

2014 Chevrolet 6L80 Six-Speed Automatic Transmission - NCAT Test Report

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# Purpose of Test

The purpose of this testing is to characterize the performance of a 2014 Chevrolet 6L80 six-speed automatic transmission used in a Chevrolet Silverado. The testing was conducted to evaluate and measure results for transmission gear efficiencies, idle fuel consumption and torque converter K-factors. In addition, during the course of this testing, test methods were also developed for use in characterizing future transmissions. Results of this study may also be used in the ALPHA (Advanced Light-Duty Powertrain & Hybrid Analysis) model.

# Definitions

|  |  |
| --- | --- |
| Controller Area Network (CAN) | Vehicle bus standard designed to allow various controllers and devices to communicate with each other |

# Description of Test Article

A 2014 Chevrolet Silverado built with a 4.3L EcoTec3 V6 engine and 6L80 six-speed automatic transmission was selected for use in this testing. Table 1 describes the vehicle and powertrain used in this test program.

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

|  |  |
| --- | --- |
| Vehicle (Model Year, Make, Model) | 2014 Chevrolet Silverado |
| Vehicle Identification Number | 1GCNCPEH2EZ171727 |
| Engine (Displacement, Name) | 4.3L EcoTec3 V6 |
| Rated Power | 285 hp (213 kw) @ 5300 RPM |
| Rated Torque | 305 lb.-ft (413 Nm) @ 3900 RPM |
| Recommended Fuel | Regular unleaded or E85 |
| Transmission | 6L80 Six-Speed Automatic |

# Test Site

This test was performed in National Center for Advanced Technology (NCAT) Test Cell 9, but the procedure is applicable to any NCAT test cells using iTest controls and RPECS data collection.

# Test Cell Capabilities

The following instrumentation, listed in Table 2, exists in Test Cell 9 although not all instrumentation listed may have been utilized during this testing.

**Table 2: Instrumentation in NCAT Test Cell 9**

|  |  |  |
| --- | --- | --- |
| Instrument Name | Purpose/Measurement Capabilities | Manufacturer |
| Dynamometer | Engine speed, torque, power | Meidensha |
| Torque Sensors | In line shaft torque | HBM |
| CVS dilution tunnel | Dilution, exhaust flow | EPA |
| Coriolis fuel meter | Fuel flow rate | Micromotion |
| Laminar flow element | Air flow rate | Merriman |
| Methane cutter | Remove methane | Horiba |
| Emissions bench | Raw and dilute exhaust gases:  CO, THC, NOx, CH4, CO2 | MEXA |

# Data Collection Systems

Test cell data acquisition and dynamometer control are performed by iTest, a software package developed by A&D Technology, Inc. Test cell data including temperatures, pressures, speed and torque are logged by iTest. Engine and transmission ECU inputs and outputs are measured using the Rapid Prototyping Engine Control System (RPECS), a hardware/software package for engine control and supplemental data acquisition developed by Southwest Research Institute (SwRI). RPECS data is logged by iTest via an Ethernet connection and combined into a single output file. The transmission control and analysis software packages are summarized below in Table 3.

**Table 3: Test Control and Analysis Software**

|  |  |  |  |
| --- | --- | --- | --- |
| Software | Developer | Description | Data Rate |
| iTest | A&D Technology, Inc. | Controls the dynamometer; collects test cell data; master data logger; commands pedal | 10 hz |
| RPECS | Southwest Research Institute | Collects TCU, CAN and analog transmission data; controls torque converter lock up solenoid | 1/engine cycle |

# 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).

# Test Methodology

**Description of Tethered Wiring Harness**

In modern vehicles, the engine control unit (ECU) is no longer the main computer. The ECU also requires communication with the body control module (BCM), the transmission control unit (TCU) and other various modules to monitor the entire vehicle operation (security, entry, key on, dash board signals, etc.). Because the ECU needs signals from these other modules to operate as calibrated by the manufacturer, the signals need to be extended to the test cell. The wiring harnesses connecting the ECU to the rest of the vehicle were lengthened to allow the engine and transmission in the dynamometer cell to be tethered to the vehicle chassis located outside the cell. Figure 1 illustrates the tethered wiring harness. Signal wires from the ECU to the engine and transmission were tapped to allow the signals to be either monitored or replaced as needed. This ensured testing could be performed without setting ECU/TCU fault codes and in a manner consistent with expected transmission operation in the vehicle.

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**Figure 1. Vehicle, Engine and Transmission Tethered Wire Harness**

# Engine Systems

A production Chevrolet Silverado 4.3L engine was used to support this transmission testing. Specific details for the engine setup and testing is described in SAE paper *SAE 2016-01-0662 Fuel Efficiency Mapping of a 2014 6-Cylinder GM EcoTec 4.3L Engine with Cylinder Deactivation.pdf*. [2] To control engine torque for this testing, the chassis throttle pedal inputs were utilized. The production vehicle throttle pedal signals were duplicated and controlled by the iTest dyno controls.

# Transmission Setup

The transmission testing requires the transmission to be held in a constant gear and the torque converter clutch locked or unlocked. The transmission gear selection was controlled by placing the PRNDL shift cable in manual mode. The shift lever +/- button controlled the gear selection.

The torque converter lock up clutch was controlled by tapping into the wires connecting the clutch solenoid and TCU. The signal coming out of the TCU was read by the RPECS and a new signal was passed to the clutch solenoid. The RPECS could pass a stock torque converter clutch signal or send a modified signal that would allow locked or unlocked clutch position. This enabled the transmission gear efficiency to be measured with torque converter locked and the torque converter K factor to be measured with torque converter unlocked. Testing was conducted in a manner consistent with expected transmission operation in the vehicle without setting the check engine light.

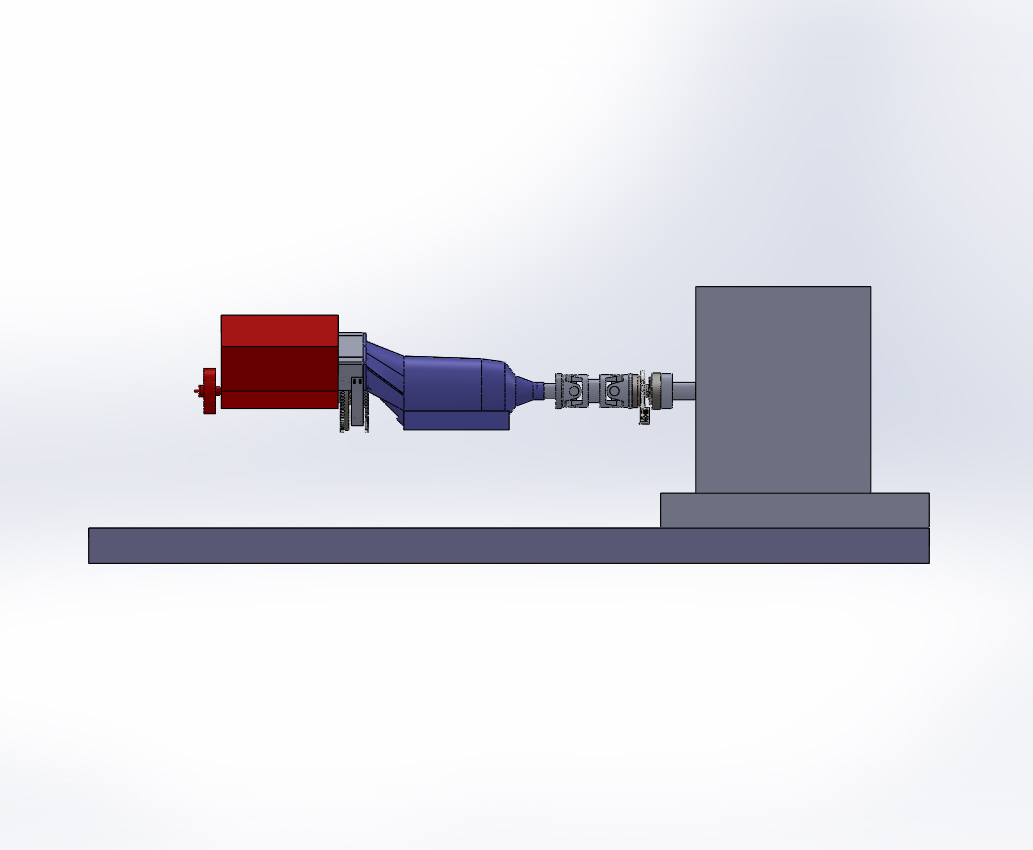
Transmission Input Inline Torque Sensor Assembly

Transmission

Engine

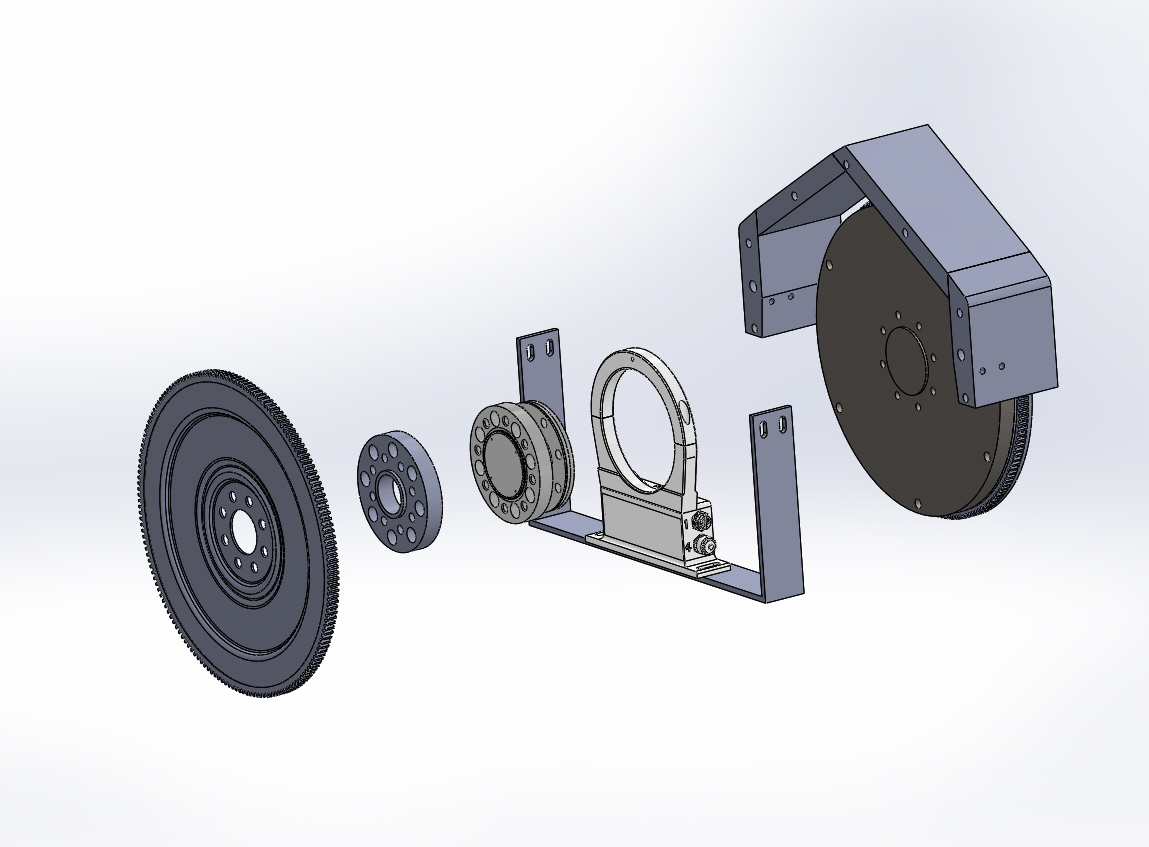
Dynamometer

Transmission Output Inline Torque Sensor



**Figure 2: Model of Engine and Transmission Testing Schematic**

The Transmission Input Inline Torque Sensor shown in Figure 2 above is illustrated with an exploded view in Figure 3. This assembly was designed to maintain the concentricity and axial spacing of the transmission torque converter and engine flywheel. Figure 4 shows the final engine and transmission assembly after having been installed into the test cell.



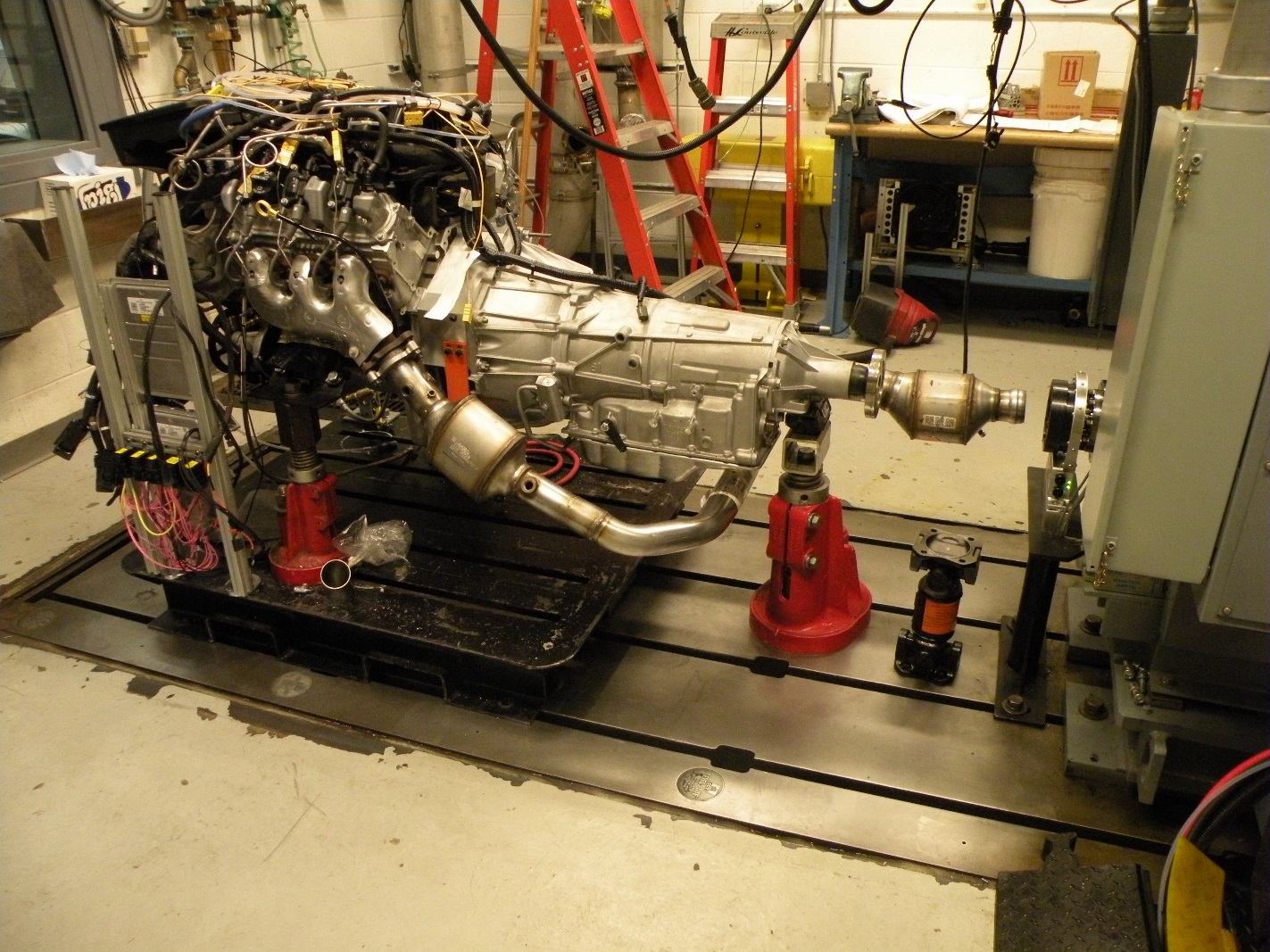
Stock Flex-plate

Transmission Input Inline Torque Sensor

Flywheel with Ring Gear

Transmission Bell Housing Spacer

**Figure 3: Transmission Input Inline Torque Sensor Setup**



**Figure 4: Final Engine and Transmission Test Cell Installation**

# Transmission Systems

Some key aspects of this streamlined transmission testing process are shifting/gear selection, fluid temperature control, engine start, and integration of an inline torque sensor. To properly control the transmission and record the appropriate data, a series of modifications and procedural steps were required as described below.

1. PRNDL Shift Controls: The transmission shifting is controlled by the PRNDL shift lever, normally mounted on the vehicle steering column. The shift lever moves a shift cable which connects to the transmission PRNDL selector mounted internally in the transmission. The steering column shift lever also has a button to control the electronic gear selection when the PRNDL is in manual mode. For the test cell setup, a PRNDL lever was mounted in the test cell and tethered to the iTest console. The PRNDL manual mode was used to hold the transmission in a specific gear and the shift lever +/- button was used to control the actual gear selection.
2. Transmission Fluid Cooling: The transmission fluid is cooled by circulating the fluid out of the transmission to a radiator cooler and then back into the transmission. For the test cell setup, and to best emulate a production cooling system, the transmission fluid was cooled by a plate-style heat exchanger which substituted for the production vehicle radiator cooler. The external cooling loop of the heat exchanger was connected to the engine coolant heater core circulation loop using production transmission cooler lines and routing. The transmission thermostat was not altered or modified for the test cell setup.
3. Input Inline Torque Sensor, Bell Housing, and Flywheel: An inline torque sensor was used to measure the transmission input torque. Adapters were fabricated to connect the inline torque sensor to the engine flywheel and transmission flex-plate as shown in Figure 3. To accommodate the torque cell, a spacer was fabricated to separate the engine and transmission, and an aftermarket flywheel mounted to the engine. The flywheel ring gear was mounted in a position similar to the production transmission configuration to allow for starting with the stock starter motor.
4. Torque Converter Clutch Lockup: The torque converter clutch is normally controlled by the transmission control unit (TCU). This testing required the torque converter clutch to be controlled directly. This was done by tapping into the wires connecting the clutch solenoid and the TCU. The signal coming out of the TCU was read by RPECS and a new signal was passed to the clutch solenoid that would allow either a locked or an unlocked clutch position as desired. This enabled the transmission gear efficiency to be measured with the torque converter locked and the torque converter K Factors to be measured with the torque converter unlocked.

# Data Set Definition

The data set logged for this testing included transmission parameters such as transmission oil pressure and temperature, input and output speed and torque, gear selection, and epid CAN data along with various engine parameters. The data were recorded by the iTest data acquisition system and logged into output files for all modes of testing. The data sets containing the transmission mapping test parameters are provided in the files:

* *4a- 2014 Chevrolet 6L80 Transmission - Efficiency With Lockup Test Data.xlsx:* Data recorded during transmission efficiency test results recorded as a function of gear, temperature, pressure, and speed.
* *4b- 2014 Chevrolet 6L80 Transmission - Idle Fuel Consumption Test Data.xlsx:* Data include idle fuel consumption results for selected gears as a function of speed and torque.
* *4c- 2014 Chevrolet 6L80 Transmission – Torque Converter Stall Test Data.xlsx:* Data recorded during torque converter stall tests with the transmission in fifth gear, torque converter unlocked, the dyno speed held constant, while sweeping input speed by ramping the engine pedal request.

# Test Data Points

The test points for the transmission efficiency test covered the torque and speed range shown in Figure 5. Data were measured in each gear for specific rpm values over increasing input torque and have no adjustments for transmission temperature. The transmission input torque in each gear was limited by the maximum transmission output torque that could be absorbed by the dynamometer (500 Nm). As a result, the number of data points able to be measured for first and second gear was limited. The input torque at or near the engine WOT line was captured for gears 3-6, which provided adequate coverage for the transmission operation.



**Figure 5: Test Data Points**

# Data Collection Procedure

The data were logged in steady state and transient modes according to the test requirements. The steady state mode consists of holding the speed and load fixed until stable and then logging the data at a 10 hz sampling rate for 10 seconds. The transient mode consists of continuous logging while sweeping speed or load and then logging at 10 hz for the appropriate number of seconds.

**Transmission Testing Procedure**

This transmission testing included measuring gearbox efficiencies, idle fuel consumption, and torque converter K-factors. The intent was to conduct the testing with transmission oil temperatures measuring at or above 90 °C. Performing all the testing at high temperature simplifies the analysis and eliminates the need to map operation of the transmission with multiple temperature sweeps.

The transmission gearbox efficiency test was done by holding the transmission in a selected gear and locking up the torque converter. The transmission input speed and load were controlled to a fixed value and held until stable. Each gear was tested in steady state mode over a range of transmission output speeds and loads. For each speed and load combination, the data were logged at a 10 Hz sampling frequency for 10 seconds, then averaged to create a single average data point.

The torque converter K-Factor test was conducted by holding the transmission in a selected gear (fifth), with the torque converter unlocked and the dyno speed held constant, and sweeping input speed by ramping engine pedal request. The data were logged at a 10 Hz sampling rate until the sweep was complete. The transmission output speed was varied between 1500 and 3000 rpm in selected increments. The transmission input torque (engine torque) was swept from 0 to 250 Nm over 50 seconds.

The idle fuel consumption testing was performed by running the engine and transmission as a unit connected to an engine dynamometer. The idle fuel consumption can only be accurately measured when the engine and transmission are operated as a unit. The low speed crankshaft accelerations when only using an engine and a dynamometer exceed the driveline limits and will resonate and the inline torque sensor will not be able to measure the idle torque accurately. The method of using the transmission with torque converter allows the best torque signal quality at idle conditions. The test is performed with the fully warmed trasmission in both neutral and drive and the throttle pedal input set to zero.

# Data Set Processing

The iTest data collection system logs each single mode at 10 hz for 10 seconds and the data is subsequently averaged and written to the data file. The variable list also includes statistical information for selected variables such as standard deviation, coefficient of variation, minimum & maximum.

# Data Processing

Transmission efficiency, reported in percentage, was calculated according to the equation below using the values obtained from iTest.

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | |  |
|  | | | |
|  | | Speed In = Transmission input shaft speed (rev/minute) | |

Torque converter K Factor was calculated according to the equation below using the measured values recorded from iTest.

# Data Quality Control

A core test data set is extracted from the iTest data logger file and includes test parameters selected to provide valuable information when evaluating transmission performance. Descriptions for the test parameter list are provided in the core test data set for reference. The core data set is analyzed for outlier data based on the statistical data included in the iTest data logger file. In addition, the core data set is plotted and reviewed using a MATLAB-based contour plotting routine. During these reviews, any outliers may be removed as needed based upon the discretion of the internal review team.

# Results

The final data sets containing the transmission mapping test parameters are provided in the data set files described above. The transmission efficiency, reported in percentage, for each individual gear as measured at various rpms is shown in the figures below.

Figure 6 shows the transmission efficiency with the gear selection held in second gear and the transmission input speed at 1185 rpm. The legend box (noting “locked up” or “unlocked”) refers to the torque converter clutch state. The data point labels are the transmission efficiency values.



Second Gear

**Figure 6. 2014 Chevrolet 6L80 Transmission 2nd Gear Efficiency**

Figures 7–10 show the transmission efficiency with the gear selection held in the listed gear. The legend box (rpm) refers to the transmission input speed. The data point labels are the transmission efficiency values for the specified data points.



**Figure 7. 2014 Chevrolet 6L80 Transmission 3rd Gear Efficiency**



**Figure 8. 2014 Chevrolet 6L80 Transmission 4th Gear Efficiency**

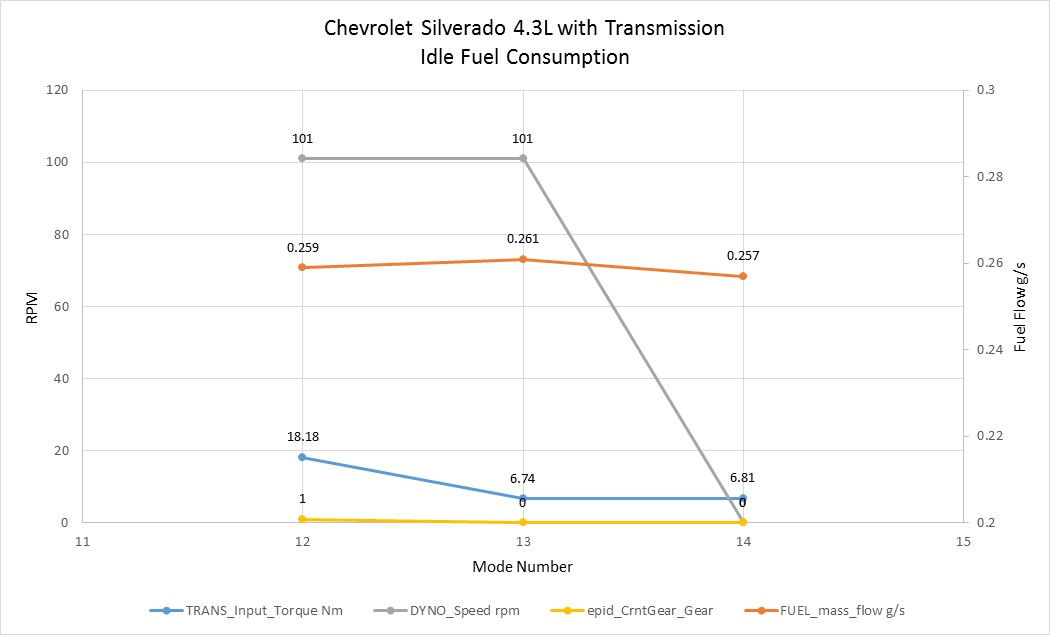


**Figure 9. 2014 Chevrolet 6L80 Transmission 5th Gear Efficiency**



**Figure 10. 2014 Chevrolet 6L80 Transmission 6th Gear Efficiency**

The idle fuel consumption testing was performed by operating the engine and transmission together as a unit. Figure 11 shows three data points with a fully warmed engine and throttle pedal at zero. The engine out torque and fuel consumption are also shown for each point. As with other NCAT engine testing, there are alternator loads affecting the results as described in NCAT’s test package *2014 Chevrolet 4.3L EcoTec3 LV3 Engine Tier 2 Fuel – Test Data Package*. The first point is operated with the transmission in drive and the output shaft (dyno speed) at 100 rpm. The second point is operated with the transmission in neutral and the output shaft (dyno speed) at 100 rpm. The third point is operated with the transmission in neutral and the output shaft (dyno speed) at 0 rpm.



**Figure 11. 2014 Chevrolet 6L80 Transmission – Idle Fuel Consumption Testing**

The torque converter K-Factor test was conducted by holding the transmission in a selected gear (fifth), with the torque converter unlocked and the dyno speed held constant, and sweeping input speed by ramping engine pedal request. The data were logged at a 10 Hz sampling rate until the sweep was complete. The transmission output speed was varied between 1500 and 3000 rpm in selected increments. The transmission input torque (engine torque) was swept from 0 to 250 Nm over 50 seconds. The results of the torque converter K Factor testing are shown in Figures 12 and include end-point measurements for three of the sampled input speeds.



**Figure 12: 2014 Chevrolet 6L80 Transmission Torque Converter K Factor Results**

# Uncertainty

General Uncertainty Notes

The dynamometer data were collected according to best engineering procedures and any uncertainty or test-to-test variation is controlled by adhering to the laboratory’s standard operating procedures documented in accordance with NVFEL’s ISO 17025 accredited quality system.

The supporting data sets include discrete sensor signals and CAN data which are reported as recorded from the test cell but have not been calibrated, checked, adjusted, or analyzed. This reported data may be valuable to use as reference parameters but should, in general, be considered reference only. Users should exercise good engineering judgement when determining the extent to which they wish to rely on these reported values for any analysis purpose.

Sensor/Signal Uncertainties

The uncertainties of the signals [u(signal)] in the data set can be based on (a) the uncertainty associated with the calibration standard, (b) the uncertainty of the sensor calibration [u(calibration)], and (c) the uncertainty of the signal during operation [u(operation)]. The uncertainty associated with the calibration standard is assumed to be negligible when compared to other uncertainties and thus this uncertainty is not considered for this calculation.

To determine the uncertainty of the sensor calibration(b), past calibration records were assessed and the difference between the standard and measured quantities were used to calculate uncertainty. The “speed in” signal was measured by a 3600-pulse per revolution shaft encoder which was not calibrated; thus, the calibration uncertainty was estimated for this sensor based on the pulse count.

To determine the uncertainty of the signal during operation(c), the standard deviations for each signal were calculated from the testing data and the average was used to calculate the variance of the mean, and thus the uncertainty,

Where n is the number of data points in a mode (100 in this case, with 10-second modes of 10 Hz recording frequency). The “speed in” signal standard deviation was not recorded, so it was assumed that the operational uncertainty of this signal was the same as that of the “speed out signal.” The standard uncertainty for each signal is given in Table 4. The operational and signal uncertainties given represent an average across a range of points, and are given as a reference only. The uncertainty of the fuel flow measurement for the idle fuel consumption testing is close to the value shown for all data points.

**Table 4: Standard Uncertainties for Signals**

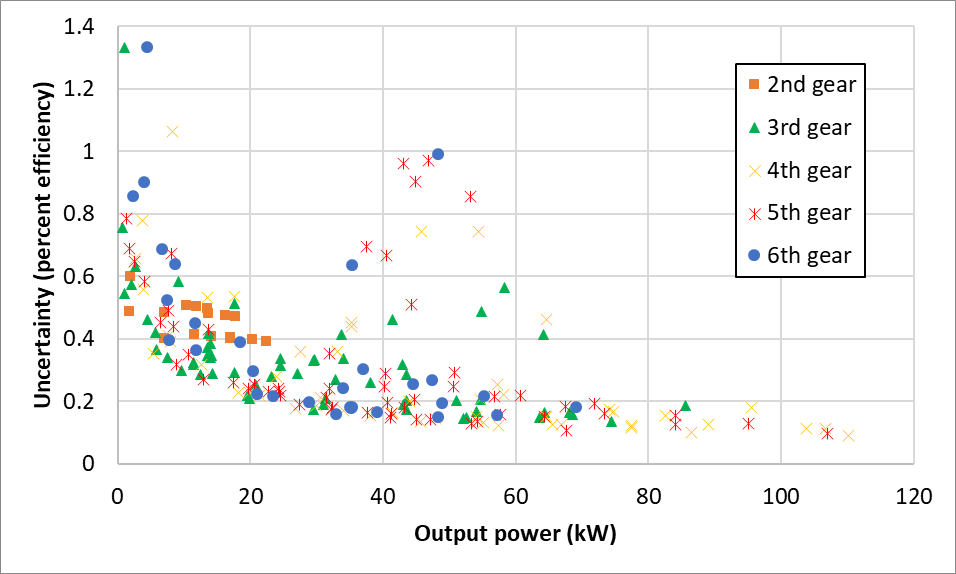
|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Signal | Symbol | u(calibration) | u(operation) (ref) | u(signal) (ref) |
| Speed In (rpm) | *ωi* | 0.656 | 0.163 | 0.688 |
| Torque In (Nm) | *Ti* | 0.0796 | 0.272 | 0.289 |
| Speed Out (rpm) | *ωo* | 2.48 | 0.163 | 2.49 |
| Torque Out (Nm) | *To* | 0.0388 | 0.306 | 0.310 |
| Fuel flow (g/s) |  | 0.00442 | 0.0008 | 0.0449 |

Uncertainty of Transmission Efficiency

The transmission efficiency is the ratio of the output power (speed\*torque) to the input power. The total uncertainty for transmission efficiency is calculated by:

or

Standard uncertainties are analogous to standard deviations, such that it would be expected that, for a given set of data, the “true” value of a parameter would fall within +/-1*uc* for 68% of the data points, the “true” value of a parameter would fall within +/-2*uc* for 95% of the data points, and the “true” value of a parameter would fall within +/-3*uc* for 99.7% of the data points. Calculated uncertainty of the transmission efficiency for all data points with output power greater than zero is reported in Figure 13.



**Figure 13. Uncertainty of Efficiency Measurement**

As a check on the uncertainty calculation, points within the data set that had near-duplicate output speed and torque were compared. Thirteen pairs of data points were analyzed; of these, the largest standard deviation was slightly over two expected standard uncertainties, indicating that the uncertainty calculation is likely reasonably representative of actual uncertainties in the data.

# Discussion and Data Usage

The intent of this testing was to characterize the performance of a 2014 Chevrolet Silverado 6L80 six-speed automatic transmission. The method of benchmarking a transmission coupled to an engine has been demonstrated and is best implemented when performed in conjunction with an engine benchmarking test. This method of adding the transmission to the engine dyno setup to include inline torque measurements is straightforward and does not add significantly to the test cell complexity. The overall project is described in more detail in the SAE paper *SAE 2017-01-5020.pdf (“Testing and Benchmarking a 2014 GM Silverado 6L80 Six Speed Automatic Transmission”*). [1] Additional details on the engine testing portion of this transmission testing are provided in SAE paper *SAE 2016-01-0662.pdf (“Fuel Efficiency Mapping of a 2014 6-Cylinder GM EcoTec 4.3L Engine with Cylinder Deactivation”)*[2] and NCAT’s test package *2014 Chevrolet 4.3L EcoTec3 LV3 Engine Tier 2 Fuel – Test Data Package*.

This streamlined benchmarking method for a transmission is lower cost and less complex than an independent transmission component benchmarking test. In addition, the tethered methodology ensures that engine and transmission are controlled in tandem according to the manufacturer’s calibrations. However, the data set for this method is limited by the dynamometer’s ability to absorb torque, especially in the lower gear ranges.

The transmission data collected using this benchmarking were supplied as inputs to the ALPHA model including transmission gear efficiency, torque converter K factors, and spin losses. Considering the limitations on the available test data from this pilot project, the ALPHA simulation results showed a very good match to the test data providing confidence in this streamlined transmission benchmarking method.

# 

# References

[1] Stuhldreher, M., Kim, Y., Kargul, J., Moskalik, A. et al., “*Testing and Benchmarking a 2014 GM Silverado 6L80 Six Speed Automatic Transmission*,” SAE Technical Paper 2017-01-5020, 2017, doi:10-4271/2017-01-5020.

[2] Stuhldreher, M., "*Fuel Efficiency Mapping of a 2014 6-Cylinder GM EcoTec 4.3L Engine with Cylinder Deactivation*," SAE Technical Paper 2016-01-0662, 2016, doi:10.4271/2016-01-0662.