Motorcycle Industry Council

MIC Recommended Practice
Riding Range Test Procedure for On-Highway Electric Motorcycles

Approved by the MIC Electric Vehicle Subcommittee, April 24, 2012

[Please note this test procedure has been revised and adopted as SAE J2982 JUN2013]

RATIONALE

This Recommended Practice has been developed to provide a reasonable and consistent basis for manufacturers of on-highway electric motorcycles to inform prospective owners of the riding range that can be expected under specified operating conditions.

FOREWORD

This Recommended Practice establishes a chassis dynamometer-based procedure for measuring the riding range of on-highway electric motorcycles under several different operating conditions. A "City" range test is specified to determine riding range during "stop-and-go" operation. Constant speed tests at 55 mph and 70 mph are specified to determine riding range during uncongested highway operation at two different cruising speeds. A "Highway Commuting" range calculation procedure is specified to determine riding range in urban areas when operation consists of 50% stop-and-go operation and 50% operation on urban freeways under levels of congestion that allow for quasi-steady speeds of 55 to 70 mph.

INTRODUCTION

Since model year 1972, the U.S. Environmental Protection Agency (EPA) has specified the use of the Urban Dynamometer Driving Schedule (UDDS) to determine compliance with exhaust emission standards for passenger cars and light-duty trucks. Beginning in model year 1978, the UDDS was also the driving cycle specified to determine the "city" fuel economy used to determine compliance with the Corporate Average Fuel Economy Standards for passenger cars. Also beginning in model year 1978, the UDDS was the driving schedule specified for testing exhaust emissions from highway motorcycles with engines >169 cubic centimeters (cc) displacement. (A modified version of the driving cycle with reduced speeds was specified for motorcycles <170 cc.) More recently, the UDDS has been specified as the driving cycle used to determine the "Urban All-Electric Range" of an electric car, which is used to determine the level of credit a manufacturer receives under California and federal standards requiring compliance to be based on the fleet average emissions of vehicles meeting various emissions standards. (The federal procedure for measuring the range of an electric vehicle, which is in 40CFR86.1770-99, is a copy of the procedure initially developed by the California Air Resources Board.)

The primary provisions of the "Urban All-Electric Range" test procedure are a specified "cold soak" period prior to the start of the test during which the battery is charged, followed by operation over repeated Urban Dynamometer Driving Schedules until the vehicle is no longer able to maintain its initial speed-time profile. (Testing is terminated for vehicles that cannot keep up with the required speed-time profile when fully charged or when their maximum speed falls below 95 percent of the maximum speed initially achieved on the UDDS.) Alternatively, the test is terminated when a warning light indicates that it is not safe to continue.

The UDDS has been shown to produce fuel economy and range values for gasoline-fueled passenger cars that are representative of consumer experience for stop-and-go driving in urban areas when a 0.9 adjustment factor is applied. No adjustment factor is required for the Urban All-Electric Range test and, due to the absence of air conditioner use and cold weather operation, no adjustment factor is believed to be necessary for electric motorcycles. In contrast, the EPA Highway Fuel Economy Test does not produce representative range or fuel economy values. This is due to the use of a driving schedule that is specifically intended to represent non-urban driving in areas where there is vigorous enforcement of a 55 mph speed limit. As a result, the Highway test has long been recognized to overstate the fuel economy and range that motorists can expect for what they consider highway driving. Beginning in 1984, federal regulations required

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manufacturers to discount results obtained using the Highway Fuel Economy Test by 22% before reporting results to consumers. Beginning in model year 2008, a more complex procedure was implemented that requires manufacturers to calculate highway fuel economy based on four separate driving cycles, which now includes portions of the UDDS. The new procedure accounts for some operation at 20°F and speeds of up to 80 mph on a driving cycle intended to represent aggressive driving. These and other provisions of the new procedure are not considered appropriate for electric motorcycles.

On limited-access highways and freeways with speed limits of 55 mph or higher, the range of electric motorcycles is generally lower than during stop-and-go operation and highly dependent on cruising speed. The top speed of some models is also lower than the cruising speeds typical with low levels of traffic congestion on limited access roadways. For these reasons, the Recommended Practice specifies two different cruising speeds: 55 mph and 70 mph. The 55 mph speed is representative of the top speed necessary to maintain the minimum legal speeds on freeways on commonly occurring grades. The 70 mph speed is representative of the cruising speed of passenger cars and light-duty trucks on urban freeways under low levels of congestion.

Because no trips in urban areas consist of 100% freeway operation, a "highway commuting" range procedure is specified which represents a 50:50 mixture of stop-and-go riding and steady speed cruising. Analysis of data collected in several California urban areas indicates that this mix of operation is representative of trips by light-duty vehicles that include some operation on freeways.

1. SCOPE

This MIC Recommended Practice incorporates dynamometer test procedures that produce riding range estimates for electric motorcycles during stop-and-go urban riding on surface streets and commuting trips in urban areas that include operation on freeways.

1.1 Purpose

This document provides testing procedures for measuring the range of on-highway electric motorcycles during urban operation and constant speed cruising.

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 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE J213 Motorcycle Classifications (Revised February 2004)

SAE J1263 Road Load Measurement and Dynamometer Simulation Using Coastdown Techniques (Revised March 2010)

SAE J2263 Road Load Measurement Using Onboard Anemometry and Coastdown Techniques (Revised December 2008)

2.1.1.1 Code of Federal Regulations

Available from U.S. Government Printing Office, 732 North Capitol Street, NW, Washington, DC 20401, Tel: 202-512-0000, http://www.gpoaccess.gov/cfr/index.html.

40 CFR, Part 86, Subparts E and F

40 CFR, Part 86, Appendix I [July 13, 2005]

2.1.2 California Code of Regulations

"California Exhaust Emission Standards and Test Procedures for 2009 and Subsequent Model Zero-Emission Vehicles and Hybrid Electric Vehicles, in the Passenger Car, Light-Duty Truck and Medium-Duty Vehicle Classes," California Air Resources Board, December 2, 2009

3. DEFINITIONS

3.1 On-Highway Electric Motorcycle

An on-highway electric motorcycle is a motorcycle as defined by SAE J213 that is legal for street use and propelled exclusively by electric motors energized by storage batteries with no on-board source of battery charging other than solar panels or a regenerative braking system.

3.2 Range

Starting with a fully charged battery, the range in kilometers (km) or miles (mi) is the total distance that can be travelled using a specified speed-time profile before the vehicle experiences a significant degradation in performance (as specified in Section 7) or the operator is warned that it is no longer safe to continue.

3.3 Charge-Discharge Cycle

As used in Section 6, "charge-discharge cycle" shall mean the process involving the vehicle battery being fully recharged following discharge to the point that the "End of Test Criteria" in Section 7 are met and then subsequently discharged to the point that the End of Test Criteria are met again.

3.4 Battery Capacity

The kilowatt-hours (kWh) of energy provided by the vehicle battery between the time it is fully charged and the time the vehicle completes a range test conducted in accordance with Section 7.

4. TEST EQUIPMENT AND INSTRUMENTATION

4.1 Dynamometer

The default dynamometer to be used for motorcycle testing is specified in 40 CFR 86.508-78. It requires a single roll with a minimum 0.40 m (16 in) diameter. The dynamometer shall be calibrated in accordance with the requirements of 40CFR86.518–78. The provisions of 40 CFR 86.529 shall be used for inertia and road load simulation settings, including coastdown calibration times. These settings may also be used on a single-roll 1.2 m (48") dynamometer.

The equipment associated with the dynamometer in § 86.508-78 includes a cooling fan operated at speeds proportional to the dynamometer roll speed, with associated specifications. Compliance with the cooling fan specifications is not required for the range test if a lower flow rate of air is sufficient to prevent overheating.

A twin-roll dynamometer may be used for this procedure, but the road load power settings must be determined using the road coastdown and dynamometer load setting determination methods specified in Appendix A, or equivalent. The driver must assume a normal upright riding posture with arms extended, not a tucked position, during the road coastdown procedure. A wheel-down dynamometer "quick check" coastdown time from 55 to 45 mph performed with the derived load settings must not exceed the road coastdown time by more than 7%.

4.2 Vehicle Speed

Vehicle speed during dynamometer testing shall be determined by the rotational speed of the dynamometer roller(s) and the measured circumference of the roller(s). The accuracy of the rotational speed measurement and dynamometer roller diameter shall be sufficient to allow speed to be accurate within 0.4 km/hr (0.25 mph).

Vehicle speed measured during coast down testing shall be accurate within 0.4 km/hr (0.25 mph).

4.3 Distance

Distance traveled during a dynamometer test shall be computed from measured roll diameter and a count of roll revolutions (or fractions of revolutions). The accuracy of the roll diameter and rotational speed shall be sufficient for the computed distance traveled to be accurate within 0.5% of the actual distance.

4.4 Temperature

Temperature during coast down testing, cold soak, and chassis dynamometer testing shall be determined using a temperature-indicating device capable of measuring to the nearest 1°C or 2°F.

4.5 Barometric Pressure

During coast down testing performed pursuant to Appendix A, the barometric pressure measurement device must have an accuracy of ±0.3 kPa or ±0.1 in Hg.

4.6 Relative Humidity

During coast down testing performed pursuant to Appendix A, the relative humidity must be measured with an accuracy of ±5%.

4.7 Wind Speed

During coast down testing performed pursuant to Appendix A, the wind speed measuring device must have an accuracy of ±1.6 km/h (±1 mph).

4.8 Time

All measurements of time must be accurate to ±0.1 s over a 60-second interval, with a resolution of 0.1 s.

4.9 Tire Pressure

The tire pressure gage should have an accuracy of ±7 kPa (±1 psi) and resolution of 7 kPa (1 psi).

All tire pressure measurements shall be taken after a minimum 4-hour soak. For single-roll dynamometers, the cold tire pressure must be set to the manufacturer's minimum recommended tire pressure. For twin-roll dynamometer testing, tire pressure shall not exceed levels normally used in dynamometer testing (SAE J1263) and necessary for safe operation. The tire pressure used for dynamometer testing shall be the same pressure as used on the test track to establish the dynamometer road load power setting.

4.10 Vehicle Weight

The vehicle weight must be measured with a device that is accurate within ±0.5% with a minimum resolution of 5 kg (10 lb). The Equivalent Inertial Mass used to set the dynamometer includes the curb weight of the bike plus 80 kg representing a typical driver.

5. TEST VEHICLE

5.1 Minimum Performance

This test procedure is limited to use on electric motorcycles legal for street use with a top speed of at least 26 mph.

5.2 Representativeness

The test vehicle shall be representative of a standard production-built vehicle equipped with any accessories or optional equipment that are installed on at least 50% of the vehicles produced. However, in the case of vehicles with removable

luggage (e.g., panniers), the vehicle may be tested using dynamometer settings representing the absence of the removable luggage as long as the fact that the luggage has been removed is reported (e.g., "range was measured with saddlebags and top case removed") along with any publication of the range values. Tires used shall be the same size and specification as those installed on the vehicle at the time of sale. Tires shall be inflated to the manufacturer's recommended inflation pressure and shall not be worn to less than 50% of the original tread depth. Prior to coast down testing, the exterior surface of the vehicle shall be clean and free of any modifications that would affect aerodynamic drag (e.g., removal of mirrors or addition of tape over seams in bodywork).

6. TEST VEHICLE PREPARATION

6.1 Battery Preconditioning

Prior to the conduct of a range test, batteries shall be conditioned according to the recommendations of the vehicle manufacturer if such conditioning is required to achieve maximum energy storage capacity. If the capacity of the vehicle's battery changes by more than 10% following a series of 40 charge-discharge cycles, then the battery shall be subjected to at least 40 charge-discharge cycles prior to dynamometer testing.

6.2 Cold Soak

Before each range test, the vehicle shall be stored at an ambient temperature not less than 68°F (20°C) and not more than 86°F (30°C) for 6 to 36 hours. During this time, the vehicle's battery shall be charged to a full state-of-charge.

7. TEST PROCEDURE

7.1 Dynamometer Setting

Road load force and inertia weight determination shall be performed in accordance with 40CFR86.529–98 except that, if the dynamometer setting is determined based on coast down testing, the more detailed procedure specified in Appendix A shall be used.

7.2 Basic Dynamometer Procedure

The dynamometer procedure shall be as specified in 40CFR86.535-90(c)-(h) except that references to "transient cold start, stabilized cold start, and transient hot start phases of the test" shall be interpreted to mean "the dynamometer driving schedule."

7.3 Cooling Air

The temperature of the air blowing over the motorcycle shall be not less than 68°F (20°C) and not more than 86°F (30°C) during dynamometer testing and the velocity of the air flowing over the motorcycle shall meet the requirements of 40CFR86.508-78(d) if required to prevent overheating

7.4 Vehicle Operation

To the extent feasible, vehicles shall be tested in accordance with the procedures specified in 40CFR86.528–78. References to "throttle" shall be interpreted as referring to the twist grip, pedal, or other device that regulates motor output. The manufacturer's recommended procedures shall be used for the operation of any transmission or clutch in lieu of the procedures specified for motorcycles with internal combustion engines in 40CFR86.528–78.

7.5 Dynamometer Driving

7.5.1 City Test

At the end of the cold soak period, the vehicle shall be disconnected from the battery charging system and placed or pushed onto the chassis dynamometer and operated through successive Urban Dynamometer Driving Schedules as defined in 40CFR86, Appendix I. The driving schedule contained in Appendix I(b) ("EPA Urban Dynamometer Driving Schedule for Light- Duty Vehicles, Light-Duty Trucks, and Motorcycles with engine displacements equal to or greater than 170 cc") shall be used for vehicles capable of maintaining a constant speed of 56.7 mph for at least 10 minutes. The

driving schedule contained in Appendix I(c) ("EPA Urban Dynamometer Driving Schedule for motorcycles with engine displacements less than 170 cc") shall be used for vehicles not capable of maintaining a speed of 56.7 mph for at least 10 minutes. A 10-minute soak (period of non-operation with the vehicle switched off) may follow each UDDS, during which there shall be no recharging. (Manufacturers have the option of skipping the 10-minute soak period.)

7.5.2 Constant Speed Tests

Vehicles capable of maintaining a speed of 70 mph for at least 10 minutes shall be tested at both 55 mph and 70 mph. Vehicles that are capable of maintaining a speed of 55 mph for at least 10 minutes shall be tested at 55 mph. Vehicles that are not capable of maintaining a speed of 55 mph for at least 10 minutes shall not be subject to testing at constant speed.

7.5.2.1 55 mph Test

At the end of the cold soak period, the vehicle shall be disconnected from the battery charging system and placed or pushed onto the chassis dynamometer and accelerated to 55 mph at a rate of 3.3 mph per second or under maximum power if the vehicle will not achieve and maintain an acceleration rate of 3.3 mph/s. The rider shall attempt to maintain 55 mph as closely as possible and shall not permit the speed to vary from the target by more than 1 mph for more than 2 seconds.

7.5.2.2 70 mph Test

At the end of the cold soak period, the vehicle shall be disconnected from the battery charging system and placed or pushed onto the chassis dynamometer and accelerated to 70 mph at a rate of 3.3 mph per second or under maximum power if the vehicle will not achieve and maintain an acceleration rate of 3.3 mph/s. The rider shall attempt to maintain 70 mph as closely as possible and shall not permit the speed to vary from the target by more than 1 mph for more than 2 seconds.

7.6 End of Test Criteria

7.6.1 End of City Cycle Test

7.6.1.1 Vehicles Capable of Maintaining a Constant Speed of 56.7 mph for 10 Minutes

For vehicles subject to the driving schedule in 40CFR86 Appendix I(b), the driving schedule shall be repeated until the vehicle is no longer able to reach a speed of at least 53.9 mph (86.7 km/hr) between second number 226 and second number 254 of the driving schedule or the illumination of a warning light informing the operator that operation should be terminated for safety reasons or to avoid permanent battery damage. At that point, the vehicle shall be decelerated to a stop at a rate of 3.3 mph/s and the test shall be terminated.

7.6.1.2 Vehicles Not Capable of Maintaining 56.7 mph for 10 minutes but Capable of Maintaining 36.5 mph for 10 Minutes

For vehicles subject to the driving schedule in 40CFR86 Appendix I(c) that are capable of maintaining a constant speed of 36.5 mph for at least 10 minutes, the vehicle shall be operated at maximum available power when the vehicle cannot achieve the speed trace within the speed and time tolerances specified in Appendix I. The test shall be terminated when the vehicle speed when operated at maximum available power falls below 34.5 mph (55.5 km/hr) between second number 226 and second number 256 of the driving schedule[1] or the illumination of a warning light informing the operator that operation should be terminated for safety reasons or to avoid permanent battery damage. At that point, the vehicle shall be decelerated to a stop at a rate of 3.3 mph/s and the test shall be terminated.

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[1] Speed variations greater than the tolerances specified in Appendix I that occur during gear changes or braking spikes are acceptable, provided they occur for less than 2 seconds on any occasion and are clearly documented as to the time and speed at that point of the driving schedule.

7.6.1.3 Vehicles Not Capable of Maintaining 36.5 mph for 10 Minutes

For vehicles subject to the driving schedule in 40CFR86 Appendix I(c) that are not capable of maintaining 36.5 mph for 10 minutes, the vehicle shall be operated at maximum available power when the vehicle cannot achieve the speed trace within the speed and time tolerances specified in Appendix I. The test shall be repeated until illumination of a warning light informing the operator that operation should be terminated for safety reasons or to avoid permanent battery damage, or the vehicle speed when operated at maximum available power falls to 2 mph (3.2 km/hr) below the maximum speed initially achieved between second number 226 and second number 256 of the driving schedule or 25 mph (40.2 km/hr), whichever is higher. At that point, the vehicle shall be decelerated to a stop at a rate of 3.3 mph/s and the test shall be terminated.

7.6.2 End of Constant Speed Tests

The target speed shall be maintained until the vehicle is no longer able to stay within 2.0 mph of the target speed or until the illumination of a warning light informing the operator that operation should be terminated for safety reasons or to avoid permanent battery damage. At that point, the vehicle shall be decelerated to a stop at a rate of 3.3 mph/s and the test shall be terminated.

8. DATA RECORDING

The following information shall be recorded for each test.

8.1 Date and time of day

8.2 Dynamometer operator

8.3 Rider/vehicle operator

8.4 Vehicle make, model, model year, vehicle identification number, transmission type, odometer reading at beginning of test, nominal battery capacity, maximum motor output, actual curb mass, and drive wheel tire pressure.

8.5 Dynamometer make, model, and serial number

8.6 Dynamometer settings (inertia and load)

8.7 Test cell temperature

8.8 The driving distance for each test as calculated from roll counts

8.9 A digital record of the vehicle speed for each second of the test

8.10 Shift speeds used for vehicles equipped with manual transmissions

9. RANGE CALCULATION AND REPORTING

The range values for each driving schedule shall be determined by measuring the total number of revolutions of the dynamometer roller from the start of the test until the point at which the End of Test Criteria described in Section 7 are achieved. Based on the distance travelled per revolution of the dynamometer roller and the total number of revolutions, the distance travelled shall be calculated in units of miles or kilometers, rounded to the nearest whole number.

For vehicles capable of maintaining a constant speed of 55 mph for 10 minutes, both a City Range value and Highway Commuting Range value shall be reported. Reporting of range values for the constant speed tests is optional.

9.1 City Range

The calculated value for the Urban Dynamometer Driving Schedule shall be reported as the range for "City" or "Stop-and-Go" riding.

9.2 Constant Speed Range

If reported, the calculated value for the Constant Speed tests shall be presented as the range for "XX mph Constant Speed" or "XX mph Steady Speed," where "XX" is the speed of the test. The speeds of the test may be reported as 89 km/h for the 55 mph test and 113 km/h for the 70 mph test.

9.3 Highway Commuting Range

For vehicles with a top speed of at least 55 mph, a "Highway Commuting Range" value may be reported with a footnote indicating that the calculation is based on "50% stop-and-go" or "50% city" riding and "50% constant speed operation at XX mph" (where "XX" is the speed used for the constant speed test). The constant speed used in the calculation shall be based on the top speed of the vehicle. For vehicles with a top speed of at least 70 mph, the calculation must be based on the 70 mph constant speed test. For vehicles with a top speed of less than 70 mph, the calculation must be based on the 55 mph constant speed test. Highway Commuting Range shall be calculated based on the VMT-weighted harmonic average of the range values for the City and Highway test using the following formula:

$$Highway\ Commuting\ Range = \frac{1}{\frac{0.5}{Range_{city}} + \frac{0.5}{Range_{constant\ speed}}}$$

10. EFFICIENCY CALCULATION AND REPORTING

The efficiency values for each driving schedule, if reported, shall be determined by using the range values calculated in accordance with Section 9 and the measured kWh of electricity required to fully recharge the battery from the point at which the End of Test Criteria described in Section 7 are achieved. The efficiency for City, Constant Speed, and/or Highway Commuting shall be reported in units of miles per kWh, kilometers per kWh, Wh per mile, or Wh per kilometer. Based on these calculated values, the cost of electricity per mile or kilometer of City, Constant Speed, and/or Highway Commuting travel may be determined for a specified cost of electricity per kWh. When on-board chargers are used, the electricity used shall be measured at the input to the charger. When off-board chargers are used, the electricity used may be measured at either the input or output of the charger, depending on the basis for electricity consumption charged to the vehicle operator. Depending on whether electricity use is measured at the input or output of the charger, the efficiency shall be reported as "including charger energy use" or "excluding charger energy use."

APPENDIX A - ROAD LOAD COASTDOWN PROCEDURE FOR TWIN-ROLL DYNAMOMETERS

A.1 APPLICABILITY

40 CFR 86.529 provides default dynamometer force settings for motorcycles tested on a single-roll dynamometer. The default settings include an assumed tire rolling resistance for the single roll interface. If a manufacturer wishes to use a twin-roll dynamometer for the range test, a track road load coastdown test must be performed to determine appropriate settings for the specific dynamometer used.

40 CFR 86.529(c) briefly describes a procedure to perform road coastdowns to determine dynamometer settings. A very detailed coastdown procedure for automobiles and light trucks tested on a hydrokinetic dynamometer is specified in SAE J1263. J2263 provides details for electric dynamometers. Both SAE procedures are very detailed but relatively expensive procedures to perform. The procedure described herein expands on the procedure contained in the Code of Federal Regulations and provides sufficient accuracy for range testing while avoiding much of the expense associated with the detailed procedures found in J1263 or J2263.

A.2 GENERAL

The road coastdown consists of driving on a smooth level track under low wind conditions, and allowing the vehicle to freely decelerate while recording speed each second. As described in J1263, the observed deceleration reflects the road load forces encountered by the vehicle during the deceleration. As the range test includes either a 50 mph or 70 mph steady-state test, the Coastdown time interval to be used for the dynamometer in this procedure will be from 55 to 45 mph.

A.3 TEST CONDITIONS

Because no corrections for wind, roadway grade or air density are performed in this simplified procedure, average wind speed must be less than 8 km/h (5 mph) with gusts less than 16 km/h (10 mph), the roadway grade must be not greater than 1%, and the air density at the time of the coast down run must be in the range of 1.14 to 1.20 kg/m^3. The air density (ρ) shall be calculated using the following equation:

$$\rho = \left[\frac{P}{R_d \times T}\right] \times \left[1 - \frac{0.378 \times P_v}{P}\right]$$

Where: ρ is the air density in kg/m^3
P = total air pressure in Pascals;
*R_d = gas constant for dry air, 287.05 J/(kg*degK);*
T = temperature in °K; and
P_v= pressure of water vapor (partial pressure) in Pascals calculated using the following equation:

$$P_v = RH \times E_s$$

Where: RH is the relative humidity; and
E_s is the saturation pressure of water vapor in Pascals calculated using the following equation:

$$E_s = c_0 \times 10^{\frac{c_1 \times T_c}{c_2 + T_c}}$$

where: c_0 = 610.78
c_1 = 7.5
c_2 = 237.3
T_c = temperature in °C

The combined weight of the vehicle, driver, and test instrumentation used during the road coastdown must match the equivalent inertial mass setting of the dynamometer within ±10 kg.

Cold tire pressures higher than those recommended during normal use may be used to prevent tire damage on the twin-roll dynamometer. The maximum tire pressure allowed is 340 kPa (45 psi). The tire pressure used during the dynamometer coastdown and range test must match the pressure used during the road coastdown procedure.

A.4 TEST PROCEDURE

Cold tire pressure must be checked, following a minimum of 4 hours of nonoperation. Immediately before the coastdown runs the vehicle must be warmed up with a minimum of 30 minutes of operation at approximately 80 km/h.

Coastdown runs must include pairs of runs performed in opposite directions on the same road. The final data set must include at least 5 pairs of valid runs. The recorded deceleration speed interval for each run must include speeds from 100 km/h (62 mph) to 50 km/h (30 mph).

A.5 DATA REDUCTION

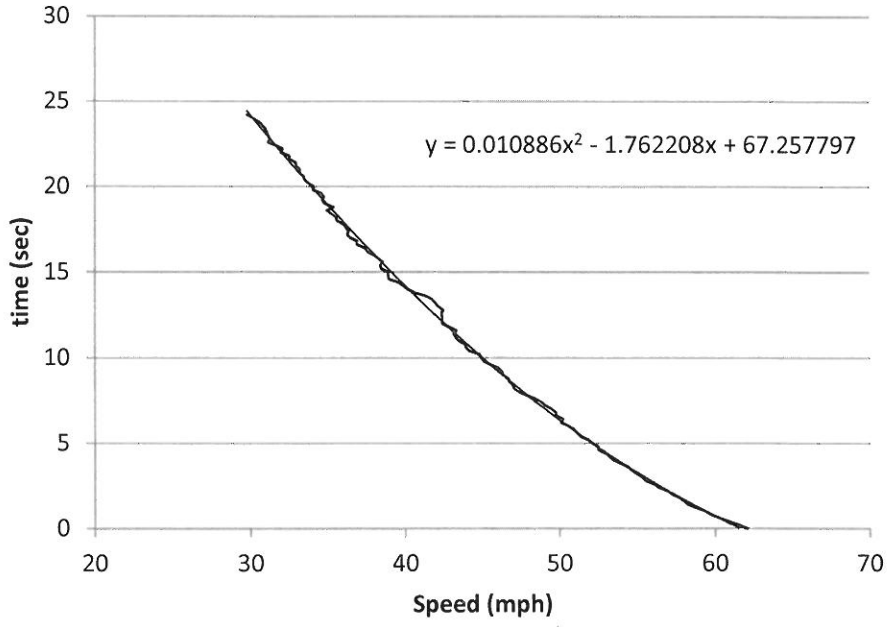
The speed versus time results should be plotted in a program such as Microsoft Excel for inspection. Coastdowns with comparatively large perturbations (>2 mph from the trend) should be discarded, being careful to retain the same number of runs in each direction in the final data set.

It is convenient to assign a time of 0.0 to the final value above 100 km/h for each coastdown run. To calculate coastdown times, fit the time versus speed results to second-order polynomial equations in the form time = a + b*speed + c*speed^2. Use these equations to calculate the time for 55 mph and for 45 mph, and subtract the two values to obtain the coastdown time for each run. Compute the arithmetic average coastdown time to arrive at the dynamometer target coastdown time.

Example using 5 Hz speed data in mph:

Time:	0.0	0.2	0.4	0.6	0.8	... ...	23.6	23.8	24.0	24.2
Speed:	62.03	61.53	60.91	60.25	59.74	... ...	30.75	30.52	30.19	29.78

Figure A-1, Plot of Speed vs. Time from Coastdown



Calculating times for 55 mph and 45 mph:

t_{55} = 0.010886*55*55-1.762208*55+67.257797 = 3.267sec

t_{45} = 0.010886*45*45-1.762208*45+67.257797 = 10.003sec

Coastdown time for 55 to 45 mph: 10.003 - 3.267 = 6.736sec

A.6 DYNAMOMETER COAST DOWNS

Dynamometer power settings which duplicate the average road coastdown time are found by varying the power setting while performing repeated wheel-down coastdowns on the dynamometer. The cold tire pressure must be set to the same value as used on the road. The vehicle must be warmed up on the dynamometer for 30 min at 80 km/h.

The recommended approach is to perform at least three dynamometer coastdowns at five different power settings. The road coastdown time must be bracketed by the dynamometer coastdown times resulting from the power settings used. Calculate inverse time (1/Coastdown time), then average the times at each power setting. Plot the power settings versus average inverse time and determine the power setting that matches the road coastdown time.