-in miles accumulated on-road inherently provide this variability, but operation on a chassis dynamometer depends on the driving cycle completed. To ensure variability while accumulating miles on a 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.

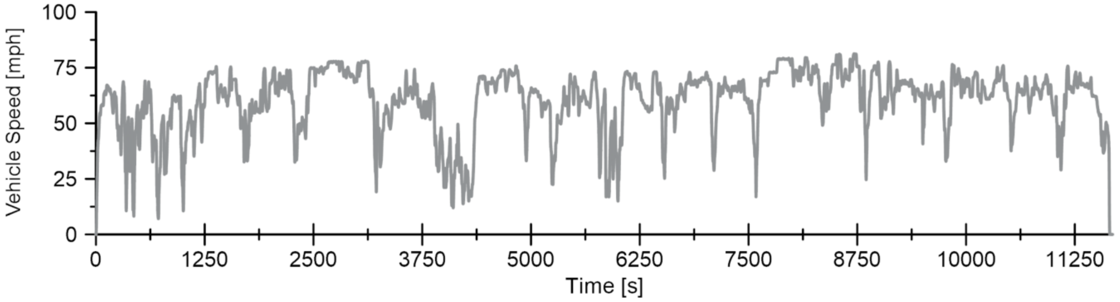


Figure 7: Drive cycle developed from on-road data for on-dyno mileage accumulation

Vehicle operation during the on-dynamometer mileage accumulation was performed by a custom-built robot driver, allowing for consistent mileage accumulation while reducing project burden. The test vehicle during mileage accumulation can be seen in Figure 8.

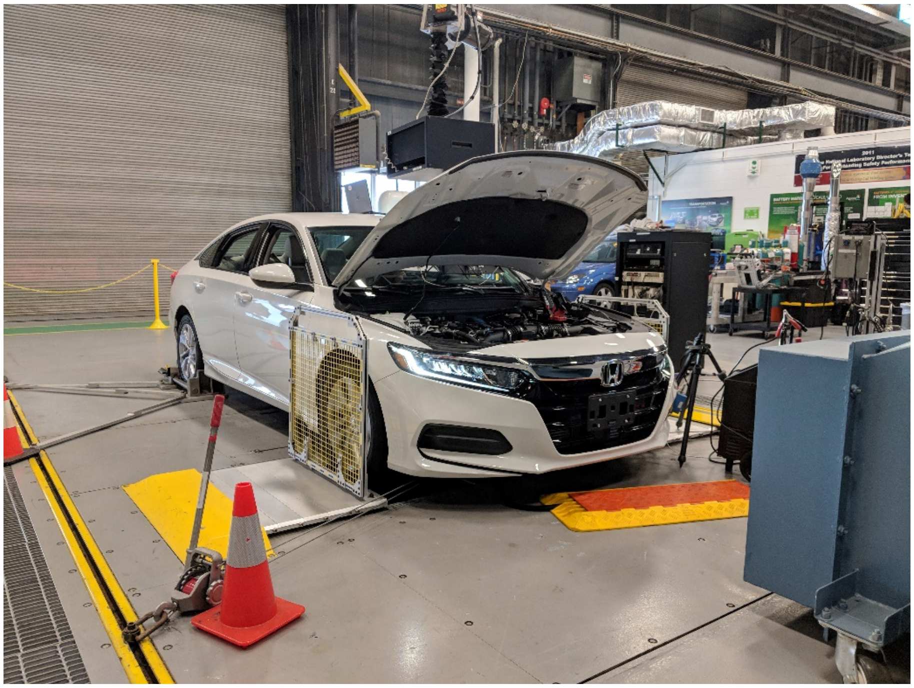


Figure 8: Vehicle mounted for mileage accumulation on the AMTL 2WD chassis dynamometer

3.2. Vehicle Dynamometer Setup

The following sections provide details of the vehicle setup and an overview of the test methodology specific to this test vehicle. Further information regarding the methods of vehicle testing, please review the general procedures document for the facility [9]. The test vehicle in the 4WD chassis dynamometer during testing at the AMTL can be seen in Figure 9.

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

3.3. Instrumentation

3.3.1 Facility Signal Overview

Figure 10 shows the general instrumentation process for technology evaluation of conventional vehicles such as the 2018 Honda Accord. This process integrates data streams from several sources.

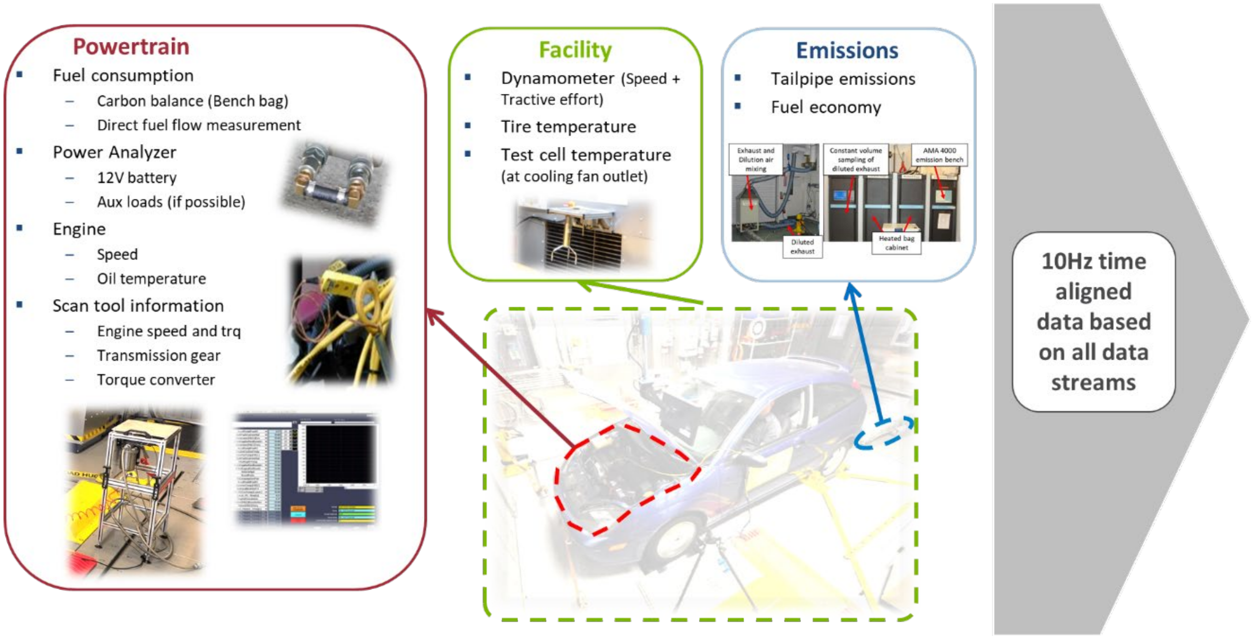


Figure 10: Overview of general instrumentation for conventional vehicle

The facility data (Table 2) captures the test cell conditions (ambient test cell temperature and relative humidity), the dynamometer data (vehicle speed and tractive effort) and emissions data (bag and modal bench data: HC, CO, NOx, and CO_2). Fuel consumption is measured in several different ways. A carbon balance fuel economy result from the emissions bench (bag and modal) is used to provide a standard method of fuel economy calculation. To provide greater insight during transient operation, the vehicle was equipped with additional inline fuel flow meters.

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 (in H2O)		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 thermocouples measuring the air temperature behind the radiator and the engine bay temperature.

3.3.2 Fuel Flow Measurements (Scale, Coriolis, Modal, Bag)

The 1.5 L I4 Earth Dreams engine uses a direct injection (DI) system for fuel injection. On the test vehicle, total fuel flow was measured using two fuel flow meters routed in series at the fuel connection on the engine firewall. Fuel was first routed to a Coriolis flow meter and then to a positive displacement fuel scale before returning to the fuel rail at the high-pressure fuel pump inlet. It should be noted that the addition of the hosing required for the direct fuel flow measurements results in some delay and dynamic effect on the direct fuel flow measurements. These effects are taken into account during post-processing. Figure 11 and Figure 12 illustrate the fuel system instrumentation of the test vehicle.

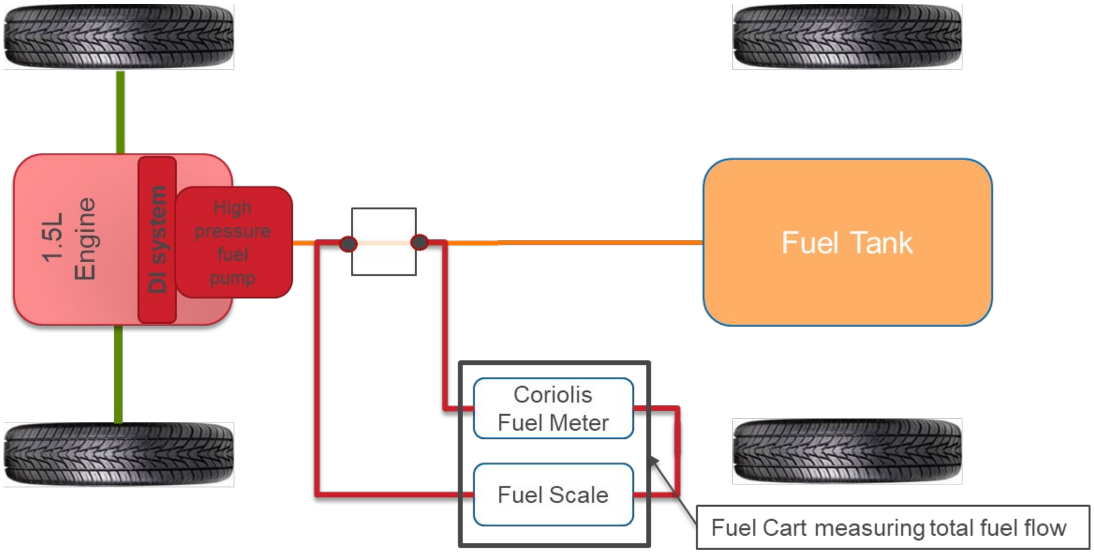


Figure 11: Instrumentation overview of direct fuel injection system on 2018 Honda Accord

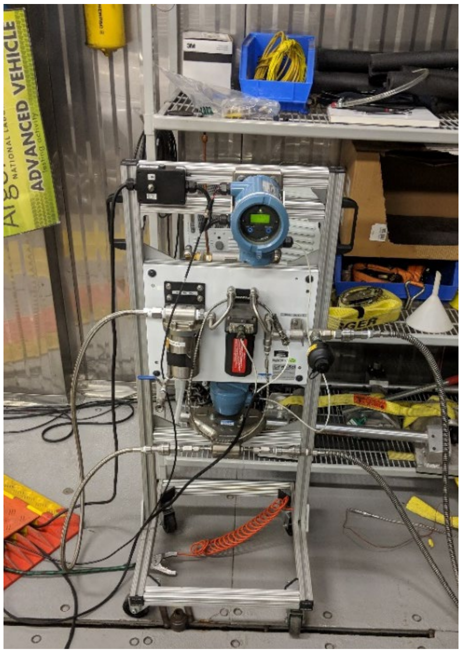


Figure 12: Direct fuel flow measurements via fuel scale and Coriolis flow meters

3.3.3 Hioki Power Analyzer Setup

Vehicle electrical system measurements were captured with a four-channel Hioki 3390-10 power analyzer. Three channels were instrumented, each with a direct current measurement with Hioki CT6843 200A current probes. These current probes were located to capture the current of the alternator, 12V loads, and the 12V battery negative terminal. Voltage for the low voltage bus was measured across the 12V battery, which was then bridged to act as the voltage source for all three channels. From the measured current and voltage channels, power and energy use were calculated within the analyzer. An overview of vehicle wiring can be seen in Figure 13.

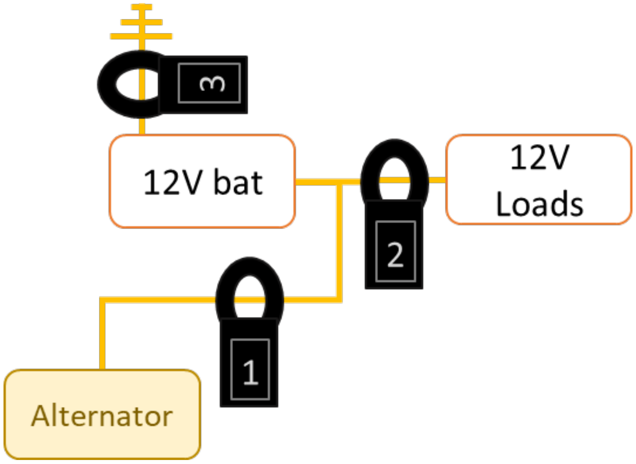


Figure 13: Wiring of Hioki power analyzer on the 2018 Honda Accord test vehicle

3.3.4 CAN Signals

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

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

The team decoded a significant list of vehicle messages for the vehicle, which is detailed in Appendix C: 2018 Honda Accord LX Test Signals. This instrumentation included the determination and probing of eight separate CAN networks across the vehicle. Each connection was then routed to an accessible location with a single connection in the center console for external instrumentation, as shown in Figure 14: CAN breakout on the 2018 Honda Accord LX.

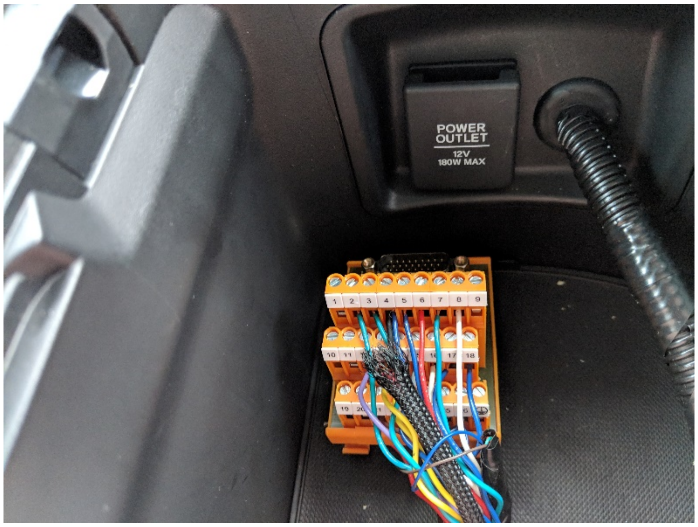


Figure 14: CAN breakout on the 2018 Honda Accord LX

The corresponding logging and communication of CAN messages was completed through a combination of custom scripting with Intrepid Control Systems Vehicle Spy software and National Instruments LabVIEW software located on the AMTL custom built data acquisition (DAQ) system. The following is a categorized list of critical signals decoded on the vehicle communication bus, from either diagnostic or broadcast CAN messaging:

- Driver input:
    - Accelerator pedal position (multiple signals)
    - Brake pedal (multiple signals)
    - Eco mode selection
    - Transmission PRNDL selection
    - HVAC system settings and states
- Engine:
    - Engine torque
    - Engine speed
    - Intake air temp
    - Throttle valve angle
    - Knock retard
    - Spark advance
    - Air fuel ratio
    - Deceleration fuel cutoff state
    - Turbocharger boost pressure
    - Turbocharger bypass state
    - Exhaust catalyst temperature
- Cooling system
    - Engine coolant temperature
- Transmission
    - Transmission temperature
    - Pulley ratio
    - Turbine speed
    - Secondary shaft speed
    - Torque converter lockup operation

The complete signal list can be found in Appendix C: 2018 Honda Accord LX Test Signals, and the datasets can be found at Argonne's Downloadable Dynamometer Database at www.anl.gov/D3.

3.4. Test Plan

3.4.1. Lists of Tests Conducted

A test plan was developed to provide a broad base of vehicle operation at varying driving conditions and test temperatures. To capture test to test variability, specific drive cycles such as the UDDS, HWFET, and US06 were repeated. Custom tests for mapping, those with a focus on specific ambient temperatures, or those on Tier 2 certification fuel, were only performed a single time to allow for a greater range of testing within the allocated project budget. A summary of the testing performed can be found in Table 3, though more details on the specific test cycles can be found in CFR[7][8], or the reference AMTL testing overview report [9].

Table 3: Summary of the number of standard test cycles in the general test plan

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

1x- test was conducted a single time

2x- 2 tests were completed

3x – 3 tests were completed

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

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

In addition to the test matrix listed in Table 2, focused testing was included to provide further insight into vehicle energy consumption and operation. The additional testing included the following.

- 23 °C cold-start idle: mapping out the idle fuel flow as a function of powertrain temperature
- 23 °C cold start LA92
- 23 °C hot start JC08
- 23 °C cold start US06
    - Varying engine and transmission mapping cycles through:
    - Constant accelerator tip-ins tests
    - Accelerator tip-ins with vehicle locked at constant speed
- Additional 23 °C testing:
    - Vehicle maximum acceleration at an emulate road grade of 25%
    - Cold start engine idle fuel flow at idle

The table in Appendix D: Test Summary, summarizes all tests performed.

3.4.2. U.S. Standard Driving Cycles

The fuel economy testing focused on the UDDS, HWFET, and US06 (high acceleration aggressive) drive cycles at 23 °C ambient temperature condition. The test sequence includes a cold start UDDS, a hot start UDDS, a third UDDS, a HWFET pair, and a US06 pair. The preparation for the cold start test consists of completing a UDDS cycle at 23 °C and leaving the vehicle to thermally soak at 23 °C for over 12 hours. As the vehicle remains in the test cell for the duration of testing, the overnight soak prior to each sequence of tests is completed with the vehicle already mounted to the chassis dynamometer. The graph in Figure 15 shows the sequence of drive cycles executed. Note that there is a 10-minute soak period between the first two UDDS cycles, while a soak time of slightly over 10 minutes occurs between the second and third UDDS cycles due to variations of emissions bag analysis and DAQ processing. As described in Table 2, this series was repeated three times to capture test-to-test variability at the test temperature of 23 °C on the Tier 3, low octane fuel.

Unless otherwise noted, the fuel economy numbers in this report are based on analysis of the test phases highlighted by the pink boxes in Figure 15. The test phases follow a prep phase of the same cycle (not highlighted), which acclimates the vehicle to the test conditions, a process described in the CFR [7]. The US06 drive cycle phases are the split city and highway phases needed to calculate the EPA five-cycle fuel economy label.

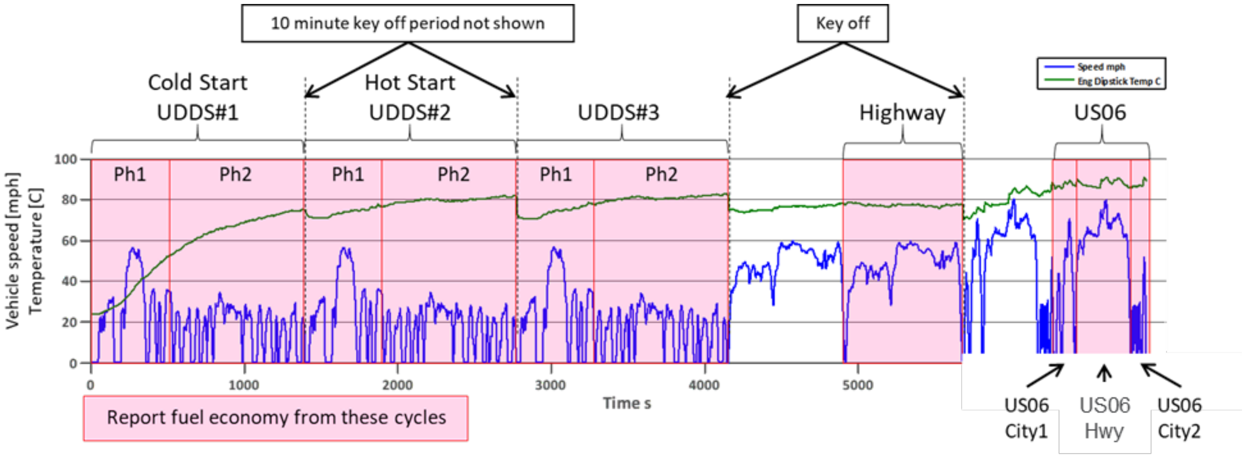


Figure 15: Daily drive cycle test sequence executed in the morning

3.4.3. Additional Testing

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 tests developed specifically for the 2018 Honda Accord. Additional operational testing discussion, and further details on the development of these custom cycles, can be found in a supplemental report [9].

3.4.3.1. Steady State Speeds

Steady-state speed tests evaluate vehicle operation while the vehicle operates at a constant speed and load point. Steady-state cycles are conducted by following a driving schedule with a minimum 30-second hold at each speed. Vehicle speed is increased in 10 mph increments up to 80 mph while held at each speed for a set period of time, and then decreased from 80 mph repeating the measurements. By holding each speed following both an acceleration and deceleration, one captures variability in powertrain operation (such as in commanded gear ratio) and thermal state. Additionally, these steady-state cycles may be repeated at varying grades to capture variations in vehicle powertrain loading.

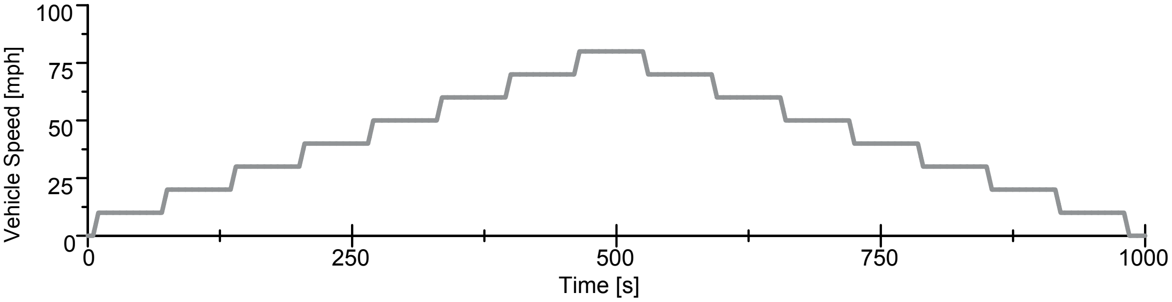


Figure 16: Overview of steady state drive cycle with preparation

Prior to each steady state speed cycle, the vehicle is warmed to an engine oil temperature of over 80 °C, or to a temperature recorded on a prior transient drive cycle. The 2018 Honda Accord, steady state speed cycles were performed at the ambient test temperatures of 23 °C (0% grade, both fuels), and 35 °C (0%, 3%, and 6% grade), seen in Appendix D: Test Summary.

3.4.3.2. Powertrain Mapping Cycles

Full vehicle powertrain operation across its speed and load range are not commonly seen during operation on standard transient drive cycles. To fully map powertrain operation, supplemental custom cycles, a robotic driver, and feedback from focused instrumentation are used to control the vehicle and precisely map component operation. This mapping was performed using several tests. The first test consisted of the dynamometer being placed in road load simulation mode (the same dynamometer mode used on certification drive cycles), and accelerated with fixed accelerator pedal inputs, as can be seen in Figure 17 below. It should be noted that a limit on the chassis dynamometer limited maximum vehicle speed to 85 mph, which can be seen at test time beyond ~3,600s.

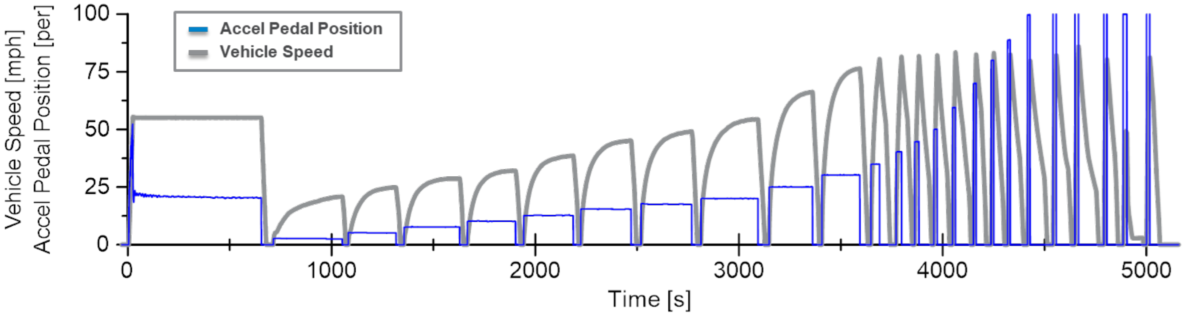


Figure 17: Vehicle acceleration with varying constant pedal inputs

This test provides a map of load demand and gear ratio selection strategy for the full range of powertrain operation. Accelerator pedal inputs were incremented a small amount at low pedal positions to provide higher granularity in torque demand, while increments increased at higher pedal inputs. The desired accelerator pedal position in this test is described in Table 4.

Table 4: Accelerator pedal position selection during constant pedal tip-in test

Event	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Accel Pedal Position (%)	2.5	5	7.5	10	12.5	15	17.5	20	25	30
Event	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	
Accel Pedal Position (%)	35	40	45	50	60	70	80	90	100	

Although transmission operation during acceleration is captured during the constant pedal position test discussed above, additional mapping is required to capture transmission operation during deceleration. As a result, another test was conducted with the dynamometer placed in a mode that provides a sequence of constant acceleration and deceleration at a rate of 2 mph/s. This rate was chosen as a compromise between the need for a low enough acceleration rate: low enough to provide adequate quantity of data at each speed/load point but a need for a high enough rate to avoid component overheating at prolonged high loads. During these ramp cycles, the accelerator pedal position is held constant while vehicle speed is varied between 3 mph and 85 mph. An overview of the cycle is shown in Figure 18 below.

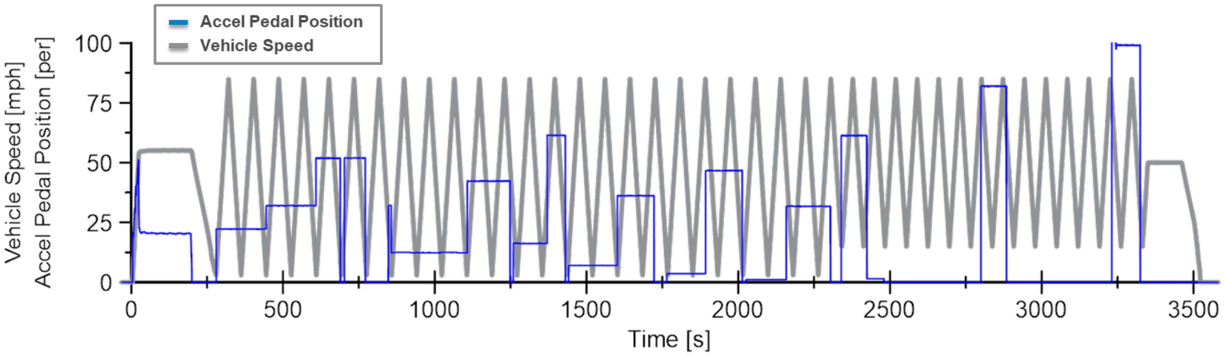


Figure 18: Constant acceleration ramp cycles with varying accelerator pedal inputs

3.4.4. Fuel Selection

Test fuel used during chassis dynamometer testing is an important factor affecting the determined fuel economy. Test fuels vary in many ways, such as: energy content, octane value, and other characteristics. The 2018 Honda Accord specifies the use of fuel with an octane rating of 87 (RON 91) or higher. Manufacturer certification testing was performed using a high-octane (RON 93) Tier 2 fuel [6]. Since a low-octane fuel is likely to be often used by consumers, while certification testing was conducted on the high-octane fuel, both high and low octane fuels were evaluated to provide an understanding of the impact of each fuel on vehicle operation.

The low-octane fuel chosen was EPA Tier 3 EEE certification fuel with an octane rating of 88 AKI and 10% ethanol content. The fuel was procured from Haltermann Solutions under the product code HF2021. Table 5 provides the major specifications for the low-octane Tier 3 certification fuel used. The complete fuel specifications sheet for each fuel can be found in Appendix E: Cert Fuel Specifications.

Table 5: Main specifications of the EPA Tier 3 EEE fuel for test for Test ID 61809017-61809052

Fuel Name:	**HF2021 EEE Tier 3 (Batch FH3021HW10)**
Ethanol content	10%
Carbon weight fraction*	0.827
Density	0.744 (g/ml)
Net heating value	17958 (BTU/lbm)
Research octane number	91.9
Motor octane number	83.3
R+M/2	87.6
Sensitivity	8.6

*Carbon weight fraction value based on ASTM D5291 results

The low-octane Tier 3 fuel used at the start of testing was depleted prior to the end of low-octane fuel testing. As certification fuel is held to tight tolerances, a second supply of Tier 3 HF2021 fuel was directly used, though it is worth noting it was from a separate batch with slight variations. This fuel change began on test number 61809053 (test numbering is described in the collaborating report [8]), which can be referenced in Appendix D: Test Summary. The fuel specifications are listed in Table 6 below.

Table 6: Main specifications of the EPA Tier 3 EEE fuel for test for Test ID 61809053-61809066

Fuel Name:	**HF2021 EEE Tier 3 (Batch GH1621LT10)**
Ethanol content	10%
Carbon weight fraction*	0.8252
Density	0.745 (g/ml)
Net heating value	17994 (BTU/lbm)
Research octane number	92.0
Motor octane number	84.3
R+M/2	88.2
Sensitivity	7.7

*Carbon weight fraction value based on ASTM D5291 results

A high-octane fuel was used to provide comparative data for engine operation as well as comparison with certification testing. The fuel used during certification testing was a high-octane, Tier 2 EEE high-octane certification fuel, and a similar fuel was procured from Haltermann Solutions with the product code HF0437. Table 7 provides the major specifications for the Haltermann Solutions Tier 2 certification fuel used for this test.

Table 7: Main specifications of the EPA Tier 2 EEE fuel for Test ID 61809067-61810004)

Fuel Name:	**HF0437 EEE Tier 2 (Batch FC2421BE10)**
Ethanol content	0%
Carbon weight fraction	0.8678
Density	0.743 (g/ml)
Net heating value	18627 (BTU/lbm)
Research octane number	96.8
Motor octane number	89.1
R+M/2	93.0
Sensitivity	7.7

*Carbon weight fraction value based on ASTM D5291 results

The certification fuel used for each test can be referenced in Appendix D: Test Summary.

The high-octane fuel has a 3.7% higher energy content by mass than the low octane fuel, which was accounted for in post-processing for all fuel economy calculations. Vehicle efficiency calculations use the fuel energy content and density, taking into account fuel variability. The specification sheets for each batch of fuel used during testing are listed in Appendix E: Cert Fuel Specifications.

3.4.5. Vehicle 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. The standard vehicle and test setup, as well as specifics on these changes, are discussed in the collaborating report [9]. Additionally, for specific details on how a specific test was performed, please consult Appendix D: Test Summary.

All the chassis dynamometer testing was conducted with the vehicle driver assistance systems (aka Honda Sensing) disabled. In addition, a manufacturer-specific tool known as the "Honda Handyman" was provided by the manufacturer to disable systems for operation on the chassis dynamometer. Following several preliminary tests, the data was reviewed to ensure consistent vehicle operation with on road data.

Argonne used the test weight and road load coefficients published by the EPA in 2018 (U.S. Enviromental Protection Agency, 2018)[6]. As the vehicle was front wheel drive, it was tested in 2WD mode using only the front rolls of the 4WD test cell. The vehicle was restrained on the chassis dynamometer from lateral motion using chains attached to straps affixed to the front sub-frame of the vehicle. The chains were connected to towers at the front corners of the vehicle. Longitudinal movement of the vehicle was restrained with specialized wheel chocks applied to the rear wheels. The team performed the vehicle coast-down and vehicle loss determination evaluations before formal testing began. Table 8 provides the chassis dynamometer setup parameters for the Honda Accord, where the target coefficient originated from the previously mentioned EPA database [6], while the dynamometer set coefficients were derived from the dynamometer coast down evaluation. Figure 19 shows a picture of the test vehicle mounted to the chassis dynamometer. Further details on vehicle dynamometer coefficients used for specific tests can be found in Appendix D: Test Summary.

Table 8: Chassis dynamometer target parameters for the 2018 Honda Accord LX test vehicle

Test weight	3,500 (lb)	
Chassis dyno setup	2WD on rolls with dyno mode	
	Target	**Set**
Road load A term	43.75 (lb)	-1.4 (lb)
Road load B term	-.6042 (lb/mph)	0.3825 (lb/mph)
Road load C term	0.02619(lb/mph^2)	0.01443 (lb/mph^2)

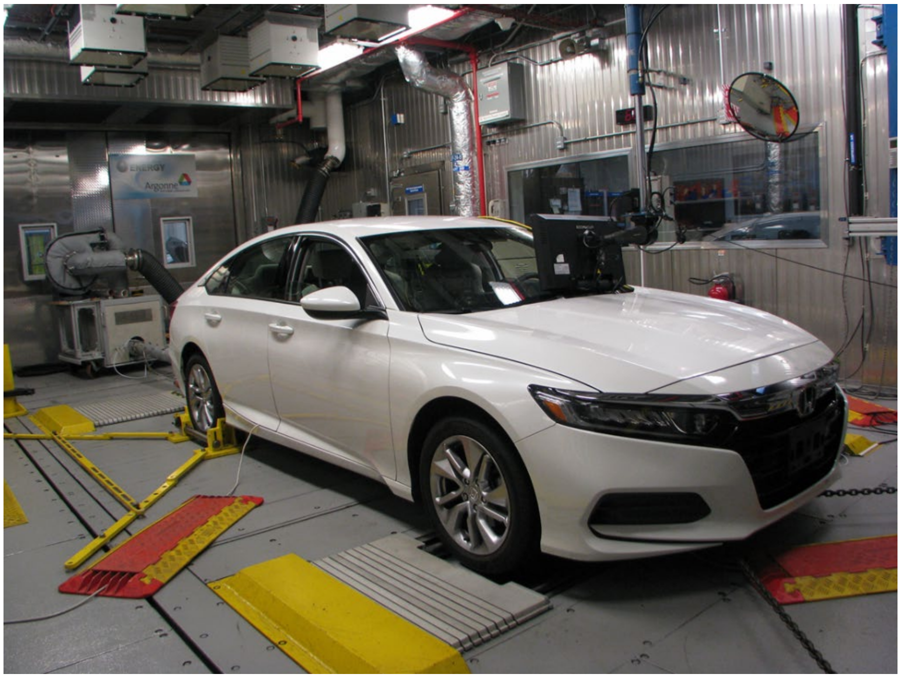


Figure 19: Honda Accord test vehicle mounted to the chassis dynamometer inside the test cell.

3.4.6. Driver Selection (Human vs Robotic)

Argonne personnel include experienced dynamometer test drivers with decades of experience operating vehicles on the chassis rolls over test cycles. Vehicle operation on all drive cycles was completed with the use of a human drive. To supplement their efforts in mapping or steady-state speed tests, Argonne uses a robot driver. These unique tests are best performed when step change inputs for braking or acceleration can be executed and subsequently held constant, an operation which is better performed by an actuator. The drivers utilized for specific tests can be found in the test plan in Appendix D: Test Summary.

4. Vehicle Testing Analysis

4.1. Comparison with EPA CAFE Fuel Economy Results

An initial validation step for vehicle operation can be completed by comparing the fuel economy results from testing with those provided from manufacturer (MFR), or EPA, certification testing [6]. The manufacturer certification testing results, published by the EPA [6], provide unadjusted fuel economy results for phases 1, 2, and 3 of the UDDS, otherwise known as the FTP, as well as the HWFET cycle. Figure 20 and Table 8 compare the manufacturer and EPA published fuel economy results to the results from AMTL testing. AMTL tests were separated into two categories; the single high-octane test, and the average of the three low-octane test sequences performed on the low-octane fuel.

The fuel economy results from the EPA published, and resulting tests are within 2% on all certification cycles. Several factors which influence this variability, which are noted in the testing reference [9], which include AMTL testing performed with the vehicle hood closed and the test cell fan in vehicle speed match mode. Some additional factors which influence this variability are how closely a driver follows a prescribed cycle, the specific test vehicle state (tire wear, etc.), and ambient conditions beyond test control (absolute pressure). In addition to providing the specific test data for future comparison (www.anl.gov/d3), and calculating SAE J2951 [10] driver metrics for the testing, repeat testing of the certification cycles was performed.

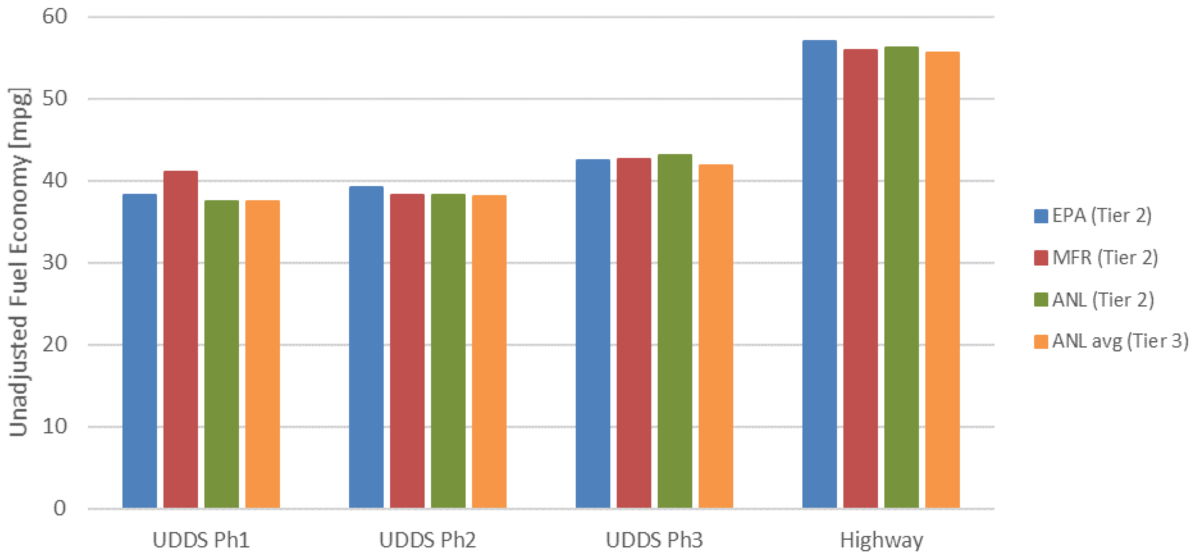


Figure 20: Raw fuel economy results: UDDS and HWFET certification cycles from EPA and Argonne

4.2. Test to Test Repeatability

Three separate repeats of the certification cycles were performed on the low-octane Tier 3 fuel at the ambient test temperature of 23 °C. The test results on the low-octane fuel demonstrate acceptable levels of repeatability. Figure 21 and Table 9 compare the three test sequences completed at the AMTL. From the test process described in Figure 15, the results differ by less than 1.3% from the average value for UDDS testing and less than 1% for HWFET testing.

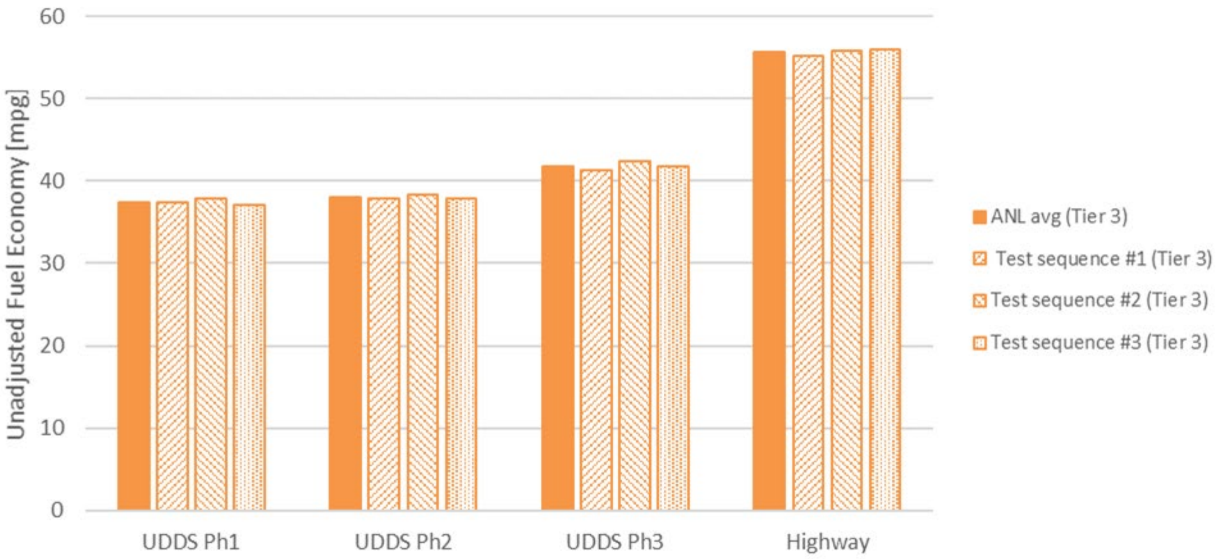


Figure 21: Test to test repeatability (UDDS AND HWFET raw fuel economy results)

Table 9: Raw fuel economy results: UDDS and HWFET certification cycles from EPA and Argonne

	EPA (Tier 2)	**MFR (Tier 2)**	**ANL (Tier 2)**	**ANL avg (Tier 3)**
UDDS Ph1	38.1	41.0	37.5	37.4
UDDS Ph2	39.1	38.2	38.2	38.0
UDDS Ph3	42.5	42.6	43.0	41.8
HWFET	57.0	55.9	56.1	55.6

4.3. U.S. Standard Drive Cycles

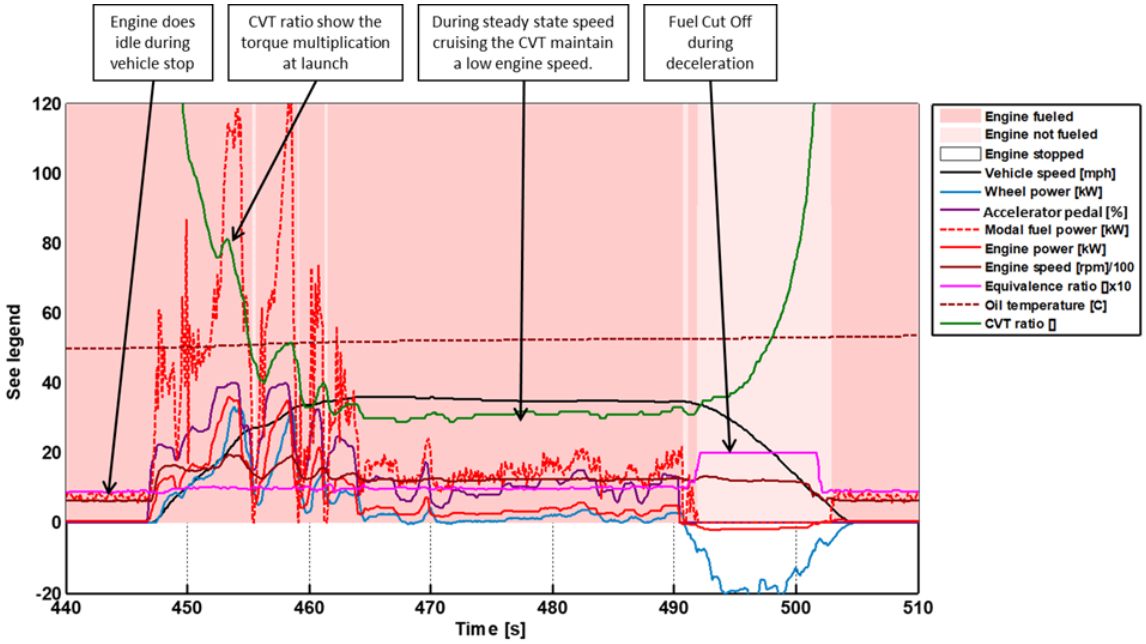
4.3.1. Vehicle Fuel Economy

The fuel economy results for standard drive cycles are presented in Table 10. The drive cycles include the cold start UDDS (Phase 1 and 2), the hot start UDDS (Phase 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; it is performed to further understanding of the fuel economy changes at higher powertrain temperature. Both the HWFET and US06 drive cycles included 2 phases of testing: a prep cycle and the test cycle. The fuel economies presented in Table 9 for HWFET and US06 are determined from the second test, as was described previously in Figure 19.

Table 10: Raw Tier 3–88 AKI average fuel economy results for drive cycle results

	Fuel economy (mpg)
UDDS #1 Cold Start	37.7
UDDS#1 Ph1	37.4
UDDS#1 Ph2	38.0
UDDS#2 Hot	39.8
UDDS#2 Ph3	41.8
UDDS#2 Ph4	38.1
UDDS#3	39.3
UDDS#3 Ph1	41.3
UDDS#3 Ph2	37.7
HWFET	55.6
US06	32.3
US06 City	21.2
US06 Highway	37.9

Figure 22 shows an example of general vehicle operation on a section of the urban dynamometer driving schedule (UDDS) cycle. The Honda Accord idles its internal combustion engine when the vehicle is stopped. When the vehicle accelerates, the CVT reduces the transmission ratio to maintain a low engine speed. At a speed of 35 mph and a low accelerator pedal position, the transmission enables engine speeds as low as 1,200 rpm. During deceleration the engine is not fueled, seen where the equivalence ratio reaches a maximum lean value. During deceleration, the engine is instead motored through the transmission using vehicle kinetic energy. Fueling is resumed and the engine transitions from a fuel cutoff mode to idle mode prior to the vehicle arriving at a full stop.



Engine does idle during vehicle stop

CVT ratio show the torque multiplication at launch

During steady state speed cruising the CVT maintain a low engine speed.

Fuel Cut Off during deceleration

Figure 22: Honda Accord powertrain operation on cold start UDDS

4.3.2. Vehicle Efficiency

Vehicle efficiency, calculated as per the SAE standard for drive cycle metrics, SAE J2951[10], is calculated by dividing positive driven cycle energy (CEd) by the fuel energy used over the drive cycle. Table 11 provides the calculated vehicle efficiencies for the drive cycles in each test sequence.

Table 11: Powertrain efficiencies based on J2951 positive cycle energy

	Test Sequence #1	Test Sequence #2	Test Sequence #3	Average
UDDS #1 Cold Start	23.8%	23.7%	24.2%	23.9%
UDDS#2 Hot Start	25.2%	25.1%	25.5%	25.2%
UDDS#3	24.7%	24.7%	25.3%	24.9%
HWFET	32.0%	31.8%	32.2%	32.0%
US06	31.0%	30.8%	31.2%	31.0%

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% from the cold start cycle to the third cycle, where the powertrain has reached its operating temperature. This efficiency increase is due to a combination of factors, largely driven by a reduction in friction typical of increasing temperatures in all components of the powertrain. The increase in efficiency due to increasing powertrain temperature is partially offset on the third UDDS cycle, as powertrain temperature reaches a point that requires additional cooling which results in increased loading of the alternator.

Average powertrain efficiency is highest on the HWFET drive cycle. On this cycle, the powertrain can take full advantage of the CVT, increasing engine loads and reducing the engine speed of the small displacement boosted engine to enable the vehicle to achieve over 30% vehicle efficiency. The average powertrain efficiency on the US06 drive cycle is also over 30%, mainly driven by increased engine loading.

4.3.3. Thermal Impact on Fuel Economy and Vehicle Efficiency

The UDDS cycles, the highway cycle, and the US06 cycle were also tested at -7 °C and at 35 °C with 850 W/m^2 of solar load, the two extreme temperature conditions established for the EPA five-cycle fuel economy label [6]. Figure 23 provides the test results for those conditions and drive cycles.

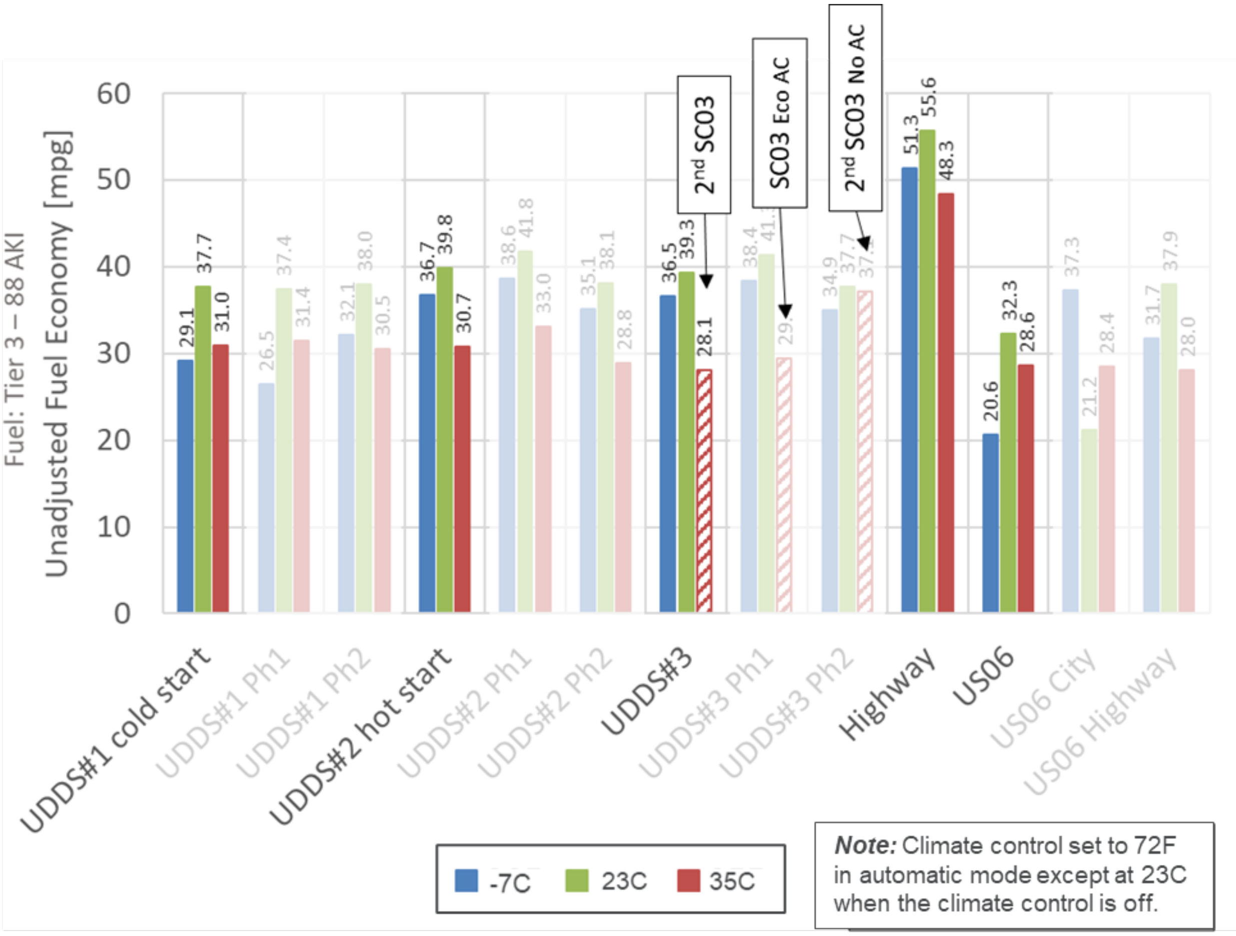


Figure 23: Raw, uncorrected, fuel economy results for certification cycles across different temperature conditions

The fuel economy for the cold start UDDS at -7 °C is 23% lower when compared to the same test at 23 °C. This impact decreases to 8% for the second UDDS cycle. The powertrain has to overcome significantly increased drive train friction losses during the cold start at -7 °C cycle, but once the powertrain reaches a steady operating temperature, those friction losses become less significant.

Vehicle fuel economy at the elevated 35 °C with solar load emulation (SCO3 testing conditions as described in the CFR [7]) is also less than at the 23 °C test condition. The fuel economy decreases by 18% and 24% for the cold start UDDS and the hot start UDDS cycles, respectively, in comparison to the 23 °C test condition. The fuel economy reduction is driven by the additional power required to operate the air conditioning system. In addition, the ability to perform deceleration fuel cutoff (DFCO) is significantly reduced (16.5% of cycle time in DFCO for UDDS cold start at 23 °C compared to 3.1% of cycle time at 35 °C) as the additional compressor load requires the engine to restart fueling sooner. Note that for the 35 °C testing, the third UDDS cycle was replaced by an SC03 (the air conditioning "supplemental FTP") drive cycle. This was change was made to capture vehicle operation on the SC03 cycle, while the first two UDDS cycles remained to provide a comparison for other ambient temperatures.

Table 12 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 air conditioning compressor at 35 °C is also apparent in this table. It is noteworthy that the efficiency impact of the air conditioning compressor is lower on the high-power US06 drive cycle, because the ratio between the air conditioning power to the average wheel power is lower than the same ratio for the UDDS cycle.

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

	-7 °C	**23 °C**	**35 °C**
UDDS #1 Cold Start	18.5%	23.9%	18.0%
UDDS#2 Hot Start	23.4%	25.2%	19.2%
UDDS#3	23.4%	24.9%	N/A
HWFET	29.8%	32.0%	28.0%
US06	30.5%	31.0%	27.5%

Figure 24 shows the engine operational 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. At -7 °C, the engine operation is slightly shifted to higher speeds, but not higher torque. At 35 °C, the engine torque is shifted upwards throughout the map due to the additional power required to run the air conditioning compressor.

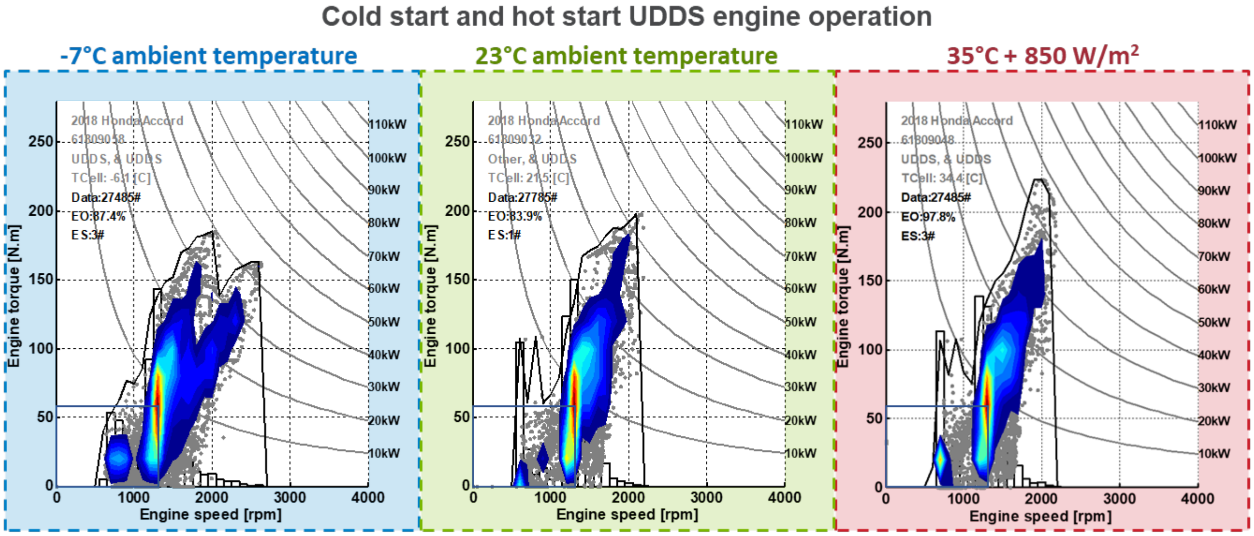


Figure 24: Engine operation on the UDDS across different temperatures

Figure 25 shows some relevant powertrain and ambient temperature profiles over the completion of the test sequence. To obtain a thermally stable result, three consecutive HWFET drive cycles were performed at -7 °C. Additionally, at the test temperature of 35 °C, the SC03 test cycle replaced the third UDDS cycle to capture operation on the air conditioning test cycle. These graphs also show the targeted 23 °C cabin temperature that the automatic climate control system tries to achieve in the -7 °C and 35 °C test condition.

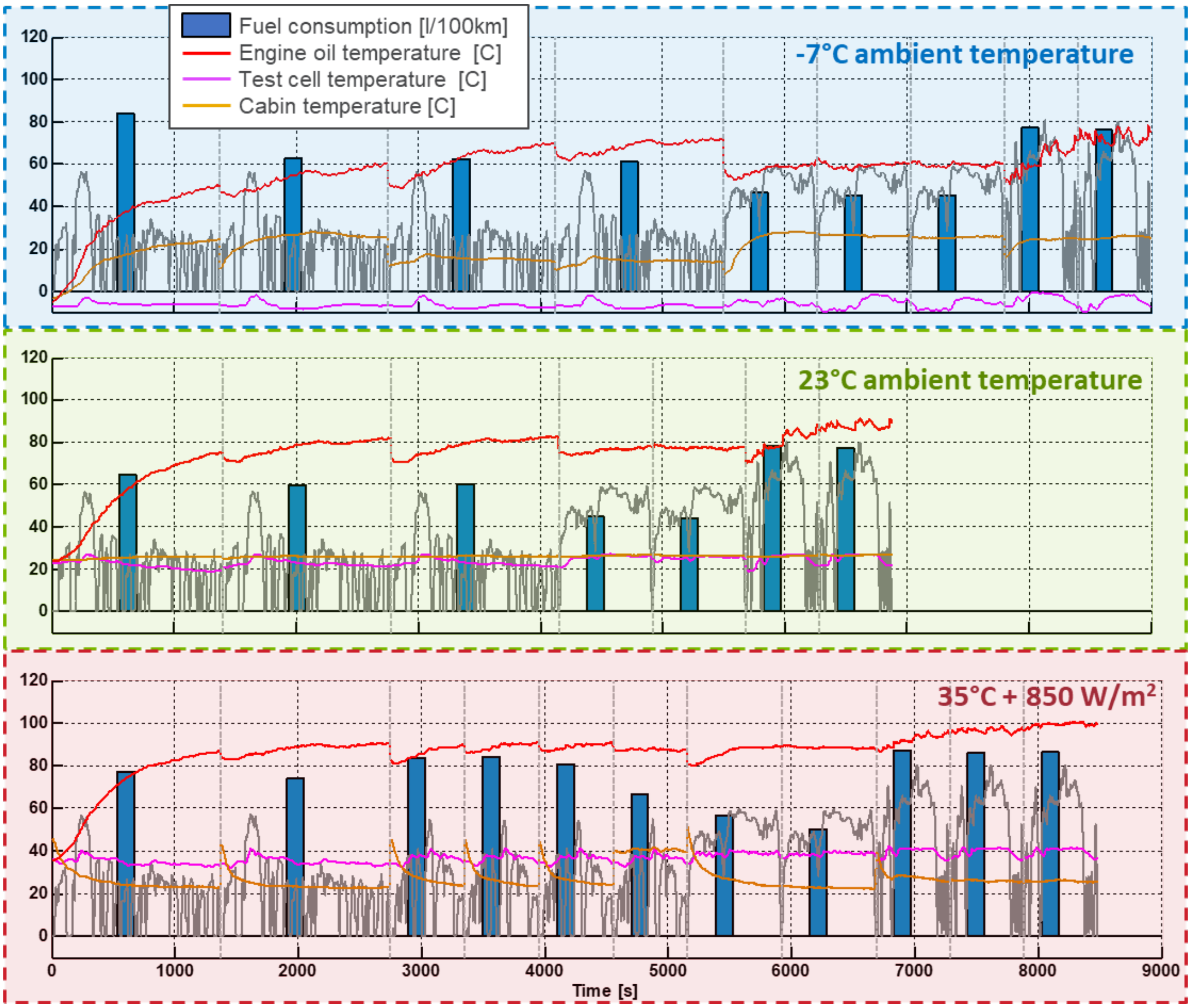


Figure 25: Powertrain and cabin temperature profiles across different temperature

The engine oil temperature is representative of the powertrain temperature. For the 23 °C and 35 °C ambient temperature conditions, the final engine oil temperature for the US06 is 95 °C to 100 °C. The engine temperature during the -7 °C test conditions required a longer duration to reach a steady state level, and once at a stable temperature remains 20 °C lower, increasing pumping losses and decreasing efficiency.

4.4. Steady State Speed

One characterization test run is the steady state speed drive cycle, which holds vehicle speed for one minute at speeds from 10 mph to 80 mph in increments of 10 mph. The vehicle is accelerated then decelerated through the set speed points in order to capture any effects that may be seen in powertrain operation. This test was conducted at several varying vehicle states and loads, including:

- Low-octane fuel at 0% grade in Drive mode at 23 °C
- High-octane fuel at 0% grade in Drive mode at 23 °C
- Low-octane fuel at 0% grade in Drive mode at 35 °C with 850 W/m^2 solar emulation
- Low-octane fuel at 0% grade in Drive mode at -7 °C

- Low-octane fuel at 0% grade in Sport mode at 23 °C
- Low-octane fuel at 0%, 3%, and 6% grade in Drive at 23 °C

Vehicle fuel economy results, along with vehicle efficiency, the power required at the wheel, engine speed, and the transmission ratio, were calculated. Results for the 0% grade test on low-octane fuel, are presented in Figure 26.

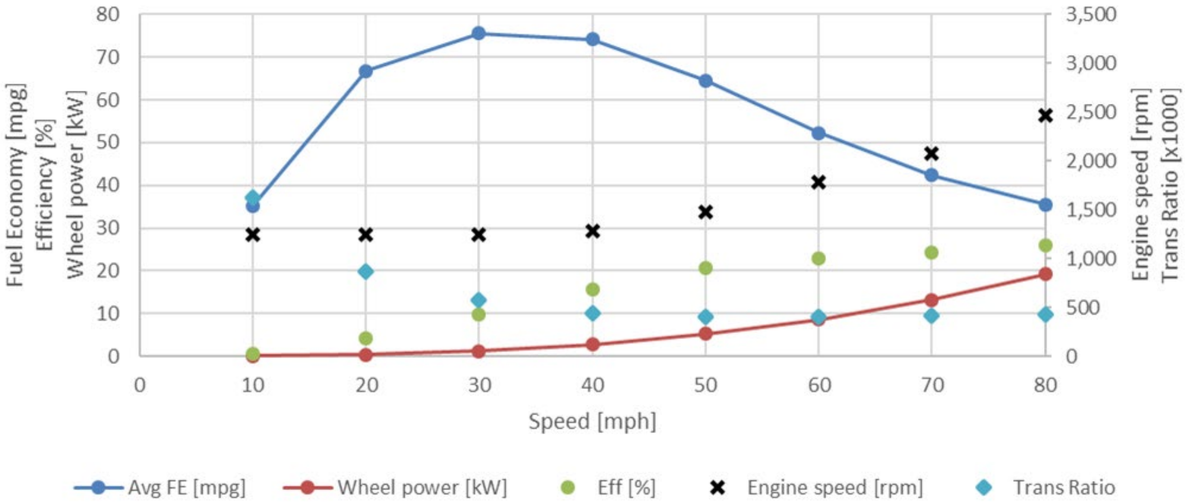


Figure 26: Steady state speed operation at 23 °C, 0% grade and Tier 3 low-octane fuel

The highest fuel economy occurred at a vehicle speed of 30 mph. Vehicle efficiency increases as vehicle speed increases due to increased powertrain loading. In Figure 24, this can be seen by a progression of engine speed and engine load into a higher efficiency band at the engine speeds of 1,100-1,400 rpm and up to 100 Nm. Vehicle efficiency continuously increases to a maximum of 26% at the maximum test speed of 80 mph. By constantly varying the CVT ratio at speeds of 10–30 mph, the engine speed is held at 1,250 rpm. A slight increase in engine speed, to 1,300 rpm, is seen at 40 mph. At speeds over 50 mph, the CVT ratio is held constant at 0.41:1, allowing the engine speed to increase with increasing vehicle speed. The maximum engine speed, at 80 mph, recorded at 2,500 rpm. Though efficiency does increase with vehicle speed, vehicle losses increase as well due to aerodynamic drag (emulated on dyno) and rotational losses. These additional losses offset improvements to vehicle efficiency, ultimately resulting in a lower fuel economy.

As discussed in greater detail in section 4.8, steady-state speed operation testing was also performed using a high-octane Tier 2 fuel. Testing on both fuels was conducted with the dynamometer in 2WD mode, with the vehicle remaining mounted to the dynamometer during the fuel swap. Figure 27 shows vehicle operation with high-octane fuel. Fuel economy, vehicle efficiency, and general vehicle operation all mirrored the behavior observed with low-octane fuel, showing typical test-to-test variability. This behavior was expected because vehicle and engine loading at 0% grade is low, and any variations to ignition timing due to low-octane fuel are likely reduced.

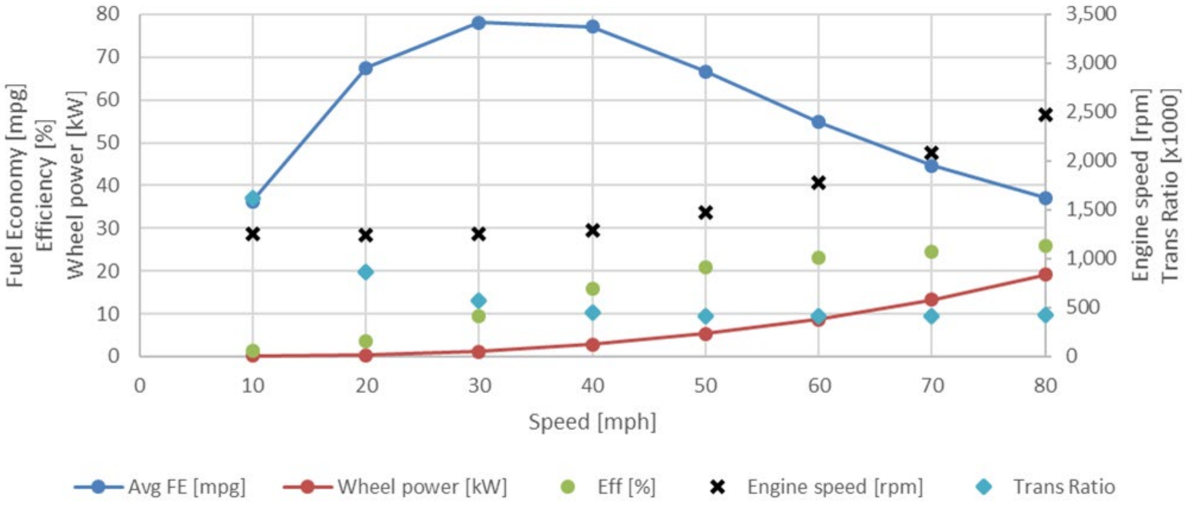


Figure 27: Steady state speed operation at 23 °C, 0% grade and Tier 2 high-octane fuel

Additional steady state testing was completed to capture comparison data at operating conditions, including:

- An elevated temperature of 35 °C with solar emulation
- A low temperature of -7 °C
- Sport mode at 23 °C
- Grades of 0%, 3%, and 6% at 23 °C

The results of the 0% grade and elevated temperature condition are shown in Figure 28.

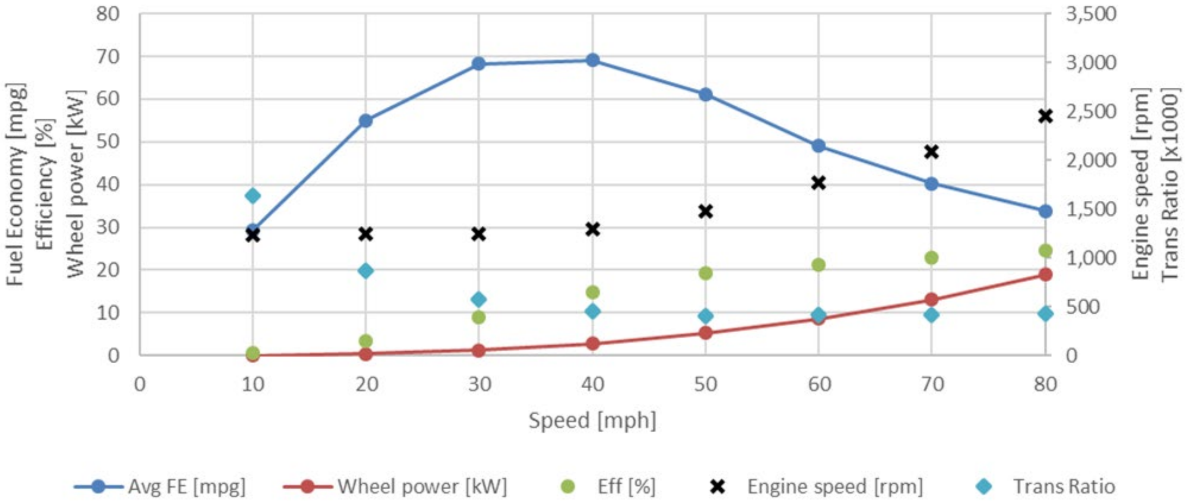


Figure 28: Steady state speed operation at 35 °C and 0% grade

Transmission operation at the elevated test temperature was similar to transmission operation during the 23 °C baseline test. Dynamometer target coefficients were held constant regardless of temperature, resulting in an equal wheel power requirement. It should be noted that though this results in equal wheel power requirements, this will result in a variation from real world operation as changes in air density were not adjusted which affect vehicle loading. Though rotating losses are reduced due to higher component temperatures, AC compressor loads result in a reduced peak fuel economy of approximately 68 mpg. This peak fuel economy remained consistent at the 30 to 40 mph speeds.

Vehicle efficiency is reduced by HVAC operation. This effect is greater at lower speeds due to the relative power requirement of HVAC compared to other loads. It should be noted the vehicle cabin reached steady state before start of test to avoid variable impacts of the "pulldown" of cabin temperature on the results.

An additional steady state speed test was completed at -7 °C to capture the impacts of cold temperatures; the results can be seen in Figure 29. As in the elevated temperature test, dynamometer target coefficients were held constant regardless of temperature to provide an equal wheel power requirement across speeds. Fuel economy and vehicle efficiency were reduced across the vehicle speed range during the low temperature test. This decrease was due to lower temperature components and fluids causing increased rotational losses, with the greatest impact demonstrated at low speeds.

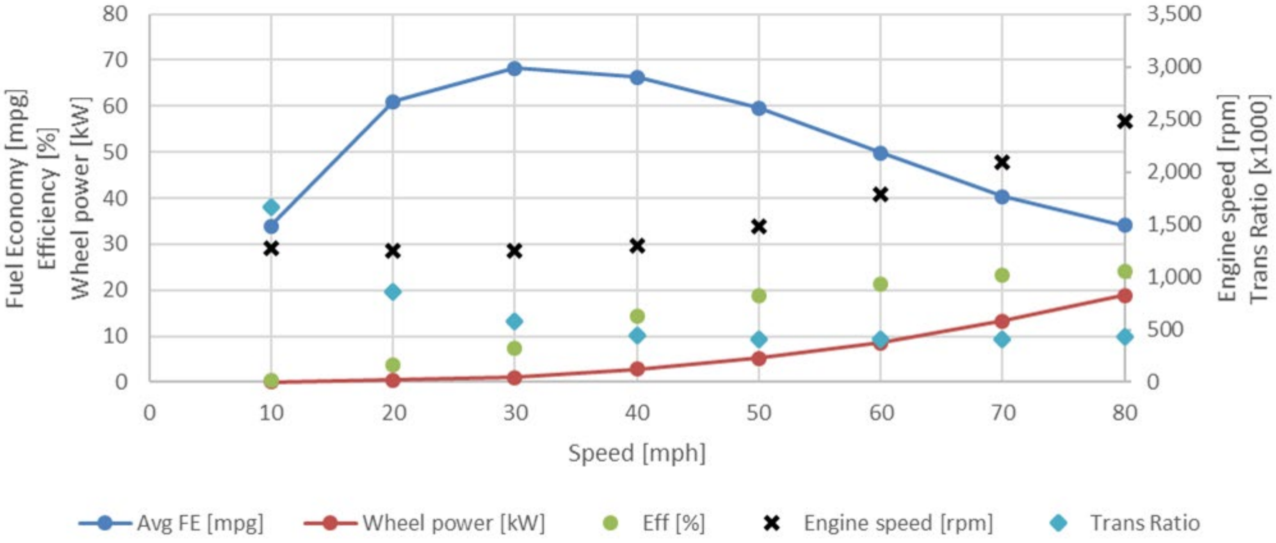


Figure 29: Steady state speed operation at -7 °C and 0% grade

Operating the transmission in Sport mode resulted in a significant change in powertrain performance. This change in operation can be seen in Figure 30. For the test speed, the CVT ratio was increased, resulting in a higher engine speed. Higher powertrain speeds resulted in higher powertrain losses, reducing fuel economy and vehicle efficiency across the speed range. The fuel economy at speeds of 30–40 mph, the speeds that yielded the highest results, was approximately 35% lower than in Drive.

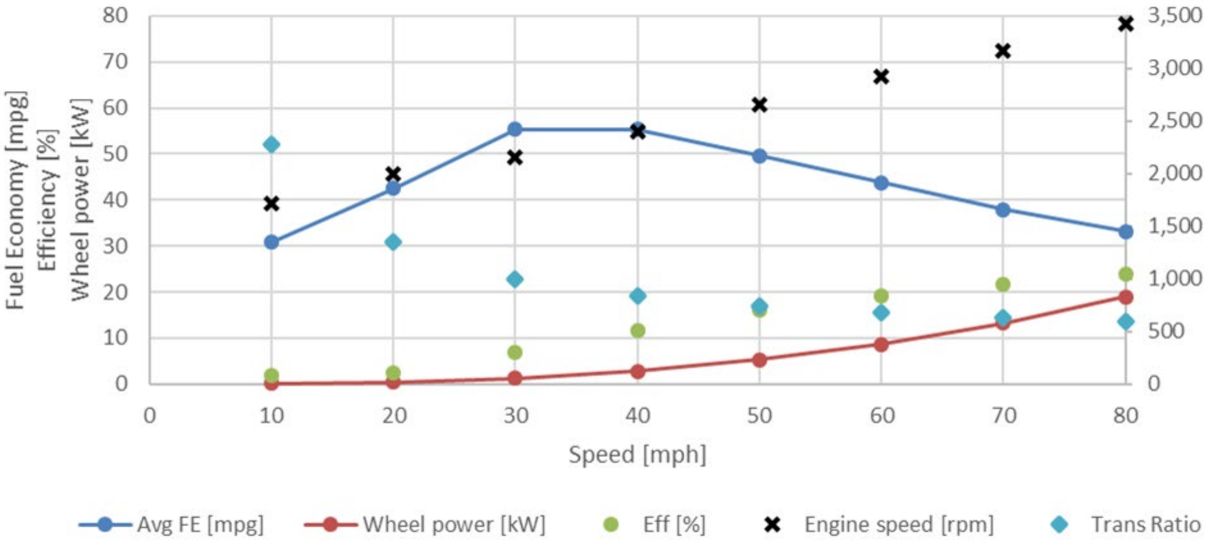


Figure 30: Steady state speed operation at 23 °C and 0% grade in Sport mode

Figure 31 and Figure 32 display vehicle operation while the vehicle is in Drive on a constant grade of 3% and 6% respectively. A change in vehicle loading can be seen as an increase in wheel power as the grade increases from baseline 0% grade to 3% and 6% grade tests. At 3% grade, the increase in required wheel power has no impact on engine speed or transmission ratio selection until a speed of 40 mph is reached. At over 40 mph, engine speed is increased, and the transmission ratio remains higher to deliver greater wheel power. The additional loading results in a considerable reduction in fuel economy, though efficiency is increased due to the change in powertrain load point. Operation at 6% grade further demonstrates these trends, with decreases in fuel economy but increased efficiency.

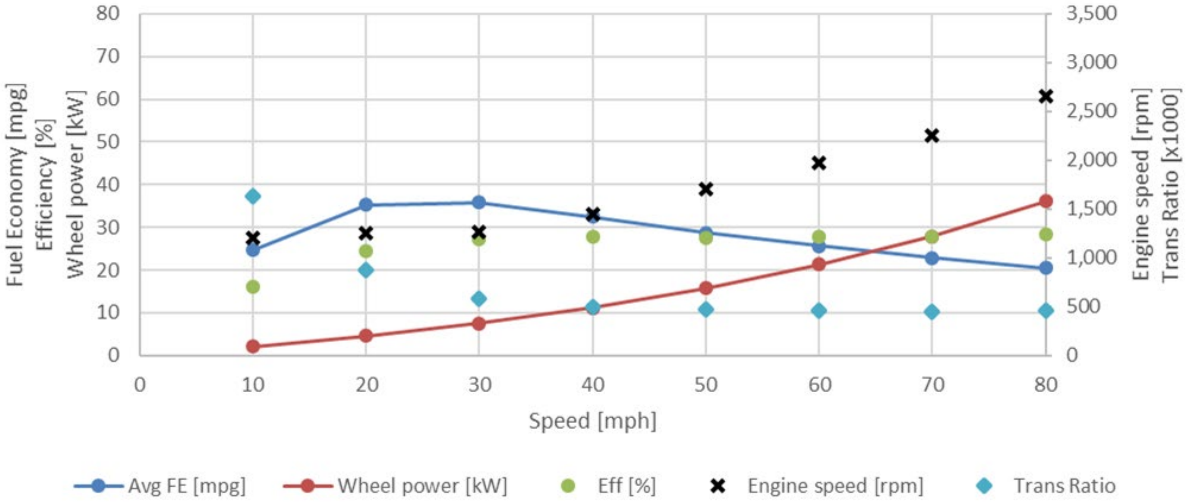


Figure 31: Steady state speed operation at 23 °C and 3% grade

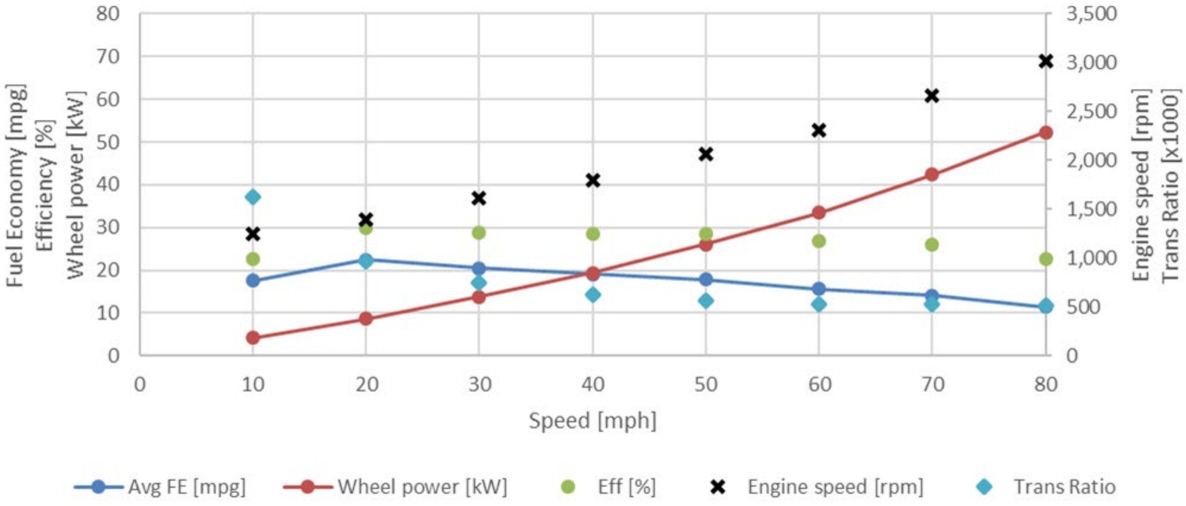


Figure 32: Steady state speed operation at 23 °C and 6% grade

4.5. Passing Maneuver

Specific tests were performed to characterize a vehicle overtaking another on a highway. 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. Additionally, 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 13 summarizes the time to complete each passing maneuver on both high- and low-octane fuels and for a passing maneuver performed in Sport mode.

Table 13: Time duration for acceleration events in seconds

Passing Maneuver Times				
	mph	**0% grade**	**3% grade**	**6% grade**
Low-Octane Drive Mode	35-55	4.1	4.5	4.9
	55-65	3.1	3.5	3.9
	35-70	7.2	8.2	9.8
	55-80	6.7	8.2	10.3
Low-Octane Sport Mode	35-55	3.9		
	55-65	2.8		
	35-70	6.8		
	55-80	6.4		
High-Octane Drive Mode	35-55	4.1	4.4	4.7
	55-65	3.0	3.3	3.6
	35-70	7.1	7.8	8.8
	55-80	6.7	7.6	8.8

A plot of powertrain details for the passing maneuver from 55 mph to 80 mph, with low-octane fuel and the vehicle in Drive, is shown in Figure 33.

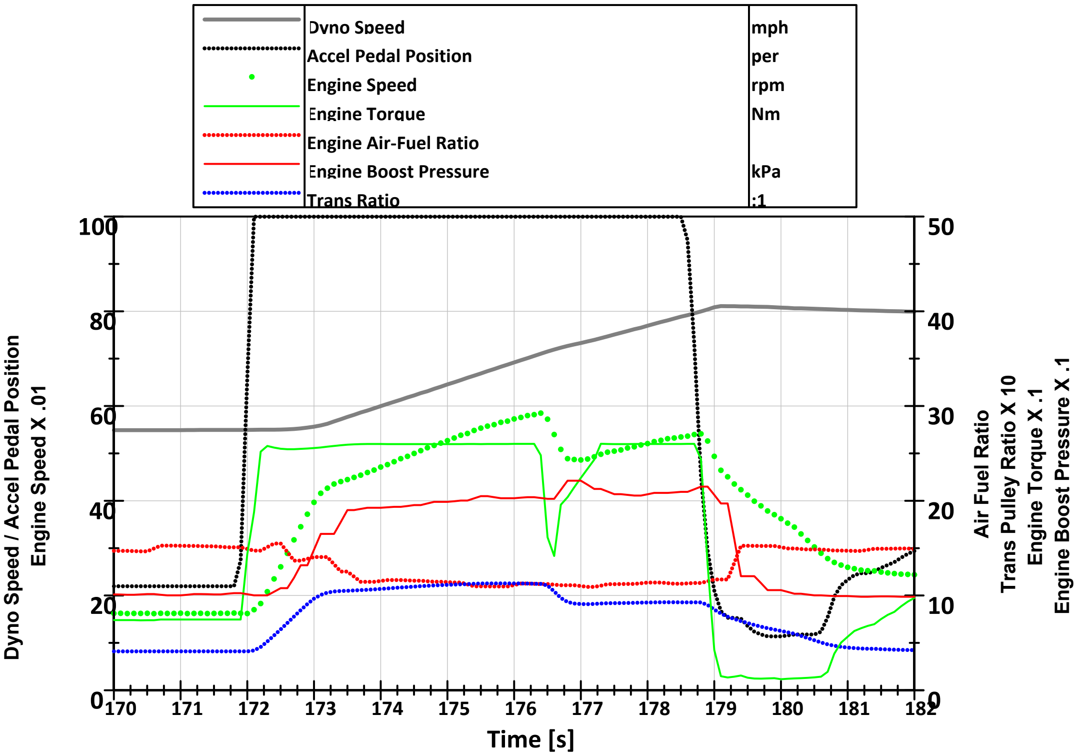


Figure 33: Powertrain operation during the 55 mph to 80 mph passing maneuver with low-octane fuel in Drive at 0% grade

In this case, the powertrain required slightly more than 0.4 seconds after application of the accelerator pedal to reach a peak torque of 250 Nm. The CVT begins to transition from an initial ratio of just below 0.5 immediately after pedal application and reaches a maximum rate of ratio change slightly after 1 second. This maximum rate of change continues until a speed of 70 mph, where a ratio change occurs, reducing the ratio to around 0.92. Fuel enrichment begins around 0.5 seconds after the 100% pedal movement and blends to a ratio of 10:1 to 11:1 once the turbocharger boost pressure rate has stabilized. The acceleration on the low-octane fuel in drive takes about 6.7 seconds.

A separate test was conducted with the vehicle in Sport mode. The same section of this test, the 55 mph to 80 mph acceleration at 0% grade, is displayed in Figure 34.

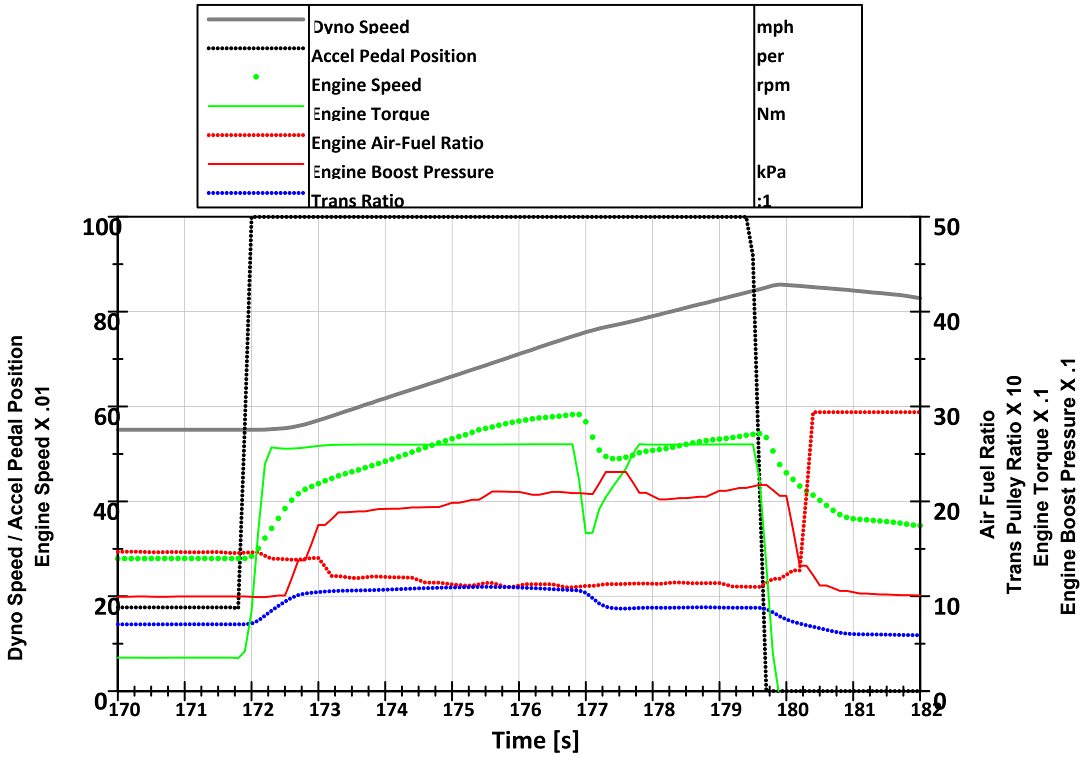


Figure 34: Powertrain operation during the 55 mph to 80 mph passing maneuver with low-octane fuel in Sport at 0% grade

The vehicle steady state operation at 55 mph changes while in Sport mode. The plot shows that the engine speed before the passing maneuver is held at 2,800 rpm, as compared to an engine speed in Drive mode of 1,625 rpm. As the engine was at a higher speed due to the higher transmission ratio, the delivered engine torque at 55 mph was reduced from 75 Nm to 35 Nm while the engine power remained constant at just above 10 kW. Following the driver's movement to 100% pedal, engine power and intake manifold pressure increased at a comparably faster rate than in Drive. This reduced the time for the passing maneuver by 0.3 s.

A third passing maneuver test was performed after the vehicle fuel swap from low-octane fuel to high-octane fuel. The same section of this test, the 55 mph to 80 mph acceleration at 0% grade, is shown in Figure 35.

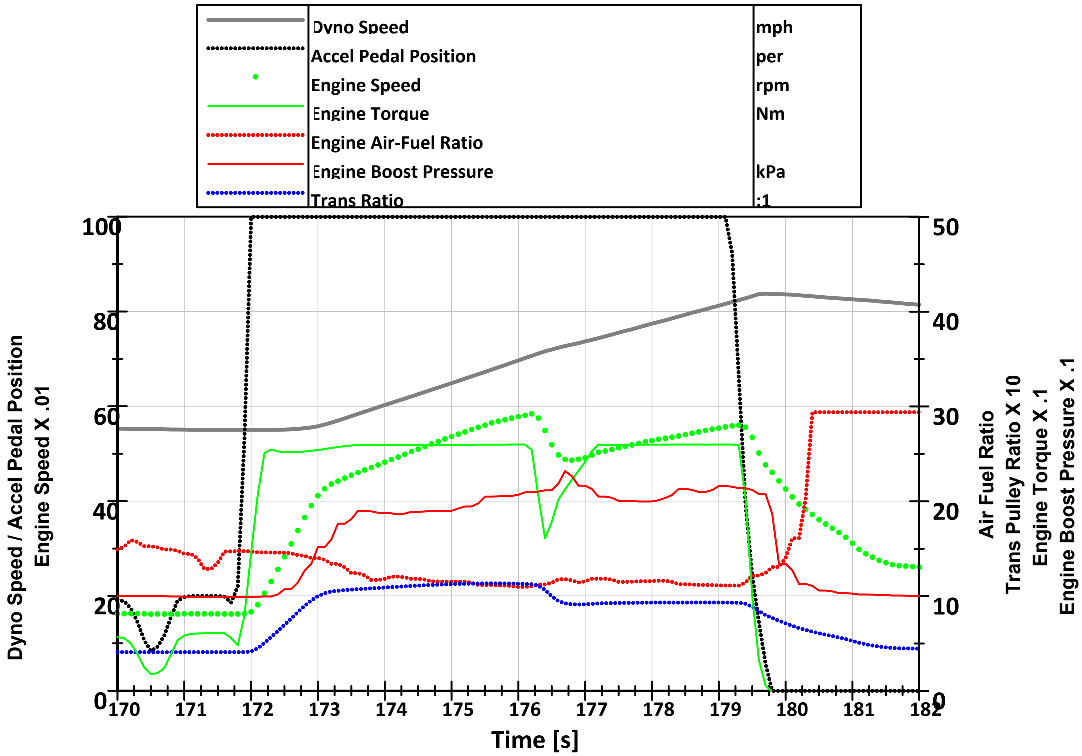


Figure 35: Powertrain operation during the 55 mph to 80 mph passing maneuver with high-octane fuel in Drive at 0% grade

At 0% grade, no significant difference in the time needed for passing maneuvers is seen between the two fuels. At a higher vehicle load, as seen on the 3% and 6% grade passing maneuver, a notable increase of 1.5 s is found. A 4-degree difference in the knock retard on the 6% grade 55 mph to 80 mph acceleration when comparing the two fuels, with the high-octane fuel holding at 6 degrees. As a result, engine boost pressure and throttle position are increased with the high-octane fuel, allowing for a reduced transmission pulley ratio. The combination of these factors results in a higher dynamometer power and a reduced acceleration time.

4.6. Maximum Acceleration

Maximum acceleration performance tests were performed on the chassis dynamometer. The test is performed from a rolling start to alleviate traction issues of the tire on a steel roll. During this testing two powertrain behaviors were observed.

In the first type of powertrain behavior, the CVT simulates fixed gear ratios at speeds above 40 mph while the accelerator is at 100%, as seen in Figure 36. The engine accelerates up to 6,300 rpm and produces 156 kW (209 hp). From vehicle background research [1], this emulated shifting is the standard behavior a driver could expect in full acceleration on the road.

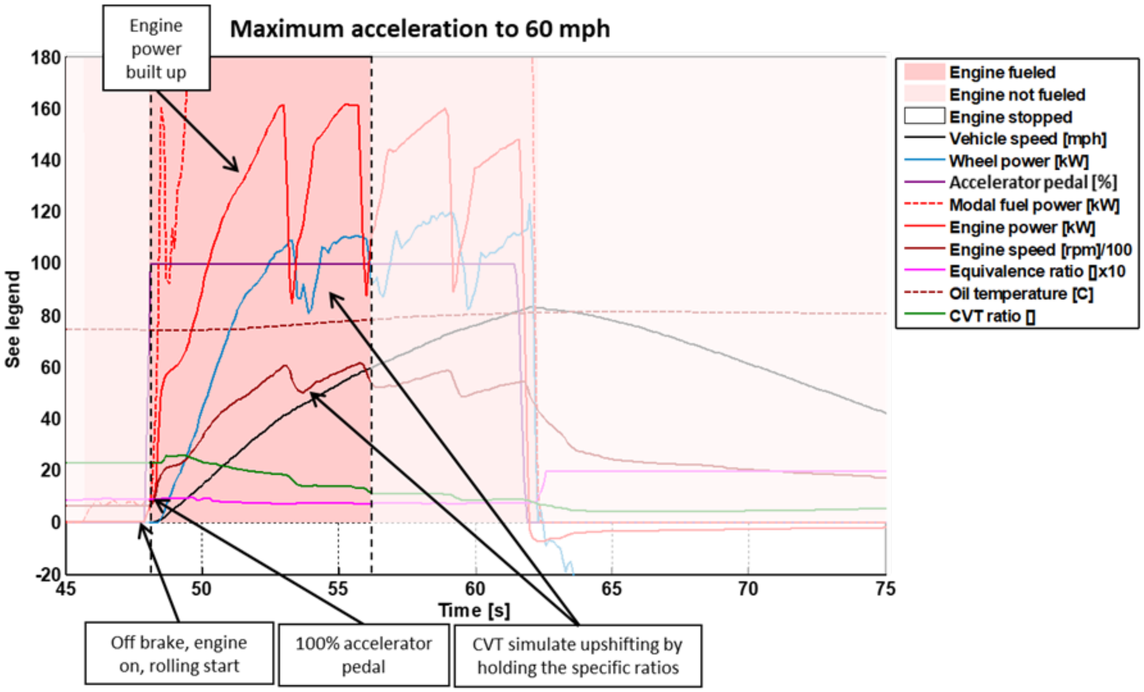


Figure 36: Powertrain operation during maximum acceleration, with a focus area highlighted

Note that in the maximum acceleration runs, the engine power of 165 kW (221 hp) is higher than the SAE rated horsepower of 143 kW (192 hp) during this short acceleration event. Argonne also tested the vehicle on a simulated 25% grade test, during which the continuous power settled at 146 kW (196 hp) with 6,300 rpm and 220 Nm, as shown in Figure 37.

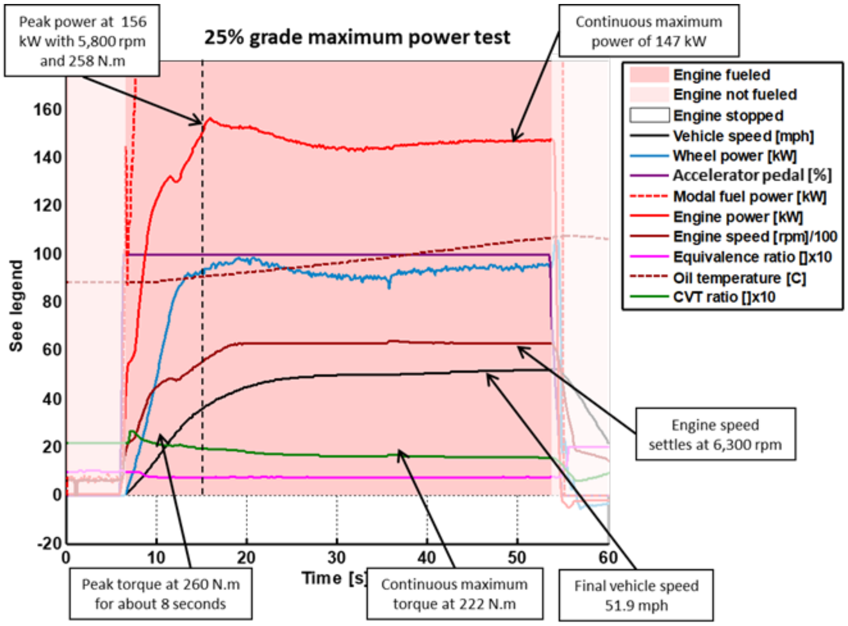


Figure 37: Honda Accord continuous power test on simulated 25% grade, with a focus area highlighted

The second powertrain behavior observed in full acceleration testing, limited the engine power while the CVT smoothly and continuously adjusts the transmission ratio, as seen in Figure 38. In this state, though no malfunctioning indicator lamp (MIL) was displayed, the engine is maintained at a roughly constant speed of around 4,000 rpm and at power levels of 110-130 kW. This limit continued over five consecutive acceleration cycles and is notable. Though the specific cause of this powertrain operation was not found, nor later repeated, it demonstrates vehicle operation in a state in which vehicle powertrain performance is reduced.

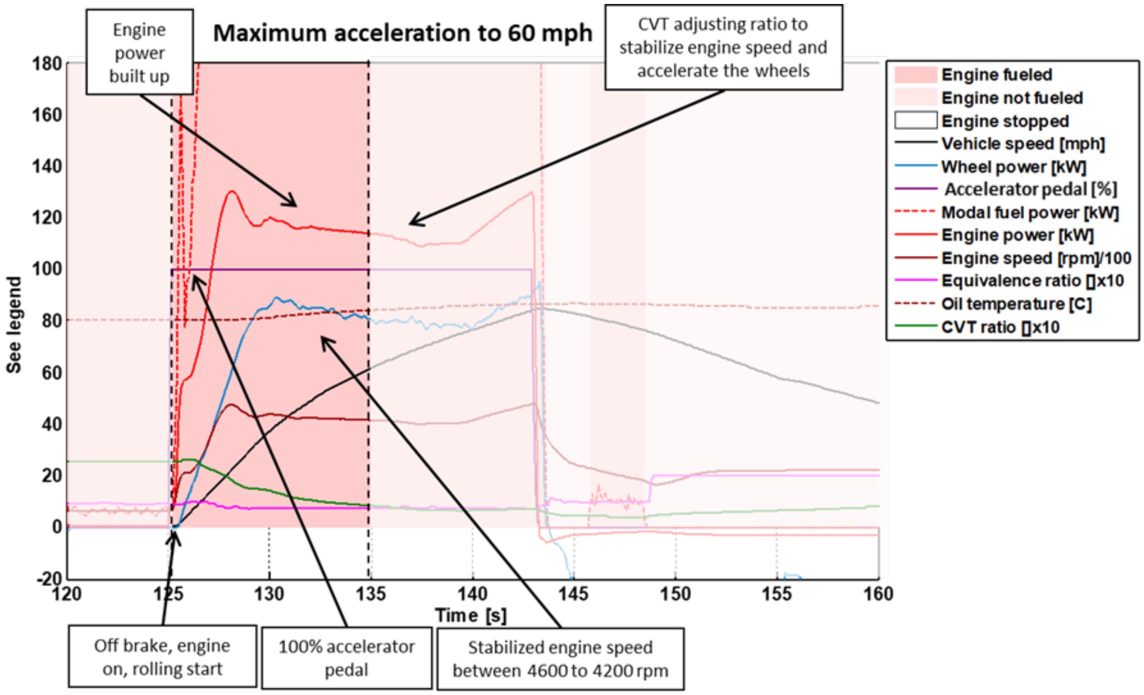


Figure 38: Powertrain operation during maximum acceleration with simulated constant gear ratios, with a focus area highlighted

4.7. Idle Fuel Flow Rate Test Results

A 30-minute engine idle test in cold start conditions was performed with the transmission in Park, following a 12-hour 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.

Figure 39 shows the first 120 seconds of the cold start engine idle test. The engine is started at 23 seconds into the test. On starting, the engine speed increases to over 1,750 rpm, and gradually settles to 1,100 rpm before transitioning to closed-loop operation about 60 seconds later. During this period, the ignition is retarded to help warm up the exhaust after-treatment system. During the transition to closed loop operation, ignition timing advances and stabilizes, and gradually engine speed and engine fuel power (calculated from fuel flow rates and fuel properties) decrease. At the transition, the catalyst temperature from diagnostics (vehicle estimated) is reported at about 200 °C.

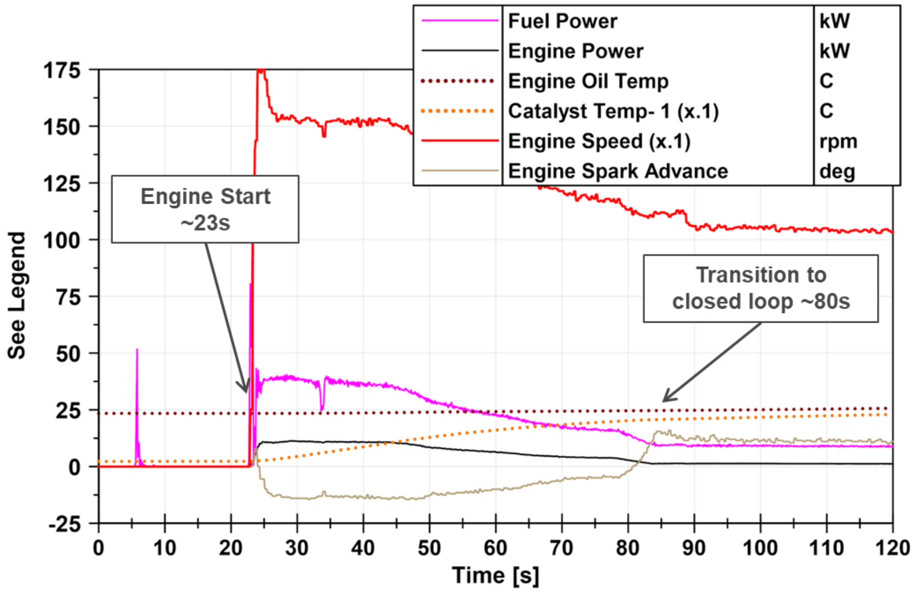


Figure 39: Initial 120 s of the idle fuel flow test

The full 30 minutes of the idle fuel flow test can be seen in Figure 40. It should be noted that the fuel spike, seen at ~5 sec is a result of the fuel system pressurizing, causing a temporary flow through the fuel scale though not used by engine operation. The engine oil temperature continues to increase over the duration of the test, ending at slightly over 73 °C. The catalyst temperature increases over the duration of the test as well, reaching a near steady state temperature at the end of the test of just under 410 °C.

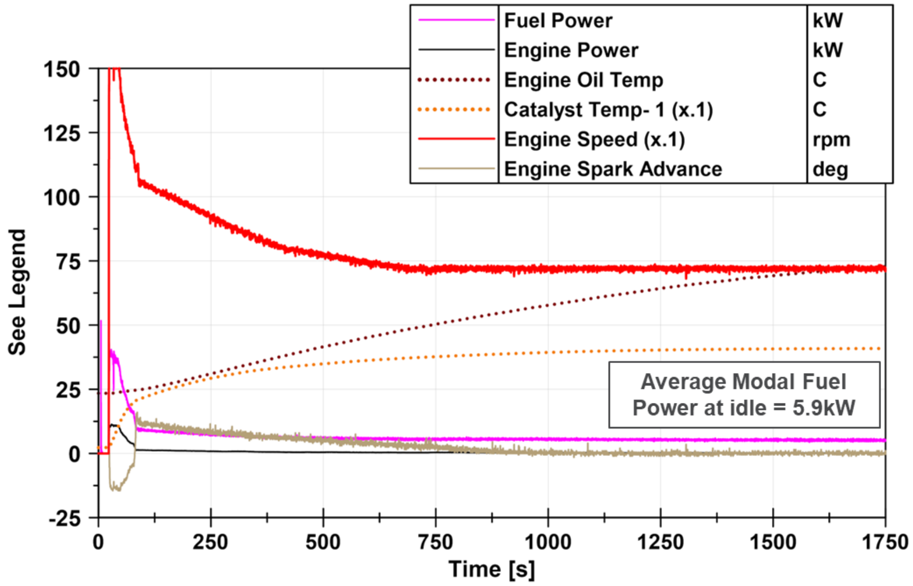


Figure 40: Idle fuel flow test—full duration

4.8. 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 the 2018 Honda Accord, and due to lower price, the lower octane fuel is expected to be the dominant fuel used by consumers. Argonne tested the vehicle on low and high octane certification fuel to investigate the effects 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 premium fuel, and the Tier 3 fuel represents regular fuel in this investigation.

The specifications for the fuels are in Table 4, Table 5, and Table 6, with full fuel specification sheets in Appendix E: Cert Fuel Specifications, and further details on these fuels can be found in section 3.4.4. Though both fuels are standard test fuels, several differences should be noted, including octane, energy content, and ethanol content. The Tier 3 – 88 AKI has a volumetric energy content that is 3.7% lower than the Tier 2 – 93 AKI's.

The unadjusted fuel economy results comparing the bench reported fuel consumption of the two fuels on certification cycles are shown in Table 14. The impacts of the lower-octane fuel on bench reported fuel economy are seen across all drive cycles, though at a higher amount on cycles with higher powertrain temperatures and powertrain loading.

Table 14: 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 of low and high octane fuels on mpg**
UDDS#1 Cold Start	37.7	37.9	**-0.3%**
UDDS#2 Hot Start	39.8	40.6	**-2.0%**
UDDS#3 Hot Start	39.3	40.9	**-4.0%**
HWFET	55.6	56.1	**-0.9%**
US06	32.3	34.4	**-6.5%**

Vehicle efficiency based on SAE J2951™[10] calculations are shown in Table 15. 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, which was outside the scope of this effort.

Table 15: Octane impact on vehicle efficiency

Vehicle Efficiency	**Tier 3 – 88 AKI**	**Tier 2 – 93 AKI**
UDDS#1 Cold Start	23.9%	23.2%
UDDS#2 Hot Start	25.2%	24.8%
UDDS#3	24.9%	25.0%
HWFET	32.0%	31.3%
US06	31.0%	31.9%

The value of knock feedback correction on a pair of UDDS cycles, with the first being a cold start, is shown in Figure 41 for the series of tests for both fuels. The correction value on the high-octane Tier 2 – 93 AKI fuel is consistently higher than the low-octane Tier 3 – 88 AKI fuel.

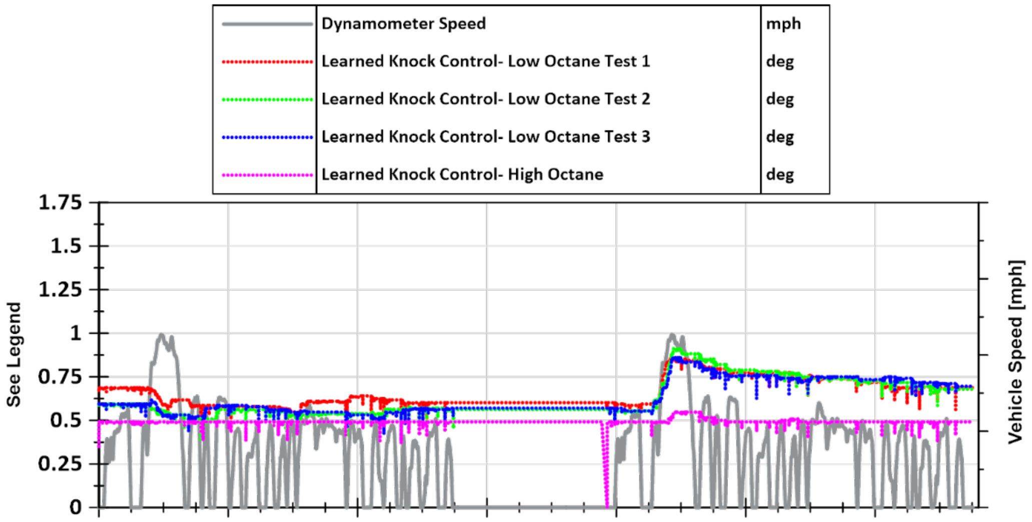


Figure 41: Knock feedback signals on UDDSx2, cold start cycles

Figure 42 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 vehicle reported engine torque was found to be equal for both fuels. With the lower octane fuel, the spark ignition timing is retarded by a few degrees at these higher loads to prevent engine knock from occurring.

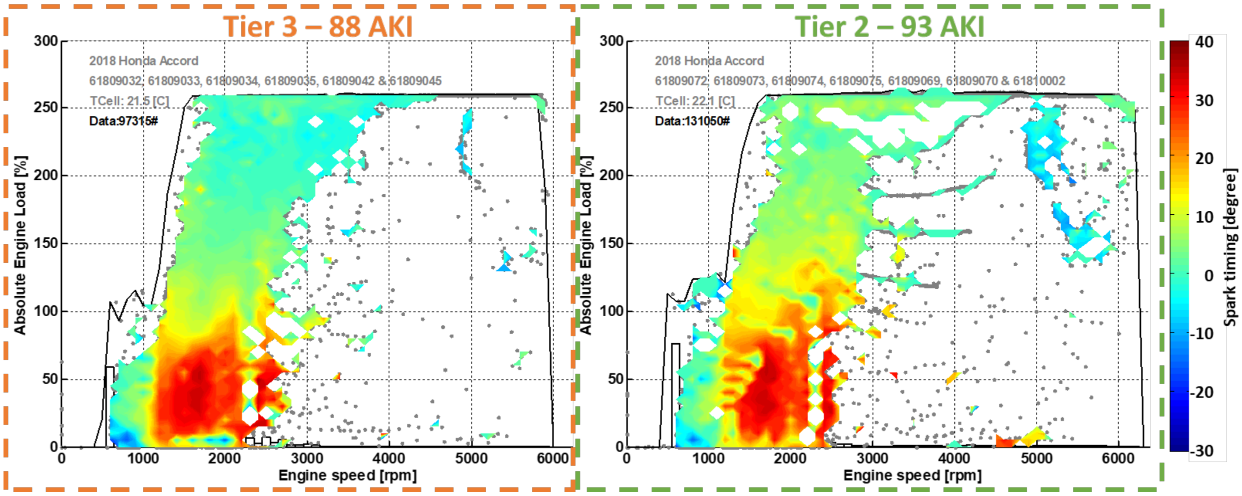


Figure 42: Spark advance comparison between Tier 2 and Tier 3 fuels

Further evaluation was completed on vehicle acceleration from a standstill. The vehicle performed better using the 93 AKI fuel compared to the 88 AKI fuel. The vehicle accelerated to 80 mph 1 second faster under maximum acceleration with the 93 AKI fuel. The performance tests suggest that the engine torque is increased with the high-octane fuel, due to spark advance. Additionally, the difference between the two fuels was outside of test-to-test uncertainty, most notably at 6.5% on the higher load US06 cycle. At the lower load cycles of the UDDS and HWFET the impact to fuel economy was reduced.

5. 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.

5.1. 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 43.

In Figure 43 the signals labeled in black, blue, and green are obtained directly from the test. At the energy management strategy level, the signals used to calculate the engine and battery power are critical, and directly obtained from the test. While not all signals can be recorded during testing, some can be easily calculated from the measured ones. For example, the output torque and speed of the transmission are 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 FRM (final rulemaking) study [7]. Techniques used in the process are described in the following section.

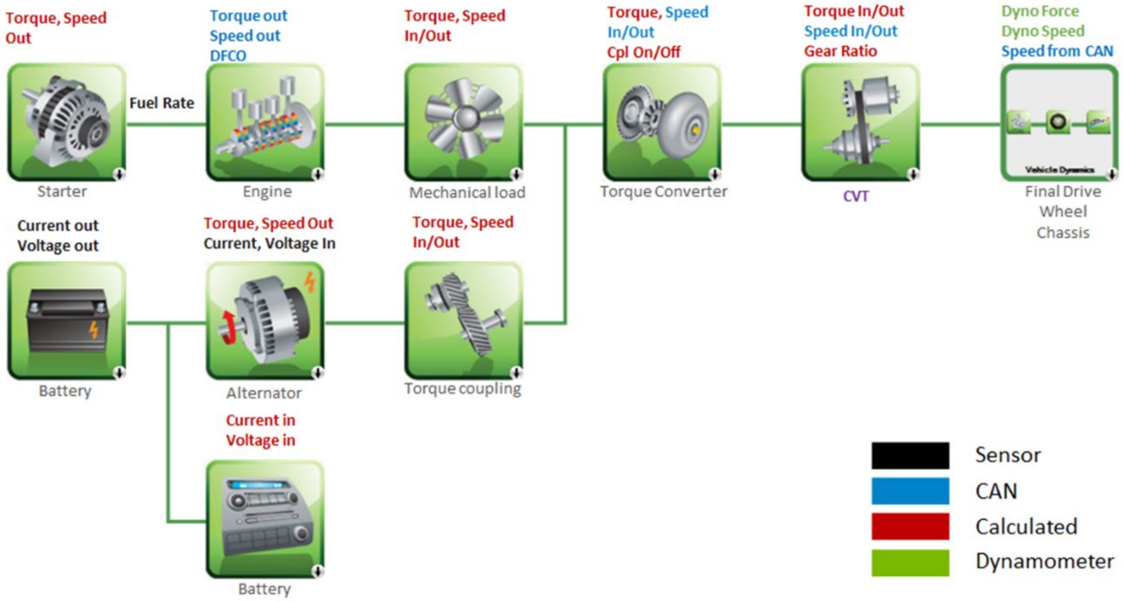


Figure 43: Schematic of the vehicle configuration

The signals marked in red in Figure 43 are calculated based on measured signals and additional information obtained from vehicle details [1], and EPA test information [6]. The details of this calculations are explained in this section. First, the time-based rotating speed and torque of each component is calculated as shown in Figure 44.

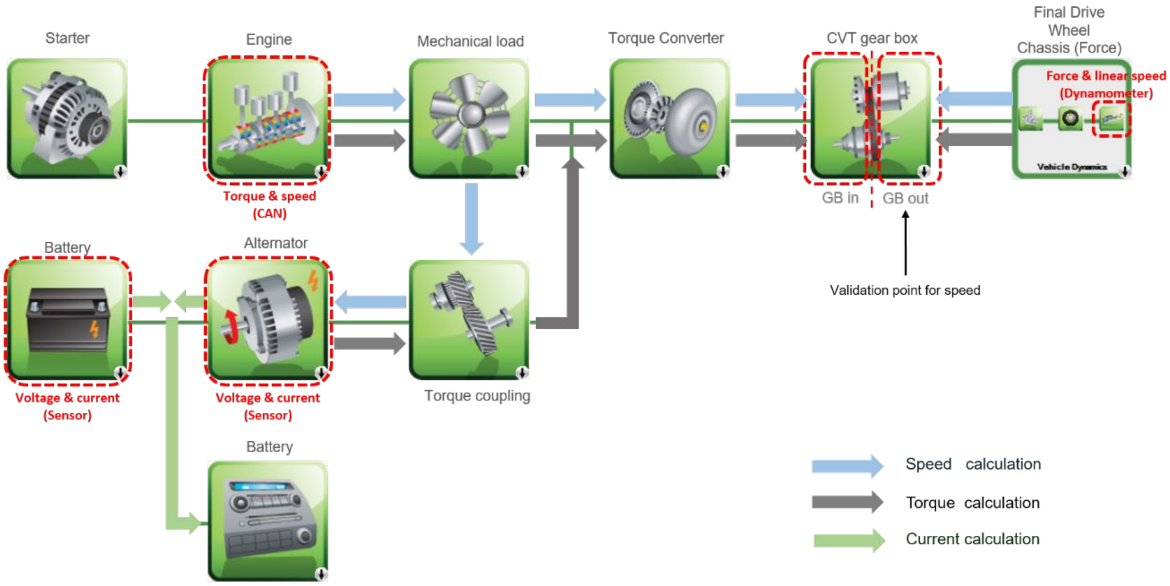


Figure 44: Calculation of missing signals for component

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

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

Equation 1

where r_t is the tire radius and γ_{fd} is the final drive ratio. Because the exact tire radius in driving conditions is not known, the speeds can be validated by comparing the two values of $\omega_{GB,out}$ and $v_{chassis}$ by adjusting the tire radius. While there may be no discrepancy in speed for the wheel and chassis, the torque calculations should be carefully handled because each component torque measurements include uncertainties.

Figure 44 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. The output torque of the final drive is calculated from the force obtained from the dynamometer:

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

Equation 2

The gearbox output torque 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 final drive transfer coefficient, and k is 1 if the power flows from the final drive to the wheel or -1 if the power flows in the other direction. These values are generic and will be applied to following calculations in this report:

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

Equation 4

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

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

Equation 5

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

Equation 6

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

The transmission input torque is calculated from the torque converter input torque and the torque converter characteristics. The speed ratio can be calculated from CAN signals for transmission input and output speed:

$$T_{gb,in} = T_{TC,out} = T_{TC,in} \cdot T_{ratio}(= f(\omega_{ratio}))$$

Equation 7

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

All the equations for torque calculation are based on static equilibrium. The parameter values used in the calculations are listed in Table 16.

Table 16: Parameter values used for calculating additional signals [1]

Parameters	**Values**
Tire radius, r_t	0.317m
Gear ratio range of CVT	0.405 ~ 2.645
Gear ratio of the final drive, γ_{fd}	5.36
Vehicle test weight	1588kg

In addition to the signals introduced in this section, other signals representing efforts and flows are calculated based on component assumptions [7].

5.2. Transmission Operation

The 2018 Honda Accord has a continuously variable transmission (CVT). The control algorithm in Autonomie used to select the CVT gear ratio relies on multiple parameters that need to be calibrated for each individual vehicle. The transmission operation was analyzed to estimate those control parameters used in Autonomie. The details of such analysis are explained in the subsequent sections.

5.2.1. Gear Ratio Control

To understand the choice of reduction ratio in CVT, we divided the infinite gear range into 55 sub-ratio segments. Figure 45 shows the comparison of time spent in each gear ratio segment for each cycle.

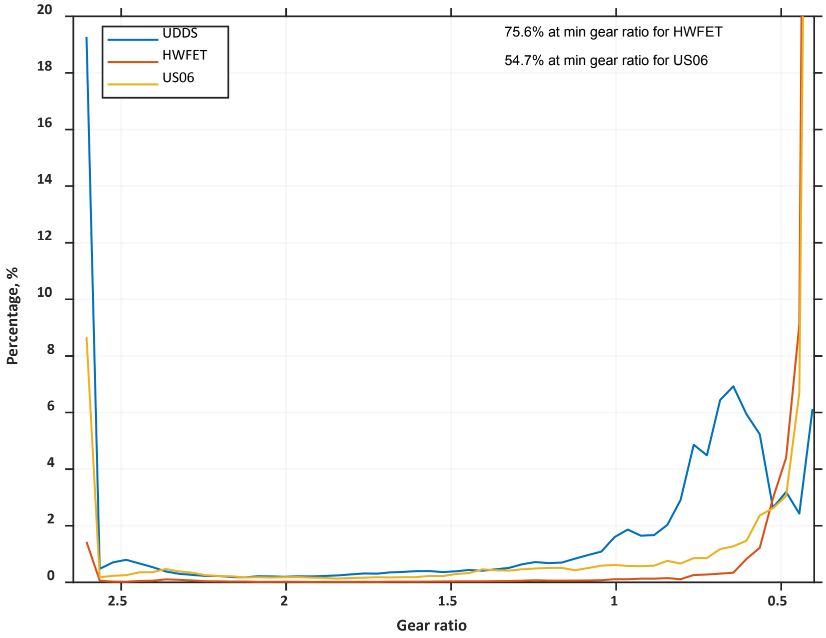


Figure 45: Time spent in each gear ratio segment for UDDS/HWFET/US06 cycles

In the urban driving cycle, the highest gear ratio (lowest gear range) is used about 19% of the time, versus just below 9% of the time in highway cycle. The low gear ratios are used more frequently, especially in the high-speed driving cycle, in which the minimum gear ratio (highest gear range) is used more than 50% of the time.

Understanding the choice of ratio at various vehicle speeds and acceleration scenario is essential in developing an accurate CVT control.

5.2.2. Torque Converter Lockup Control

In order to see the overall behavior of the torque converter lockup status, all operating points of the vehicle from testing are shown in Figure 46 and Figure 47. The graphs show the torque converter is locked above a certain speed regardless of wheel torque. In Figure 46, the clutch is locked at approximately 9mph or greater vehicle speed. However, in the high torque region at lower vehicle speeds, it can be seen that the torque converter is unlocked to use the torque multiplication effect.

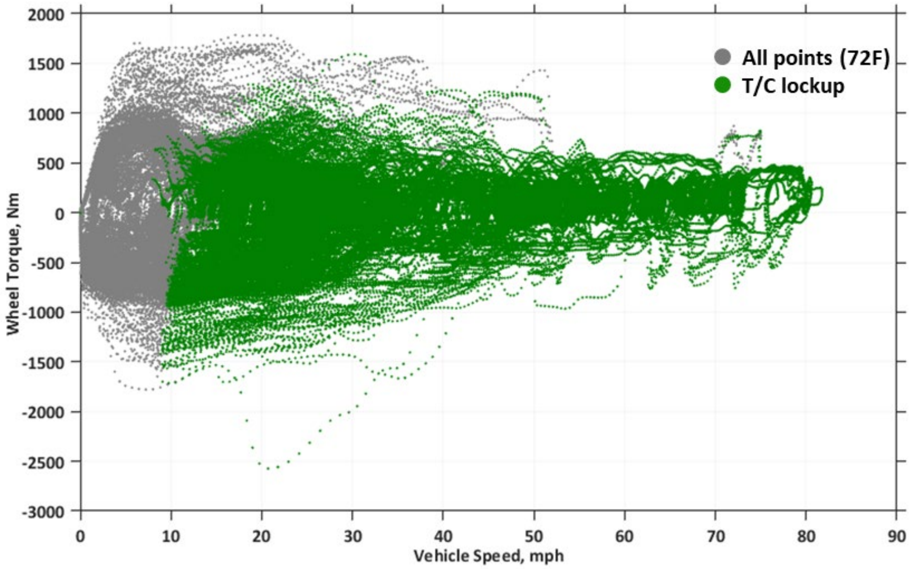


Figure 46: Torque converter lockup operation – wheel torque vs vehicle speed

In Figure 47, the torque converter lockup appears to occur when the CVT gear ratio drops below ~1.6.

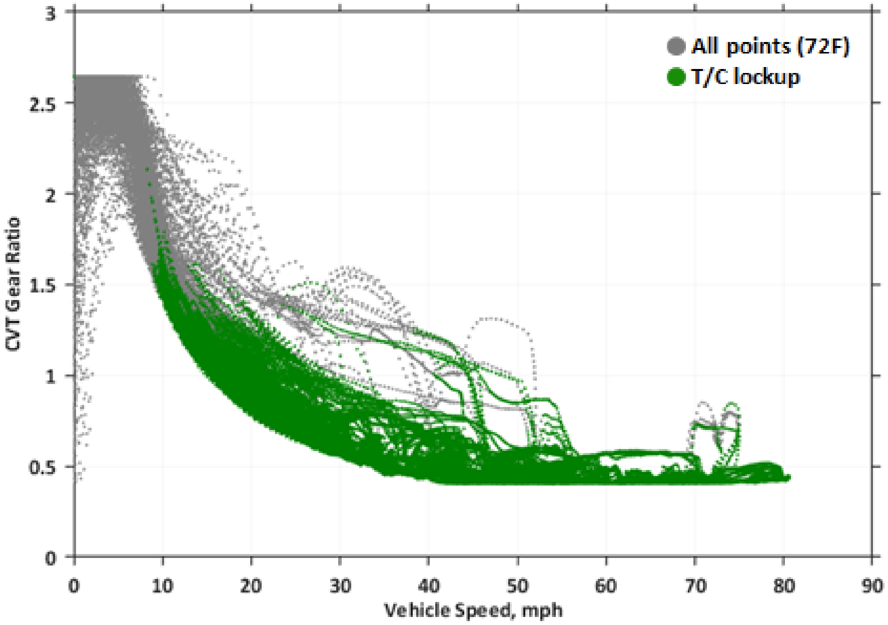


Figure 47: Torque converter lockup operation — vehicle speed vs CVT gear ratio

The percentage of torque converter lockup per test cycle is summarized in Table 17. When the vehicle is driven in the urban cycle the torque converter is locked approximately 67% of the time. During the highway cycle the torque converter can be seen locked over 97% of the time. Locking the torque converter helps improve the overall drivetrain efficiency. Hence the algorithm to govern the locking of torque converter is very important in improving fuel economy.

Table 17: Percentage time of torque converter locked per each test cycle

Test Cycle	UDDS	HWFET	US06	WLTP	JC08	LA92
%	67.01	97.95	80.49	69.87	62.12	50.54

5.2.3. Lockup Variability

To analyze how torque converter lockup is controlled for CVT operation, the points at which the clutch is engaged and the points at which the clutch is released were analyzed.

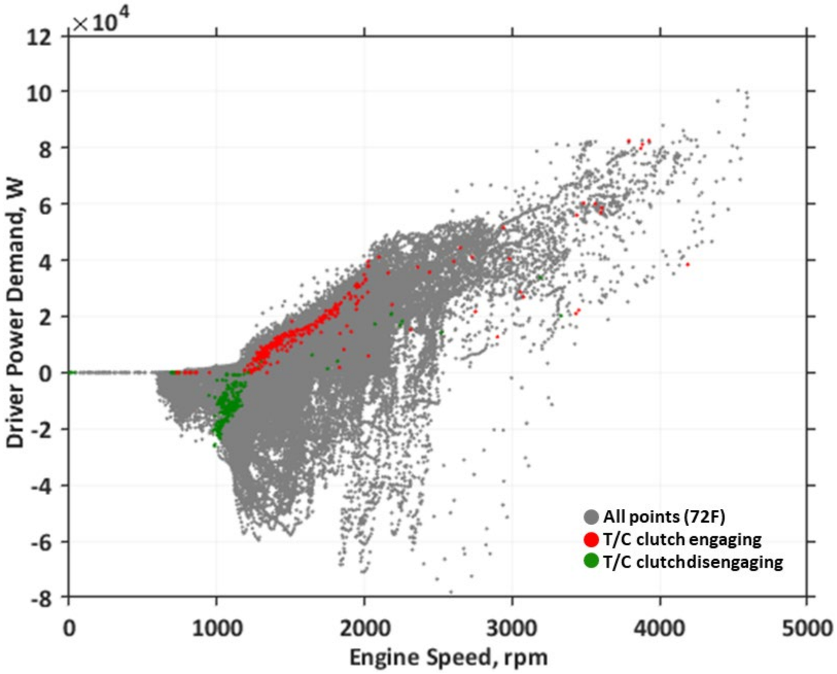


Figure 48: Torque converter operation points for clutch engaging vs. disengaging

In Figure 48 the points at which the torque converter clutch is engaging are the red points, and the points at which the clutch is disengaging are the green points, in the domain of engine speed and driver power demand. The points at which the clutch of the torque converter is engaging and disengaging are clearly visible in the form of lines. When the power demand increases, the clutch is engaged to minimize power loss from the torque converter.

5.3. Deceleration Fuel Cutoff

Deceleration fuel cutoff (DFCO), a feature that many modern-day engine control units (ECUs) support, detects whether the vehicle is coasting and, if certain operating conditions are met, cuts fuel to the engine and allows the wheels to keep the engine running. In this section, the DFCO enabling conditions will be determined in terms of vehicle speed, wheel torque requirement and CVT ratio choices.

In Figure 49 DFCO is active only when the wheel torque is negative, especially when the vehicle speed is above about 8 mph. In low vehicle speed cases (below about 14 mph), the wheel torque criterion of DFCO is decreased by 100 Nm or less.

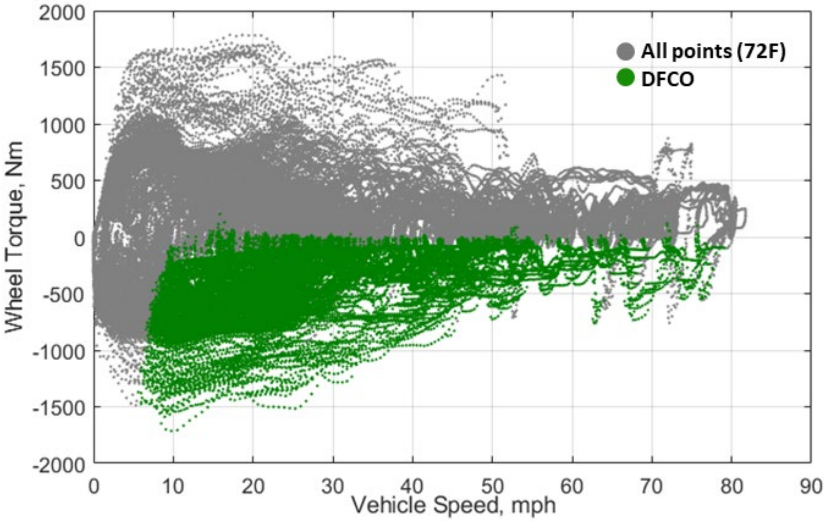


Figure 49: Operation of DFCO — vehicle speed vs wheel torque

Figure 50 shows that DFCO does not activate above a CVT gear ratio of about 2.2, even when the vehicle is braking.

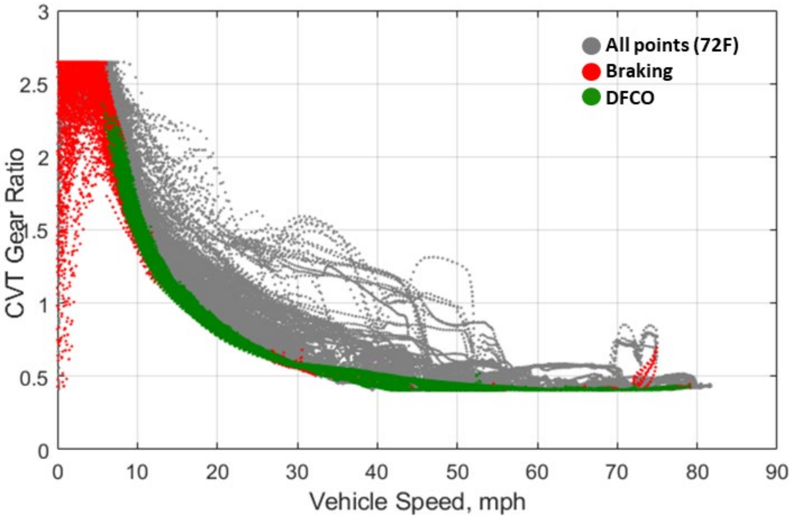


Figure 50: Operation of DFCO — vehicle speed vs CVT gear ratio

5.4. Brake Energy Regeneration Systems

Unlike a mechanical braking device, Brake energy recovery systems convert otherwise dissipated energy of the vehicle during deceleration into electrical energy using an alternator. This feature is similar to regenerative braking common in electric drive vehicles, but results in lower levels of power and stores the energy within a traditional low-voltage battery. Figure 51 shows the brake energy regeneration system points in a plot of engine output power against alternator mechanical power.

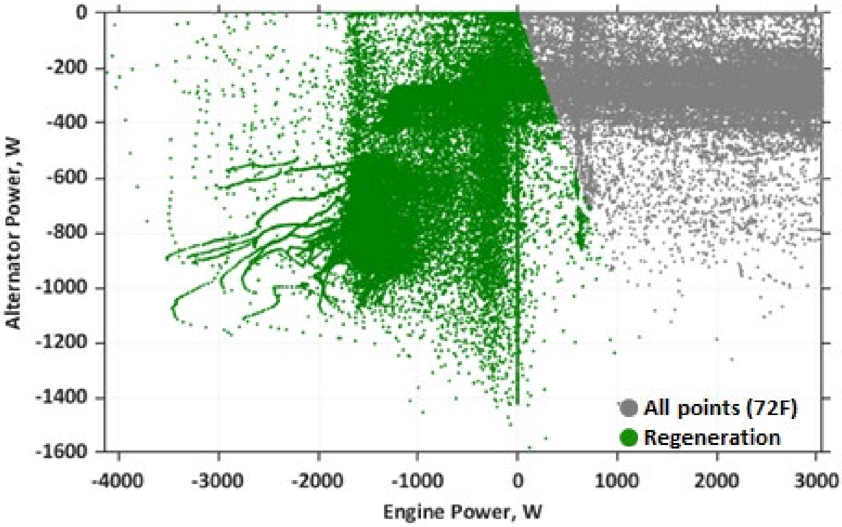


Figure 51: Brake energy regeneration system points — engine power vs alternator power

Figure 52 shows brake energy regeneration events as a function of vehicle speed against wheel torque. It can be seen that this system works in most deceleration situations except at low vehicle speeds (below about 3 mph).

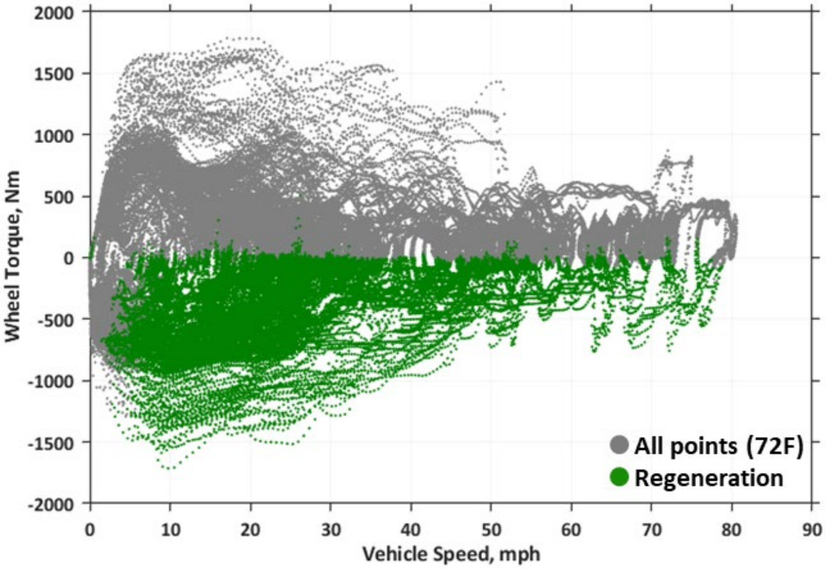


Figure 52: Regenerative braking points — vehicle speed vs wheel torque

Figure 53 shows mechanical braking power and alternator power on the UDDS cycle. The alternator power ranges from about 300 to 1,000 W when the vehicle is decelerating. The electric machine of the Honda Accord is not designed to maximize this energy capture as a means to reduce the overall energy consumption.

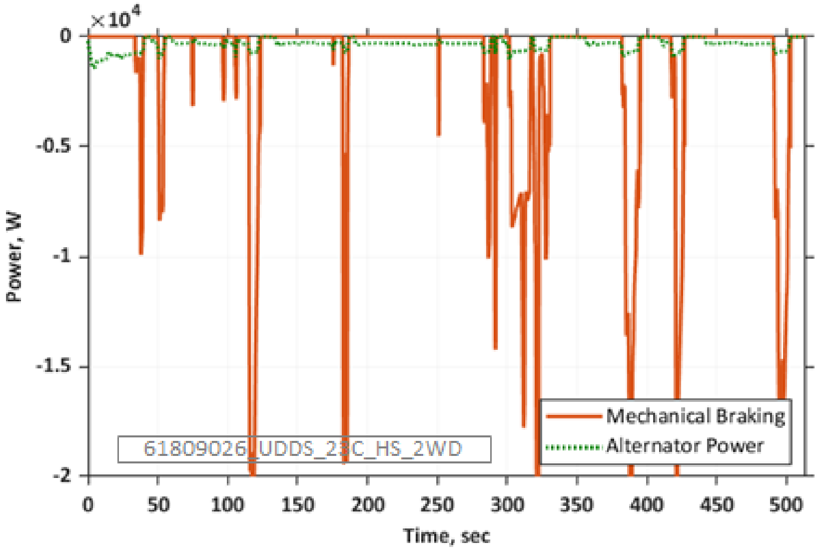


Figure 53: Mechanical braking power and alternator power on UDDS cycle

5.5. Engine Operation

5.5.1. Fuel Rate Map

The engine fuel rate map was generated from the engine mapping test data, shown in Figure 54. Since the components modeled in Autonomie were assumed to be in their warmup state, data where the engine coolant temperature was above 60 °C is used for Autonomie. Figure 54 only shows the points at which the time derivative of the acceleration pedal is below 0.1/s, and the engine coolant temperature is above 60 °C, from which it is assumed that the points are obtained under quasi-steady operating conditions.

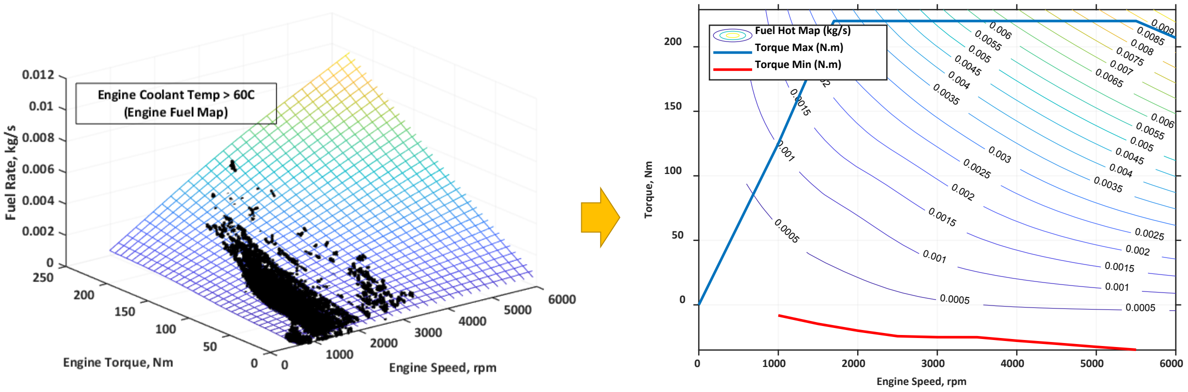


Figure 54: Engine fuel rate map according to engine speed and torque

5.5.2. Torque Pedal Map

The accelerator pedal is not a simple way of directly moving the throttle on the engine, because with an ECU, the traditional Bowden cable between the pedal and throttle is replaced with a pedal position sensor and a map. The torque pedal map does not depend on conditions like engine speed or transmission gear ratio. Instead, the engine throttle has a linear correlation with the middle of accelerator pedal in positions 0.25 to 0.6. A given pedal position and a given engine speed generate an engine torque demand, which is fed to the ECU to deliver the required amount of torque. In the low and high accelerator pedal positions, the engine throttle responds in a more gradual manner as shown in Figure 55.

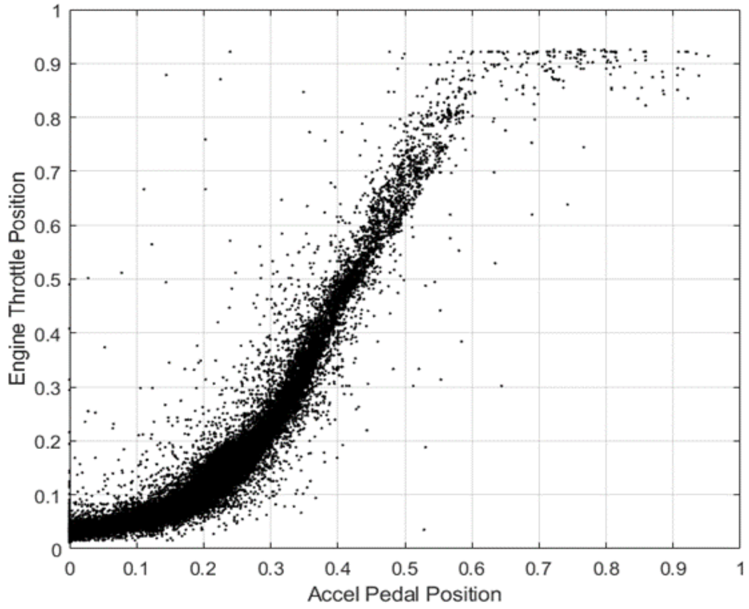


Figure 55: Torque pedal map

5.6. Thermal Management Impact on Vehicle Controls

In this section, we will focus on additional vehicle controls and how they are affected by thermal conditions. The impact of thermal conditions on performance and on the vehicle control are important issues. The effect of thermal conditions on control behavior will be discussed first, followed by performance analysis in different thermal conditions.

5.6.1. Engine Operation in Cold Conditions

Engine thermal management systems are designed to warm up the engine as quickly as possible with advanced techniques. However, it is difficult to completely avoid operating the engine at a low temperature. 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.

Figure 56 shows three different control behaviors based on different engine coolant temperatures:

- The engine operates normally and the coolant temperature is warm at start-up (hot start).
- When the coolant temperature is between 20 °C and 70 °C, the engine stays at a higher than normal idle speed, even if without power demand. This control behavior is specific to vehicle start-up, and the engine operates normally once the coolant temperature rises above approximately 70 °C.
- When the engine coolant temperature is very low (below 0 °C) in cold ambient temperatures, the engine operates at an higher speed until the engine coolant temperature warms up as shown in the figure below.

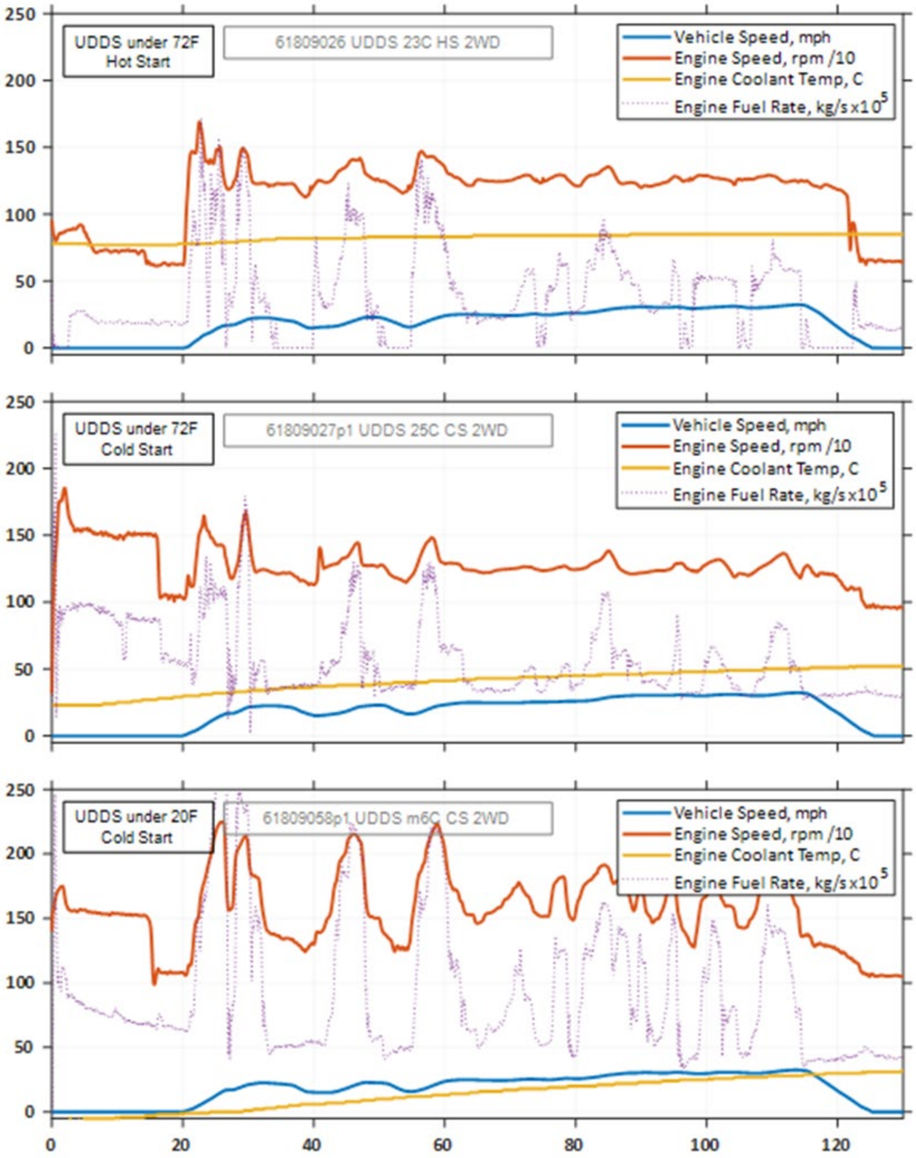


Figure 56: Engine operation at vehicle start-up differs according to the engine coolant temperature

As shown in Figure 57, the engine speed is controlled based on the engine coolant temperature, which means that the idle speed has a strong correlation with the engine coolant temperature in cold conditions.

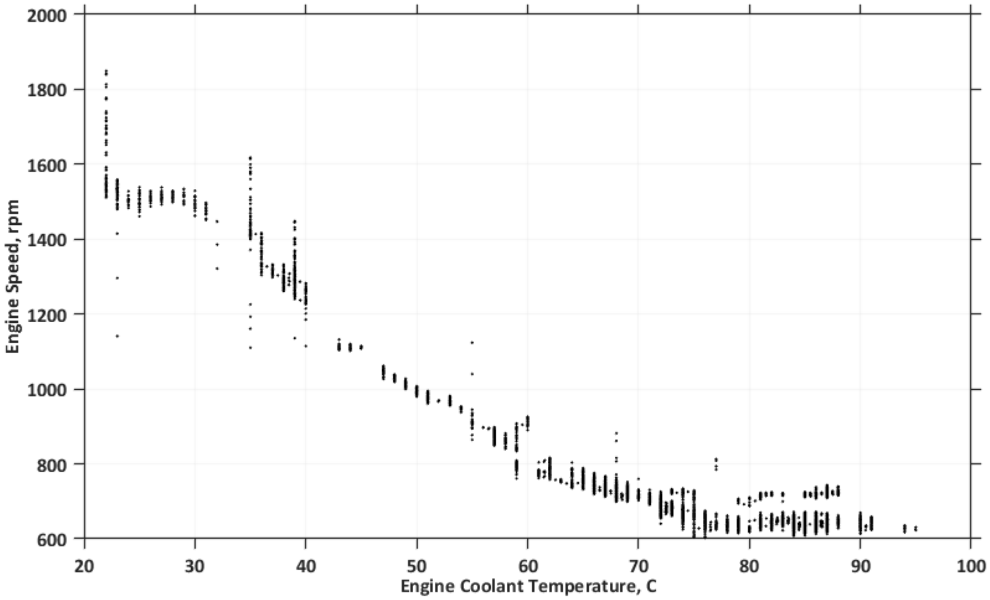


Figure 57: Engine idle speed is controlled by the coolant temperature

On the other hand, Figure 58 shows the effect of start-up coolant temperatures in driving conditions. The coolant does not reach its optimal coolant temperature within 1,200 second data window, as shown in the figure, when the vehicle is operated with the heater on in cold ambient temperatures.

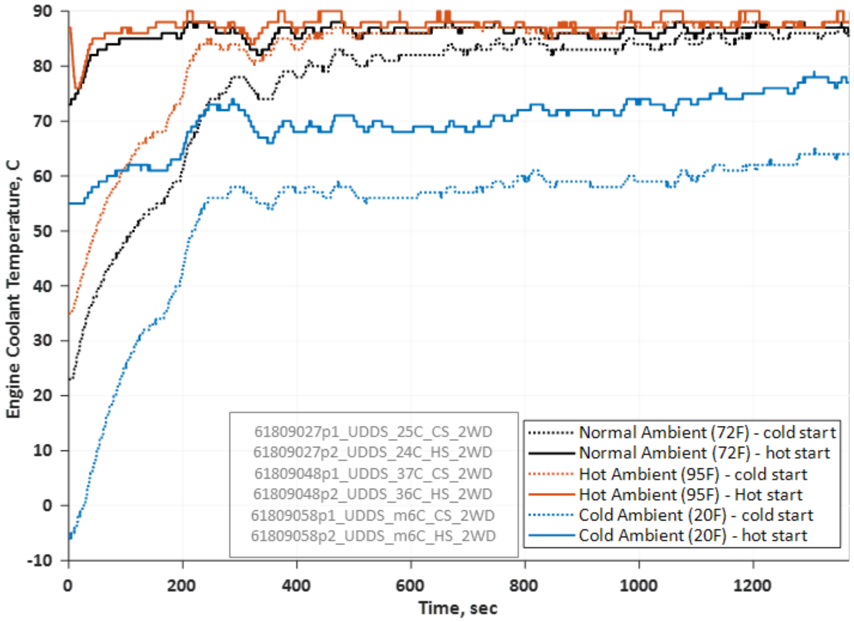


Figure 58: Behaviors of engine coolant temperatures on UDDS in different test conditions

5.6.2. Engine Performance

Thermal conditions affect not only components control but their performances as well. Engine performance noticeably deteriorates in very cold conditions. While we do not have complete component test data for different steady thermal conditions, the performance degradation caused by thermal conditions can be analyzed from the vehicle test data.

An engine generates a lot of heat. Approximately one third of the input power is converted to mechanical work, another third is removed through exhaust, and the last third contributes to heating the engine block and cooling system. Therefore, the engine temperature increases very quickly as long as the engine is operating, but a high coolant temperature is not sustained if the ambient temperature is very cold. Figure 59 shows that the fuel consumption rate is significantly affected by the thermal conditions.

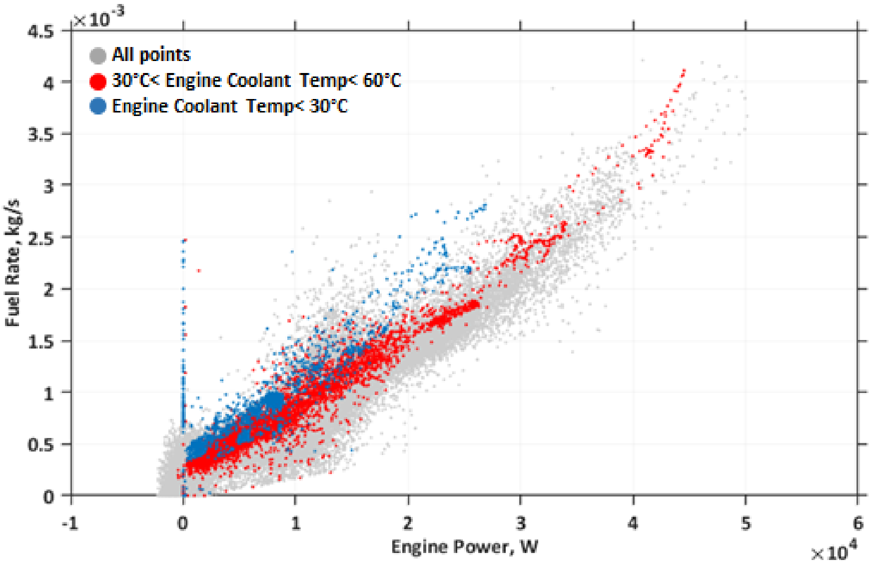


Figure 59: Fuel rate of engine by engine power for different coolant temperatures

The operating points in Figure 59 are grouped by engine coolant temperature range and show meaningful trends in fuel consumption. Although cylinder temperature might have a stronger correlation with engine efficiency than coolant temperature, it is not measured in our tests, and coolant temperature can be considered as the temperature closest to the heat source.

5.6.3. Fuel Consumption Analysis

Changes in engine temperature affects the vehicle fuel consumption. Figure 60 shows the fuel consumption in several UDDS tests under different test conditions.

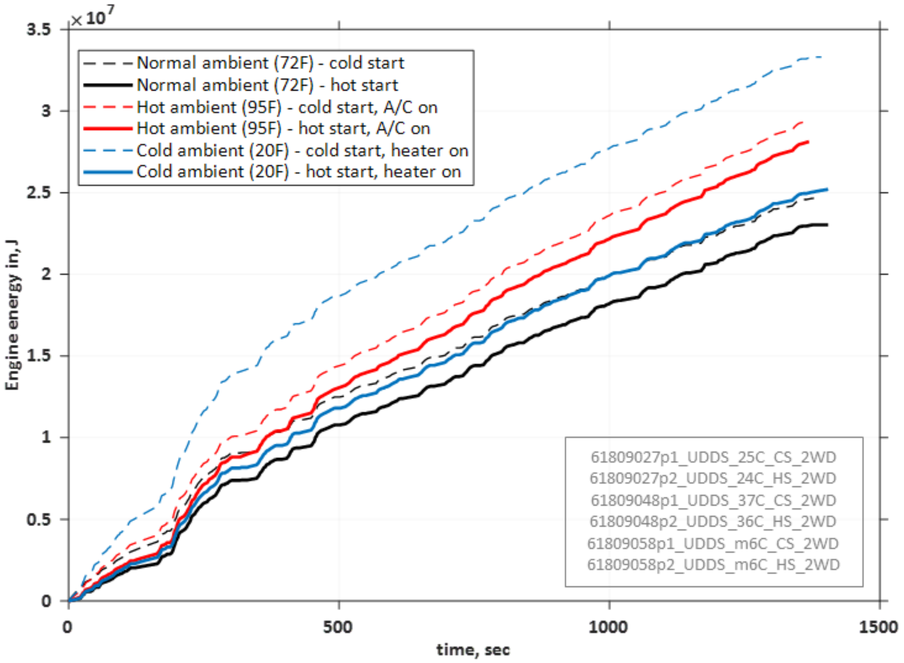


Figure 60: Accumulated fuel consumption trajectories on UDDS under different test conditions

The colors of the lines in Figure 62 indicate the ambient temperature, and a dotted line means that the engine was started at a cold temperature (cold-start). The results show that the car operated in normal ambient temperatures with the HVAC off shows the best fuel economy and that fuel economy decreases when the AC system is operating, although there are variations with initial engine temperature and transmission temperature. However, the vehicle operated at cold ambient temperatures consumed only about 10% more fuel if the engine was started in a “hot” condition. At certain hot ambient temperatures, fuel consumption is higher than at cold ambient temperatures, since the AC system consumes more energy than the heating system. 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. When the engine temperature is not well maintained, the engine consumes more fuel, which leads to lower fuel economy.

Figure 61 shows the effect of ambient temperature and engine coolant temperature on engine efficiency. If we look at the losses in engine, computed as the difference between fuel energy input and the mechanical energy output, we can see this impact. In cold ambient and cold start conditions, the engine loses more energy in the energy conversion process. However, in normal ambient conditions, if the engine temperature rises, even after a cold start, the energy loss becomes similar to that with a hot start.

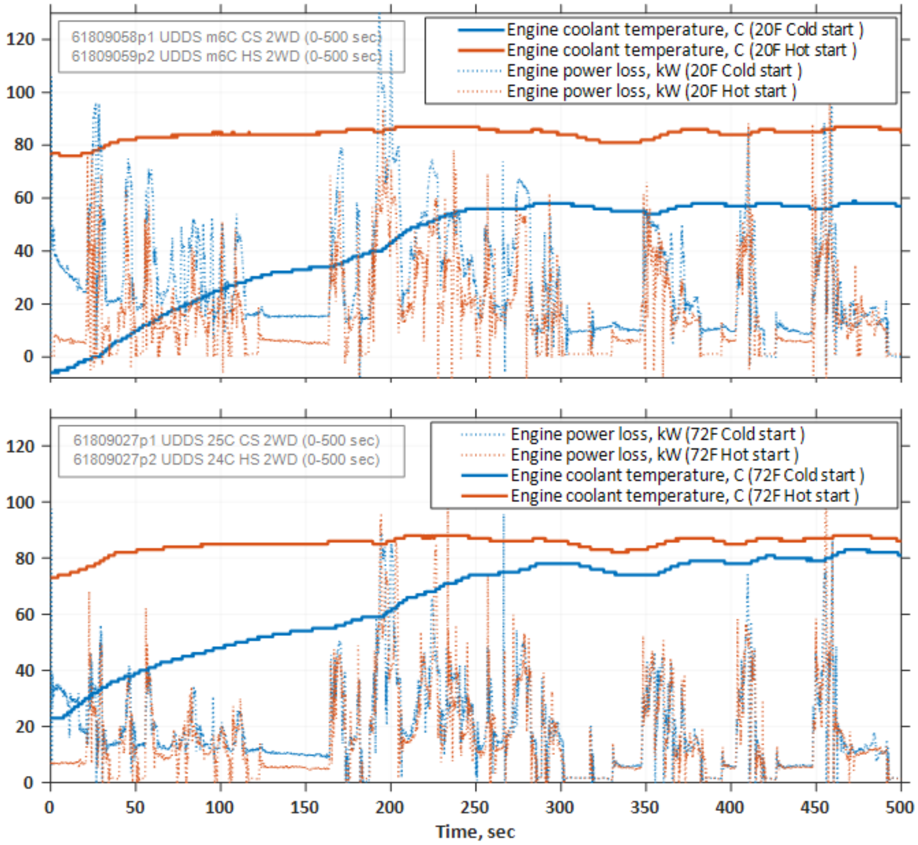


Figure 61: Engine power loss and engine coolant temperature according to driving conditions

5.7. Accessory Load

There is no electrical heater for the cabin in 2018 Honda Accord, so the most significant impact on the accessory load is caused by the HVAC system in hot ambient conditions. There are two kinds of accessory loads for HVAC: the first is the electrical accessory load from the battery for operating the ventilation fan, and the second is the mechanical accessory load from the engine for operating the water pump and compressor. While we have data for the electrical accessory load in our test data, we do not have the specific mechanical accessory load. However, we can deduce it from the information shown in Figure 62, which shows the engine output power when the vehicle is fully stopped in both hot and cold ambient conditions. More energy is consumed in hot ambient conditions than in cold ambient condition, and with the vehicle stopped it can be deduced that the AC compressor consumes about 280 W.

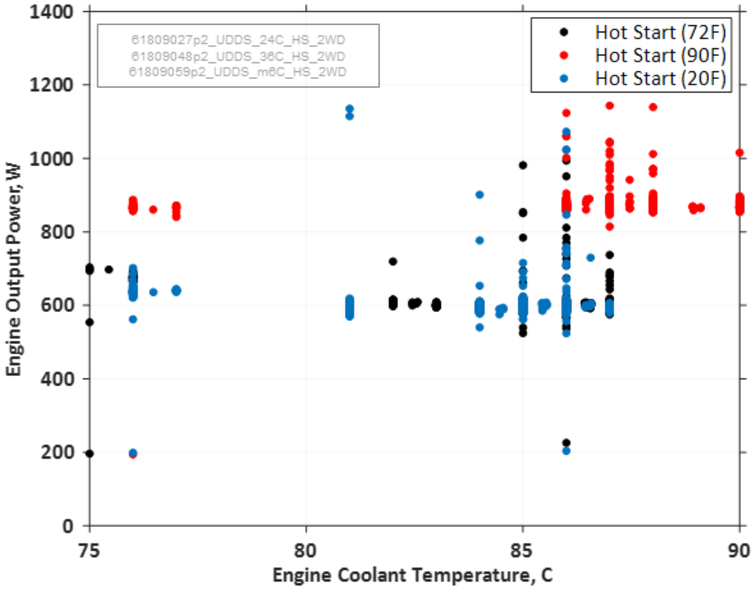


Figure 62: Engine output power when the vehicle is fully stopped

Figure 63 shows the accessory power when the vehicle is fully stopped. The operating points are grouped according to operating conditions: The black points are the accessory power consumed when the AC and heater are turned off. The required power without HVAC is about 230 W, regardless of the thermal conditions. The battery power consumption increases 180 W when the AC system in the passenger compartment is turned on in hot conditions (red points). In cold conditions (ambient temperature below 0 °C) when the heater is turned on, the battery power consumption increases by about 80 W (blue dots). Because only the fan operates, blowing hot air from the engine into the cabin, the power required for heating is relatively small compared to that for the AC system.

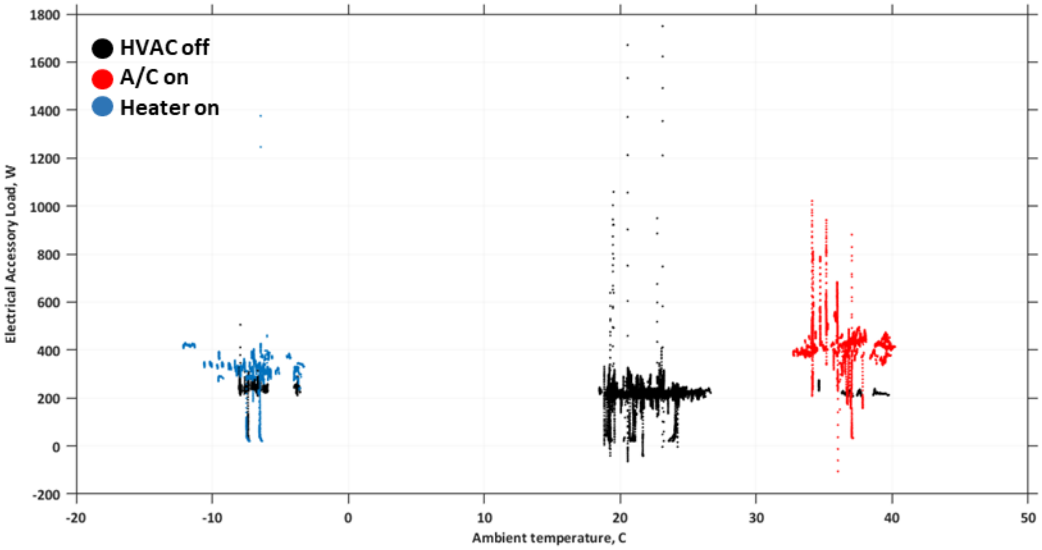


Figure 63: Electrical consumption when the vehicle is fully stopped

5.8. Energy Balance Diagram

In section 5.1 we saw that the signals which were not recorded in test data were calculated based on other signals. This is based on vehicle characteristics and other component assumptions. Based on these additional signals for each component, the total amounts of energy in and out are computed by post-processing in Autonomie. The terms “input” and “output” can be confusing, because their roles can be exchanged. Therefore, in this discussion, each port means one power flow, and all components have two ports in Autonomie. For example, Figure 64 shows the energy in and out for two ports, and the efficiency values for the final drive component.

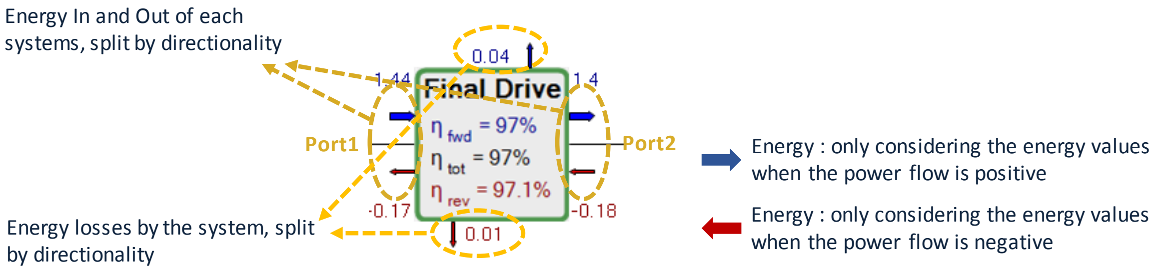


Figure 64: Example of energy calculation for one component on Autonomie

Where the total efficiency is computed on a given port in different ways, the following is the definition 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 the effort and flow signals recorded or estimated for those components. Figure 65 and Figure 66 show the final diagrams from the Autonomie graphical interface after post-processing for the energy balance on UDDS and HWFET cycles.

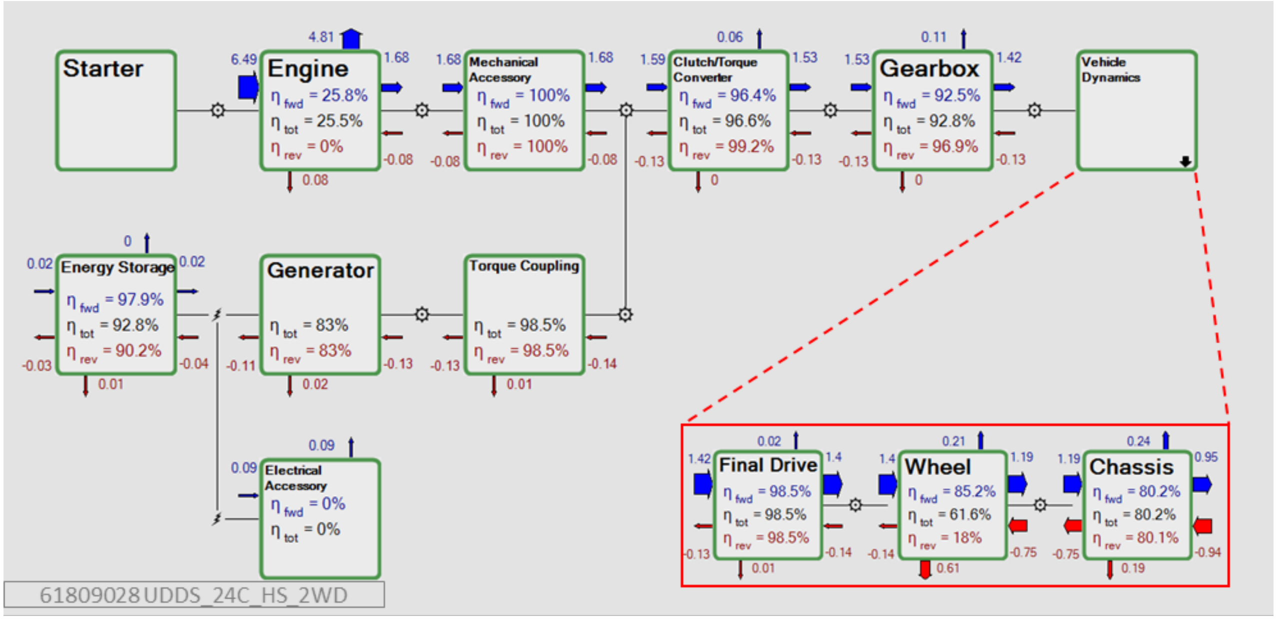


Figure 65: Energy balance diagram on UDDS in Autonomie

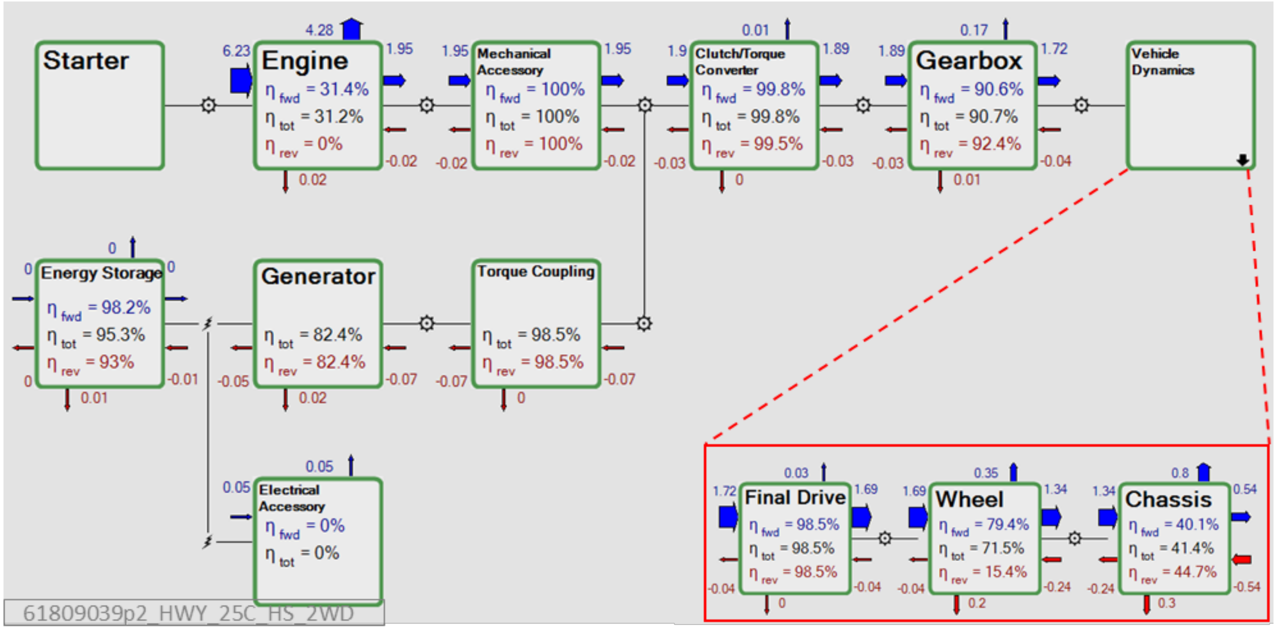


Figure 66: Energy balance diagram on HWFET in Autonomie

6. Autonomie Model Validation

An analysis of controls parameters was done based on the test data. Vehicle and component control logics and component models were updated based on this analysis. The component controls include transmission shifting, torque converter lockup, engine fuel cutoff, and so on. The updated component models, including control models, were implemented and integrated in Autonomie to create a vehicle simulation model for the 2018 Honda Accord. The vehicle model is simulated as a “warmed up” vehicle. Since all the simulations considered in this report assume a “hot start,” where the engine coolant temperature is steady at around 95 °C, the cold start condition was not a factor for the simulations.

The validation process for this study is shown in Figure 67.

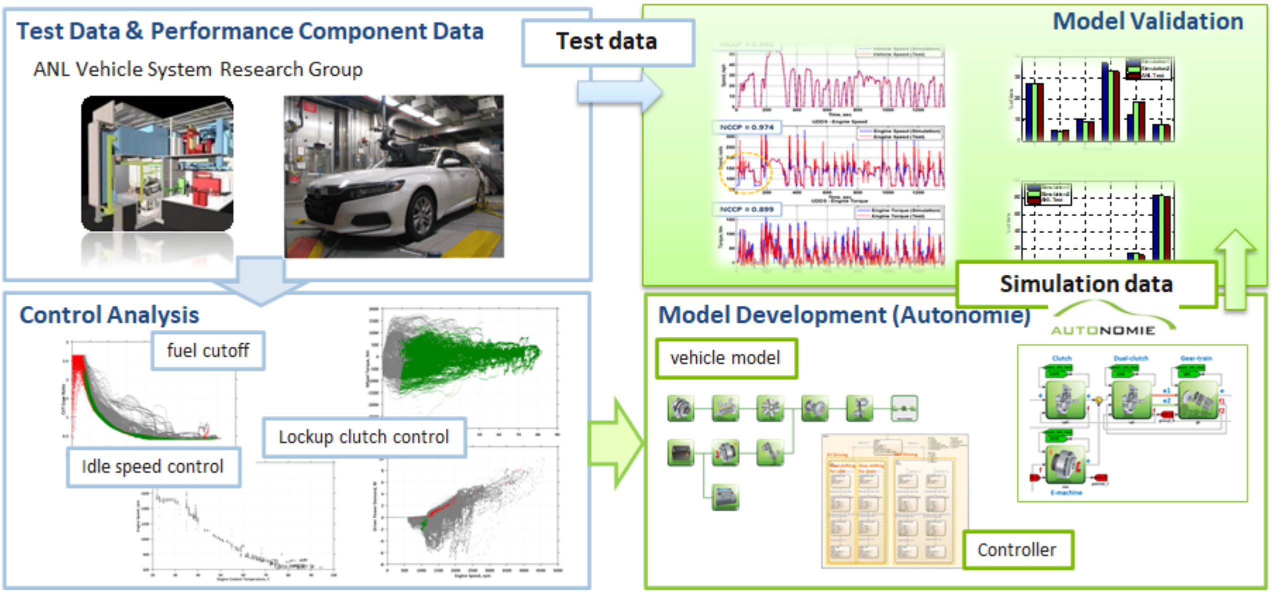


Figure 67: Validation process for 2018 Honda Accord in Autonomie

The simulation was conducted in urban dynamometer driving schedule (UDDS), highway fuel economy test (HWFET), and US06 cycles. Figure 68, Figure 69 and Figure 70 show the vehicle speed, engine speed, engine torque, wheel power, gear number, and fuel integrated of the simulation results and the test data, which match well for each cycle.

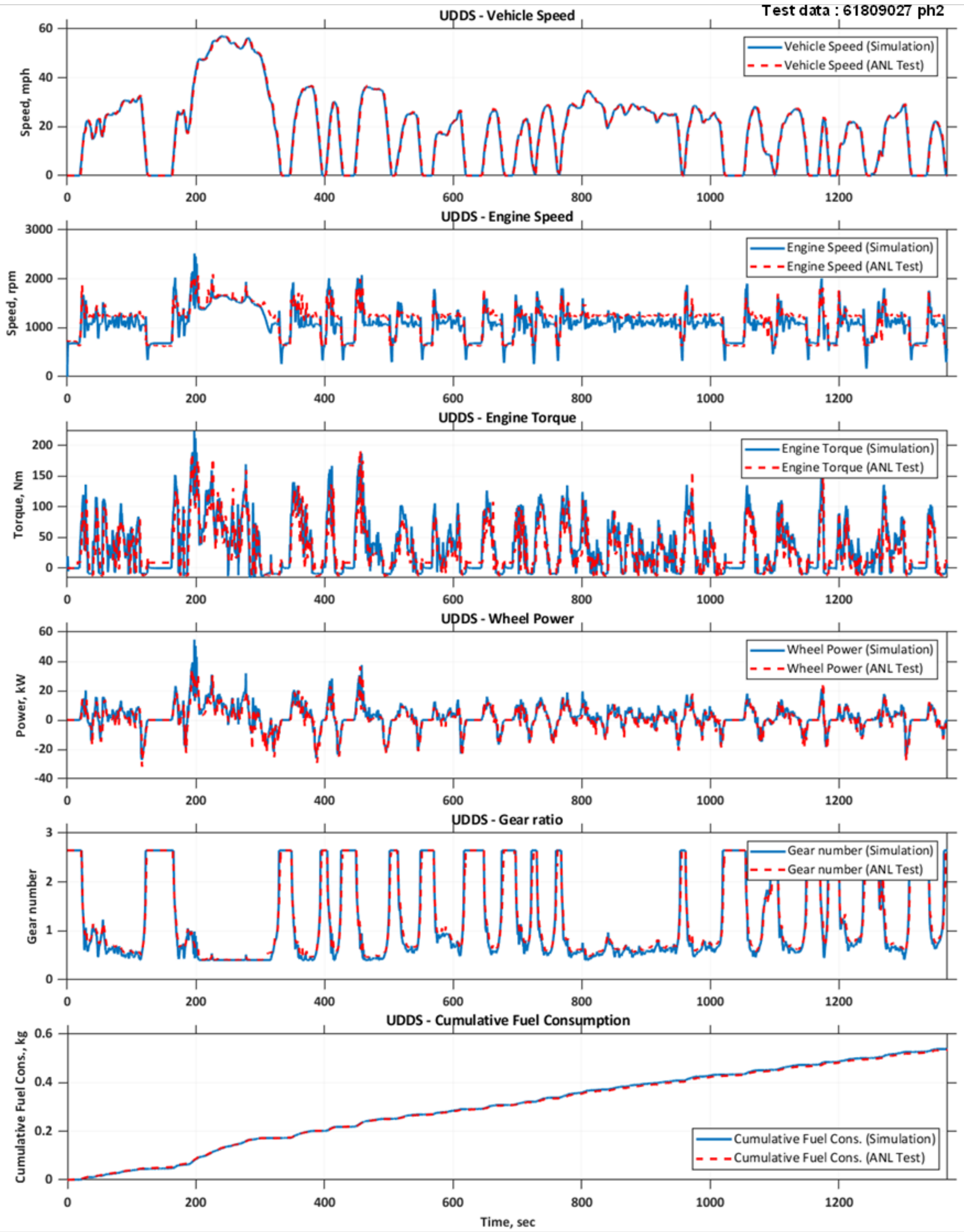


Figure 68: Simulation results and test data for UDDS cycle

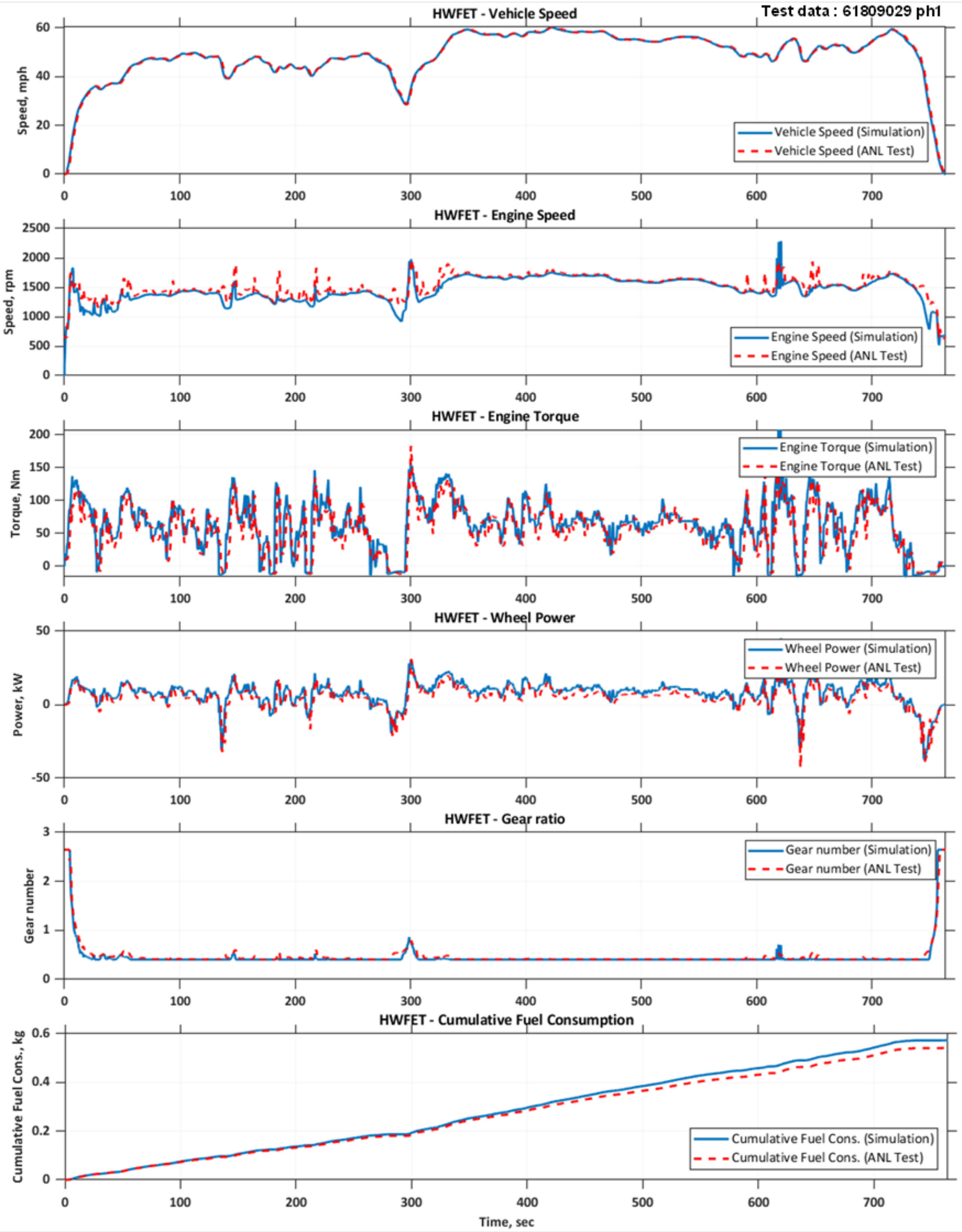


Figure 69: Simulation results and test data for HWFET cycle

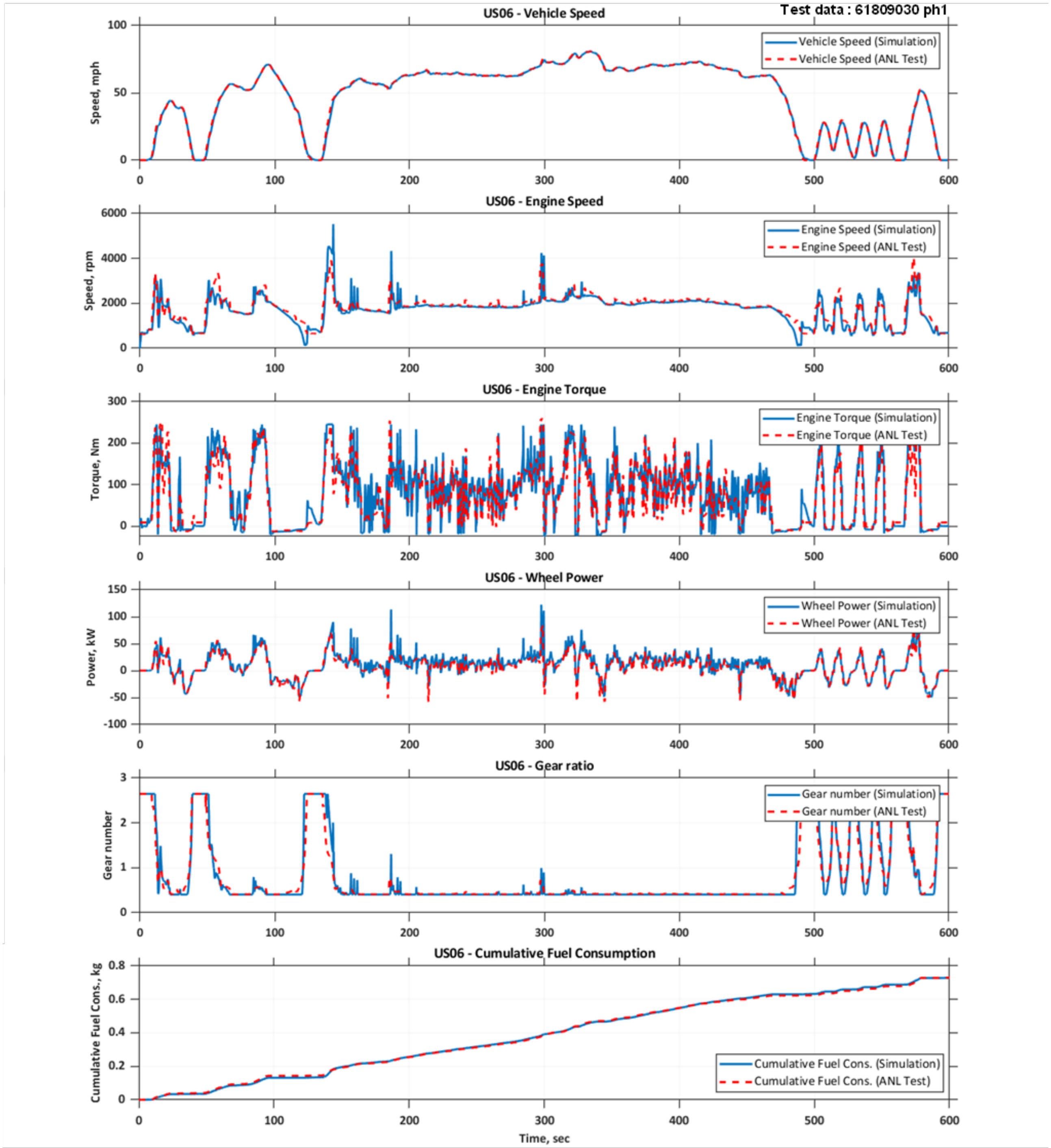


Figure 70: Simulation results and test data for US06 cycle

Normalized cross-correlation power (NCCP) was used to compare second-by-second time-varying signal traces between test and simulation [8]. The NCCP was calculated using Equations 9 and 10 as follows: Here x and y represent individual signals.

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

Equation 8

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

Equation 9

The NCCP values of simulation results for UDDS, HWFET and US06 cycles are shown in Table 18. It can be seen that the values for vehicle speed, gear number and engine speed, which all exceed 0.9, indicate a high level of correlation, while there is relatively lower correlation in the engine torque.

Table 18: The NCCP values for UDDS, HWFET and US06 cycle

	UDDS **(test data: 61809027 Ph2)**	**HWFET** **(test data: 61809029 Ph1)**	**US06** **(test data: 61809030 Ph1)**
Vehicle speed	0.994	0.999	0.997
Gear number	0.932	0.970	0.945
Engine speed	0.925	0.959	0.956
Engine torque	0.837	0.895	0.917

Figure 71 and Figure 72 show the vehicle speed when the torque converter is locked. The torque converter lockup status, based on vehicle speed and engine speed, for the simulation results and test data was compared for UDDS (test data: 61809027 Ph2), HWFET (test data: 61809029 Ph1), and US06 cycles (test data: 61809030 Ph1) in Figure 71, which shows that the simulated torque converter operation was similar to that in the test data. In Figure 72, the engine fuel cutoff status was compared with the test data for UDDS (test data: 61809027 Ph2), HWFET (test data: 61809029 Ph1), and US06 cycles (test data: 61809030 Ph1). The engine fuel cutoff in simulation showed tendencies similar to the test data.

The percentages of times for torque converter lockup and engine fuel cutoff are shown in Table 18.

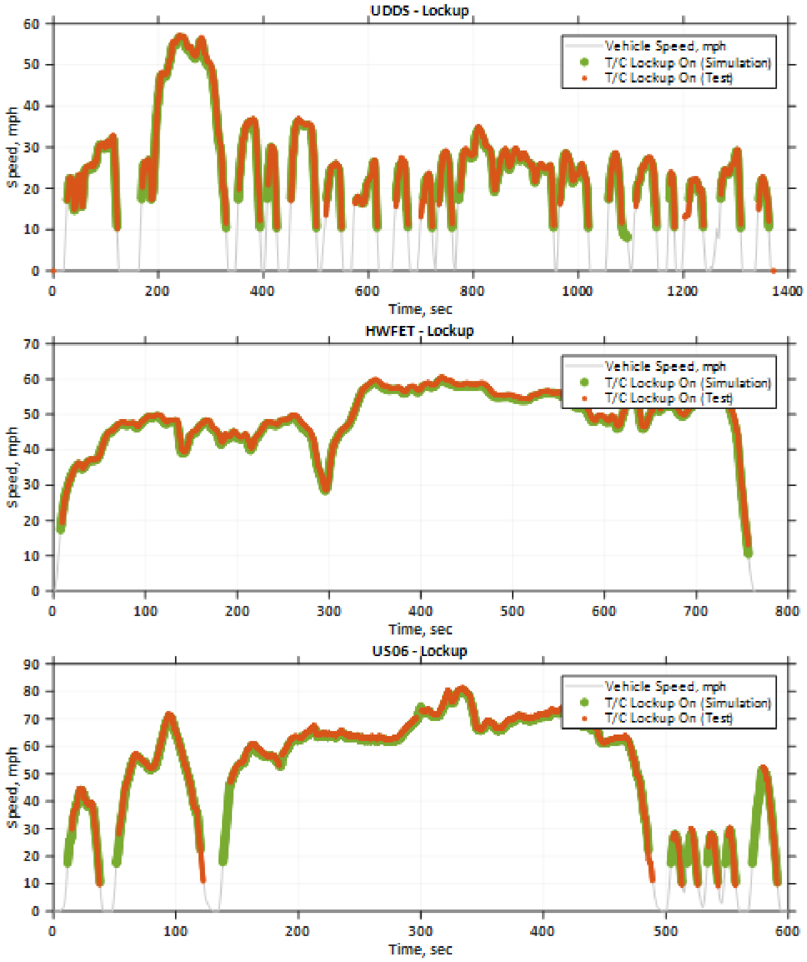


Figure 71: Torque converter locked vs vehicle speed

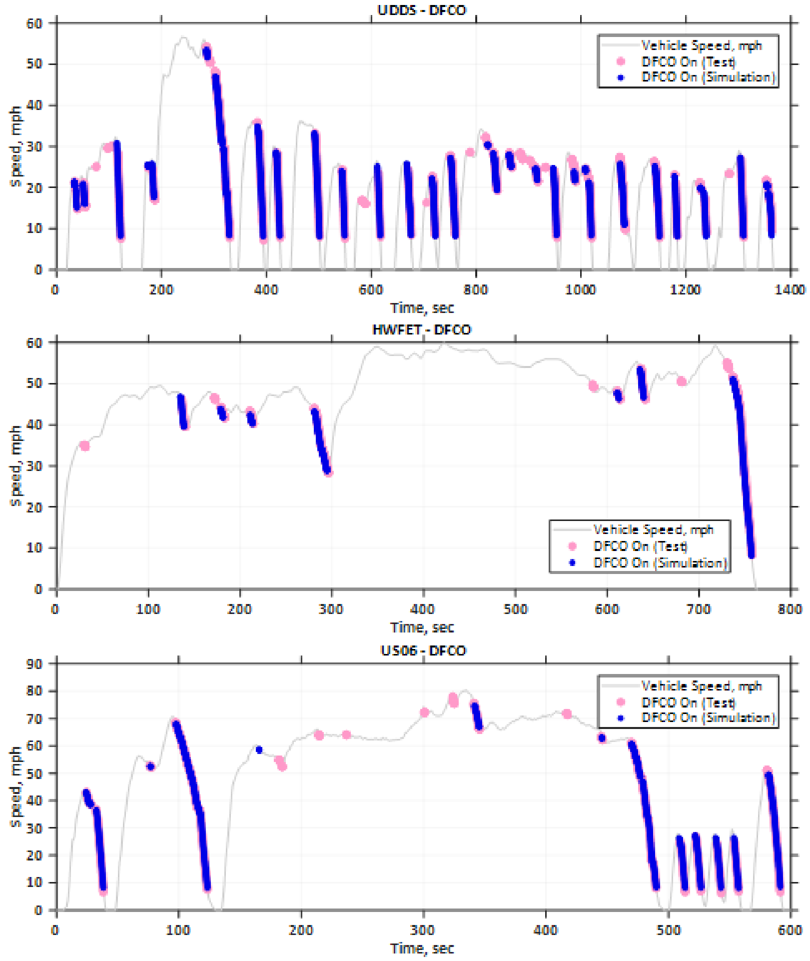


Figure 72: Engine fuel cutoff vs vehicle speed

Table 19: Percentage of times torque converter lockup and DFCO on

		UDDS **(test data: 61809027 Ph2)**	**HWFET** **(test data: 61809029 Ph1)**	**US06** **(test data: 61809030 Ph1)**
TC lockup (%)	Test	67.01	97.85	78.02
	Simulation	65.42	98.00	83.05
DFCO on (%)	Test	14.04	8.40	15.95
	Simulation	13.03	6.56	14.57

In Table 19, the simulated fuel consumption is compared to the measured average fuel consumption under hot conditions to validate the simulation performance. The results showed that the fuel consumption of the simulation, 6.4, 4.5 and 7.7 L/100km on UDDS, HWFET & US06 cycles, differed from the test result by 0,2%, 4% and 1%, respectively.

Table 20: Fuel consumption of test data and simulation results

Fuel economy (L/100km)	**UDDS**	**HWFET**	**US06**
Test average	6.1	4.51	7.73
Simulation (error)	6.09 (0.2%)	4.69 (4%)	7.65 (1%)
Test data for UDDS: 61809027 Ph2 Test data for HWFET: 61809029 Ph1 Test data for US06: 61809030 Ph1			

7. Conclusions

The vehicle benchmarked in this report is a 2018 Honda Accord equipped with the 1.5 L, I4, “Earth Dreams” engine coupled to a continuously variable automatic transmission. This particular powertrain configuration provided higher than average fuel economy compared to other vehicles in its class, without sacrificing vehicle performance. The focus of the benchmark was to understand the usage of the 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 to providing the data for the analysis in the report. The vehicle was 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.

Vehicle control aspects pertaining to CVT, torque converter, DFCO, use of alternator to recuperate part of the braking energy, techniques adopted to manage the operating temperature of the engine were explained. HVAC loads for compressor and fan under both hot and cold ambient temperatures were quantified. This information was used to develop and calibrate the Autonomie models. The fuel economy results and operating conditions of various components predicted by Autonomie models were found to be well correlated to the test data. This effort increases the confidence in the modelling capabilities of Autonomie, and provides us a validated benchmark for a midsize car with a downsized boosted SI engine paired with a CVT. Lessons learned from this effort will be applied to all future work where similar technologies are evaluated.

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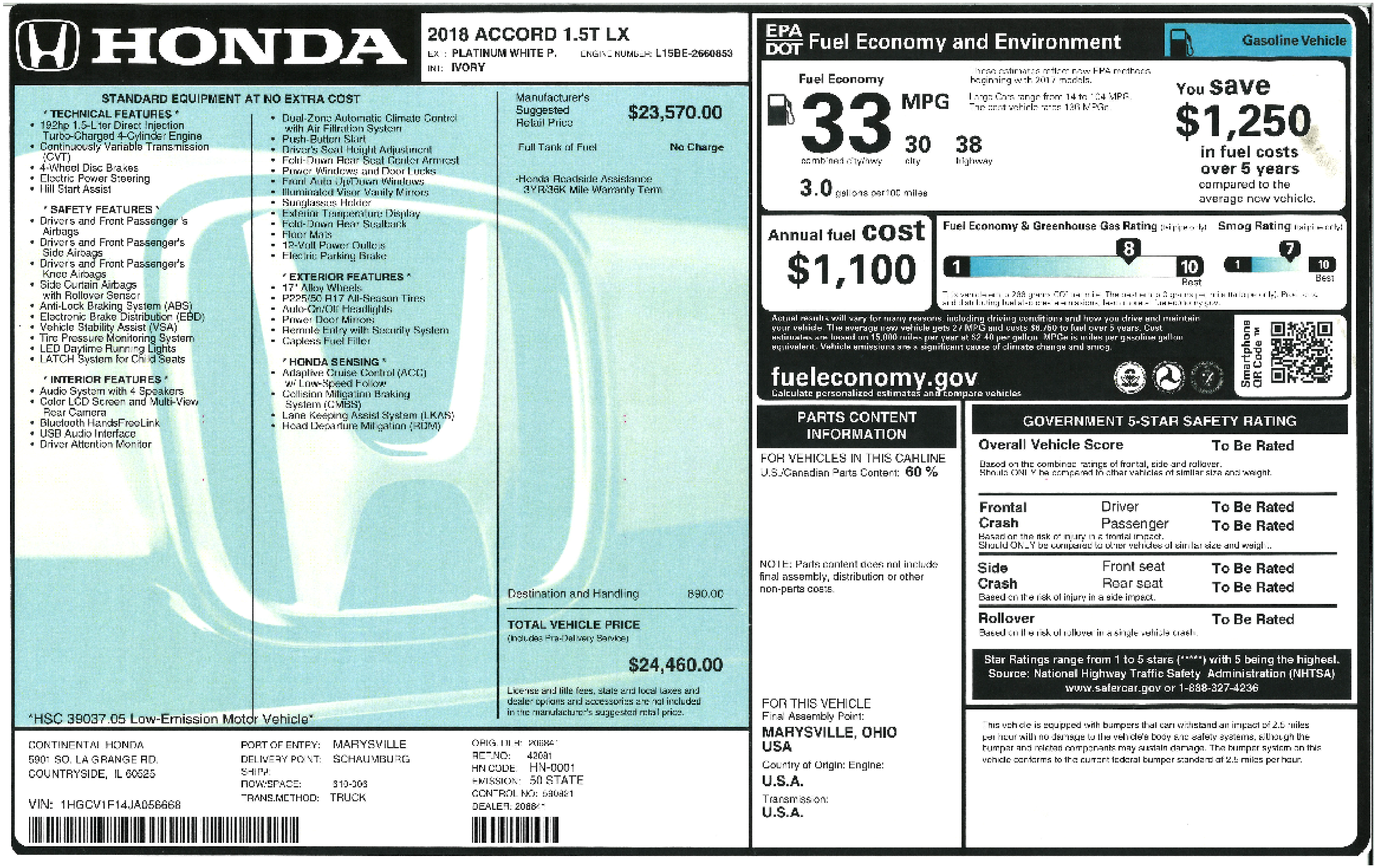
Finally, the authors want to acknowledge that this work would not have been possible without the entire team at the Center for Transportation Research. Special thanks go to Mike Kern, Geoffrey Amann, George Tsigolis, and Miriam Di Russo for their support during the vehicle evaluation process.

Appendix A: Vehicle Build Sheet



HONDA

2018 ACCORD 1.5T LX
EXT: **PLATINUM WHITE P.** ENGINE NUMBER: L15BE-2660853
INT: **IVORY**

STANDARD EQUIPMENT AT NO EXTRA COST

*** TECHNICAL FEATURES ***
- 192hp 1.5-Liter Direct Injection Turbo-Charged 4-Cylinder Engine
- Continuously Variable Transmission (CVT)
- 4-Wheel Disc Brakes
- Electric Power Steering
- Hill Start Assist

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

*** INTERIOR FEATURES ***
- Audio System with 4 Speakers
- Color LCD Screen and Multi-View Rear Camera
- Bluetooth HandsFreeLink
- USB Audio Interface
- Driver Attention Monitor
- Dual-Zone Automatic Climate Control with Air Filtration System
- Push-Button Start
- Driver's Seat Height Adjustment
- Fold-Down Rear Seat Center Armrest
- Power Windows and Door Locks
- Front Auto Up/Down Windows
- Illuminated Visor Vanity Mirrors
- Sunglasses Holder
- Exterior Temperature Display
- Fold-Down Rear Seatback
- Floor Mats
- 12-Volt Power Outlets
- Electric Parking Brake

*** EXTERIOR FEATURES ***
- 17" Alloy Wheels
- P225/50 R17 All-Season Tires
- Auto-On/Off Headlights
- Power Door Mirrors
- Remote Entry with Security System
- Capless Fuel Filler

*** HONDA SENSING ***
- Adaptive Cruise Control (ACC) w/ Low-Speed Follow
- Collision Mitigation Braking System (CMBS)
- Lane Keeping Assist System (LKAS)
- Road Departure Mitigation (RDM)

Manufacturer's Suggested Retail Price	**$23,570.00**
Full Tank of Fuel	**No Charge**
-Honda Roadside Assistance 3YR/36K Mile Warranty Term	
Destination and Handling	890.00
TOTAL VEHICLE PRICE (Includes Pre-Delivery Service)	**$24,460.00**

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

HSC 39037.05 Low-Emission Motor Vehicle

CONTINENTAL HONDA
5901 SO. LA GRANGE RD.
COUNTRYSIDE, IL 60525

VIN: 1HGCV1F14JA056668

PORT OF ENTRY: MARYSVILLE
DELIVERY POINT: SCHAUMBURG
SHIP#:
ROW/SPACE: 310-303
TRANS.METHOD: TRUCK

ORIG. DLR: 208841
RET.NO: 42091
HN CODE: HN-0001
EMISSION: 50 STATE
CONTROL NO: 590481
DEALER: 208841

EPA DOT Fuel Economy and Environment **Gasoline Vehicle**

Fuel Economy
33 MPG combined city/hwy
30 city **38** highway
3.0 gallons per 100 miles

These estimates reflect new EPA methods beginning with 2017 models.
Large Cars range from 14 to 124 MPG. The best vehicle rates 136 MPGe.

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) 1 — **8** — 10 Best

Smog Rating (tailpipe only) 1 — **7** — 10 Best

This vehicle emits 288 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™

PARTS CONTENT INFORMATION

FOR VEHICLES IN THIS CARLINE
U.S./Canadian Parts Content: **60 %**

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

FOR THIS VEHICLE
Final Assembly Point:
MARYSVILLE, OHIO USA
Country of Origin: Engine:
U.S.A.
Transmission:
U.S.A.

GOVERNMENT 5-STAR SAFETY RATING

Overall Vehicle Score		**To Be Rated**
Frontal Crash	Driver	**To Be Rated**
	Passenger	**To Be Rated**
Side Crash	Front seat	**To Be Rated**
	Rear seat	**To Be Rated**
Rollover		**To Be Rated**

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: Based on the risk of injury in a frontal impact. Should ONLY be compared to other vehicles of similar size and weight.

Side Crash: 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

This vehicle is equipped with bumpers that can withstand an impact of 2.5 miles per hour with no damage to the vehicle's body and safety systems, although the bumper and related components may sustain damage. The bumper system on this vehicle conforms to the current federal bumper standard of 2.5 miles per hour.

Appendix B: Subset of Midsized 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: A018 Honda Accord LX Test Signals

The following signals were collected at 10Hz for each test, and are publicly posted for reference. Note, signal sampling rate for CAN and diagnostic messages is dependent on the vehicle, and the actual transmission rate may be faster or slower than the 10hz sample rate. Additionally, though most signals are available for the duration of testing, some errors in acquisition can occur.

Facility, dyno, bench, and cell data	**Analog data from vehicle**	**CAN: Broadcast data**	**CAN: Diagnostic data**
Time[s]_RawFacilities	Engine_Oil_Dipstick_Temp__C	Eng_speed_CAN7__rpm	12VBatt_estimated_temp_PGM__C
Dyno_Spd__mph	Radiator_Air_Outlet_Temp__C	Eng_torque_trans_demand_CAN7__Nm	Brake_pressure_1_ABS__bar
Dyno_TractiveForce__N	Engine_Bay_Temp__C	Trans_secondary_shaft_spd__CAN7__rpm	Eng_airfuel_FB_commanded_PGM
Dyno_LoadCell__N	Cabin_Temp__C	Eng_DFCO_signal_1_CAN7	Eng_airfuel_FB_ST_fuel_trim_level_PGM
Distance__mi	Cabin_Upper_Vent_Temp__C	Pedal_brake_press_CAN2	Eng_airfuel_FB_ST_LT_fuel_trim_level_PGM
Tailpipe_Press__inH2O	Cabin_Lower_Vent_Temp__C	Pedal_accel_pos_CAN2__per	Eng_airfuel_ratio_PGM
Cell_Temp__C	12VBatt_Volt_Hioki_U1__V	Pedal_brake_state_CAN2	Eng_CMP_control_PGM__deg
Cell_RH__%	Alternator_Curr_Hioki_I1__A	Vehicle_speed_CAN2__mph	Eng_EVAP_PC_duty_PGM__per
Cell_Press__inHg	Alternator_Power_Hioki_P1__kW	Veh_odometer_displayed_BCAN	Eng_FSS_PGM
Tire_Front_Temp__C	12VBatt_Pos_Curr_Hioki_I2__A	Pedal_brake_press_CAN2	Eng_fuel_injector_duration_PGM__ms
Tire_Rear_Temp__C	12VBatt_Pos_Power_Hioki_P2__W	Pedal_accel_pos_CAN2__per	Eng_idling_PGM
Drive_Schedule_Time__s	12VBatt_Power_Hioki_P3__W	Pedal_brake_state_CAN2	Eng_intakeair_temp_1_PGM__C
Drive_Trace_Schedule__mph	12VBatt_Curr_Hioki_I3__A	Vehicle_speed_CAN2__mph	Eng_knock_control_PGM
Exhaust_Bag	12VBatt_Volt_Hioki_U3__V	Veh_odometer_displayed_BCAN	Eng_knock_retard_PGM__deg
Solar_Array_Ind_Temp__C	12VBatt_Volt_Hioki_U1__V	Veh_fuel_use_current_drive_BCAN	Eng_MAF_sensor_PGM__gps
AMA_Dilute_THC[mg/s]	Eng_FuelFlow_Direct2__gps	Veh_fuel_use_prev_drive_BCAN	Eng_MIL_indication_PGM
AMA_Dilute_CH4[mg/s]	Eng_FuelFlow_Direct__ccps	Veh_PRNDL_drive_BCAN	Eng_MIL_status_PGM
AMA_Dilute_NOx[mg/s]	Eng_Fuel_Temp_Direct__C	Veh_PRNDL_low_BCAN	Eng_rocker_arm_oil_pressure_sensor_PGM__kPA
AMA_Dilute_COlow[mg/s]		Veh_PRNDL_neutral_BCAN	Eng_run_time_PGM__s
AMA_Dilute_COmid[mg/s]		Veh_PRNDL_park_BCAN	Eng_spark_advance_PGM__deg
AMA_Dilute_CO2[mg/s]		Veh_PRNDL_rev_BCAN	Eng_starting_engine_coolant_temp_PGM__C
AMA_Dilute_HFID[mg/s]		Veh_PRNDL_sport_BCAN	Eng_TC_air_bypass_sol_valve_position_PGM
AMA_Dilute_NMHC[mg/s]		Veh_econ_mode_BCAN	Eng_TC_boost_pressure_PGM__kPa
AMA_Dilute_Fuel[g/s]		HVAC_AC_button_BCAN	Eng_throttle_valve_PGM__deg
		HVAC_auto_set_BCAN	Eng_VTEC_solenoid_valve_PGM
		HVAC_driver_temp_BCAN__F	Exhaust_catalyst_temp_PGM
		HVAC_fan_setting_BCAN	Fuel_level_average_PGM__per
		HVAC_outside_air_BCAN	HVAC_AC_clutch_PGM
		HVAC_pass_temp_BCAN__F	HVAC_AC_pressure_sensor_PGM__kPa
		HVAC_rear_defrost_BCAN	HVAC_AC_switch_PGM
		HVAC_sync_button_BCAN	Trans_ATF_temp_AT__C
		HVAC_vent_pos_BCAN	Trans_driven_pulley_pressure_AT__kPa
		Eng_MAP_sensor_highres_CAN7__kPa	Trans_input_shart_drive_pulley_speed_AT__rpm
		Trans_pulley_ratio__CAN7	Trans_LCC_linear_sol_actual_AT__A
			Trans_secondary_shaft_spd_1_AT__rpm
			Trans_secondary_shaft_spd_AT__kph
			Trans_torque_converter_turbine_spd_AT__rpm
			Veh_speed_PGM__KPH
			Veh_wheel_spd_LF_ABS__kph
			Veh_wheel_spd_LR_ABS__kph
			Veh_wheel_spd_RF_ABS__kph
			Veh_wheel_spd_RR_ABS__kph

Appendix D: Test Summary

(Also available at www.anl.gov/d3)

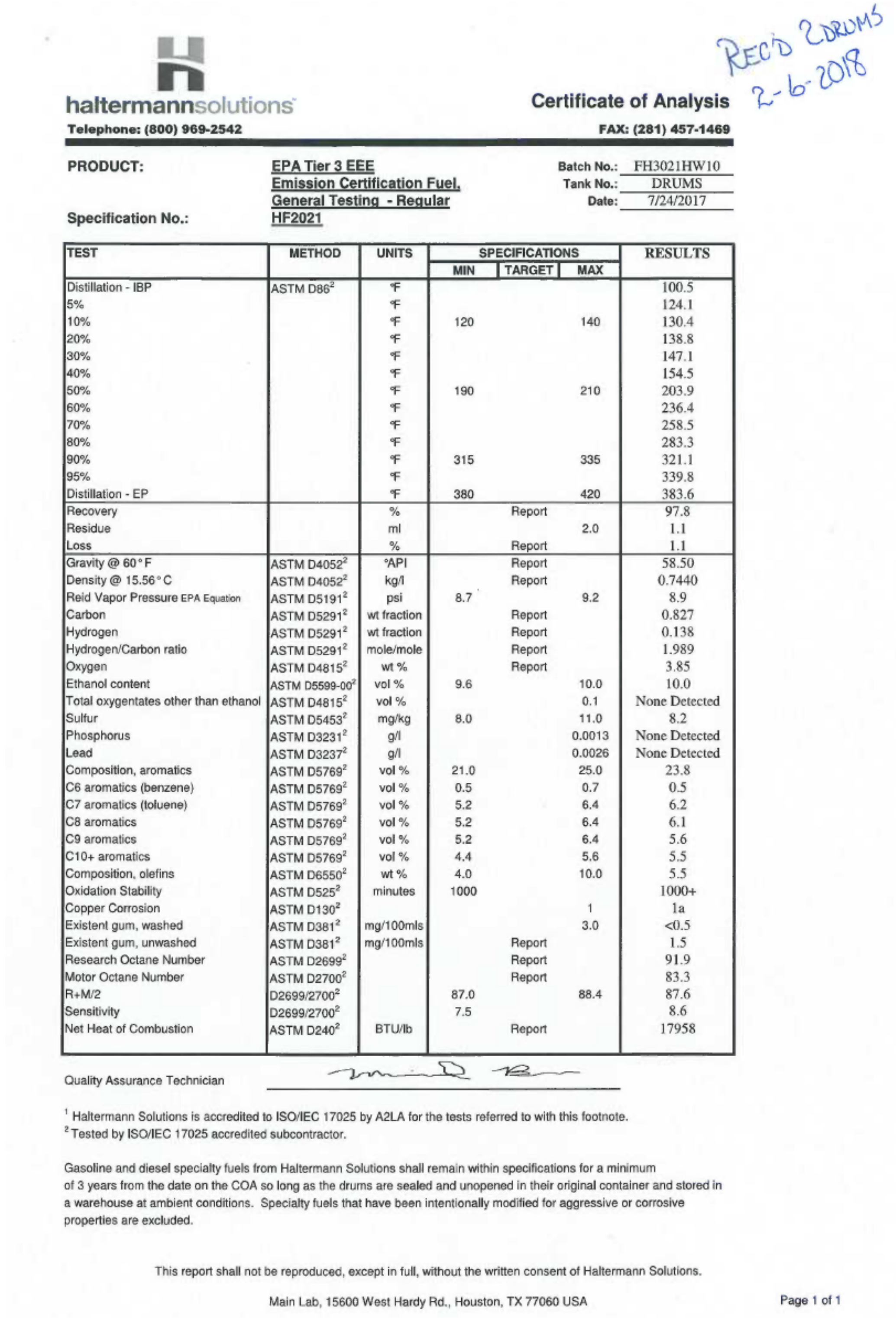
													Liquid Fuel usage			
Test ID [#]	Cycle	Test Time	Start Comments	End Comments	Test Cell Temp [C]	Test Cell RH [%]	Test Cell Baro [in/Hg]	Test weight [lb]	Dyno Target A:	Dyno Target B:	Dyno Target C:	Cycle Distance [mi]	Cycle Fuel Consumed [gal] (Emiss Bag)	Cycle Fuel economy [mpg] (Emiss Bag)	Fuel used modal [gal]	Fuel Economy Modal [mpg]
Day 1, Coastdowns and UDDS Prep																
61809025	HWYx2 with coastdowns p1	09/17/18, 02:56:33 PM	HWYx2 and coastdown, 2 bag, with Handyman, vehicle changed to 2WD mode with chalks just prior to test.	ok, saved dyno sets aquired after 4 adjustments	25	43	29	3500	43.75	-0.6042	0.02619	10.26	0.194	53.0	0.194	52.9
61809025	HWYx2 with coastdowns p2	09/17/18, 02:56:33 PM	HWYx2 and coastdown, 2 bag, with Handyman, vehicle changed to 2WD mode with chalks just prior to test.	ok, saved dyno sets aquired after 4 adjustments	25	41	29	3500	43.75	-0.6042	0.02619	10.26	0.189	54.4	0.188	54.6
61809026	UDDS prep	09/17/18, 03:56:34 PM	UDDS prep, 1 bag, bags off, with dyno new 2WD dyno sets	ok	23	49	29	3500	43.75	-0.6042	0.02619	7.45	0.192	38.7	0.188	39.6
Day 2, Certification cycles in 2WD, closed hood and variable speed fan																
61809027	UDDS cold start p1	09/18/18, 07:35:54 AM	UDDSx2, 4 bag (FTP), cold start	ok, some delays seen in PGM diagnostic signals on random basis.	25	43	29	3500	43.75	-0.6042	0.02619	3.58	0.096	37.4	0.097	37.1
61809027	UDDS cold start p2	09/18/18, 07:35:54 AM	UDDSx2, 4 bag (FTP), cold start	ok, some delays seen in PGM diagnostic signals on random basis.	21	54	29	3500	43.75	-0.6042	0.02619	3.84	0.102	37.8	0.100	38.5
61809027	UDDS cold start p1+2	09/18/18, 07:35:54 AM	UDDSx2, 4 bag (FTP), cold start	ok, some delays seen in PGM diagnostic signals on random basis.	23	49	29					7.43	0.197	37.60	0.196	37.82
61809027	UDDS hot start p3	09/18/18, 07:35:54 AM	UDDSx2, 4 bag (FTP), cold start	ok, some delays seen in PGM diagnostic signals on random basis.	24	46	29	3500	43.75	-0.6042	0.02619	3.59	0.087	41.2	0.088	41.1
61809027	UDDS hot start p4	09/18/18, 07:35:54 AM	UDDSx2, 4 bag (FTP), cold start	ok, some delays seen in PGM diagnostic signals on random basis.	22	49	29	3500	43.75	-0.6042	0.02619	3.88	0.103	37.9	0.101	38.6
61809027	UDDS hot start p3+4	09/18/18, 07:35:54 AM	UDDSx2, 4 bag (FTP), cold start	ok, some delays seen in PGM diagnostic signals on random basis.	23	48	29					7.48	0.190	39.42	0.188	39.75
61809028	UDDS #3 start p1	09/18/18, 08:55:27 AM	UDDSx1, 2 bag (FTP)	ok	24	45	29	3500	43.75	-0.6042	0.02619	3.60	0.089	40.5	0.089	40.4
61809028	UDDS #3 start p2	09/18/18, 08:55:27 AM	UDDSx1, 2 bag (FTP)	ok	22	49	29	3500	43.75	-0.6042	0.02619	3.88	0.103	37.5	0.102	38.2
61809028	UDDS #3 start p1+2	09/18/18, 08:55:27 AM	UDDSx1, 2 bag (FTP)	ok	23	47	29					7.48	0.192	38.88	0.191	39.21
61809029	HWYx2 p1	09/18/18, 09:39:05 AM	HWY x 2	ok	26	40	29	3500	43.75	-0.6042	0.02619	10.26	0.190	54.1	0.190	54.0
61809029	HWYx2 p2	09/18/18, 09:39:05 AM	HWY x 2	ok	25	41	29	3500	43.75	-0.6042	0.02619	10.26	0.186	55.1	0.186	55.2
61809030	US06x2 p1	09/18/18, 10:27:30 AM	US06x2, 4 bag	ok	22	51	29	3500	43.75	-0.6042	0.02619	1.78	0.085	20.9	0.087	20.5
61809030	US06x2 p2	09/18/18, 10:27:30 AM	US06x2, 4 bag	ok	27	40	29	3500	43.75	-0.6042	0.02619	6.24	0.164	37.9	0.166	37.7
61809030	US06x2 p1+2	09/18/18, 10:27:30 AM	US06x2, 4 bag	ok	25	45	29					8.01	0.250	32.12	0.252	31.79
61809030	US06x2 p3	09/18/18, 10:27:30 AM	US06x2, 4 bag	ok	23	45	29	3500	43.75	-0.6042	0.02619	1.78	0.084	21.1	0.085	20.8
61809030	US06x2 p4	09/18/18, 10:27:30 AM	US06x2, 4 bag	ok	27	38	29	3500	43.75	-0.6042	0.02619	6.24	0.166	37.6	0.166	37.5
61809030	US06x2 p3+4	09/18/18, 10:27:30 AM	US06x2, 4 bag	ok	25	41	29					8.02	0.250	32.08	0.252	31.83
61809031	UDDS prep	09/18/18, 03:04:25 PM	UDDS Prep	ok	22	49	29	3500	43.75	-0.6042	0.02619	7.48	0.198	37.9	0.195	38.4
Day 3, Certification cycles in 2WD, closed hood and variable speed fan																
61809032	UDDS cold start p1	09/19/18, 07:48:26 AM	UDDSx2, 4 bag (FTP), cold start), Repeat Day #1	ok	24	44	29	3500	43.75	-0.6042	0.02619	3.58	0.095	37.8	0.096	37.4
61809032	UDDS cold start p2	09/19/18, 07:48:26 AM	UDDSx2, 4 bag (FTP), cold start), Repeat Day #1	ok	21	54	29	3500	43.75	-0.6042	0.02619	3.85	0.100	38.4	0.099	38.9
61809032	UDDS cold start p1+2	09/19/18, 07:48:26 AM	UDDSx2, 4 bag (FTP), cold start), Repeat Day #1	ok	22	49	29					7.44	0.195	38.10	0.195	38.15
61809032	UDDS hot start p3	09/19/18, 07:48:26 AM	UDDSx2, 4 bag (FTP), cold start), Repeat Day #1	ok	24	46	29	3500	43.75	-0.6042	0.02619	3.60	0.085	42.4	0.086	41.8
61809032	UDDS hot start p4	09/19/18, 07:48:26 AM	UDDSx2, 4 bag (FTP), cold start), Repeat Day #1	ok	22	49	29	3500	43.75	-0.6042	0.02619	3.88	0.101	38.4	0.099	39.1
61809032	UDDS hot start p3+4	09/19/18, 07:48:26 AM	UDDSx2, 4 bag (FTP), cold start), Repeat Day #1	ok	23	47	29					7.48	0.186	40.21	0.185	40.34
61809033	UDDS #3 start p1	09/19/18, 09:07:40 AM	UDDS, 2 bag, warm start, Repeat Day #1	ok	24	46	29	3500	43.75	-0.6042	0.02619	3.59	0.086	41.9	0.087	41.4
61809033	UDDS #3 start p2	09/19/18, 09:07:40 AM	UDDS, 2 bag, warm start, Repeat Day #1	ok	22	49	29	3500	43.75	-0.6042	0.02619	3.86	0.101	38.1	0.099	38.9
61809033	UDDS #3 start p1+2	09/19/18, 09:07:40 AM	UDDS, 2 bag, warm start, Repeat Day #1	ok	23	48	29					7.44	0.187	39.82	0.186	40.06
61809034	HWYx2 p1	09/19/18, 09:45:37 AM	HWYx2, 2 bag, warm start, Repeat Day #1	ok	25	42	29	3500	43.75	-0.6042	0.02619	10.26	0.189	54.3	0.188	54.5
61809034	HWYx2 p2	09/19/18, 09:45:37 AM	HWYx2, 2 bag, warm start, Repeat Day #1	ok	25	41	29	3500	43.75	-0.6042	0.02619	10.25	0.184	55.7	0.184	55.8
61809035	US06x2 p1	09/19/18, 10:30:23 AM	US06x2, 4 bag, warm start, Repeat Day #1	ok	22	52	29	3500	43.75	-0.6042	0.02619	1.77	0.085	20.8	0.085	20.8
61809035	US06x2 p2	09/19/18, 10:30:23 AM	US06x2, 4 bag, warm start, Repeat Day #1	ok	26	42	29	3500	43.75	-0.6042	0.02619	6.24	0.164	38.0	0.163	38.2
61809035	US06x2 p1+2	09/19/18, 10:30:23 AM	US06x2, 4 bag, warm start, Repeat Day #1	ok	24	47	29					8.02	0.250	32.11	0.249	32.24
61809035	US06x2 p3	09/19/18, 10:30:23 AM	US06x2, 4 bag, warm start, Repeat Day #1	ok	23	47	29	3500	43.75	-0.6042	0.02619	1.78	0.084	21.1	0.084	21.2
61809035	US06x2 p4	09/19/18, 10:30:23 AM	US06x2, 4 bag, warm start, Repeat Day #1	ok	26	39	29	3500	43.75	-0.6042	0.02619	6.24	0.164	38.0	0.164	38.1
61809035	US06x2 p3+4	09/19/18, 10:30:23 AM	US06x2, 4 bag, warm start, Repeat Day #1	ok	25	43	29					8.02	0.249	32.25	0.248	32.36
61809036	UDDS prep	09/19/18, 03:18:25 PM	UDDS prep, 1 bag	ok	21	52	29	3500	43.75	-0.6042	0.02619	7.46			0.191	39.1
Day 4, Certification cycles in 2WD, closed hood and variable speed fan																
61809037	UDDS cold start p1	09/20/18, 07:47:08 AM	UDDSx2, 4 bag (FTP), cold start, repeat day #2	ok	25	44	29	3500	43.75	-0.6042	0.02619	3.59	0.097	37.1	0.097	36.8
61809037	UDDS cold start p2	09/20/18, 07:47:08 AM	UDDSx2, 4 bag (FTP), cold start, repeat day #2	ok	21	53	29	3500	43.75	-0.6042	0.02619	3.86	0.102	37.8	0.101	38.3
61809037	UDDS cold start p1+2	09/20/18, 07:47:08 AM	UDDSx2, 4 bag (FTP), cold start, repeat day #2	ok	23	48	29					7.45	0.199	37.47	0.198	37.60
61809037	UDDS hot start p3	09/20/18, 07:47:08 AM	UDDSx2, 4 bag (FTP), cold start, repeat day #2	ok	24	47	29	3500	43.75	-0.6042	0.02619	3.60	0.086	41.7	0.087	41.3
61809037	UDDS hot start p4	09/20/18, 07:47:08 AM	UDDSx2, 4 bag (FTP), cold start, repeat day #2	ok	22	49	29	3500	43.75	-0.6042	0.02619	3.88	0.102	38.1	0.100	38.7
61809037	UDDS hot start p3+4	09/20/18, 07:47:08 AM	UDDSx2, 4 bag (FTP), cold start, repeat day #2	ok	23	48	29					7.48	0.188	39.76	0.187	39.94
61809038	UDDS #3 start p1	09/20/18, 09:05:21 AM	UDDS, 2 bag, warm start, repeat day #2	ok	24	45	29	3500	43.75	-0.6042	0.02619	3.60	0.087	41.4	0.088	41.0
61809038	UDDS #3 start p2	09/20/18, 09:05:21 AM	UDDS, 2 bag, warm start, repeat day #2	ok	22	50	29	3500	43.75	-0.6042	0.02619	3.87	0.104	37.4	0.101	38.2
61809038	UDDS #3 start p1+2	09/20/18, 09:05:21 AM	UDDS, 2 bag, warm start, repeat day #2	ok	23	47	29					7.47	0.190	39.23	0.189	39.53
61809039	HWYx2 p1	09/20/18, 09:41:10 AM	Hwyx2, 2 bag, warm start with 3 VEHICLE ON coastdowns to verify vehicle losses	ok	25	42	29	3500	43.75	-0.6042	0.02619	10.25	0.189	54.4	0.189	54.3
61809039	HWYx2 p2	09/20/18, 09:41:10 AM	Hwyx2, 2 bag, warm start with 3 VEHICLE ON coastdowns to verify vehicle losses	ok	25	42	29	3500	43.75	-0.6042	0.02619	10.26	0.183	56.0	0.183	56.0
61809040	US06x2 p1	09/20/18, 10:34:28 AM	US06x2, 4 (split) bag, warm start	ok	22	51	29	3500	43.75	-0.6042	0.02619	1.78	0.086	20.6	0.086	20.6
61809040	US06x2 p2	09/20/18, 10:34:28 AM	US06x2, 4 (split) bag, warm start	ok	27	39	29	3500	43.75	-0.6042	0.02619	6.24	0.166	37.5	0.165	37.7
61809040	US06x2 p1+2	09/20/18, 10:34:28 AM	US06x2, 4 (split) bag, warm start	ok	25	45	29					8.02	0.253	31.74	0.252	31.87
61809040	US06x2 p3	09/20/18, 10:34:28 AM	US06x2, 4 (split) bag, warm start	ok	23	46	29	3500	43.75	-0.6042	0.02619	1.78	0.083	21.4	0.083	21.4
61809040	US06x2 p4	09/20/18, 10:34:28 AM	US06x2, 4 (split) bag, warm start	ok	27	39	29	3500	43.75	-0.6042	0.02619	6.24	0.164	38.1	0.163	38.2
61809040	US06x2 p3+4	09/20/18, 10:34:28 AM	US06x2, 4 (split) bag, warm start	ok	25	43	29					8.02	0.247	32.51	0.246	32.57
Day 5, Performance Cycles																
61809041	WOTsx5	09/20/18, 11:24:45 AM	WOTsx5, hot start	ok	25	44	29	3500	43.75	-0.6042	0.02619	4.37			0.300	14.6
61809042	SSS 0-80-0 30 sec 0,3,6% grade - SSS warmup	09/20/18, 12:50:15 PM	SSS. 0-80-0, 30 second hold at 0%, 3% and 6% grade	ok	26	40	29	3500	43.75	-0.6042	0.02619	9.46			0.179	52.9
61809042	SSS 0-80-0 30 sec 0% grade	09/20/18, 12:50:15 PM	SSS. 0-80-0, 30 second hold at 0%, 3% and 6% grade	ok	25	43	29	3500	43.75	-0.6042	0.02619	6.23			0.139	44.9
61809042	SSS 0-80-0 30 sec 3% grade	09/20/18, 12:50:15 PM	SSS. 0-80-0, 30 second hold at 0%, 3% and 6% grade	ok	24	44	29	3500	43.75	-0.6042	0.02619	6.21			0.248	25.0
61809042	SSS 0-80-0 30 sec 6% grade - FAULT	09/20/18, 12:50:15 PM	SSS. 0-80-0, 30 second hold at 0%, 3% and 6% grade	CVS crashed during 80MPH at 6% grade	24	45	29	3500	43.75	-0.6042	0.02619	3.68			0.241	15.2
61809043	SSS 0-80-0 30 sec 6% grade	09/20/18, 01:41:01 PM	SSS. 0-80-0, 6% grade repeat due to CVS failure	ok	24	46	29	3500	43.75	-0.6042	0.02619	6.22			0.382	16.3
61809044	SSS 0-80-0 1 min hold	09/20/18, 01:59:23 PM	SSS. 0-80-0, 60 second hold	ok	24	46	29	3500	43.75	-0.6042	0.02619	11.54			0.235	49.0
61809045	Passing Manuevers 0,3,6%	09/20/18, 02:21:41 PM	Passing manuevers at 0, 3 & 6% grade		25	42	29	3500	43.75	-0.6042	0.02619	10.02			0.556	18.0
61809046	25% grade	09/20/18, 02:47:14 PM	25% grade until derate	ok	23	48	29	3500	43.75	-0.6042	0.02619	0.65			0.172	3.8
61809047	UDDS Prep	09/20/18, 02:56:12 PM	UDDS prep for Hot Test day	ok	20	55	29	3500	43.75	-0.6042	0.02619	7.47			0.192	38.9
Day 6, Certification cycles in 2WD, 95F w/ solar																
61809048	UDDS cold start p1	09/21/18, 07:57:51 AM	UDDSx2, 4 bag (FTP), cold start in hot test cell, solar load 850W/m^2, HVAC-AUTO-72°F	ok	37	40	29	3500	43.75	-0.6042	0.02619	3.59	0.114	31.4	0.115	31.2
61809048	UDDS cold start p2	09/21/18, 07:57:51 AM	UDDSx2, 4 bag (FTP), cold start in hot test cell, solar load 850W/m^2, HVAC-AUTO-72°F	ok	34	47	29	3500	43.75	-0.6042	0.02619	3.85	0.126	30.5	0.130	29.6
61809048	UDDS cold start p1+2	09/21/18, 07:57:51 AM	UDDSx2, 4 bag (FTP), cold start in hot test cell, solar load 850W/m^2, HVAC-AUTO-72°F	ok	35	44	29					7.44	0.240	30.96	0.245	30.33
61809048	UDDS hot start p3	09/21/18, 07:57:51 AM	UDDSx2, 4 bag (FTP), cold start in hot test cell, solar load 850W/m^2, HVAC-AUTO-72°F	ok	36	41	29	3500	43.75	-0.6042	0.02619	3.59	0.109	33.0	0.109	32.9
61809048	UDDS hot start p4	09/21/18, 07:57:51 AM	UDDSx2, 4 bag (FTP), cold start in hot test cell, solar load 850W/m^2, HVAC-AUTO-72°F	ok	34	45	29	3500	43.75	-0.6042	0.02619	3.86	0.134	28.8	0.132	29.3
61809048	UDDS hot start p3+4	09/21/18, 07:57:51 AM	UDDSx2, 4 bag (FTP), cold start in hot test cell, solar load 850W/m^2, HVAC-AUTO-72°F	ok	35	43	29					7.45	0.242	30.71	0.241	30.93
61809049	SC03x4 p1	09/21/18, 09:16:17 AM	SC03x4, 4 bag in 95°F hot test cell , solar load 850W/m^2, HVAC-AUTO-72°F, Cycle sequence AUTO-AUTO-ECON-OFF	ok, Vspy start and stopped between cycles 2-3	37	42	29	3500	43.75	-0.6042	0.02619	3.57	0.124	28.8	0.125	28.5
61809049	SC03x4 p2	09/21/18, 09:16:17 AM	SC03x4, 4 bag in 95°F hot test cell , solar load 850W/m^2, HVAC-AUTO-72°F, Cycle sequence AUTO-AUTO-ECON-OFF	ok, Vspy start and stopped between cycles 2-3	37	42	29	3500	43.75	-0.6042	0.02619	3.59	0.128	28.1	0.128	28.0
61809049	SC03x4 p3	09/21/18, 09:16:17 AM	SC03x4, 4 bag in 95°F hot test cell , solar load 850W/m^2, HVAC-AUTO-72°F, Cycle sequence AUTO-AUTO-ECON-OFF	ok, Vspy start and stopped between cycles 2-3	36	43	29	3500	43.75	-0.6042	0.02619	3.58	0.122	29.4	0.123	29.1
61809049	SC03x4 p4	09/21/18, 09:16:17 AM	SC03x4, 4 bag in 95°F hot test cell , solar load 850W/m^2, HVAC-AUTO-72°F, Cycle sequence AUTO-AUTO-ECON-OFF	ok, Vspy start and stopped between cycles 2-3	36	43	29	3500	43.75	-0.6042	0.02619	3.58	0.096	37.1	0.098	36.4
61809050	HWYx2 p1	09/21/18, 10:46:51 AM	Hwyx2, 2 bag in 95°F hot test cell , solar load 850W/m^2, HVAC-AUTO-72°F,	ok, left vehicle running after cycles to be prepped for SSS	39	36	29	3500	43.75	-0.6042	0.02619	10.24	0.237	43.3	0.237	43.2
61809050	HWYx2 p2	09/21/18, 10:46:51 AM	Hwyx2, 2 bag in 95°F hot test cell , solar load 850W/m^2, HVAC-AUTO-72°F,	ok, left vehicle running after cycles to be prepped for SSS	39	35	29	3500	43.75	-0.6042	0.02619	10.24	0.212	48.3	0.212	48.4
61809051	SSS 0-80-0 1 min hold	09/21/18, 11:22:22 AM	SSS, 0-80-0, 1 minute hold, 1 bag, bags OFF, in 95°F hot test cell , solar load 850W/m^2, HVAC-AUTO-72°F, vehicle running prior to test to keep HVAC stable at temp	ok	38	40	29	3500	43.75	-0.6042	0.02619	11.55			0.269	43.0
61809052	US06x3 p1	09/21/18, 11:48:19 AM	US06x3, 3 bag, in 95°F hot test cell , solar load 850W/m^2, HVAC-AUTO-72°F, cycle sequence Normal Drive-Normal Drive-Sport Drive	ok	39	35	29	3500	43.75	-0.6042	0.02619	8.00	0.279	28.6	0.277	28.9
61809052	US06x3 p2	09/21/18, 11:48:19 AM	US06x3, 3 bag, in 95°F hot test cell , solar load 850W/m^2, HVAC-AUTO-72°F, cycle sequence Normal Drive-Normal Drive-Sport Drive	ok	40	33	29	3500	43.75	-0.6042	0.02619	7.99	0.281	28.4	0.279	28.6
61809052	US06x3 p3	09/21/18, 11:48:19 AM	US06x3, 3 bag, in 95°F hot test cell , solar load 850W/m^2, HVAC-AUTO-72°F, cycle sequence Normal Drive-Normal Drive-Sport Drive	ok	40	33	29	3500	43.75	-0.6042	0.02619	8.00	0.285	28.0	0.284	28.1

		Electrical Energy Use									SAE J2951 Metrics								
Test ID [#]	Cycle	Alternator Δ [Wh]	Alternator Energy consumption [Wh/mi]	12V Pos Out Δ WP2 [Wh]	12V Pos Out Δ WP2 [Wh/mi]	12V Neg Out Δ WP2 [Wh]	12V Neg Out Δ WP2 [Wh/mi]	Test Driver	Fuel Batch	Fuel Heating Value [BTU/lbm]	APCtime	ASCR	ASC_d	ASC_t	CE_d	CE_t	EER	ER	IWR
Day 1, Coastdowns and UDDS Prep																			
61809025	HWYx2 with coastdowns p1	54.669	5.327	-1.008	-0.098	-0.015	-0.001	GA	FH3021HW10	17958	1607.5258	3.6958015	1355.1612	1306.8622	6.6969934	6.6832091	0.147882	0.20625301	0.279481
61809025	HWYx2 with coastdowns p2	54.248	5.289	-0.727	-0.071	-0.112	-0.011	GA	FH3021HW10	17958	1607.9451	3.2000759	1348.6822	1306.8616	6.6573377	6.6832075	-0.3902077	-0.3870862	0.279482
61809026	UDDS prep	99.192	13.307	-10.611	-1.423	-7.711	-1.034	MK	FH3021HW10	17958	1528.0512	-0.1428474	5457.8516	5465.6591	5.3242272	5.2866449	0.6627817	0.71089099	0.635777
Day 2, Certification cycles in 2WD, closed hood and variable speed fan																			
61809027	UDDS cold start p1	30.903	8.626	2.356	0.658	2.362	0.659	GA	FH3021HW10	17958	2000.9181	-1.7864595	2012.4368	2049.0421	2.7112944	2.7196002	-0.0651609	-0.3054054	0.582645
61809027	UDDS cold start p2	51.420	13.379	4.043	1.052	4.115	1.071	GA	FH3021HW10	17958	1233.8004	-0.0025654	3416.4733	3416.5609	2.5739553	2.5670852	0.6926031	0.26762249	0.692036
61809027	UDDS cold start p1+2	82.323	11.086	6.399	0.9	6.478	0.9		FH3021HW10										
61809027	UDDS hot start p3	34.061	9.476	-0.815	-0.227	-0.355	-0.099	GA	FH3021HW10	17958	2001.9313	0.5348656	2059.9912	2049.0317	2.7391449	2.7195854	0.6159493	0.7192063	0.582643
61809027	UDDS hot start p4	53.683	13.828	1.291	0.333	1.781	0.459	GA	FH3021HW10	17958	1233.6444	1.3831318	3463.8092	3416.5538	2.6288646	2.5670665	1.7852563	2.40734096	0.692039
61809027	UDDS hot start p3+4	87.744	11.735	0.476	0.1	1.426	0.2		FH3021HW10										
61809028	UDDS #3 start p1	52.183	14.478	-18.642	-5.172	-16.828	-4.669	GA	FH3021HW10	17958	2005.7466	0.0422534	2049.8872	2049.0214	2.7370795	2.719581	0.2716658	0.64342544	0.582639
61809028	UDDS #3 start p2	58.230	15.017	-2.176	-0.561	-1.598	-0.412	GA	FH3021HW10	17958	1233.7634	0.8961406	3447.1729	3416.5557	2.6151311	2.5670795	1.3919662	1.87183802	0.692036
61809028	UDDS #3 start p1+2	110.413	14.758	-20.818	-2.8	-18.426	-2.5		FH3021HW10										
61809029	HWYx2 p1	59.717	5.818	-5.783	-0.563	-4.863	-0.474	GA	FH3021HW10	17958	1607.98	1.3638515	1324.6976	1306.8738	6.6792621	6.6832315	-0.1300934	-0.0593933	0.279483
61809029	HWYx2 p2	55.425	5.401	-1.705	-0.166	-1.501	-0.146	GA	FH3021HW10	17958	1608.3621	2.9630534	1345.5966	1306.8732	6.6953104	6.6832311	0.1239963	0.18074064	0.279483
61809030	US06x2 p1	14.640	8.245	0.568	0.320	0.730	0.411	GA	FH3021HW10	17958	4628.6376	0.7929137	2479.2632	2459.7594	2.6657016	2.6619604	-0.050183	0.14054166	0.808736
61809030	US06x2 p2	25.520	4.090	-0.210	-0.034	0.098	0.016	GA	FH3021HW10	17958	9869.9542	1.8423001	1160.9892	1139.9872	6.0859783	6.0651857	0.2697963	0.34281855	0.336274
61809030	US06x2 p1+2	40.160	5.011	0.358	0.0	0.828	0.1		FH3021HW10										
61809030	US06x2 p3	16.561	9.328	-1.513	-0.852	-1.285	-0.724	GA	FH3021HW10	17958	4616.5099	-0.0547189	2458.4074	2459.7533	2.6520294	2.6619513	-0.563069	-0.3727277	0.808736
61809030	US06x2 p4	25.660	4.110	-0.410	-0.066	-0.142	-0.023	GA	FH3021HW10	17958	9868.9379	0.4349742	1144.9262	1139.9676	6.0491034	6.0651459	-0.3916237	-0.2645034	0.33627
61809030	US06x2 p3+4	42.221	5.266	-1.924	-0.2	-1.428	-0.2		FH3021HW10										
61809031	UDDS prep	106.548	14.236	-15.158	-2.025	-14.170	-1.893	GA	FH3021HW10	17958	1527.5865	0.713301	5504.6065	5465.6202	5.3686697	5.2865859	1.0844796	1.55268092	0.635774
Day 3, Certification cycles in 2WD, closed hood and variable speed fan																			
61809032	UDDS cold start p1	31.230	8.713	3.138	0.875	3.148	0.878	MK/GA	FH3021HW10	17958	1895.2834	-1.0141415	2028.2463	2049.0263	2.6837652	2.7195437	-1.1450815	-1.3156081	0.58265
61809032	UDDS cold start p2	51.992	13.502	3.632	0.943	3.449	0.896	MK/GA	FH3021HW10	17958	1243.818	-0.0877364	3413.5472	3416.5447	2.5767051	2.5670129	0.6152197	0.37756752	0.692049
61809032	UDDS cold start p1+2	83.222	11.193	6.770	0.9	6.597	0.9		FH3021HW10										
61809032	UDDS hot start p3	34.740	9.644	-1.562	-0.434	-1.232	-0.342	MK/GA	FH3021HW10	17958	2008.7099	0.2758756	2054.6716	2049.0188	2.7356123	2.7195207	0.2754039	0.59170697	0.582652
61809032	UDDS hot start p4	54.171	13.964	0.804	0.207	1.084	0.279	MK/GA	FH3021HW10	17958	1243.9807	0.9754496	3449.8657	3416.5391	2.6193024	2.5669974	1.5062461	2.03759596	0.692054
61809032	UDDS hot start p3+4	88.911	11.884	-0.758	-0.1	-0.148	0.0		FH3021HW10										
61809033	UDDS #3 start p1	42.403	11.824	-9.442	-2.633	-8.475	-2.363	MK	FH3021HW10	17958	2012.6808	-0.6350511	2035.9962	2049.0084	2.7172018	2.719541	0.0506631	-0.0860149	0.582644
61809033	UDDS #3 start p2	58.590	15.194	-3.192	-0.828	-2.768	-0.718	MK	FH3021HW10	17958	1244.2074	0.3383832	3428.1182	3416.5571	2.5954182	2.5670325	1.1916763	1.10577519	0.692049
61809033	UDDS #3 start p1+2	100.993	13.570	-12.633	-1.7	-11.243	-1.5		FH3021HW10										
61809034	HWYx2 p1	56.900	5.546	-3.690	-0.360	-3.146	-0.307	GA	FH3021HW10	17958	1606.9794	1.7534009	1329.7738	1306.8593	6.6717734	6.6831977	-0.1967095	-0.1709403	0.279481
61809034	HWYx2 p2	55.556	5.420	-2.322	-0.227	-2.302	-0.225	GA	FH3021HW10	17958	1607.8226	0.3278443	1311.1434	1306.8589	6.6553677	6.683202	-0.3532694	-0.4164826	0.279481
61809035	US06x2 p1	18.381	10.358	-3.291	-1.854	-2.958	-1.667	GA	FH3021HW10	17958	4628.4433	-0.0110862	2459.4718	2459.7445	2.6558186	2.6619518	-0.3658859	-0.2304022	0.808731
61809035	US06x2 p2	25.700	4.118	-0.544	-0.087	-0.352	-0.056	GA	FH3021HW10	17958	9868.7214	-0.0901587	1138.9316	1139.9594	6.0672756	6.0651254	-0.0586843	0.03545222	0.336267
61809035	US06x2 p1+2	44.081	5.500	-3.835	-0.5	-3.311	-0.4		FH3021HW10										
61809035	US06x2 p3	18.166	10.217	-3.271	-1.839	-2.997	-1.685	GA	FH3021HW10	17958	4616.154	-0.7644802	2440.9263	2459.7305	2.6351304	2.6619329	-1.3573196	-1.0068799	0.808738
61809035	US06x2 p4	25.630	4.106	-0.640	-0.102	-0.500	-0.080	GA	FH3021HW10	17958	9869.7732	0.1467299	1141.6856	1140.0128	6.0309307	6.0651972	-0.6764703	-0.5649705	0.336284
61809035	US06x2 p3+4	43.796	5.461	-3.911	-0.5	-3.496	-0.4		FH3021HW10										
61809036	UDDS prep	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	GA	FH3021HW10	17958	1527.3987	0.379191	5486.2885	5465.5636	5.3240491	5.2865563	0.5825976	0.70921028	0.63577
Day 4, Certification cycles in 2WD, closed hood and variable speed fan																			
61809037	UDDS cold start p1	30.414	8.478	2.922	0.814	2.580	0.719	MK/GA	FH3021HW10	17958	2000.7359	-1.0275379	2027.975	2049.0295	2.7065849	2.7195914	-0.3740917	-0.4782513	0.582641
61809037	UDDS cold start p2	51.779	13.418	3.989	1.034	3.548	0.919	MK/GA	FH3021HW10	17958	1233.633	0.9663885	3449.5802	3416.5629	2.6107908	2.5670956	1.7035722	1.70212673	0.692033
61809037	UDDS cold start p1+2	82.193	11.038	6.910	0.9	6.128	0.8		FH3021HW10										
61809037	UDDS hot start p3	35.670	9.909	-1.142	-0.317	-1.958	-0.544	MK/GA	FH3021HW10	17958	2001.88	-0.1483893	2045.9772	2049.0178	2.7238606	2.7195705	-0.0804001	0.15774893	0.582642
61809037	UDDS hot start p4	54.117	13.954	1.725	0.445	0.839	0.216	MK/GA	FH3021HW10	17958	1233.4949	0.5614223	3435.7038	3416.5227	2.604968	2.5670469	0.9884963	1.47722859	0.692037
61809037	UDDS hot start p3+4	89.787	12.007	0.583	0.1	-1.119	-0.1		FH3021HW10										
61809038	UDDS #3 start p1	36.339	10.100	-1.437	-0.399	-2.423	-0.673	GA	FH3021HW10	17958	2012.4858	0.2617788	2054.3925	2049.0286	2.7420202	2.7195423	0.630036	0.82652979	0.58265
61809038	UDDS #3 start p2	65.450	16.903	-7.002	-1.808	-8.382	-2.165	GA	FH3021HW10	17958	1244.0242	0.8578855	3445.8437	3416.5338	2.598722	2.5670079	0.911477	1.23545106	0.692047
61809038	UDDS #3 start p1+2	101.789	13.626	-8.439	-1.1	-10.805	-1.4		FH3021HW10										
61809039	HWYx2 p1	57.679	5.625	-1.881	-0.183	-3.296	-0.321	GA	FH3021HW10	17958	1607.4793	1.0101643	1320.0635	1306.862	6.6683115	6.6832183	-0.2028966	-0.2230487	0.279481
61809039	HWYx2 p2	55.302	5.391	-0.601	-0.059	-1.564	-0.152	GA	FH3021HW10	17958	1607.9036	1.3228998	1324.152	1306.8635	6.6634786	6.6831943	-0.3159999	-0.2950028	0.279483
61809040	US06x2 p1	15.009	8.424	0.596	0.334	0.362	0.203	GA	FH3021HW10	17958	4628.3709	-0.0666635	2458.0942	2459.7339	2.6576208	2.6619525	-0.6961778	-0.1627228	0.808731
61809040	US06x2 p2	19.390	3.106	5.558	0.890	5.611	0.899	GA	FH3021HW10	17958	9867.1635	3.8084558	1183.3071	1139.8947	6.0937003	6.0650157	0.3556888	0.47295214	0.336248
61809040	US06x2 p1+2	34.399	4.287	6.153	0.8	5.973	0.7		FH3021HW10										
61809040	US06x2 p3	18.322	10.321	-2.643	-1.489	-3.086	-1.739	GA	FH3021HW10	17958	4616.1647	-0.0199587	2459.2635	2459.7545	2.6611746	2.6619433	-0.2093464	-0.0288772	0.808739
61809040	US06x2 p4	25.310	4.054	0.148	0.024	-0.162	-0.026	GA	FH3021HW10	17958	9867.5883	0.6378166	1147.2108	1139.94	6.0765735	6.0650921	0.0535572	0.18930342	0.336262
61809040	US06x2 p3+4	43.632	5.441	-2.495	-0.3	-3.249	-0.4		FH3021HW10										
Day 5, Performance Cycles																			
61809041	WOTsx5	38.670	8.851	-10.447	-2.391	-12.200	-2.792	KS	FH3021HW10	17958	0	Inf	4379.9135	0	7.9939155	0	NaN	Inf	NaN
61809042	SSS 0-80-0 30 sec 0,3,6% grade - SSS warmup	52.584	5.557	-5.211	-0.551	-6.315	-0.667	GA	FH3021HW10	17958	174.66278	7.4079038	528.17192	491.744	6.4193652	6.4413793	-0.2373339	-0.3417594	0.075616
61809042	SSS 0-80-0 30 sec 0% grade	36.967	5.936	0.352	0.057	-0.298	-0.048	GA	FH3021HW10	17958	1116.676	14.182681	816.70761	715.264	4.9248013	4.9863378	-1.329733	-1.2341018	0.206666
61809042	SSS 0-80-0 30 sec 3% grade	36.548	5.881	0.433	0.070	-0.195	-0.031	GA	FH3021HW10	17958	1117.3296	23.081074	880.35461	715.264	4.9477746	4.9865337	-0.6515121	-0.7772759	0.206657
61809042	SSS 0-80-0 30 sec 6% grade - FAULT	21.592	5.873	0.065	0.018	-0.335	-0.091	GA	FH3021HW10	17958	1570.4746	16.279373	831.70449	715.264	3.5325791	4.5264572	-2.3312691	-21.957085	0.227662
61809043	SSS 0-80-0 30 sec 6% grade	38.190	6.145	0.026	0.004	-1.193	-0.192	GA	FH3021HW10	17958	1117.0629	16.907118	836.19453	715.264	4.9878368	4.985989	0.1479047	0.03706014	0.20668
61809044	SSS 0-80-0 1 min hold	73.378	6.356	-2.445	-0.212	-4.459	-0.386	MK	FH3021HW10	17958	605.10611	16.243184	831.44565	715.264	8.6307582	8.6669325	-0.3208822	-0.4173827	0.118901
61809045	Passing Manuevers 0,3,6%	60.411	6.031	-3.228	-0.322	-4.557	-0.455	GA	FH3021HW10	17958	12724.918	12.584358	3774.7283	3352.8	11.751166	12.005862	0.2072717	-2.1214245	0.453643
61809046	25% grade	17.168	26.357	-2.942	-4.517	-3.744	-5.748	GA	FH3021HW10	17958	0	Inf	469.16186	0	0.7556167	0	NaN	Inf	NaN
61809047	UDDS Prep	90.098	12.054	0.966	0.129	-0.439	-0.059	GA	FH3021HW10	17958	1527.403	0.2543036	5479.4588	5465.5597	5.3347585	5.2865429	0.5904286	0.91204518	0.635773
Day 6, Certification cycles in 2WD, 95F w/ solar																			
61809048	UDDS cold start p1	69.853	19.463	5.274	1.469	4.341	1.210	MK	FH3021HW10	17958	1999.5272	-0.6724628	2035.2359	2049.0147	2.6954399	2.7195683	-0.8354836	-0.8872133	0.582641
61809048	UDDS cold start p2	87.004	22.621	11.306	2.940	10.340	2.688	MK	FH3021HW10	17958	1233.5682	-0.17635	3410.5178	3416.5429	2.5557149	2.5670535	-0.0849939	-0.4416967	0.692039
61809048	UDDS cold start p1+2	156.857	21.097	16.580	2.2	14.681	2.0		FH3021HW10										
61809048	UDDS hot start p3	75.804	21.142	-9.391	-2.619	-11.829	-3.299	MK	FH3021HW10	17958	2001.7828	-0.2086266	2044.7437	2049.0185	2.684783	2.7195686	-1.1391195	-1.2790863	0.582641
61809048	UDDS hot start p4	102.686	26.603	-0.656	-0.170	-2.674	-0.693	MK	FH3021HW10	17958	1233.5554	0.3809739	3429.568	3416.5518	2.5604909	2.5670632	-0.2570666	-0.2560222	0.692041
61809048	UDDS hot start p3+4	178.490	23.973	-10.047	-1.3	-14.503	-1.9		FH3021HW10										
61809049	SC03x4 p1	90.998	25.473	-4.403	-1.233	-7.611	-2.131	MK/GT	FH3021HW10	17958	1960.0001	0.2916413	2539.273	2531.889	2.7636458	2.7766379	-0.2656744	-0.4679065	0.680416
61809049	SC03x4 p2	86.491	24.106	-1.576	-0.439	-4.364	-1.216	MK/GT	FH3021HW10	17958	1956.0668	1.549443	2571.1109	2531.8808	2.8233759	2.7766367	1.425992	1.68330088	0.680415
61809049	SC03x4 p3	82.678	23.108	-1.333	-0.372	-4.138	-1.157	MK/GT	FH3021HW10	17958	1960.0705	-0.6985334	2514.2021	2531.8881	2.7854566	2.7766409	0.3618869	0.31749524	0.680418
61809049	SC03x4 p4	46.330	12.956	-4.540	-1.270	-6.668	-1.865	MK/GT	FH3021HW10	17958	1953.606	0.3507725	2540.77	2531.8888	2.8122494	2.7766303	1.3635643	1.28281891	0.680421
61809050	HWYx2 p1	128.488	12.542	-3.656	-0.357	-7.637	-0.745	MK	FH3021HW10	17958	1607.3889	2.2024077	1335.6382	1306.8559	6.6591758	6.6831929	-0.2440955	-0.3593652	0.27948
61809050	HWYx2 p2	96.569	9.430	0.173	0.017	-1.953	-0.191	MK	FH3021HW10	17958	1607.9668	3.2323813	1349.1056	1306.8628	6.6671204	6.6831964	-0.082181	-0.2405442	0.279482
61809051	SSS 0-80-0 1 min hold	105.423	9.126	8.062	0.698	6.577	0.569	MK	FH3021HW10	17958	605.09584	19.751311	856.53802	715.264	8.5783818	8.6669306	-1.0008712	-1.0216859	0.118901
61809052	US06x3 p1	76.420	9.552	-0.358	-0.045	-2.203	-0.275	GT	FH3021HW10	17958	7841.1928	-1.7786088	3535.6723	3599.6968	8.6718672	8.7270803	-0.5540366	-0.6326644	0.480376
61809052	US06x3 p2	74.684	9.344	-1.980	-0.248	-3.573	-0.447	GT	FH3021HW10	17958	7851.786	-0.6173513	3578.0784	3600.305	8.6833746	8.7273898	-0.3351437	-0.5043339	0.480482
61809052	US06x3 p3	71.976	9.000	0.996	0.124	-0.277	-0.035	GT	FH3021HW10	17958	7876.8408	-0.5472317	3581.5676	3601.2749	8.7174126	8.7288315	-0.0110812	-0.1308181	0.480651

													Liquid Fuel usage				Electrical Energy Use									SAE J2951 Metrics								
Test ID [#]	Cycle	Test Time	Start Comments	End Comments	Test Cell Temp [C]	Test Cell RH [%]	Test Cell Baro [in/Hg]	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 Δ [Wh]	Alternator Energy consumption [Wh/mi]	12V Pos Out Δ WP2 [Wh]	12V Pos Out Δ WP2 [Wh/mi]	12V Neg Out Δ WP2 [Wh]	12V Neg Out Δ WP2 [Wh/mi]	Test Driver	Fuel Batch	Fuel Heating Value [BTU/lbm]	APCtime	ASCR	ASC_d	ASC_t	CE_d	CE_t	EER	ER	IWR
Day 7, LA92, JC08, additional performance cycles																																	
61809053	LA92x2 ph1	09/24/18, 08:21:27 AM	LA92x2, 2 bag, cold start	ok	24	46	29	3500	43.75	-0.6042	0.02619	9.80	0.293	33.5	0.295	33.2	89.767	9.159	3.339	0.341	1.685	0.172	MK/GA	GH1621LT10	17994	3074.8229	0.9037829	7348.0877	7282.2717	8.9878392	8.9785253	0.255044	0.10373445	0.632006
61809053	LA92x2 ph2	09/24/18, 08:21:27 AM	LA92x2, 2 bag, cold start	ok	21	51	29	3500	43.75	-0.6042	0.02619	9.81	0.284	34.6	0.285	34.4	89.302	9.103	3.114	0.317	1.450	0.148	MK/GA	GH1621LT10	17994	3011.766	1.0125005	7355.9082	7282.1761	9.0236197	8.9784178	0.5661912	0.50345019	0.632007
61809054	JC08x2 ph1	09/24/18, 09:27:49 AM	JC08x2, 2 bag, prep + hot start	ok	23	47	29	3500	43.75	-0.6042	0.02619	5.06	0.141	35.9	0.138	36.6	77.642	15.335	-0.133	-0.026	-2.257	-0.446	GT/MK	GH1621LT10	17994	1112.8304	3.1326627	3775.9366	3661.2423	3.5316125	3.4763511	1.7017728	1.58963686	0.662083
61809054	JC08x2 ph2	09/24/18, 09:27:49 AM	JC08x2, 2 bag, prep + hot start	ok	21	52	29	3500	43.75	-0.6042	0.02619	5.06	0.138	36.6	0.135	37.4	75.901	15.002	0.901	0.178	-0.821	-0.162	GT/MK	GH1621LT10	17994	1113.0004	1.030673	3698.9632	3661.2279	3.4918534	3.4763433	0.6558084	0.44616145	0.662084
61809055	SSS 0-80-0 Sport Mode- warmup @ 55mph	09/24/18, 10:41:08 AM	Steady State Speeds, 2 bag, 0-80-0, bags OFF, vehicle in sport mode	ok	26	38	29	3500	43.75	-0.6042	0.02619	9.46			0.219	43.2	61.537	6.502	-11.941	-1.262	-14.500	-1.532	KS	GH1621LT10	17994	174.68808	5.8992701	520.75331	491.744	6.4241694	6.4413824	-0.1831025	-0.2672252	0.075616
61809055	SSS 0-80-0 Sport Mode- stairs	09/24/18, 10:41:08 AM	Steady State Speeds, 2 bag, 0-80-0, bags OFF, vehicle in sport mode	ok	25	42	29	3500	43.75	-0.6042	0.02619	6.22			0.172	36.1	36.444	5.864	0.355	0.057	-0.325	-0.052	KS	GH1621LT10	17994	1117.1573	23.196001	881.17664	715.264	5.0957564	4.9860335	2.2618721	2.20060437	0.206678
61809056	Passing Manuevers 0% Sport Mode	09/24/18, 11:05:21 AM	Passing manuevers, 1 bag, bags OFF, vehicle in sport mode	ok	24	44	29	3500	43.75	-0.6042	0.02619	3.37			0.141	23.9	17.664	5.243	-0.143	-0.043	-0.593	-0.176	KS	GH1621LT10	17994	13791.729	23.513324	1380.3849	1117.6	4.1636583	4.0019773	5.2774536	4.04002757	0.453641
61809057	UDDS Prep	09/24/18, 02:48:40 PM	UDDS, 1 bag prep for Cold CO test	ok	-8	33	29	3500	43.75	-0.6042	0.02619	7.44	0.211	35.2	0.208	35.8	174.608	23.480	-35.446	-4.767	-38.773	-5.214	MK	GH1621LT10	17994	1527.3706	0.6058611	5498.7041	5465.5902	5.308168	5.2865648	0.6020717	0.40864344	0.635774
Day 8, Certification cycles in 2WD, 20F																																	
61809058	UDDS cold start p1	09/25/18, 07:38:11 AM	UDDSx2, 4 bag (Cold CO), in cold test cell @ 20°F, HVAC ON-AUTO-72°F	ok	-6	17	29	3500	43.75	-0.6042	0.02619	3.58	0.135	26.5	0.137	26.2	46.478	12.978	1.044	0.292	-0.101	-0.028	MK	GH1621LT10	17994	2000.3643	-0.1979771	2044.9547	2049.0113	2.699657	2.7195768	-0.463246	-0.7324604	0.582635
61809058	UDDS cold start p2	09/25/18, 07:38:11 AM	UDDSx2, 4 bag (Cold CO), in cold test cell @ 20°F, HVAC ON-AUTO-72°F	ok	-6	17	29	3500	43.75	-0.6042	0.02619	3.86	0.120	32.1	0.119	32.5	88.879	23.051	3.192	0.828	1.252	0.325	MK	GH1621LT10	17994	1233.6178	1.3320202	3462.0397	3416.5309	2.6006246	2.5670618	1.3998864	1.3074436	0.692033
61809058	UDDS cold start p1+2	09/25/18, 07:38:11 AM	UDDSx2, 4 bag (Cold CO), in cold test cell @ 20°F, HVAC ON-AUTO-72°F	ok	-6	17	29					7.44	0.255	29.12	0.255	29.13	135.357	18.201	4.236	0.6	1.151	0.2		GH1621LT10										
61809058	UDDS hot #2 start p1	09/25/18, 07:38:11 AM	UDDSx2, 4 bag (Cold CO), in cold test cell @ 20°F, HVAC ON-AUTO-72°F	ok	-6	17	29	3500	43.75	-0.6042	0.02619	3.59	0.093	38.6	0.094	38.1	50.326	14.033	1.394	0.389	0.115	0.032	MK	GH1621LT10	17994	2001.6679	-0.4602447	2039.5876	2049.0181	2.7195165	2.7195729	0.1309023	-0.002074	0.58264
61809058	UDDS hot #2 start p2	09/25/18, 07:38:11 AM	UDDSx2, 4 bag (Cold CO), in cold test cell @ 20°F, HVAC ON-AUTO-72°F	ok	-7	19	29	3500	43.75	-0.6042	0.02619	3.86	0.110	35.1	0.109	35.5	74.545	19.296	3.230	0.836	1.310	0.339	MK	GH1621LT10	17994	1233.3793	1.1180944	3454.7423	3416.5421	2.6119749	2.5670463	1.6374274	1.75020531	0.69204
61809058	UDDS hot #2 start p1+2	09/25/18, 07:38:11 AM	UDDSx2, 4 bag (Cold CO), in cold test cell @ 20°F, HVAC ON-AUTO-72°F	ok	-6	18	29					7.45	0.203	36.70	0.203	36.73	124.872	16.762	4.624	0.6	1.425	0.2		GH1621LT10										
61809059	UDDS hot #3 start p3	09/25/18, 08:57:33 AM	UDDSx2, 4 bag, warm start in cold test cell @ 20°F, HVAC ON-AUTO-72°F, second UDDS to verify fully stable temp	ok	-6	16	29	3500	43.75	-0.6042	0.02619	3.59	0.093	38.4	0.094	38.2	43.982	12.254	-6.412	-1.786	-7.502	-2.090	GT	GH1621LT10	17994	2000.5306	1.5150985	2080.059	2049.0144	2.7369314	2.719577	0.6853441	0.638128	0.582638
61809059	UDDS hot #3 start p4	09/25/18, 08:57:33 AM	UDDSx2, 4 bag, warm start in cold test cell @ 20°F, HVAC ON-AUTO-72°F, second UDDS to verify fully stable temp	ok	-7	18	29	3500	43.75	-0.6042	0.02619	3.86	0.110	34.9	0.108	35.6	66.896	17.342	-4.298	-1.114	-5.700	-1.478	GT	GH1621LT10	17994	1233.5988	2.6602934	3507.4553	3416.5646	2.6296835	2.5670772	2.4465436	2.43881663	0.692039
61809059	UDDS hot #3 start p3+4	09/25/18, 08:57:33 AM	UDDSx2, 4 bag, warm start in cold test cell @ 20°F, HVAC ON-AUTO-72°F, second UDDS to verify fully stable temp	ok	-7	17	29					7.45	0.204	36.53	0.202	36.82	110.878	14.890	-10.710	-1.4	-13.202	-1.8		GH1621LT10										
61809059	UDDS hot #4 start p3	09/25/18, 08:57:33 AM	UDDSx2, 4 bag, warm start in cold test cell @ 20°F, HVAC ON-AUTO-72°F, second UDDS to verify fully stable temp	ok	-6	16	29	3500	43.75	-0.6042	0.02619	3.59	0.091	39.5	0.091	39.4	41.136	11.465	-2.970	-0.828	-4.548	-1.268	GT	GH1621LT10	17994	2001.6851	0.6629152	2062.5991	2049.0158	2.7348428	2.7195657	0.644004	0.56174995	0.582641
61809059	UDDS hot #4 start p4	09/25/18, 08:57:33 AM	UDDSx2, 4 bag, warm start in cold test cell @ 20°F, HVAC ON-AUTO-72°F, second UDDS to verify fully stable temp	ok	-7	18	29	3500	43.75	-0.6042	0.02619	3.85	0.110	35.1	0.108	35.8	63.684	16.530	-0.100	-0.026	-2.358	-0.612	GT	GH1621LT10	17994	1233.4899	2.7067707	3509.0138	3416.536	2.6297519	2.5670473	2.5733859	2.44267222	0.692041
61809059	UDDS hot #4 start p3+4	09/25/18, 08:57:33 AM	UDDSx2, 4 bag, warm start in cold test cell @ 20°F, HVAC ON-AUTO-72°F, second UDDS to verify fully stable temp	ok	-6	17	29					7.44	0.200	37.13	0.199	37.44	104.820	14.088	-3.070	-0.4	-6.906	-0.9		GH1621LT10										
61809060	HWYx3 ph1	09/25/18, 10:19:59 AM	Hwyx3, 3 bag, warm start in cold test cell @ 20°F, HVAC ON-AUTO-72°F,	ok	-5	16	29	3500	43.75	-0.6042	0.02619	10.26	0.203	50.6	0.203	50.5	86.716	8.448	-2.174	-0.212	-4.284	-0.417	KS	GH1621LT10	17994	1606.9255	2.9172484	1344.9894	1306.8649	6.721465	6.6832132	0.4899314	0.57235682	0.279482
61809060	HWYx3 ph2	09/25/18, 10:19:59 AM	Hwyx3, 3 bag, warm start in cold test cell @ 20°F, HVAC ON-AUTO-72°F,	ok	-5	17	29	3500	43.75	-0.6042	0.02619	10.27	0.200	51.3	0.200	51.4	78.032	7.597	0.850	0.083	-0.910	-0.089	KS	GH1621LT10	17994	1605.8457	3.8992548	1357.8204	1306.8625	6.7071438	6.6832139	0.2195645	0.3580601	0.279481
61809060	HWYx3 ph3	09/25/18, 10:19:59 AM	Hwyx3, 3 bag, warm start in cold test cell @ 20°F, HVAC ON-AUTO-72°F,	ok	-6	17	29	3500	43.75	-0.6042	0.02619	10.28	0.200	51.4	0.200	51.4	75.862	7.380	1.287	0.125	-0.490	-0.048	KS	GH1621LT10	17994	1634.7523	3.8609708	1357.3187	1306.8612	6.7252305	6.686668	0.4552713	0.57670651	0.279337
61809061	US06x2 p1	09/25/18, 11:17:39 AM	Hwyx3, 3 bag,US06x2, 4 bag, warm start in cold test cell @ 20°F, HVAC AUTO-72°F	ok	-6	17	29	3500	43.75	-0.6042	0.02619	1.77	0.085	20.8	0.084	21.0	25.911	14.630	-2.586	-1.460	-3.406	-1.923	GT	GH1621LT10	17994	4628.0429	0.7486429	2478.1505	2459.7358	2.662183	2.6619217	0.0675741	0.0098182	0.808742
61809061	US06x2 p2	09/25/18, 11:17:39 AM	Hwyx3, 3 bag,US06x2, 4 bag, warm start in cold test cell @ 20°F, HVAC AUTO-72°F	ok	-2	13	29	3500	43.75	-0.6042	0.02619	6.23	0.169	36.8	0.168	37.0	38.952	6.252	-1.645	-0.264	-2.648	-0.425	GT	GH1621LT10	17994	9866.4041	-1.1979615	1126.2326	1139.888	6.0316035	6.0650417	-0.4845298	-0.5513273	0.336246
61809061	US06x2 p1+2	09/25/18, 11:17:39 AM	Hwyx3, 3 bag,US06x2, 4 bag, warm start in cold test cell @ 20°F, HVAC AUTO-	ok	-4	15	29					8.00	0.254	31.44	0.253	31.67	64.863	8.106	-4.231	-0.5	-6.054	-0.8		GH1621LT10										
61809061	US06x2 p3	09/25/18, 11:17:39 AM	Hwyx3, 3 bag,US06x2, 4 bag, warm start in cold test cell @ 20°F, HVAC AUTO-	ok	-7	16	29	3500	43.75	-0.6042	0.02619	1.77	0.086	20.6	0.084	21.0	19.940	11.263	0.325	0.184	-0.250	-0.141	GT	GH1621LT10	17994	4616.1493	0.0560594	2461.1227	2459.7438	2.6453759	2.6619332	-0.5324223	-0.6220034	0.808739
61809061	US06x2 p4	09/25/18, 11:17:39 AM	Hwyx3, 3 bag,US06x2, 4 bag, warm start in cold test cell @ 20°F, HVAC AUTO-72°F	ok	-3	16	29	3500	43.75	-0.6042	0.02619	6.23	0.167	37.3	0.166	37.5	33.934	5.445	0.600	0.096	-0.310	-0.050	GT	GH1621LT10	17994	9867.7304	1.9841364	1162.5505	1139.9327	6.0289878	6.0651122	-0.5573027	-0.5956101	0.336259
61809061	US06x2 p3+4	09/25/18, 11:17:39 AM	Hwyx3, 3 bag,US06x2, 4 bag, warm start in cold test cell @ 20°F, HVAC AUTO-72°F	ok	-5	16	29					8.00	0.253	31.65	0.251	31.92	53.874	6.732	0.925	0.1	-0.560	-0.1		GH1621LT10										
61809062	SSS 0-80-0 Sport Mode- warmup @ 55mph	09/25/18, 12:01:41 PM	SSS 0-80-0, w _55MPH 10 minute warmup, 2 bag, warm start in cold test cell @ 20°F, HVAC AUTO-72°F	ok	-4	16	29	3500	43.75	-0.6042	0.02619	9.46	0.188	50.3	0.188	50.4	72.056	7.617	-3.458	-0.365	-5.268	-0.557	MK	GH1621LT10	17994	174.6772	10.758971	544.65059	491.744	6.419431	6.4413727	-0.2142218	-0.3406366	0.075617
61809062	SSS 0-80-0 Sport Mode- stairs	09/25/18, 12:01:41 PM	SSS 0-80-0, w _55MPH 10 minute warmup, 2 bag, warm start in cold test cell @ 20°F, HVAC AUTO-72°F	ok	-7	17	29	3500	43.75	-0.6042	0.02619	6.21	0.149	41.7	0.151	41.2	53.919	8.677	1.030	0.166	-0.180	-0.029	MK	GH1621LT10	17994	1059.3381	17.268454	838.77903	715.264	4.9956791	4.9859986	0.3320073	0.19415223	0.20668
61809063	UDDS Prep	09/25/18, 02:57:24 PM	UDDS, 1 bag prep for CERT style testing at 72°F with HF2021 fuel, Hood Up/Fan at 6 MPH (5300CFM)	ok	17	57	29	3500	43.75	-0.6042	0.02619	7.45	0.204	36.6	0.200	37.2	112.008	15.025	-11.735	-1.574	-14.752	-1.979	MK	GH1621LT10	17994	1527.2337	0.619391	5499.4005	5465.5474	5.3288487	5.2865397	0.7405765	0.80031494	0.635769
Day 9, Fuel change to Tier II high octane fuel																																	
Transfer to Tier II HF0437 high octane fuel																																	
61809067	OA- Warmup and US06	09/26/18, 11:13:44 AM	Octane adjuster cycle with warmup and extra hills to adjust for HF0437 Tier 2 EEE CERT 92 Octane fuel	ok	25	40	29	3500	43.75	-0.6042	0.02619	14.34	0.412	34.8	0.411	34.9	89.463	6.239	-8.692	-0.606	-5.992	-0.418	GA	FC2421BE10	18627	5188.7366	-0.1692564	5967.3729	5977.4901	14.950255	14.926788	-0.0356766	0.15721596	0.434096
61809068	OA- Warmup and SSS	09/26/18, 01:00:16 PM	SSS, 0-80-0, 60 second hold with 55MPH warmup	ok	26	40	29	3500	43.75	-0.6042	0.02619	9.48	0.171	55.3	0.172	55.1	52.009	5.487	-1.790	-0.189	-0.267	-0.028	GA	FC2421BE10	18627	174.6737	12.296055	552.20911	491.744	6.447344	6.4413741	0.020696	0.09268059	0.075617
61809069	WOTsx5, first limited power	09/26/18, 01:50:38 PM	WOTs X 5 with HF0437 Tier 2 Cert EEE	ok, first WOT was limited power	25	44	29	3500	43.75	-0.6042	0.02619	4.23			0.233	18.1	25.921	6.130	-2.797	-0.661	-1.807	-0.427	GA	FC2421BE10	18627	0	Inf	3691.8933	0	6.3355224	0	NaN	Inf	NaN
61809070	Passing Manuevers 0, 3, 6% grade	09/26/18, 02:05:41 PM	Passing manuevers at 0, 3 & 6% grade with HF0437 Tier 2 CERT fuel 92 octane	ok	25	41	29	3500	43.75	-0.6042	0.02619	9.88			0.478	20.7	61.766	6.252	-3.870	-0.392	-1.700	-0.172	GA	FC2421BE10	18627	12728.137	15.732596	3880.2825	3352.8	11.403969	12.005853	-1.4217682	-5.0132529	0.453644
61809071	UDDS Prep	09/26/18, 02:42:19 PM	UDDS prep, 1 bag, for FTP test with HF0437 Tier 2 CERT fuel 92 octane	ok	22	52	29	3500	43.75	-0.6042	0.02619	7.44	0.189	39.4	0.185	40.1	109.143	14.671	-14.052	-1.889	-10.034	-1.349	MK	FC2421BE10	18627	1527.1757	0.5389177	5495.0053	5465.5504	5.3181251	5.2865458	0.7501185	0.59735308	0.63577
Day 10, Certification cycles w/ high octane fuel																																	
61809072	UDDS cold start p1	09/27/18, 07:39:50 AM	UDDSx2, 4 bag (FTP), cold start, with HF0437 Tier 2 CERT fuel 92 octane	ok	24	42	29	3500	43.75	-0.6042	0.02619	3.59	0.096	37.5	0.081	44.6	0.000	0.000	0.000	0.000	0.000	0.000	MK/GA	FC2421BE10	18627	2001.5461	-0.4807925	2039.179	2049.0306	2.7230218	2.719578	0.1362024	0.12663057	0.582645
61809072	UDDS cold start p2	09/27/18, 07:39:50 AM	UDDSx2, 4 bag (FTP), cold start, with HF0437 Tier 2 CERT fuel 92 octane	ok	21	52	29	3500	43.75	-0.6042	0.02619	3.86	0.101	38.2	0.084	46.0	43.122	11.181	0.938	0.243	1.373	0.356	MK/GA	FC2421BE10	18627	1233.2495	0.5981761	3436.985	3416.548	2.5949125	2.5670565	1.1586688	1.0851344	0.692039
61809072	UDDS cold start p1+2	09/27/18, 07:39:50 AM	UDDSx2, 4 bag (FTP), cold start, with HF0437 Tier 2 CERT fuel 92 octane	ok	23	47	29					7.45	0.197	37.85	0.164	45.28	43.122	5.790	0.938	0.1	1.373	0.2		FC2421BE10										
61809072	UDDS hot #2 start p3	09/27/18, 07:39:50 AM	UDDSx2, 4 bag (FTP), cold start, with HF0437 Tier 2 CERT fuel 92 octane	ok	24	46	29	3500	43.75	-0.6042	0.02619	3.60	0.084	43.0	0.072	50.3	34.490	9.586	-1.817	-0.505	-1.149	-0.319	MK/GA	FC2421BE10	18627	2001.5533	-0.5618698	2037.4964	2049.0091	2.7212534	2.7195632	-0.125994	0.06215081	0.582639
61809072	UDDS hot #2 start p4	09/27/18, 07:39:50 AM	UDDSx2, 4 bag (FTP), cold start, with HF0437 Tier 2 CERT fuel 92 octane	ok	22	49	29	3500	43.75	-0.6042	0.02619	3.88	0.101	38.6	0.084	46.0	57.155	14.727	-2.271	-0.585	-1.614	-0.416	MK/GA	FC2421BE10	18627	1233.4944	0.5801069	3436.3667	3416.5471	2.617523	2.5670494	1.3951516	1.9662092	0.692043
61809072	UDDS hot #2 start p3+4	09/27/18, 07:39:50 AM	UDDSx2, 4 bag (FTP), cold start, with HF0437 Tier 2 CERT fuel 92 octane	ok	23	47	29					7.48	0.184	40.60	0.156	47.99	91.645	12.254	-4.088	-0.5	-2.763	-0.4		FC2421BE10										
61809073	UDDS hot #3 start p1	09/27/18, 09:01:02 AM	UDDS, 2bag, hot start, with HF0437 Tier 2 CERT fuel 92 octane	ok	24	44	29	3500	43.75	-0.6042	0.02619	3.60	0.083	43.4	0.084	42.9	36.218	10.069	-3.479	-0.967	-2.889	-0.803	GA	FC2421BE10	18627	2012.7601	-0.2961168	2042.9551	2049.0226	2.7231127	2.7195365	-0.0342501	0.13150022	0.582649
61809073	UDDS hot #3 start p2	09/27/18, 09:01:02 AM	UDDS, 2bag, hot start, with HF0437 Tier 2 CERT fuel 92 octane	ok	22	49	29	3500	43.75	-0.6042	0.02619	3.88	0.100	38.8	0.099	39.3	55.956	14.415	-1.228	-0.316	-0.821	-0.211	GA	FC2421BE10	18627	1243.9834	0.8083653	3444.1452	3416.5272	2.6091207	2.5670041	1.0591268	1.64069078	0.692048
61809073	UDDS hot #3 start p1+2	09/27/18, 09:01:02 AM	UDDS, 2bag, hot start, with HF0437 Tier 2 CERT fuel 92 octane	ok	23	46	29					7.48	0.183	40.89	0.183	40.95	92.174	12.325	-4.707	-0.6	-3.709	-0.5		FC2421BE10										
61809074	HWYx2 p1	09/27/18, 09:44:48 AM	Hwyx2, 2bag, hot start, with HF0437 Tier 2 CERT fuel 92 octane	ok	26	40	29	3500	43.75	-0.6042	0.02619	10.24	0.187	54.7	0.186	55.1	71.636	6.996	-17.669	-1.725	-16.365	-1.598	MK	FC2421BE10	18627	1607.4684	1.1320461	1321.6534	1306.8591	6.6617975	6.6832048	-0.1599372	-0.3203152	0.279481
61809074	HWYx2 p2	09/27/18, 09:44:48 AM	Hwyx2, 2bag, hot start, with HF0437 Tier 2 CERT fuel 92 octane	ok	25	40	29	3500	43.75	-0.6042	0.02619	10.24	0.182	56.1	0.182	56.3	55.173	5.387	-2.027	-0.198	-1.727	-0.169	MK	FC2421BE10	18627	1607.7915	0.5526402	1314.0804	1306.8582	6.6599407	6.6831993	-0.2014369	-0.3480152	0.279481
61809075	US06x2 p1	09/27/18, 10:24:46 AM	US06x2, 4 bag, hot start, with HF0437 Tier 2 CERT fuel 92 octane	ok	22	53	29	3500	43.75	-0.6042	0.02619	1.78	0.079	22.4	0.079	22.6	20.808	11.705	-5.515	-3.102	-5.068	-2.851	GA	FC2421BE10	18627	4628.1281	-0.3954663	2450.0075	2459.7349	2.6432518	2.6619483	-1.0212031	-0.7023603	0.808733
61809075	US06x2 p2	09/27/18, 10:24:46 AM	US06x2, 4 bag, hot start, with HF0437 Tier 2 CERT fuel 92 octane	ok	26	43	29	3500	43.75	-0.6042	0.02619	6.25	0.155	40.3	0.154	40.4	25.650	4.107	-0.475	-0.076	-0.222	-0.036	GA	FC2421BE10	18627	9867.5179	-3.5967047	1098.9347	1139.9348	6.0162082	6.065091	-0.9802992	-0.8059698	0.336261
61809075	US06x2 p1+2	09/27/18, 10:24:46 AM	US06x2, 4 bag, hot start, with HF0437 Tier 2 CERT fuel 92 octane	ok	24	48	29					8.02	0.234	34.22	0.233	34.40	46.458	5.791	-5.990	-0.7	-5.290	-0.7		FC2421BE10										
61809075	US06x2 p3	09/27/18, 10:24:46 AM	US06x2, 4 bag, hot start, with HF0437 Tier 2 CERT fuel 92 octane	ok	22	46	29	3500	43.75	-0.6042	0.02619	1.78	0.079	22.6	0.078	22.7	16.612	9.357	-1.651	-0.930	-1.432	-0.806	GA	FC2421BE10	18627	4615.778	-0.1056901	2457.1436	2459.7433	2.6528481	2.6619329	-0.5236844	-0.3412848	0.808737
61809075	US06x2 p4	09/27/18, 10:24:46 AM	US06x2, 4 bag, hot start, with HF0437 Tier 2 CERT fuel 92 octane	ok	26	38	29	3500	43.75	-0.6042	0.02619	6.24	0.155	40.4	0.154	40.5	25.570	4.097	-0.522	-0.084	-0.302	-0.048	GA	FC2421BE10	18627	9867.2805	-4.3965591	1089.8043	1139.9216	6.0330888	6.065103	-0.6422387	-0.5278427	0.336253
61809075	US06x2 p3+4	09/27/18, 10:24:46 AM	US06x2, 4 bag, hot start, with HF0437 Tier 2 CERT fuel 92 octane	ok	24	42	29					8.02	0.233	34.37	0.232	34.49	42.182	5.261	-2.173	-0.3	-1.734	-0.2		FC2421BE10										
61809076	HWYx2 p1	09/27/18, 01:02:46 PM	Hwyx2, 2 bag, cool start, with HF0437 Tier 2 CERT fuel 92 octane, CERT style with hood up abd constant speed fan @ 6MPH (5300CFM)	ok	21	52	29	3500	43.75	-0.6042	0.02619	10.24	0.187	54.7	0.187	54.8	40.555	3.959	13.321	1.300	7.762	0.758	MK	FC2421BE10	18627	1607.5135	1.1551077	1321.9549	1306.8593	6.6775006	6.6832112	0.0327152	-0.0854476	0.279481
61809076	HWYx2 p2	09/27/18, 01:02:46 PM	Hwyx2, 2 bag, cool start, with HF0437 Tier 2 CERT fuel 92 octane, CERT style with hood up abd constant speed fan @ 6MPH (5300CFM)	ok	21	54	29	3500	43.75	-0.6042	0.02619	10.24	0.182	56.1	0.182	56.4	55.124	5.381	2.394	0.234	-2.290	-0.224	MK	FC2421BE10	18627	1607.8651	1.3058995	1323.9253	1306.859	6.6783018	6.6831905	0.0481657	-0.0731493	0.279482
61809077	UDDS cold start p1	09/27/18, 01:41:58 PM	UDDSx2, 4 bag, hot start, with HF0437 Tier 2 CERT fuel 92 octane, CERT style with hood up abd constant speed fan @ 6MPH (5300CFM)	ok	23	45	29	3500	43.75	-0.6042	0.02619	3.60	0.082	43.7	0.084	43.1	36.537	10.144	-2.428	-0.674	-1.839	-0.511	GA/MK	FC2421BE10	18627	2001.2807	0.6780271	2062.9117	2049.0188	2.7392326	2.7195853	0.4218623	0.72243763	0.582639
61809077	UDDS cold start p2	09/27/18, 01:41:58 PM	UDDSx2, 4 bag, hot start, with HF0437 Tier 2 CERT fuel 92 octane, CERT style with hood up abd constant speed fan @ 6MPH (5300CFM)	ok	22	47	29	3500	43.75	-0.6042	0.02619	3.88	0.100	38.9	0.098	39.5	58.105	14.972	-0.632	-0.163	-0.056	-0.015	GA/MK	FC2421BE10	18627	1233.2758	1.3861743	3463.8856	3416.5266	2.6323239	2.5670466	1.9481849	2.5428948	0.692037
61809077	UDDS cold start p1+2	09/27/18, 01:41:58 PM	UDDSx2, 4 bag, hot start, with HF0437 Tier 2 CERT fuel 92 octane, CERT style with hood up abd constant speed fan @ 6MPH (5300CFM)	ok	23	46	29					7.48	0.182	41.05	0.182	41.12	94.642	12.648	-3.060	-0.4	-1.895	-0.3		FC2421BE10										
61809077	UDDS hot #2 start p1	09/27/18, 01:41:58 PM	UDDSx2, 4 bag, hot start, with HF0437 Tier 2 CERT fuel 92 octane, CERT style with hood up abd constant speed fan @ 6MPH (5300CFM)	ok	21	57	29	3500	43.75	-0.6042	0.02619	3.59	0.084	42.8	0.084	42.5	37.520	10.462	-3.508	-0.978	-2.812	-0.784	GA/MK	FC2421BE10	18627	2001.6193	0.6400322	2062.1299	2049.0155	2.7508502	2.7195701	1.2661985	1.15018316	0.582639
61809077	UDDS hot #2 start p2	09/27/18, 01:41:58 PM	UDDSx2, 4 bag, hot start, with HF0437 Tier 2 CERT fuel 92 octane, CERT style with hood up abd constant speed fan @ 6MPH (5300CFM)	ok	22	49	29	3500	43.75	-0.6042	0.02619	3.86	0.100	38.5	0.098	39.3	63.927	16.558	-6.271	-1.624	-5.441	-1.409	GA/MK	FC2421BE10	18627	1233.4763	0.6703534	3439.4585	3416.5555	2.5976124	2.5670512	1.1574111	1.19051913	0.692043
61809077	UDDS hot #2 start p1+2	09/27/18, 01:41:58 PM	UDDSx2, 4 bag, hot start, with HF0437 Tier 2 CERT fuel 92 octane, CERT style with hood up abd constant speed fan @ 6MPH (5300CFM)	ok	22	53	29					7.45	0.184	40.42	0.183	40.80	101.447	13.622	-9.779	-1.3	-8.253	-1.1		FC2421BE10										
Day 11, Certification cycles w/ high octane fuel, constant speed fan and hood up																																	
61809078	UDDS cold start p1	09/28/18, 08:22:15 AM	UDDSx2, 4 bag, cold start, using HF0437 Tier 2, 92 octane test fuel, CERT style with hood up and fan at 5300CFM (6MPH) constant speed	bench fault on emissions analysis	23	46	29	3500	43.75	-0.6042	0.02619	3.60	-0.007	-524.4	0.096	37.6	32.700	9.073	-0.113	-0.031	0.251	0.070	GA	FC2421BE10	18627	2001.269	-0.7481636	2033.6879	2049.0179	2.719636	2.7195791	-0.358568	0.00209308	0.582639
61809078	UDDS cold start p2	09/28/18, 08:22:15 AM	UDDSx2, 4 bag, cold start, using HF0437 Tier 2, 92 octane test fuel, CERT style with hood up and fan at 5300CFM (6MPH) constant speed	bench fault on emissions analysis	22	48	29	3500	43.75	-0.6042	0.02619	3.88	-0.012	-336.3	0.099	39.1	54.038	13.912	0.855	0.220	1.126	0.290	GA	FC2421BE10	18627	1233.3342	1.4517094	3466.1328	3416.5346	2.6228693	2.5670664	1.5097889	2.17380017	0.692034
61809078	UDDS cold start p1+2	09/28/18, 08:22:15 AM	UDDSx2, 4 bag, cold start, using HF0437 Tier 2, 92 octane test fuel, CERT style with hood up and fan at 5300CFM (6MPH) constant speed	bench fault on emissions analysis	23	47	29					7.49	-0.018	-406.48	0.195	38.36	86.738	11.583	0.742	0.1	1.377	0.2		FC2421BE10										
61809078	UDDS hot #2 start p1	09/28/18, 08:22:15 AM	UDDSx2, 4 bag, cold start, using HF0437 Tier 2, 92 octane test fuel, CERT style with hood up and fan at 5300CFM (6MPH) constant speed	bench fault on emissions analysis	21	55	29	3500	43.75	-0.6042	0.02619	3.60	-0.007	-545.4	0.084	42.8	36.010	9.989	-2.326	-0.645	-1.987	-0.551	GA	FC2421BE10	18627	2001.6332	-0.1598853	2045.7444	2049.0205	2.7308952	2.7195627	0.031736	0.41670386	0.582644
61809078	UDDS hot #2 start p2	09/28/18, 08:22:15 AM	UDDSx2, 4 bag, cold start, using HF0437 Tier 2, 92 octane test fuel, CERT style with hood up and fan at 5300CFM (6MPH) constant speed	bench fault on emissions analysis	23	50	29	3500	43.75	-0.6042	0.02619	3.89	-0.012	-315.4	0.099	39.4	58.118	14.956	-0.733	-0.189	-0.458	-0.118	GA	FC2421BE10	18627	1233.4482	1.0125504	3451.1413	3416.5471	2.6090214	2.5670431	0.9503075	1.63528017	0.692043
61809078	UDDS hot #2 start p1+2	09/28/18, 08:22:15 AM	UDDSx2, 4 bag, cold start, using HF0437 Tier 2, 92 octane test fuel, CERT style with hood up and fan at 5300CFM (6MPH) constant speed	bench fault on emissions analysis	22	52	29					7.49	-0.019	-395.69	0.183	40.96	94.128	12.566	-3.058	-0.4	-2.445	-0.3		FC2421BE10										
61809079	HWYx2 p1	09/28/18, 09:41:41 AM	Hwyx2, 2 bag, hot start, using HF0437 Tier 2, 92 octane test fuel, CERT style with hood up and fan at 5300CFM (6MPH) constant speed	ok	21	57	29	3500	43.75	-0.6042	0.02619	10.24	0.184	55.6	0.184	55.6	56.643	5.530	-1.408	-0.137	-1.085	-0.106	MK	FC2421BE10	18627	1607.5651	3.1113454	1347.5224	1306.8614	6.6685695	6.6832179	-0.093458	-0.2191807	0.279481
61809079	HWYx2 p2	09/28/18, 09:41:41 AM	Hwyx2, 2 bag, hot start, using HF0437 Tier 2, 92 octane test fuel, CERT style with hood up and fan at 5300CFM (6MPH) constant speed	ok	23	48	29	3500	43.75	-0.6042	0.02619	10.24	0.180	56.8	0.180	57.0	59.142	5.777	-1.494	-0.146	-1.194	-0.117	MK	FC2421BE10	18627	1607.9214	1.4373147	1325.6444	1306.8607	6.6790707	6.6832095	0.1199662	-0.0619291	0.279481
61809080	UDDS Prep	09/28/18, 01:22:10 PM	UDDS prep, 1 bag, cool start, using HF0437 Tier 2, 92 octane test fuel, CERT style with hood up and fan at 5300CFM (6MPH) constant speed, with Robtic Driver	ok	21	53	29	3500	43.75	-0.6042	0.02619	7.49	0.198	37.9	0.194	38.6	135.572	18.092	-42.734	-5.703	-40.843	-5.450	Robot	FC2421BE10	18627	1527.3263	0.7582307	5507.0027	5465.5612	5.3952528	5.2865494	1.4543356	2.05622708	0.635773
Day 12, Certification cycles w/ high octane fuel, constant speed fan and hood up																																	
61810001	UDDS cold start p1	10/01/18, 07:44:48 AM	UDDSx2, 4 bag, cold start, CERT style with hood up and constant speed fan at 5300CFM 96MPH), repeat due to bad CO2 read, Phase II, high octane HF-0437 fuel	ok	21	55	29	3500	43.75	-0.6042	0.02619	3.59	0.094	38.1	0.096	37.6	32.014	8.907	0.467	0.130	0.769	0.214	MK/KS	FC2421BE10	18627	2000.7333	-0.3786818	2041.2748	2049.0341	2.7352799	2.7195919	0.4819397	0.57685222	0.582643
61810001	UDDS cold start p2	10/01/18, 07:44:48 AM	UDDSx2, 4 bag, cold start, CERT style with hood up and constant speed fan at 5300CFM 96MPH), repeat due to bad CO2 read, Phase II, high octane HF-0437 fuel	ok	23	50	30	3500	43.75	-0.6042	0.02619	3.87	0.100	38.5	0.099	39.0	52.823	13.661	1.745	0.451	2.090	0.540	MK/KS	FC2421BE10	18627	1233.5764	1.0726452	3453.1809	3416.5336	2.6131013	2.5670545	1.5920249	1.79376162	0.692036
61810001	UDDS cold start p1+2	10/01/18, 07:44:48 AM	UDDSx2, 4 bag, cold start, CERT style with hood up and constant speed fan at 5300CFM 96MPH), repeat due to bad CO2 read, Phase II, high octane HF-0437 fuel	ok	22	52	30					7.46	0.195	38.32	0.195	38.33	84.837	11.371	2.212	0.3	2.859	0.4		FC2421BE10										
61810001	UDDS hot #2 start p1	10/01/18, 07:44:48 AM	UDDSx2, 4 bag, cold start, CERT style with hood up and constant speed fan at 5300CFM 96MPH), repeat due to bad CO2 read, Phase II, high octane HF-0437 fuel	ok	22	48	29	3500	43.75	-0.6042	0.02619	3.59	0.083	43.5	0.084	42.8	35.299	9.826	-1.876	-0.522	-1.551	-0.432	MK/KS	FC2421BE10	18627	2001.5761	2.3030109	2096.2117	2049.0225	2.7400155	2.7195743	0.7097835	0.75163415	0.582642
61810001	UDDS hot #2 start p2	10/01/18, 07:44:48 AM	UDDSx2, 4 bag, cold start, CERT style with hood up and constant speed fan at 5300CFM 96MPH), repeat due to bad CO2 read, Phase II, high octane HF-0437 fuel	ok	21	51	29	3500	43.75	-0.6042	0.02619	3.86	0.101	38.2	0.099	39.0	59.230	15.341	-2.194	-0.568	-1.704	-0.441	MK/KS	FC2421BE10	18627	1233.4467	1.8312336	3479.1112	3416.5463	2.6259729	2.5670447	2.2183427	2.29556947	0.692043
61810001	UDDS hot #2 start p1+2	10/01/18, 07:44:48 AM	UDDSx2, 4 bag, cold start, CERT style with hood up and constant speed fan at 5300CFM 96MPH), repeat due to bad CO2 read, Phase II, high octane HF-0437 fuel	ok	22	50	29					7.45	0.184	40.57	0.183	40.74	94.529	12.683	-4.071	-0.5	-3.255	-0.4		FC2421BE10										
61810002	Pedal mapping	10/01/18, 12:04:47 PM	Constant pedal tip-ins, 1bag, Bags OFF, Phase II, high octane HF-0437 fuel	ok	26	38	29	3500	43.75	-0.6042	0.02619	9.20			0.163	56.3	67.529	7.342	-24.518	-2.666	-23.363	-2.540	Robot	FC2421BE10	18627	6488.3224	4.0882704	511.84782	491.744	6.4071698	6.3792552	0.2472338	0.43758287	0.076353
61810003	Varying pedal pos on ramps	10/01/18, 02:20:44 PM	Transmission mapping ramps at varying pedal positions, ramps at 2 mph/s, 1bag, Bags OFF, Phase II, high octane HF-0437 fuel	Diagnostic data dropped out for several hills during test	26	38	29	3500	43.75	-0.6042	0.02619	7.48			0.309	24.3							Robot	FC2421BE10	18627	6488.3224	744.55956	4153.071	491.744	9.5948495	6.3792557	45.789249	50.4070363	0.076353

Appendix E: Cert Fuel Specifications

Table 21: Certificate of Analysis for Tier 3 test fuel used in tests 61809017-61809052



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**	**Batch No.:**	FH3021HW10
		Tank No.:	DRUMS
		Date:	7/24/2017
Specification No.:	**HF2021**		

TEST	METHOD	UNITS	SPECIFICATIONS			RESULTS
			MIN	TARGET	MAX	
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.

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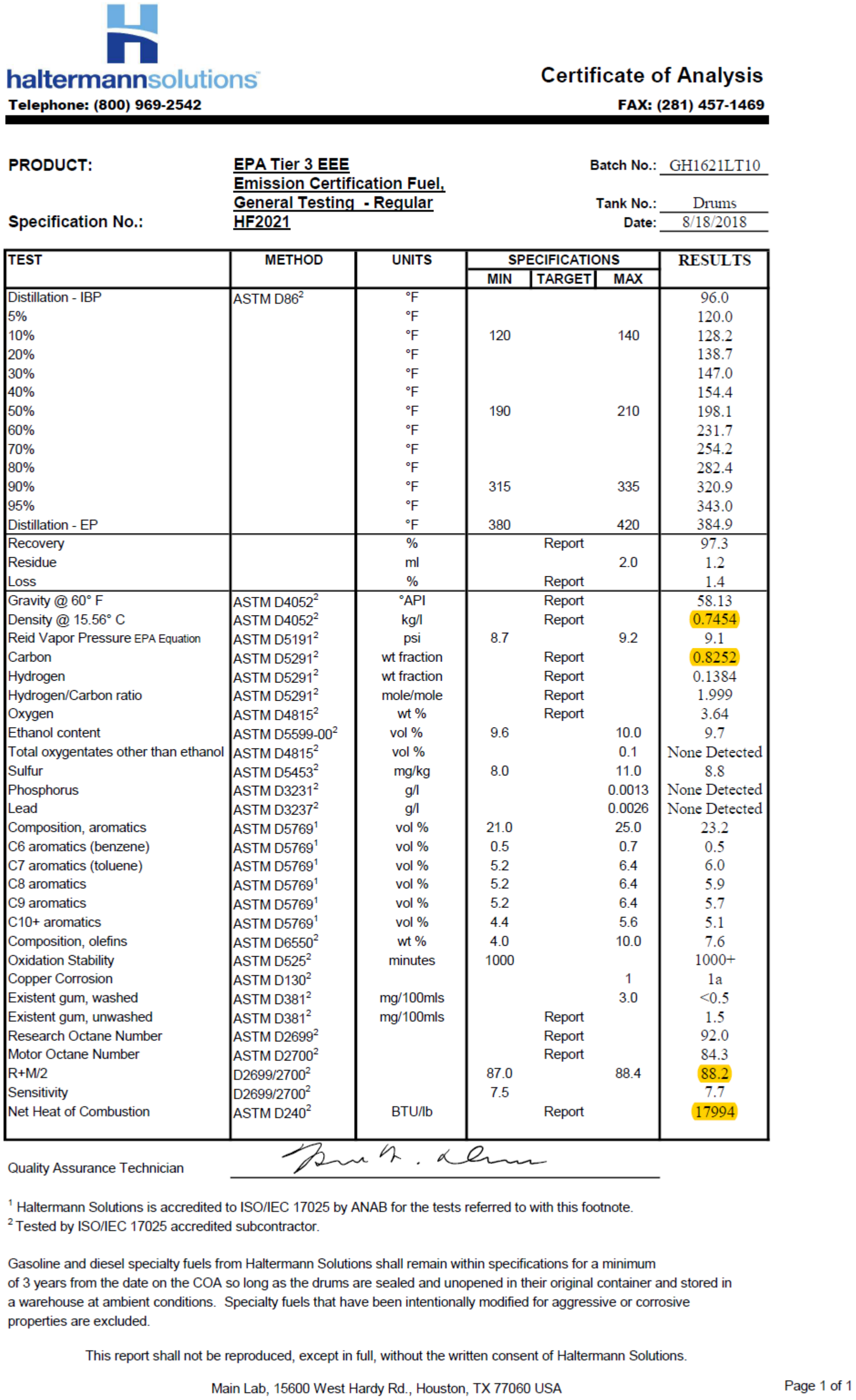
Table 22: Certificate of Analysis for Tier 3 test fuel used in tests 61809053 -61809066



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.: GH1621LT10

Tank No.: Drums

Date: 8/18/2018

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

Quality Assurance Technician

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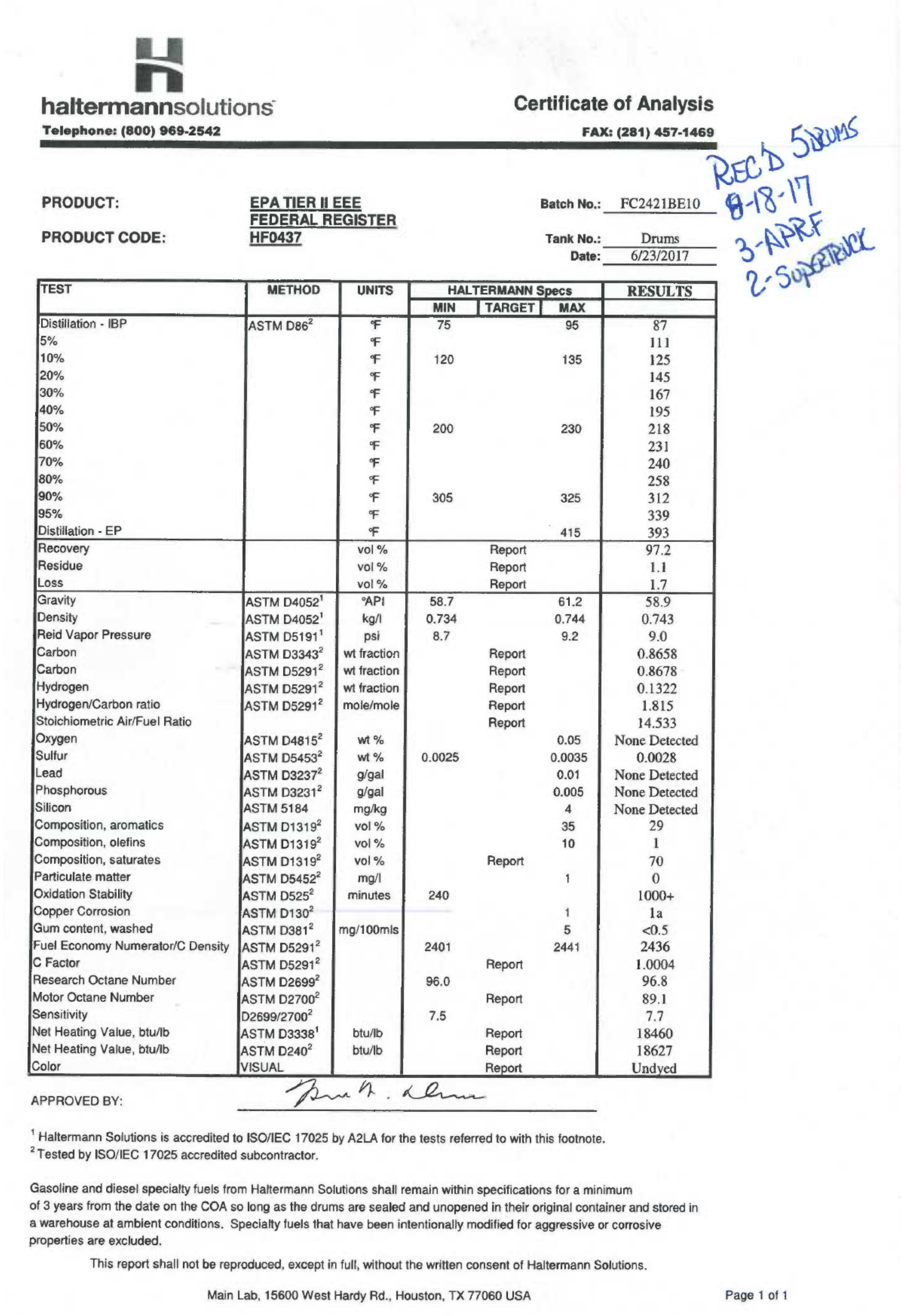
Table 23: Certificate of Analysis for Tier 2 test fuel used in tests 61809067-61810004



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			RESULTS
			MIN	TARGET	MAX	
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:

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Appendix F: Test ID to Figure Matrix

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

Figure #	**Test IDs**
Figure 1: Fuel economy trends: car 3,500 lb weight class	Not applicable
Figure 2: Summary distributions of weight and horsepower of mid-size cars reviewed	Not applicable
Figure 3: FTP unadjusted fuel economy of 2018 midsize vehicles	Not applicable
Figure 4: FTP unadjusted fuel economy of 2018 midsize vehicles by vehicle	Not applicable
Figure 5: Highway unadjusted fuel economy of 2018 midsize vehicles	Not applicable
Figure 6: Highway unadjusted 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 2WD chassis dynamometer	Not applicable
Figure 9: Vehicle mounted for full testing inside the AMTL 4WD chassis dynamometer	Not applicable
Figure 10: Overview of general instrumentation for conventional vehicle	Not applicable
Figure 11: Instrumentation overview of direct fuel injection system on 2018 Honda Accord	Not applicable
Figure 12: Direct fuel flow measurements via fuel scale and Coriolis flow meters	Not applicable
Figure 13: Wiring of Hioki power analyzer on the 2018 Honda Accord test vehicle	Not applicable
Figure 14: CAN breakout on the 2018 Honda Accord LX	Not applicable
Figure 15: Daily drive cycle test sequence executed in the morning	61809044
Figure 16: Overview of steady state drive cycle with preparation	61809044
Figure 17: Vehicle acceleration with varying constant pedal inputs	61810002
Figure 18: Constant acceleration ramp cycles with varying accelerator pedal inputs	61810003
Figure 19: Honda Accord test vehicle mounted to the chassis dynamometer inside the test cell.	Not applicable
Figure 20: Raw fuel economy results: UDDS and HWFET certification cycles from EPA and Argonne	TS#1: 61809027, 61809029 TS#2: 61809032, 61809034 TS#3: 61809037, 61809039 Tier 2 – 93 AKI: 61809072, 61809076
Figure 21: Test to test repeatability (UDDS AND HWFET raw fuel economy results)	61809032, 61809033, 61809034, 61809035
Figure 22: Honda Accord powertrain operation on cold start UDDS	61809032
Figure 23: Raw, uncorrected, fuel economy results for certification cycles across different temperature conditions	23C avg: • TS#1: 61809027, 61809028, 61809029, 61809030 • TS#2: 61809032, 61809033, 61809034, 61809035

Figure #	Test IDs
	• TS#3: 61809037, 61809038, 61809039, 61809040 -7C: • 61809058, 61809059, 61809060, 61809061 35C: • 61809048, 61809049, 61809050, 61809052
Figure 24: Engine operation on the UDDS across different temperatures	61809058, 61809032, 61809048
Figure 25: Powertrain and cabin temperature profiles across different temperature	• -7C: 61809058, 61809059, 61809060, 61809061 • 23C: 61809032, 61809033, 61809034, 61809035 • 35C: 61809048, 61809049 (SC03), 61809050, 61809052
Figure 26: Steady state speed operation at 23 °C, 0% grade and Tier 3 low-octane fuel	61809042
Figure 27: Steady state speed operation at 23 °C, 0% grade and Tier 2 high-octane fuel	61809068
Figure 28: Steady state speed operation at 35 °C and 0% grade	61809051
Figure 29: Steady state speed operation at -7 °C and 0% grade	61809062
Figure 30: Steady state speed operation at 23 °C and 0% grade in Sport mode	61809055
Figure 31: Steady state speed operation at 23 °C and 3% grade	61809042
Figure 32: Steady state speed operation at 23 °C and 6% grade	61809043
Figure 33: Powertrain operation during the 55 mph to 80 mph passing maneuver with low-octane fuel in Drive at 0% grade	61809045
Figure 34: Powertrain operation during the 55 mph to 80 mph passing maneuver with low-octane fuel in Sport at 0% grade	61809056
Figure 35: Powertrain operation during the 55 mph to 80 mph passing maneuver with high-octane fuel in Drive at 0% grade	61809070
Figure 36: Powertrain operation during maximum acceleration, with a focus area highlighted	61809069
Figure 37: Honda Accord continuous power test on simulated 25% grade, with a focus area highlighted	61809046
Figure 38: Powertrain operation during maximum acceleration with simulated constant gear ratios, with a focus area highlighted	61809041
Figure 39: Initial 120 s of the idle fuel flow test	61809018
Figure 40: Idle fuel flow test—full duration	61809018
Figure 41: Knock feedback signals on UDDSx2, cold start cycles	61809027, 61809032, 61809037, 61809072
Figure 42: Spark advance comparison between Tier 2 and Tier 3 fuels	Tier 3 – 88 AKI: 61809032, 61809033, 61809034, 61809035, 61809042, 618090345 Tier 2 – 93 AKI: 61809072, 61809073, 61809074, 61809075, 61809069, 61809070, 61810002

Figure #	**Test IDs**
Figure 43: Schematic of the vehicle configuration	Not applicable
Figure 44: Calculation of missing signals for component	Not application
Figure 45: Time spent in each gear ratio segment for UDDS/HWFET/US06 cycles	Not application
Figure 46: Torque converter lockup operation – wheel torque vs vehicle speed	Autonomie
Figure 47: Torque converter lockup operation — vehicle speed vs CVT gear ratio	Autonomie
Figure 48: Torque converter operation points for clutch engaging vs. disengaging	Autonomie
Figure 49: Operation of DFCO — vehicle speed vs wheel torque	Autonomie
Figure 50: Operation of DFCO — vehicle speed vs CVT gear ratio	Autonomie
Figure 51: Brake energy regeneration system points — engine power vs alternator power	Autonomie
Figure 52: Regenerative braking points — vehicle speed vs wheel torque	Autonomie
Figure 53: Mechanical braking power and alternator power on UDDS cycle	Autonomie
Figure 54: Engine fuel rate map according to engine speed and torque	Autonomie
Figure 55: Torque pedal map	Autonomie
Figure 56: Engine operation at vehicle start-up differs according to the engine coolant temperature	Autonomie
Figure 57: Engine idle speed is controlled by the coolant temperature	Autonomie
Figure 58: Behaviors of engine coolant temperatures on UDDS in different test conditions	Autonomie
Figure 59: Fuel rate of engine by engine power for different coolant temperatures	Autonomie
Figure 60: Accumulated fuel consumption trajectories on UDDS under different test conditions	Autonomie
Figure 61: Engine power loss and engine coolant temperature according to driving conditions	Autonomie
Figure 62: Engine output power when the vehicle is fully stopped	Autonomie
Figure 63: Electrical consumption when the vehicle is fully stopped	Autonomie

Figure #	**Test IDs**
Figure 64: Example of energy calculation for one component on Autonomie	Autonomie
Figure 65: Energy balance diagram on UDDS in Autonomie	Autonomie
Figure 66: Energy balance diagram on HWFET in Autonomie	Autonomie
Figure 67: Validation process for 2018 Honda Accord in Autonomie	Autonomie
Figure 68: Simulation results and test data for UDDS cycle	Autonomie
Figure 69: Simulation results and test data for HWFET cycle	Autonomie
Figure 70: Simulation results and test data for US06 cycle	Autonomie
Figure 71: Torque converter locked vs vehicle speed	Autonomie
Figure 72: Engine fuel cutoff vs vehicle speed	Autonomie

Appendix G: Guide to Test IDs for Analysis

Table 24: Recommended tests for analysis

Ambient Temperature	**Engine Start Condition**	**Cycle**	**Test ID (#)**
Normal (23°C)	**Cold**	UDDS	61809032 (1st UDDS)
		LA92	61809053 (1st cycle)
		30 minute idle test	61809018
		Octane adjuster	61809067-61809071
	Hot	UDDS	61809032 (2nd UDDS), 61809033
		HWFET	61809034
		US06	61809035
		Steady state speed	61809042
		LA92	61809053 (2nd cycle)
		JC08	61809054
		Passing manuevers @ 0, 3 & 6% grade	61809045
		25% grade test	61809046
		Wide open throttle	61809041
		Transmission mapping, constant pedal tip ins	61810002
		Transmission mapping with ramps	61810003
		Accessory load test	61810004
Hot (35°C)	**Cold**	UDDS	61809048 (1st UDDS)
	Hot	UDDS	61809048 (2nd UDDS)
		SC03	61809049
		US06	61809052
		Steady state speed	61809051
Cold (-7°C)	**Cold**	UDDS	61809058 (1st UDDS)
	Hot	UDDS	61809058 (2nd UDDS)
		HWFET	61809060
		US06	61809051

Appendix H: Comments From External Reviewers

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

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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 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 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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