

2018 Toyota Camry LE Vehicle Tested with Tier 2 Fuel – NCAT Test Report

**NCAT – National Center for Advanced Technology**

*National Vehicle and Fuel Emissions Laboratory* – *Office of Transportation and Air Quality*

*U.S. Environmental Protection Agency*

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**Purpose of Test**

This test report describes the testing of a 2018 Toyota Camry LE vehicle on NVFEL (National Vehicle and Fuel Emissions Laboratory) chassis dynamometers collecting data from CAN, discrete sensors, dynamometer control system, and emissions reports to determine vehicle behavior over standard vehicle cycles (FTP, HWFET, US06, etc.). Results of this study may also be used in the ALPHA (Advanced Light-Duty Powertrain & Hybrid Analysis) model.

# Definitions

|  |  |
| --- | --- |
| CAN | Controller Area Network, method of communication for pertinent on-board vehicle information and conditions |

# Description of Test Article

The vehicle tested was a 2018 Toyota Camry LE with a 4-cylinder, 2.5-liter I4 engine which produces 203 HP (151 kW) and 184 ft-lbs (249 Nm). The powertrain includes an 8-speed automatic transmission with a torque converter. Table 1 below summarizes information that identifies the vehicle description and target dynamometer coefficients used in this test program.

**Table 1: Summary of Vehicle and Engine Identification Information**

|  |  |
| --- | --- |
| Vehicle (MY, Make, Model) | 2018 Toyota Camry LE |
| Vehicle Identification Number | JTNB11HKXJ3007695 |
| Tires | Toyo Proxes A35 215/55R17 94V |
| Engine Family | 2.5L “Dynamic Force” 4-Cyl DOHC 16V D-4S  Dual Injection w/ Dual VVT-I Engine  151kW @ 6600 rpm / 249 Nm @ 4800 rpm |
| Test Group | JTYXV02.5P3A |
| Equivalent Test Weight | 3625 lb |
| Target Coefficient A | 25.587 lbf |
| Target Coefficient B | 0.19688 lbf/mph |
| Target Coefficient C | 0. 016371 lbf/mph2 |

# Test Site

This testing is performed in the National Vehicle & Fuel Emissions Laboratory (NVFEL) test site dynamometer #001 (D001).

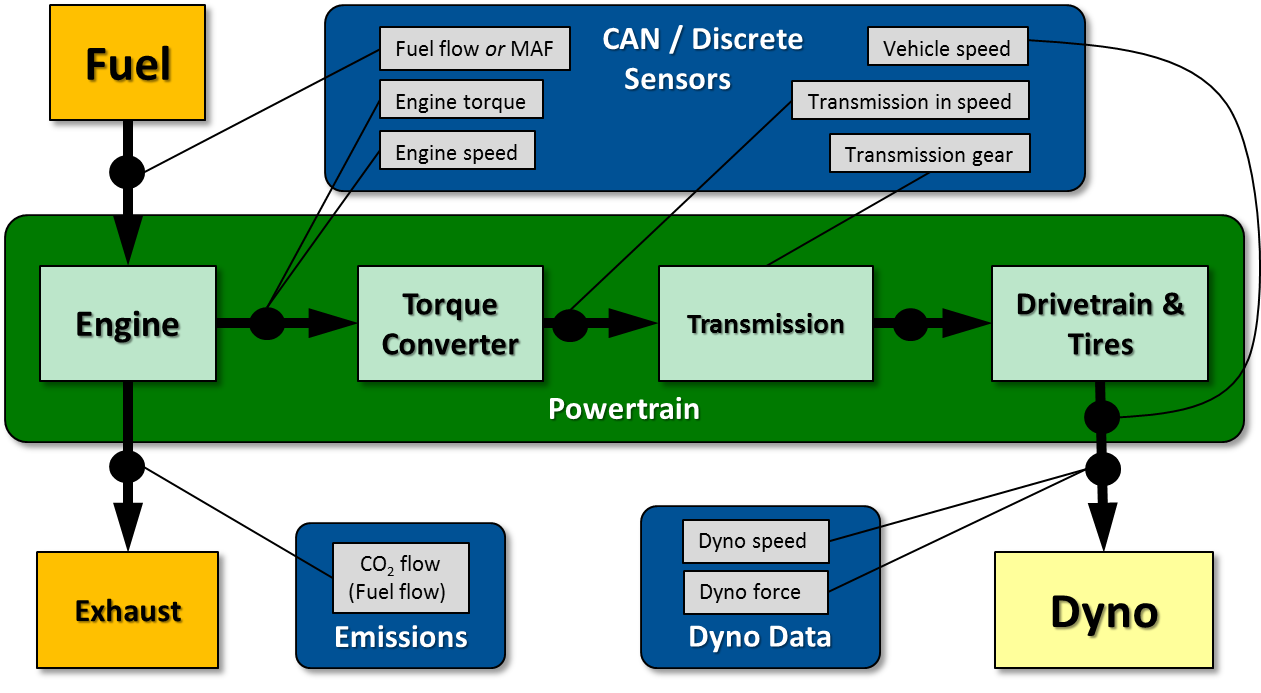
# Test Equipment

The test equipment installed in the NVFEL test site includes a chassis dynamometer and an emissions bench. The D001 site includes a 2WD Horiba chassis dynamometer, a Horiba CVS sampling system and a Horiba Motor Exhaust Gas Analyzer MEXA-7200H emissions bench. This equipment is maintained and calibrated according to the testing requirements specified in 40CFR§86 and 40CFR§1065 referencing relevant work instructions documented in accordance with NVFEL’s ISO 17025 accredited quality system.

Vehicle operational data is obtained from discrete sensors and onboard vehicle CAN using an RPECS IV system. Southwest Research Institute's Rapid Prototyping Electronic Control System IV (RPECS-IV) is an advanced programmable controller for custom control and data acquisition applications.

# Vehicle and Engine Setup

Figure 1 illustrates the engine setup and data collection method utilized in the test cell. The signals shown in Figure 1 are not a complete set of the signals collected, but rather the most important signals used for the validation of the ALPHA model



**Figure 1: Schematic of the Vehicle on the Dynamometer**

## 

## Vehicle Preparation

The vehicle was received after 4,000 miles of mileage accumulation over a combination of unspecified city and highway driving. The vehicle was put into dynamometer mode using a procedure provided by the manufacturer to allow the vehicle to be tested on a 2WD dynamometer. The dynamometer set coefficients were derived by performing a road load derivation and are listed below in Table 2.

**Table 2: Dynamometer Set Coefficients**

|  |  |
| --- | --- |
| Equivalent Test Weight | 3625 lb |
| Set Coefficient A | 8.07 lbf |
| Set Coefficient B | -0.0538 lbf/mph |
| Set Coefficient C | 0.01855 lbf/mph2 |

# Test Methodology

## Test Fuel

The primary properties of the Tier 2 Certification fuel used in this test program are shown in Table 3 below. A summary of the fuel analysis performed, and results measured, can be found in the file: 6*– NVFEL Fuel Analysis Report 26864.pdf*.

**Table 3: Fuel Properties**

|  |  |  |
| --- | --- | --- |
| FTAG | 26864 | |
| Antiknock | 93.30 | AKI |
| Net Heating Value | 18447 | BTU/lb |
| Alcohol Content | 0.00 | % |

# Quality Procedures

This test program is covered by the Light-Duty Greenhouse Gas Test Program: Evaluating Potential Future Vehicle Technologies Quality Assurance Project Plan (QAPP).

# Data Set Definition

There were multiple sources of data being logged during this testing. The test data sets are divided into several portions based upon the testing conducted and are provided for each type of test. Detailed descriptions of the data sources and the data results files are provided below.

# Data Sources

An overview description and examples of the various sources of test data being logged along with specifics on how they were sampled is provided below.

1. *Analog Parameters* - Voltages and currents are measured directly as they are produced by their corresponding transducers. These signals are sampled every 5ms and the latest sample is latched into the log buffer at each log interval.
2. *Dynamometer Controller and Emissions Bench Data (DCEBD) -* The Horiba dynamometer controller collects 10 Hz dynamometer speed and force in a separate data file.
3. *CAN Bus Parameters -* The RPECS IV system receives each message transmitted from vehicle modules and parses them into their corresponding parameter values. A Toyota service tool was used to identify any engineering units and zero/span points for each CAN signal. Each CAN signal was plotted and reviewed to verify its reasonableness based on engineering judgement; no attempt was made to determine accuracy with independent measurements, and therefore data should be considered reference only. At each log interval the latest value for each CAN parameter is latched into the log buffer.

# Test Data Set Overview

The data set results are provided for each of the tests conducted and include a list of the test parameters in each individual data file. The list includes a description, unit of measure, sampling rate, and source for each measured test parameter. Post-processing of the test data, including time alignment is described in the Data Set Processing section below. The data set files include:

1. *4a- 2018 Toyota Camry LE Vehicle Tier 2 Fuel – UDDS Test Data.xlsx*
2. *4b- 2018 Toyota Camry LE Vehicle Tier 2 Fuel – HWFET Test Data.xlsx*
3. *4c- 2018 Toyota Camry LE Vehicle Tier 2 Fuel – US06 Test Data.xlsx*
4. *4d- 2018 Toyota Camry LE Vehicle Tier 2 Fuel – LA92 Test Data.xlsx*
5. *4e- 2018 Toyota Camry LE Vehicle Tier 2 Fuel – WLTC Test Data.xlsx*
6. *4f- 2018 Toyota Camry LE Vehicle Tier 2 Fuel – NEDC Test Data.xlsx*
7. *4g- 2018 Toyota Camry LE Vehicle Tier 2 Fuel –Steady State Test Data.xlsx*
8. *4h- 2018 Toyota Camry LE Vehicle Tier 2 Fuel – NVFEL Laboratory Test Data.xlsx*
9. *4i- 2018 Toyota Camry LE Vehicle Tier 2 Fuel – TC Stall Test Data.xlsx*
10. *4j- 2018 Toyota Camry LE Vehicle Tier 2 Fuel – Acceleration and Deceleration Test Data.xlsx*

# Data Collection Procedure

## Vehicle Cycle and Emission Testing

Multiple 4-bag FTP (Federal Test Procedure), HWFET (Highway Fuel Economy Test), US06, and LA-92 tests are performed on the chassis dynamometer and the data is recorded. A 4-bag FTP is composed of two UDDS’s (Urban Dynamometer Driving Schedules) with an approximate soak time of ten minutes between schedules. The engine is off during the soak time. The tests are performed according to the test procedure requirements specified in 40CFR§86 and 40CFR§1065 referencing relevant work instructions documented in accordance with NVFEL’s ISO 17025 accredited quality system. Further testing was also performed using the New European Driving Cycle (NEDC) and the Worldwide Harmonized Light Vehicles (WLTC) Class 3 driving cycles. A summary of the vehicle cycle and emission testing is shown later in the report in Table 4. All cycle tests, aside from those prefaced in Table 4 with “Cold Start” and those labeled “UDDS (Bags 3 & 4)” that immediately followed a “Cold Start UDDS (Bags 1 & 2) (Test Numbers 20180091005b, 20180091006b, and 20180091007b),” are performed on a “warm” vehicle. The vehicle was warmed up by running US06 cycles or steady states with vehicle speeds up to 70 mph. The vehicle was considered “warm” when the engine coolant temperature was stable, and the transmission oil temperature was over 80 °C.

## Steady State Testing

Steady state testing is performed at vehicle speeds between 10 and 80 mph at 10 mph increments. For each test the vehicle speed is held constant over a test period of 505 seconds. The NVFEL laboratory test data emission result reports state a “udds505” drive schedule, however a steady state test was run. The UDDS-505 test procedure was used for the steady state tests to avoid the needless work of creating new test procedures and vehicle traces for the test site. Finally, these tests were performed on a warm vehicle and cruise control was used when feasible.

## Torque Converter Stall Testing

To help estimate the torque converter properties, the following test is performed in-vehicle. The vehicle is keyed on and the shifter is put in drive. The brakes are applied to prevent any revolution of the wheels and, in turn, the transmission input shaft. The accelerator pedal is then fully depressed for approximately 2 seconds. This process is repeated several times. These tests were performed on a warm vehicle.

## Acceleration and Deceleration Testing

To assist in characterizing the transmission shifting and estimate some transmission spin losses, acceleration and deceleration testing is performed*.* To perform these tests, the vehicle is warmed up with the dynamometer in a road simulation mode. Next, the vehicle is brought to 0 kph and then mildly accelerated to a speed near 130 kph. Subsequently the accelerator pedal is put at 0 % and the transmission either remains in drive or is put in neutral. If the transmission remains in drive, the vehicle coasts down to a minimal creep speed. The brake is then applied to bring the vehicle to 0 kph. If the transmission is put in neutral, the vehicle is allowed to coast down to 0 kph. The process is repeated three times with the transmission placed in both drive and neutral. These tests were performed on a warm vehicle.

# Data Set Processing

## Data Processing

Chassis dynamometer test data sets are processed in according to the test procedure requirements specified in 40CFR§86 and 40CFR§1065. A set of software applications retrieved, transmitted, processed and stored test data in a specified manner described in procedures developed in support of NVFEL’s ISO 17025 accredited quality system.

## 

## Signal Collection and Time Alignment

The RPECS-IV is used to merge data from multiple sources (CAN and discrete sensors) at a variable log rate per engine cycle. Every row of data corresponds to one complete log interval and each column represents one variable that is being logged. Each source of data may be asynchronous to another and is sampled according to the type of data it is. When a timer within RPECS-IV expires, at the programmed log interval, the most recent value for every parameter is latched into a buffer.

The final data sets for the cycle testing contain 10Hz data that is a result of merging the RPECS IV data with a set of DCEBD. First, the time and vehicle speed found in the data set containing the DCEBD is statistically compared to the target vehicle time and speed of the associated cycle and shifted to align with the target time and speed. Second, an interpolation is performed on the DCEBD data so there is a time stamp starting at 0.0 seconds and ending at the exact time of the target cycle duration. Thirdly, the two steps are repeated, comparing the vehicle speed in the RPECS IV data to the product created in the preceding steps and merging the data to create the final data set.

# Data Quality Control

NVFEL’s ISO 17025 accredited quality system uses quality control to ensure the accuracy and precision of laboratory tests to provide reliable, interpretable, repeatable and defendable results. In accordance with the ISO/IEC 17025 standard, there are established procedures for monitoring the validity of the testing conducted including auditing, corrective action and continuous improvement. Vehicle test packets are audited following approved processes prior to data release.

# Results

A summary of the vehicle cycle and emission testing is shown in the Table 4 below. The 10 Hz vehicle activity test results for each vehicle cycle test are provided in the files: *4a- 2018 Toyota Camry LE Vehicle Tier 2 Fuel – UDDS Test Data.xlsx, 4b- 2018 Toyota Camry LE Vehicle Tier 2 Fuel – HWFET Test Data.xlsx, 4c- 2018 Toyota Camry LE Vehicle Tier 2 Fuel – US06 Test Data.xlsx, 4d- 2018 Toyota Camry LE Vehicle Tier 2 Fuel – LA92 Test Data.xlsx, 4e- 2018 Toyota Camry LE Vehicle Tier 2 Fuel – WLTC Test Data.xlsx and 4f- 2018 Toyota Camry LE Vehicle Tier 2 Fuel – NEDC Test Data.xlsx.* During each vehicle cycle test, bag emissions and summary dynamometer data were recorded and used to determine cycle fuel economy. The emissions and fuel economy test results for each vehicle cycle test are provided in the *4h- 2018 Toyota Camry LE Vehicle Tier 2 Fuel – NVFEL Laboratory Test Data.xlsx* file*.* The test results for the first Cold Start UDDS (Bags 1 & 2) Test # 20180091005 and the first HWFET Test # 20180091010 were plotted for reference and are included in the test package for reference.

The 10 Hz vehicle activity test results for the vehicle steady state and TC stall tests are provided in the following respective files: *4g- 2013 Toyota Camry LE Vehicle Tier 2 Fuel – Steady State Test Data.xlsx and 4i- 2013 Toyota Camry LE Vehicle Tier 2 Fuel – TC Stall Test Data.xlsx.*

The 10 Hz vehicle activity test results for the vehicle acceleration and deceleration tests are provided in the *4j- 2018 Toyota Camry LE Vehicle Tier 2 Fuel – Acceleration and Deceleration Test Data.xlsx* file. All six tests, three performed with the transmission in drive for the acceleration portion and three performed with the transmission in neutral for the deceleration portion, are included in the file. A transmission in neutral state is denoted by a “0” for the “Command Trans Gear” signal.

The results of the acceleration and deceleration testing are used to assist in characterizing the transmission shifting and estimate some transmission spin losses in the ALPHA model. In addition, the results of the torque converter stall testing are used to estimate the torque converter properties in the ALPHA model.

**Table 4: Summary of Standard Vehicle Cycle Testing**

|  |  |  |  |
| --- | --- | --- | --- |
| **Test Date** | **Test Number** | **Vehicle Cycle Results** | **Vehicle Emissions Results** |
| 2/1/2018 | 20180091005 | a - Cold Start UDDS (Bags 1 & 2) \* | FTP 4Bag Emissions |
| b - UDDS (Bags 3 & 4) \*\* |
| 2/2/2018 | 20180091006 | a - Cold Start UDDS (Bags 1 & 2) | FTP 4Bag Emissions |
| b - UDDS (Bags 3 & 4) \*\* |
| 2/6/2018 | 20180091007 | a - Cold Start UDDS (Bags 1 & 2) | FTP 4Bag Emissions |
| b - UDDS (Bags 3 & 4) \*\* |
| 2/2/2018 | 20180091008 | a - UDDS (Bags 1 & 2) | FTP 4Bag Emissions |
| b - UDDS (Bags 3 & 4) |
| 2/2/2018 | 20180091009 | a - UDDS (Bags 1 & 2) | FTP 4Bag Emissions |
| b - UDDS (Bags 3 & 4) |
| 2/6/2018 | 20180091010 | HWFET \* | HWFET Emissions |
| 2/6/2018 | 20180091013 | HWFET | HWFET Emissions |
| 2/7/2018 | 20180091016 | HWFET | HWFET Emissions |
| 2/6/2018 | 20180091011 | US06 | US06 2Bag Emissions |
| 2/6/2018 | 20180091014 | US06 | US06 2Bag Emissions |
| 2/6/2018 | 20180091017 | US06 | US06 2Bag Emissions |
| 2/2/2018 | 20180091012 | LA92 | LA92 2Bag Emissions |
| 2/2/2018 | 20180091015 | LA92 | LA92 2Bag Emissions |
| 2/6/2018 | 20180091018 | LA92 | LA92 2Bag Emissions |
| 2/7/2018 | 20180091019 | Cold Start LA92 | LA92 2Bag Emissions |
| 2/7/2018 | 20180091024 | WLTC | WLTC Emissions |
| 2/7/2018 | 20180091025 | WLTC | WLTC Emissions |
| 2/7/2018 | 20180091026 | WLTC | WLTC Emissions |
| 2/9/2018 | 20180091035 | Cold Start WLTC | WLTC Emissions |
| 2/8/2018 | 20180091020 | Cold Start NEDC | NEDC Emissions |
| 2/7/2018 | 20180091021 | NEDC | NEDC Emissions |
| 2/7/2018 | 20180091022 | NEDC | NEDC Emissions |
| 2/7/2018 | 20180091023 | NEDC | NEDC Emissions |
| 2/8/2018 | 20180091027 | Steady State 10 mph | 505 Emissions |
| 2/8/2018 | 20180091028 | Steady State 20 mph | 505 Emissions |
| 2/8/2018 | 20180091029 | Steady State 30 mph | 505 Emissions |
| 2/8/2018 | 20180091030 | Steady State 40 mph | 505 Emissions |
| 2/8/2018 | 20180091031 | Steady State 50 mph | 505 Emissions |
| 2/8/2018 | 20180091032 | Steady State 60 mph | 505 Emissions |
| 2/8/2018 | 20180091033 | Steady State 70 mph | 505 Emissions |
| 2/8/2018 | 20180091034 | Steady State 80 mph | 505 Emissions |

\*Plots are provided for Tests 20180091005a - Cold Start UDDS (Bags 1 & 2) and 20180091010 - HWEFT

\*\*UDDS (Bags 3 & 4) tests that are immediately preceded by a Cold Start UDDS (Bags 1 & 2) have a lower transmission oil temperature than the UDDS tests performed on 2/2/2018.

# 

# Uncertainty

The dynamometer and emissions data were collected according to the test procedure requirements specified in 40CFR§86 and 40CFR§1065 referencing relevant work instructions documented in accordance with NVFEL’s ISO 17025 accredited quality system. Any uncertainty and test-to-test variation is controlled by adhering to the laboratory’s standard procedures.

The supporting data sets include CAN data as recorded from the vehicle which have not been calibrated, adjusted or analyzed. This reported data may be valuable to use as reference parameters and therefore are labeled in the data file Test Parameter List tab as “reference only.” While we have found CAN data to be generally reliable, information on the accuracy and responsiveness of the onboard vehicle sensors chosen by the manufacturer is unknown. Users should exercise good engineering judgement when relying on these reported values for any analysis.

### Acronyms and Abbreviations

ALPHA Advanced Light-Duty Powertrain & Hybrid Analysis

CAN Controller Area Network

CFR Code of Federal Regulations

CVS Constant Volume Sampler

DCEBD Dynamometer Controller and Emissions Bench Data

FTP Federal Test Procedure

HWFET Highway Fuel Economy Test Procedure

ISO International Organization for Standardization

LA92 California Light-duty Unified Cycle Test

NCAT National Center for Advanced Technology

NEDC New European Driving Cycle

NVFEL National Vehicle & Fuel Emissions Laboratory

RPECS Rapid Prototyping Electronic Control System

TATD Testing and Advanced Technology Division

TC Torque Converter

UDDS Urban Dynamometer Driving Schedule

US06 Supplemental Federal Test Procedure Aggressive Driving Test

WLTC Worldwide Harmonized Light Vehicles

2WD Two Wheel Drive