



U.S. Department  
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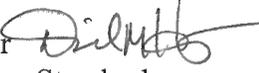
# Memorandum

**National Highway  
Traffic Safety  
Administration**

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Subject: **ACTION:** Docket Submission – “Analysis of Indoor  
Test Data for Hybrid and Electric Vehicles”

Date:

From: David M. Hines, Director   
Office of Crash Avoidance Standards

To: DOT Docket NHTSA-2016-0125

Thru: Paul A. Hemmersbaugh  
Chief Counsel

 For PH

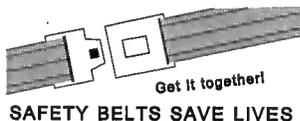
We are submitting the enclosed research report, “*Analysis of Indoor Test Data for Hybrid and Electric Vehicles,*” to Docket No. NHTSA-2016-0125.

This research report is referenced in the preamble of the recently published final rule establishing FMVSS No. 141, “Minimum Sound Level for Hybrid and Electric Vehicles.”

If you have any questions, please contact Michael Pyne of my office at (202) 366-4171, [mike.pyne@dot.gov](mailto:mike.pyne@dot.gov).

Attachment

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U.S. Department  
of Transportation

**National Highway  
Traffic Safety  
Administration**

April 2015

# **Analysis of Acoustic Data for Hybrid and Electric Vehicles Measured on Hemi- Anechoic Chambers**

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## TABLE OF CONTENTS

<b>Executive Summary</b> .....	<b>i</b>
<b>I. Introduction</b> .....	<b>1</b>
<b>II. Methods</b> .....	<b>1</b>
Test Facilities.....	1
Data Analyses.....	1
Test Vehicles .....	2
Ambient Corrections.....	2
<b>III. Results</b> .....	<b>3</b>
Ambient noise (comparison at two indoor test facilities).....	3
Measurement repeatability (run-to-run at each of two indoor test facilities) .....	5
Measurement reproducibility (comparison between two indoor test facilities).....	6
Measurement reproducibility (comparison indoor vs. outdoor) .....	9
<b>IV. Summary</b> .....	<b>16</b>
<b>V. References</b> .....	<b>17</b>
<b>Appendix A: Acoustic Data</b> .....	<b>17</b>

## LIST OF TABLES

Table 1. Vehicle Make, Model, Model Year, Test Location.....	2
Table 2. Standard Deviation (dB) of Site Differences across all Speeds and Vehicles .....	7
Table 3. Standard Deviation (dB) of Differences between TRC and Indoor Sites across all Speeds and Vehicles .....	11
Table 4. Averaged Event Levels Operation Max corrected for Min Ambient (Location: MPG) .....	18
Table 5. Averaged Event Levels Operation Max corrected for Min Ambient (Location: IAC).....	19
Table 6. IAC Indoor Data. All events were corrected for the ambient if needed except the Toyota Camry Hybrid events at 10 km/h and 315 Hz.....	20
Table 7. MPG Indoor Data. All events were corrected for the ambient if needed .....	23
Table 8. VRTC Outdoor Data. All events were corrected for ambient if needed except for the Nissan Leaf, Nissan Versa, and Chevrolet Cruze (no ambients).....	25

## LIST OF FIGURES

Figure 1. Correction for Background Noise in NHTSA's Notice of Proposed Rulemaking, Jan 14, 2013 <sup>3</sup> .....	3
Figure 2. Ambient Levels at Two Indoor Facilities .....	4
Figure 3. Standard Errors as a Function of Frequency .....	5
Figure 4. Average Differences between Indoor Test Facilities, MPG – IAC .....	6
Figure 5. Site Comparison MPG and IAC, 10 kph .....	7
Figure 6. Site Comparison MPG and IAC, 20 kph .....	8
Figure 7. Site Comparison MPG and IAC, 30 kph .....	8
Figure 8. Site Comparison MPG and IAC, All Speeds.....	9
Figure 9. Average Differences: Outdoor Test Facility TRC and Indoor Test Facility MPG, TRC- MPG.....	10
Figure 10. Average Differences: Outdoor Test Facility TRC and Indoor Test Facility IAC, TRC-IAC .....	10
Figure 11. Site Comparison TRC and MPG .....	12
Figure 12. Site Comparison TRC and IAC.....	13

## Executive Summary

The purpose of this technical report is to provide the results of the analysis of acoustic data collected at two hemi-anechoic chambers equipped with a chassis dynamometer for electric, hybrid, and internal combustion engine vehicles and a comparison between sound pressure levels obtained from these indoor measurements and outdoor testing. The analysis examines ambient noise, repeatability and reproducibility of vehicle acoustic signals (measurements). This effort was conducted in support of the goal to establish performance requirements for an alert sound that allows blind and other pedestrians to reasonably detect a nearby electric or hybrid vehicle.<sup>i</sup>

Indoor test data were collected at General Motors Milford Proving Grounds (MPG) in Milford, MI and International Automotive Components (IAC) in Plymouth, MI. These indoor data were provided by Transport Canada<sup>2</sup>. Outdoor test data were collected at the Transportation Research Center (TRC) in East Liberty, OH and were provided by the National Highway Traffic Safety Administration's (NHTSA) Vehicle Research and Test Center (VRTC).<sup>ii iii</sup> On behalf of NHTSA, the U.S. Department of Transportation Volpe Center analyzed the acoustic measurements.

The analysis included comparison of ambient noise at two indoor test facilities, measurement repeatability (run-to-run at each of two indoor test facilities, measurement reproducibility (comparison between two indoor test facilities), and measurement reproducibility (comparison indoor vs. outdoor) for 10 kph, 20 kph, and 20 kph constant speed pass-by vehicle operations.

The vehicles included in this analysis include the 2012 Chevy Cruze, 2012 (2010) Nissan Leaf, 2012 Nissan Versa, 2010 Tesla Roadster, 2012 Toyota Camry LE Hybrid, 2012 Toyota Camry LE ICE, and 2010 Ford Fusion SEL. Vehicle make and model were consistent between indoor and outdoor testing<sup>1</sup> and the exact same vehicles were used at both indoor test sites. With the exception of the Ford Fusion, all vehicles were included in each of the four analyses. The Fusion was included in all but the repeatability analysis for MPG and the indoor site reproducibility analysis.

Results in maximum A-weighted one-third octave band sound pressure levels are summarized as follows:

- Repeatability, as measured by standard errors for each indoor site was good. The estimated mean value is expected to be within 0.5 to 0.75 dB of the true mean, with 95 percent confidence, depending on the one-third octave band being analyzed.
- Reproducibility of estimated means between the two indoor test sites was about 2 dB on average; however, individual measurements had significant variation resulting in a 95 percent confidence interval range of +/- 2.5 dB to +/- 6.7 dB depending on the one-third octave band.
- Reproducibility between the two indoor test sites and the outdoor test sites was poorer still with a 95 percent confidence interval range of +/- 9.2 dB to +/- 9.8 dB depending on the one-third octave band. Because the vehicles tested at the indoor test sites were only similar (same make/model) but not identical, it is expected that this confidence interval would be reduced if identical vehicles were tested.

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<sup>1</sup> Indoor results from the 2012 Nissan Leaf were compared to outdoor results from the 2010 Nissan Leaf.

## I. Introduction

Pedestrian Safety Enhancement Act of 2010 requires the National Highway Traffic Safety Administration (NHTSA) to conduct a rulemaking to establish a Federal motor vehicle safety standard requiring an alert sound for pedestrians to be emitted by electric and hybrid vehicles (EVs and HVs). The goal is to establish performance requirements for an alert sound that allows blind and other pedestrians to reasonably detect a nearby electric or hybrid vehicle.<sup>i</sup>

The technical report includes the analysis of acoustic data collected at two hemi-anechoic chambers equipped with a chassis dynamometer. The analysis also includes a limited comparison of sound pressure levels obtained from these indoor measurements and outdoor testing. Indoor test data were provided by Transport Canada.<sup>iv</sup> NHTSA's Vehicle Research and Test Center (VRTC) and the Transportation Research Center (TRC) provided outdoor test data for this analysis.<sup>ii iii</sup> The U.S. Department of Transportation Volpe Center, on behalf of NHTSA, analyzed acoustic measurements for electric, hybrid, and internal combustion engine vehicles. The analysis examines ambient noise, repeatability and reproducibility of vehicle acoustic signals (measurements).

## II. Methods

### Test Facilities

Acoustic data were collected at two indoor facilities and one outdoor site:

- Indoor: General Motors Milford Proving Grounds (MPG) / Milford, MI
- Indoor: International Automotive Components (IAC) / Plymouth, MI
- Outdoor: Transportation Research Center (TRC) / East Liberty, OH

A description of the test facilities and measurement procedure has been documented in detail in the referenced reports.<sup>iv iii</sup>

### Data Analyses

The following analyses were completed:

1. Ambient noise (comparison at two indoor test facilities)
2. Measurement repeatability (run-to-run at each of two indoor test facilities)
3. Measurement reproducibility (comparison between two indoor test facilities)
4. Measurement reproducibility (comparison indoor vs. outdoor)

The following metrics were examined:

- Ambient Minimum,  $L_{Af,Min}$ 
  - Minimum A-weighted level using a fast time window<sup>2</sup>
  - Used for estimating ambient
- Operation Maximum,  $L_{Af,Max}$ 
  - Maximum A-weighted level using a fast time window
  - Most consistent with SAE J2889-1 (May 2012)<sup>v</sup> for outdoor pass-by measurements

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<sup>2</sup> Sound level meters have fast and slow time weighting options with time constants of 0.125 seconds (fast) and 1 second (slow). When set to fast, more detail is captured in the measurement.

The sound levels were analyzed for the following vehicle operations:

- 10 km/h constant speed pass-by
- 20 km/h constant speed pass-by
- 30 km/h constant speed pass-by

**Test Vehicles**

Table 1 describes the dataset available to support these analyses. Vehicle make and model were consistent between indoor and outdoor testing and the exact same vehicles were used at both indoor test sites. The outdoor testing results have been aggregated over several testing efforts and therefore do not represent the exact same vehicles and are not necessarily from the same model year. For example, a single 2012 Nissan Leaf was tested at MPG and IAC, however, a different Nissan Leaf (model year 2010) was tested at TRC. With the exception of the Ford Fusion, all vehicles were included in each of the four analyses. The Fusion was included in all but the repeatability analysis for MPG and the indoor site reproducibility analysis.

**Table 1. Vehicle Make, Model, Model Year, Test Location**

ID	Vehicle Make/Model/MY			Indoor Test		Outdoor Test	Support Analysis			
	Make	Model	MY <sup>3</sup>	MPG	IAC	TRC	#1	#2	#3	#4
1	Chevy	Cruze	2012	x	x	x	x	x	x	x
2	Nissan	Leaf	2012	x	x	x	x	x	x	x
3	Nissan	Versa	2012	x	x	x	x	x	x	x
4	Tesla	Roadster	2010	x	x	x	x	x	x	x
5	Toyota	Camry LE Hybrid	2012	x	x	x	x	x	x	x
6	Toyota	Camry LE ICE	2012	x	x	x	x	x	x	x
7	Ford	Fusion SEL	2010	-	x	x	x	x	-	x

**Ambient Corrections**

Ambient corrections were made for both indoor and outdoor ambient measurements following the procedure described in the NPRM and summarized in Figure 1. In short, if the ambient in a given one-third octave band was at least 10 dB less than the signal level in the one-third octave band, then no correction was made. If the ambient level was in the range 10 to 3 dB less than the signal level in the one-third octave band, then the corrections in the NPRM were applied as shown in Figure 1<sup>vi</sup>. If the ambient level in the one-third octave band was not more than 3 dB lower than the signal level in the one-third octave band, then a correction was not possible and the data were not used. In most cases ambient corrections were not needed for indoor measurements due to the extremely low ambient levels in the frequency range of interest.

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<sup>3</sup> Model years for indoor testing

TABLE 6—CORRECTIONS FOR BACKGROUND NOISE			
1/3 Octave band noise level OBL <sub>bgn,fc</sub>	*Peak-to-Peak 1/3 octave band background noise level OBL <sub>bgn,fc,p-p</sub>	1/3 Octave band level of jth test result, ith frequency, minus 1/3 octave band noise level DL = OBL <sub>test,j,fc</sub> - OBL <sub>bgn,fc</sub>	Correction L <sub>corr</sub>
≥ 25 dB(A) .....	** .....	> 10 dB .....	0 dB.
	< 8 dB .....	> 8-10 dB .....	0.5 dB.
		> 6-8 dB .....	1.0 dB.
	< 6 dB .....	> 4.5-6 dB .....	1.5 dB.
		> 3-4.5 dB .....	2.5 dB.
		≤ 3 dB .....	Do not correct, but report OBL <sub>testcorr,j</sub> < OBL <sub>testj</sub> .
< 25 dB(A) .....		≤ 10 dB .....	Do not correct, but report: OBL <sub>testcorr,j</sub> < OBL <sub>testj</sub> .
	** .....	> 10 dB .....	0 dB.

\* Ensure that maximum allowable peak-to-peak variation occurs in not more than one measurement for each operation during the portion of the measurement that will be reported, e.g. within the second prior to pass-by or during an entire active but stationary measurement.  
\*\* Ensure that the background level is at least 10 dB below the measurement during any portion of the measurement that will be reported, e.g. within the second prior to pass-by or during an entire active but stationary measurement.

Figure 1. Correction for Background Noise in NHTSA’s Notice of Proposed Rulemaking, Jan 14, 2013<sup>3</sup>

### III. Results

#### Ambient noise (comparison at two indoor test facilities)

The measured ambient levels for the two indoor test facilities are shown in Figure 2. Red squares are used to indicate sample minimum ambient levels measured at IAC, which were used for signal corrections. Blue circles are used to indicate sample minimum ambient levels measured at MPG, which were used for signal corrections. Mean values and 95 percent prediction intervals are also shown as well as the minimum sound levels proposed in the NPRM (extended over the range from 100 Hz to 5000 Hz). The green region shows where ambient levels could be and have correctable signal levels that would require correction but activated levels in the NPRM. It can be seen that only three ambient data points were in this region. Overall, these results show that these two indoor facilities have ambient conditions that would allow for, in most cases, the measurement of alert signals without the need for ambient corrections.

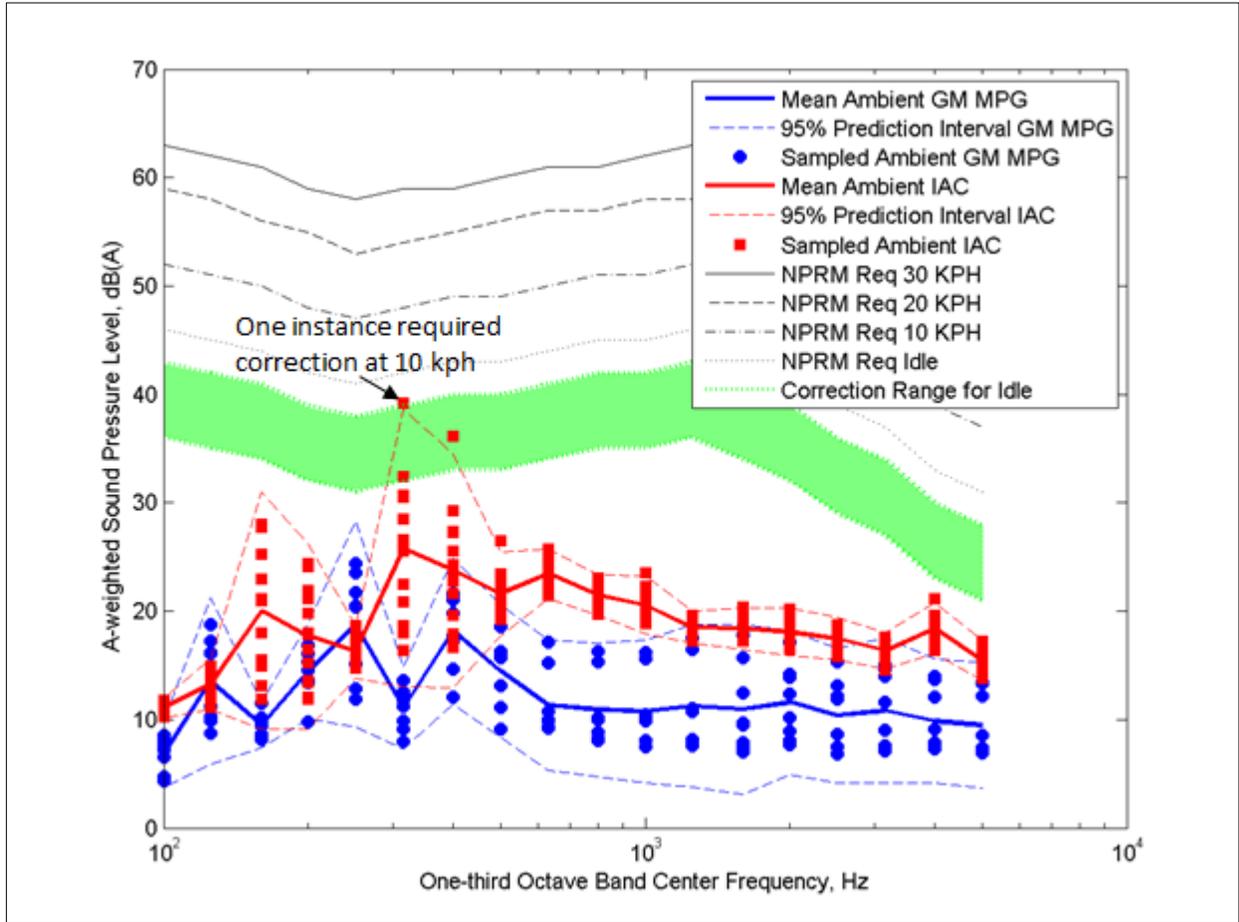


Figure 2. Ambient Levels at Two Indoor Facilities

### Measurement repeatability (run-to-run at each of two indoor test facilities)

Repeatability at each site was evaluated by considering the standard error of the mean value, considering each measurement as an estimate of the mean for each vehicle. Standard errors were considered rather than standard deviations because this allows all vehicles to be considered together, by effectively removing the effect of the mean value. For example, if there are four measurements of the sound pressure level for a vehicle in the 1000 Hz one-third octave band at 10 km/h: 30, 32, 31, and 34. The mean value would be 31.75 and the standard error would be the standard deviation of the residuals, 1.48. If another vehicle had the same variation but with a mean value of 33.75, that is, sample measurements of 33, 35, 34, and 37, the standard error for these data would also be 1.48. The combined standard error of both vehicles would be 1.48, but the combined standard deviation would be 2.11.

The standard errors are shown for both indoor test facilities as a function of frequency in Figure 3. The standard errors for these two sites are typically around 0.5 to 0.75 dB for the 315 Hz one-third octave band and above. This indicates that about 95 percent of measured one-third octave band levels for a given vehicle / operation will be within a range of +/- 1 to +/- 1.5 dB and when estimating a mean value using four samples, the mean value should be within about 0.5 to 0.75 dB of the true mean with 95 percent confidence. The high standard error at 125 Hz is caused predominantly by one ICE vehicle. It is not known why this vehicle has so much variation at 125 Hz, but the variation occurs mostly at 10 km/h, so it may be related to low engine speed.

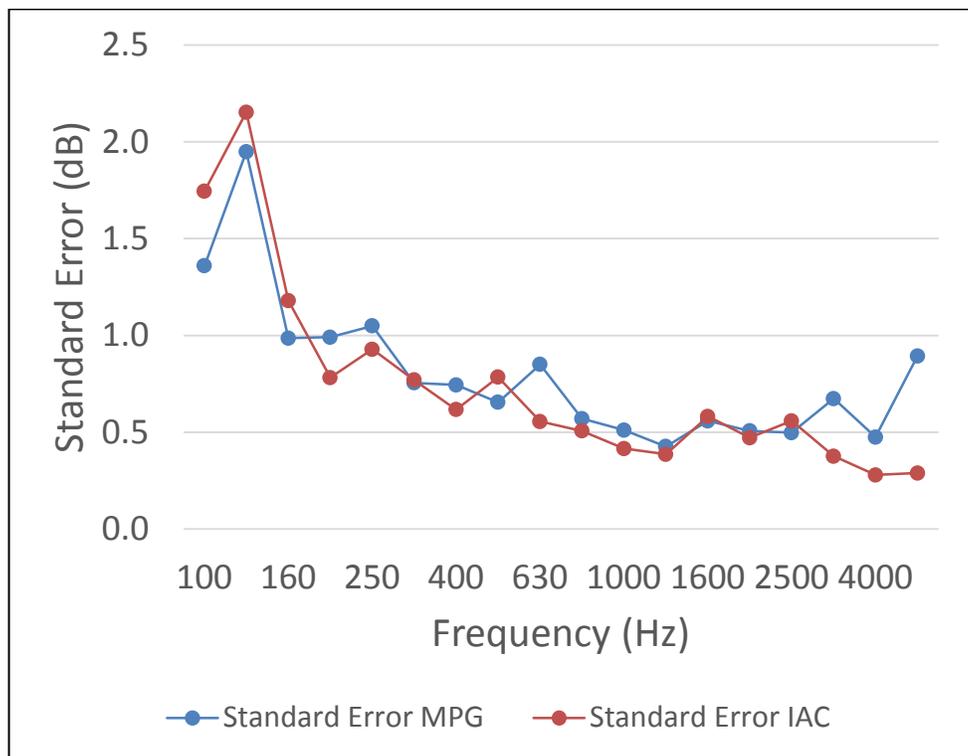


Figure 3. Standard Errors as a Function of Frequency

### Measurement reproducibility (comparison between two indoor test facilities)

Measurement reproducibility between the two indoor test facilities was evaluated by comparing the average values of each vehicle at each one-third octave band for each speed. The results are summarized in Figure 4. Because the repeatability for both sites is very good, the differences in Figure 4 are associated with site specific differences, for example, different dynamometer / tire interaction or variation in the setup procedure ( e.g., slightly different microphone locations). The differences between sites are about 2 dB on average at 10 km/h, with MPG generally having lower levels for one-third octave bands below 500 Hz and generally having higher levels at 500 Hz and above. The trends are reversed at 20 and 30 km/h, but the differences are only about 1 dB on average.

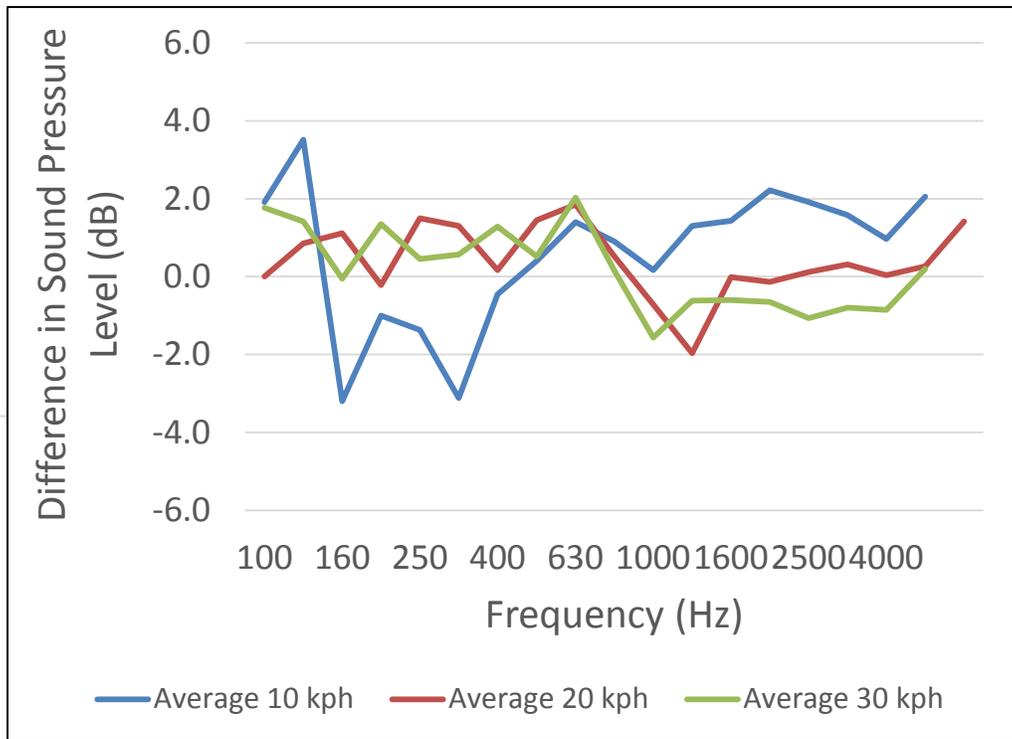


Figure 4. Average Differences between Indoor Test Facilities, MPG – IAC

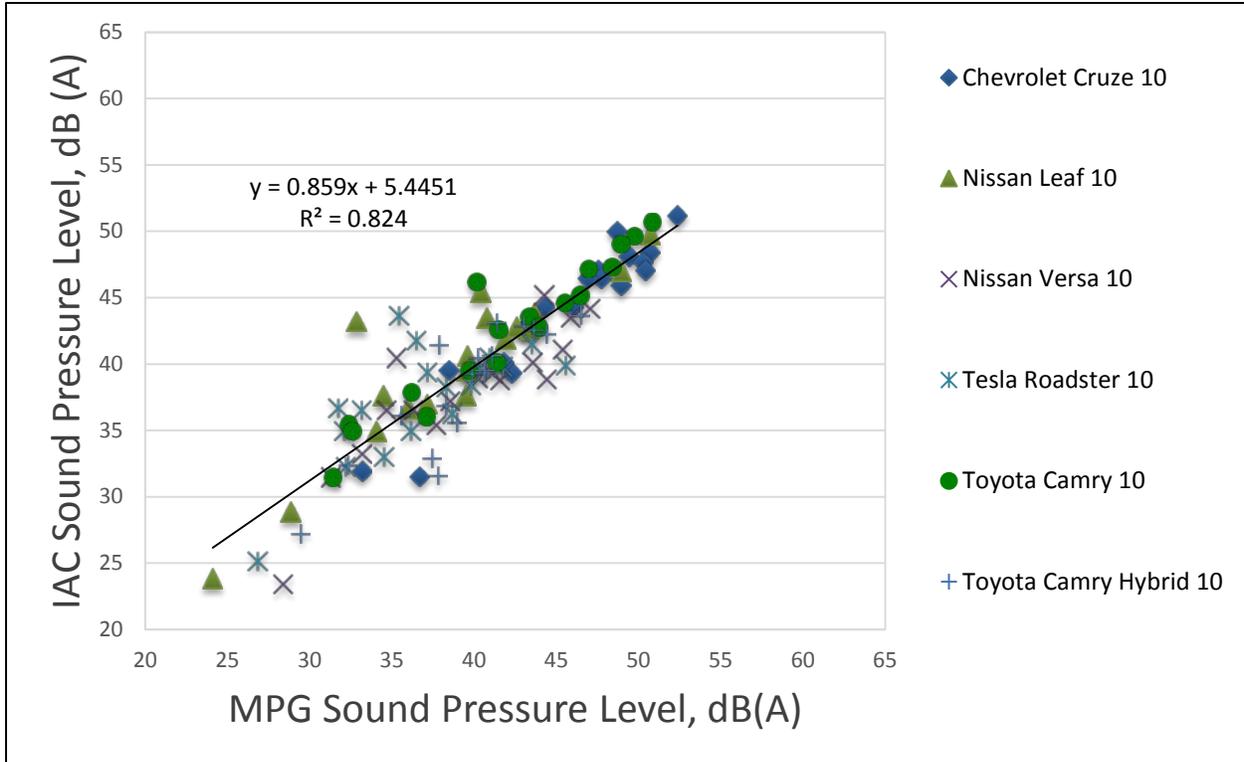
Although the average difference is generally less than 2 dB between the two sites, differences for specific vehicle / speed / frequency pairs are still significant. When considering site-to-site differences, the 95 percent confidence intervals for estimated means range from +/- 6.7 dB at 315 Hz to +/- 2.5 dB at 1600 Hz.

Table 2 shows the standard deviation of site differences across all speed and vehicles for each one-third octave band between 100 Hz and 5000 Hz. It should be noted that, although the 400 Hz one-third octave band and below, consistently have standard deviations greater than 2 dB, the 500 Hz one-third octave band and above typically have standard deviations less than 2 dB. The exceptions being 630 and 800 Hz.

**Table 2. Standard Deviation (dB) of Site Differences across all Speeds and Vehicles**

One-third Octave Band Center Frequency																	
100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
2.4	2.0	3.0	2.7	2.6	3.4	2.5	1.5	2.3	2.1	1.5	1.5	1.3	1.7	1.6	1.4	1.9	1.6

The variation of individual measurements between the two sites is further illustrated by the scatter plots in Figure 5, Figure 6, Figure 7, and Figure 8. It can be seen in the figures, that on average there is very good correlation between the two sites, but individual measurements have significant differences between the two sites and these differences appear to be random.



**Figure 5. Site Comparison of 1/3 Octave Band Levels for MPG and IAC, 10 kph**

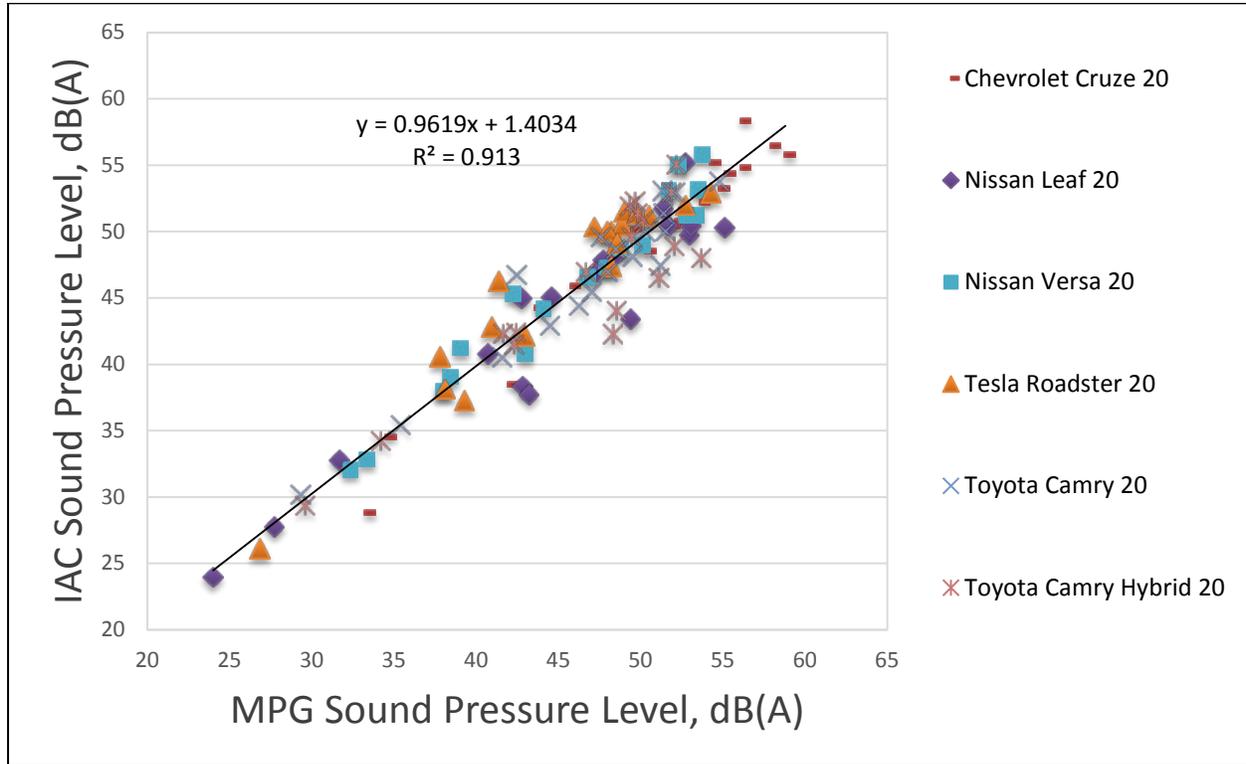


Figure 6. Site Comparison of 1/3 Octave Band Levels MPG and IAC, 20 kph

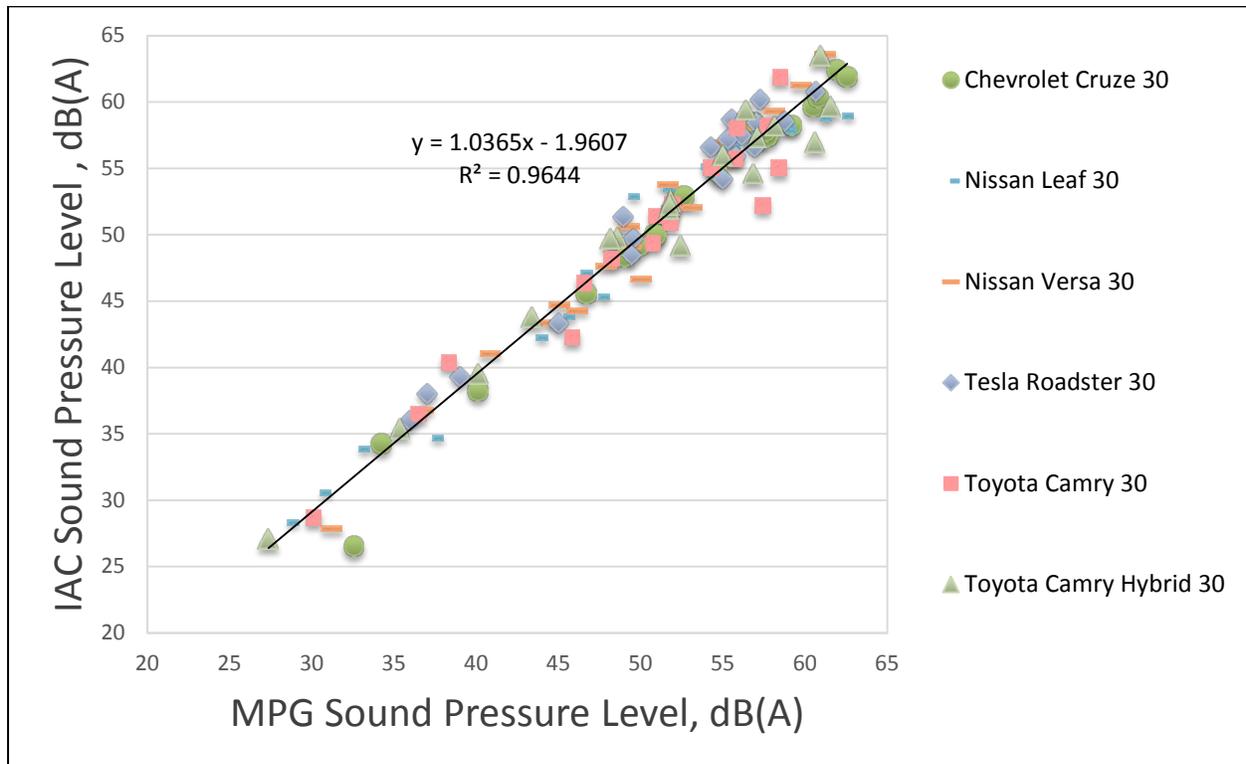


Figure 7. Site Comparison of 1/3 Octave Band Levels MPG and IAC, 30 kph

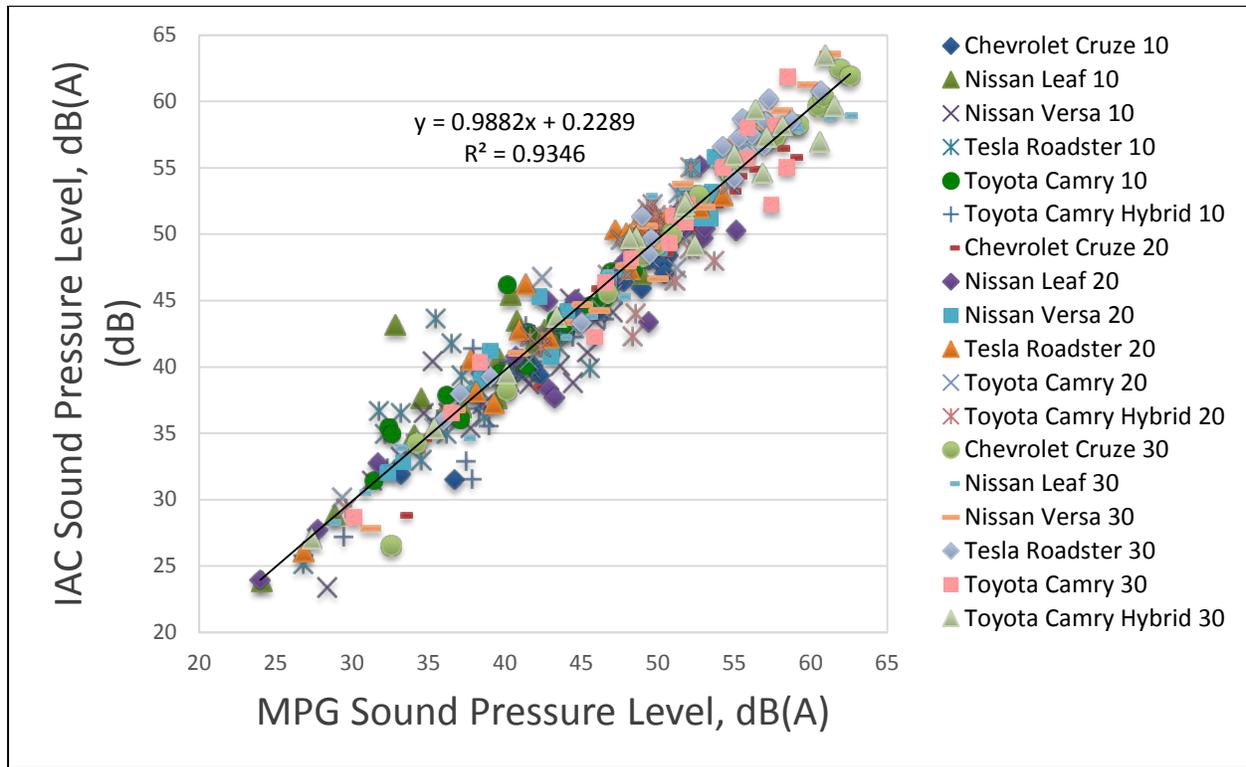


Figure 8. Site Comparison of 1/3 Octave Band Levels MPG and IAC, All Speeds

**Measurement reproducibility (comparison indoor vs. outdoor)**

In addition to comparing the two indoor test facilities to one another, both facilities were also compared with outdoor facility measurements made at TRC. Measurement reproducibility between each indoor test facilities and TRC was evaluated by comparing the average values of each vehicle at each one-third octave band for each speed at the respective sites. The results are summarized in Figure 9 and Figure 10. Comparing the results in these figures, it can be seen that the indoor facilities tend to have higher levels, especially at 20 and 30 km/h. Because the differences are smaller at 10 km/h, it is not likely that the differences in acoustic reflections from the indoor floor and the outdoor pavement are causing the difference. Rather, it is likely that the tire / dynamometer interaction is producing the higher sound pressure levels. Since this may also explain some of the indoor reproducibility differences, it may be necessary to further study this interaction before there can be confidence in a test procedure that utilizes a dynamometer.

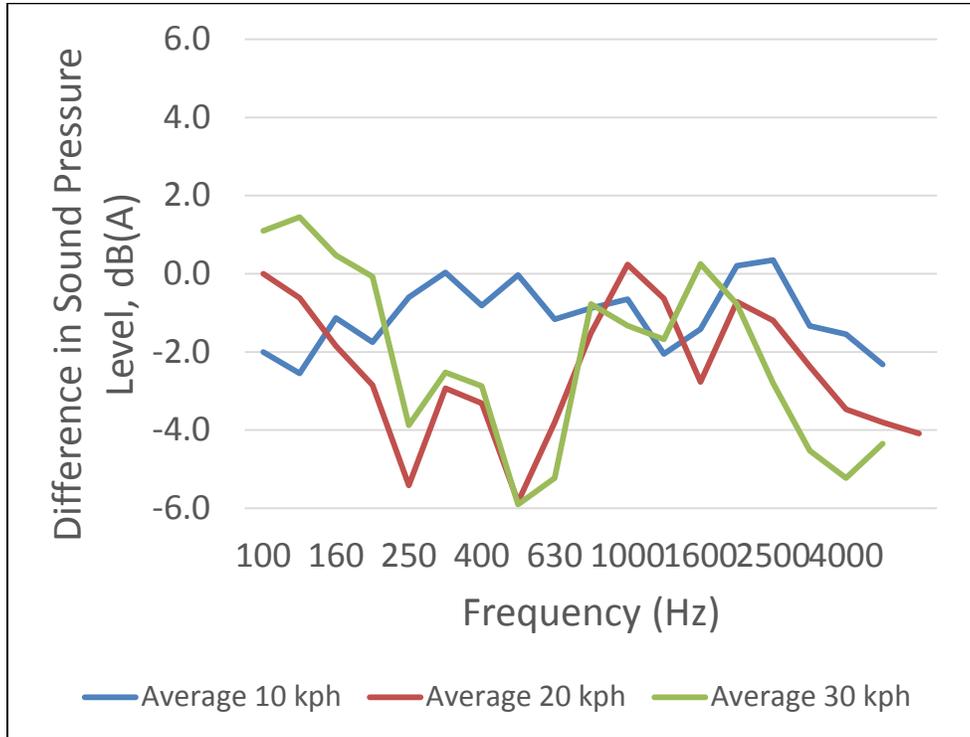


Figure 9. Average Differences: Outdoor Test Facility TRC and Indoor Test Facility MPG, TRC- MPG

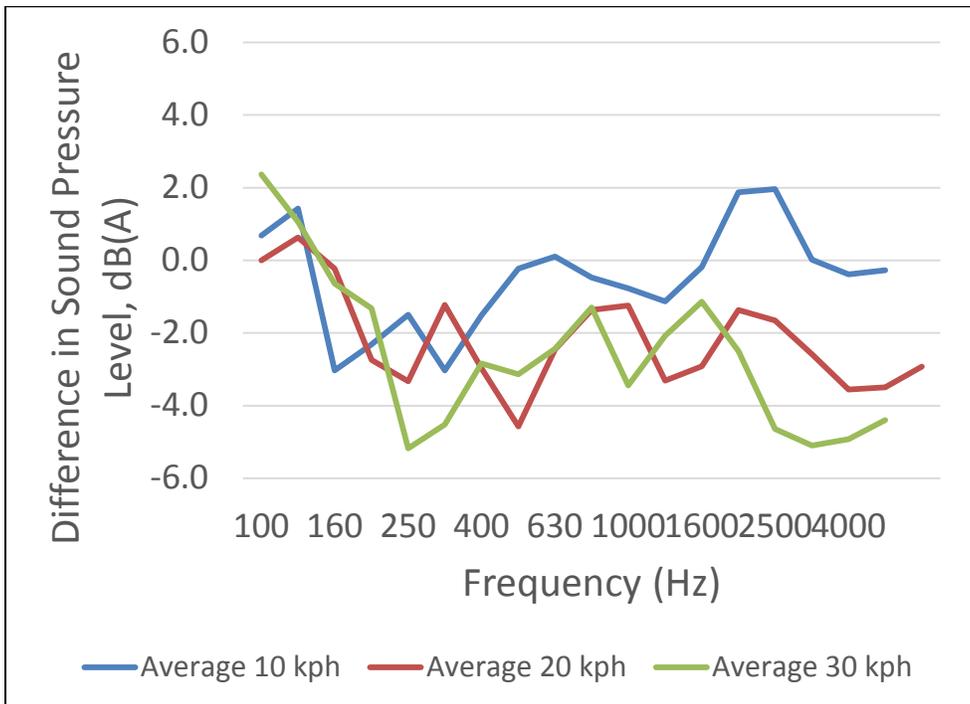


Figure 10. Average Differences: Outdoor Test Facility TRC and Indoor Test Facility IAC, TRC-IAC

Considering confidence intervals of estimated mean values for individual vehicle / speed / frequency pairs, the standard deviation between TRC and MPG was as high as 5 dB and the standard deviation between TRC and IAC was as high as 4.7 dB (see Table 3)<sup>4</sup>. Thus 95 percent confidence intervals would be as large as +/- 9.8 and +/- 9.2 dB respectively. It is important to keep in mind that these confidence intervals included not only site-to-site differences but also include differences as a result of using different vehicles and in some cases different model years, therefore, these confidence intervals can be considered a worst case. It is expected that confidence intervals for the same vehicles would be smaller.

**Table 3. Standard Deviation (dB) of Differences between TRC and Indoor Sites across all Speeds and Vehicles**

One-third Octave Band Center Frequency																		
Site	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
MPG	2.6	3.8	4.2	5.0	3.5	3.4	3.3	3.2	3.6	2.3	2.0	1.5	2.0	1.7	2.8	3.3	3.5	2.7
IAC	3.4	3.2	4.7	3.7	3.3	2.6	2.1	2.4	2.6	2.1	2.7	1.5	1.8	3.0	3.8	3.4	3.8	3.0

Individual differences between outdoor and indoor test facilities are shown by speed in Figure 11-Figure 18. Differences between facilities for all speeds are most readily observed by considering the scatter plots in Figure 14 and Figure 18. The correlation is lower between indoor and outdoor than between indoor and indoor and although there is a significant bias in the trend, 5.0 dB between TRC and MPG and 1.2 between TRC and IAC, there is no clear pattern for individual vehicles, with the possible exception of the Nissan Leaf. The Nissan Leaf at 10 km/h produced significantly higher levels when on a dynamometer than when on an outdoor track. The two Nissan Leafs being compared were from different model years, 2012 (indoor) and 2010(outdoor), so it is conceivable that the alert signal has been changed by the manufacturer over this time period. This is a specific example of how differences between two vehicles of the same model affect the reproducibility in the analysis between indoor and outdoor test sites. For the 315 to 5000 Hz frequency range, the standard deviation between TRC and MPG was as high as 3.6 dB and for MPG and the standard deviation between TRC and IAC was as high as 3.8 dB.

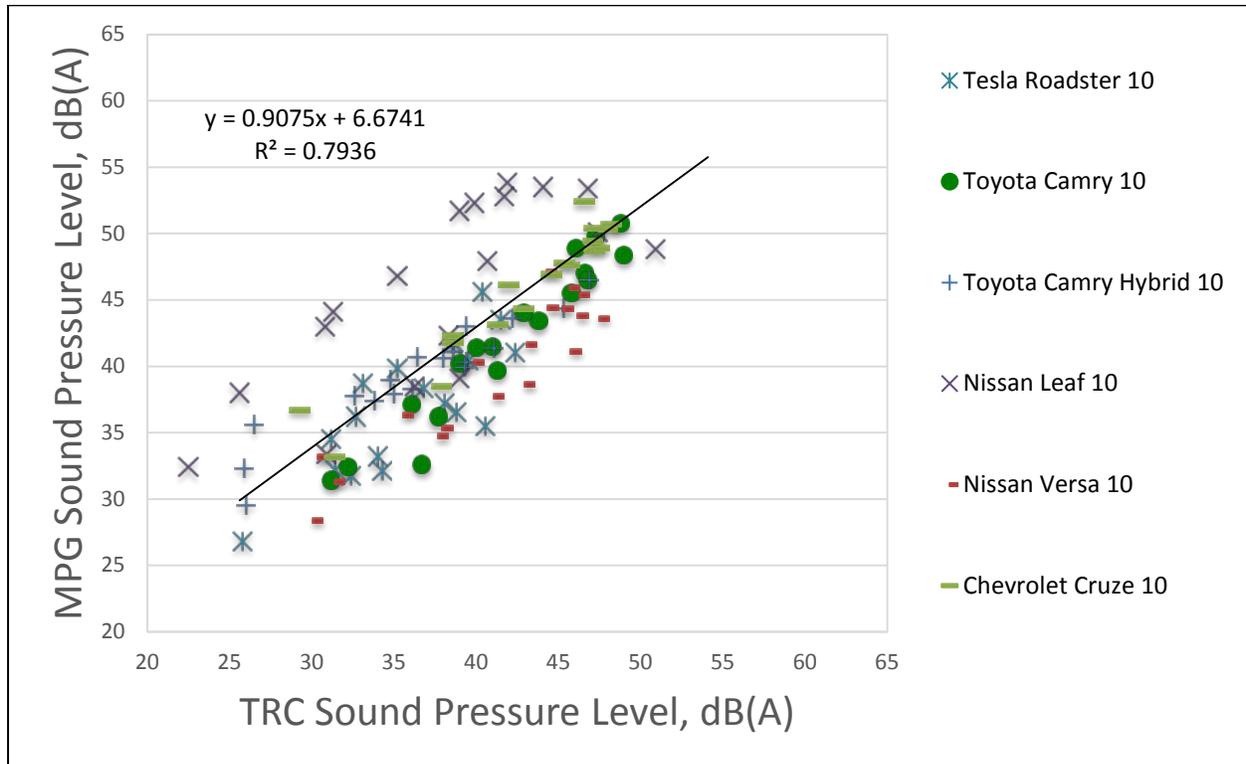


Figure 11. Site Comparison of 1/3 Octave Band Levels TRC and MPG, 10 kph

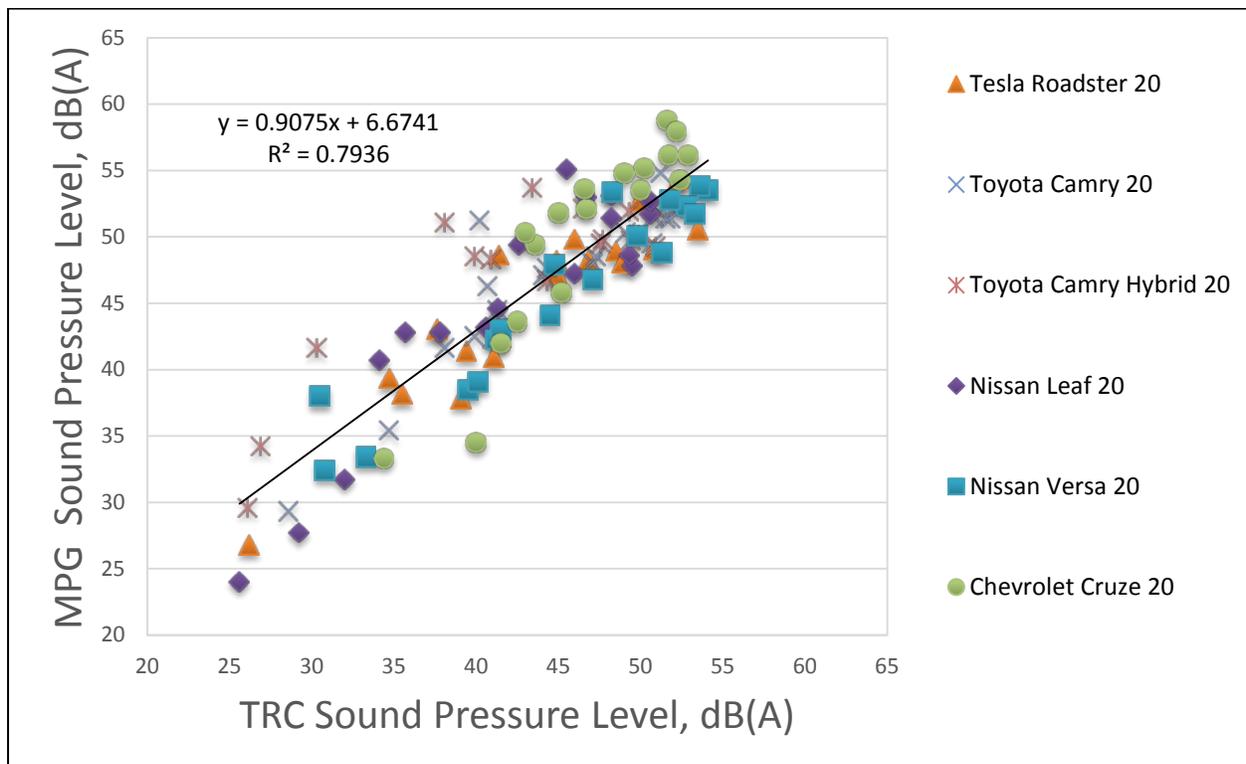


Figure 12. Site Comparison of 1/3 Octave Band Levels TRC and MPG, 20 kph

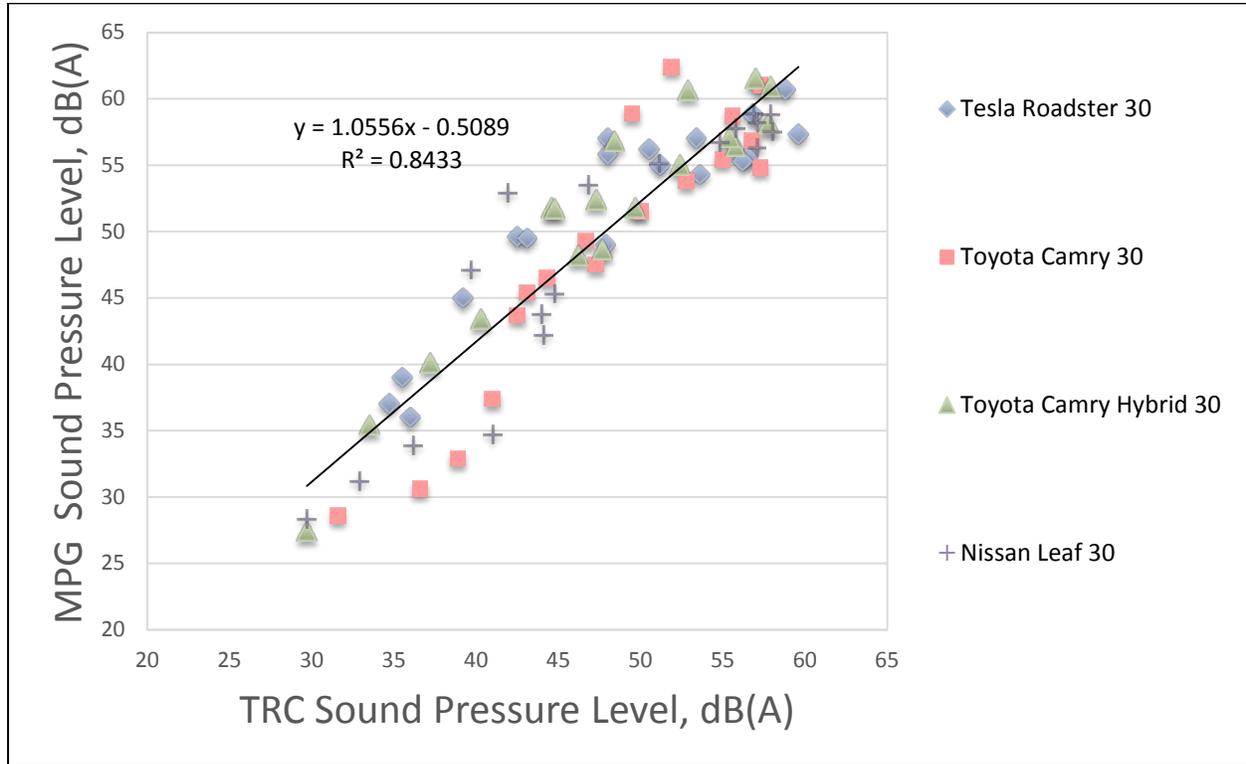


Figure 13. Site Comparison of 1/3 Octave Band Levels TRC and MPG, 30 kph

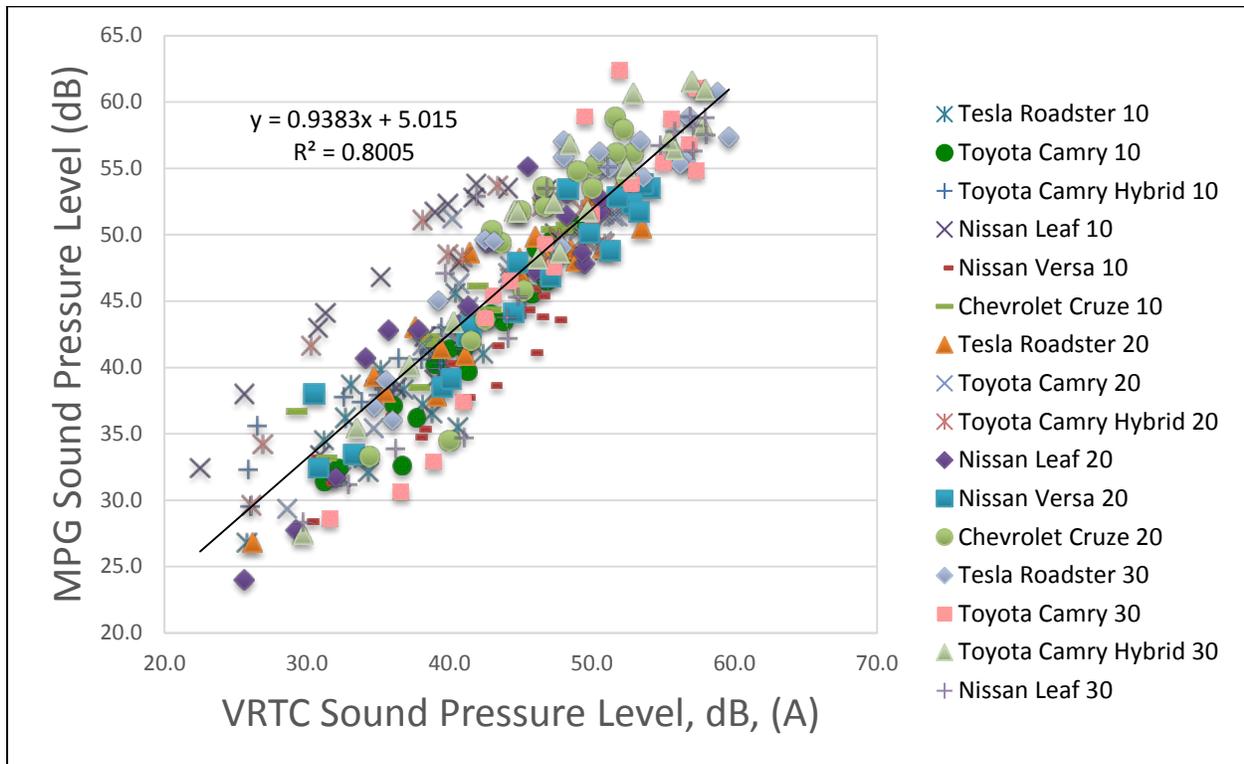


Figure 14. Site Comparison of 1/3 Octave Band Levels TRC and MPG, All Speeds

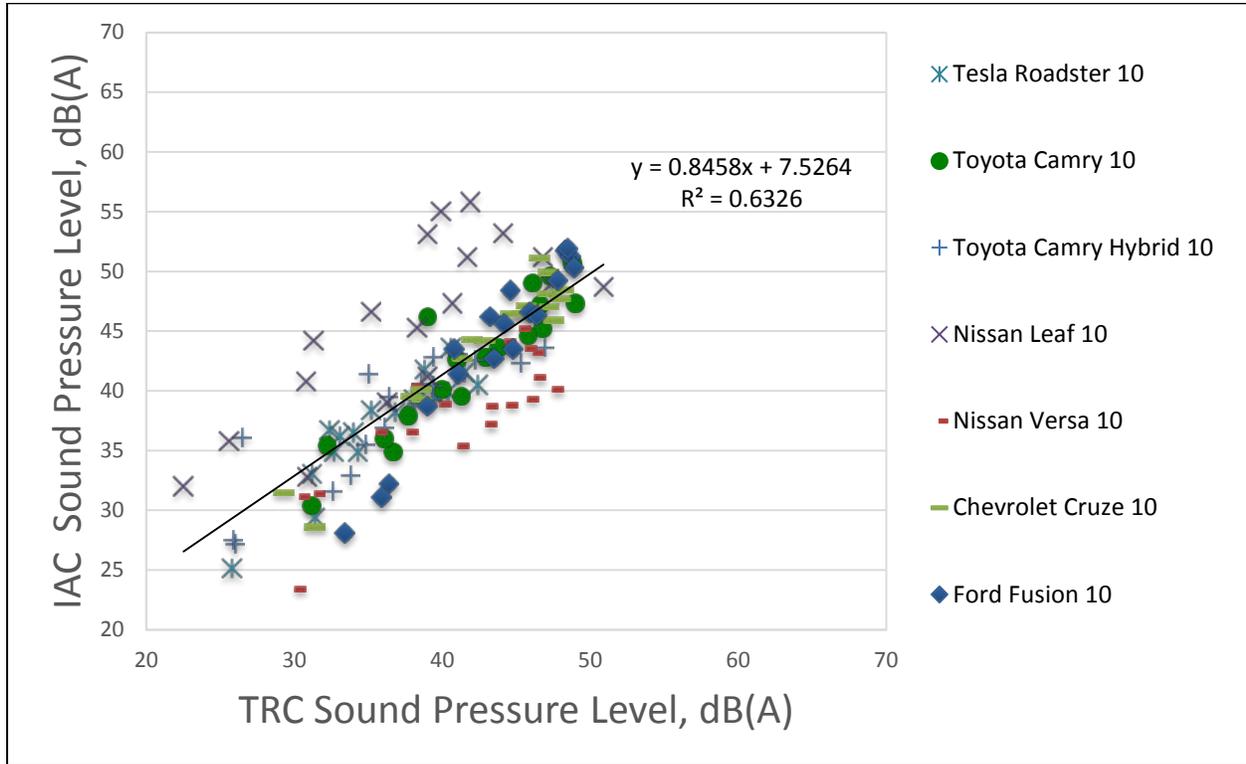


Figure 15. Site Comparison of 1/3 Octave Band Levels TRC and IAC, 10 kph

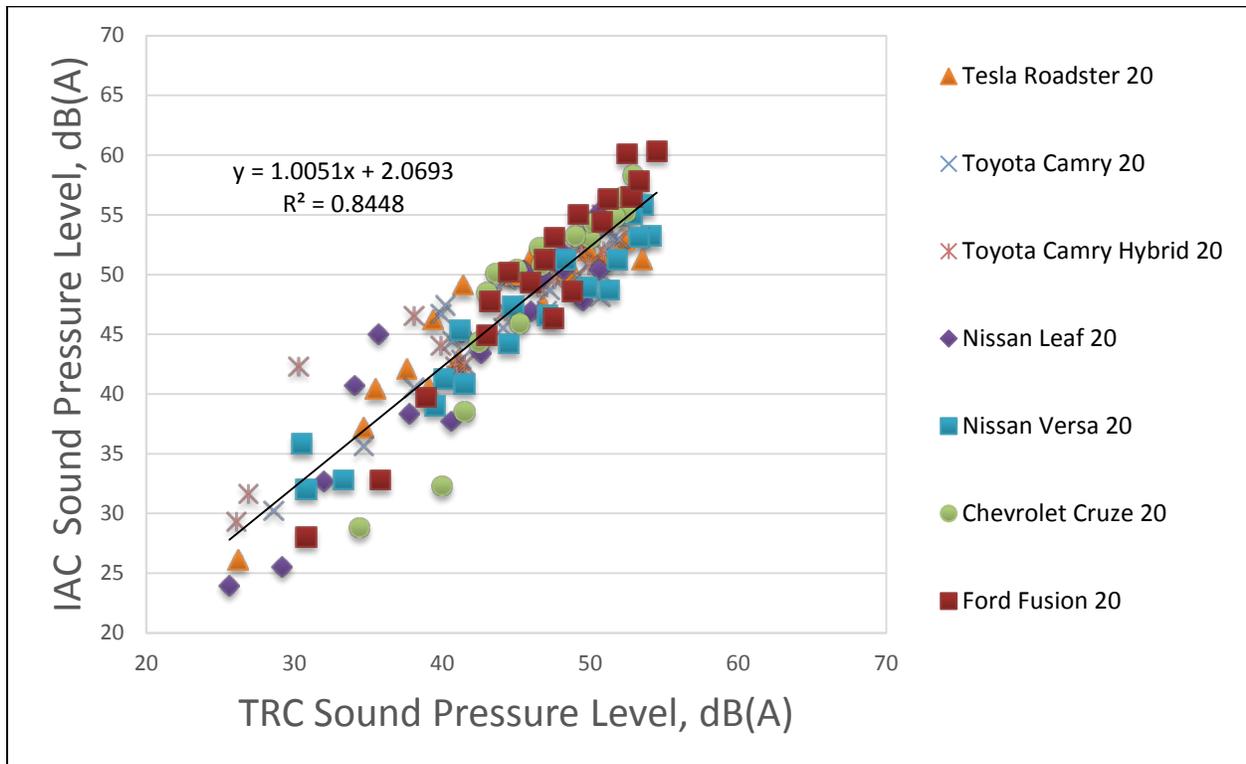


Figure 16. Site Comparison of 1/3 Octave Band Levels TRC and IAC, 20 kph

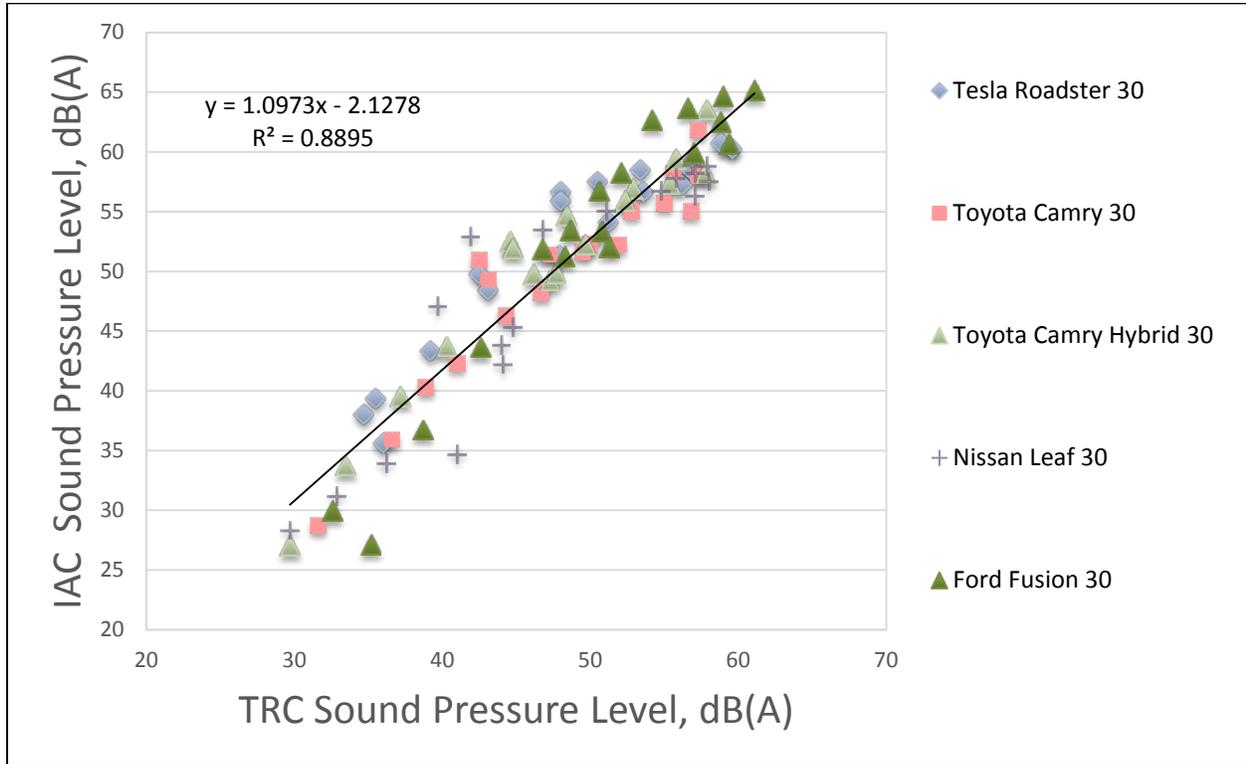


Figure 17. Site Comparison of 1/3 Octave Band Levels TRC and IAC, 30 kph

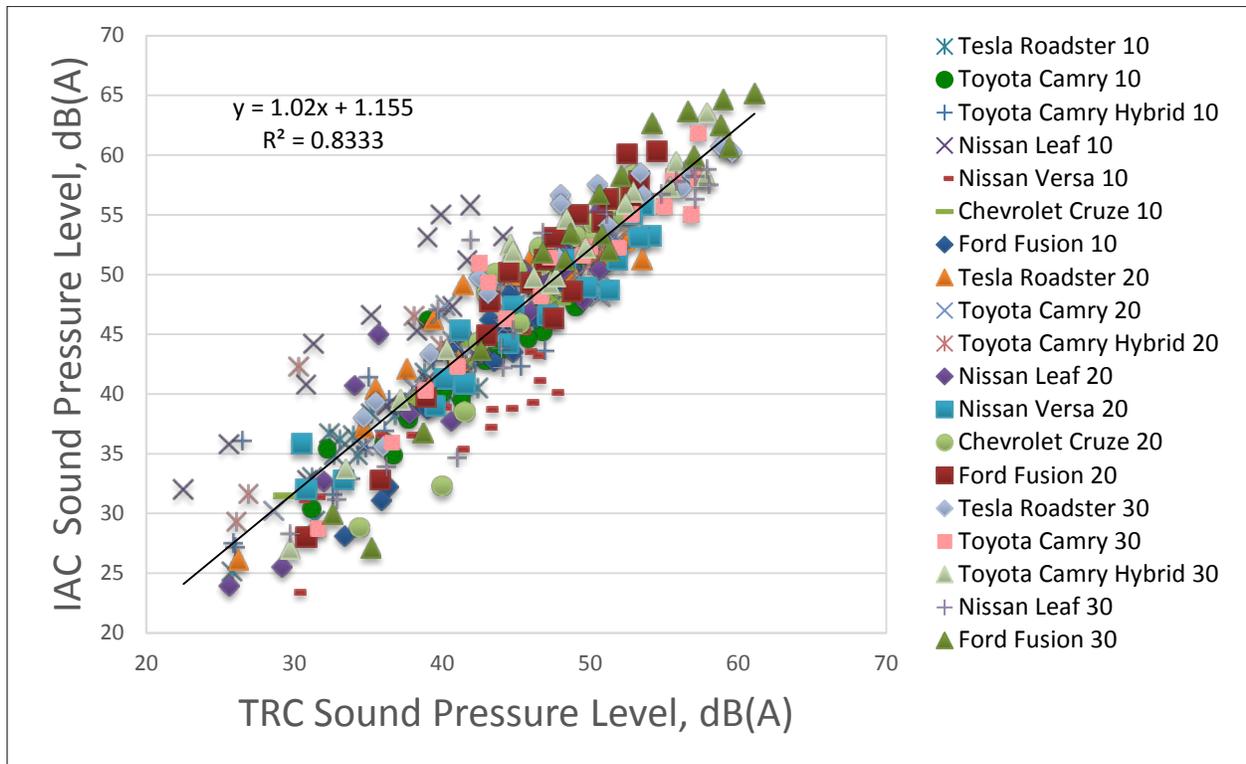


Figure 18. Site Comparison of 1/3 Octave Band Levels TRC and IAC, All Speeds

#### **IV. Summary**

Maximum A-weighted one-third octave band sound pressure levels were measured for several vehicles at two indoor test sites and one outdoor test facility. Data were used to examine measurement repeatability (run-to-run); reproducibility between the two indoor sites; and reproducibility between indoor and outdoor sites.

- Repeatability, as measured by standard errors for each indoor site was good. The estimated mean value is expected to be within 0.5 to 0.75 dB of the true mean, with 95 percent confidence, depending on the one-third octave band being analyzed.
- Reproducibility of estimated means between the two indoor tests sites was about 2 dB on average; however, individual measurements had significant variation resulting in a 95 percent confidence interval range of +/- 2.5 dB to +/- 6.7 dB depending on the one-third octave band.
- Reproducibility between the two indoor test sites and the outdoor tests sites was poorer still with a 95 percent confidence interval range of +/- 9.2 dB to +/- 9.8 dB depending on the one-third octave band. Because the vehicles tested at the indoor test sites were only similar (same make/model) but not identical, it is expected that this confidence interval would be reduced if identical vehicles were tested.

## V. References

- <sup>i</sup> Public Law 111-373, 124 Stat. 4086 (January 4, 2011). Pedestrian Safety Enhancement Act of 2010.
- <sup>ii</sup> Evans, L. and Harris, J. (2012, June). Quieter Vehicle Performance Test Development Research Report. National Highway Traffic Safety Administration. Washington D.C. Docket NHTSA-2011-0148-0047.
- <sup>iii</sup> Harris, J.; Gerdus, E.; Evans, L. & Garrott, R. W (TBD). Quieter Vehicle Test Report – 2012: Comparison of Sound Pressure Levels. National Highway Traffic Safety Administration. Washington D.C.
- <sup>iv</sup> Whittal, I.; Jonasch, R.; and Meyer, N. (2013, September). Quiet Vehicle Sounds Test Data Report. Transport Canada. Docket NHTSA-2011-0148-0321.
- <sup>v</sup> SAE International (2012, May). Measurement of Minimum Noise Emitted by Road Vehicles, SAE 2889-1. Warrendale, PA
- <sup>vi</sup> Federal Register / Vol. 78, No. 9, January 14, 2013. *Proposed Rule. Minimum Sound Requirements for Hybrid and Electric Vehicles*. Docket NHTSA-2011-0148.

## Appendix A: Acoustic Data

**Table 4. Averaged Event Levels Operation Max corrected for Min Ambient (Location: MPG)**

Make/Model	Speed	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
Chevrolet Cruze	10	36.7	33.2	38.5	42.3	43.1	41.8	44.3	48.7	52.4	47.6	49.4	50.7	50.3	48.9	50.4	47.8	46.9	46.1
Nissan Leaf	10	24.1	28.9	32.9	40.4	43.7	39.6	43.4	48.9	50.7	40.8	41.9	39.6	37.2	39.5	42.6	36	34.5	34.1
Nissan Versa	10	28.4	33.2	31.3	36.3	35.3	34.7	40.3	41.6	44.4	43.8	44.3	47.1	45.9	45.4	43.6	41.1	38.6	37.7
Tesla Roadster	10	26.8	32.2	31.7	33.2	32.1	35.5	36.5	37.2	40.4	45.6	41	43.5	41.8	38.3	39.8	38.7	36.2	34.5
Toyota Camry	10	32.4	31.4	32.6	36.2	37.1	40.2	41.5	39.7	43.4	49.8	47	48.9	50.8	48.4	46.5	45.5	44	41.4
Toyota Camry Hybrid	10	29.5	32.3	35.6	40.7	41.4	37.9	38.3	39.9	40.3	43.6	43	41.1	40.6	46.5	44.4	39	37.4	37.8
<b>Average</b>		29.7	31.9	33.8	38.2	38.8	38.3	40.7	42.7	45.3	45.2	44.4	45.2	44.4	44.5	44.6	41.4	39.6	38.6
<b>20</b>																			
Chevrolet Cruze	20	33.3	34.5	42	49.4	43.6	45.8	52.1	53.5	58.8	54.3	56.1	57.9	56.1	55.2	54.8	53.6	51.8	50.3
Nissan Leaf	20	24	27.7	31.7	42.8	43.2	49.4	55.1	53	53.1	51.7	52.7	51.4	47.8	48.6	47.2	44.6	42.8	40.7
Nissan Versa	20	32.4	38	33.4	38.5	42.3	39.1	47.9	53.4	48.8	53.5	53.8	52.3	51.7	52.8	50.1	46.8	44.1	43
Tesla Roadster	20	26.8	38.1	41.4	37.8	40.9	47.2	48.2	48.2	48.9	49	50.5	54.3	52.7	48	49.8	48.6	43	39.3
Toyota Camry	20	29.3	35.4	41.6	51.2	46.3	42.5	47.6	48	49.5	51.4	51.4	54.8	52.1	51.5	50.3	48.5	47.1	44.5
Toyota Camry Hybrid	20	29.6	34.2	41.6	51.1	48.3	48.5	53.7	52.1	49.7	49.3	52.2	51.9	50.2	49.8	49.5	46.7	42.4	42.3
<b>Average</b>		29.2	34.7	38.6	45.1	44.1	45.4	50.8	51.4	51.5	51.5	52.8	53.8	51.8	51.0	50.3	48.1	45.2	43.4
<b>30</b>																			
Chevrolet Cruze	30	32.6	34.2	40.1	46.7	49.9	50.9	49	56.9	59.2	57.7	61.9	62.6	60.5	60.8	57.6	54.7	52.7	51
Nissan Leaf	30	28.6	30.6	32.9	37.4	43.7	45.4	47.5	58.9	62.4	56.8	61	58.7	54.8	55.4	53.8	51.5	49.3	46.5
Nissan Versa	30	31.2	36.8	45.1	44.5	40.9	46.2	50	49.5	53.1	57.2	61.3	59.8	57.3	58.2	55.1	51.7	49.3	47.9
Tesla Roadster	30	37	36	39	49.6	57	49	56.2	55	54.3	55.6	57.3	60.7	58.8	55.3	57	55.8	49.5	45
Toyota Camry	30	30.1	36.5	38.4	45.9	51.8	50.8	51	51.7	57.4	58.4	58.5	57.7	55.9	55.8	54.3	52	48.3	46.6
Toyota Camry Hybrid	30	27.4	35.4	40.1	43.4	51.8	51.7	52.4	56.8	60.6	61.5	60.9	56.4	58.1	57.1	55	51.8	48.6	48.2
<b>Average</b>		31.2	34.9	39.3	44.6	49.2	49.0	51.0	54.8	57.8	57.9	60.2	59.3	57.6	57.1	55.5	52.9	49.6	47.5

**Table 5. Averaged Event Levels Operation Max corrected for Min Ambient (Location: IAC)**

Make/Model	Spd	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
<b>Chevrolet Cruze</b>	10	31.5	28.6	39.5	39.3	42.7	40.1	44.2	49.9	51.1	47.1	48.1	48.4	47.7	45.9	47	46.4	46.4	44.3
<b>Nissan Leaf</b>	10	23.8	23.1	43.2	45.4	43.8	40.6	42.6	46.9	49.7	43.4	41.8	39.5	37	37.6	42.8	36.6	37.6	34.9
<b>Nissan Versa</b>	10	23.4	31.1	31.4	36.5	40.4	36.5	38.9	38.7	38.8	43.2	45.2	44.1	43.5	41.1	40.1	39.3	37.2	35.4
<b>Tesla Roadster</b>	10	25.1	29.4	36.7	36.5	34.9	43.6	41.8	39.3	39.6	39.9	40.5	41.5	39.8	38.2	38.4	36.2	34.9	33
<b>Toyota Camry</b>	10	35.4	30.4	34.9	37.9	36	46.2	42.6	39.5	43.6	49.6	47.2	49	50.7	47.3	45.2	44.6	42.8	40.1
<b>Toyota Camry Hybrid</b>	10	27.2	27.5	36.1	39.5	43.1	41.4	36.9	39.3	40.4	42.6	42.8	40.6	39.3	43.6	42.3	35.5	32.9	31.6
<b>Ford Fusion</b>	10	28.1	32.2	31.1	38.7	43.5	43.5	46.2	48.4	46.6	51.7	51.2	51.9	50.3	49.2	46.3	45.6	42.7	41.4
<b>Average</b>		27.8	28.9	36.1	39.1	40.6	41.7	41.9	43.1	44.3	45.4	45.3	45.0	44.0	43.3	43.2	40.6	39.2	37.2
<b>Chevrolet Cruze</b>	20	28.8	32.3	38.5	50.1	44.3	45.9	50.8	53	55.8	55.2	58.3	56.5	54.8	54.3	53.2	52.2	50.4	48.5
<b>Nissan Leaf</b>	20	23.9	25.5	32.7	38.3	37.7	43.4	50.3	49.7	50.4	50.4	55.2	51.7	47.8	48.3	46.9	45.1	45	40.7
<b>Nissan Versa</b>	20	32	35.8	32.8	39	45.3	41.2	47.3	51.2	48.7	53.2	55.8	55	53.1	51.2	48.9	46.6	44.2	40.8
<b>Tesla Roadster</b>	20	26.1	40.4	46.2	40.5	42.8	50.3	50	47.4	50.4	51.4	51.2	52.9	52	50	51.3	49.1	42.1	37.2
<b>Toyota Camry</b>	20	30.2	35.6	40.5	47.4	44.4	46.7	49.5	46.9	48.1	51.4	53	53.7	52.9	50	49.9	48.7	45.5	42.9
<b>Toyota Camry Hybrid</b>	20	29.3	31.6	42.3	46.5	42.3	44	48	48.9	52.3	51.9	55	52.9	50.8	51.4	49.6	46.9	42.4	41.5
<b>Ford Fusion</b>	20	32.8	28	39.7	48.6	46.3	44.9	50.2	53.1	54.4	60.3	60.1	56.5	57.8	56.3	55	51.2	49.3	47.7
<b>Average</b>		29.0	32.7	39.0	44.3	43.3	45.2	49.4	50.0	51.4	53.4	55.5	54.2	52.7	51.6	50.7	48.5	45.6	42.8
<b>Chevrolet Cruze</b>	30	26.5	31.9	38.2	45.6	49.2	50.1	48.3	58.5	58.2	57.4	62.4	61.9	59.6	60.3	57.8	54.7	52.9	50
<b>Nissan Leaf</b>	30	28.3	31.2	33.9	34.7	42.2	43.8	45.3	57.8	58.9	57.5	58.8	58.2	56.3	56.7	55.1	53.5	52.9	47.1
<b>Nissan Versa</b>	30	27.8	32.7	44.7	43.4	41	44.2	46.7	49.1	52	58.1	63.6	61.2	58.4	59.3	56.9	53.7	50.6	47.6
<b>Tesla Roadster</b>	30	38	35.6	39.3	49.7	56.6	51.3	57.5	54.1	56.6	58.7	60.2	60.7	58.5	57.2	58.5	55.9	48.4	43.3
<b>Toyota Camry</b>	30	28.7	35.9	40.3	42.3	50.9	49.3	51.4	51.6	52.2	55	61.8	58.2	58	55.7	55	52.3	48.2	46.3
<b>Toyota Camry Hybrid</b>	30	27	33.7	39.5	43.7	52.5	51.9	49.2	54.6	56.9	59.6	63.5	59.4	58.2	57.3	55.9	52.2	49.8	49.7
<b>Ford Fusion</b>	30	27.1	29.9	36.7	43.6	51.2	58.2	52	53.3	59.9	65.1	64.6	60.6	62.5	63.6	62.6	56.7	53.4	51.8
<b>Average</b>		29.1	33.0	38.9	43.3	49.1	49.8	50.1	54.1	56.4	58.8	62.1	60.0	58.8	58.6	57.4	54.1	50.9	48.0

**Table 6. IAC Indoor Data. All events were corrected for the ambient if needed except the Toyota Camry Hybrid events at 10 km/h and 315 Hz**

Vehicle	Event	Speed	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
Chevrolet Cruze	1	10	31.1	29.5	38.9	40.3	42.5	40.0	44.5	49.8	51.3	46.4	48.0	48.2	48.0	46.0	46.9	46.3	46.2	43.8
Chevrolet Cruze	2	10	31.0	29.0	40.1	39.4	43.9	40.3	44.7	49.8	50.9	47.9	47.9	48.6	47.7	46.0	46.9	46.2	46.4	44.3
Chevrolet Cruze	3	10	32.4	27.2	39.5	38.2	41.6	40.0	43.5	50.2	51.2	46.9	48.4	48.4	47.3	45.7	47.3	46.7	46.7	44.8
Chevrolet Cruze	1	20	23.8	29.4	39.5	51.5	44.6	45.0	50.9	52.2	55.1	54.6	58.4	57.3	55.5	54.4	53.1	52.9	50.1	48.6
Chevrolet Cruze	2	20	36.6	36.3	38.2	48.8	43.5	44.9	51.7	53.7	56.8	55.6	58.8	55.8	54.1	54.1	53.0	51.1	50.2	48.1
Chevrolet Cruze	3	20	26.0	31.3	37.8	50.1	44.7	47.8	49.8	53.1	55.4	55.4	57.8	56.3	54.9	54.5	53.5	52.6	50.9	48.8
Chevrolet Cruze	1	30	25.6	32.5	38.0	44.8	47.5	49.0	47.4	58.5	59.4	57.9	62.0	62.2	59.1	60.2	58.0	54.9	53.3	49.7
Chevrolet Cruze	2	30	27.9	31.5	38.8	45.9	50.2	50.8	48.8	57.8	57.5	56.8	63.0	61.6	60.0	60.6	57.7	54.7	52.3	49.9
Chevrolet Cruze	3	30	26.0	31.6	37.8	46.0	49.8	50.5	48.8	59.1	57.8	57.4	62.3	61.9	59.7	60.1	57.7	54.4	53.0	50.3
Ford Fusion	1	10	28.5	31.4	31.8	41.1	42.9	44.2	46.8	47.8	46.3	52.7	51.1	51.5	50.6	48.9	46.1	46.3	42.7	40.9
Ford Fusion	2	10	29.5	33.0	29.2	38.4	44.8	43.7	46.0	48.5	47.1	51.4	51.3	52.0	50.6	49.7	46.4	45.7	43.1	42.8
Ford Fusion	3	10	26.3	32.2	32.4	36.6	42.7	42.6	45.9	48.9	46.4	51.0	51.1	52.2	49.6	49.0	46.4	44.7	42.2	40.6
Ford Fusion	1	20	31.7	27.2	41.9	51.3	48.4	47.1	50.1	53.5	53.6	59.4	60.0	57.8	57.3	55.9	56.2	51.2	50.1	48.9
Ford Fusion	2	20	32.7	27.5	39.1	47.3	45.9	43.4	49.8	53.8	55.1	60.7	60.0	55.8	58.2	56.6	54.5	51.2	48.8	46.8
Ford Fusion	3	20	34.1	29.4	38.0	47.2	44.5	44.1	50.7	51.9	54.4	60.9	60.4	56.0	57.9	56.4	54.2	51.2	48.9	47.3
Ford Fusion	1	30	28.3	31.7	39.8	43.5	51.1	58.5	51.5	53.8	60.6	65.7	64.0	61.3	62.6	63.4	62.3	56.5	53.1	51.4
Ford Fusion	2	30	25.0	28.1	36.5	44.7	51.2	58.7	52.9	53.0	59.3	64.6	65.3	60.3	62.3	63.5	62.8	56.7	53.7	51.9
Ford Fusion	3	30	28.1	29.8	33.9	42.6	51.3	57.4	51.5	53.0	59.9	64.9	64.4	60.3	62.5	63.8	62.7	56.9	53.5	52.0
Nissan Leaf	1	10	25.0	21.6	41.5	45.7	43.9	40.9	43.1	47.0	49.6	43.6	42.0	39.4	36.6	37.8	42.7	37.0	37.8	35.4
Nissan Leaf	2	10	23.2	25.0	44.1	45.0	45.1	40.7	42.9	46.8	49.9	42.9	41.6	39.6	37.4	37.3	43.0	36.2	36.7	34.5
Nissan Leaf	3	10	23.2	22.6	43.9	45.5	42.5	40.1	41.9	47.0	49.6	43.8	41.9	39.4	36.9	37.7	42.6	36.6	38.3	34.7
Nissan Leaf	1	20	23.6	26.4	34.4	39.3	38.4	42.8	50.0	50.6	51.5	50.5	54.6	52.0	47.8	48.1	47.1	45.1	44.6	40.6
Nissan Leaf	2	20	24.0	24.7	33.0	38.6	38.1	43.2	50.3	49.1	50.0	49.9	55.6	51.8	47.9	48.3	46.5	44.9	45.2	40.9
Nissan Leaf	3	20	24.2	25.4	30.8	37.1	36.6	44.1	50.5	49.4	49.8	50.8	55.3	51.2	47.8	48.6	47.1	45.2	45.1	40.7
Nissan Leaf	1	30	27.8	32.4	32.1	34.8	41.9	42.6	44.6	57.8	59.1	57.9	59.1	58.6	55.9	56.7	55.1	53.6	53.0	47.3
Nissan Leaf	2	30	27.5	30.1	33.9	34.8	42.2	44.9	45.9	59.0	59.1	56.6	59.1	58.0	56.5	56.5	55.1	53.3	52.6	47.0

Vehicle	Event	Speed	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
Nissan Leaf	3	30	29.6	31.1	35.6	34.4	42.6	43.9	45.4	56.7	58.6	58.0	58.1	58.0	56.6	56.8	55.2	53.6	53.0	46.9
Nissan Versa	1	10	26.7	39.8	34.6	35.3	40.2	38.6	40.2	40.3	40.0	43.5	46.2	45.4	46.2	43.7	43.0	40.4	37.3	35.7
Nissan Versa	2	10	21.8	25.0	31.5	38.3	41.0	36.0	38.0	37.6	37.9	43.1	44.2	43.3	42.4	39.7	39.1	38.8	37.1	35.0
Nissan Versa	3	10	21.6	28.4	28.2	36.0	40.1	35.0	38.4	38.3	38.5	43.0	45.1	43.7	41.8	39.9	38.1	38.7	37.1	35.5
Nissan Versa	1	20	31.8	32.1	32.2	39.0	45.6	42.4	48.4	49.2	48.4	53.7	55.4	55.1	53.0	51.0	48.3	46.5	44.3	41.1
Nissan Versa	2	20	33.2	38.0	34.5	39.2	45.4	41.5	48.0	52.3	49.0	52.9	55.9	55.3	53.0	51.1	49.3	47.0	44.3	40.8
Nissan Versa	3	20	31.1	37.3	31.7	38.9	44.9	39.7	45.5	52.1	48.7	52.9	56.1	54.6	53.3	51.5	49.2	46.2	43.9	40.4
Nissan Versa	1	30	27.9	30.7	45.5	43.2	40.7	43.5	46.1	48.3	51.9	57.8	64.2	60.6	57.8	59.1	56.7	53.7	50.4	47.6
Nissan Versa	2	30	26.5	29.7	45.4	43.8	39.3	44.5	46.5	50.6	52.0	58.3	63.3	61.0	59.3	59.4	57.2	53.6	50.7	47.6
Nissan Versa	3	30	29.1	37.6	43.1	43.1	43.0	44.7	47.4	48.4	52.2	58.1	63.3	62.1	58.2	59.3	56.8	53.9	50.7	47.6
Tesla Roadster	1	10	25.6	28.4	37.9	37.5	34.9	44.6	41.5	38.9	39.2	38.9	40.0	41.4	39.6	38.2	38.5	36.3	34.9	32.8
Tesla Roadster	2	10	25.1	28.7	35.8	35.8	34.0	43.3	41.8	39.2	39.4	40.3	41.5	41.5	40.1	38.2	38.6	36.5	35.1	33.3
Tesla Roadster	3	10	24.7	31.0	36.3	36.2	35.9	43.0	42.0	39.9	40.3	40.5	40.0	41.6	39.6	38.3	38.0	35.9	34.8	32.8
Tesla Roadster	1	20	25.5	39.4	46.8	39.0	42.5	50.8	49.8	48.1	50.5	51.1	50.8	53.1	52.1	49.8	50.9	49.1	42.2	37.5
Tesla Roadster	2	20	24.8	41.4	46.6	42.4	42.9	49.5	49.4	46.7	51.0	51.4	51.1	53.0	51.9	50.2	51.8	48.7	42.3	37.0
Tesla Roadster	3	20	27.9	40.4	45.3	40.2	42.9	50.6	50.7	47.3	49.8	51.8	51.6	52.5	51.9	50.1	51.3	49.4	41.9	37.2
Tesla Roadster	1	30	36.5	35.7	39.1	49.5	57.0	52.1	57.4	56.3	58.1	59.2	59.5	60.8	57.4	57.5	58.0	55.3	49.1	44.3
Tesla Roadster	2	30	39.2	35.1	41.2	49.8	58.4	50.2	56.6	53.0	56.3	58.4	60.5	60.6	59.3	57.0	58.4	56.0	48.1	42.7
Tesla Roadster	3	30	38.3	36.0	37.5	49.7	54.4	51.7	58.4	53.1	55.3	58.4	60.5	60.8	58.9	57.1	59.0	56.4	48.1	42.9
Toyota Camry	1	10	35.1	32.2	36.5	38.5	38.4	46.9	43.5	40.1	43.9	47.8	47.5	48.6	51.0	47.0	45.1	45.5	43.0	40.0
Toyota Camry	2	10	33.7	29.4	35.4	38.1	35.3	45.9	42.2	38.6	43.2	50.5	47.1	49.8	50.1	47.4	45.2	44.2	42.8	40.1
Toyota Camry	3	10	37.5	29.6	32.9	37.0	34.4	45.7	42.0	39.7	43.6	50.5	46.9	48.6	51.0	47.5	45.2	44.1	42.5	40.3
Toyota Camry	1	20	29.0	35.0	40.0	47.4	44.7	46.6	49.5	46.5	48.2	51.6	53.1	53.9	52.8	49.6	49.9	48.6	45.5	43.1
Toyota Camry	2	20	31.0	35.5	41.1	46.6	44.8	47.5	49.1	46.3	48.7	51.1	53.1	53.8	53.0	50.5	50.2	48.7	45.5	42.9
Toyota Camry	3	20	30.5	36.3	40.4	48.3	43.7	46.1	50.0	48.0	47.4	51.5	52.9	53.5	53.0	49.9	49.7	48.7	45.4	42.7
Toyota Camry	1	30	29.4	35.7	41.2	41.5	50.5	48.7	50.8	51.5	52.1	55.6	61.5	58.7	58.4	55.7	55.2	52.2	48.5	46.0
Toyota Camry	2	30	28.6	35.0	41.3	43.2	50.8	49.5	52.1	51.5	52.5	54.8	62.0	58.1	57.7	55.6	55.0	52.1	47.9	46.4

Vehicle	Event	Speed	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
Toyota Camry	3	30	28.0	37.1	38.5	42.1	51.4	49.8	51.3	51.9	52.0	54.6	62.0	57.8	58.0	55.8	54.8	52.5	48.1	46.6
Toyota Camry Hybrid	1	10	28.2	28.6	36.4	37.6	42.8	41.0	36.7	38.9	40.8	42.8	42.2	40.7	39.5	43.8	42.9	35.1	32.8	31.3
Toyota Camry Hybrid	2	10	28.1	26.7	37.0	40.4	42.8	41.2	37.0	39.4	39.8	42.0	43.4	40.8	39.3	43.6	41.8	35.9	32.9	31.4
Toyota Camry Hybrid	3	10	25.3	27.1	34.8	40.5	43.7	43.7	36.9	39.5	40.6	42.9	42.9	40.4	39.2	43.5	42.1	35.6	32.9	32.0
Toyota Camry Hybrid	1	20	32.0	33.4	42.9	45.7	41.8	45.1	47.6	49.2	52.3	52.0	54.7	52.9	50.9	51.1	49.5	47.0	42.3	41.7
Toyota Camry Hybrid	2	20	28.2	29.2	41.8	46.7	42.5	43.5	48.1	49.1	51.8	52.0	55.3	53.2	51.1	51.7	49.5	46.9	42.1	41.4
Toyota Camry Hybrid	3	20	27.7	32.1	42.2	47.0	42.5	43.5	48.3	48.4	52.7	51.6	55.0	52.7	50.5	51.4	49.7	46.9	42.7	41.4
Toyota Camry Hybrid	1	30	26.0	31.7	39.7	43.6	54.1	52.0	49.5	55.1	57.4	59.9	63.3	59.4	57.9	57.3	56.0	52.0	49.7	49.7
Toyota Camry Hybrid	2	30	26.8	35.5	38.9	43.9	52.4	51.6	49.5	55.1	57.1	59.9	63.2	59.1	58.3	57.4	56.0	52.6	49.8	49.6
Toyota Camry Hybrid	3	30	28.3	33.9	39.8	43.7	51.1	52.2	48.5	53.5	56.3	59.1	63.9	59.6	58.3	57.3	55.8	52.1	49.8	49.7

**Table 7. MPG Indoor Data. All events were corrected for the ambient if needed**

Vehicle	Event	Speed	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
Chevrolet Cruze	1	10	34.7	33.7	38.0	42.9	43.8	42.6	43.7	49.2	52.8	47.8	49.7	52.0	51.0	49.5	49.9	48.0	47.3	46.1
Chevrolet Cruze	2	10	34.6	31.6	37.5	40.6	42.4	40.4	44.6	47.6	51.4	46.3	48.3	48.7	48.7	47.6	51.6	46.9	46.7	46.2
Chevrolet Cruze	3	10	40.8	34.3	40.0	43.3	43.1	42.4	44.7	49.3	52.9	48.6	50.3	51.4	51.2	49.7	49.8	48.4	46.8	45.9
Chevrolet Cruze	1	20	33.9	33.7	41.8	48.3	43.3	45.8	52.0	53.1	59.4	54.7	56.1	57.4	56.0	55.1	55.3	54.2	51.7	50.2
Chevrolet Cruze	2	20	32.1	34.0	42.5	51.3	43.6	45.1	52.0	53.6	58.5	53.5	56.1	58.5	56.2	55.0	54.7	53.5	51.8	50.5
Chevrolet Cruze	3	20	33.8	35.9	41.6	48.7	43.9	46.4	52.4	53.8	58.5	54.6	56.1	57.9	56.1	55.4	54.4	53.2	52.0	50.3
Chevrolet Cruze	1	30	34.1	35.4	41.7	48.3	51.0	50.3	49.0	55.2	58.7	57.6	62.6	63.0	61.2	60.5	57.5	54.5	52.8	50.6
Chevrolet Cruze	2	30	33.9	34.8	40.3	45.8	49.6	50.0	48.2	57.3	59.4	58.1	62.3	62.3	60.2	60.8	57.9	55.3	52.8	50.8
Chevrolet Cruze	3	30	29.7	32.5	38.3	46.1	49.1	52.4	49.9	58.2	59.5	57.5	60.9	62.4	60.1	61.2	57.5	54.4	52.4	51.5
Nissan Leaf	1	10	22.7	28.8	32.4	39.7	43.1	40.0	42.8	49.1	50.9	40.7	42.0	39.6	36.8	39.6	42.9	35.8	34.2	34.3
Nissan Leaf	2	10	24.3	31.4	33.2	41.1	45.1	40.0	44.1	48.9	50.4	40.2	41.5	39.4	36.8	39.2	42.4	36.1	34.9	33.9
Nissan Leaf	3	10	25.3	26.4	33.0	40.4	42.8	38.8	43.2	48.8	50.9	41.5	42.3	39.7	37.9	39.7	42.5	36.1	34.4	34.0
Nissan Leaf	1	20	23.8	27.9	30.4	42.1	42.5	50.7	55.3	52.6	53.7	51.1	52.0	51.3	47.9	48.2	47.3	45.1	42.8	40.7
Nissan Leaf	2	20	22.5	28.0	31.3	43.4	44.0	48.4	54.9	52.5	53.2	52.3	53.9	51.5	47.9	48.5	46.9	44.4	42.7	40.7
Nissan Leaf	3	20	25.7	27.3	33.4	43.0	43.2	49.1	55.2	53.8	52.3	51.7	52.3	51.4	47.5	49.0	47.5	44.3	42.8	40.8
Nissan Leaf	1	30	29.4	30.4	33.9	36.8	43.6	45.2	47.5	58.7	62.7	57.0	61.0	58.3	54.8	55.7	53.8	51.3	49.1	46.2
Nissan Leaf	2	30	28.2	30.5	33.2	39.6	44.0	46.5	48.3	58.4	62.7	56.8	60.8	58.9	54.7	55.2	53.5	51.7	49.3	46.3
Nissan Leaf	3	30	28.2	30.8	31.7	35.8	43.6	44.5	46.8	59.6	61.7	56.7	61.2	59.0	55.0	55.3	54.0	51.4	49.6	46.9
Nissan Versa	1	10	29.8	40.2	29.6	38.9	37.9	35.6	42.0	39.9	40.3	42.5	44.1	46.6	46.2	46.5	43.6	41.5	38.2	37.6
Nissan Versa	2	10	28.1	29.0	31.1	34.6	33.5	33.5	38.2	42.3	46.4	44.7	43.9	46.8	45.6	44.3	43.4	40.6	38.4	37.6
Nissan Versa	3	10	27.3	30.4	33.2	35.5	34.5	35.0	40.6	42.6	46.6	44.1	44.8	47.8	45.9	45.4	43.8	41.3	39.1	38.0
Nissan Versa	1	20	34.0	41.0	34.6	38.0	41.4	39.3	48.3	53.7	48.4	52.6	54.6	52.3	51.6	53.3	50.0	46.8	43.9	42.7
Nissan Versa	2	20	31.7	38.8	34.0	38.8	43.4	39.3	48.1	53.5	49.0	53.5	53.5	52.4	51.5	52.5	50.1	47.2	44.1	43.2
Nissan Versa	3	20	31.4	34.2	31.5	38.6	42.0	38.6	47.4	53.1	49.0	54.5	53.2	52.2	52.1	52.5	50.3	46.4	44.3	43.1
Nissan Versa	1	30	31.8	38.4	44.8	44.3	41.9	47.0	51.0	50.0	54.4	56.4	61.4	59.6	56.8	58.2	55.1	51.5	49.3	47.6
Nissan Versa	2	30	29.8	32.8	43.2	44.3	40.2	45.4	49.0	49.2	52.3	57.6	60.7	59.8	57.4	58.0	55.1	52.2	49.4	48.0

Vehicle	Event	Speed	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
Nissan Versa	3	30	32.1	39.1	47.2	45.0	40.5	46.1	50.1	49.2	52.6	57.6	61.7	60.0	57.8	58.3	55.0	51.3	49.3	48.2
Tesla Roadster	1	10	27.7	34.4	32.1	32.9	34.0	35.3	37.2	37.5	40.8	45.4	40.7	44.2	42.1	38.1	38.9	37.9	35.5	33.8
Tesla Roadster	2	10	25.7	27.3	31.6	33.3	32.7	36.5	36.7	37.9	40.2	46.4	41.4	43.0	41.4	37.4	38.9	39.1	36.4	33.5
Tesla Roadster	3	10	27.1	34.9	31.5	33.3	29.7	34.6	35.6	36.1	40.1	44.9	40.8	43.4	41.8	39.5	41.7	39.0	36.6	36.3
Tesla Roadster	1	20	28.1	37.8	41.6	38.5	42.5	46.7	48.4	46.6	48.6	49.0	50.7	54.3	52.6	48.3	49.9	48.3	42.6	39.3
Tesla Roadster	2	20	24.5	37.9	40.4	36.2	39.0	47.3	48.9	48.9	49.2	49.1	50.5	54.1	52.8	47.8	49.4	49.3	43.4	39.3
Tesla Roadster	3	20	27.9	38.6	42.1	38.7	41.3	47.6	47.3	49.2	48.9	48.9	50.3	54.4	52.8	47.8	50.0	48.1	42.9	39.3
Tesla Roadster	1	30	37.9	35.0	38.5	48.9	57.8	49.2	56.0	55.3	54.1	54.7	56.9	61.0	58.3	55.3	57.0	55.6	49.6	44.6
Tesla Roadster	2	30	36.7	36.8	39.5	50.3	56.9	48.8	56.0	54.4	53.5	56.0	57.4	60.5	59.3	55.4	56.6	55.2	49.3	44.8
Tesla Roadster	3	30	36.5	36.1	39.1	49.5	56.2	48.9	56.5	55.3	55.2	56.0	57.5	60.5	58.7	55.2	57.5	56.6	49.5	45.6
Toyota Camry	1	10	33.8	30.1	33.0	35.9	37.8	40.7	41.2	39.2	43.6	49.0	47.2	48.8	51.1	48.9	46.6	45.5	43.8	41.3
Toyota Camry	2	10	29.5	32.0	32.2	35.2	35.8	39.2	42.2	40.1	43.9	50.0	46.7	49.2	50.6	48.5	46.2	45.6	43.8	41.2
Toyota Camry	3	10	33.9	32.2	32.6	37.5	37.7	40.6	41.1	39.8	42.6	50.3	47.0	48.8	50.8	47.8	46.6	45.5	44.3	41.6
Toyota Camry	1	20	28.3	35.6	42.2	52.0	46.0	42.4	47.3	48.7	50.0	50.6	51.1	54.5	52.1	51.6	50.1	48.4	46.6	44.1
Toyota Camry	2	20	30.4	34.9	41.0	50.3	46.4	42.5	47.2	47.6	49.1	51.9	51.5	54.9	52.3	51.5	50.2	48.1	47.2	44.7
Toyota Camry	3	20	29.3	35.8	41.6	51.3	46.4	42.5	48.2	47.8	49.5	51.7	51.5	54.9	51.9	51.4	50.6	48.9	47.4	44.7
Toyota Camry	1	30	29.8	35.9	38.2	46.5	52.6	50.1	49.7	50.9	57.4	57.9	58.9	58.0	56.0	55.7	54.1	51.2	48.0	46.2
Toyota Camry	2	30	31.7	35.7	39.2	47.0	52.0	51.7	52.3	51.9	57.1	59.2	57.8	57.5	55.4	56.0	54.3	52.2	48.7	46.7
Toyota Camry	3	30	28.9	37.9	37.7	44.1	50.8	50.5	51.0	52.4	57.8	58.2	58.8	57.7	56.2	55.7	54.5	52.5	48.1	46.9
Toyota Camry Hybrid	1	10	28.4	32.6	36.4	40.2	43.2	38.1	38.6	40.2	40.1	43.6	42.2	41.0	39.4	46.3	43.8	37.0	35.9	35.2
Toyota Camry Hybrid	2	10	31.3	33.4	35.6	42.1	42.0	39.5	39.6	39.6	40.0	44.3	42.6	40.9	39.5	45.5	43.6	37.7	36.6	35.6
Toyota Camry Hybrid	3	10	28.7	31.0	34.7	39.7	38.9	36.1	36.7	39.8	40.7	43.0	44.3	41.4	43.0	47.7	45.8	42.2	39.8	42.7
Toyota Camry Hybrid	1	20	30.1	35.8	41.9	52.0	49.2	48.1	53.7	52.2	49.6	48.8	52.2	51.8	49.9	49.2	49.0	46.2	42.4	42.3
Toyota Camry Hybrid	2	20	28.5	33.7	43.0	51.1	47.7	48.0	53.8	52.2	48.8	49.7	51.7	51.9	50.4	49.5	49.1	46.6	42.1	42.1
Toyota Camry Hybrid	3	20	30.3	33.1	40.0	50.3	48.1	49.5	53.6	51.8	50.6	49.5	52.6	52.0	50.2	50.8	50.3	47.3	42.8	42.6
Toyota Camry Hybrid	1	30	28.7	33.2	40.3	43.2	50.1	50.8	50.9	56.7	60.1	61.8	61.5	56.4	57.9	57.3	55.1	51.8	48.4	48.3
Toyota Camry Hybrid	2	30	26.4	36.5	38.5	43.9	52.3	52.0	53.6	56.4	60.3	61.7	61.3	56.4	57.8	56.7	54.9	51.7	48.5	47.8
Toyota Camry Hybrid	3	30	27.0	36.4	41.5	43.0	53.1	52.4	52.8	57.4	61.4	61.1	60.0	56.4	58.7	57.3	55.0	51.8	48.9	48.4

**Table 8. VRTC Outdoor Data. All events were corrected for ambient if needed except for the Nissan Leaf, Nissan Versa, and Chevrolet Cruze (no ambients)**

	Event	Speed	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
Chevrolet Cruze	1	10	29.9	31.6	37.6	40.2	40.7	40.5	42.9	47.1	45.1	44.5	46.3	48.5	47.2	47.3	46.9	45.1	44.4	42.1
Chevrolet Cruze	2	10	30.8	33.3	37.9	38.3	41.9	38.9	43.2	47.5	46.9	47.0	47.8	48.3	48.2	47.4	47.2	45.5	45.1	42.1
Chevrolet Cruze	3	10	27.1	29.4	38.2	37.4	41.3	36.4	42.5	46.9	47.7	45.7	47.3	47.7	48.5	47.7	47.5	45.7	44.4	41.8
Chevrolet Cruze	1	20	35.5	39.0	41.5	43.5	41.5	44.5	46.1	50.0	51.7	51.5	52.7	51.8	51.6	50.2	48.4	47.8	44.8	43.0
Chevrolet Cruze	2	20	34.7	40.2	42.6	44.4	44.1	45.5	47.1	50.1	51.4	52.6	52.1	52.0	51.6	49.8	49.4	45.5	44.6	43.0
Chevrolet Cruze	3	20	33.1	40.7	40.3	42.9	41.9	45.5	46.9	49.9	51.6	53.2	54.0	52.7	52.0	50.6	49.2	46.6	45.5	43.0
Ford Fusion	1	10	32.6	37.5	36.0	38.5	42.8	41.3	42.7	43.8	45.5	47.7	47.7	48.5	48.9	48.2	46.4	44.5	43.4	40.8
Ford Fusion	2	10	38.5	33.3	36.2	40.0	44.5	39.5	41.9	44.1	44.2	47.0	48.8	48.3	47.9	46.8	45.3	42.8	42.3	40.8
Ford Fusion	3	10	31.6	38.4	36.0	39.3	44.7	41.9	45.0	46.2	47.6	48.5	49.4	49.2	50.6	48.6	46.8	45.1	44.1	41.5
Ford Fusion	4	10	30.8	36.3	35.4	38.0	47.3	40.3	43.2	44.3	46.1	49.9	48.8	47.8	48.3	47.4	46.9	44.4	44.2	41.5
Ford Fusion	1	20	40.9	34.5	38.2	50.2	49.2	45.6	44.8	48.2	51.4	54.6	52.8	53.7	54.9	52.0	51.0	48.1	47.8	44.9
Ford Fusion	2	20	36.8	30.5	38.3	48.5	49.6	43.0	45.2	49.4	52.0	54.6	52.7	53.0	53.4	51.5	49.9	47.5	47.4	44.7
Ford Fusion	3	20	33.0	29.0	39.3	47.9	46.0	40.6	42.7	46.3	49.6	54.7	51.8	52.5	52.8	50.3	47.8	46.0	44.0	40.8
Ford Fusion	4	20	32.7	29.3	39.9	48.6	45.1	43.0	45.5	46.5	50.1	53.9	52.6	51.8	52.0	50.8	48.1	46.1	44.9	42.6
Ford Fusion	1	30	33.8	31.9	38.3	41.3	48.0	53.6	51.0	51.1	57.3	61.4	59.0	58.2	58.0	55.5	53.4	49.5	48.1	46.4
Ford Fusion	2	30	35.1	31.3	37.8	43.6	45.8	52.6	50.3	50.3	55.6	60.2	58.3	59.8	58.3	56.0	54.5	50.2	48.5	46.2
Ford Fusion	3	30	34.2	33.3	38.6	43.3	49.0	51.1	51.1	50.5	57.4	62.3	59.2	59.9	58.6	56.8	54.0	51.0	48.8	47.4
Ford Fusion	4	30	37.7	34.0	40.2	42.2	50.4	50.9	52.7	51.1	57.6	60.5	59.3	59.5	60.1	58.1	54.9	51.8	49.3	47.2
Nissan Leaf	1	10	23.6	26.8	30.7	34.6	40.2	42.1	42.3	46.0	52.5	43.4	42.6	41.0	38.5	40.9	44.5	34.4	31.0	30.7
Nissan Leaf	2	10	21.4	24.5	31.1	37.9	36.3	35.8	39.1	47.5	49.2	44.9	41.2	38.8	39.4	42.5	50.3	36.0	31.5	30.9
Nissan Leaf	1	20	24.4	29.5	30.2	36.6	39.8	39.9	46.9	47.7	49.8	51.6	50.0	48.6	50.1	49.4	47.0	41.8	36.2	35.0
Nissan Leaf	2	20	26.8	28.9	33.8	39.0	41.5	45.4	44.2	45.7	46.6	49.6	51.2	47.8	49.0	49.1	45.1	40.8	35.1	33.3
Nissan Leaf	1	30	30.7	33.8	37.6	40.9	44.2	44.8	45.6	58.3	58.1	57.7	58.7	58.7	57.7	55.2	51.6	47.8	43.5	41.1
Nissan Leaf	2	30	28.8	34.9	35.1	39.1	43.8	43.8	44.6	53.4	56.3	57.2	56.5	56.7	56.2	54.0	50.5	47.0	41.4	39.2
Nissan Leaf	3	30	29.2	31.7	37.1	42.8	44.4	44.1	44.0	56.7	56.7	58.3	58.4	56.0	57.6	54.9	51.0	46.4	42.0	39.5
Nissan Leaf	4	30	30.2	31.1	35.0	41.2	43.9	43.5	45.2	54.9	56.5	58.7	58.0	56.9	57.1	55.0	51.3	46.0	40.8	39.0

Vehicle	Event	Speed	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
Nissan Versa	1	10	30.2	32.2	34.7	35.3	40.0	39.0	38.4	42.0	44.6	45.9	44.9	44.1	44.8	45.4	47.7	45.9	42.8	40.8
Nissan Versa	2	10	34.5	30.3	31.1	39.7	38.6	36.7	41.0	43.2	45.1	46.3	45.1	44.6	45.9	46.0	47.3	45.8	43.2	41.9
Nissan Versa	3	10	27.7	28.4	29.9	33.9	36.2	36.7	40.4	43.8	44.1	46.0	45.6	44.5	46.8	47.3	48.1	46.1	43.3	40.9
Nissan Versa	4	10	28.0	30.6	30.0	33.4	37.2	38.2	39.7	43.4	43.6	46.7	45.5	44.2	45.4	46.4	47.0	45.5	42.5	40.8
Nissan Versa	1	20	32.1	32.0	32.9	39.1	41.7	38.8	44.4	48.6	50.4	54.0	53.6	52.4	53.1	51.1	49.6	47.5	44.2	41.3
Nissan Versa	2	20	28.9	27.6	31.9	38.4	41.5	40.4	44.3	48.0	50.1	54.2	54.0	52.9	53.5	51.5	49.8	47.1	44.7	42.0
Nissan Versa	3	20	30.9	31.5	34.0	41.1	42.3	40.2	45.1	47.8	52.3	54.4	53.6	53.0	53.3	52.2	50.2	47.3	44.8	41.5
Nissan Versa	4	20	31.1	31.0	34.2	39.6	39.3	41.1	45.3	48.7	52.3	54.0	53.1	52.7	53.4	52.5	49.7	46.6	44.2	41.1
Tesla Roadster	1	10	25.2	30.1	32.6	33.4	34.2	39.7	39.1	39.3	39.6	41.0	43.6	41.7	38.4	37.9	36.2	33.8	34.2	31.9
Tesla Roadster	2	10	27.2	30.8	31.9	33.6	34.9	41.3	39.9	38.7	38.7	40.8	42.5	40.7	39.0	36.2	35.2	33.1	32.8	32.1
Tesla Roadster	3	10	26.3	34.6	35.0	36.5	36.0	42.6	38.9	38.3	39.8	39.8	42.3	42.0	38.7	36.7	35.5	33.4	32.3	31.1
Tesla Roadster	4	10	24.3	30.0	30.2	32.4	32.3	38.7	37.1	36.2	39.9	40.1	41.3	41.4	38.1	36.4	34.0	32.0	31.6	29.7
Tesla Roadster	1	20	26.8	34.7	39.3	41.0	40.9	45.8	44.4	46.1	47.3	51.7	53.4	53.4	50.0	49.4	46.1	41.9	38.1	35.1
Tesla Roadster	2	20	24.7	37.0	40.3	38.8	41.4	46.4	45.8	48.0	49.2	50.6	53.9	51.1	50.1	48.1	46.1	40.6	37.0	34.3
Tesla Roadster	3	20	24.6	36.3	39.2	38.6	42.0	43.0	45.2	45.7	49.2	50.5	53.7	52.1	50.1	49.1	45.8	41.5	37.9	34.8
Tesla Roadster	4	20	28.7	34.2	38.7	38.1	40.3	44.4	44.2	47.2	48.3	50.5	52.8	52.4	49.5	49.0	46.0	41.4	37.4	34.7
Tesla Roadster	1	30	33.8	37.2	34.5	43.5	48.7	46.8	50.3	51.2	53.2	56.0	60.2	58.5	56.5	55.6	53.3	48.0	42.9	39.2
Tesla Roadster	2	30	34.3	36.2	35.7	41.6	49.1	47.9	50.1	51.1	52.1	56.0	58.7	58.2	56.1	55.5	52.9	47.5	43.2	39.1
Tesla Roadster	3	30	33.2	35.2	35.7	44.0	47.9	47.4	49.9	52.1	55.0	57.5	60.5	60.9	57.7	57.9	54.5	48.6	43.5	39.3
Tesla Roadster	4	30	37.5	35.3	36.3	40.9	46.4	49.6	51.5	50.4	53.9	56.6	58.9	57.7	56.7	55.8	52.8	47.8	42.9	39.1
Toyota Camry	1	10	32.6	31.5	36.8	38.1	35.5	39.4	41.4	41.9	44.3	47.4	46.0	46.1	49.3	49.5	46.1	46.3	42.9	40.3
Toyota Camry	2	10	32.4	32.0	37.7	35.5	35.8	40.0	41.6	42.1	42.7	47.4	47.8	47.2	48.1	48.6	47.4	44.9	43.0	39.6
Toyota Camry	3	10	30.8	28.7	34.7	39.8	36.8	37.9	39.3	40.1	45.5	46.7	45.4	46.0	49.0	49.7	47.1	46.8	43.0	40.2
Toyota Camry	4	10	33.1	32.7	37.5	37.5	36.2	38.8	41.6	40.9	42.5	47.5	47.4	45.2	48.7	48.3	46.7	45.0	42.6	39.9
Toyota Camry	1	20	34.5	36.6	38.1	42.1	41.3	39.5	44.0	47.0	50.3	51.0	50.8	51.1	51.8	50.2	48.3	47.3	43.9	40.9
Toyota Camry	2	20	28.2	34.7	39.2	40.4	40.0	40.1	46.1	46.9	51.5	53.3	52.3	51.4	52.1	51.3	49.2	47.3	44.3	41.2
Toyota Camry	3	20	29.0	35.2	36.9	38.8	39.4	39.7	43.6	47.6	49.8	51.7	51.0	50.8	51.8	50.3	49.1	47.0	43.7	41.1

Vehicle	Event	Speed	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
Toyota Camry	4	20	22.6	32.1	38.0	39.6	42.2	40.2	43.3	46.8	51.3	51.3	51.7	51.3	52.4	51.3	49.7	47.8	44.5	41.9
Toyota Camry	1	30	34.0	34.0	37.7	40.7	42.5	42.4	46.9	49.2	52.0	56.6	57.0	55.5	57.5	55.0	53.3	50.8	46.7	44.8
Toyota Camry	2	30	30.0	37.6	39.8	41.4	41.7	43.4	45.6	49.4	51.3	56.4	56.6	55.4	56.7	54.1	51.7	49.4	46.1	43.5
Toyota Camry	3	30	29.7	38.7	40.0	41.1	43.9	43.8	48.1	49.8	52.1	56.7	57.1	55.9	57.7	55.9	53.3	50.3	46.7	44.9
Toyota Camry	4	30	32.6	36.0	38.1	40.9	42.0	43.0	48.6	49.8	52.1	57.6	58.7	55.5	57.4	55.0	53.0	49.6	47.2	44.1
Toyota Camry Hybrid	1	10	24.5	28.5	24.3	36.6	39.0	34.5	36.3	38.3	39.1	42.6	39.2	38.7	37.9	47.5	45.4	34.0	33.7	30.7
Toyota Camry Hybrid	2	10	26.9	24.9	26.4	36.8	40.2	35.4	35.6	40.5	40.6	42.9	40.3	38.8	39.0	45.4	44.4	36.1	34.2	33.8
Toyota Camry Hybrid	3	10	25.6	23.7	29.0	35.5	41.0	34.6	36.3	39.1	37.2	41.6	39.7	39.7	38.1	47.3	45.1	34.0	33.4	32.0
Toyota Camry Hybrid	4	10	27.0	26.5	26.4	36.5	44.2	35.4	36.1	39.4	40.6	41.8	38.3	37.4	37.2	47.3	46.2	34.9	33.9	33.8
Toyota Camry Hybrid	1	20	25.2	27.3	31.3	36.9	41.9	39.2	43.5	45.4	50.5	52.0	51.3	49.0	50.2	47.6	47.4	44.6	41.7	41.3
Toyota Camry Hybrid	2	20	24.4	25.8	30.5	39.3	39.7	37.3	42.7	46.0	48.8	50.6	51.4	49.4	49.0	47.3	47.4	44.7	41.2	39.8
Toyota Camry Hybrid	3	20	26.8	26.2	29.2	37.2	40.1	40.0	43.0	46.4	50.3	50.1	50.3	50.0	50.9	47.8	47.8	44.5	41.6	41.6
Toyota Camry Hybrid	4	20	28.0	28.5	30.2	39.1	42.0	42.9	44.5	48.1	48.1	51.1	50.0	48.6	49.6	48.2	47.8	43.4	41.3	41.2
Toyota Camry Hybrid	1	30	29.9	31.2	39.0	40.5	45.7	44.9	47.7	48.8	52.2	59.0	58.6	55.8	56.7	55.9	53.2	49.9	47.8	45.7
Toyota Camry Hybrid	2	30	30.8	38.0	37.0	41.2	44.2	45.8	46.3	48.3	54.2	56.9	58.1	56.4	58.5	55.1	51.3	49.5	47.1	45.8
Toyota Camry Hybrid	3	30	29.9	34.1	39.8	42.9	46.7	46.2	47.4	48.8	53.1	56.5	57.8	55.6	58.7	55.6	53.1	50.7	49.2	47.5
Toyota Camry Hybrid	4	30	28.3	30.7	33.0	36.8	41.8	42.3	47.6	47.6	52.0	55.4	57.0	55.5	57.1	55.1	52.1	48.8	46.6	45.9