SAE International™

SURFACE VEHICLE RECOMMENDED PRACTICE

SAE J2711

ISSUED
Prop Dft
SEP2002

Issued Proposed Draft
2002-09

Recommended Practice for Measuring Fuel Economy and Emissions of Hybrid-Electric and Conventional Heavy-Duty Vehicles

Foreword—Major advancements in electric drivetrain technology and system integration have led to increased interest in hybrid-electric drive systems for both light-duty and heavy-duty vehicle applications. Hybrid-electric vehicles (HEVs) combine powertrain elements of conventional vehicles and electric vehicles (EVs), offering reduced fuel consumption and lower exhaust emissions. A growing number of companies are developing and beginning to supply commercial hybrid-electric drive products to the truck and bus markets. There are already significant numbers of heavy-duty HEVs in service, and deployment of heavy-duty hybrids will likely grow dramatically over the next few years.

One challenge for the successful commercial introduction of heavy-duty HEVs is the absence of a broadly applicable and widely accepted procedure for measuring heavy-duty HEV exhaust emissions and fuel economy.

The SAE Truck and Bus Hybrid and Electric Vehicle Committee and the Northeast Advanced Vehicle Consortium (NAVC) Hybrid Transit Bus Certification Workgroup collaborated on development of a heavy-duty HEV chassis testing protocol, based on SAE J1711, the light duty HEV chassis protocol. The NAVC Workgroup was comprised of transit operators, bus manufacturers, hybrid system developers, engine manufacturers, environmental advocacy groups, industry associations, and federal and California regulators. This recommended practice draws from a large body of test data collected by West Virginia University on its transportable chassis dynamometer on both hybrid and conventional heavy-duty vehicles. In addition, the Workgroup received input from the other major chassis dynamometer testing laboratories in the U.S.

This document should be viewed as a starting point for standardizing heavy-duty HEV testing. Heavy-duty HEVs are still a relatively new technology. Over the next several years, hybrid-electric systems will be evolving, and many new types of hybrid drive systems may become commercially available. It is likely, therefore, that this testing protocol will need to be revisited and, possibly, revised, as the heavy-duty HEV industry matures.

TO PLACE A DOCUMENT ORDER:
Tel: 877-606-7323 (inside USA and Canada)
Tel: 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: custsvc@sae.org
SAE WEB ADDRESS: http://www.sae.org

TABLE OF CONTENTS

1. ***Scope—***This SAE Recommended Practice was established to provide an accurate, uniform and reproducible procedure for simulating use of heavy-duty hybrid-electric vehicles (HEVs) and conventional vehicles on dynamometers for the purpose of measuring emissions and fuel economy. Although the recommended practice can be applied using any driving cycle, the practice recommends three cycles: the Manhattan cycle, representing low-speed transit bus operation; the Orange County Transit Cycle, representing intermediate-speed bus operation; and the Urban Dynamometer Driving Schedule (UDDS) cycle representing high-speed operation for buses and tractor-trailers. This document does not specify which emissions constituents to measure (e.g., HC, CO, NOx, PM, CO_2), as that decision will depend on the objectives of the tester. While the recommended practice was developed specifically to address the issue of measuring fuel economy and emissions for hybrid-electric heavy-duty vehicles on a chassis dynamometer, the document can also be applied to chassis testing of other heavy-duty vehicles.

This document builds upon SAE J1711, the light-duty HEV chassis recommended practice. As in SAE J1711, this document defines a hybrid vehicle as having both a rechargeable energy storage system (RESS) capable of releasing and capturing energy and an energy-generating device that converts consumable fuels into propulsion energy. RESS specifically included in the recommended practice are batteries, capacitors and flywheels, although other RESS can be evaluated utilizing the guidelines provided in the document. Further, the recommended practice provides a detailed description of state of charge (SOC) correction for charge-sustaining HEVs. This document also has a section which provides recommendations for calculating fuel economy and emissions for charge-depleting hybrid-electric vehicles. It should be noted that most heavy-duty vehicles addressed in this document would be powered by engines that are certified separately for emissions. The engine certification procedure appears in the Code of Federal Regulations, Title 40.

NOTE— This document does not make specific provisions or recommendations for testing of bus and truck emissions with air conditioning deployed because the complexity of such tests is significant and is beyond the scope of the original document. It is recognized that a future practice that addresses air conditioning and other potentially large auxiliary loads is needed.

1.1 Requirements Used to Develop the Recommended Practice—This document was developed to allow for the fair, representative, repeatable and accurate testing of heavy-duty vehicles so that direct comparisons can be made between hybrid-electric and conventional vehicles. To meet this goal, the following guidelines have been followed:

a. This document will provide a recommended practice to measure emissions and fuel economy of any type of conventional and HEV design including charge depleting and charge sustaining.
b. Where applicable, driver selectable modes may be evaluated (e.g., turning off regenerative braking and evaluating air conditioning influences).
c. The use of the existing chassis test cycles provided with this document is highly recommended, but this document allows for the creation or adjustment of test cycles to better represent the vehicle's in-use application.
d. Testing shall not require defeating or otherwise forcing a vehicle's control system to perform differently from the way in which it would perform in use (potential exceptions include antilock brakes, traction control and other systems that may affect dynamometer testing).

2. References

2.1 Applicable Publications—The following publications form a part of this specification to the extent specified herein. Unless otherwise specified, the latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096, and on its website (http://www.sae.org):

SAE J1634—Electric Vehicle Energy Consumption and Range Test Procedure
SAE J1711—Recommended Practice for Measuring the Exhaust Emissions and Fuel Economy of Hybrid-Electric Vehicles
SAE J2263—Road Load Measurement Using On-Board Anemometry And Coastdown Techniques
SAE J2264—Chassis Dynamometer Simulation Of Road Load Using Coastdown Techniques
Clark, N. N., Xie, W., Gautam, M., Lyons, D., Norton, P. and Balon, T., "Hybrid Diesel-Electric Heavy Duty Bus Emissions: Benefits of Regeneration and Need for State of Charge Correction," SAE Paper 2000-01-2955, 2000
McKain, D.L., Clark, N.N., Balon, T.H., Moynihan, P.J., Lynch, S.A. and Webb, T.C., "Characterization of Emissions from Hybrid and Conventional Transit Buses," SAE Fuels & Lubricants Meeting, Paris, France, June 2000, SAE Paper 2000-01-2011

2.1.2 CODE OF FEDERAL REGULATIONS—The Code of Federal Regulations (CFR) is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402, and on its website (http://www.access.gpo.gov/nara/cfr.html).

40 CFR Part 86 -- Control of Air Pollution from New and In-Use Motor Vehicles and New and In-Use Motor Vehicle Engines; Certification and Test Procedure

2.1.3 ASTM PUBLICATIONS—Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM D 240—Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter
ASTM D 4809-95—Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter

3. Definitions

3.1 Battery—A device that stores chemical energy and releases electrical energy.

3.2 Battery C/3 Current Rate—The constant current (Ampere-hours) at which the battery can be discharged from its rated Ampere-hour capacity in three hours to its manufacturer's recommended minimum. Battery manufacturers typically provide ratings from C/1 to C/6. These ratings have no direct impact on this recommended practice.

3.3 Battery Depth of Discharge (DOD)—The percentage of rated capacity to which a cell/battery is discharged. State of charge (SOC) % + DOD% = 100%.

3.4 Battery Rated Ampere-Hour Capacity—The manufacturer-rated capacity of a battery in Ampere-hours obtained from a battery discharged at the manufacturer's recommended discharge rate (C/1 to C/6) such that a specified minimum cut-off terminal voltage is reached.

3.5 Battery State of Charge (SOC)—Based on the actual measured energy content of a battery and expressed as a percentage of the battery's maximum rated Ampere hour (Ah) capacity.

3.6 Capacitor—A device that stores energy electrostatically and releases electrical energy.

3.7 Capacitor State of Charge (SOC)—Based on the actual measured energy content of a capacitor and expressed as a percentage of the capacitor's maximum rated voltage squared (V^2).

3.8 Charge-Depleting HEV—A type of HEV that is designed to be recharged off-board under normal usage.

3.9 Charge-Sustaining HEV—The charge-sustaining HEV derives all of its energy from on board fuel under normal usage. Over a short period of time charge-sustaining hybrid-electric vehicles may be either charge depleting or charge increasing. The definition means that that in the long term (24 hours) a RESS charge is sustained. The document includes provisions for calculating SOC corrections in the short term that reflect emissions from the vehicle as if it was charge sustaining in the short term.

3.10 Consumable Fuel—Any solid, liquid, or gaseous material that releases energy and is depleted as a result.

3.11 Electromechanical Flywheel—A device that stores rotational kinetic energy and can release that kinetic energy to an electric motor-generator system, thereby producing electrical energy.

3.12 Electromechanical Flywheel State of Charge (SOC)—Based on the actual measured energy content of an electromechanical flywheel and expressed as a percentage of the flywheel's maximum-rated revolutions per minute squared (rpm^2).

3.13 Hybrid-Electric Vehicle (HEV)—A road vehicle that can draw propulsion energy from both of the following on-vehicle sources of stored energy: (a) one consumable fuel and (b) one RESS that is recharged by an on-board electric generating system and/or an off-board charging system or power supply.

3.14 Net Energy Change (NEC)—The net change in energy level of an RESS expressed in Joules (watt-seconds)

3.15 Propulsion Energy—Energy that is derived from the vehicle's consumable fuel and/or rechargeable energy storage system to drive the wheels. If an energy source is supplying energy only to vehicle accessories (e.g., a 12 V battery on a conventional vehicle), it is not acting as a source of propulsion energy.

3.16 Propulsion System— A system that, when started, provides propulsion for the vehicle in an amount proportional to what the driver commands.

3.17 Regenerative Braking—Deceleration of the vehicle caused by operating an electric motor-generator system, thereby returning energy to the vehicle propulsion system and providing charge to the RESS or to operate on-board auxiliaries.

3.18 Rechargeable Energy Storage System (Ress)—A component or system of components that stores energy and for which its supply of energy is rechargeable by an electric motor-generator system, an off-vehicle electric energy source, or both. Examples of RESS for HEVs include batteries, capacitors, and electromechanical flywheels.

3.19 State of Charge—See "Battery state of charge"

3.20 Total Fuel Energy—The total energy content of the fuel in British Thermal Units (Btu) or kWh consumed during a test as determined by carbon balance or other acceptable method and calculated based on the lower heating value of the fuel.

4. State of Charge – Charge-Sustaining Hybrid-Electric Vehicles—When a conventional vehicle completes a chassis test, the energy provided by the combustion engine is equal to the total energy necessary to complete the cycle, and this value is consistent from test run to test run. There is no energy storage on board the vehicle other than consumable fuel, and no need for state of charge (SOC) correction.

In an HEV, however, a significant amount of motive energy is stored on board the vehicle within the RESS, and the vehicle may remove or add energy to this energy reservoir during a relatively short period of time. In order to compare the emission results of an HEV to a conventional vehicle, the data from the HEV must be corrected so that the net change in RESS energy is essentially zero (i.e., all of the energy and emissions are essentially provided by the APU).

This document does allow for some level of tolerance between the initial SOC and final SOC to avoid correcting data that is already effectively at a net zero change in energy level. A determination of ±1% or less net change in stored energy when compared to total cycle energy expended is within tolerance levels and does not require SOC correction calculations in determining fuel economy and emissions. If the percent change in net energy change (NEC) is greater than ±1% but less than ±5%, this document allows for correction of emissions and fuel economy calculations to account for the change in energy storage if a clear relationship between NEC and emissions and fuel economy can be established. This procedure is outlined in 4.4. If the vehicle has a NEC greater than 5%, the collected data may not be reliably corrected and the test should be considered invalid. Vehicles that consistently yield net energy values of –5% on a given test cycle may follow the steps for estimating emissions as outlined in the charge-depleting section of the recommended practice (see Section 8).

4.1 SOC Terminology—The SOC of a battery, capacitor and electromechanical flywheel is defined in Section 3 and calculations are outlined in 4.2. The following terms are used to distinguish the two different values of SOC in the test procedure.

$SOC_{initial}$: SOC at the beginning of the test run (Ah, V^2 or rpm^2)
SOC_{final}: SOC at the end of the test run (Ah, V^2 or rpm^2)
SOC_{delta} Delta ampere-hours measured during a test

NEC calculations in 4.2 are presented in Joules (watt-seconds).

4.2 Net Energy Change (NEC)—Provision must be made for recording the RESS SOC at the start and stop of each test run. For each different test cycle a minimum of three test runs must be performed to provide sufficient data for a SOC correction, if needed. It is also recommended that at least one test run have a net positive and another a net negative NEC value so that net SOC calculations are based on interpolation and not extrapolation. Since different types of RESS store energy differently, each type of RESS will use different equations to define NEC. The following section gives the NEC calculations for batteries, capacitors and

electro-mechanical flywheels.

4.2.1 BATTERIES—Equations 1 and 2 calculate the NEC for batteries.

$$NEC = [SOC_{final} - SOC_{initial}]*V_{system}*k_1 \quad \text{(Eq. 1)}$$

where:

SOC = Battery SOC at the beginning and end of the test run, in Ampere-hours (Ah).
NOTE—If the SOC_{final} and $SOC_{initial}$ values are in amp-seconds, the conversion factor is not used.
V_{system} = Battery's DC nominal system voltage as specified by the manufacturer, in volts (V)
K_1 = Conversion factor = 3600 (seconds/hour) (not used if SOC_{final} and $SOCi_{nitial}$ values are in amp seconds)

or,

$$NEC = [SOC_{delta}]*V_{system}*K_1 \quad \text{(Eq. 2)}$$

where:

SOC_{delta} = Delta ampere-hours during a test
V_{system} = Battery's DC nominal system voltage as specified by the manufacturer, in volts (V)
K_1 = Conversion factor = 3600 (seconds/hour) (not used if SOC_{final} and $SOC_{initial}$ values are in amp seconds)

4.2.2 CAPACITORS—Equation 3 calculates NEC for capacitors.

$$NEC = (C/2)*[SOC_{final} - SOC_{initial}] \quad \text{(Eq. 3)}$$

where:

SOC = The capacitor SOC at the beginning and end of the test run, in $(V)^2$
C = Rated capacitance of the capacitor as specified by the manufacturer, in Farads (F)

4.2.3 ELECTROMECHANICAL FLYWHEELS—Equation 4 calculates NEC for electromechanical flywheels.

$$NEC = (1/2)*I*[SOC_{final} - SOC_{initial}]*K_2 \quad \text{(Eq. 4)}$$

where:

SOC = Flywheel state-of-charge at the beginning and end of the test run, in $(rpm)^2$
I = Rated moment of inertia of the flywheel system, in kilogram-$meter^2$ (kg/m^2)
K_2 = Conversion factor = $4\pi^2/3600$ ($rad^2/sec^2/rpm^2$)

4.3 Determining NEC Variance

4.3.1 TOTAL CYCLE ENERGY—This document uses total cycle energy to determine NEC tolerances, as opposed to total fuel energy, which can vary from test run to test run. To remain consistent with the calculations for NEC, either the total cycle energy must be reported in watt-seconds or the NEC must be converted to kWh.

$$\text{Total Cycle Energy} = \text{Total Fuel Energy} - NEC \quad \text{(Eq. 5)}$$

Total fuel energy is the energy value of the fuel consumed by the APU during the test and is calculated as shown in Equation 6.

$$\text{Total Fuel Energy} - NHV_{fuel} * m_{fuel} \quad \text{(Eq. 6)}$$

where

NHV_{fuel} = Net heating value (per consumable fuel analysis as specified by ASTM D 240), in Joules per kilogram (J/kg)

m_{fuel} = Total mass of fuel consumed over test, in kilograms (kg)

4.3.2 DETERMINATION PROCEDURE—To determine if a test run has an acceptable NEC that does not require SOC correction, divide NEC by total cycle energy. If the absolute value of the calculation yields a number less than or equal to 1%, as shown in Equation 7, the NEC variance is within tolerance levels and the emissions and fuel economy values for that test run do not need to be corrected for SOC.

$$\left|\frac{NEC}{\text{total cycle energy}}\right| * 100\% \leq 1\% \quad \text{(Eq. 7)}$$

If the absolute value of the calculation yields a number greater 1%, but less than or equal to 5%, as shown in Equation 8, emissions and fuel economy values from the test run need to be corrected for SOC as described below. Test runs with NEC variance greater than ±5% are considered invalid or, if the vehicle is consistently charge depleting, may have to be tested under the charge-depleting vehicle recommendations.

$$1\% < \left|\frac{NEC}{\text{total cycle energy}}\right| *100\% \leq 5\% \quad \text{(Eq. 8)}$$

4.3.3 EXAMPLE OF DETERMINATION PROCEDURE—A 40 ft hybrid-electric transit bus that achieves 3 mpg (NEC equal to zero) on the Manhattan cycle would consume about 2 gallons of diesel fuel on a 6 mile, 30-minute test cycle. The 2 gallons of diesel fuel equates to about (128000 Btu/gal x 2 gal/ 3412 Btu/kWh) 75 kWh (about 12.5 kWh per mile). In this example, a 1% NEC translates to about 750 Wh while a 5% NEC translates to 3.75 kWh. If NEC is determined to be less than 0.750 kWh, then the results can be used as is; otherwise, the results should be corrected according to the procedure outlined in 4.4.

4.4 SOC Correction Procedure—In order to compute a state of charge correction for each emissions species and for fuel economy, the emission and fuel economy values for each run must be plotted against the NEC for each run. A linear interpolation (in some cases extrapolation may be allowed) is performed to establish the fuel economy or emissions at a NEC of zero (i.e., the data is corrected to reflect a net zero change in SOC). This methodology is described in SAE Paper 2000-01-2955.

4.4.1 SOC CORRECTION EXAMPLE—A sample SOC correction from the above-cited SAE Paper 2000-01-2955 is shown in Figure 1. The figure shows data collected from five runs on a single 2-mile CBD-14 with a total cycle energy of approximately 25 kWh. The two runs at about –400 Wh and +300 Wh, respectively, have NEC values in excess of 1% (1.6% and 1.2%, respectively); as a result, a SOC correction was necessary. The three inner runs were within the 1% variance, and, as a result, these three test runs could have simply been averaged to determine the representative emission at zero NEC. The end result (about 20 gram per mile) is the result for both the average and the SOC linear interpolation.

4.4.2 ACCURACY COMBINED WITH SOC CORRECTION—On a hybrid vehicle, NEC values approaching 5% of the total cycle energy can result in emission data that can vary significantly from data with a NEC of effectively zero. This is because the vehicle was propelled by energy that is not accounted for. The only way to determine acceptable variance is to correct the data first using the SOC correction procedure. Because using the SOC correction procedure effectively turns multiple test values into a single value, the coefficient of determination, R^2, of the linear best fit is used to determine whether the collected data is valid. For the purposes of this recommended practice the data is considered acceptable if the R^2, which compares the predicted and actual values of the linear regression, is equal to or greater than 0.80.

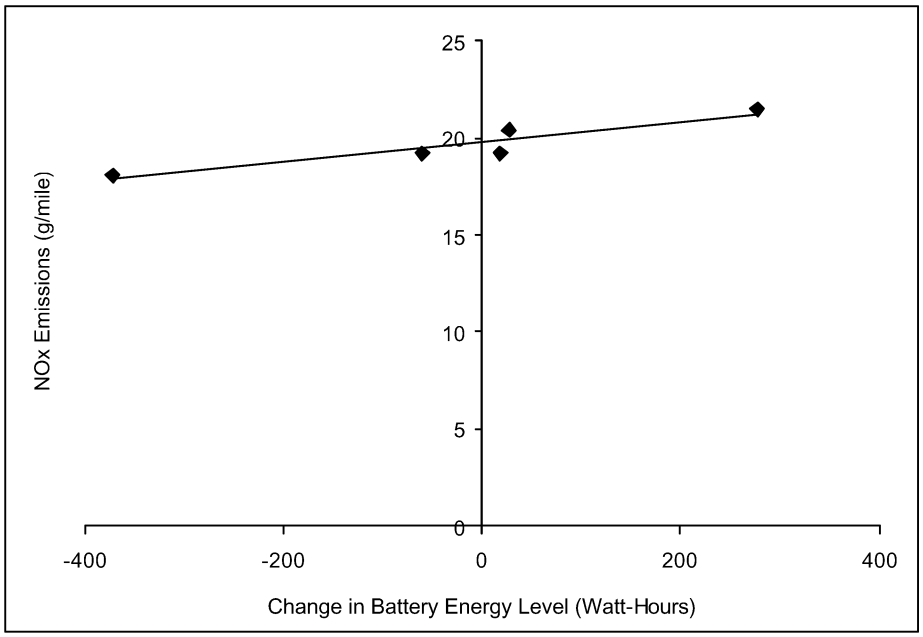

FIGURE 1—EXAMPLE SOC CORRECTION FACTOR FOR NOx

5. Driving Cycles and Routes—The purpose of this document is to measure the emissions and fuel economy of heavy-duty vehicles on a chassis dynamometer over one or more driving schedules so that the in-use emissions can be compared under like operating conditions. The vehicle is mounted on the chassis dynamometer so that it can be driven through a test cycle. A visual display of the desired and actual vehicle speed will be provided to the driver to allow the driver to operate the vehicle on the prescribed cycle. It is recommended that the vehicle be tested using three different driving cycles, representing low-, intermediate- and high-speed operation.

5.1 Recommended Driving Cycles—The first recommended cycle, representing lower speed operation, is the Manhattan Cycle, which is representative of transit bus operation in city service. (See SAE Paper 2000-01-2011.) The Manhattan Cycle (Figure 2) was developed by West Virginia University from data logged from buses in operation in New York City.

The second recommended cycle (Figure 3) is the heavy-duty Urban Dynamometer Driving Schedule (UDDS) (also known as “Test D”), which appears in 40 CFR Part 86.1215-85 and 40 CFR Part 86 Appendix I. This cycle mimics higher speed operation. It was developed as part of the “CAPE 21” effort, and is a Monte Carlo simulation of behavior of trucks and buses under freeway and non-freeway operation. Statistics for both of these recommended test cycles are provided in Table 1.

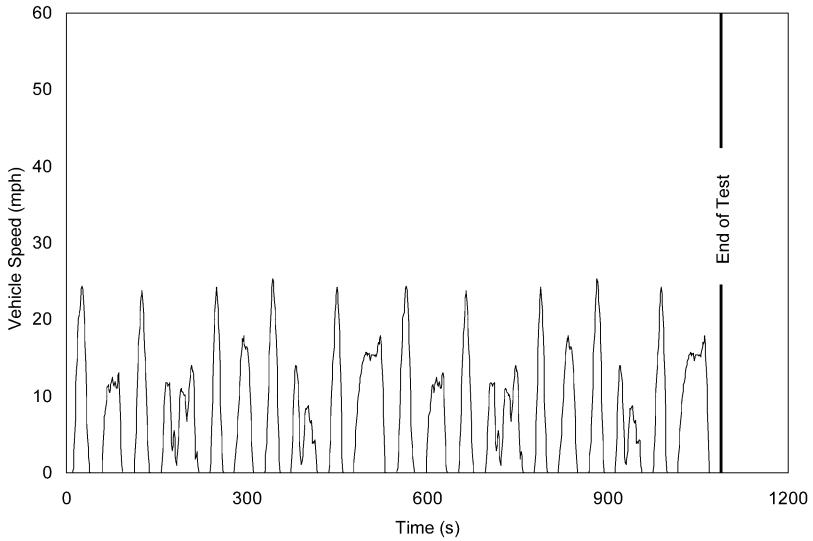

FIGURE 2—THE MANHATTAN DRIVING CYCLE

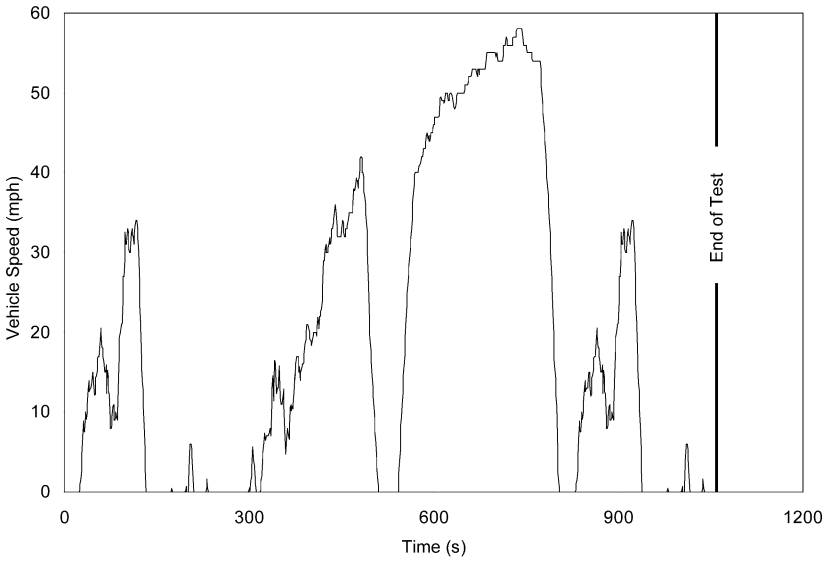

FIGURE 3—UDDS DRIVING CYCLE

TABLE 1—CHASSIS DYNAMOMETER DRIVING CYCLE STATISTICS

	Ave. Speed (mph)	Std. Dev. Speed	Max. Speed (mph)	Max. Accel. (mph/s)	Max. Decel. (mph/s)	Total Time (s)	Idle Time (s)	Total Dist. (miles)	No. of Idle Periods
Manhattan x 2	6.83	7.34	25.3	3.98	–5.73	2178	786	4.13	41
Test D x 2	18.84	19.84	58	4.19	–4.51	2121	706	11.1	27
Orange County	12.33	10.3	40.63	4.05	–5.13	1909	406	6.54	30
CBD x 3	12.58	8.36	20	2.4	–4.5	1722	345	6.2	43

The third cycle (Figure 4) recommended by this document is an intermediate test cycle recently developed from the operation of buses in Orange County, California. This cycle represents mid-speed heavy-duty vehicle operation and is being recommended for this type of operation over the Central Business District (CBD) cycle. West Virginia University contributed to the development and documentation of the Orange County cycle.

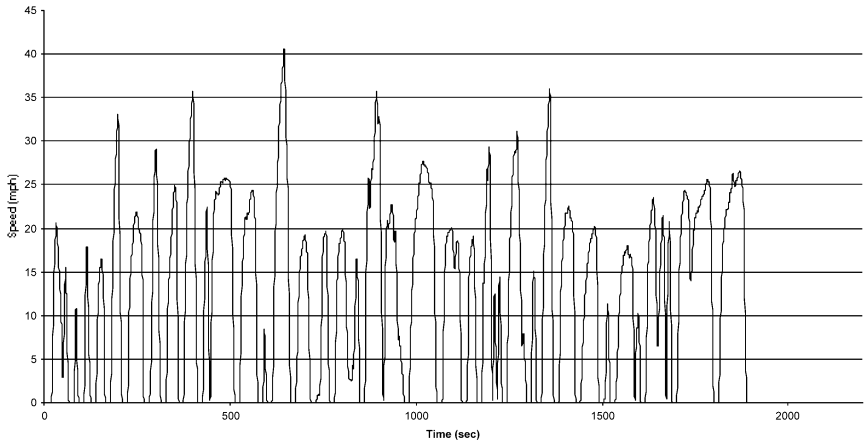

FIGURE 4—ORANGE COUNTY CYCLE

The CBD cycle was originally configured to determine the fuel consumption of a bus driven on an oval track. Although it was subsequently adopted for determining emissions on chassis dynamometers, it does not mimic true bus operation sufficiently for accurate emissions characterization. A major issue with using the CBD is the fact that all cruise operation occurs at 20 mph, and the whole cycle contains only one (repeated) example of an acceleration ramp and one deceleration rate. This limited modal operation, in particular the cruise, can affect one bus configuration over another relative to real use. In some cases conventional automatic buses may shift gear near to 20 mph, so that the cruise speed can have a profound effect on emissions by altering the engine-operating envelope from two fairly similar buses with slightly different shift points.

The Orange County bus cycle is derived from real bus operating data and reflects a wide variety of accelerations, decelerations and cruise operations. In this way the cycle more closely imitates the variety of operation found during real bus use. The Orange County cycle does have an average speed (12.33 mph) similar to that of the CBD (12.58 mph), and so does not imply operation that is substantially slower or more freeway-oriented than the CBD. Use of the Orange County cycle is also in keeping with the national trend of employing real world cycles that closely mimic real vehicle operation for emissions factor development. The only reason to employ the CBD in future studies is for comparison with archival data. (Statistics for these two cycles can be found in Table 1.)

Data from all three recommended cycles can be found in the Appendix A. The CBD also appears in the Appendix A. While this document does not recommend use of the CBD as an intermediate cycle, it has been included because it is recognized that some may find it useful due to the large amount of historical data on the CBD.

5.2 Driving Cycle Duration—Charge-sustaining HEV evaluation requires longer test runs, because a single drive cycle is unlikely to affect SOC at a level sufficient to cause the engine management system to provide additional power to the RESS. The use of a longer cycle increases the probability of a smaller NEC between initial and final values on a percentage basis. The use of a longer test also facilitates the detection of emissions produced at laboratory threshold limits, such as PM from a vehicle with post-combustion emission control devices. It also allows for the better evaluation of emission control devices where there may be batch control (accumulation and regeneration) so that sufficient emission control events occur during the course of the drive cycle.

The absolute upper limit for the length of an individual test run is about 2 hours due to the potential for analyzer drift, increased driver fatigue, and memory storage capacity limitations. This document recommends that back-to-back drive cycles be combined to produce a test run of approximately 30 minutes. The test run must include an idle period of approximately 1 minute at the end of the test run to capture any emissions lags at the end of a drive cycle.

6. Test Preparations

6.1 Test Site—The ambient temperature levels encountered by the test vehicle shall be no less than 7 °C (45 °F) or more than 38 °C (100 °F). This represents the temperature window adopted by the U.S. Environmental Protection Agency (EPA) for in-use testing. However, if emissions from the vehicle are intended to reflect engine operation under certification conditions, the temperature window should lie between 20 °C (68 °F) and 30 °C (86 °F). Ambient temperatures must be recorded at the beginning and end of the test period. Adequate test site capabilities for safe venting and cooling of batteries, containment of flywheels, protection from exposure to high voltage, or any other necessary safety precaution shall be provided during testing. Test conditions specified in 40 CFR Part 86 shall apply, where appropriate. A fixed-speed-cooling fan shall direct cooling air to the vehicle to maintain the engine operating temperature as specified by the manufacturer during testing. These fans shall only be operating when the vehicle is in operation and shall be switched off for all key off dwell periods. Fans for brake cooling can be utilized at all times.

6.2 Pre-Test Data Collection—Prior to testing, detailed demographics of the vehicle should be recorded. These data should include, at a minimum, the vehicle identification number, engine serial number, gross vehicle weight (from vehicle data plate), curb weight (from vehicle data plate or by weighing), engine manufacturer, model year and type, engine serial number, engine displacement and number of cylinders, engine rated power and speed, tire size, transmission type, number of speeds, presence or absence of retarder, exhaust gas aftertreatment type, and rear axle ratio. Pre-test data should also include details of the type, power and speed of the electric motor(s); type and capacity of the RESS; and, exhaust aftertreatment device type(s). The chassis test laboratory will be used to measure actual cycle distance during a test, as it is generally considered a more accurate method of calculation; as a result, an odometer on the vehicle is not required.

If fuel properties are not known, a fuel sample should be gathered for subsequent analysis. Fuel properties to be determined and reported are listed in 40 CFR 86.307-82; however, at a minimum, they should include:

a. For Liquid Compression Ignition Fuels—The heating value, sulfur content and aromatic density
b. For natural Gas Information—The methane content, non-methane organic content and inert content
c. For Liquid Spark Ignition Fuels—Heating value and octane number

Deviation from the basic procedure, such as testing the vehicle in a different mode other than HEV, must be properly documented for later reproduction.

6.3 Condition of the Vehicle

6.3.1 VEHICLE STABILIZATION—Prior to testing, the vehicle shall be stabilized to a manufacturer-determined distance or to 4000 miles. Charge-depleting vehicles for which regular, off-vehicle charging is recommended shall have their RESS fully recharged. This recharge should occur at least once between each refilling of consumable fuel; however, charging frequency for the RESS shall not be greater than is anticipated during normal vehicle use.

6.3.2 VEHICLE APPENDAGES—Vehicles shall be tested with normal appendages (mirrors, bumpers, etc.). Certain items (e.g., hub caps) may be removed where necessary for safety on the dynamometer.

6.3.3 VEHICLE TEST WEIGHT—Buses are tested at curb weight plus driver weight and one half seated passenger load using a weight of 150 lb per passenger. Class 8 Trucks are tested at 70% of gross combined weight rating.

6.3.4 TIRES—Manufacturer's recommended tires shall be used.

6.3.4.1 Tire Pressure—For dynamometer testing, tire pressures should be set at the beginning of the test at the pressure used to establish the dynamometer road-load coefficients and shall not exceed levels necessary for safe operation.

6.3.4.2 Tire Conditioning—Tires shall be conditioned as recommended by the vehicle manufacturer and shall be the same size as would be used in service.

6.3.5 LUBRICANTS—The vehicle lubricants normally specified by the manufacturer shall be used.

6.3.6 GEAR SHIFTING—The vehicle shall be driven with appropriate accelerator pedal movement to achieve the time versus speed relationship prescribed by the driving cycle. Both smoothing of speed variations and excessive acceleration pedal perturbations are to be avoided and may cause invalidation of the test run. In the case of test vehicles equipped with manual transmissions, the transmission shall be shifted in accordance with procedures that are representative of shift patterns that may reasonably be expected to be followed by vehicles in use. For additional instructions see 40 CFR 86.1228-85.

6.3.7 REGENERATIVE BRAKING—If the vehicle has regenerative braking, the vehicle should be tested on the dynamometer with the identical control strategy as used in service. If a vehicle is equipped with an Antilock Braking System (ABS) or a Traction Control System (TCS) and is tested on a two-wheel dynamometer, the vehicle's ABS or TCS may inadvertently interpret the non-movement of the (front) set of wheels as a malfunctioning system. If so, then modifications (defeat) to the ABS or TCS shall be made to achieve normal operation of the remaining vehicle systems, including the regenerative braking system.

6.3.8 AIR SUSPENSION—All vehicles with air suspensions shall be aired up from an external source prior to testing. After the vehicle has reached sufficient air pressure to achieve proper suspension leveling and service brake operation, external air shall be disconnected from the vehicle and shall not be reconnected during actual emission testing. External air should only be utilized prior to the first test and should not be utilized between testing events during the key off period

6.3.9 VEHICLE PREPARATION AND PRECONDITIONING—Vehicle preparation is described in 40 CFR 86.1231-90. Preconditioning is described in 40 CFR 89.1232-90. Preconditioning, at a minimum, should include:

a. Fuel tank drain-and-refill or utilize fuel from a remote tank to ensure only test fuel is utilized
b. For warm start tests the vehicle should be preconditioned using a complete circuit of the test cycle followed by the appropriate key off dwell period
c. Initial SOC setting

6.4 Conditioning of Rechargeable Energy Storage System

6.4.1 OFF-VEHICLE CHARGING—The RESS of charge-depleting vehicles should be fully charged prior to testing. Off-vehicle charging is only allowed for the battery conditioning of charge-sustaining HEVs.

6.4.2 RESS FAILURE—In the event that the RESS is damaged or has an energy storage capability below the manufacturer's specified rating, the RESS shall be repaired or replaced and stabilized, and then the test procedure should be repeated. Data from tests with a faulty RESS shall be considered invalid.

6.5 Dynamometer Specifications—The evaluation of the emissions and fuel economy from a heavy-duty HEV should be performed using a laboratory that incorporates a chassis dynamometer, a full-scale dilution tunnel, and laboratory-grade exhaust gas analyzers as described in 40 CFR Part 86.315-79. The chassis dynamometer should be capable of mimicking the transient inertial load, aerodynamic drag and rolling resistance associated with normal operations of heavy-duty vehicles. At this time, grade of the roadway is not typically considered in executing a test schedule. The transient inertial load should be simulated using appropriately sized flywheels or electronically controlled power absorbers. The aerodynamic drag and rolling resistance may be implemented by power absorbers with an appropriate computer control system. The drag and rolling resistance should be established as a function of vehicle speed using the procedure described in 40CFR Part 86, or by matching coastdown curves on the dynamometer and on the road. Coastdown procedures are described by SAE J2263. Coastdowns should not be calculated numerically unless the drive system inertia in an HEV can be properly accounted for. The actual vehicle weight for the on-road coast down should be the same as the anticipated vehicle testing weight as simulated on the dynamometer. The vehicle should be mounted on the chassis dynamometer so that it can be driven through a test cycle. The driver should be provided a visual display of the desired and actual vehicle speed to allow the driver to operate the vehicle on the prescribed cycle.

6.5.1 DYNAMOMETER CAPABILITIES—Generally speaking, the dynamometer needs to be able to duplicate the inertial, road and aerodynamic losses associated with operating a vehicle in actual use. Issues such as damping within the dynamometer may need to be addressed so that mechanical effects of the dynamometer do not have a substantial negative effect on vehicle energy economy (e.g., where the electric propulsion system is consuming energy in an attempt to damp vibrations in the dynamometer).

6.5.2 DYNAMOMETER CALIBRATIONS—The dynamometer laboratory should provide its calibration procedures as recommended by the manufacturer.

6.5.3 INERTIAL LOAD—Inertial load needs to be simulated correctly from a complete stop (e.g., total energy used to accelerate the vehicle plus road and aerodynamic losses should equal theoretical calculations and actual coastdowns). For HEVs this may be determined by measuring the power delivered to the dynamometer at the drive motors.

6.5.4 ROAD LOAD—Road load and wind losses are non-recoverable and should be simulated by an energy device such as a power absorber. Road load should be verified by comparison of coastdown analysis where possible. There is the potential that relative errors in road load losses and inertial load may not be uncovered. For this reason it may also be prudent to test the vehicle with road and wind losses excluded so that kinetic vehicle energy can be analyzed separately.

6.5.5 POTENTIAL UNMEASURED LOADS—There is the potential for unmeasurable losses in the dynamometer, typically between the last measured energy point on the vehicle (drive motors for hybrid vehicles, engines for conventional vehicles) and the first energy measured point on the dynamometer (torque cells on the drive section, or the electric inertia motor). While losses in the rear drive reduction gears (ring and pinion) can be isolated and accounted for using coastdown analysis, additional losses at the tire interface at the dynamometer rollers have the potential to be quite large, but still go unmeasured. Tire overheating is a good indicator of this problem. However, correcting the problem by using jacks to lift the vehicle higher off the dynamometer has certain drawbacks, such as limiting differential effects (a single locked drive roller system effectively locks the rear differential) and potentially limiting braking speeds. On a two-wheel dynamometer, all of the braking is directed through the rear wheels, and in certain cases the outside rear wheels may need to be removed, further limiting traction. In cases where the rear wheels are directly connected to the load via shafts, the largest load will be differential effects initiated by rear brakes that do not apply simultaneously, forcing one rear tire to decelerate the other.

6.5.6 DYNAMOMETER LOAD COEFFICIENT DETERMINATION—The dynamometer coefficients that simulate road-load forces shall be determined as specified in SAE J2263 and J2264, with the following provisions:

a. Vehicles equipped with regenerative braking systems that are actuated only by the brake pedal shall require no special actions for coastdown testing on both the test track and dynamometer.
b. Vehicles equipped with regenerative braking systems that are activated at least in part when the brake pedal is not depressed shall have regenerative braking disabled during the deceleration portion of coastdown testing on both the test track and dynamometer, preferably through temporary software changes in the vehicle's control system. Mechanical changes to the vehicle to deactivate regenerative braking (such as completely removing the drive shaft) are discouraged. However, if this practice becomes necessary as a last resort, every safety precaution shall be taken during vehicle operation, and the same mechanical modifications shall occur on both the test track and dynamometer. Methods to accelerate a vehicle without a drive shaft on both the test track and the dynamometer shall be determined by the manufacturer. However, pushing the vehicle with another vehicle is not an option.
c. The vehicles shall be weighted to the correct dynamometer test weight when the on road coastdowns are performed.

6.5.7 DYNAMOMETER SETTINGS—The dynamometer's power absorption and inertia simulation shall be set as specified in 40 CFR Part 86-1229-85. It is preferable to insure that the dynamometer system provides the appropriate retarding force at all speeds, rather than simply satisfying a coastdown time between two specified speeds. Regenerative braking should be disabled for all coastdowns both on road and on the dynamometer. The remaining operating conditions of the vehicle should be set to the same operating mode during coastdowns on road and on the dynamometer (e.g., air conditioning off, etc).

6.6 Test Instrumentation—Equipment referenced in 40 CFR Part 86.1301-90 to 40 CFR 86.1326-90 (including exhaust emissions sampling and analytical systems) is required for emissions measurements, where appropriate. All instrumentation shall be NIST-traceable (National Institute of Standards and Technology). The following instruments are required or recommended for as-needed usage.

a. DC wideband Ampere-hour meter: Any Ampere-hour meter using an integration technique shall have an integration period of less than 0.05 seconds so that abrupt changes of current can be accommodated without introducing significant integration errors.
b. An instrument to measure a capacitor's voltage
c. An instrument to measure an electromechanical flywheel's rotational speed
d. AC Watt-hour meter to measure AC Recharge Energy
e. A voltmeter and ammeter for as-needed usage (recommended)
f. An instrument to measure throttle pedal position (or an equivalent indicator of the driver's acceleration demands)

The accuracy of each instrument shall be as specified in 40 CFR Part 86.1309 and SAE J1634, as applicable. Instrument accuracy for coastdown measurements shall be as specified in SAE J2263 and SAE J2264, as applicable.

6.6.1 ANALYZERS AND TUNNEL FLOW

6.6.1.1 Detection Limit—Tunnel flow rate is typically established on ability to achieve acceptable PM sample zone temps over the test cycle, and high enough to avoid condensation. Tunnel flow volume should be set at the minimum level possible for vehicles such that a carbon balance for fuel efficiency and a hydrocarbon balance for tunnel integrity can still be performed accurately and the lowest possible detection limits can be determined. Where possible, laboratories should determine and submit estimated lower detection limits with all test data. The detection limits should be expressed in the same units as the data (e.g., grams per mile for emission data.) Emission levels that are determined to be below detection limit shall be cited as less than the detection limit value.

The detection limit for a laboratory should be determined by one of two methods. For laboratories with a large base of repeat run data, the measurement error may be determined statistically from run-to-run variations, and the detection limit may be equated to the measurement error. In other cases the detection error must be determined by considering the stated accuracy of the analyzers, calibration gases, balance (for PM) and assigning these potential errors as a root-mean-square error to detection limit. These errors must be considered twice, since they are also applied to the background measurement, and introduce error into the background correction.

7. Test Procedure

7.1 Vehicle Propulsion System Starting and Restarting—The vehicle's propulsion system – specifically, the unit that provides the primary motive energy, e.g., the internal combustion engine -- shall be started according to the manufacturer's recommended starting procedures in the owner's manual. Only equipment necessary to the primary propulsion of the vehicle during normal service shall be operated. The air conditioner and other auxiliary on-board equipment not generally used during normal service shall be disabled during testing, except in the case where specific evaluations of air conditioning loads are required. For cold start testing the starting event and subsequent 1-minute idle stabilization period shall be included in the measurement of emissions.

7.2 Dynamometer Driving Procedure—As discussed in Section 5, a standard cycle length of approximately 30minutes shall be used for all chassis tests, which results in emission tests of the same duration. This will allow for an acceptable level of cold and hot vehicle operation as well as sufficiently low detection limits for gravimetric particulate measurement. Chassis tests shall also consist of a normalized condition prior to the test including either a 12-hour cold soak or a warm up followed by a 20 to 30-minute "key off" period.

Based on the historical emission data collected to date, even relatively short key off conditions can result in significant excess emissions with heavy-duty vehicles. As a result, this recommended practice allows for the collection of "cold" and "hot" test emissions. Most chassis emission laboratories require a 20 to 30 minute "key off" dwell between testing events to allow for swapping out PM filters, analyzer calibration and bag sampling change outs. It is recommended that "normal" emission test sequences start with a "hot" vehicle that can be utilized to warm the dynamometer to operating temperature and allow for vehicle rolling loss calibration. Once the vehicle is at operating temperature the vehicle shall be turned off and remain in the "key off" position for 20 to 30 minutes. "Cold" start tests can only be conducted after the proper vehicle loss calibrations have been conducted followed by the appropriate cold soak period of 12 hours. Cold start tests should also verify that the vehicle is fully aired up and supported properly.

7.3 Dynamometer Warm-up—Because many dynamometers require that the vehicle be partially supported to accurately reflect rolling losses, the test vehicle is used to warm the dynamometer and operated to allow for proper laboratory and vehicle loss calibrations. Unrecoverable rolling and aerodynamic losses should be determined using a suitable coast down or several steady state speed tests. Once warm unrecoverable losses are determined, cold laboratory losses may be measured the following day to determine if there is an appreciable effect of the laboratory being at less than normal operating temperature. If the losses are acceptable, "cold" start testing may be conducted with a cold dynamometer.

7.4 Practice and Warm Up Runs—The test vehicle will be operated through a preliminary run of the desired test cycle. During this preliminary cycle, the driver will become familiar with the vehicle operation, and the suitability of the selected operating range of gas analyzers will be verified. Additional preliminary runs will be made, if necessary, to assure that the vehicle, driver, and laboratory instrumentation are performing satisfactorily. Once the vehicle has reached operating temperature the vehicle shall be returned to the "key off" condition in anticipation of the subsequent emission test cycle.

7.4.1 "COLD" AND "HOT" EMISSION TESTS

7.4.2 COLD EMISSION TEST—"Cold" start test cycles shall consider all emission data from the moment the vehicle is started including the actual start event. The vehicle shall be cold soaked for a minimum of 12 hours such that all components are at ambient temperature. The vehicle shall remain in the "key off" position for 30minutes until testing begins. A separate vehicle or other equipment (e.g., electric heaters) as necessary shall be utilized to bring the dynamometer to operating temperature. The vehicle shall be started and idled for one minute after which time the 30-minute test cycle shall commence. Emission measurements will be taken starting one minute before the vehicle is started through test cycle completion, resulting in a total sampling duration of about 32 minutes. At the end of the test cycle the vehicle shall be returned to the "key off" condition. Figure 5 provides a visual display of the time elements described in this section as well as those described in 7.4.3.

7.4.3 HOT EMISSION TEST—"Hot" test cycles shall consider all emission data from the moment the vehicle is started, excluding the actual start event. The vehicle shall be started and warmed to operating temperature utilizing the same test cycle that will be used for emission characterization. This procedure allows for multiple "hot" test events back to back with only a 20 to 30 minute "key off" condition in between each test event. Once the vehicle is at operating temperature the vehicle shall be turned off and will remain in the "key off" position for approximately 20 to 30 minutes. The vehicle shall be restarted and idled for one minute, at which time the 30-minute test cycle shall begin and emission measurements will be taken. At the end of the test cycle the vehicle shall be returned to the "key off" condition.

A minimum of three test runs of 30 minutes each must be performed under each different test cycle. If the test sequence lapses in timing, another preliminary warm up run must be performed, after which the schedule can be resumed. Valid data gained prior to the breaking of the schedule may be preserved and reported. It is important to adhere to the time schedule and soak periods because engines and aftertreatment devices are sensitive to operating temperature. In order to conduct three "cold" start emissions tests the vehicle would necessarily have to be available for three separate days. The remainder of the test days would be used to conduct "hot" emission testing. (See Figure 5.)

7.5 Test Termination—The test shall terminate at the conclusion of the test run. However, sufficient idle time should be included at the end of a run, such that the analyzers are not missing emissions that are still in the sampling train. The lag time between when the vehicle emits the emissions and when the emissions are actually analyzed in the dilution tunnel can be as much as 10 to 20 seconds. As a result, all 30 minute test cycles are expected to have a minimum of one minute idle at the end of the cycle before it terminates.

7.6 Intra-Test Pauses—Between two test events, the vehicle shall dwell for 20 to 30 minutes with the key switch in the "key off" position, the engine enclosure closed and the brake pedal not depressed. The RESS may or may not be recharged from an off-vehicle electric energy source depending upon the needs of the emission test. Hybrid-electric vehicles that are charge depleting shall have their energy economy determined with the RESS starting from 100% SOC. If the auxiliary power unit (APU) fails to start during the first 10 minutes of a 30-minute test cycle, the vehicle shall be operated until the vehicle APU starts. The vehicle shall then return to the "key off" condition for 30 minutes after which time the vehicle shall be restarted and commence the 30-minute test cycle. Once the starting SOC of the vehicle is known, this SOC can be used as a target for the start of subsequent emission tests. Average representative emissions can then be determined based on the state of charge correction method outlined in this document.

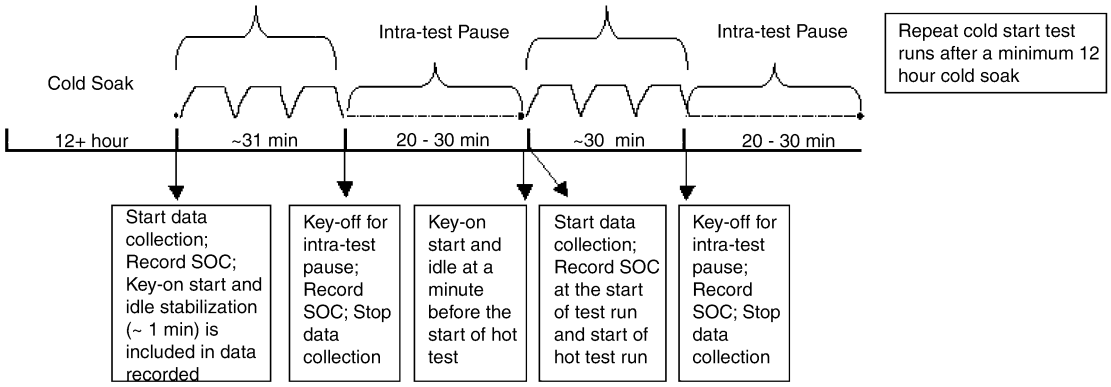

FIGURE 5—COLD AND HOT TESTS

7.7 Air Conditioning—Air conditioning loads in heavy-duty vehicles can be a significant consumer of on-board vehicle power and, as a result, a large potential contributor to excess emissions. A holistic view of vehicle efficiency and inventory contribution should consider typical air conditioning (AC) load. The actual refrigeration unit configuration, design and operational control strategy largely determine air conditioning performance on a unit-by-unit basis; however, AC unit efficiency (coefficient of performance) is strongly influenced by operational temperature differentials. The degree to which the vehicle is insulated or reflective, and the relative heat and humidity loads imparted by passengers are the largest contribution to load. All of these factors come together making the simulation of typical air conditioning loads a complicated task to say the least.

Regrettably, the typical air conditioning load is not readily described, and its emissions contribution is not readily measured. Typical air conditioning tests performed by manufacturers include “pull down” and “steady state” tests, which are used to determine the capability of the AC unit to provide rapid cooling of a vehicle placed into service and continuous performance in use with the maximum gross passenger load. Both of these tests are used to determine the maximum capability of the systems, and this method could lead to overstating emissions if performed in this manner on a chassis dynamometer.

Several factors will influence the load imparted on the vehicle by the AC system, and these factors apply whether the AC system is directly engine coupled or driven by an electric compressor. Environmental and vehicle factors include target temperature and humidity inside the vehicle, temperature and humidity outside of the vehicle and heat transfer characteristics, convection inside the and outside of the vehicle, internal vehicle component mass as well as vehicle air infiltration rates. Load is further established by several additional loads applied to the vehicle including those related to drive system heat, passenger heat, a humidity load, solar radiative load, as well as operational factors such as door openings for passenger egress. While all of these may be determined and specified, there are several additional things to consider, including what combination of factors would represent average load given that ambient conditions vary considerably throughout the country.

Characterizing emissions with air conditioning employed and operating will call for the determination of values for the variables discussed above, followed by careful control of all of these variables during emissions testing, which is presently beyond the scope of any heavy duty chassis dynamometer laboratory. In light duty vehicle emissions characterization, 40 CFR 86.160-00 clarifies that the dynamometer testing of the light duty vehicle must be conducted in an environmental enclosure. The ambient conditions are specified as 95 °F with 100grains/lb humidity (about 40% relative humidity), a solar load of 850 Watts per square meter and vehicle cooling airflow proportional to speed. Great attention is placed on the nature and positioning of the solar radiative load. In light duty vehicles, the passenger load as a heat source is also less critical than in buses.

There is a temptation simply to test with the air conditioning activated and attempt to correct for ambient conditions, but this approach would be fraught with problems and inaccuracies. Automotive air conditioners employ a compressor, expander, condenser and evaporator to implement a vapor-compression refrigeration cycle. Air conditioner efficiency is usually classified through a coefficient of performance, which describes the ratio heat pumped by the refrigeration circuit (between the condenser and evaporator) to the energy required by the compressor, or the compressor and air handler. Although it is clear that this coefficient of performance is large when the heat difference between the condenser and evaporator is small, and vice versa, performing a correction for varying operating conditions would require detailed empirical knowledge of the performance of the specific air conditioner. Also, it would be insufficient merely to quantify this difference in temperature because that would not account properly for solar loading, on-board heat generation, and cooling of the environment surrounding the evaporator. Moreover, the air conditioning loads will have synergistic interactions with the propulsion loads from the bus, for instance, so the AC system control strategy will play a role in determining overall performance. This control strategy may also depend on the air conditioner load, and hence the operating and ambient conditions.

For these reasons, this document does not make specific provisions or recommendations for testing of heavy-duty vehicle emissions with air conditioning deployed, although it is recognized that a future practice that addresses air conditioning and other potentially large auxiliary loads is needed. Such a document would define the environmental conditions, internal and external heat and humidity loads, other practical considerations and hardware configurations including cooling fans as well as the required target conditions and how those conditions will be measured.

Evaluation of emissions while the air conditioner is employed and operating is possible, and may follow the guidelines of this practice, but these emissions cannot be equitably compared to those of another vehicle with air conditioning unless all operating variables are similar and reasonable. The results may simply be presented, and should be accompanied by a thorough account of the prevailing conditions during testing.

While not an exhaustive list, the following includes a list of variables and potential values for consideration assuming that the AC system itself is in working order and all system components are within manufacturers specifications.

a.	Ambient Temperature:	95 °F
b.	Ambient Humidity:	>50% relative
c.	Interior Target Temperature:	75 °F
d.	Interior Target Humidity:	>50% relative
e.	Interior Initial Temperature:	95 °F
f.	Interior Initial Humidity:	>50% relative
g.	Temperature Allowance Margins:	±3 °F
h.	Solar Load:	850 Watts/Meter^2
i.	Per Passenger Heat Load:	230 Btu/h
j.	Per Passenger Humidity Load:	190 Btu/h
k.	Defined Passenger Load:	half seated plus driver
l.	Vehicle operating cycle:	same as SAE J2711
m.	Door Openings:	None
n.	Fresh air intakes:	Open
o.	Interior Thermocouple Placement:	4-ft height front and rear axle locations plus driver
p.	Exterior Thermocouple Placement:	Front on bus immediately below windshield
q.	Thermocouple location:	>1 ft from any surface
r.	Measurement Systems:	Continuous data logging not manual

7.8 Data Recording—The emissions from the vehicle exhaust will be ducted to a full-scale dilution tunnel where the gaseous emissions of hydrocarbons, carbon monoxide, oxides of nitrogen (both nitric oxide and nitrogen dioxide) and carbon dioxide will be measured on a continuous basis at a frequency of 5 Hz or greater. It is also recommended that an integrated bag sample of the dilution tunnel be collected and analyzed for carbon monoxide and carbon dioxide levels, and that these levels be compared to the continuous measurements for carbon monoxide and carbon dioxide as a quality assurance check. Alternatively, the measured values for carbon monoxide and carbon dioxide may be obtained from the integrated bag sample. Particulate matter will be measured gravimetrically using fluorocarbon-coated glass fiber filters by weighing the filters before and after testing. Filters will be conditioned to temperature and humidity conditions as specified by 40 CFR 86.1312-88.

For each constituent, a background sample using the same sampling train as used during the actual testing must be measured before and after the emission test, and the background correction must be performed as specified by 40 CFR 86-1343-88. For a compressed natural gas-fueled vehicle, and in cases where non-methane hydrocarbons are a species of interest, the integrated methane and non-methane content of hydrocarbons will also be measured, using gas chromatography analysis of integrated bag samples for each run. In cases where some specialty fuels are examined by the test procedure, it may prove necessary to sample for additional species, including alcohols, aldehydes, ketones, or organic toxics if it suspected that for these fuels the levels of these additional species might be significantly higher than is normally found for diesel fuel. It is recommended that the tunnel inlet be filtered for PM with a HEPA filter to aid in lowering the detection limits.

Fuel consumed shall typically be determined by carbon balance from the analytical analyzers, and the actual distance traveled by the dynamometer roll surface shall determine the actual distance traveled during the driving cycles. Alternative methods for fuel consumption, such as direct mass measurement of the fuel tank, shall be considered if they are sufficiently accurate. This would require that the mass measurement system have an accuracy of greater than 1% of the fuel amount consumed during the test cycle. This method would be required for vehicles consuming hydrogen fuel. Mass measurement is preferred to volumetric measurement.

7.8.1 SOC—SOC of the vehicle shall be measured continuously (at a rate of 1 Hz or greater) and recorded throughout the entire test. Recorded data must then be time integrated against the emission measurement data at the beginning and end to coincide with the emission measurement portion of the chassis test. Provided the SOC is measured, time sequenced and integrated according to the procedures listed earlier in this document, only the actual beginning and ending SOC values are necessary in the final test report. Alternatively the SOC of the RESS may be recorded at the beginning and end of the test. It is recommended that both Ah and system voltage be recorded during the test as outlined in the method for determining NEC.

7.8.2 EXHAUST EMISSIONS AND FUEL ECONOMY — CHARGE-SUSTAINING HEVS—Exhaust emission economy should be reported on a gram of pollutant emitted per mile covered during the emission test; fuel economy on a mile per gallon (US) basis. Emissions detection limit should also be reported. Because a carbon balance is used to calculate fuel consumption and hence fuel economy, the determination of fuel economy from gaseous hydrogen fueled fuel cell buses will have to be determined by some other method such as differential hydrogen tank pressure and temperature or differential fuel tank mass.

7.9 Test Validation—The value of the mass emission rates for each species will be averaged. There will be a minimum of three valid runs for each type of drive cycle. The coefficient of variance will be determined for each species. If the coefficient of variance is poor, additional runs should be performed until acceptable repeatability of emissions values are obtained. For hybrid vehicles the SOC correction is conducted first, and the R^2 of the linear best fit must be greater than 0.8. If a hybrid vehicle has three valid runs with less than the 1% NEC delta, then the data can be treated the same as a conventional vehicle. Under these circumstances, the R^2 of the best fit would be poor since all data points are essentially on the same axis (0% SOC correction). However, there still exists the possibility of laboratory related failures that need quality assurance, such as the loss of a sampling pump or analyzer drift that may result in three 0% SOC runs with emission differences of

greater than 5%. Any obvious error in the data should be identified and removed from the dataset; however, a minimum of three successful runs should be used in reporting the data.

At the end of each run, the total distance traveled by the vehicle over the test run will be noted from the dynamometer distance measurements. Adherence of the driver to the test cycle target speeds will be noted, and a regression will be performed to compare actual speeds with target speeds on a second-by-second basis. Target speed (x) and actual speed (y) should be charted in 1 Hz increments and a trend line inserted with a zero intercept. If the resulting trend line has a slope that varies from unity by more than 10% or an R^2 of less than 0.8 the test run should be considered an invalid representation of that test cycle. The lower of the actual distance traveled or the target cycle distance should be used for the test cycle distance value.

If at any point during the test, vehicle propulsion is not possible or the driver is warned by the vehicle to discontinue driving because the RESS energy supply is too low, the test is considered invalid. The RESS should be recharged and the testing procedure restarted from the beginning of the interrupted test run.

7.10 Test Product—The following information will be the product of this testing:

7.10.1 EXHAUST EMISSIONS AND FUEL ECONOMY—The exhaust emissions and fuel economy of the vehicle shall be measured during each test phase in which such measurements are required; the measurements shall be reported in grams per mile and miles per diesel equivalent gallon, respectively. Total fuel energy shall be reported in British Thermal Units (Btu).

7.10.2 ACTUAL DISTANCE TRAVELED—The actual distance that the dynamometer roll surface traveled shall be measured during each test phase in which such measurements are required.

7.10.3 SOC DIFFERENCE AND NEC—The state of charge difference of the RESS shall be measured during the test and reported along with the RESS NEC.

7.10.4 FINAL TEST REPORT—The final test report shall include all measured parameters including vehicle configuration, vehicle statistics, test cycle, measured parameters and calculated test results.

8. Charge-Depleting Hybrid-Electric Vehicles

8.1 Emissions and Fuel Economy of Charge-Depleting HEVs—Tailpipe mass emissions from charge-depleting HEVs are likely to be less than those of charge-sustaining HEVs because charge-depleting HEVs draw down the stored energy of the RESS, which means less energy is provided by the APU. However, to provide a true accounting of the emissions and fuel economy of the vehicle, emissions and energy associated with consumed electricity generation for the RESS must be accounted for. In theory, the “cold” test would have the APU started within the first 10 minutes of a 30-minute test. Under these conditions, the HEV would be driven in electric mode until the APU starts; the vehicle then continues for a 30-minute test after which subsequent “hot” test runs can be completed. During the first part of the test where the charge-depleting HEV is operating as an electric-only vehicle, the electric-only DC energy economy should be determined for the cycle in question as it may be used in later calculations. It will also aid in the determination of APU efficiency.

8.1.1 FUEL ECONOMY AND EMISSIONS —— CHARGE-DEPLETING CALCULATIONS—After conducting a test run, testers must measure -- at the wall meter upstream from the vehicle charger -- the energy required (kilowatt-hours) to recharge the RESS to the SOC at the beginning of the test run. The energy consumed is then divided by the total distance traveled by the vehicle over the test run as noted by the dynamometer or the target cycle distance, whichever is lower. The resulting energy input (kilowatt-hours per mile gross AC) is then adjusted for energy efficiency factors. These factors are the efficiency of the charger, transmission lines and utility generators. These factors have an approximate efficiency of 70, 90, and 35 percent, respectively. In order to compare electric energy economy with fuel economy, the value is converted into diesel equivalent gallons as shown in Equation 9. Alternatively if the fossil electric generating rate for the region is known, this rate may be applied directly to the AC kWh consumption. Note that the difference between AC kWh and DC kWh

consumed represents charger and RESS inefficiency.

$$FE_e = \{[(HV_{Fuel\ Oil})*(E_G)*(E_T)*(E_C)]/[(EU)*K_3]\} \quad \text{(Eq. 9)}$$

where:

FE_e	=	Fuel Economy of the electrical energy (mpg) in diesel equivalent gallons
$HV_{Fuel\ Oil}$	=	Lower Heating Value of Fuel Oil = 128 000 (Btu/gallon)
E_G	=	Generation Efficiency = 35%
E_T	=	Transmission Efficiency = 90%
E_C	=	Charging Efficiency (accounts for battery efficiency and standing losses) = 70%
E_U	=	Energy Usage (average) by vehicle (kWh/mi)
K_3	=	Conversion Factor (Btu/kWh) = 3412 (Btu/kWh)

FE_e should then be combined with the fuel economy (miles per diesel equivalent gallon) calculated from the fuel consumed by the APU for the total fuel economy of a charge-depleting HEV.

Emissions from the electricity consumption side of HEVs are traced back to the electricity generator. Emission rates vary widely nationally due to generation fuel mixes. Ideally testers should identify the emission rates from the electricity supplier. The energy consumed to recharge the RESS, EU as described in this section is multiplied by the electricity generation emission rates to yield emissions (grams per mile), accounting for the electricity consumption of the HEV. Total emissions for the HEV are calculated by adding the electricity used emission value to exhaust emissions.

8.1.2 ALTERNATIVE CHARGE-DEPLETING METHOD—The task of combining local electric utility emissions and energy economy with vehicle APU emissions and energy economy is a burdensome task that will yield different results for the same vehicle when deployed in different locations. If a consistent value is desired, the energy output emissions from the APU should be determined on a given cycle. These values would then be applied to the vehicle energy consumption as if the vehicle RESS was recharged from only the APU in much the same way as a charge-sustaining HEV. This method requires that the electricity generated by the APU be monitored continuously during the emission testing.

PREPARED BY THE SAE TRUCK AND BUS HYBRID AND ELECTRIC VEHICLE COMMITTEE

APPENDIX A

DRIVING CYCLES DATA

A.1 See Table A1.

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
1.00	0.00	1	0	1	0	1	0
2.00	0.00	2	0	2	0	2	0
3.00	0.00	3	0	3	0	3	0
4.00	0.00	4	0	4	0	4	0
5.00	0.00	5	0	5	0	5	0
6.00	0.00	6	0	6	0	6	0
7.00	0.00	7	0	7	0	7	0
8.00	0.00	8	0	8	0	8	0
9.00	0.00	9	0	9	0	9	0
10.00	0.00	10	0	10	0	10	0
11.00	0.00	11	0.3	11	0	11	0
12.00	0.00	12	0.6	12	0	12	0
13.00	0.00	13	2.8	13	0	13	0
14.00	0.00	14	4.9	14	0	14	0
15.00	0.00	15	7.1	15	0	15	0
16.00	0.00	16	11.7	16	0	16	0
17.00	0.00	17	13.4	17	0	17	0
18.00	0.00	18	14.9	18	0	18	0
19.00	0.00	19	17.7	19	0	19	0
20.00	0.00	20	20.1	20	0.2	20	0
21.00	0.00	21	20.6	21	2.5	21	0.24444444
22.00	0.00	22	20.9	22	4.8	22	1.25454546
23.00	0.00	23	21.4	23	7	23	3.56
24.00	0.00	24	23.5	24	9	24	6.2
25.00	0.19	25	24	25	11.1	25	8.81
26.00	1.00	26	24.3	26	13	26	11.4
27.00	1.51	27	23.9	27	14.9	27	13.74
28.00	2.66	28	23.5	28	16.7	28	15.89
29.00	4.64	29	22	29	18.4	29	17.26
30.00	6.96	30	19.4	30	20	30	18.1454546
31.00	8.86	31	17.1	31	20	31	19.06
32.00	7.71	32	14.7	32	20	32	19.94
33.00	7.45	33	10.1	33	20	33	20.59
34.00	9.22	34	6.4	34	20	34	20.59
35.00	10.00	35	4.7	35	20	35	20.08
36.00	9.08	36	3.3	36	20	36	19.44
37.00	10.08	37	2.2	37	20	37	18.7
38.00	11.24	38	1.1	38	20	38	17.82
39.00	12.79	39	0.1	39	20	39	16.9181818
40.00	14.00	40	0	40	20	40	15.99
41.00	12.58	41	0	41	20	41	15.15
42.00	12.87	42	0	42	20	42	14.27

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
43.00	13.00	43	0	43	20	43	13.39
44.00	13.00	44	0	44	20	44	12.46
45.00	13.68	45	0	45	20	45	11.58
46.00	15.00	46	0	46	20	46	10.72
47.00	15.00	47	0	47	20	47	9.87272727
48.00	13.37	48	0	48	20	48	8.63
49.00	12.08	49	0	49	16.2	49	6
50.00	12.26	50	0	50	11.8	50	3.19
51.00	14.29	51	0	51	7.3	51	2.91
52.00	14.56	52	0	52	2.9	52	4.25
53.00	15.20	53	0	53	0	53	5.96
54.00	16.76	54	0	54	0	54	7.92
55.00	17.00	55	0	55	0	55	10.06
56.00	17.00	56	0	56	0	56	12.3181818
57.00	17.23	57	0	57	0	57	14.65
58.00	18.77	58	0	58	0	58	15.54
59.00	20.54	59	0	59	0	59	14.56
60.00	19.60	60	1.7	60	1.1	60	13.2
61.00	18.14	61	4	61	3.4	61	11.98
62.00	17.98	62	5.9	62	5.7	62	9.6
63.00	17.00	63	7.3	63	7.8	63	7.1
64.00	16.34	64	7.7	64	9.9	64	4.63636364
65.00	15.00	65	8.1	65	11.9	65	1.77
66.00	15.00	66	8.8	66	13.8	66	0.46
67.00	15.00	67	9.5	67	15.6	67	0.12
68.00	15.96	68	11.2	68	17.4	68	0
69.00	12.35	69	11.3	69	19.1	69	0
70.00	15.28	70	11.5	70	20	70	0
71.00	14.27	71	10.9	71	20	71	0
72.00	12.59	72	10.4	72	20	72	0
73.00	12.25	73	11	73	20	73	0
74.00	9.28	74	11.5	74	20	74	0
75.00	8.00	75	11.9	75	20	75	0
76.00	8.00	76	12.5	76	20	76	0
77.00	8.38	77	12.3	77	20	77	0
78.00	9.53	78	11.5	78	20	78	0
79.00	10.69	79	11.3	79	20	79	0
80.00	11.00	80	11.5	80	20	80	0
81.00	9.00	81	11.9	81	20	81	0.59
82.00	9.00	82	11.2	82	20	82	2.37
83.00	9.32	83	11	83	20	83	4.85
84.00	10.00	84	11.1	84	20	84	7.09
85.00	9.36	85	11.8	85	20	85	8.88
86.00	9.00	86	12.7	86	20	86	10.35
87.00	9.95	87	13.1	87	20	87	10.77
88.00	14.33	88	12.4	88	18.9	88	9.24545455
89.00	17.53	89	9.7	89	14.5	89	6.14
90.00	19.42	90	6.2	90	10	90	3.74
91.00	20.00	91	3.5	91	5.6	91	2.24

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
92.00	20.74	92	1.1	92	1.1	92	1.28
93.00	21.00	93	0.3	93	0	93	0.53
94.00	21.11	94	0	94	0	94	0.13333333
95.00	23.84	95	0	95	0	95	0
96.00	27.00	96	0	96	0	96	0
97.00	27.00	97	0	97	0	97	0
98.00	29.05	98	0	98	0	98	0
99.00	32.52	99	0	99	0	99	0
100.00	31.01	100	0	100	2.1	100	0
101.00	31.00	101	0	101	4.3	101	0
102.00	31.62	102	0	102	6.5	102	0
103.00	33.00	103	0	103	8.6	103	0
104.00	32.37	104	0	104	10.7	104	0
105.00	30.43	105	0	105	12.6	105	0
106.00	30.00	106	0	106	14.5	106	0
107.00	30.00	107	0	107	16.3	107	0
108.00	30.51	108	0	108	18.1	108	0.3
109.00	32.41	109	0	109	19.8	109	1.95
110.00	33.00	110	0	110	20	110	5.05
111.00	32.27	111	0	111	20	111	8.07272727
112.00	32.00	112	0	112	20	112	10.95
113.00	31.04	113	0	113	20	113	13.52
114.00	32.20	114	1.6	114	20	114	15.81
115.00	33.36	115	3.5	115	20	115	17.83
116.00	34.00	116	5.4	116	20	116	17.84
117.00	34.00	117	8.1	117	20	117	15.86
118.00	34.00	118	11	118	20	118	13.43
119.00	33.01	119	14.3	119	20	119	10.92
120.00	31.86	120	16.7	120	20	120	8.66
121.00	30.10	121	18	121	20	121	6.7
122.00	26.17	122	19.1	122	20	122	4.61
123.00	23.39	123	21.1	123	20	123	3.01
124.00	21.46	124	22.8	124	20	124	2.02
125.00	17.28	125	23.4	125	20	125	1.29
126.00	15.83	126	23.8	126	20	126	0.5625
127.00	13.76	127	22.4	127	20	127	0
128.00	12.60	128	20.7	128	17.1	128	0
129.00	10.33	129	18.9	129	12.7	129	0
130.00	8.28	130	16.2	130	8.2	130	0
131.00	5.38	131	14.6	131	3.8	131	0
132.00	2.91	132	13.1	132	0	132	0
133.00	0.00	133	9.9	133	0	133	0
134.00	0.00	134	6.3	134	0	134	0
135.00	0.00	135	4.2	135	0	135	0
136.00	0.00	136	2.2	136	0	136	0
137.00	0.00	137	1.1	137	0	137	0
138.00	0.00	138	0.1	138	0	138	0
139.00	0.00	139	0	139	0.7	139	0
140.00	0.00	140	0	140	3	140	0.1875

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
141.00	0.00	141	0	141	5.2	141	1.25
142.00	0.00	142	0	142	7.4	142	3.29
143.00	0.00	143	0	143	9.5	143	5.97
144.00	0.00	144	0	144	11.5	144	8.57272727
145.00	0.00	145	0	145	13.4	145	10.25
146.00	0.00	146	0	146	15.3	146	11.7
147.00	0.00	147	0	147	17	147	12.95
148.00	0.00	148	0	148	18.8	148	14.05
149.00	0.00	149	0	149	20	149	15.04
150.00	0.00	150	0	150	20	150	15.5
151.00	0.00	151	0	151	20	151	15.55
152.00	0.00	152	0	152	20	152	15.5727273
153.00	0.00	153	0	153	20	153	15.98
154.00	0.00	154	0	154	20	154	16.32
155.00	0.00	155	0	155	20	155	16.47
156.00	0.00	156	0	156	20	156	16.23
157.00	0.00	157	0	157	20	157	15.7
158.00	0.00	158	0	158	20	158	14.69
159.00	0.00	159	1.5	159	20	159	13.89
160.00	0.00	160	3.3	160	20	160	13.04
161.00	0.00	161	4.9	161	20	161	10.8090909
162.00	0.00	162	6.8	162	20	162	7.43
163.00	0.00	163	8.6	163	20	163	3.53
164.00	0.00	164	10.3	164	20	164	1.59
165.00	0.00	165	11.6	165	20	165	0.5375
166.00	0.00	166	11.8	166	20	166	0
167.00	0.00	167	11.8	167	20	167	0
168.00	0.00	168	11.6	168	15.3	168	0
169.00	0.00	169	11.3	169	10.9	169	0
170.00	0.00	170	11.5	170	6.5	170	0
171.00	0.00	171	11.6	171	2	171	0
172.00	0.00	172	11.8	172	0	172	0
173.00	0.00	173	9.1	173	0	173	0
174.00	0.51	174	6.2	174	0	174	0
175.00	0.33	175	4.1	175	0	175	0
176.00	0.00	176	2.9	176	0	176	0
177.00	0.00	177	3.6	177	0	177	0
178.00	0.00	178	4.6	178	0	178	0
179.00	0.00	179	5.5	179	1.6	179	0.1
180.00	0.00	180	4.5	180	3.9	180	0.97
181.00	0.00	181	2.2	181	6.1	181	4.1
182.00	0.00	182	1.5	182	8.2	182	7.67
183.00	0.00	183	1	183	10.3	183	10.5
184.00	0.00	184	1.8	184	12.2	184	13.15
185.00	0.00	185	3.1	185	14.1	185	15.57
186.00	0.00	186	4.7	186	16	186	17.64
187.00	0.00	187	5.9	187	17.7	187	19.46
188.00	0.00	188	8.4	188	19.5	188	21.04
189.00	0.00	189	9.6	189	20	189	22.45

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
190.00	0.00	190	10.8	190	20	190	23.82
191.00	0.00	191	11	191	20	191	25.03
192.00	0.00	192	10.7	192	20	192	26.23
193.00	0.00	193	10.6	193	20	193	27.47
194.00	0.00	194	10.5	194	20	194	28.58
195.00	0.00	195	10.3	195	20	195	29.64
196.00	0.00	196	10.1	196	20	196	30.61
197.00	0.13	197	10.2	197	20	197	31.62
198.00	0.71	198	9.3	198	20	198	32.59
199.00	0.00	199	7.8	199	20	199	33.03
200.00	0.00	200	6.7	200	20	200	31.78
201.00	0.00	201	7.2	201	20	201	29.22
202.00	0.00	202	8.2	202	20	202	26.44
203.00	4.15	203	9.5	203	20	203	23.16
204.00	6.00	204	10.8	204	20	204	19.3
205.00	6.00	205	11.9	205	20	205	15.8
206.00	6.00	206	12.7	206	20	206	12.55
207.00	5.30	207	13.4	207	18	207	8.14
208.00	4.14	208	14.1	208	13.6	208	4.51
209.00	1.96	209	13.2	209	9.1	209	1.95
210.00	0.00	210	13.4	210	4.7	210	0.42
211.00	0.00	211	13	211	0.2	211	0.14444444
212.00	0.00	212	10.8	212	0	212	0
213.00	0.00	213	7.7	213	0	213	0
214.00	0.00	214	4.4	214	0	214	0
215.00	0.00	215	1.8	215	0	215	0
216.00	0.00	216	2.1	216	0	216	0
217.00	0.00	217	2.8	217	0	217	0
218.00	0.00	218	2.2	218	0.2	218	0
219.00	0.00	219	0.8	219	2.5	219	0
220.00	0.00	220	0.1	220	4.8	220	0
221.00	0.00	221	0	221	7	221	0
222.00	0.00	222	0	222	9	222	0
223.00	0.00	223	0	223	11.1	223	0
224.00	0.00	224	0	224	13	224	0
225.00	0.00	225	0	225	14.9	225	0.51
226.00	0.00	226	0	226	16.7	226	1.88181818
227.00	0.00	227	0	227	18.4	227	4.14
228.00	0.00	228	0	228	20	228	6.64
229.00	0.00	229	0	229	20	229	9.1
230.00	0.00	230	0	230	20	230	11.29
231.00	0.48	231	0	231	20	231	12.56
232.00	1.64	232	0	232	20	232	13.63
233.00	0.41	233	0	233	20	233	14.76
234.00	0.00	234	0	234	20	234	15.75
235.00	0.00	235	0	235	20	235	16.4272727
236.00	0.00	236	0	236	20	236	17.03
237.00	0.00	237	0	237	20	237	17.59
238.00	0.00	238	0	238	20	238	18.06

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
239.00	0.00	239	0	239	20	239	18.43
240.00	0.00	240	1.3	240	20	240	18.97
241.00	0.00	241	2.7	241	20	241	19.61
242.00	0.00	242	6.8	242	20	242	20.06
243.00	0.00	243	9.5	243	20	243	20.6
244.00	0.00	244	11.9	244	20	244	20.99
245.00	0.00	245	15.9	245	20	245	21.24
246.00	0.00	246	19.3	246	20	246	21.42
247.00	0.00	247	21	247	16.2	247	21.68
248.00	0.00	248	22.5	248	11.8	248	21.8
249.00	0.00	249	24.2	249	7.3	249	21.81
250.00	0.00	250	24.2	250	2.9	250	21.77
251.00	0.00	251	22.8	251	0	251	21.5818182
252.00	0.00	252	21.3	252	0	252	21.17
253.00	0.00	253	19.6	253	0	253	20.77
254.00	0.00	254	17.9	254	0	254	20.33
255.00	0.00	255	14.1	255	0	255	20.06
256.00	0.00	256	9.1	256	0	256	19.78
257.00	0.00	257	6.8	257	0	257	19.55
258.00	0.00	258	4.8	258	1.1	258	19.48
259.00	0.00	259	2.5	259	3.4	259	19.4
260.00	0.00	260	0.2	260	5.7	260	19.1636364
261.00	0.00	261	0	261	7.8	261	18.77
262.00	0.00	262	0	262	9.9	262	18.2
263.00	0.00	263	0	263	11.9	263	17
264.00	0.00	264	0	264	13.8	264	15.63
265.00	0.00	265	0	265	15.6	265	13.45
266.00	0.00	266	0	266	17.4	266	9.86
267.00	0.00	267	0	267	19.1	267	6.06
268.00	0.00	268	0	268	20	268	1.76363636
269.00	0.00	269	0	269	20	269	0.1
270.00	0.00	270	0	270	20	270	0
271.00	0.00	271	0	271	20	271	0
272.00	0.00	272	0	272	20	272	0
273.00	0.00	273	0	273	20	273	0
274.00	0.00	274	0	274	20	274	0
275.00	0.00	275	0	275	20	275	0
276.00	0.00	276	0	276	20	276	0
277.00	0.00	277	0	277	20	277	0
278.00	0.00	278	0	278	20	278	0
279.00	0.00	279	0	279	20	279	0
280.00	0.00	280	1.6	280	20	280	0
281.00	0.00	281	2.7	281	20	281	0
282.00	0.00	282	3	282	20	282	0
283.00	0.00	283	3.8	283	20	283	0.16666667
284.00	0.00	284	5.1	284	20	284	0.49
285.00	0.00	285	7	285	20	285	1.01
286.00	0.00	286	8.4	286	18.9	286	1.76
287.00	0.00	287	9.9	287	14.5	287	2.73

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
288.00	0.00	288	11.3	288	10	288	4.75
289.00	0.00	289	13	289	5.6	289	7.43
290.00	0.00	290	14.5	290	1.1	290	10.08
291.00	0.00	291	15.5	291	0	291	12.75
292.00	0.00	292	16.6	292	0	292	15.43
293.00	0.00	293	17.5	293	0	293	17.79
294.00	0.00	294	17.1	294	0	294	19.89
295.00	0.00	295	17.9	295	0	295	21.82
296.00	0.00	296	16.8	296	0	296	23.46
297.00	0.00	297	16.4	297	0	297	25.1
298.00	0.00	298	16.1	298	2.1	298	26.59
299.00	0.00	299	16.4	299	4.3	299	27.92
300.00	0.24	300	16.4	300	6.5	300	28.77
301.00	0.60	301	16.1	301	8.6	301	29.08
302.00	0.00	302	16	302	10.7	302	28.66
303.00	1.42	303	14.7	303	12.6	303	26.98
304.00	2.00	304	13.1	304	14.5	304	25.19
305.00	3.08	305	11.7	305	16.3	305	23.35
306.00	5.63	306	9.4	306	18.1	306	21.44
307.00	4.00	307	6.8	307	19.8	307	19.34
308.00	4.00	308	4.1	308	20	308	16.64
309.00	3.34	309	2	309	20	309	13.18
310.00	1.37	310	0.2	310	20	310	9.97
311.00	1.00	311	0	311	20	311	6.82
312.00	0.00	312	0	312	20	312	4.08
313.00	0.00	313	0	313	20	313	1.6
314.00	0.00	314	0	314	20	314	0.25
315.00	0.00	315	0	315	20	315	0.1
316.00	0.00	316	0	316	20	316	0
317.00	0.00	317	0	317	20	317	0
318.00	0.00	318	0	318	20	318	0
319.00	0.23	319	0	319	20	319	0
320.00	1.39	320	0	320	20	320	0
321.00	2.00	321	0	321	20	321	0
322.00	4.11	322	0	322	20	322	0
323.00	5.00	323	0	323	20	323	0
324.00	6.02	324	0	324	20	324	0
325.00	7.18	325	0	325	20	325	0
326.00	7.33	326	0	326	17.1	326	0
327.00	6.49	327	0	327	12.7	327	0
328.00	7.00	328	0	328	8.2	328	0.15
329.00	7.00	329	0	329	3.8	329	1.3
330.00	7.00	330	0.2	330	0	330	4.11
331.00	7.00	331	2.3	331	0	331	6.80909091
332.00	7.00	332	3.3	332	0	332	8.63
333.00	7.43	333	4.1	333	0	333	10.15
334.00	8.00	334	5.9	334	0	334	11.53
335.00	8.00	335	8.6	335	0	335	12.73
336.00	7.09	336	11.3	336	0	336	13.7

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
337.00	11.06	337	15.5	337	0.7	337	14.42
338.00	12.89	338	17	338	3	338	15.17
339.00	14.49	339	18.2	339	5.2	339	16.06
340.00	11.46	340	20.1	340	7.4	340	16.9818182
341.00	13.08	341	22.8	341	9.5	341	17.8
342.00	16.55	342	24.1	342	11.5	342	18.62
343.00	16.00	343	25.3	343	13.4	343	19.41
344.00	15.34	344	25	344	15.3	344	20.15
345.00	12.32	345	23.8	345	17	345	20.97
346.00	13.00	346	22.5	346	18.8	346	21.7
347.00	13.00	347	21.2	347	20	347	22.43
348.00	13.00	348	19.3	348	20	348	23.1454546
349.00	15.86	349	17.4	349	20	349	23.78
350.00	12.00	350	14	350	20	350	24.29
351.00	11.73	351	9.6	351	20	351	24.71
352.00	11.00	352	6.8	352	20	352	24.86
353.00	11.00	353	4.2	353	20	353	24.58
354.00	11.00	354	1.7	354	20	354	24.01
355.00	11.90	355	0.1	355	20	355	23.57
356.00	12.89	356	0	356	20	356	23
357.00	10.36	357	0	357	20	357	20.9636364
358.00	7.26	358	0	358	20	358	17.55
359.00	4.95	359	0	359	20	359	13.88
360.00	4.68	360	0	360	20	360	9.77
361.00	6.68	361	0	361	20	361	4.83
362.00	8.00	362	0	362	20	362	1.1125
363.00	7.84	363	0	363	20	363	0.1
364.00	7.00	364	0	364	20	364	0
365.00	6.53	365	0	365	20	365	0
366.00	7.89	366	0	366	15.3	366	0
367.00	10.57	367	0	367	10.9	367	0
368.00	11.00	368	0	368	6.5	368	0
369.00	10.10	369	0	369	2	369	0
370.00	10.74	370	0	370	0	370	0
371.00	10.42	371	0	371	0	371	0
372.00	11.00	372	0	372	0	372	0
373.00	12.46	373	0	373	0	373	0
374.00	14.77	374	0.6	374	0	374	0
375.00	14.09	375	2.4	375	0	375	0
376.00	16.20	376	4.8	376	0	376	0.98
377.00	17.00	377	7.5	377	1.6	377	4.21
378.00	17.00	378	10	378	3.9	378	7.76
379.00	17.00	379	11.9	379	6.1	379	10.46
380.00	17.00	380	13.2	380	8.2	380	12.82
381.00	15.02	381	14.1	381	10.3	381	14.99
382.00	15.71	382	13.8	382	12.2	382	16.95
383.00	14.00	383	13.3	383	14.1	383	18.83
384.00	14.92	384	12.7	384	16	384	20.66
385.00	15.38	385	11.6	385	17.7	385	22.18

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
386.00	15.78	386	9.5	386	19.5	386	23.58
387.00	16.00	387	7.2	387	20	387	24.76
388.00	16.00	388	4.1	388	20	388	25.93
389.00	16.25	389	2.1	389	20	389	27.11
390.00	17.41	390	1.3	390	20	390	28.19
391.00	18.56	391	1.1	391	20	391	29.3
392.00	19.00	392	1.5	392	20	392	30.35
393.00	19.88	393	2.3	393	20	393	31.25
394.00	21.00	394	3	394	20	394	32.14
395.00	21.00	395	4.5	395	20	395	32.97
396.00	21.00	396	6.2	396	20	396	33.54
397.00	20.49	397	7.5	397	20	397	33.73
398.00	20.00	398	8.4	398	20	398	34.12
399.00	19.18	399	8.3	399	20	399	34.77
400.00	19.00	400	8.4	400	20	400	35.52
401.00	18.86	401	8.6	401	20	401	35.67
402.00	18.29	402	8.8	402	20	402	34.3818182
403.00	19.00	403	8.6	403	20	403	31.49
404.00	19.61	404	7	404	20	404	28.21
405.00	20.00	405	6.5	405	18	405	24.55
406.00	20.00	406	6.5	406	13.6	406	21.06
407.00	20.00	407	6.8	407	9.1	407	17.75
408.00	20.00	408	5.4	408	4.7	408	14.31
409.00	20.00	409	3.8	409	0.2	409	11.47
410.00	19.45	410	4.1	410	0	410	8.69
411.00	20.42	411	3.9	411	0	411	6.05
412.00	21.87	412	4	412	0	412	3.25
413.00	20.97	413	4.3	413	0	413	1.05
414.00	20.37	414	4.2	414	0	414	0.1
415.00	22.00	415	2.4	415	0	415	0
416.00	22.00	416	0.8	416	0.2	416	0
417.00	22.66	417	0.4	417	2.5	417	0
418.00	23.00	418	0	418	4.8	418	0
419.00	23.97	419	0	419	7	419	0
420.00	25.51	420	0	420	9	420	0
421.00	29.00	421	0	421	11.1	421	0
422.00	29.00	422	0	422	13	422	0
423.00	29.00	423	0	423	14.9	423	0
424.00	30.51	424	0	424	16.7	424	0
425.00	31.00	425	0	425	18.4	425	0
426.00	30.00	426	0	426	20	426	0
427.00	30.00	427	0	427	20	427	0.22
428.00	30.00	428	0	428	20	428	1.54
429.00	30.54	429	0	429	20	429	5.2
430.00	31.00	430	0	430	20	430	8.85
431.00	31.86	431	0	431	20	431	11.89
432.00	31.00	432	0	432	20	432	14.23
433.00	31.17	433	0	433	20	433	15.64
434.00	32.33	434	0	434	20	434	16.72

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
435.00	33.00	435	0	435	20	435	18.02
436.00	33.00	436	0	436	20	436	19.39
437.00	33.80	437	1	437	20	437	21.08
438.00	34.00	438	2.6	438	20	438	22.44
439.00	35.12	439	4.2	439	20	439	21.47
440.00	36.00	440	7.4	440	20	440	19.17
441.00	36.00	441	10.5	441	20	441	15.77
442.00	34.82	442	12.4	442	20	442	11.9
443.00	33.25	443	14.1	443	20	443	7.88
444.00	32.09	444	15.3	444	20	444	4.77
445.00	32.00	445	16.4	445	16.2	445	1.84
446.00	32.00	446	18.9	446	11.8	446	0.275
447.00	32.00	447	21.1	447	7.3	447	0.66666667
448.00	32.00	448	22.3	448	2.9	448	2.68181818
449.00	32.00	449	23.3	449	0	449	5.26
450.00	32.85	450	24.2	450	0	450	7.85
451.00	33.01	451	23.3	451	0	451	10.43
452.00	34.00	452	22.1	452	0	452	12.87
453.00	33.68	453	20.2	453	0	453	15.18
454.00	32.52	454	18.2	454	0	454	17.25
455.00	32.00	455	15.5	455	0	455	19.24
456.00	32.00	456	12.7	456	1.1	456	20.9545455
457.00	32.95	457	7.1	457	3.4	457	22.18
458.00	33.00	458	2.2	458	5.7	458	22.78
459.00	33.00	459	0.2	459	7.8	459	23.18
460.00	33.42	460	0	460	9.9	460	23.45
461.00	34.00	461	0	461	11.9	461	23.78
462.00	34.74	462	0	462	13.8	462	24.06
463.00	35.00	463	0	463	15.6	463	24.23
464.00	35.00	464	0	464	17.4	464	24.14
465.00	35.00	465	0	465	19.1	465	24.0090909
466.00	35.00	466	0	466	20	466	23.97
467.00	35.00	467	0	467	20	467	23.94
468.00	35.00	468	0	468	20	468	23.91
469.00	35.84	469	0	469	20	469	23.86
470.00	37.99	470	0	470	20	470	24
471.00	38.00	471	0	471	20	471	24.31
472.00	37.69	472	0	472	20	472	24.46
473.00	38.41	473	0	473	20	473	24.7454546
474.00	39.37	474	0	474	20	474	24.97
475.00	39.00	475	0	475	20	475	25.21
476.00	39.00	476	0	476	20	476	25.3
477.00	38.10	477	0	477	20	477	25.37
478.00	39.00	478	1.3	478	20	478	25.38
479.00	39.41	479	2.4	479	20	479	25.35
480.00	40.57	480	3.6	480	20	480	25.22
481.00	41.73	481	5.4	481	20	481	25.2454546
482.00	42.00	482	6.7	482	20	482	25.42
483.00	41.92	483	7.9	483	20	483	25.63

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
484.00	40.00	484	9	484	18.9	484	25.82
485.00	40.00	485	10	485	14.5	485	25.68
486.00	39.49	486	10.7	486	10	486	25.65
487.00	37.66	487	11.5	487	5.6	487	25.59
488.00	37.00	488	11.8	488	1.1	488	25.54
489.00	36.01	489	12.5	489	0	489	25.67
490.00	34.86	490	12.9	490	0	490	25.7
491.00	33.70	491	13.7	491	0	491	25.66
492.00	32.54	492	14.1	492	0	492	25.62
493.00	29.54	493	14.5	493	0	493	25.58
494.00	26.46	494	14.8	494	0	494	25.58
495.00	22.28	495	15	495	0	495	25.58
496.00	19.91	496	15.3	496	2.1	496	25.53
497.00	18.76	497	15.5	497	4.3	497	25.51
498.00	17.60	498	15.7	498	6.5	498	25.4090909
499.00	16.44	499	15.7	499	8.6	499	25.31
500.00	14.57	500	15.2	500	10.7	500	25.21
501.00	13.13	501	15.6	501	12.6	501	25.07
502.00	11.97	502	15.5	502	14.5	502	24.89
503.00	10.81	503	15.6	503	16.3	503	24.44
504.00	9.31	504	15.4	504	18.1	504	23.27
505.00	7.50	505	14.7	505	19.8	505	20.81
506.00	6.34	506	15.2	506	20	506	17.79
507.00	4.37	507	15.3	507	20	507	14.5636364
508.00	3.03	508	15.3	508	20	508	11.63
509.00	1.87	509	15.3	509	20	509	8.63
510.00	0.71	510	15.3	510	20	510	5.17
511.00	0.00	511	15.3	511	20	511	2.32
512.00	0.00	512	15.2	512	20	512	0.88
513.00	0.00	513	15.3	513	20	513	0.175
514.00	0.00	514	15.4	514	20	514	0
515.00	0.00	515	15.1	515	20	515	0
516.00	0.00	516	15.5	516	20	516	0
517.00	0.00	517	16	517	20	517	0
518.00	0.00	518	16.4	518	20	518	0
519.00	0.00	519	17	519	20	519	0
520.00	0.00	520	16.8	520	20	520	0
521.00	0.00	521	17.4	521	20	521	0
522.00	0.00	522	17.9	522	20	522	0
523.00	0.00	523	16.8	523	20	523	0
524.00	0.00	524	15.4	524	17.1	524	0
525.00	0.00	525	13.6	525	12.7	525	0
526.00	0.00	526	11.2	526	8.2	526	0.13333333
527.00	0.00	527	8.3	527	3.8	527	0.98181818
528.00	0.00	528	4.9	528	0	528	3.09
529.00	0.00	529	1.6	529	0	529	5.66
530.00	0.00	530	0.1	530	0	530	8.35
531.00	0.00	531	0	531	0	531	10.93
532.00	0.00	532	0	532	0	532	13.38

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
533.00	0.00	533	0	533	0	533	15.09
534.00	0.00	534	0	534	0	534	15.82
535.00	0.00	535	0	535	0.7	535	16.56
536.00	0.00	536	0	536	3	536	17.4545455
537.00	0.00	537	0	537	5.2	537	18.41
538.00	0.00	538	0	538	7.4	538	19.32
539.00	0.00	539	0	539	9.5	539	20.2
540.00	0.00	540	0	540	11.5	540	20.85
541.00	0.00	541	0	541	13.4	541	21.1
542.00	0.00	542	0	542	15.3	542	21.27
543.00	0.00	543	0	543	17	543	21.18
544.00	2.36	544	0	544	18.8	544	21.0454546
545.00	3.94	545	0	545	20	545	21.09
546.00	5.31	546	0	546	20	546	21.39
547.00	8.26	547	0	547	20	547	21.69
548.00	9.42	548	0	548	20	548	21.79
549.00	11.15	549	0	549	20	549	21.65
550.00	12.73	550	0.3	550	20	550	21.65
551.00	14.78	551	0.6	551	20	551	21.9
552.00	16.05	552	2.8	552	20	552	22.23
553.00	17.41	553	4.9	553	20	553	22.5909091
554.00	19.72	554	7.1	554	20	554	22.94
555.00	21.52	555	11.7	555	20	555	23.42
556.00	23.35	556	13.4	556	20	556	23.75
557.00	24.83	557	14.9	557	20	557	24.02
558.00	25.99	558	17.7	558	20	558	24.17
559.00	27.15	559	20.1	559	20	559	24.36
560.00	28.31	560	20.6	560	20	560	24.42
561.00	29.46	561	20.9	561	20	561	24.3909091
562.00	30.62	562	21.4	562	20	562	24.27
563.00	31.78	563	23.5	563	20	563	23.93
564.00	32.94	564	24	564	15.3	564	23.5
565.00	34.18	565	24.3	565	10.9	565	22.84
566.00	36.25	566	23.9	566	6.5	566	22.15
567.00	37.41	567	23.5	567	2	567	21.59
568.00	38.56	568	22	568	0	568	20.98
569.00	39.72	569	19.4	569	0	569	19.71
570.00	40.00	570	17.1	570	0	570	16.8272727
571.00	40.00	571	14.7	571	0	571	12.46
572.00	40.00	572	10.1	572	0	572	8.45
573.00	40.00	573	6.4	573	0	573	4.85
574.00	40.00	574	4.7	574	0	574	1.82
575.00	40.00	575	3.3	575	0	575	0.51428571
576.00	40.82	576	2.2	576	0	576	0
577.00	41.00	577	1.1	577	0	577	0
578.00	41.00	578	0.1	578	0	578	0
579.00	41.30	579	0	579	0	579	0
580.00	42.00	580	0	580	0	580	0
581.00	42.00	581	0	581	0	581	0

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
582.00	42.00	582	0	582	0	582	0
583.00	42.93	583	0	583	0	583	0
584.00	43.00	584	0	584	0	584	0
585.00	43.00	585	0	585	0	585	0
586.00	43.00	586	0	586	0	586	0
587.00	43.56	587	0	587	0	587	0
588.00	44.71	588	0	588	0	588	0.1
589.00	45.00	589	0	589	0	589	0.69
590.00	44.97	590	0	590	0	590	3.05
591.00	44.18	591	0	591	0	591	4.99
592.00	44.66	592	0	592	0	592	7.09
593.00	44.00	593	0	593	0	593	8.45
594.00	44.00	594	0	594	0.2	594	7.24
595.00	44.81	595	0	595	2.5	595	5.6
596.00	45.00	596	0	596	4.8	596	4.43
597.00	45.00	597	0	597	7	597	3.2
598.00	45.00	598	0	598	9	598	1.72
599.00	45.44	599	1.7	599	11.1	599	0.4875
600.00	46.00	600	4	600	13	600	0.15
601.00	46.00	601	5.9	601	14.9	601	0
602.00	46.92	602	7.3	602	16.7	602	0
603.00	47.00	603	7.7	603	18.4	603	0
604.00	47.00	604	8.1	604	20	604	0
605.00	47.00	605	8.8	605	20	605	0
606.00	47.00	606	9.5	606	20	606	0
607.00	47.00	607	11.2	607	20	607	0
608.00	47.00	608	11.3	608	20	608	0
609.00	47.04	609	11.5	609	20	609	0
610.00	49.00	610	10.9	610	20	610	0
611.00	49.33	611	10.4	611	20	611	0
612.00	49.51	612	11	612	20	612	0
613.00	49.00	613	11.5	613	20	613	0.23
614.00	49.00	614	11.9	614	20	614	0.54
615.00	49.00	615	12.5	615	20	615	1.76
616.00	49.00	616	12.3	616	20	616	4.18
617.00	48.72	617	11.5	617	20	617	7.07
618.00	48.87	618	11.3	618	20	618	9.64
619.00	50.00	619	11.5	619	20	619	12.1
620.00	50.00	620	11.9	620	20	620	14.59
621.00	50.00	621	11.2	621	20	621	16.8
622.00	50.00	622	11	622	20	622	18.71
623.00	49.78	623	11.1	623	16.2	623	20.45
624.00	49.00	624	11.8	624	11.8	624	22.03
625.00	49.00	625	12.7	625	7.3	625	23.45
626.00	49.69	626	13.1	626	2.9	626	24.75
627.00	50.00	627	12.4	627	0	627	25.97
628.00	50.00	628	9.7	628	0	628	27.01
629.00	50.00	629	6.2	629	0	629	28.09
630.00	49.68	630	3.5	630	0	630	29.16

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
631.00	49.00	631	1.1	631	0	631	30.21
632.00	49.00	632	0.3	632	0	632	31.26
633.00	48.20	633	0	633	0	633	32.15
634.00	48.00	634	0	634	1.1	634	33.05
635.00	48.00	635	0	635	3.4	635	33.82
636.00	48.27	636	0	636	5.7	636	34.61
637.00	49.00	637	0	637	7.8	637	35.42
638.00	49.58	638	0	638	9.9	638	36.09
639.00	50.00	639	0	639	11.9	639	36.8
640.00	50.00	640	0	640	13.8	640	37.38
641.00	50.00	641	0	641	15.6	641	38.05
642.00	50.00	642	0	642	17.4	642	38.6818182
643.00	50.00	643	0	643	19.1	643	39.34
644.00	50.00	644	0	644	20	644	39.86
645.00	50.00	645	0	645	20	645	40.41
646.00	50.00	646	0	646	20	646	40.63
647.00	50.00	647	0	647	20	647	39.81
648.00	50.00	648	0	648	20	648	37.98
649.00	50.00	649	0	649	20	649	35.89
650.00	50.47	650	0	650	20	650	33.71
651.00	51.00	651	0	651	20	651	31.62
652.00	51.00	652	0	652	20	652	29.47
653.00	51.00	653	1.6	653	20	653	28.02
654.00	51.00	654	3.5	654	20	654	26.56
655.00	51.00	655	5.4	655	20	655	24.67
656.00	51.42	656	8.1	656	20	656	22.02
657.00	52.00	657	11	657	20	657	19.47
658.00	52.00	658	14.3	658	20	658	16.04
659.00	52.00	659	16.7	659	20	659	12.49
660.00	52.00	660	18	660	20	660	8.9
661.00	52.20	661	19.1	661	20	661	5.63
662.00	53.00	662	21.1	662	18.9	662	2.86
663.00	53.00	663	22.8	663	14.5	663	0.725
664.00	53.00	664	23.4	664	10	664	0
665.00	53.00	665	23.8	665	5.6	665	0
666.00	53.00	666	22.4	666	1.1	666	0
667.00	53.00	667	20.7	667	0	667	0
668.00	53.00	668	18.9	668	0	668	0
669.00	53.00	669	16.2	669	0	669	0
670.00	52.38	670	14.6	670	0	670	0
671.00	52.00	671	13.1	671	0	671	0
672.00	52.93	672	9.9	672	0	672	0
673.00	52.91	673	6.3	673	0	673	0
674.00	52.25	674	4.2	674	2.1	674	0
675.00	53.00	675	2.2	675	4.3	675	0
676.00	53.00	676	1.1	676	6.5	676	0.23333333
677.00	53.00	677	0.1	677	8.6	677	1.15
678.00	53.00	678	0	678	10.7	678	2.4
679.00	53.00	679	0	679	12.6	679	3.7

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
680.00	53.00	680	0	680	14.5	680	4.77
681.00	53.00	681	0	681	16.3	681	5.87
682.00	53.00	682	0	682	18.1	682	7.47
683.00	53.00	683	0	683	19.8	683	9.14
684.00	53.00	684	0	684	20	684	10.76
685.00	53.98	685	0	685	20	685	12.15
686.00	55.00	686	0	686	20	686	13.41
687.00	55.00	687	0	687	20	687	14.41
688.00	55.00	688	0	688	20	688	15.4181818
689.00	55.00	689	0	689	20	689	16.09
690.00	55.00	690	0	690	20	690	16.48
691.00	55.00	691	0	691	20	691	16.89
692.00	55.00	692	0	692	20	692	17.21
693.00	55.00	693	0	693	20	693	17.51
694.00	55.00	694	0	694	20	694	17.79
695.00	55.00	695	0	695	20	695	18
696.00	55.00	696	0	696	20	696	18.2636364
697.00	55.00	697	0	697	20	697	18.47
698.00	55.00	698	1.5	698	20	698	18.66
699.00	55.00	699	3.3	699	20	699	18.86
700.00	55.00	700	4.9	700	20	700	19.03
701.00	54.50	701	6.8	701	20	701	19.16
702.00	54.66	702	8.6	702	17.1	702	19.29
703.00	55.00	703	10.3	703	12.7	703	18.98
704.00	54.03	704	11.6	704	8.2	704	18.4
705.00	54.00	705	11.8	705	3.8	705	17.91
706.00	54.00	706	11.8	706	0	706	17.48
707.00	54.00	707	11.6	707	0	707	17.14
708.00	54.00	708	11.3	708	0	708	16.77
709.00	54.00	709	11.5	709	0	709	16.13
710.00	54.00	710	11.6	710	0	710	14.16
711.00	54.00	711	11.8	711	0	711	11.96
712.00	54.00	712	9.1	712	0	712	9.78
713.00	54.77	713	6.2	713	0.7	713	7.43636364
714.00	56.00	714	4.1	714	3	714	4.9
715.00	56.00	715	2.9	715	5.2	715	2.52
716.00	56.00	716	3.6	716	7.4	716	0.89
717.00	56.02	717	4.6	717	9.5	717	0.13333333
718.00	57.00	718	5.5	718	11.5	718	0.1
719.00	56.67	719	4.5	719	13.4	719	0
720.00	56.00	720	2.2	720	15.3	720	0
721.00	56.00	721	1.5	721	17	721	0
722.00	56.00	722	1	722	18.8	722	0
723.00	56.00	723	1.8	723	20	723	0
724.00	56.00	724	3.1	724	20	724	0
725.00	56.00	725	4.7	725	20	725	0
726.00	56.00	726	5.9	726	20	726	0
727.00	56.00	727	8.4	727	20	727	0
728.00	56.00	728	9.6	728	20	728	0

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
729.00	56.91	729	10.8	729	20	729	0
730.00	57.00	730	11	730	20	730	0
731.00	57.00	731	10.7	731	20	731	0.12
732.00	57.00	732	10.6	732	20	732	0.25
733.00	57.00	733	10.5	733	20	733	0.35
734.00	57.00	734	10.3	734	20	734	0.64
735.00	57.85	735	10.1	735	20	735	0.84
736.00	58.00	736	10.2	736	20	736	0.9
737.00	58.00	737	9.3	737	20	737	0.9
738.00	58.00	738	7.8	738	20	738	0.97
739.00	58.00	739	6.7	739	20	739	1
740.00	58.00	740	7.2	740	20	740	1
741.00	58.00	741	8.2	741	20	741	0.9
742.00	58.00	742	9.5	742	15.3	742	1.25
743.00	58.00	743	10.8	743	10.9	743	2.75
744.00	58.00	744	11.9	744	6.5	744	4.99090909
745.00	57.15	745	12.7	745	2	745	7.46
746.00	56.00	746	13.4	746	0	746	9.89
747.00	56.00	747	14.1	747	0	747	12.32
748.00	56.00	748	13.2	748	0	748	14.63
749.00	56.00	749	13.4	749	0	749	16.26
750.00	56.00	750	13	750	0	750	17.26
751.00	55.63	751	10.8	751	0	751	18.12
752.00	55.00	752	7.7	752	0	752	18.65
753.00	55.00	753	4.4	753	1.6	753	19.0818182
754.00	55.00	754	1.8	754	3.9	754	19.41
755.00	55.00	755	2.1	755	6.1	755	19.4
756.00	55.00	756	2.8	756	8.2	756	19.45
757.00	55.00	757	2.2	757	10.3	757	19.72
758.00	55.00	758	0.8	758	12.2	758	19.58
759.00	55.00	759	0.1	759	14.1	759	19.16
760.00	54.22	760	0	760	16	760	17.98
761.00	54.00	761	0	761	17.7	761	16.5727273
762.00	54.00	762	0	762	19.5	762	15
763.00	54.00	763	0	763	20	763	11.56
764.00	54.00	764	0	764	20	764	8.14
765.00	54.00	765	0	765	20	765	5.22
766.00	54.00	766	0	766	20	766	3.8
767.00	54.00	767	0	767	20	767	2.48
768.00	54.00	768	0	768	20	768	0.75
769.00	54.00	769	0	769	20	769	0
770.00	54.00	770	0	770	20	770	0
771.00	54.00	771	0	771	20	771	0
772.00	54.00	772	0	772	20	772	0
773.00	54.00	773	0	773	20	773	0
774.00	53.01	774	0	774	20	774	0
775.00	50.86	775	0	775	20	775	0
776.00	49.70	776	0	776	20	776	0
777.00	48.54	777	0	777	20	777	0

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
778.00	47.39	778	0	778	20	778	0
779.00	46.23	779	1.3	779	20	779	0
780.00	45.07	780	2.7	780	20	780	0
781.00	43.91	781	6.8	781	18	781	0.2
782.00	42.51	782	9.5	782	13.6	782	1.17
783.00	40.60	783	11.9	783	9.1	783	3.18
784.00	39.44	784	15.9	784	4.7	784	5.67
785.00	38.28	785	19.3	785	0.2	785	8.18
786.00	37.13	786	21	786	0	786	10.53
787.00	35.94	787	22.5	787	0	787	12.7363636
788.00	33.81	788	24.2	788	0	788	13.65
789.00	32.66	789	24.2	789	0	789	14.22
790.00	30.50	790	22.8	790	0	790	15.16
791.00	28.34	791	21.3	791	0	791	16.25
792.00	26.37	792	19.6	792	0.2	792	17.3
793.00	25.03	793	17.9	793	2.5	793	17.78
794.00	21.87	794	14.1	794	4.8	794	18.13
795.00	19.85	795	9.1	795	7	795	18.28
796.00	16.56	796	6.8	796	9	796	18.6
797.00	15.40	797	4.8	797	11.1	797	18.76
798.00	14.24	798	2.5	798	13	798	18.97
799.00	12.17	799	0.2	799	14.9	799	19.18
800.00	10.71	800	0	800	16.7	800	19.41
801.00	6.08	801	0	801	18.4	801	19.59
802.00	2.61	802	0	802	20	802	19.82
803.00	1.45	803	0	803	20	803	19.9
804.00	0.30	804	0	804	20	804	19.7818182
805.00	0.00	805	0	805	20	805	19.55
806.00	0.00	806	0	806	20	806	19.16
807.00	0.00	807	0	807	20	807	18.69
808.00	0.00	808	0	808	20	808	18.43
809.00	0.00	809	0	809	20	809	17.38
810.00	0.00	810	0	810	20	810	15.5
811.00	0.00	811	0	811	20	811	13.8
812.00	0.00	812	0	812	20	812	12.31
813.00	0.00	813	0	813	20	813	10.6727273
814.00	0.00	814	0	814	20	814	9.42
815.00	0.00	815	0	815	20	815	8.09
816.00	0.00	816	0	816	20	816	6.6
817.00	0.00	817	0	817	20	817	4.86
818.00	0.00	818	0	818	20	818	3.61
819.00	0.00	819	1.6	819	20	819	3.14
820.00	0.00	820	2.7	820	20	820	2.88
821.00	0.00	821	3	821	16.2	821	2.68181818
822.00	0.00	822	3.8	822	11.8	822	2.69
823.00	0.00	823	5.1	823	7.3	823	2.63
824.00	0.00	824	7	824	2.9	824	2.6
825.00	0.00	825	8.4	825	0	825	2.53
826.00	0.00	826	9.9	826	0	826	2.5

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
827.00	0.00	827	11.3	827	0	827	2.5
828.00	0.00	828	13	828	0	828	2.68
829.00	0.00	829	14.5	829	0	829	3.56
830.00	0.00	830	15.5	830	0	830	4.34545455
831.00	0.19	831	16.6	831	0	831	4.18
832.00	1.00	832	17.5	832	1.1	832	3.9
833.00	1.51	833	17.1	833	3.4	833	4.78
834.00	2.66	834	17.9	834	5.7	834	6.24
835.00	4.64	835	16.8	835	7.8	835	8.05
836.00	6.96	836	16.4	836	9.9	836	10.04
837.00	8.86	837	16.1	837	11.9	837	12.05
838.00	7.71	838	16.4	838	13.8	838	13.7909091
839.00	7.45	839	16.4	839	15.6	839	15.31
840.00	9.22	840	16.1	840	17.4	840	16.28
841.00	10.00	841	16	841	19.1	841	16.43
842.00	9.08	842	14.7	842	20	842	15.75
843.00	10.08	843	13.1	843	20	843	14.64
844.00	11.24	844	11.7	844	20	844	13.99
845.00	12.79	845	9.4	845	20	845	12.32
846.00	14.00	846	6.8	846	20	846	9.35
847.00	12.58	847	4.1	847	20	847	5.14545455
848.00	12.87	848	2	848	20	848	1.08
849.00	13.00	849	0.2	849	20	849	0.15
850.00	13.00	850	0	850	20	850	0
851.00	13.68	851	0	851	20	851	0
852.00	15.00	852	0	852	20	852	0
853.00	15.00	853	0	853	20	853	0
854.00	13.37	854	0	854	20	854	0
855.00	12.03	855	0	855	20	855	0
856.00	12.26	856	0	856	20	856	0
857.00	14.29	857	0	857	20	857	0
858.00	14.56	858	0	858	20	858	0
859.00	15.20	859	0	859	20	859	0
860.00	16.76	860	0	860	18.9	860	0
861.00	17.00	861	0	861	14.5	861	0
862.00	17.00	862	0	862	10	862	0.54444444
863.00	17.23	863	0	863	5.6	863	3.28
864.00	18.77	864	0	864	1.1	864	7.3
865.00	20.54	865	0	865	0	865	10.56
866.00	19.60	866	0	866	0	866	13.49
867.00	18.14	867	0	867	0	867	16.27
868.00	17.98	868	0	868	0	868	18.74
869.00	17.00	869	0.2	869	0	869	20.88
870.00	16.34	870	2.3	870	0	870	22.68
871.00	15.00	871	3.3	871	0	871	24.44
872.00	15.00	872	4.1	872	2.1	872	25.78
873.00	15.00	873	5.9	873	4.3	873	25.65
874.00	15.96	874	8.6	874	6.5	874	23.71
875.00	12.35	875	11.3	875	8.6	875	22.31

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
876.00	15.28	876	15.5	876	10.7	876	22.38
877.00	14.27	877	17	877	12.6	877	22.83
878.00	12.59	878	18.2	878	14.5	878	23.59
879.00	12.25	879	20.1	879	16.3	879	24.69
880.00	9.28	880	22.8	880	18.1	880	26
881.00	8.00	881	24.1	881	19.8	881	26.52
882.00	8.00	882	25.3	882	20	882	26.83
883.00	8.38	883	25	883	20	883	26.76
884.00	9.53	884	23.8	884	20	884	26.94
885.00	10.69	885	22.5	885	20	885	27.28
886.00	11.00	886	21.2	886	20	886	27.91
887.00	9.00	887	19.3	887	20	887	28.83
888.00	9.00	888	17.4	888	20	888	29.94
889.00	9.32	889	14	889	20	889	30.98
890.00	10.00	890	9.6	890	20	890	31.95
891.00	9.36	891	6.8	891	20	891	32.94
892.00	9.00	892	4.2	892	20	892	33.94
893.00	9.95	893	1.7	893	20	893	34.88
894.00	14.33	894	0.1	894	20	894	35.68
895.00	17.53	895	0	895	20	895	35.46
896.00	19.42	896	0	896	20	896	34.15
897.00	20.00	897	0	897	20	897	32.48
898.00	20.74	898	0	898	20	898	31.94
899.00	21.00	899	0	899	20	899	32.13
900.00	21.11	900	0	900	17.1	900	32.5090909
901.00	23.84	901	0	901	12.7	901	32.83
902.00	27.00	902	0	902	8.2	902	31.85
903.00	27.00	903	0	903	3.8	903	29.25
904.00	29.05	904	0	904	0	904	26.18
905.00	32.52	905	0	905	0	905	22.75
906.00	31.01	906	0	906	0	906	19.47
907.00	31.00	907	0	907	0	907	16.14
908.00	31.62	908	0	908	0	908	12.37
909.00	33.00	909	0	909	0	909	8.44
910.00	32.37	910	0	910	0	910	5.04
911.00	30.43	911	0	911	0.7	911	2.12
912.00	30.00	912	0	912	3	912	0.325
913.00	30.00	913	0.6	913	5.2	913	0.35714286
914.00	30.51	914	2.4	914	7.4	914	2.46
915.00	32.41	915	4.8	915	9.5	915	6.28
916.00	33.00	916	7.5	916	11.5	916	9.4
917.00	32.27	917	10	917	13.4	917	12
918.00	32.00	918	11.9	918	15.3	918	14.52
919.00	31.04	919	13.2	919	17	919	16.68
920.00	32.20	920	14.1	920	18.8	920	18.36
921.00	33.36	921	13.8	921	20	921	19.35
922.00	34.00	922	13.3	922	20	922	20.32
923.00	34.00	923	12.7	923	20	923	20.96
924.00	34.00	924	11.6	924	20	924	20.58

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
925.00	33.01	925	9.5	925	20	925	19.93
926.00	31.86	926	7.2	926	20	926	19.97
927.00	30.10	927	4.1	927	20	927	20.29
928.00	26.17	928	2.1	928	20	928	20.68
929.00	23.39	929	1.3	929	20	929	20.95
930.00	21.46	930	1.1	930	20	930	21.15
931.00	17.28	931	1.5	931	20	931	21.39
932.00	15.83	932	2.3	932	20	932	21.81
933.00	13.76	933	3	933	20	933	22.26
934.00	12.60	934	4.5	934	20	934	22.64
935.00	10.33	935	6.2	935	20	935	22.71
936.00	8.28	936	7.5	936	20	936	22.58
937.00	5.38	937	8.4	937	20	937	22.28
938.00	2.91	938	8.3	938	20	938	21.41
939.00	0.00	939	8.4	939	20	939	20.2
940.00	0.00	940	8.6	940	15.3	940	19.06
941.00	0.00	941	8.8	941	10.9	941	18.39
942.00	0.00	942	8.6	942	6.5	942	18.43
943.00	0.00	943	7	943	2	943	18.78
944.00	0.00	944	6.5	944	0	944	19.36
945.00	0.00	945	6.5	945	0	945	19.65
946.00	0.00	946	6.8	946	0	946	18.8
947.00	0.00	947	5.4	947	0	947	16.84
948.00	0.00	948	3.8	948	0	948	14.77
949.00	0.00	949	4.1	949	0	949	12.63
950.00	0.00	950	3.9	950	0	950	10.51
951.00	0.00	951	4	951	1.6	951	8.47
952.00	0.00	952	4.3	952	3.9	952	7.21818182
953.00	0.00	953	4.2	953	6.1	953	7.35
954.00	0.00	954	2.4	954	8.2	954	7.57
955.00	0.00	955	0.8	955	10.3	955	7.59
956.00	0.00	956	0.4	956	12.2	956	7.25
957.00	0.00	957	0	957	14.1	957	6.5
958.00	0.00	958	0	958	16	958	6.48
959.00	0.00	959	0	959	17.7	959	6.12
960.00	0.00	960	0	960	19.5	960	5.26
961.00	0.00	961	0	961	20	961	4.55
962.00	0.00	962	0	962	20	962	4.04
963.00	0.00	963	0	963	20	963	3.53
964.00	0.00	964	0	964	20	964	3.12
965.00	0.00	965	0	965	20	965	2.11
966.00	0.00	966	0	966	20	966	1.35
967.00	0.00	967	0	967	20	967	0.73
968.00	0.00	968	0	968	20	968	0.23333333
969.00	0.00	969	0	969	20	969	0
970.00	0.00	970	0	970	20	970	0
971.00	0.00	971	0	971	20	971	0
972.00	0.00	972	0	972	20	972	0
973.00	0.00	973	0	973	20	973	0

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
974.00	0.00	974	0	974	20	974	0
975.00	0.00	975	0	975	20	975	0
976.00	0.00	976	1	976	20	976	0
977.00	0.00	977	2.6	977	20	977	0
978.00	0.00	978	4.2	978	20	978	0
979.00	0.00	979	7.4	979	18	979	0
980.00	0.51	980	10.5	980	13.6	980	0
981.00	0.33	981	12.4	981	9.1	981	0.21666667
982.00	0.00	982	14.1	982	4.7	982	0.96
983.00	0.00	983	15.3	983	0.2	983	2.24
984.00	0.00	984	16.4	984	0	984	3.98
985.00	0.00	985	18.9	985	0	985	5.95
986.00	0.00	986	21.1	986	0	986	7.71
987.00	0.00	987	22.3	987	0	987	9.27
988.00	0.00	988	23.3	988	0	988	10.78
989.00	0.00	989	24.2	989	0	989	12.22
990.00	0.00	990	23.3	990	0.2	990	13.6
991.00	0.00	991	22.1	991	2.5	991	14.91
992.00	0.00	992	20.2	992	4.8	992	16.04
993.00	0.00	993	18.2	993	7	993	17.05
994.00	0.00	994	15.5	994	9	994	17.84
995.00	0.00	995	12.7	995	11.1	995	18.37
996.00	0.00	996	7.1	996	13	996	18.98
997.00	0.00	997	2.2	997	14.9	997	19.61
998.00	0.00	998	0.2	998	16.7	998	20.2545455
999.00	0.00	999	0	999	18.4	999	20.82
1000.00	0.00	1000	0	1000	20	1000	21.13
1001.00	0.00	1001	0	1001	20	1001	21.4
1002.00	0.00	1002	0	1002	20	1002	21.78
1003.00	0.13	1003	0	1003	20	1003	22.31
1004.00	0.71	1004	0	1004	20	1004	22.87
1005.00	0.00	1005	0	1005	20	1005	23.38
1006.00	0.00	1006	0	1006	20	1006	23.79
1007.00	0.00	1007	0	1007	20	1007	24.2545455
1008.00	0.00	1008	0	1008	20	1008	24.71
1009.00	4.15	1009	0	1009	20	1009	25
1010.00	6.00	1010	0	1010	20	1010	25.17
1011.00	6.00	1011	0	1011	20	1011	25.37
1012.00	6.00	1012	0	1012	20	1012	25.84
1013.00	5.30	1013	0	1013	20	1013	26.35
1014.00	4.14	1014	0	1014	20	1014	26.79
1015.00	1.96	1015	0	1015	20	1015	27.1363636
1016.00	0.00	1016	0	1016	20	1016	27.4
1017.00	0.00	1017	1.3	1017	20	1017	27.51
1018.00	0.00	1018	2.4	1018	20	1018	27.61
1019.00	0.00	1019	3.6	1019	16.2	1019	27.69
1020.00	0.00	1020	5.4	1020	11.8	1020	27.64
1021.00	0.00	1021	6.7	1021	7.3	1021	27.5
1022.00	0.00	1022	7.9	1022	2.9	1022	27.35

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
1023.00	0.00	1023	9	1023	0	1023	27.32
1024.00	0.00	1024	10	1024	0	1024	27.2272727
1025.00	0.00	1025	10.7	1025	0	1025	27.15
1026.00	0.00	1026	11.5	1026	0	1026	27.1
1027.00	0.00	1027	11.8	1027	0	1027	27.1
1028.00	0.00	1028	12.5	1028	0	1028	26.95
1029.00	0.00	1029	12.9	1029	0	1029	26.81
1030.00	0.00	1030	13.7	1030	1.1	1030	26.66
1031.00	0.00	1031	14.1	1031	3.4	1031	26.41
1032.00	0.00	1032	14.5	1032	5.7	1032	26.2454546
1033.00	0.00	1033	14.8	1033	7.8	1033	25.86
1034.00	0.00	1034	15	1034	9.9	1034	25.61
1035.00	0.00	1035	15.3	1035	11.9	1035	25.45
1036.00	0.00	1036	15.5	1036	13.8	1036	25.22
1037.00	0.48	1037	15.7	1037	15.6	1037	25.07
1038.00	1.64	1038	15.7	1038	17.4	1038	25.13
1039.00	0.41	1039	15.2	1039	19.1	1039	25.14
1040.00	0.00	1040	15.6	1040	20	1040	24.94
1041.00	0.00	1041	15.5	1041	20	1041	24.7272727
1042.00	0.00	1042	15.6	1042	20	1042	24.49
1043.00	0.00	1043	15.4	1043	20	1043	24.23
1044.00	0.00	1044	14.7	1044	20	1044	23.82
1045.00	0.00	1045	15.2	1045	20	1045	23.19
1046.00	0.00	1046	15.3	1046	20	1046	22.6
1047.00	0.00	1047	15.3	1047	20	1047	21.78
1048.00	0.00	1048	15.3	1048	20	1048	20.49
1049.00	0.00	1049	15.3	1049	20	1049	17.8
1050.00	0.00	1050	15.3	1050	20	1050	15.09
1051.00	0.00	1051	15.2	1051	20	1051	12.18
1052.00	0.00	1052	15.3	1052	20	1052	8.33
1053.00	0.00	1053	15.4	1053	20	1053	4.87
1054.00	0.00	1054	15.1	1054	20	1054	2.48
1055.00	0.00	1055	15.5	1055	20	1055	1.28
1056.00	0.00	1056	16	1056	20	1056	0.42
1057.00	0.00	1057	16.4	1057	20	1057	0.1
1058.00	0.00	1058	17	1058	18.9	1058	0
1059.00	0.00	1059	16.8	1059	14.5	1059	0
1060.00	0.00	1060	17.4	1060	10	1060	0
1061.00	0.00	1061	17.9	1061	5.6	1061	0
1062.00	0.00	1062	16.8	1062	1.1	1062	0
1063.00	0.00	1063	15.4	1063	0	1063	0
1064.00	0.00	1064	13.6	1064	0	1064	0
1065.00	0.00	1065	11.2	1065	0	1065	0
1066.00	0.00	1066	8.3	1066	0	1066	0
1067.00	0.00	1067	4.9	1067	0	1067	0
1068.00	0.00	1068	1.6	1068	0	1068	0
1069.00	0.00	1069	0.1	1069	0	1069	0
1070.00	0.00	1070	0	1070	2.1	1070	0.1
1071.00	0.00	1071	0	1071	4.3	1071	0.46

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
1072.00	0.00	1072	0	1072	6.5	1072	1.91
1073.00	0.00	1073	0	1073	8.6	1073	4.21
1074.00	0.00	1074	0	1074	10.7	1074	6.78
1075.00	0.00	1075	0	1075	12.6	1075	9.43
1076.00	0.00	1076	0	1076	14.5	1076	11.96
1077.00	0.00	1077	0	1077	16.3	1077	14.04
1078.00	0.00	1078	0	1078	18.1	1078	15.82
1079.00	0.00	1079	0	1079	19.8	1079	17.0727273
1080.00	0.00	1080	0	1080	20	1080	17.9
1081.00	0.00	1081	0	1081	20	1081	18.36
1082.00	0.00	1082	0	1082	20	1082	18.67
1083.00	0.00	1083	0	1083	20	1083	18.92
1084.00	0.00	1084	0	1084	20	1084	19.07
1085.00	0.00	1085	0	1085	20	1085	19.25
1086.00	0.19	1086	0	1086	20	1086	19.33
1087.00	1.00	1087	0	1087	20	1087	19.4636364
1088.00	1.51	1088	0	1088	20	1088	19.57
1089.00	2.66	1089	0	1089	20	1089	19.63
1090.00	4.64	1090	0	1090	20	1090	19.68
1091.00	6.96	1091	0	1091	20	1091	19.79
1092.00	8.86	1092	0	1092	20	1092	19.96
1093.00	7.71	1093	0	1093	20	1093	19.98
1094.00	7.45	1094	0	1094	20	1094	19.99
1095.00	9.22	1095	0	1095	20	1095	20.04
1096.00	10.00	1096	0	1096	20	1096	20.0545455
1097.00	9.08	1097	0	1097	20	1097	19.64
1098.00	10.08	1098	0	1098	17.1	1098	18.85
1099.00	11.24	1099	0	1099	12.7	1099	17.94
1100.00	12.79	1100	0.3	1100	8.2	1100	17.17
1101.00	14.00	1101	0.6	1101	3.8	1101	16.68
1102.00	12.58	1102	2.8	1102	0	1102	16.23
1103.00	12.87	1103	4.9	1103	0	1103	15.7
1104.00	13.00	1104	7.1	1104	0	1104	15.3272727
1105.00	13.00	1105	11.7	1105	0	1105	15.64
1106.00	13.68	1106	13.4	1106	0	1106	16.35
1107.00	15.00	1107	14.9	1107	0	1107	17.14
1108.00	15.00	1108	17.7	1108	0	1108	17.68
1109.00	13.37	1109	20.1	1109	0.7	1109	18.22
1110.00	12.08	1110	20.6	1110	3	1110	18.51
1111.00	12.26	1111	20.9	1111	5.2	1111	18.58
1112.00	14.29	1112	21.4	1112	7.4	1112	18.5363636
1113.00	14.56	1113	23.5	1113	9.5	1113	18.31
1114.00	15.20	1114	24	1114	11.5	1114	17.29
1115.00	16.76	1115	24.3	1115	13.4	1115	16.24
1116.00	17.00	1116	23.9	1116	15.3	1116	15.67
1117.00	17.00	1117	23.5	1117	17	1117	14.99
1118.00	17.23	1118	22	1118	18.8	1118	13.38
1119.00	18.77	1119	19.4	1119	20	1119	10.91
1120.00	20.54	1120	17.1	1120	20	1120	7.84

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
1121.00	19.60	1121	14.7	1121	20	1121	3.86363636
1122.00	18.14	1122	10.1	1122	20	1122	0.75
1123.00	17.98	1123	6.4	1123	20	1123	0.1
1124.00	17.00	1124	4.7	1124	20	1124	0
1125.00	16.34	1125	3.3	1125	20	1125	0
1126.00	15.00	1126	2.2	1126	20	1126	0
1127.00	15.00	1127	1.1	1127	20	1127	0
1128.00	15.00	1128	0.1	1128	20	1128	0
1129.00	15.96	1129	0	1129	20	1129	0
1130.00	12.35	1130	0	1130	20	1130	0
1131.00	15.28	1131	0	1131	20	1131	0
1132.00	14.27	1132	0	1132	20	1132	0
1133.00	12.59	1133	0	1133	20	1133	0
1134.00	12.25	1134	0	1134	20	1134	0
1135.00	9.28	1135	0	1135	20	1135	0
1136.00	8.00	1136	0	1136	20	1136	0.26
1137.00	8.00	1137	0	1137	20	1137	1.18
1138.00	8.38	1138	0	1138	15.3	1138	3.06
1139.00	9.53	1139	0	1139	10.9	1139	5.6
1140.00	10.69	1140	0	1140	6.5	1140	8.23
1141.00	11.00	1141	0	1141	2	1141	10.87
1142.00	9.00	1142	0	1142	0	1142	13.34
1143.00	9.00	1143	0	1143	0	1143	15.3
1144.00	9.32	1144	0	1144	0	1144	15.99
1145.00	10.00	1145	0	1145	0	1145	16.36
1146.00	9.36	1146	0	1146	0	1146	16.85
1147.00	9.00	1147	0	1147	0	1147	17.34
1148.00	9.95	1148	0	1148	0	1148	17.7
1149.00	14.33	1149	1.7	1149	0	1149	18.01
1150.00	17.53	1150	4	1150	0	1150	18.29
1151.00	19.42	1151	5.9	1151	0	1151	18.52
1152.00	20.00	1152	7.3	1152	0	1152	18.7
1153.00	20.74	1153	7.7	1153	0	1153	18.89
1154.00	21.00	1154	8.1	1154	0	1154	19.06
1155.00	21.11	1155	8.8	1155	0	1155	18.77
1156.00	23.84	1156	9.5	1156	0	1156	17.65
1157.00	27.00	1157	11.2	1157	0	1157	16.59
1158.00	27.00	1158	11.3	1158	0	1158	14.68
1159.00	29.05	1159	11.5	1159	0	1159	11.97
1160.00	32.52	1160	10.9	1160	0	1160	9.03636364
1161.00	31.01	1161	10.4	1161	0	1161	5.88
1162.00	31.00	1162	11	1162	0	1162	2.76
1163.00	31.62	1163	11.5	1163	0	1163	0.6
1164.00	33.00	1164	11.9	1164	0	1164	0
1165.00	32.37	1165	12.5	1165	0	1165	0
1166.00	30.43	1166	12.3	1166	0	1166	0
1167.00	30.00	1167	11.5	1167	0	1167	0
1168.00	30.00	1168	11.3	1168	0.2	1168	0
1169.00	30.51	1169	11.5	1169	2.5	1169	0

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
1170.00	32.41	1170	11.9	1170	4.8	1170	0
1171.00	33.00	1171	11.2	1171	7	1171	0
1172.00	32.27	1172	11	1172	9	1172	0
1173.00	32.00	1173	11.1	1173	11.1	1173	0
1174.00	31.04	1174	11.8	1174	13	1174	0
1175.00	32.20	1175	12.7	1175	14.9	1175	0
1176.00	33.36	1176	13.1	1176	16.7	1176	0.18
1177.00	34.00	1177	12.4	1177	18.4	1177	1.65454546
1178.00	34.00	1178	9.7	1178	20	1178	5.71
1179.00	34.00	1179	6.2	1179	20	1179	9.38
1180.00	33.01	1180	3.5	1180	20	1180	12.42
1181.00	31.86	1181	1.1	1181	20	1181	13.56
1182.00	30.10	1182	0.3	1182	20	1182	13.74
1183.00	26.17	1183	0	1183	20	1183	14.51
1184.00	23.39	1184	0	1184	20	1184	15.32
1185.00	21.46	1185	0	1185	20	1185	16.76
1186.00	17.28	1186	0	1186	20	1186	18.72
1187.00	15.83	1187	0	1187	20	1187	20.78
1188.00	13.76	1188	0	1188	20	1188	22.74
1189.00	12.60	1189	0	1189	20	1189	24.52
1190.00	10.33	1190	0	1190	20	1190	26.3
1191.00	8.28	1191	0	1191	20	1191	26.81
1192.00	5.38	1192	0	1192	20	1192	25.48
1193.00	2.91	1193	0	1193	20	1193	25.46
1194.00	0.00	1194	0	1194	20	1194	26.24
1195.00	0.00	1195	0	1195	20	1195	27.37
1196.00	0.00	1196	0	1196	20	1196	28.73
1197.00	0.00	1197	0	1197	16.2	1197	29.36
1198.00	0.00	1198	0	1198	11.8	1198	27.82
1199.00	0.00	1199	0	1199	7.3	1199	24.38
1200.00	0.00	1200	0	1200	2.9	1200	20.99
1201.00	0.00	1201	0	1201	0	1201	16.35
1202.00	0.00	1202	0	1202	0	1202	11.31
1203.00	0.00	1203	1.6	1203	0	1203	6.18
1204.00	0.00	1204	3.5	1204	0	1204	2.52
1205.00	0.00	1205	5.4	1205	0	1205	0.55
1206.00	0.00	1206	8.1	1206	0	1206	0.34285714
1207.00	0.00	1207	11	1207	0	1207	2.28
1208.00	0.00	1208	14.3	1208	1.1	1208	5.91
1209.00	0.00	1209	16.7	1209	3.4	1209	8.97
1210.00	0.00	1210	18	1210	5.7	1210	11.59
1211.00	0.00	1211	19.1	1211	7.8	1211	12.43
1212.00	0.00	1212	21.1	1212	9.9	1212	10.6
1213.00	0.00	1213	22.8	1213	11.9	1213	8.23
1214.00	0.00	1214	23.4	1214	13.8	1214	5.91
1215.00	0.00	1215	23.8	1215	15.6	1215	4.74
1216.00	0.00	1216	22.4	1216	17.4	1216	3.22
1217.00	0.00	1217	20.7	1217	19.1	1217	1.52
1218.00	0.00	1218	18.9	1218	20	1218	0.36666667

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
1219.00	0.00	1219	16.2	1219	20	1219	0.45
1220.00	0.00	1220	14.6	1220	20	1220	2.79
1221.00	0.00	1221	13.1	1221	20	1221	6.47
1222.00	0.00	1222	9.9	1222	20	1222	9.47
1223.00	0.00	1223	6.3	1223	20	1223	12.09
1224.00	0.00	1224	4.2	1224	20	1224	14.41
1225.00	0.00	1225	2.2	1225	20	1225	13.91
1226.00	0.00	1226	1.1	1226	20	1226	11.78
1227.00	0.00	1227	0.1	1227	20	1227	8.82
1228.00	0.00	1228	0	1228	20	1228	6.23
1229.00	0.00	1229	0	1229	20	1229	3.54
1230.00	0.00	1230	0	1230	20	1230	1.04
1231.00	0.00	1231	0	1231	20	1231	0.1
1232.00	0.00	1232	0	1232	20	1232	0
1233.00	0.00	1233	0	1233	20	1233	0
1234.00	0.00	1234	0	1234	20	1234	0
1235.00	0.51	1235	0	1235	20	1235	0
1236.00	0.33	1236	0	1236	18.9	1236	0
1237.00	0.00	1237	0	1237	14.5	1237	0
1238.00	0.00	1238	0	1238	10	1238	0
1239.00	0.00	1239	0	1239	5.6	1239	0
1240.00	0.00	1240	0	1240	1.1	1240	0
1241.00	0.00	1241	0	1241	0	1241	0
1242.00	0.00	1242	0	1242	0	1242	0
1243.00	0.00	1243	0	1243	0	1243	0
1244.00	0.00	1244	0	1244	0	1244	0.22
1245.00	0.00	1245	0	1245	0	1245	1.63
1246.00	0.00	1246	0	1246	0	1246	5.13
1247.00	0.00	1247	0	1247	0	1247	8.45
1248.00	0.00	1248	1.5	1248	2.1	1248	10.86
1249.00	0.00	1249	3.3	1249	4.3	1249	13.01
1250.00	0.00	1250	4.9	1250	6.5	1250	14.99
1251.00	0.00	1251	6.8	1251	8.6	1251	16.85
1252.00	0.00	1252	8.6	1252	10.7	1252	18.42
1253.00	0.00	1253	10.3	1253	12.6	1253	19.17
1254.00	0.00	1254	11.6	1254	14.5	1254	20.07
1255.00	0.00	1255	11.8	1255	16.3	1255	21.18
1256.00	0.00	1256	11.8	1256	18.1	1256	22.52
1257.00	0.00	1257	11.6	1257	19.8	1257	23.54
1258.00	0.13	1258	11.3	1258	20	1258	24.7
1259.00	0.71	1259	11.5	1259	20	1259	25.5
1260.00	0.00	1260	11.6	1260	20	1260	26.21
1261.00	0.00	1261	11.8	1261	20	1261	27.02
1262.00	0.00	1262	9.1	1262	20	1262	27.93
1263.00	0.00	1263	6.2	1263	20	1263	28.5
1264.00	4.15	1264	4.1	1264	20	1264	28.54
1265.00	6.00	1265	2.9	1265	20	1265	28.75
1266.00	6.00	1266	3.6	1266	20	1266	28.72
1267.00	6.00	1267	4.6	1267	20	1267	28.72

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
1268.00	5.30	1268	5.5	1268	20	1268	28.78
1269.00	4.14	1269	4.5	1269	20	1269	29.1
1270.00	1.96	1270	2.2	1270	20	1270	29.65
1271.00	0.00	1271	1.5	1271	20	1271	30.51
1272.00	0.00	1272	1	1272	20	1272	31.12
1273.00	0.00	1273	1.8	1273	20	1273	30.3272727
1274.00	0.00	1274	3.1	1274	20	1274	28.31
1275.00	0.00	1275	4.7	1275	20	1275	26.37
1276.00	0.00	1276	5.9	1276	17.1	1276	24.39
1277.00	0.00	1277	8.4	1277	12.7	1277	22.38
1278.00	0.00	1278	9.6	1278	8.2	1278	20.4
1279.00	0.00	1279	10.8	1279	3.8	1279	18.3
1280.00	0.00	1280	11	1280	0	1280	16.19
1281.00	0.00	1281	10.7	1281	0	1281	14.01
1282.00	0.00	1282	10.6	1282	0	1282	11.8
1283.00	0.00	1283	10.5	1283	0	1283	9.63
1284.00	0.00	1284	10.3	1284	0	1284	7.58
1285.00	0.00	1285	10.1	1285	0	1285	6.53
1286.00	0.00	1286	10.2	1286	0	1286	6.79
1287.00	0.00	1287	9.3	1287	0.7	1287	7.19
1288.00	0.00	1288	7.8	1288	3	1288	7.7
1289.00	0.00	1289	6.7	1289	5.2	1289	7.95
1290.00	0.00	1290	7.2	1290	7.4	1290	6.8
1291.00	0.00	1291	8.2	1291	9.5	1291	5.56
1292.00	0.48	1292	9.5	1292	11.5	1292	4.67
1293.00	1.64	1293	10.8	1293	13.4	1293	3.98
1294.00	0.41	1294	11.9	1294	15.3	1294	3.22
1295.00	0.00	1295	12.7	1295	17	1295	2.03
1296.00	0.00	1296	13.4	1296	18.8	1296	0.72
1297.00	0.00	1297	14.1	1297	20	1297	0.13333333
1298.00	0.00	1298	13.2	1298	20	1298	0
1299.00	0.00	1299	13.4	1299	20	1299	0
1300.00	0.00	1300	13	1300	20	1300	0
1301.00	0.00	1301	10.8	1301	20	1301	0
1302.00	0.00	1302	7.7	1302	20	1302	0
1303.00	0.00	1303	4.4	1303	20	1303	0
1304.00	0.00	1304	1.8	1304	20	1304	0
1305.00	0.00	1305	2.1	1305	20	1305	0
1306.00	0.00	1306	2.8	1306	20	1306	0
1307.00	0.00	1307	2.2	1307	20	1307	0
1308.00	0.00	1308	0.8	1308	20	1308	0
1309.00	0.00	1309	0.1	1309	20	1309	0
1310.00	0.00	1310	0	1310	20	1310	0.75
1311.00	0.00	1311	0	1311	20	1311	3.89
1312.00	0.00	1312	0	1312	20	1312	7.33
1313.00	0.00	1313	0	1313	20	1313	10.04
1314.00	0.00	1314	0	1314	20	1314	12.59
1315.00	0.00	1315	0	1315	20	1315	14.88
1316.00	0.00	1316	0	1316	15.3	1316	15.07

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
1317.00	0.00	1317	0	1317	10.9	1317	14.56
1318.00	0.00	1318	0	1318	6.5	1318	14.2
1319.00	0.00	1319	0	1319	2	1319	12.13
1320.00	0.00	1320	0	1320	0	1320	9.67
1321.00	0.00	1321	0	1321	0	1321	7.38
1322.00	0.00	1322	0	1322	0	1322	5.2
1323.00	0.00	1323	0	1323	0	1323	2.79
1324.00	0.00	1324	0	1324	0	1324	0.74444444
1325.00	0.00	1325	0	1325	0	1325	0
1326.00	0.00	1326	0	1326	0	1326	0
1327.00	0.00	1327	0	1327	1.6	1327	0
1328.00	0.00	1328	0	1328	3.9	1328	0
1329.00	0.00	1329	1.3	1329	6.1	1329	0
1330.00	0.00	1330	2.7	1330	8.2	1330	0
1331.00	0.00	1331	6.8	1331	10.3	1331	0
1332.00	0.00	1332	9.5	1332	12.2	1332	0
1333.00	0.00	1333	11.9	1333	14.1	1333	0
1334.00	0.00	1334	15.9	1334	16	1334	0
1335.00	0.00	1335	19.3	1335	17.7	1335	0
1336.00	0.00	1336	21	1336	19.5	1336	0
1337.00	0.00	1337	22.5	1337	20	1337	0.15
1338.00	0.00	1338	24.2	1338	20	1338	1.13
1339.00	0.00	1339	24.2	1339	20	1339	4.47
1340.00	0.00	1340	22.8	1340	20	1340	8.03
1341.00	0.00	1341	21.3	1341	20	1341	10.88
1342.00	0.00	1342	19.6	1342	20	1342	13.51
1343.00	0.00	1343	17.9	1343	20	1343	15.98
1344.00	0.00	1344	14.1	1344	20	1344	18.1
1345.00	0.00	1345	9.1	1345	20	1345	19.96
1346.00	0.00	1346	6.8	1346	20	1346	21.69
1347.00	0.00	1347	4.8	1347	20	1347	23.21
1348.00	0.00	1348	2.5	1348	20	1348	24.66
1349.00	0.00	1349	0.2	1349	20	1349	25.97
1350.00	0.00	1350	0	1350	20	1350	27.2
1351.00	0.00	1351	0	1351	20	1351	28.34
1352.00	0.00	1352	0	1352	20	1352	29.44
1353.00	0.00	1353	0	1353	20	1353	30.59
1354.00	0.00	1354	0	1354	20	1354	31.66
1355.00	0.00	1355	0	1355	18	1355	32.66
1356.00	0.00	1356	0	1356	13.6	1356	33.62
1357.00	0.00	1357	0	1357	9.1	1357	34.57
1358.00	0.00	1358	0	1358	4.7	1358	35.45
1359.00	0.00	1359	0	1359	0.2	1359	36.03
1360.00	0.00	1360	0	1360	0	1360	34.66
1361.00	0.24	1361	0	1361	0	1361	31.01
1362.00	0.60	1362	0	1362	0	1362	27.98
1363.00	0.00	1363	0	1363	0	1363	24.96
1364.00	1.42	1364	0	1364	0	1364	21.03
1365.00	2.00	1365	0	1365	0	1365	17.2

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
1366.00	3.08	1366	0	1366	0.2	1366	13
1367.00	5.63	1367	0	1367	2.5	1367	8.36
1368.00	4.00	1368	0	1368	4.8	1368	4.44
1369.00	4.00	1369	1.6	1369	7	1369	1.73
1370.00	3.34	1370	2.7	1370	9	1370	0.33333333
1371.00	1.37	1371	3	1371	11.1	1371	0
1372.00	1.00	1372	3.8	1372	13	1372	0
1373.00	0.00	1373	5.1	1373	14.9	1373	0
1374.00	0.00	1374	7	1374	16.7	1374	0
1375.00	0.00	1375	8.4	1375	18.4	1375	0
1376.00	0.00	1376	9.9	1376	20	1376	0
1377.00	0.00	1377	11.3	1377	20	1377	0
1378.00	0.00	1378	13	1378	20	1378	0
1379.00	0.00	1379	14.5	1379	20	1379	0
1380.00	0.23	1380	15.5	1380	20	1380	0
1381.00	1.39	1381	16.6	1381	20	1381	0
1382.00	2.00	1382	17.5	1382	20	1382	0
1383.00	4.11	1383	17.1	1383	20	1383	0.1
1384.00	5.00	1384	17.9	1384	20	1384	0.83
1385.00	6.02	1385	16.8	1385	20	1385	3.01
1386.00	7.18	1386	16.4	1386	20	1386	5.61
1387.00	7.33	1387	16.1	1387	20	1387	8.25
1388.00	6.49	1388	16.4	1388	20	1388	10.47
1389.00	7.00	1389	16.4	1389	20	1389	12.04
1390.00	7.00	1390	16.1	1390	20	1390	13.3909091
1391.00	7.00	1391	16	1391	20	1391	14.6
1392.00	7.00	1392	14.7	1392	20	1392	15.7
1393.00	7.00	1393	13.1	1393	20	1393	16.67
1394.00	7.43	1394	11.7	1394	20	1394	17.56
1395.00	8.00	1395	9.4	1395	16.2	1395	18.21
1396.00	8.00	1396	6.8	1396	11.8	1396	18.82
1397.00	7.09	1397	4.1	1397	7.3	1397	19.35
1398.00	11.06	1398	2	1398	2.9	1398	19.8545455
1399.00	12.89	1399	0.2	1399	0	1399	20.32
1400.00	14.49	1400	0	1400	0	1400	20.83
1401.00	11.46	1401	0	1401	0	1401	21.28
1402.00	13.08	1402	0	1402	0	1402	21.58
1403.00	16.55	1403	0	1403	0	1403	21.72
1404.00	16.00	1404	0	1404	0	1404	21.78
1405.00	15.34	1405	0	1405	0	1405	21.74
1406.00	12.32	1406	0	1406	1.1	1406	21.76
1407.00	13.00	1407	0	1407	3.4	1407	21.9818182
1408.00	13.00	1408	0	1408	5.7	1408	22.22
1409.00	13.00	1409	0	1409	7.8	1409	22.4
1410.00	15.86	1410	0	1410	9.9	1410	22.51
1411.00	12.00	1411	0	1411	11.9	1411	22.33
1412.00	11.73	1412	0	1412	13.8	1412	21.97
1413.00	11.00	1413	0	1413	15.6	1413	21.56
1414.00	11.00	1414	0	1414	17.4	1414	21.31

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
1415.00	11.00	1415	0	1415	19.1	1415	21.2090909
1416.00	11.90	1416	0	1416	20	1416	21.17
1417.00	12.89	1417	0	1417	20	1417	21.08
1418.00	10.36	1418	0	1418	20	1418	20.89
1419.00	7.26	1419	0.2	1419	20	1419	20.81
1420.00	4.95	1420	2.3	1420	20	1420	20.37
1421.00	4.68	1421	3.3	1421	20	1421	19.77
1422.00	6.68	1422	4.1	1422	20	1422	19.38
1423.00	8.00	1423	5.9	1423	20	1423	17.39
1424.00	7.84	1424	8.6	1424	20	1424	14.2727273
1425.00	7.00	1425	11.3	1425	20	1425	10.34
1426.00	6.53	1426	15.5	1426	20	1426	6.46
1427.00	7.89	1427	17	1427	20	1427	3.56
1428.00	10.57	1428	18.2	1428	20	1428	1.75
1429.00	11.00	1429	20.1	1429	20	1429	0.45
1430.00	10.10	1430	22.8	1430	20	1430	0
1431.00	10.74	1431	24.1	1431	20	1431	0
1432.00	10.42	1432	25.3	1432	20	1432	0
1433.00	11.00	1433	25	1433	20	1433	0
1434.00	12.46	1434	23.8	1434	18.9	1434	0
1435.00	14.77	1435	22.5	1435	14.5	1435	0
1436.00	14.09	1436	21.2	1436	10	1436	0
1437.00	16.20	1437	19.3	1437	5.6	1437	0
1438.00	17.00	1438	17.4	1438	1.1	1438	0
1439.00	17.00	1439	14	1439	0	1439	0
1440.00	17.00	1440	9.6	1440	0	1440	0
1441.00	17.00	1441	6.8	1441	0	1441	0
1442.00	15.02	1442	4.2	1442	0	1442	0.225
1443.00	15.71	1443	1.7	1443	0	1443	0.88
1444.00	14.00	1444	0.1	1444	0	1444	1.82
1445.00	14.92	1445	0	1445	0	1445	2.83
1446.00	15.38	1446	0	1446	2.1	1446	4.25454546
1447.00	15.78	1447	0	1447	4.3	1447	5.76
1448.00	16.00	1448	0	1448	6.5	1448	6.99
1449.00	16.00	1449	0	1449	8.6	1449	7.92
1450.00	16.25	1450	0	1450	10.7	1450	8.86
1451.00	17.41	1451	0	1451	12.6	1451	9.77
1452.00	18.56	1452	0	1452	14.5	1452	10.57
1453.00	19.00	1453	0	1453	16.3	1453	11.28
1454.00	19.88	1454	0	1454	18.1	1454	12.0090909
1455.00	21.00	1455	0	1455	19.8	1455	12.61
1456.00	21.00	1456	0	1456	20	1456	13.15
1457.00	21.00	1457	0	1457	20	1457	13.76
1458.00	20.49	1458	0	1458	20	1458	14.4
1459.00	20.00	1459	0	1459	20	1459	15.05
1460.00	19.18	1460	0	1460	20	1460	15.6
1461.00	19.00	1461	0	1461	20	1461	16.06
1462.00	18.86	1462	0	1462	20	1462	16.53
1463.00	18.29	1463	0.6	1463	20	1463	16.9363636

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
1464.00	19.00	1464	2.4	1464	20	1464	17.38
1465.00	19.61	1465	4.8	1465	20	1465	17.66
1466.00	20.00	1466	7.5	1466	20	1466	17.92
1467.00	20.00	1467	10	1467	20	1467	18.19
1468.00	20.00	1468	11.9	1468	20	1468	18.39
1469.00	20.00	1469	13.2	1469	20	1469	18.55
1470.00	20.00	1470	14.1	1470	20	1470	18.65
1471.00	19.45	1471	13.8	1471	20	1471	18.8181818
1472.00	20.42	1472	13.3	1472	20	1472	19
1473.00	21.87	1473	12.7	1473	20	1473	19.18
1474.00	20.97	1474	11.6	1474	17.1	1474	19.36
1475.00	20.37	1475	9.5	1475	12.7	1475	19.58
1476.00	22.00	1476	7.2	1476	8.2	1476	19.7
1477.00	22.00	1477	4.1	1477	3.8	1477	19.88
1478.00	22.66	1478	2.1	1478	0	1478	20.01
1479.00	23.00	1479	1.3	1479	0	1479	20.22
1480.00	23.97	1480	1.1	1480	0	1480	20.2363636
1481.00	25.51	1481	1.5	1481	0	1481	20.07
1482.00	29.00	1482	2.3	1482	0	1482	19.63
1483.00	29.00	1483	3	1483	0	1483	19.38
1484.00	29.00	1484	4.5	1484	0	1484	18.98
1485.00	30.51	1485	6.2	1485	0.7	1485	18.59
1486.00	31.00	1486	7.5	1486	3	1486	17.09
1487.00	30.00	1487	8.4	1487	5.2	1487	13.42
1488.00	30.00	1488	8.3	1488	7.4	1488	9.11818182
1489.00	30.00	1489	8.4	1489	9.5	1489	4.98
1490.00	30.54	1490	8.6	1490	11.5	1490	1.22
1491.00	31.00	1491	8.8	1491	13.4	1491	0.1
1492.00	31.86	1492	8.6	1492	15.3	1492	0
1493.00	31.00	1493	7	1493	17	1493	0
1494.00	31.17	1494	6.5	1494	18.8	1494	0
1495.00	32.33	1495	6.5	1495	20	1495	0
1496.00	33.00	1496	6.8	1496	20	1496	0
1497.00	33.00	1497	5.4	1497	20	1497	0
1498.00	33.80	1498	3.8	1498	20	1498	0
1499.00	34.00	1499	4.1	1499	20	1499	0
1500.00	35.12	1500	3.9	1500	20	1500	0
1501.00	36.00	1501	4	1501	20	1501	0
1502.00	36.00	1502	4.3	1502	20	1502	0
1503.00	34.82	1503	4.2	1503	20	1503	0
1504.00	33.25	1504	2.4	1504	20	1504	0.13
1505.00	32.09	1505	0.8	1505	20	1505	0.2
1506.00	32.00	1506	0.4	1506	20	1506	0.31
1507.00	32.00	1507	0	1507	20	1507	0.43
1508.00	32.00	1508	0	1508	20	1508	0.55454546
1509.00	32.00	1509	0	1509	20	1509	1.54
1510.00	32.00	1510	0	1510	20	1510	3.46
1511.00	32.85	1511	0	1511	20	1511	5.77
1512.00	33.01	1512	0	1512	20	1512	7.98

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
1513.00	34.00	1513	0	1513	20	1513	10.12
1514.00	33.68	1514	0	1514	15.3	1514	11.35
1515.00	32.52	1515	0	1515	10.9	1515	11.05
1516.00	32.00	1516	0	1516	6.5	1516	10.1909091
1517.00	32.00	1517	0	1517	2	1517	9.59
1518.00	32.95	1518	0	1518	0	1518	8.26
1519.00	33.00	1519	0	1519	0	1519	5.97
1520.00	33.00	1520	0	1520	0	1520	4.03
1521.00	33.42	1521	0	1521	0	1521	1.31
1522.00	34.00	1522	0	1522	0	1522	0.13333333
1523.00	34.74	1523	0	1523	0	1523	0
1524.00	35.00	1524	0	1524	0	1524	0
1525.00	35.00	1525	0	1525	1.6	1525	0
1526.00	35.00	1526	1	1526	3.9	1526	0
1527.00	35.00	1527	2.6	1527	6.1	1527	0
1528.00	35.00	1528	4.2	1528	8.2	1528	0
1529.00	35.00	1529	7.4	1529	10.3	1529	0
1530.00	35.84	1530	10.5	1530	12.2	1530	0
1531.00	37.99	1531	12.4	1531	14.1	1531	0
1532.00	38.00	1532	14.1	1532	16	1532	0
1533.00	37.69	1533	15.3	1533	17.7	1533	0
1534.00	38.41	1534	16.4	1534	19.5	1534	0
1535.00	39.37	1535	18.9	1535	20	1535	0.16666667
1536.00	39.00	1536	21.1	1536	20	1536	0.4
1537.00	39.00	1537	22.3	1537	20	1537	1.01
1538.00	38.10	1538	23.3	1538	20	1538	1.89
1539.00	39.00	1539	24.2	1539	20	1539	2.87
1540.00	39.41	1540	23.3	1540	20	1540	3.95
1541.00	40.57	1541	22.1	1541	20	1541	5.14545455
1542.00	41.73	1542	20.2	1542	20	1542	6.31
1543.00	42.00	1543	18.2	1543	20	1543	7.41
1544.00	41.92	1544	15.5	1544	20	1544	8.53
1545.00	40.00	1545	12.7	1545	20	1545	9.51
1546.00	40.00	1546	7.1	1546	20	1546	10.42
1547.00	39.49	1547	2.2	1547	20	1547	11.22
1548.00	37.66	1548	0.2	1548	20	1548	11.92
1549.00	37.00	1549	0	1549	20	1549	12.6545455
1550.00	36.01	1550	0	1550	20	1550	13.5
1551.00	34.86	1551	0	1551	20	1551	14.29
1552.00	33.70	1552	0	1552	20	1552	14.98
1553.00	32.54	1553	0	1553	18	1553	15.5
1554.00	29.54	1554	0	1554	13.6	1554	15.68
1555.00	26.46	1555	0	1555	9.1	1555	15.8
1556.00	22.28	1556	0	1556	4.7	1556	16.06
1557.00	19.91	1557	0	1557	0.2	1557	16.4272727
1558.00	18.76	1558	0	1558	0	1558	16.74
1559.00	17.60	1559	0	1559	0	1559	16.9
1560.00	16.44	1560	0	1560	0	1560	17.11
1561.00	14.57	1561	0	1561	0	1561	17.26

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
1562.00	13.13	1562	0	1562	0	1562	17.23
1563.00	11.97	1563	0	1563	0	1563	17.3
1564.00	10.81	1564	0	1564	0.2	1564	17.29
1565.00	9.31	1565	0	1565	2.5	1565	17.57
1566.00	7.50	1566	0	1566	4.8	1566	17.8545455
1567.00	6.34	1567	1.3	1567	7	1567	18.04
1568.00	4.37	1568	2.4	1568	9	1568	18.01
1569.00	3.03	1569	3.6	1569	11.1	1569	17.86
1570.00	1.87	1570	5.4	1570	13	1570	17.48
1571.00	0.71	1571	6.7	1571	14.9	1571	17.17
1572.00	0.00	1572	7.9	1572	16.7	1572	16.9
1573.00	0.00	1573	9	1573	18.4	1573	16.58
1574.00	0.00	1574	10	1574	20	1574	16.6454546
1575.00	0.00	1575	10.7	1575	20	1575	16.97
1576.00	0.00	1576	11.5	1576	20	1576	16.99
1577.00	0.00	1577	11.8	1577	20	1577	16.79
1578.00	0.00	1578	12.5	1578	20	1578	16.62
1579.00	0.00	1579	12.9	1579	20	1579	16.35
1580.00	0.00	1580	13.7	1580	20	1580	16.01
1581.00	0.00	1581	14.1	1581	20	1581	15.31
1582.00	0.00	1582	14.5	1582	20	1582	15.05
1583.00	0.00	1583	14.8	1583	20	1583	13.8272727
1584.00	0.00	1584	15	1584	20	1584	10.88
1585.00	0.00	1585	15.3	1585	20	1585	8.28
1586.00	0.00	1586	15.5	1586	20	1586	5.36
1587.00	0.00	1587	15.7	1587	20	1587	1.65
1588.00	0.00	1588	15.7	1588	20	1588	0.25
1589.00	0.00	1589	15.2	1589	20	1589	1.47
1590.00	0.00	1590	15.6	1590	20	1590	4.11
1591.00	0.00	1591	15.5	1591	20	1591	6.94
1592.00	0.00	1592	15.6	1592	20	1592	8.51
1593.00	0.00	1593	15.4	1593	16.2	1593	8.57
1594.00	0.00	1594	14.7	1594	11.8	1594	8.54
1595.00	0.00	1595	15.2	1595	7.3	1595	9.20909091
1596.00	0.00	1596	15.3	1596	2.9	1596	9.94
1597.00	0.00	1597	15.3	1597	0	1597	10.31
1598.00	0.00	1598	15.3	1598	0	1598	10.02
1599.00	0.00	1599	15.3	1599	0	1599	9.11
1600.00	0.00	1600	15.3	1600	0	1600	7.69
1601.00	0.00	1601	15.2	1601	0	1601	5.98
1602.00	0.00	1602	15.3	1602	0	1602	2.97
1603.00	0.00	1603	15.4	1603	0	1603	0.6
1604.00	0.00	1604	15.1	1604	1.1	1604	0
1605.00	2.36	1605	15.5	1605	3.4	1605	0
1606.00	3.94	1606	16	1606	5.7	1606	0
1607.00	5.31	1607	16.4	1607	7.8	1607	0
1608.00	8.26	1608	17	1608	9.9	1608	0
1609.00	9.42	1609	16.8	1609	11.9	1609	0
1610.00	11.15	1610	17.4	1610	13.8	1610	0

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
1611.00	12.73	1611	17.9	1611	15.6	1611	0
1612.00	14.78	1612	16.8	1612	17.4	1612	0
1613.00	16.05	1613	15.4	1613	19.1	1613	0
1614.00	17.41	1614	13.6	1614	20	1614	0
1615.00	19.72	1615	11.2	1615	20	1615	0
1616.00	21.52	1616	8.3	1616	20	1616	0.16
1617.00	23.35	1617	4.9	1617	20	1617	1.25
1618.00	24.83	1618	1.6	1618	20	1618	3.46
1619.00	25.99	1619	0.1	1619	20	1619	6.08181818
1620.00	27.15	1620	0	1620	20	1620	8.79
1621.00	28.31	1621	0	1621	20	1621	11.36
1622.00	29.46	1622	0	1622	20	1622	13.7
1623.00	30.62	1623	0	1623	20	1623	15.25
1624.00	31.78	1624	0	1624	20	1624	16.23
1625.00	32.94	1625	0	1625	20	1625	17.14
1626.00	34.18	1626	0	1626	20	1626	17.99
1627.00	36.25	1627	0	1627	20	1627	18.7727273
1628.00	37.41	1628	0	1628	20	1628	19.43
1629.00	38.56	1629	0	1629	20	1629	20.06
1630.00	39.72	1630	0	1630	20	1630	20.65
1631.00	40.00	1631	0	1631	20	1631	21.22
1632.00	40.00	1632	0	1632	18.9	1632	21.79
1633.00	40.00	1633	0	1633	14.5	1633	22.18
1634.00	40.00	1634	0	1634	10	1634	22.54
1635.00	40.00	1635	0	1635	5.6	1635	22.8454546
1636.00	40.00	1636	0	1636	1.1	1636	23.15
1637.00	40.82	1637	0	1637	0	1637	23.4
1638.00	41.00	1638	0	1638	0	1638	23.59
1639.00	41.00	1639	0.3	1639	0	1639	23.29
1640.00	41.30	1640	0.6	1640	0	1640	22.34
1641.00	42.00	1641	2.8	1641	0	1641	21.37
1642.00	42.00	1642	4.9	1642	0	1642	20.65
1643.00	42.00	1643	7.1	1643	0	1643	19.82
1644.00	42.93	1644	11.7	1644	2.1	1644	17.0727273
1645.00	43.00	1645	13.4	1645	4.3	1645	13.53
1646.00	43.00	1646	14.9	1646	6.5	1646	11.36
1647.00	43.00	1647	17.7	1647	8.6	1647	9.65
1648.00	43.56	1648	20.1	1648	10.7	1648	7.88
1649.00	44.71	1649	20.6	1649	12.6	1649	6.46
1650.00	45.00	1650	20.9	1650	14.5	1650	6.55
1651.00	44.97	1651	21.4	1651	16.3	1651	7.56
1652.00	44.18	1652	23.5	1652	18.1	1652	9.01
1653.00	44.66	1653	24	1653	19.8	1653	10.8
1654.00	44.00	1654	24.3	1654	20	1654	12.63
1655.00	44.00	1655	23.9	1655	20	1655	14.25
1656.00	44.81	1656	23.5	1656	20	1656	15.8
1657.00	45.00	1657	22	1657	20	1657	16.99
1658.00	45.00	1658	19.4	1658	20	1658	17.77
1659.00	45.00	1659	17.1	1659	20	1659	18.67

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
1660.00	45.44	1660	14.7	1660	20	1660	19.26
1661.00	46.00	1661	10.1	1661	20	1661	19.9727273
1662.00	46.00	1662	6.4	1662	20	1662	20.79
1663.00	46.92	1663	4.7	1663	20	1663	21.4
1664.00	47.00	1664	3.3	1664	20	1664	20.87
1665.00	47.00	1665	2.2	1665	20	1665	19.66
1666.00	47.00	1666	1.1	1666	20	1666	18.68
1667.00	47.00	1667	0.1	1667	20	1667	16.35
1668.00	47.00	1668	0	1668	20	1668	13.31
1669.00	47.00	1669	0	1669	20	1669	10.0636364
1670.00	47.04	1670	0	1670	20	1670	6.34
1671.00	49.00	1671	0	1671	20	1671	1.74
1672.00	49.33	1672	0	1672	17.1	1672	0.45
1673.00	49.51	1673	0	1673	12.7	1673	2.93
1674.00	49.00	1674	0	1674	8.2	1674	6.63
1675.00	49.00	1675	0	1675	3.8	1675	9.72
1676.00	49.00	1676	0	1676	0	1676	12.47
1677.00	49.00	1677	0	1677	0	1677	15.07
1678.00	48.72	1678	0	1678	0	1678	17.29
1679.00	48.87	1679	0	1679	0	1679	19.06
1680.00	50.00	1680	0	1680	0	1680	20.59
1681.00	50.00	1681	0	1681	0	1681	20.8
1682.00	50.00	1682	0	1682	0	1682	18.46
1683.00	50.00	1683	0	1683	0.7	1683	15.56
1684.00	49.78	1684	0	1684	3	1684	12.47
1685.00	49.00	1685	0	1685	5.2	1685	8.84
1686.00	49.00	1686	0	1686	7.4	1686	5.57
1687.00	49.69	1687	0	1687	9.5	1687	2.71
1688.00	50.00	1688	1.7	1688	11.5	1688	0.6
1689.00	50.00	1689	4	1689	13.4	1689	0
1690.00	50.00	1690	5.9	1690	15.3	1690	0
1691.00	49.68	1691	7.3	1691	17	1691	0
1692.00	49.00	1692	7.7	1692	18.8	1692	0
1693.00	49.00	1693	8.1	1693	20	1693	0
1694.00	48.20	1694	8.8	1694	20	1694	0
1695.00	48.00	1695	9.5	1695	20	1695	0
1696.00	48.00	1696	11.2	1696	20	1696	0
1697.00	48.27	1697	11.3	1697	20	1697	0
1698.00	49.00	1698	11.5	1698	20	1698	0
1699.00	49.58	1699	10.9	1699	20	1699	0
1700.00	50.00	1700	10.4	1700	20	1700	0
1701.00	50.00	1701	11	1701	20	1701	0.24285714
1702.00	50.00	1702	11.5	1702	20	1702	1.6
1703.00	50.00	1703	11.9	1703	20	1703	3.96
1704.00	50.00	1704	12.5	1704	20	1704	6.67
1705.00	50.00	1705	12.3	1705	20	1705	9.33
1706.00	50.00	1706	11.5	1706	20	1706	12.0090909
1707.00	50.00	1707	11.3	1707	20	1707	14.38
1708.00	50.00	1708	11.5	1708	20	1708	16.13

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
1709.00	50.00	1709	11.9	1709	20	1709	17.43
1710.00	50.00	1710	11.2	1710	20	1710	18.54
1711.00	50.47	1711	11	1711	20	1711	19.34
1712.00	51.00	1712	11.1	1712	15.3	1712	20.04
1713.00	51.00	1713	11.8	1713	10.9	1713	20.64
1714.00	51.00	1714	12.7	1714	6.5	1714	21.23
1715.00	51.00	1715	13.1	1715	2	1715	21.7909091
1716.00	51.00	1716	12.4	1716	0	1716	22.34
1717.00	51.42	1717	9.7	1717	0	1717	22.75
1718.00	52.00	1718	6.2	1718	0	1718	23.26
1719.00	52.00	1719	3.5	1719	0	1719	23.65
1720.00	52.00	1720	1.1	1720	0	1720	24.07
1721.00	52.00	1721	0.3	1721	0	1721	24.37
1722.00	52.20	1722	0	1722	0	1722	24.37
1723.00	53.00	1723	0			1723	24.2
1724.00	53.00	1724	0			1724	24.05
1725.00	53.00	1725	0			1725	23.91
1726.00	53.00	1726	0			1726	23.88
1727.00	53.00	1727	0			1727	23.81
1728.00	53.00	1728	0			1728	23.74
1729.00	53.00	1729	0			1729	23.59
1730.00	53.00	1730	0			1730	23.41
1731.00	52.38	1731	0			1731	23.32
1732.00	52.00	1732	0			1732	22.7818182
1733.00	52.93	1733	0			1733	21.64
1734.00	52.91	1734	0			1734	20.73
1735.00	52.25	1735	0			1735	18.14
1736.00	53.00	1736	0			1736	14.96
1737.00	53.00	1737	0			1737	13.98
1738.00	53.00	1738	0			1738	14.01
1739.00	53.00	1739	0			1739	14.57
1740.00	53.00	1740	0			1740	15
1741.00	53.00	1741	0			1741	15.06
1742.00	53.00	1742	1.6			1742	15.86
1743.00	53.00	1743	3.5			1743	16.96
1744.00	53.00	1744	5.4			1744	18.2
1745.00	53.00	1745	8.1			1745	19.17
1746.00	53.98	1746	11			1746	19.65
1747.00	55.00	1747	14.3			1747	19.86
1748.00	55.00	1748	16.7			1748	20.4
1749.00	55.00	1749	18			1749	21.08
1750.00	55.00	1750	19.1			1750	21.28
1751.00	55.00	1751	21.1			1751	21.25
1752.00	55.00	1752	22.8			1752	21.52
1753.00	55.00	1753	23.4			1753	21.75
1754.00	55.00	1754	23.8			1754	21.8
1755.00	55.00	1755	22.4			1755	21.86
1756.00	55.00	1756	20.7			1756	21.99
1757.00	55.00	1757	18.9			1757	21.9181818

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
1758.00	55.00	1758	16.2			1758	22.04
1759.00	55.00	1759	14.6			1759	22.24
1760.00	55.00	1760	13.1			1760	22.4
1761.00	55.00	1761	9.9			1761	22.52
1762.00	54.50	1762	6.3			1762	22.63
1763.00	54.66	1763	4.2			1763	22.77
1764.00	55.00	1764	2.2			1764	22.9
1765.00	54.03	1765	1.1			1765	22.9909091
1766.00	54.00	1766	0.1			1766	23.17
1767.00	54.00	1767	0			1767	23.43
1768.00	54.00	1768	0			1768	23.69
1769.00	54.00	1769	0			1769	23.68
1770.00	54.00	1770	0			1770	23.65
1771.00	54.00	1771	0			1771	23.62
1772.00	54.00	1772	0			1772	23.73
1773.00	54.00	1773	0			1773	23.92
1774.00	54.77	1774	0			1774	24.0818182
1775.00	56.00	1775	0			1775	24.2
1776.00	56.00	1776	0			1776	24.39
1777.00	56.00	1777	0			1777	24.57
1778.00	56.02	1778	0			1778	24.72
1779.00	57.00	1779	0			1779	24.9
1780.00	56.67	1780	0			1780	25.17
1781.00	56.00	1781	0			1781	25.43
1782.00	56.00	1782	0			1782	25.6090909
1783.00	56.00	1783	0			1783	25.6
1784.00	56.00	1784	0			1784	25.55
1785.00	56.00	1785	0			1785	25.44
1786.00	56.00	1786	0			1786	25.38
1787.00	56.00	1787	1.5			1787	25.27
1788.00	56.00	1788	3.3			1788	25.18
1789.00	56.00	1789	4.9			1789	24.67
1790.00	56.91	1790	6.8			1790	24.29
1791.00	57.00	1791	8.6			1791	23.9363636
1792.00	57.00	1792	10.3			1792	22.08
1793.00	57.00	1793	11.6			1793	20.04
1794.00	57.00	1794	11.8			1794	17.26
1795.00	57.00	1795	11.8			1795	13.73
1796.00	57.85	1796	11.6			1796	9.7
1797.00	58.00	1797	11.3			1797	6.77
1798.00	58.00	1798	11.5			1798	3.46
1799.00	58.00	1799	11.6			1799	0.65555556
1800.00	58.00	1800	11.8			1800	0.1
1801.00	58.00	1801	9.1			1801	0
1802.00	58.00	1802	6.2			1802	0
1803.00	58.00	1803	4.1			1803	0
1804.00	58.00	1804	2.9			1804	0
1805.00	58.00	1805	3.6			1805	0
1806.00	57.15	1806	4.6			1806	0

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
1807.00	56.00	1807	5.5			1807	0
1808.00	56.00	1808	4.5			1808	0
1809.00	56.00	1809	2.2			1809	0
1810.00	56.00	1810	1.5			1810	0
1811.00	56.00	1811	1			1811	0
1812.00	55.63	1812	1.8			1812	0
1813.00	55.00	1813	3.1			1813	0.42
1814.00	55.00	1814	4.7			1814	1.7
1815.00	55.00	1815	5.9			1815	3.2
1816.00	55.00	1816	8.4			1816	4.84
1817.00	55.00	1817	9.6			1817	6.78181818
1818.00	55.00	1818	10.8			1818	8.67
1819.00	55.00	1819	11			1819	10.52
1820.00	55.00	1820	10.7			1820	12.18
1821.00	54.22	1821	10.6			1821	13.62
1822.00	54.00	1822	10.5			1822	15.04
1823.00	54.00	1823	10.3			1823	16.42
1824.00	54.00	1824	10.1			1824	17.57
1825.00	54.00	1825	10.2			1825	18.5909091
1826.00	54.00	1826	9.3			1826	19.44
1827.00	54.00	1827	7.8			1827	19.78
1828.00	54.00	1828	6.7			1828	20.05
1829.00	54.00	1829	7.2			1829	20.49
1830.00	54.00	1830	8.2			1830	20.86
1831.00	54.00	1831	9.5			1831	21.05
1832.00	54.00	1832	10.8			1832	21.51
1833.00	54.00	1833	11.9			1833	21.92
1834.00	54.00	1834	12.7			1834	22.0272727
1835.00	53.01	1835	13.4			1835	22.16
1836.00	50.86	1836	14.1			1836	22.16
1837.00	49.70	1837	13.2			1837	22.16
1838.00	48.54	1838	13.4			1838	22.24
1839.00	47.39	1839	13			1839	22.44
1840.00	46.23	1840	10.8			1840	22.81
1841.00	45.07	1841	7.7			1841	23.03
1842.00	43.91	1842	4.4			1842	23.4181818
1843.00	42.51	1843	1.8			1843	23.81
1844.00	40.60	1844	2.1			1844	24.1
1845.00	39.44	1845	2.8			1845	24.03
1846.00	38.28	1846	2.2			1846	24.09
1847.00	37.13	1847	0.8			1847	24.37
1848.00	35.94	1848	0.1			1848	24.62
1849.00	33.81	1849	0			1849	25.22
1850.00	32.66	1850	0			1850	26.0818182
1851.00	30.50	1851	0			1851	26.3
1852.00	28.34	1852	0			1852	25.89
1853.00	26.37	1853	0			1853	25.56
1854.00	25.03	1854	0			1854	25.16
1855.00	21.87	1855	0			1855	24.92

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
1856.00	19.85	1856	0			1856	24.97
1857.00	16.56	1857	0			1857	24.85
1858.00	15.40	1858	0			1858	24.99
1859.00	14.24	1859	0			1859	25.2454546
1860.00	12.17	1860	0			1860	25.47
1861.00	10.71	1861	0			1861	25.43
1862.00	6.08	1862	0			1862	25.46
1863.00	2.61	1863	0			1863	25.59
1864.00	1.45	1864	0			1864	25.85
1865.00	0.30	1865	0			1865	26.04
1866.00	0.00	1866	0			1866	26.21
1867.00	0.00	1867	0			1867	26.4
1868.00	0.00	1868	1.3			1868	26.52
1869.00	0.00	1869	2.7			1869	26.63
1870.00	0.00	1870	6.8			1870	26.58
1871.00	0.00	1871	9.5			1871	26.38
1872.00	0.00	1872	11.9			1872	26.17
1873.00	0.00	1873	15.9			1873	25.91
1874.00	0.00	1874	19.3			1874	25.59
1875.00	0.00	1875	21			1875	25.31
1876.00	0.00	1876	22.5			1876	25.0363636
1877.00	0.00	1877	24.2			1877	24.61
1878.00	0.00	1878	24.2			1878	24.25
1879.00	0.00	1879	22.8			1879	23.84
1880.00	0.00	1880	21.3			1880	22.15
1881.00	0.00	1881	19.6			1881	19.7
1882.00	0.00	1882	17.9			1882	17.01
1883.00	0.00	1883	14.1			1883	13.69
1884.00	0.00	1884	9.1			1884	10.2181818
1885.00	0.00	1885	6.8			1885	6.8
1886.00	0.00	1886	4.8			1886	4.38
1887.00	0.00	1887	2.5			1887	2.9
1888.00	0.00	1888	0.2			1888	1.07
1889.00	0.00	1889	0			1889	0.13333333
1890.00	0.00	1890	0			1890	0
1891.00	0.00	1891	0			1891	0
1892.00	0.19	1892	0			1892	0
1893.00	1.00	1893	0			1893	0
1894.00	1.51	1894	0			1894	0
1895.00	2.66	1895	0			1895	0
1896.00	4.64	1896	0			1896	0
1897.00	6.96	1897	0			1897	0
1898.00	8.86	1898	0			1898	0
1899.00	7.71	1899	0			1899	0
1900.00	7.45	1900	0			1900	0
1901.00	9.22	1901	0			1901	0
1902.00	10.00	1902	0			1902	0
1903.00	9.08	1903	0			1903	0
1904.00	10.08	1904	0			1904	0

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
1905.00	11.24	1905	0			1905	0
1906.00	12.79	1906	0			1906	0
1907.00	14.00	1907	0			1907	0
1908.00	12.58	1908	1.6			1908	0
1909.00	12.87	1909	2.7			1909	0
1910.00	13.00	1910	3				
1911.00	13.00	1911	3.8				
1912.00	13.68	1912	5.1				
1913.00	15.00	1913	7				
1914.00	15.00	1914	8.4				
1915.00	13.37	1915	9.9				
1916.00	12.03	1916	11.3				
1917.00	12.26	1917	13				
1918.00	14.29	1918	14.5				
1919.00	14.56	1919	15.5				
1920.00	15.20	1920	16.6				
1921.00	16.76	1921	17.5				
1922.00	17.00	1922	17.1				
1923.00	17.00	1923	17.9				
1924.00	17.23	1924	16.8				
1925.00	18.77	1925	16.4				
1926.00	20.54	1926	16.1				
1927.00	19.60	1927	16.4				
1928.00	18.14	1928	16.4				
1929.00	17.98	1929	16.1				
1930.00	17.00	1930	16				
1931.00	16.34	1931	14.7				
1932.00	15.00	1932	13.1				
1933.00	15.00	1933	11.7				
1934.00	15.00	1934	9.4				
1935.00	15.96	1935	6.8				
1936.00	12.35	1936	4.1				
1937.00	15.28	1937	2				
1938.00	14.27	1938	0.2				
1939.00	12.59	1939	0				
1940.00	12.25	1940	0				
1941.00	9.28	1941	0				
1942.00	8.00	1942	0				
1943.00	8.00	1943	0				
1944.00	8.38	1944	0				
1945.00	9.53	1945	0				
1946.00	10.69	1946	0				
1947.00	11.00	1947	0				
1948.00	9.00	1948	0				
1949.00	9.00	1949	0				
1950.00	9.32	1950	0				
1951.00	10.00	1951	0				
1952.00	9.36	1952	0				
1953.00	9.00	1953	0				

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
1954.00	9.95	1954	0				
1955.00	14.33	1955	0				
1956.00	17.53	1956	0				
1957.00	19.42	1957	0				
1958.00	20.00	1958	0.2				
1959.00	20.74	1959	2.3				
1960.00	21.00	1960	3.3				
1961.00	21.11	1961	4.1				
1962.00	23.84	1962	5.9				
1963.00	27.00	1963	8.6				
1964.00	27.00	1964	11.3				
1965.00	29.05	1965	15.5				
1966.00	32.52	1966	17				
1967.00	31.01	1967	18.2				
1968.00	31.00	1968	20.1				
1969.00	31.62	1969	22.8				
1970.00	33.00	1970	24.1				
1971.00	32.37	1971	25.3				
1972.00	30.43	1972	25				
1973.00	30.00	1973	23.8				
1974.00	30.00	1974	22.5				
1975.00	30.51	1975	21.2				
1976.00	32.41	1976	19.3				
1977.00	33.00	1977	17.4				
1978.00	32.27	1978	14				
1979.00	32.00	1979	9.6				
1980.00	31.04	1980	6.8				
1981.00	32.20	1981	4.2				
1982.00	33.36	1982	1.7				
1983.00	34.00	1983	0.1				
1984.00	34.00	1984	0				
1985.00	34.00	1985	0				
1986.00	33.01	1986	0				
1987.00	31.86	1987	0				
1988.00	30.10	1988	0				
1989.00	26.17	1989	0				
1990.00	23.39	1990	0				
1991.00	21.46	1991	0				
1992.00	17.28	1992	0				
1993.00	15.83	1993	0				
1994.00	13.76	1994	0				
1995.00	12.60	1995	0				
1996.00	10.33	1996	0				
1997.00	8.28	1997	0				
1998.00	5.38	1998	0				
1999.00	2.91	1999	0				
2000.00	0.00	2000	0				
2001.00	0.00	2001	0				
2002.00	0.00	2002	0.6				

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
2003.00	0.00	2003	2.4				
2004.00	0.00	2004	4.8				
2005.00	0.00	2005	7.5				
2006.00	0.00	2006	10				
2007.00	0.00	2007	11.9				
2008.00	0.00	2008	13.2				
2009.00	0.00	2009	14.1				
2010.00	0.00	2010	13.8				
2011.00	0.00	2011	13.3				
2012.00	0.00	2012	12.7				
2013.00	0.00	2013	11.6				
2014.00	0.00	2014	9.5				
2015.00	0.00	2015	7.2				
2016.00	0.00	2016	4.1				
2017.00	0.00	2017	2.1				
2018.00	0.00	2018	1.3				
2019.00	0.00	2019	1.1				
2020.00	0.00	2020	1.5				
2021.00	0.00	2021	2.3				
2022.00	0.00	2022	3				
2023.00	0.00	2023	4.5				
2024.00	0.00	2024	6.2				
2025.00	0.00	2025	7.5				
2026.00	0.00	2026	8.4				
2027.00	0.00	2027	8.3				
2028.00	0.00	2028	8.4				
2029.00	0.00	2029	8.6				
2030.00	0.00	2030	8.8				
2031.00	0.00	2031	8.6				
2032.00	0.00	2032	7				
2033.00	0.00	2033	6.5				
2034.00	0.00	2034	6.5				
2035.00	0.00	2035	6.8				
2036.00	0.00	2036	5.4				
2037.00	0.00	2037	3.8				
2038.00	0.00	2038	4.1				
2039.00	0.00	2039	3.9				
2040.00	0.00	2040	4				
2041.00	0.51	2041	4.3				
2042.00	0.33	2042	4.2				
2043.00	0.00	2043	2.4				
2044.00	0.00	2044	0.8				
2045.00	0.00	2045	0.4				
2046.00	0.00	2046	0				
2047.00	0.00	2047	0				
2048.00	0.00	2048	0				
2049.00	0.00	2049	0				
2050.00	0.00	2050	0				
2051.00	0.00	2051	0				

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
2052.00	0.00	2052	0				
2053.00	0.00	2053	0				
2054.00	0.00	2054	0				
2055.00	0.00	2055	0				
2056.00	0.00	2056	0				
2057.00	0.00	2057	0				
2058.00	0.00	2058	0				
2059.00	0.00	2059	0				
2060.00	0.00	2060	0				
2061.00	0.00	2061	0				
2062.00	0.00	2062	0				
2063.00	0.00	2063	0				
2064.00	0.13	2064	0				
2065.00	0.71	2065	1				
2066.00	0.00	2066	2.6				
2067.00	0.00	2067	4.2				
2068.00	0.00	2068	7.4				
2069.00	0.00	2069	10.5				
2070.00	4.15	2070	12.4				
2071.00	6.00	2071	14.1				
2072.00	6.00	2072	15.3				
2073.00	6.00	2073	16.4				
2074.00	5.30	2074	18.9				
2075.00	4.14	2075	21.1				
2076.00	1.96	2076	22.3				
2077.00	0.00	2077	23.3				
2078.00	0.00	2078	24.2				
2079.00	0.00	2079	23.3				
2080.00	0.00	2080	22.1				
2081.00	0.00	2081	20.2				
2082.00	0.00	2082	18.2				
2083.00	0.00	2083	15.5				
2084.00	0.00	2084	12.7				
2085.00	0.00	2085	7.1				
2086.00	0.00	2086	2.2				
2087.00	0.00	2087	0.2				
2088.00	0.00	2088	0				
2089.00	0.00	2089	0				
2090.00	0.00	2090	0				
2091.00	0.00	2091	0				
2092.00	0.00	2092	0				
2093.00	0.00	2093	0				
2094.00	0.00	2094	0				
2095.00	0.00	2095	0				
2096.00	0.00	2096	0				
2097.00	0.00	2097	0				
2098.00	0.48	2098	0				
2099.00	1.64	2099	0				
2100.00	0.41	2100	0				

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
2101.00	0.00	2101	0				
2102.00	0.00	2102	0				
2103.00	0.00	2103	0				
2104.00	0.00	2104	0				
2105.00	0.00	2105	0				
2106.00	0.00	2106	1.3				
2107.00	0.00	2107	2.4				
2108.00	0.00	2108	3.6				
2109.00	0.00	2109	5.4				
2110.00	0.00	2110	6.7				
2111.00	0.00	2111	7.9				
2112.00	0.00	2112	9				
2113.00	0.00	2113	10				
2114.00	0.00	2114	10.7				
2115.00	0.00	2115	11.5				
2116.00	0.00	2116	11.8				
2117.00	0.00	2117	12.5				
2118.00	0.00	2118	12.9				
2119.00	0.00	2119	13.7				
2120.00	0.00	2120	14.1				
2121.00	0.00	2121	14.5				
		2122	14.8				
35.38		2123	15				
		2124	15.3				
		2125	15.5				
		2126	15.7				
		2127	15.7				
		2128	15.2				
		2129	15.6				
		2130	15.5				
		2131	15.6				
		2132	15.4				
		2133	14.7				
		2134	15.2				
		2135	15.3				
		2136	15.3				
		2137	15.3				
		2138	15.3				
		2139	15.3				
		2140	15.2				
		2141	15.3				
		2142	15.4				
		2143	15.1				
		2144	15.5				
		2145	16				
		2146	16.4				
		2147	17				
		2148	16.8				
		2149	17.4				

TABLE A1—DRIVING CYCLES DATA

UDDS x 2 Time (s)	UDDS x 2 Speed (mph)	Manhattan x 2 Time (s)	Manhattan x 2 Speed (mph)	CBD x 3 Time (se	CBD x 3 Speed (mph)	Orange County Cycle Time (s)	Orange County Cycle Speed (mph)
		2150	17.9				
		2151	16.8				
		2152	15.4				
		2153	13.6				
		2154	11.2				
		2155	8.3				
		2156	4.9				
		2157	1.6				
		2158	0.1				
		2159	0				
		2160	0				
		2161	0				
		2162	0				
		2163	0				
		2164	0				
		2165	0				
		2166	0				
		2167	0				
		2168	0				
		2169	0				
		2170	0				
		2171	0				
		2172	0				
		2173	0				
		2174	0				
		2175	0				
		2176	0				
		2177	0				
		2178	0				

SAE J2711 Issued Prop Dft SEP2002

Rationale—Not applicable.

Relationship of SAE Standard to ISO Standard—Not applicable.

Application—This SAE Recommended Practice was established to provide an accurate, uniform and reproducible procedure for simulating use of heavy-duty hybrid-electric vehicles (HEVs) and conventional vehicles on dynamometers for the purpose of measuring emissions and fuel economy. Although the recommended practice can be applied using any driving cycle, the practice recommends three cycles: the Manhattan cycle, representing low-speed transit bus operation; the Orange County Transit Cycle, representing intermediate-speed bus operation; and the Urban Dynamometer Driving Schedule (UDDS) cycle representing high-speed operation for buses and tractor-trailers. This document does not specify which emissions constituents to measure (e.g., HC, CO, NO_x, PM, CO_2), as that decision will depend on the objectives of the tester. While the recommended practice was developed specifically to address the issue of measuring fuel economy and emissions for hybrid-electric heavy-duty vehicles on a chassis dynamometer, the document can also be applied to chassis testing of other heavy-duty vehicles.

This document builds upon SAE J1711, the light-duty HEV chassis recommended practice. As in SAE J1711, this document defines a hybrid vehicle as having both a rechargeable energy storage system (RESS) capable of releasing and capturing energy and an energy-generating device that converts consumable fuels into propulsion energy. RESS specifically included in the recommended practice are batteries, capacitors and flywheels, although other RESS can be evaluated utilizing the guidelines provided in the document. Further, the recommended practice provides a detailed description of state of charge (SOC) correction for charge-sustaining HEVs. This document also has a section which provides recommendations for calculating fuel economy and emissions for charge-depleting hybrid-electric vehicles. It should be noted that most heavy-duty vehicles addressed in this recommended practice would be powered by engines that are certified separately for emissions. The engine certification procedure appears in the Code of Federal Regulations, Title 40.

NOTE—This document does not make specific provisions or recommendations for testing of bus and truck emissions with air conditioning deployed because the complexity of such tests is significant and is beyond the scope of the original document. It is recognized that a future practice that addresses air conditioning and other potentially large auxiliary loads is needed.

Reference Section

SAE J1634—Electric Vehicle Energy Consumption and Range Test Procedure

SAE J1711—Recommended Practice for Measuring the Exhaust Emissions and Fuel Economy of Hybrid-Electric Vehicles

SAE J2263—Road Load Measurement Using On-Board Anemometry And Coastdown Techniques

SAE J2264—Chassis Dynamometer Simulation Of Road Load Using Coastdown Techniques

Clark, N. N., Xie, W., Gautam, M., Lyons, D., Norton, P. and Balon, T., “Hybrid Diesel-Electric Heavy Duty Bus Emissions: Benefits of Regeneration and Need for State of Charge Correction,” SAE Paper 2000-01-2955, 2000.

McKain, D.L., Clark, N.N., Balon, T.H., Moynihan, P.J., Lynch, S.A. and Webb, T.C., “Characterization of Emissions from Hybrid and Conventional Transit Buses,” SAE Fuels & Lubricants Meeting, Paris, France, June 2000, SAE Paper 2000-01-2011.

40 CFR Part 86 -- Control of Air Pollution from New and In-Use Motor Vehicles and New and In-Use Motor Vehicle Engines; Certification and Test Procedure

ASTM D 240—Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter

ASTM D 4809-95—Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter

Developed by the SAE Truck and Bus Hybrid and Electric Vehicle Committee