

ETA-NTP006

Revision 1

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Braking Test

Prepared by

Electric Transportation Applications

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1.0 Objective

This procedure identifies the methods for the control and conduct of a Braking Test being conducted as part of the NEV America Performance Test Program. These methods are not meant to supersede those of the testing facility, those specifically addressed by SAE Test Standards, nor of any regulatory agency who may have or exercise control over the covered activities.

2.0 Purpose

The purpose of this test is to subjectively evaluate the controllability of a vehicle during braking on wet and dry surfaces. Both the stopping distance and the ability to maintain the vehicle in control (defined as staying in the course lane) are tested. This test is not intended to satisfy the requirements of Section 105 of 49 CFR 571, which is not required per 49 CFR 571.500. This activity is meant to test the vehicle as a total system. Tests of specific subsystems or portions of individual subsystems are addressed by other Test Procedures, as appropriate. This testing and data acquisition meets the requirements specified in the NEV America Technical Requirements.

3.0 Documentation

Documentation addressed by this procedure shall be consistent, easy to understand, easy to read and readily reproducible. This documentation shall contain enough information to "stand alone"; that is, be self-contained to the extent that all individuals qualified to review it could be reasonably expected to reach a common conclusion, without the need to review additional documentation. Review and approval of test documentation shall be in accordance with ETA-NAC004, "Review of Test Results." Storage and retention of records during and following testing activities shall be completed as described in Procedure ETA-NAC001, "Control, Close-out and Storage of Documentation."

4.0 Initial Conditions and Prerequisites

Prior to conduct of any portion of the testing, the following initial conditions and prerequisites shall be met. Satisfactory completion of these items shall be verified as complete and recorded on the appropriate Test Data Sheet.

- 4.1 Personnel conducting testing under this procedure shall be familiar with the requirements of this procedure, and when applicable, the appropriate SAE Test Instructions, Administrative Control Procedures, and be certified by the Program Manager, Test Director or Test Manager prior to commencing any testing activities.
- 4.2 Ambient temperature during road testing shall be >40 F (>5 C).
- 4.3 Battery temperatures at the beginning of testing shall be within a range of 60 F to 120 F (16 C to 49 C). Record on Appendix A.
- 4.4 The recorded wind speed at the test site during the test should not exceed 10 mph (16 km/h).
- 4.5 Testing shall be completed on a rolled asphalt "braking course" defined by Electric Transportation Applications at the test facility of E^xponent - Failure Analysis Associates (FaAA). This pad will be either dry or wet, as required by the specific test being conducted.
- 4.6 Vehicles shall be tested in their normal configuration with normal appendages (mirrors, bumpers, hubcaps, etc.). Certain items (hubcaps, etc.) may be removed where necessary for safety.
- 4.7 Vehicles shall be tested at delivered curb weight plus 332 pounds.
- 4.8 Tires provided with the vehicle shall be the standard tire offered by the Electric Vehicle Supplier.
- 4.9 Supplier's recommended lubricants shall be employed.
- 4.10 Accessories shall not be used or operated during testing.
- 4.11 For tests requiring a battery at X% SOC at the start of testing, the required initial SOC will be established as follows:
 - 4.11.1 The battery shall be fully charged to the requirements of the battery Supplier until the battery is at 100% State of Charge.
 - 4.11.2 The battery energy capacity (mileage based) shall be obtained from the Constant Speed Range Test completed as part of ETA-NTP004, "Constant Speed Range Test."
 - 4.11.3 To achieve X% SOC, the battery will be discharged by driving the vehicle on the test track at constant speed until 1-(1-X%) capacity, measured in ampere-hours, kilowatt-hours or miles, have been removed from the battery.

- 4.11.4 Tests conducted with the battery partially discharged at the test start should be initiated no more than 10 minutes after the desired initial state-of-discharge is reached.
- 4.12 The overall error of recording or indicating instruments shall not exceed $\pm 2\%$ of the maximum value of the variable being measured. Periodic calibration shall be performed and documented to ensure compliance with this requirement.
- 4.13 Complete or verify completed procedures ETA-NAC006, "Vehicle Verification" and ETA-NTP011, "Receipt Inspection," for the vehicle being tested.
- 4.14 The road surface type and condition (SAE J688), and lengths of test route shall be noted.
- 4.15 For instrumentation used in the test, at a minimum, record the following information for each instrument on Appendix C:
 - 4.15.1 Supplier
 - 4.15.2 Model Number
 - 4.15.3 Serial Number
 - 4.15.4 Last Calibration date
 - 4.15.5 Next Calibration date
- 4.16 Any deviation from the test procedure and the reason for the deviation shall be recorded in accordance with ETA-NAC002, "Control of Test Conduct."
- 4.17 Speed-time measuring devices and other necessary equipment shall be installed in a manner that does not hinder vehicle operation or alter the operating characteristics of the vehicle.
- 4.18 All steps shall be completed in the order written. Deviations from any step or requirement must have the prior written approval of the Program Manager, Test Director or Test Manager in accordance with Procedure ETA-NAC002, "Control of Test Conduct."
- 4.19 All documentation required to complete the testing identified in the contract/proposal/technical guidelines shall be completed, approved and issued prior to the effective date of the procedure. In no case shall the procedure be utilized for official testing or data collection prior to its effective date.
- 4.20 Testing MAY take place over the course of several days. Page 1 of Appendix A shall be completed for each day testing is commenced.

5.0 Testing Activity Requirements

This test subjectively evaluates the controllability of a vehicle when attempting to stop from 20 mph on both wet and dry surfaces. It objectively measures the distance required to do so. Sections 5.1 and 5.2 apply to all of the test sections identified, and all of the SOCs the vehicle will be tested at.

The handling pad shall be assembled as a straight path with a nominal length of 150 feet. The width of the lane should be 12 feet. Lane width shall be marked by the use of traffic cones or similar devices. Markers shall be a soft resilient material which can withstand a vehicle impact, without damaging the vehicle.

NOTE

During this testing, if a vehicle fails electrically or mechanically for any reason other than a propulsion battery reaching its design Depth of Discharge (DOD) limit, testing of the vehicle shall be halted, and the vehicle removed from the test program until the Supplier has effected repairs. See ETA-NAC002, "Control of Test Conduct" for additional details.

NOTE

If the vehicle is equipped with regenerative braking, the regenerative braking system shall be engaged during this test. If the level of regenerative braking can be adjustable by the driver, it shall be set to the maximum value of regenerative.

5.1 Test Preparation

Instrument the vehicle to obtain the following data:

- 5.1.1 Speed versus time
- 5.1.2 Distance versus time
- 5.1.3 Battery temperature

5.2 Ambient Conditions

Record the following environmental conditions on Appendix A. These data shall be obtained from the FaAA Facility Site Meteorological Instrumentation and attached to Appendix A.

- 5.2.1 Range of ambient temperature during the test;
- 5.2.2 Range of wind velocity during the test;
- 5.2.3 Range of wind direction during the test.

5.3 Dry Pad Testing

- 5.3.1 Verify the traction battery is not greater than 50% SOC. If not, charge the battery to achieve full charge in accordance with the requirements of ETA-NTP008, "Battery Charging" and then discharge the vehicle to the 50% SOC point (determined in procedure ETA-NTP004). Discharging the battery to 50% SOC shall be accomplished by driving the vehicle at a constant speed of 20 mph until the 50% point has been reached.
- 5.3.2 Move the vehicle to the handling pad start area, and record the vehicle odometer reading.
- 5.3.3 Record the following information:
 - 5.3.3.1 Battery kilowatt-hour meter indicator reading
 - 5.3.3.2 Ambient temperature
 - 5.3.3.3 Wind speed and direction
- 5.3.4 Engage the fifth wheel.
- 5.3.5 Accelerate the vehicle to at least 20 mph (32 km/h) and enter the handling pad.
- 5.3.6 From a speed of not less than 20 mph decelerate the vehicle in a controlled manner as rapidly as possible to a complete stop.
- 5.3.7 Measure the total distance required for the vehicle to stop. Record on Appendix A.
- 5.3.8 Note any test deficiencies, moved or dislodged cones/markers, and any driver comments, on Appendix A.
- 5.3.9 Return the vehicle to the start/staging area, and allow at least 15 minutes to pass before proceeding. Note the actual time duration on Appendix A.
- 5.3.10 Record the kilowatt-hour indicator reading on Appendix A.
- 5.3.11 Accelerate the vehicle to at least 20 mph (32 km/h) and enter the handling pad from the opposite direction.
- 5.3.12 From a speed of not less than 20 mph decelerate the vehicle in a controlled manner to a complete stop as rapidly as possible.
- 5.3.13 Measure the total distance required for the vehicle to stop. Record on Appendix A.

- 5.3.14 Note any test deficiencies, moved or dislodged cones/markers, and any driver comments, on Appendix A. Driver shall specifically note whether any adverse interaction with regenerative braking was detected.
- 5.3.15 Return the vehicle to the charging area, and place the vehicle on charge as required by ETA-NTP008, 'Battery Charging.'
- 5.3.16 Record the following information on Appendix A:
 - 5.3.16.1 Date and time of test completion
 - 5.3.16.2 Equipment failures, if any;
 - 5.3.16.3 Equipment abnormalities, if any;
 - 5.3.16.4 Driver Notes, if any.

5.4 Wet Pad Testing

For this test, the handling pad shall be wetted to an even consistency. Wetting of the pavement surface shall be accomplished using a tanker truck with rear sprayer. The pad shall be re-wetted anytime there is drying of the test surface, or as the Test Manager or Test Engineer may deem appropriate.

- 5.4.1 Verify the traction battery is not greater than 50% SOC, as stated by the Supplier. If not, charge the battery to achieve full charge in accordance with the requirements of ETA-NTP008, "Battery Charging," and then discharge the vehicle to the 50% SOC point (determined in procedure ETA-NTP004). Discharging the battery to 50% SOC shall be accomplished by driving the vehicle at a constant speed of 20 mph until the 50% point has been reached.
- 5.4.2 Move the vehicle to the handling pad start area, and record the vehicle odometer reading.
- 5.4.3 Record the following information:
 - 5.4.3.1 Battery kilowatt-hour indicator reading, in kilowatt-hours
 - 5.4.3.2 Ambient temperature
 - 5.4.3.3 Wind speed and direction
- 5.4.4 Engage the fifth wheel.
- 5.4.5 Accelerate the vehicle to at least 20 mph (32 km/h) and enter the handling pad.
- 5.4.6 From a speed of not less than 20 mph decelerate the vehicle in a controlled manner as rapidly as possible to a complete stop.
- 5.4.7 Measure the total distance required for the vehicle to stop. Record on Appendix A.

- 5.4.8 Note any test deficiencies, moved or dislodged cones/markers, and any driver comments, on Appendix A.
- 5.4.9 Return the vehicle to the start/staging area, and allow at least 15 minutes to pass before proceeding. Note the actual time duration on Appendix A.
- 5.4.10 Record the actual SOC on Appendix A.
- 5.4.11 Accelerate the vehicle to at least 20 mph (32 km/h) and enter the handling pad from the opposite direction.
- 5.4.12 From a speed of not less than 20 mph decelerate the vehicle in a controlled manner to a complete stop as rapidly as possible.
- 5.4.13 Measure the total distance required for the vehicle to stop. Record on Appendix A.
- 5.4.14 Note any test deficiencies, moved or dislodged cones/markers, and any driver comments, on Appendix A. Driver shall specifically note whether any adverse interaction with regenerative braking was detected.
- 5.4.15 Record the following information on Appendix A:
 - 5.4.15.1 Date and time of test completion
 - 5.4.15.2 Equipment failures, if any;
 - 5.4.15.3 Equipment abnormalities, if any;
 - 5.4.15.4 Driver Notes, if any.

5.5 Panic Stop

This test is intended to demonstrate the vehicle's characteristics during a "panic-stop" on a wet surface. The distance to stop shall be measured via a fifth wheel. Should the vehicle strike any lane markers or veer off of the course, the distance between the resting place of the vehicle, the edge of the course and the point at which the vehicle exited the course shall be measured. This stop shall be completed only once, following the second wet stop. It shall be completed while traveling west, and immediately following the Controlled Wet Test in Section 5.4.

NOTE

During this test, the driver shall not provide any steering input.

- 5.5.1 The handling pad shall be wetted to an even consistency.
- 5.5.2 Move the vehicle to the test start area.
- 5.5.3 Record the following information:
 - 5.5.3.1 Battery kilowatt-hour indicator reading, in kilowatt-hours
 - 5.5.3.2 Ambient temperature
 - 5.5.3.3 Wind speed and direction
- 5.5.4 Engage the fifth wheel.
- 5.5.5 Accelerate the vehicle to at least 20 mph (32 km/h) and enter the handling pad.
- 5.5.6 From a speed of not less than 20 mph decelerate the vehicle by depressing the brake pedal as quickly and as firmly as possible until the vehicle has come to a complete stop. This step is intended to achieve a locked brake condition as soon as possible.
- 5.5.7 Measure the total distance required for the vehicle to stop. Record on Appendix A.
- 5.5.8 Note the following, on Appendix A:
 - 5.5.8.1 Any test deficiencies
 - 5.5.8.2 Any moved or dislodged cones/markers
 - 5.5.8.3 Distance of the stopped vehicle from the test course
 - 5.5.8.4 Distance of the stopped vehicle from where the it exited the course
 - 5.5.8.5 Any driver comments. Driver shall specifically note whether any adverse interaction with regenerative braking was detected.

5.6 Data Reduction

During data reduction stopping distances shall be normalized to 20 mph (32 km/h) using the following formula.

$$NormalizedStoppingDistance = ActualStoppingDistance * \left\{ \frac{20}{ActualSpeed} \right\}^2$$

Stopping distance data presented in the Summary Data Sheet shall be normalized to 20 mph (32 km/h).

6.0 Glossary

- 6.1 Curb Weight - The total weight of the vehicle including batteries, lubricants, and other expendable supplies but excluding the driver, passengers, and other payloads.
- 6.2 Effective Date - After a procedure has been reviewed and approved, the first date the procedure can be utilized official data collection and testing.
- 6.3 Fifth Wheel - A calibrated mechanical instrument used to measure a vehicle's speed and distance independent of the vehicles on-board systems.
- 6.4 Gross Vehicle Weight - The maximum design loaded weight of the vehicle specified by the Supplier.
- 6.5 Initial Conditions - Conditions that must exist prior to an event occurring.
- 6.6 Initial State of Charge (SOC) - The residual capacity of a battery after a discharge (full or partial) expressed as a percent of the total battery energy capacity. May be portrayed in ampere-hours, miles or kilowatt-hours. Initial State of Charge is the SOC at the beginning of a test.
- 6.7 Prerequisites - Requirements that must be met or resolved prior to an event occurring.
- 6.8 Program Manager - As used in this procedure, the individual within Electric Transportation Applications responsible for oversight of the NEV America Performance Test Program. [Subcontract organizations may have similarly titled individuals, but they are not addressed by this procedure.]
- 6.9 Safe Stopping Distance - The distance required to bring a vehicle to a complete stop from a pre-determined speed, without losing control of the vehicle.
- 6.10 Shall - This word is used to indicate an item which requires adherence without deviation. Shall statements identify binding requirements. A go, no-go criterion.
- 6.11 Should - This word is used to identify an item which requires adherence if at all possible. Should statements identify preferred conditions.
- 6.12 Summary Data Sheet - A stylized presentation of test results in the form shown in ETTA-NTP003 Revision 1, Appendix A.
- 6.13 Test Director - The individual within Electric Transportation Applications responsible for all testing activities associated with the NEV America Performance Test Program.

6.0 Glossary (continued)

- 6.14 Test Director's Log - A daily diary kept by the Test Director, Program Manager, Test Manager or Test Engineer to document major activities and decisions that occur during the conduct of a Performance Test Evaluation Program. This log is normally a running commentary, utilizing timed and dated entries to document the day's activities. This log is edited to develop the Daily Test Log published with the final report for each vehicle.
- 6.15 Test Engineer - The individual(s) assigned responsibility for the conduct of any given test. [Each contractor/subcontractor should have at least one individual filling this position. If so, they shall be responsible for adhering to the requirements of this procedure.]
- 6.16 Test Manager - The individual within Electric Transportation Applications responsible for the implementation of the test program for any given vehicle(s) being evaluated to the requirements of the NEV America Performance Test Program. [Subcontract organizations may have similarly titled individuals, but they are not addressed by this procedure.]

7.0 References

- 7.1 NEV America Vehicle Technical Specification
Revision 1, April 15, 2002
- 7.2 ETA-NAC001 - "Control, Close-out and Storage of Documentation"
- 7.3 ETA-NAC002 - "Control of Test Conduct"
- 7.4 ETA-NAC004 - "Review of Test Results"
- 7.5 ETA-NAC006 - "Vehicle Verification"
- 7.6 ETA-NTP004 - "Electric Vehicle Constant Speed Range Test"
- 7.7 ETA-NTP005 - "Electric Vehicle Rough Road Test"
- 7.8 ETA-NTP008 - "Battery Charging"
- 7.9 ETA-NTP011 - "Receipt Inspection"
- 7.10 SAE Standard J688

APPENDIX-A
Braking Test Data Sheet
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Vehicle Number: _____

Project No.:	Test Date(s):
Root File No.:	
Test Driver: <small>(Initials) (Date)</small>	
Test Engineer: <small>(Initials) (Date)</small>	

Vehicle Setup

VEHICLE WEIGHTS AS TESTED WITH DRIVER & INSTRUMENTATION (Curb weight plus 332 pounds)			
Left Front: <small>(lbs or kg)</small>	Right Front: <small>(lbs or kg)</small>	Total Front: <small>(lbs or kg)</small>	Percent Front: %
Left Rear: <small>(lbs or kg)</small>	Right Rear: <small>(lbs or kg)</small>	Total Rear: <small>(lbs or kg)</small>	Percent Rear: %
		Total Weight: <small>(lbs or kg)</small>	
INSTALLED TIRES (Placard or sidewall whichever is less)			
Left Front		Right Front	
Pressure: <small>(psi or kPa)</small>		Pressure: <small>(psi or kPa)</small>	
Left Rear		Right Rear	
Pressure: <small>(psi or kPa)</small>		Pressure: <small>(psi or kPa)</small>	

Track/Weather Conditions

Test Track Location:	Track Grade: %
Ambient Temperature (initial): <small>(≥40°F or 5°C)</small>	Ambient Temperature (final): <small>(≥40°F or 5°C)</small>
Track Temperature (initial): <small>(°F or °C)</small>	Track Temperature (final): <small>(°F or °C)</small>
Wind Velocity (initial): <small>(<10 mph or 16 km/h)</small>	Wind Velocity (final): <small>(<10 mph or 16 km/h)</small>
Wind Direction (initial): °	Wind Direction (completion): °

APPENDIX-A
Braking Test Data Sheet
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Test Data Sheet (Controlled Dry Test with Battery <50% SOC)

Sequence No: 1	File No.:	Direction of Travel:
Time (initial):		Time (final):
Odometer (initial): <small>(miles or kilometers)</small>		Odometer (final): <small>(miles or kilometers)</small>
Status of Charge (initial): <small>(SOC,kWh,Ah)</small>		Status of Charge (final): <small>(SOC,kWh,Ah)</small>
Battery Temp (initial): <small>(60-120°F or 16-49°C)</small>		Battery Temp (final): <small>(°F or °C)</small>
Comments (initials/date): Speed at the Start of Braking: _____ Distance Required to Stop Vehicle: _____		

Sequence No: 2	File No.:	Direction of Travel:
Time (initial):		Time (final):
Odometer (initial): <small>(miles or kilometers)</small>		Odometer (final): <small>(miles or kilometers)</small>
Status of Charge (initial): <small>(SOC,kWh,Ah)</small>		Status of Charge (final): <small>(SOC,kWh,Ah)</small>
Battery Temp (initial): <small>(°F or °C)</small>		Battery Temp (final): <small>(°F or °C)</small>
Comments (initials/date): Speed at the Start of Braking: _____ Distance Required to Stop Vehicle: _____		

APPENDIX-A
Braking Test Data Sheet
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Test Data Sheet (Wet Controlled Test with Battery <50% SOC)

Sequence No: 3	File No.:	Direction of Travel:
Time (initial):		Time (final):
Odometer (initial): <small>(miles or kilometers)</small>		Odometer (final): <small>(miles or kilometers)</small>
Status of Charge (initial): <small>(SOC,kWh,Ah)</small>		Status of Charge (final): <small>(SOC,kWh,Ah)</small>
Battery Temp (initial): <small>(°F or °C)</small>		Battery Temp (final): <small>(°F or °C)</small>
Comments (initials/date): Speed at the Start of Braking: _____ Distance Required to Stop Vehicle: _____		
Sequence No: 4	File No.:	Direction of Travel:
Time (initial):		Time (final):
Odometer (initial): <small>(miles or kilometers)</small>		Odometer (final): <small>(miles or kilometers)</small>
Status of Charge (initial): <small>(SOC,kWh,Ah)</small>		Status of Charge (final): <small>(SOC,kWh,Ah)</small>
Battery Temp (initial): <small>(°F or °C)</small>		Battery Temp (final): <small>(°F or °C)</small>
Comments (initials/date): Speed at the Start of Braking: _____ Distance Required to Stop Vehicle: _____		

APPENDIX-A
Braking Test Data Sheet
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Test Data Sheet (Wet Panic Stop)

Sequence No: 5	File No.:	Direction of Travel:
Time (initial):		Time (final):
Odometer (initial): <small>(miles or kilometers)</small>		Odometer (final): <small>(miles or kilometers)</small>
Status of Charge (initial): <small>(SOC,kWh,Ah)</small>		Status of Charge (final): <small>(SOC,kWh,Ah)</small>
Battery Temp (initial): <small>(°F or °C)</small>		Battery Temp (final): <small>(°F or °C)</small>
Comments (initials/date): Speed at the Start of Braking: _____ Distance Required to Stop Vehicle: _____		

APPENDIX-B
Vehicle Metrology Setup Sheets
(Page 1 of 1)

VIN _____

Instrument/Device:	Calibration Due Date:	Initials / Date:
Fifth Wheel S/N:		
Fifth Wheel Calibrator S/N:		
DAQ S/N:		
DAQ Set-up Sheet S/N		
kWh Meter S/N:		
Shunt S/N:		
Tire Pressure Gauge S/N:		
Accelerometer:		
Misc:		
Misc:		
Misc:		
Comments (initials/date):		
Completed By:		
<small>(Printed Name)</small>	<small>(Signature)</small>	<small>(Date)</small>
Reviewed By (QA):		
<small>(Printed Name)</small>	<small>(Signature)</small>	<small>(Date)</small>
Approved By:		
<small>(Printed Name)</small>	<small>(Signature)</small>	<small>(Date)</small>