

ETA-HTP05

Revision 0

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"Hybrid Electric Vehicle Rough Road Course Test"

Prepared by

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1. Objective

The objective of this procedure is to provide methods for evaluating the durability of vehicles participating in HEV America. These methods are not meant to supersede those of the testing facility, those specifically addressed by SAE Test Standards, nor of any regulatory agency which may have or exercise control over the covered activities.

2. Purpose

The purpose of this test is to (1) accumulate standardized test-mileage on each vehicle over a test track that includes both rough road, water hazard and smooth track; and (2) test the vehicles ability to endure extreme conditions over a short time frame. This test is not intended to determine range or speed capabilities of any vehicle. No inferences concerning a vehicle's speed, range or gradeability characteristics should be drawn from this test. 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. This testing and data acquisition meets the requirements specified in the HEV America Vehicle Specification.

3. 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, to be self-contained to the extent that all individuals qualified to review it could reasonably be 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-HAC04, "Review of Test Results." Storage and retention of records during and following testing activities shall be completed as described in Procedure ETA-HAC01, "Control, Close-out and Storage of Documentation."

4. 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 Test Data Sheet.

- 4.1 Personnel conducting testing under this procedure shall be familiar with the requirements of this procedure, and when applicable, any and all appropriate SAE Standards, Test Instructions and Administrative Control Procedures. They shall also be certified by the Program Manager or Test Director prior to commencing any testing activities.

- 4.2 Ambient temperature during road testing shall be $\geq 61^{\circ}\text{F}$ (16°C).
- 4.3 RESS temperatures at the beginning of the test shall be greater than 60°F (16°C), shall be less than 120°F (49°C) and should be less than 100°F (38°C)
- 4.4 The average wind speed at the test site during the test shall not exceed 10 mph (16 km/h). Wind gusts shall not exceed 12.3 mph (20 kph).
- 4.5 Testing shall be completed over a "rough road" course defined by Electric Transportation Applications which contains smooth asphalt, potholes, cobblestones, washboard and standing water. The test facility at Exponent Failure Analysis in Phoenix, Arizona has such features.
- 4.6 Speeds identified for each hazard have been determined to be the optimum speed for testing the vehicle at that hazard. Attempting to negotiate a hazard at a speed different than that identified should be avoided.
- 4.7 Vehicles shall be tested in their normal configuration with normal appendages (mirrors, bumpers, hubcaps, etc.). Certain items (hub caps, etc.) may be removed where necessary for safety.
- 4.8 Vehicles shall be loaded at curb weight plus 332 pounds.
- 4.9 Tires provided with the vehicle shall be the standard tires offered by the Supplier. Tires shall be inflated to the Supplier's recommended (placard) cold inflation pressure.
- 4.10 Supplier's recommended lubricants shall be employed.
- 4.11 For vehicles operable in "RESS only mode," verify the RESS is at 100% SOC in accordance with the requirements of ETA-TP008, "RESS Charging Procedure." For vehicles operable in "normal operation mode," verify the RESS is at an Initial State of Charge (SOC) achieved by operating the vehicle for at least 5 miles (8 kilometers) at a constant speed of 35 mph (56 kph).
- 4.12 Overall error in recording or indicating instruments shall not exceed $\pm 2\%$ of the maximum value of the variable being measured unless otherwise excepted. Periodic calibration shall be performed and documented to ensure compliance with this requirement.
- 4.13 Complete or verify completed Procedures ETA-HAC06, "Receipt Inspection," and ETA-HTP11, "Vehicle Verifications," for the vehicle being tested.

- 4.14 The road surface type and condition as defined in SAE J688, "Truck Ability Prediction Procedure," and lengths and grades of test route shall be noted.
- 4.15 Instrumentation used in the test shall be identified on Appendix B, and attached to the test results. It shall include the following information:
 - 4.16.1 Manufacturer
 - 4.16.2 Model Number
 - 4.16.3 Serial Number
 - 4.16.4 Last Calibration date
 - 4.16.5 Next Calibration date
- 4.16 Any deviation from the test procedure and the reason for the deviation shall be approved in advance and so noted on the appropriate data sheet(s).
- 4.17 Any necessary equipment shall be installed in a manner that does not hinder vehicle operation or alter the operating characteristics of the vehicle.
- 4.18 Accessories shall not be used during the rough road testing.
- 4.19 Speeds for each hazard or groups of hazards shall be posted on the test track in a manner which allows the driver(s) to achieve the required speed prior to encountering the hazard.
- 4.20 Prior to the initial test sequence, the vehicle's underside shall have been inspected to identify pre-existing damage. Any damage shall have been recorded in writing. Photographs may be taken to document the conditions.
- 4.21 Subsequent to each completed test cycle, the vehicle's underside shall again be inspected to ascertain any additional damage resulting from conduct of the test. Any additional damage shall be recorded in the comments section.

5. Rough Road Testing

CAUTION

Deviations from these prescribed speeds can present a safety issue for vehicles. All vehicles should maintain posted speed. If any vehicle cannot maintain or achieve speed, it shall be removed from the course.

CAUTION

Should any vehicle be unable to complete the requirements of the hazards or attain the required speed through the hazards, the driver of that vehicle shall move the test vehicle out of the test path.

NOTE

This procedure was written specifically for implementation at the Test Track at Exponent Failure Analysis. in Phoenix, Arizona. As such, hazards and appropriate speeds for negotiation of those hazards are specific, and must be adhered to. All steps shall be completed in the order written. These hazards and their appropriate speeds are listed here:

NOTE

Conduct of this procedure should be coordinated with the conduct of charging efficiency testing as presented in ETA-HTP08, "Rechargeable Energy Storage System (RESS) Charging."

FRONT SIDE

3" Deep Random Chuck Holes	5 mph (8 km/h)
Sine Wave	10 mph (16 km/h)
Railroad Crossing	15 mph (24 km/h)
Perpendicular Dip	15 mph (24 km/h)
Diagonal Dip	15 mph (24 km/h)
Single Wheel Dip	15 mph (24 km/h)
1" Deep Random Chuck Holes	20 mph (32 km/h)
Adjustable Irregularities (tar strips)	25 mph (40 km/h)
Road Crown	30 mph (48 km/h)

BACK SIDE

1" Deep Random Chuck Holes	25 mph (40 km/h)
Belgian Blocks (cobblestone)	25 mph (40 km/h)
Railroad crossing	25 mph (40 km/h)
2" Standing Water	20 mph (32 km/h)

- 5.1 Record the VIN/Test number of the vehicle being tested on Appendix A.
- 5.2 Record the vehicle's cold inflation tire pressure. Adjust the cold inflation tire pressure to meet the requirements of the Supplier's placard, if necessary.

- 5.3 For vehicles operable in "RESS only mode." verify the RESS is at 100% SOC in accordance with the requirements of ETA-TP008, "RESS Charging Procedure" and place the vehicle in the "RESS only mode." For vehicles operable in "normal operation mode," verify the RESS is at a beginning State of Charge (SOC) achieved by operating the vehicle for at least 5 miles (8 kilometers) at a constant speed of 35 mph (56 kph).
- 5.4 Record the following environmental conditions:
- 5.4.1 Ambient temperature;
 - 5.4.2 RESS temperature (at the discretion of the Test Manager);
 - 5.4.4 Wind velocity;
 - 5.4.5 Wind direction;
 - 5.4.6 Record Vehicle odometer reading.

NOTE

If more than one vehicle is being tested, test vehicles shall maintain a nominal safe distance between themselves and the vehicle in front of them, in accordance with accepted standards.

NOTE

During this testing, if a vehicle fails electrically or mechanically for any reason, then that vehicle shall be removed from this testing scheme until such time as the Supplier can repair it. See procedure ETA-HAC02, "Control of Test Conduct" for additional details.

NOTE

The test sequence for this procedure will be to complete an 8-hour soak; complete ten stop/start evolutions; complete five laps through the rough road course, and then complete 20 laps at 55 mph. Specific direction is provided as follows.

NOTE

When instructed to decelerate in Steps 5.4 through 5.23, the driver shall begin the deceleration approximately 135 feet prior to the stop sign. These deceleration points shall be marked on the test track.

NOTE

Vehicle odometer readings shall be recorded on Appendix A upon initiation and also completion of testing.

- 5.5 Move the vehicle to the handling pad (Exponent) or similar area. The vehicle's windows shall be completely closed, except for the driver's and front passenger's windows, which may each be left open no more than one-half ($1/2$) inch. Vehicle shall be parked with the windshield facing South.
- 5.6 The vehicle shall be soaked for at least six hours, during which time it shall have been exposed to a minimum ambient temperature of at least 100°F (27°C) for at least one hour of the six-hour soak. If ambient temperatures will not reach 100°F, the vehicle may be soaked in a suitable soak chamber at a minimum of 100°F for six hours before being moved to the handling pad in lieu of performing a soak on the handling pad. At the completion of this soak period, move the vehicle to the test track starting point.
- 5.7 From the starting point, smoothly accelerate the vehicle at maximum achievable acceleration to 45 mph, and continue approximately one (1) mile to the stop sign.
- 5.8 Decelerate the vehicle and bring it to a complete stop at the stop sign.
- 5.9 From the stop sign, rapidly accelerate the vehicle to 45 mph and continue approximately one (1) mile to the next stop sign.
- 5.10 Decelerate the vehicle and bring it to a complete stop at the stop sign. The first lap is complete.
- 5.11 From the stop sign, rapidly accelerate the vehicle to 45 mph and continue approximately one (1) mile to the next stop sign
- 5.12 Decelerate the vehicle and bring it to a complete stop at the stop sign.
- 5.13 From the stop sign, rapidly accelerate the vehicle to 45 mph and continue approximately one (1) mile to the next stop sign.
- 5.14 Decelerate the vehicle and bring it to a complete stop at the stop sign. The second lap is complete.
- 5.15 From the stop sign, rapidly accelerate the vehicle to 45 mph and continue approximately one (1) mile to the next stop sign
- 5.16 Decelerate the vehicle and bring it to a complete stop at the stop sign.
- 5.17 From the stop sign, rapidly accelerate the vehicle to 45 mph and continue approximately one (1) mile to the next stop sign.
- 5.18 Decelerate the vehicle and bring it to a complete stop at the stop sign. The third lap is complete.

- 5.19 From the stop sign, rapidly accelerate the vehicle to 45 mph and continue approximately one (1) mile to the next stop sign
- 5.20 Decelerate the vehicle and bring it to a complete stop at the stop sign.
- 5.21 From the stop sign, rapidly accelerate the vehicle to 45 mph and continue approximately one (1) mile to the next stop sign.
- 5.22 Decelerate the vehicle and bring it to a complete stop at the stop sign. The fourth lap is complete.
- 5.23 From the stop sign, rapidly accelerate the vehicle to 45 mph and continue approximately one (1) mile to the next stop sign
- 5.24 Decelerate the vehicle and bring it to a complete stop at the stop sign.
- 5.25 From the stop sign, rapidly accelerate the vehicle to 45 mph and continue approximately one (1) mile to the next stop sign.
- 5.26 Decelerate the vehicle and bring it to a complete stop at the stop sign. The fifth lap is complete.
- 5.27 Stop-Start Portion of the test is complete.
- 5.28 From the Stop sign, accelerate the vehicle to 5 mph and negotiate the 3" deep random Chuck Holes.
- 5.29 After completing negotiation of the 3" Random Chuck Holes, smoothly accelerate the vehicle so as to enter the Sine Wave at 10 mph.
- 5.30 After completing negotiation of the sine wave, smoothly accelerate the vehicle so as to enter the Railroad Crossing at 15 mph.
- 5.31 After completing negotiation of the Railroad Crossing, maintain the vehicle speed so as to enter the Perpendicular Dip at 15 mph.
- 5.32 After completing negotiation of the Perpendicular Dip, maintain the vehicle speed so as to enter the Diagonal Dip at 15 mph.
- 5.33 After completing negotiation of the Diagonal Dip, maintain the vehicle speed so as to enter the Single Wheel Dip at 15 mph.
- 5.34 After completing negotiation of the Single Wheel Dip, smoothly accelerate the vehicle speed so as to enter the 1" Random Chuck Holes at 20 mph.
- 5.35 After completing negotiation of the 1" Random Chuck Holes, smoothly accelerate the vehicle speed so as to enter the Tie Down Area (simulated Tar Strips) at 25 mph.

- 5.36 After completing negotiation of the Tie Down Area (simulated Tar Strips), smoothly accelerate the vehicle speed so as to enter the High Crown Intersection at 30 mph.
- 5.37 After completing negotiation of the High Crown Intersection, maintain speed at 30 mph and negotiate the transition to the back side of the track.
- 5.38 Smoothly decelerate the vehicle so as to enter the 1" Random Chuck Holes at 25 mph.
- 5.39 Maintain speed so as to negotiate the Belgian Block section at 25 mph.
- 5.40 Maintain this vehicle speed so as to negotiate the Railroad Crossing section at 25 mph.
- 5.41 Smoothly decelerate the vehicle to achieve a speed of 20 mph through the Shallow (~2 inches) Water Bath.
- 5.42 After completing negotiation of the Shallow Water Bath, smoothly accelerate the vehicle to 45 mph [55 mph if completing for the fifth (5th) time]. Maintain this speed through the back turn.
- 5.43 Decelerate the vehicle to 5 mph so as to enter the 3" Random Chuck Holes at 5 mph.
- 5.44 Repeat steps 5.28 through 5.42, IN ORDER, until the vehicle has traveled five (5) laps (approximately 10 miles).
- 5.45 Accelerate the vehicle to 55 mph.
- 5.46 Drive the vehicle at 55 mph for 20 Laps (approximately 40 miles). If this is the first test sequence, continue to step 5.47. If this is the second test sequence, skip to Step 5.51.
- 5.47 When the vehicle has completed 20 Laps at 55 mph, the first phase of this test is complete. Move the vehicle to the garage area and record the following:
 - 5.47.1 Record the RESS leakage current (RESS-to-chassis). Current shall be less than 0.5 MIU.
 - 5.47.2 For vehicles capable of grid connection, place the vehicle on charge in accordance with ETA-HTP08, "RESS Charging." Within 5 minutes of placing the vehicle on charge (if applicable), read and record the charger leakage current (chassis to ground). Current shall be less than 5 mA.
- 5.48 Record or verify as recorded the following data on Appendix A:
 - 5.48.1 Date and time of test phase completion
 - 5.48.2 SOC reading (kWh consumed and percent)

- 5.48.3 Miles traveled / laps completed
 - 5.48.4 Equipment failures, if any;
 - 5.48.5 Equipment abnormalities, if any;
 - 5.48.6 Damage to vehicle underside
 - 5.48.7 Damage to any vehicle components
 - 5.48.8 RESS leakage current
 - 5.48.9 Driver Notes, if any
- 5.49 For vehicles capable of grid connection, move the vehicle to the charging station and recharge the RESS to 100% SOC in accordance with ETA-HTP08, "RESS Charging." Record the AC energy used for this charge in accordance with ETA-HTP08, "Rechargeable Energy Storage System (RESS) Charging" for use in determining charging efficiency.
- 5.50 Repeat steps 5.2 through 5.48.

6. Glossary

- 6.1 Rechargeable Energy Storage System (RESS) – The supplementary propulsion system, either electrical (battery or capacitor) or mechanical (flywheel).
- 6.2 Curb Weight - The total weight of the vehicle including batteries, lubricants, and other expendable supplies but excluding the driver, passengers, and other payloads.
- 6.3 Effective Date - The date, after which a procedure has been reviewed and approved, that the procedure can be utilized in the field for official testing.
- 6.4 Gross Vehicle Weight Rating (GVWR) - The maximum design loaded weight of the vehicle specified by the Supplier.
- 6.5 HEV America – Hybrid Electric Vehicle America Performance Test Program, the DOE sponsored test program for independently assessing the performance of vehicles submitted for testing.
- 6.6 Initial Conditions - Conditions that shall exist prior to an event occurring.
- 6.7 Initial State of Charge (SOC) - RESS SOC at the beginning of a test.
- 6.8 Prerequisites - Requirements that shall be met or resolved prior to an event occurring.
- 6.9 Program Manager - As used in this procedure, the individual within Electric Transportation Applications responsible for oversight of the HEV

- America Performance Test Program. [Subcontract organizations may have similarly titled individuals, but they are not addressed by this procedure.]
- 6.10 Shall - Items which require adherence without deviation. Shall statements identify binding requirements. A go, no-go criterion.
- 6.11 Should - Items which require adherence if at all possible. Should statements identify preferred conditions.
- 6.12 State of Charge (SOC) - For vehicles operable in "RESS only mode," the SOC of the RESS is defined as the present capacity, (amperes-hours or watt-hours or miles), expressed as a percentage of the total available. The 100% SOC basis (available ampere-hours, kilowatt hours or miles) is determined by the actual discharge capability of the RESS when discharged to the requirements of the 45 mph Constant Speed Range Test portion of procedure ETA-HTP04.
- 6.13 Test Director - The individual within Electric Transportation Applications responsible for all testing activities associated with the HEV America Performance Test Program.
- 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 days 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 HEV America. [Subcontract organizations may have similarly titled individuals, but they are not addressed by this procedure.]
- 6.17 Test Weight - The weight of the vehicle as tested including driver, operator (if necessary), and all instrumentation.

7. References

- 7.1 HEV America Vehicle Specification
- 7.2 ETA-HA001 - "Control, Close-out and Storage of Documentation"

- 7.3 ETA-HAC02 - "Control of Test Conduct"
- 7.4 ETA-HAC04 - "Review of Test Results"
- 7.5 ETA-HAC05 - "Training and Certification Requirements for Individuals Utilizing ETA Procedures"
- 7.6 ETA-HAC06 - "Receipt Inspection"
- 7.7 ETA-HTP11 - "Vehicle Verification"

**APPENDIX-A
Hybrid Vehicle Rough Road
Test Data Sheet (Page 1 of 2)**

VIN Number: _____

Project No.:	Test Date(s):
Root File No.:	
Test Driver:	(Initials) (Date)
Test Engineer:	(Initials) (Date)

Vehicle Setup

VEHICLE WEIGHTS AS TESTED (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>(≥90°F or 32°C)</small>	Ambient Temperature (final): <small>(≥90°F or 32°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-B
Vehicle Metrology Setup Sheets
(Page 1 of 1)**

VIN Number: _____

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