ETA-HITP02

Revision 0

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Implementation of SAE Standard J1666 May93

"HICE Vehicle Acceleration, Gradeability, and Deceleration Test Procedure"

Prepared by

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1. Objective

The objective of this procedure is to provide methods for the testing of acceleration and gradeability of vehicles participating in HICEV America. Testing is conducted in accordance with SAE J1666, "Electric Vehicle Acceleration, Gradeability and Deceleration Test Procedure", as the methods can be applied to Hydrogen Internal Combustion Engine Vehicles (HICEVs). 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 procedure is to identify acceptable methods for the implementation of the test requirements of SAE Standard J1666. The SAE-J1666 Recommended Practice establishes uniform procedures for testing electric battery-powered vehicles as a total system rather than its individual subsystems. This procedure collects and retains test data as specified in the HICEV 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, 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-HIAC04, "Review of Test Results." Storage and retention of records during and following testing activities shall be completed as described in Procedure ETA-HIAC01, "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 should 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 the appropriate SAE Test Instructions and the Administrative Control Procedures, and be certified by the Program Manager or the Test Manager prior to commencing any testing activities.

4.3 Road Testing

4.3.1 Acceleration tests will be performed on a road or closed track which is level to within 1% (±0.5%).

4.3.2 Tests shall be run in opposite directions when they are performed on an open test track.

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4.3.3 The direction of travel need not be reversed when operating on a closed test track.

4.3.4 Ambient temperature during road testing shall be within the range of 40°F to 100°F (5°C to 38°C), or as noted in the individual test section..

4.3.5 Average wind speed at the test site during the test shall not exceed 10 mph (16 kph), or as noted in the individual test section.

4.3.6 Wind gusts shall not exceed 12.3 mph (20 kph), or as noted in the individual test section.

4.4 Vehicle shall be tested in its normal configuration with normal appendages (mirrors, bumpers, hubcaps, etc.). Certain items (hub caps, etc.) may be removed where necessary for safety on the dynamometer.

4.5 Vehicles shall be tested at curb weight plus 332 pounds. Consideration should be given to how adding instrumentation will affect the test weight and balance of the vehicle.

4.6 Supplier's recommended tires shall be used.

4.7 Normal Supplier's recommended lubricants shall be employed.

4.8 Accessories shall not be used during testing.

4.9 The following data shall be collected during conduct of the various tests specified by this procedure. Overall error in recording or indicating instruments shall not exceed ±2% of the maximum value of the variable being measured, unless otherwise excepted and noted. Periodic calibration shall be performed and documented to ensure compliance with this requirement.

4.9.1 Vehicle speed versus time;

4.9.2 Distance versus time;

4.10 Environmental conditions during the testing shall be recorded and include, at a minimum, the following:

4.10.1 Range of ambient temperature during the test;

4.10.2 Range of wind velocity during the test;

4.10.3 Range of wind direction during the test.

4.11 The running surface upon which the test is being conducted shall be noted.

4.12 A description of the test route, road surface type and condition (SAE J688, "Truck Ability Prediction Procedure") and lengths and grades of test route, shall be recorded.

4.13 The date and starting and ending times of test shall be recorded.

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4.14 All instrumentation used in the test shall be listed on Appendix E and attached to the test data sheets/results and shall include the following information:

4.14.1 Manufacturer

4.14.2 Model Number

4.14.3 Serial Number

4.14.4 Last Calibration date

4.14.5 Next Calibration date

4.15 Any deviation from the test procedure and the reason for the deviation shall be recorded in accordance with ETA-HIA02, "Test Conduct."

4.16 The speed-time measuring device and other necessary equipment shall be installed so that they do not hinder vehicle operation or alter the operating characteristics of the vehicle.

4.17 All documentation required to complete testing shall be completed, approved and ready for issue prior to commencing the testing it addresses.

4.18 Complete or verify complete procedure ETA-HIAC06, "Receipt Inspection," and ETA-HITP11, "Vehicle Verification," for the vehicle being tested.

5. Test Activity Requirements

This section addresses all of the test types required to meet the stated purpose and objectives of this procedure. To this end, it selectively implements portions of SAE J1666. For ease of use and consistency of format with other Test Procedures, this section is divided into subsections for the Major Test Sections. Unless otherwise noted, each section may be completed independent of all the other sections.

NOTE

Activities necessary to complete the test are identified in the following sections. All items shall be completed, whether they are required by J1666 or not. Any section which cannot be completed shall be so annotated, along with the appropriate justification in accordance with ETA-HIAC02, "Control of Test Conduct," on Appendix A.

NOTE

The following sections may be completed in any order. However, the steps within each section shall be completed in the order written. Deviations shall have the approval of the Program Manager or Test Manager in accordance with ETA-HIAC02, "Control of Test Conduct."

NOTE

Vehicle odometer readings shall be recorded within the appropriate test appendices upon initiation and completion of testing.

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5.1 Acceleration to a Pre-Determined Speed

NOTE
Vehicles should have a 0-50 mph acceleration time of 13.5 seconds or less when loaded with two 166-pound occupants.

5.1.1 Record the vehicle being tested on Appendix A.

5.1.2 Determine the speed to be achieved, and record on Appendix A.

5.1.3 Vehicle shall be instrumented to obtain, at a minimum, the data identified in Section 4.13.

NOTE
The last 3000 feet of the track for this test shall be straightaway.

5.1.4 Ensure the vehicle is weighted to curb weight plus 332 pounds. This shall include the driver and instrumentation.

5.1.5 From a standing start, accelerate the vehicle at its maximum attainable acceleration or the Supplier's maximum permissible acceleration rate(s) (whichever is less) until the target speed has been exceeded or the vehicle has traveled one mile, whichever occurs first. Note the speed achieved and the time required to achieve it on Appendix A. If the data are being accumulated into a DAS, these data may be transcribed subsequent to the data download.

5.1.6 The maximum time interval between the completion of the acceleration portion of one run to the beginning of the next successive run shall not exceed 5 minutes. Record elapsed time on Appendix A. If the data are being accumulated into a DAS, this time interval may be transcribed subsequent to the data download.

5.1.7 Reverse the direction of travel on the test track.

5.1.8 From a standing start, accelerate the vehicle at its maximum attainable acceleration or the Supplier's maximum permissible acceleration rate(s) (whichever is less) until the target speed has been exceeded or the vehicle has traveled one mile, whichever occurs first. Note the speed achieved and the time required to achieve it on Appendix A. If the data are being accumulated into a DAS, these data may be transcribed subsequent to the data download.

5.1.9 Record completion of this test portion on Appendix A.

5.2 Maximum Achievable Speed on a Level Road

The purpose of this section is to determine the maximum speed the vehicle can achieve on a level grade. This testing is to be completed subject to the initial conditions and prerequisites stated in Section 4 of this procedure.

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NOTE
Vehicles should have a minimum top speed of 70 mph when loaded with two 166-pound occupants.

NOTE
A level grade, paved test route upon which the vehicle can be safely accelerated to speeds near its peak speed shall be selected. Note location on Appendix B.

NOTE
At least two consecutive runs shall be made over the test course.

5.2.1 The vehicle shall be weighted to curb weight plus 332 pounds. This shall include the weight of the driver.

NOTE
The last 3000 feet of the track length for this test shall be straightaway.

5.2.2 From a standing start, accelerate the vehicle at its maximum attainable acceleration or the Supplier's maximum permissible acceleration point(s) (whichever is less) until the vehicle has traveled one mile. Note speed achieved on Appendix B.

5.2.3 The maximum time interval between the completion of the acceleration portion of one run to the beginning of the next successive run shall not exceed 5 minutes. Record elapsed time on Appendix B. If the data are being accumulated into a Data Acquisition System (DAS), this time interval may be transcribed subsequent to the data download.

5.2.4 Reverse the direction of travel on the test track.

5.2.5 From a standing start, accelerate the vehicle at its maximum attainable acceleration or the Supplier's maximum permissible acceleration point(s) (whichever is less) until the vehicle has traveled one mile. Note speed achieved on Appendix B.

5.2.6 Record completion of this section on Appendix B.

5.3 Gradeability Limit

5.3.1 Limit By Test

The purpose of this test is to determine the maximum grade on which the vehicles can start and move forward. Vehicles should be capable of starting and ascending a 25% grade when loaded with two 166-pound occupants. Because it is impractical to obtain direct measurement of gradeability limit on steep test grades, the gradeability limit is to be calculated using the vehicle's measured receipt curb weight plus 332 pounds and the measured tractive force delivered by the vehicle at a speed near zero. **This is a deviation from SAE J1666.**

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This test shall be performed with the vehicle at curb weight plus 332 pounds. If the traction force is limited by slippage between the drive wheels and the road surface, this should be noted.

The percent gradeability limit shall be determined using the following relationship:

$$\text{Percent Gradeability Limit} = 100 \tan\left(\sin^{-1}\frac{P}{W}\right) \qquad EQ.1$$

Where: P = Measured traction force, lb
W = Curb Weight plus 332 pounds, lb

5.3.1.1 Attach the test vehicle to a mass that can be dragged at low speed. Adjust the mass or road friction such that the test vehicle is capable of dragging the mass at approximately 2 mph while at full power. Instrument the connection between the vehicle and the mass with a force gauge capable of reading at least 3000 pounds force with an accuracy of ±2%.

5.3.1.2 The vehicle shall be weighted at curb weight plus 332 pounds. Record on Appendix C.

5.3.1.3 The tractive force shall be measured with the vehicle on a level grade road surface. Record the percent grade on Appendix C.

5.3.1.4 Record the maximum force the vehicle's propulsion system can maintain for a period of 20 seconds while moving the vehicle at a minimum speed of 1 mph (1.5 km/h) on Appendix C.

5.3.1.5 Record test section completion on Appendix C.

5.3.2 Limit By Analysis

The purpose of this test is to determine the maximum grade on which the vehicles can move forward. Because the discharge rates associated with the constant low speed pulls are high, it is possible to obtain gradeability limits which are lower than what might actually be experienced by a vehicle operator. An alternative method is to determine the tractive force from the data obtained during the maximum acceleration tests. After calculating this force, implement this value into *EQ. 1* to calculate the maximum gradeability.

5.3.2.1 Determine the maximum acceleration value from Section 5.1 of this procedure.

5.3.2.2 Obtain the vehicle weight value used during Section 5.1 of this procedure.

5.3.2.3 Using the formula *EQ.2*, determine the maximum force available:

$$\text{Force} = (\text{mass}) \times (\text{acceleration}) \qquad EQ.\ 2$$

5.3.2.4 Insert this value into *EQ. 1*, as value P

5.3.2.5 Solve for the Maximum Gradeability Limit

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5.4 Gradeability at Speed

This test determines the maximum speed which can be achieved on roads with 3% and 6% grades. Vehicles should achieve a minimum sustainable speed of 55 mph when loaded with two 166-pound occupants on a 3% grade, and 45 mph on a 6% grade.

5.4.1 Analytical Method - 3% Grade

Using the speed-time data from the road tests of section 5.1, the vehicle's acceleration characteristics shall be plotted. Data for successive time intervals shall to be used to determine the vehicle's average acceleration during the nth time interval

$$\bar{a}_n = (V_n - V_{n-1})/(t_n - t_{n-1}) \qquad EQ.\ 3$$

when the vehicle has reached the average speed,

$$\bar{V} = (V_n + V_{n-1})/2 \qquad EQ.\ 4$$

The data derived from these calculations shall be plotted as average acceleration versus speed as a smooth curve through the calculated points. (If the vehicle was equipped with a recording accelerometer, the acceleration curve information shall be obtained directly.) The percent grade the vehicle is able to traverse at any selected speed is now to be calculated using the following relationship:

Percent Gradeability at Speed = $100 \tan (\sin^{-1} 0.0455a)$ *EQ. 5*

where:

a = Vehicle acceleration at the selected speed, mph/s

(The constant 0.0455 in this equation becomes 0.0283 when acceleration is in units of kph/s.)

5.4.2 Analytical Method - 6% Grade

Using the speed-time data from the road tests of section 5.1, the vehicle's acceleration characteristics shall be plotted. Data for successive time intervals are to be used to determine the vehicles average acceleration during the nth time interval

$$\bar{a}_n = (V_n - V_{n-1})/(t_n - t_{n-1}) \qquad EQ.\ 3$$

when the vehicle has reached the average speed,

$$\bar{V} = (V_n + V_{n-1})/2 \qquad EQ.\ 4$$

The data derived from these calculations shall be plotted as average acceleration versus speed as a smooth curve through the calculated points. (If the vehicle was equipped with a recording accelerometer, the acceleration curve information shall be obtained

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directly.) The percent grade the vehicle is able to traverse at any selected speed shall now be calculated using the following relationship:

Percent Gradeability at Speed = 100 tan ($\sin^{-1}$ 0.0455a) *EQ. 5*

where:

a = Vehicle acceleration at the selected speed, mph/s

(The constant 0.0455 in this equation becomes 0.0283 when acceleration is in units of kph/s.)

5.4.3 Record test section completion on Appendix D.

6. Glossary

6.1 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.

6.2 Gradeability - The maximum percent grade which the vehicle can traverse for a specified time at a specified speed. The gradeability limit is the grade upon which the vehicle can just move forward.

6.3 HICEV America – Hydrogen Internal Combustion Engine Vehicle America Performance Test Program, the DOE sponsored test program for independently assessing the performance of vehicles submitted for testing.

6.4 Initial Conditions - Conditions that shall exist prior to an event occurring.

6.5 Prerequisites - Requirements that shall be met or resolved prior to an event occurring.

6.6 Program Manager - As used in this procedure, the individual within Electric Transportation Applications responsible for oversight of HEV America.

6.7 Shall - Items which require adherence without deviation. Shall statements identify binding requirements. A go, no-go criterion.

6.8 Should - Items which require adherence if at all possible. Should statements identify preferred conditions.

6.9 Test Director - The individual within Electric Transportation Applications responsible for all testing activities associated with HICEV America.

6.10 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.

6.11 Test Engineer - The individual(s) assigned responsibility for the conduct of any given test.

6.12 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 HICEV America.

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6.13 Test Mass [Weight] - The mass [weight] of the vehicle as tested; including driver, operator (if necessary) and all instrumentation.

6.14 Tractive Force - The force available from the driving wheels at the driving wheel/ground interface.

7. References

7.1 SAE Recommended Practice - "Electric Vehicle Acceleration, Gradeability, and Deceleration Test Procedure" SAE J1666, May93

7.2 “HICEV America Vehicle Specification"

7.3 ETA-HIAC01, "Control, Close-out and Storage of Documentation"

7.4 ETA-HIAC02, "Control of Test Conduct"

7.5 ETA-HIAC04, "Review of Test Results”

7.6 ETA-HIAC05, "Qualifications, Certifications & Training of Test Personnel"

7.7 ETA-HIAC06, “Receipt Inspection”

7.8 ETA-HIAC07, “Control of Measuring and Test Equipment”

7.9 ETA-HITP04, "HICE Vehicle Constant Speed Fuel Economy Test"

7.10 SAE Recommended Practice - "Truck Ability Prediction Procedure" SAE J688, Supplement 82, 1958.

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APPENDIX-A
HICEV Acceleration to a Pre-Determined Speed
Test Data Sheet
(Page 1 of 3)

VIN Number: _____

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

Vehicle Setup

VEHICLE WEIGHTS AS TESTED WITH DRIVER & INSTRUMENTATION (Curb weight plus 332 pounds)			
Left Front: (lbs or kg)	Right Front: (lbs or kg)	Total Front: (lbs or kg)	Percent Front: %
Left Rear: (lbs or kg)	Right Rear: (lbs or kg)	Total Rear: (lbs or kg)	Percent Rear: %
		Total Weight: (lbs or kg)	

INSTALLED TIRES (Placard or sidewall whichever is less)			
Preparation Area Temperature: (°F or °C)			
Left Front		Right Front	
Pressure: (psi or kPa)		Pressure: (psi or kPa)	
Left Rear		Right Rear	
Pressure: (psi or kPa)		Pressure: (psi or kPa)	

Track/Weather Conditions

Test Track Location:	Track Grade: % (Within 1%)
Ambient Temperature (initial): (40-90°F or 5-32°C)	Ambient Temperature (final): (40-90°F or 5-32°C)
Track Temperature (initial): (°F or °C)	Track Temperature (final): (°F or °C)
Wind Velocity (initial): (<10 mph or 16 km/h)	Wind Velocity (final): (<10 mph or 16 km/h)
Wind Direction (initial): °	Wind Direction (completion): °

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APPENDIX-A
HICEV Acceleration to a Pre-Determined Speed
Test Data Sheet
(Page 2 of 3)

VIN Number:_____

Sequence No: 1	File No.:	Direction of Travel:
Time (initial):		Time (final):
Odometer (initial): (miles or kilometers)		Odometer (final): (miles or kilometers)
Comments (initials/date): *Note: Vehicles should have a 0-50 mph acceleration time of 13.5 sec or less when loaded with two 166 pound occupants* *Note: Maximum time between runs is 5 minutes.*		
Sequence No: 2	File No.:	Direction of Travel:
Time (initial):		Time (final):
Odometer (initial): (miles or kilometers)		Odometer (final): (miles or kilometers)
Comments (initials/date): *Note: Vehicles should have a 0-50 mph acceleration time of 13.5 sec or less when loaded with two 166 pound occupants*		

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APPENDIX-A
HICEV Acceleration to a Pre-Determined Speed
Test Data Sheet
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VIN Number:_____

General Comments (initials/date):

Completed By:	(Printed Name)	(Signature)	(Date)
Reviewed By:	(Printed Name)	(Signature)	(Date)
Approved By:	(Printed Name)	(Signature)	(Date)

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APPENDIX-B
Maximum Achievable Speed on a Level Road
Test Log
(Page 1 of 3)

VIN Number: _____

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

Vehicle Setup

VEHICLE WEIGHTS AS TESTED WITH DRIVER & INSTRUMENTATION (Curb weight plus 332 pounds)			
Left Front: (lbs or kg)	Right Front: (lbs or kg)	Total Front: (lbs or kg)	Percent Front: %
Left Rear: (lbs or kg)	Right Rear: (lbs or kg)	Total Rear: (lbs or kg)	Percent Rear: %
		Total Weight: (lbs or kg)	

INSTALLED TIRES (Placard or sidewalk whichever is less)			
Preparation Area Temperature: (°F or °C)			
Left Front		Right Front	
Pressure: (psi or kPa)		Pressure: (psi or kPa)	
Left Rear		Right Rear	
Pressure: (psi or kPa)		Pressure: (psi or kPa)	

Track/Weather Conditions

Test Track Location:	Track Grade: % (Within 1%)
Ambient Temperature (initial): (40-90°F or 5-32°C)	Ambient Temperature (final): (40-90°F or 5-32°C)
Track Temperature (initial): (°F or °C)	Track Temperature (final): (°F or °C)
Wind Velocity (initial): (<10 mph or 16 km/h)	Wind Velocity (final): (<10 mph or 16 km/h)
Wind Direction (initial): °	Wind Direction (completion): °

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APPENDIX-B
Maximum Achievable Speed on a Level Road
Test Log
(Page 2 of 3)

VIN Number:_____

Sequence No: 1	File No.:	Direction of Travel:
Time (initial):		Time (final):
Odometer (initial): (miles or kilometers)		Odometer (final): (miles or kilometers)
Comments (initials/date): *Note: Maximum speed achievable within 1 mile.* *Note: Maximum time between runs is 5 minutes.*		
Sequence No: 2	File No.:	Direction of Travel:
Time (initial):		Time (final):
Odometer (initial): (miles or kilometers)		Odometer (final): (miles or kilometers)
Comments (initials/date): *Note: Maximum speed achievable within 1 mile.*		

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APPENDIX-B
Maximum Achievable Speed on a Level Road
Test Log
(Page 3 of 3)

VIN Number:_____

General Comments (initials/date):

Completed By:	(Printed Name)	(Signature)	(Date)
Reviewed By:	(Printed Name)	(Signature)	(Date)
Approved By:	(Printed Name)	(Signature)	(Date)

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APPENDIX-C
HICEV Gradeability Limit
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 WITH DRIVER & INSTRUMENTATION (Rated vehicle GVWR)			
Left Front: (lbs or kg)	Right Front: (lbs or kg)	Total Front: (lbs or kg)	Percent Front: %
Left Rear: (lbs or kg)	Right Rear: (lbs or kg)	Total Rear: (lbs or kg)	Percent Rear: %
		Total Weight: (lbs or kg)	

INSTALLED TIRES (Placard or sidewall whichever is less)			
Preparation Area Temperature: (°F or °C)			
Left Front		Right Front	
Pressure: (psi or kPa)		Pressure: (psi or kPa)	
Left Rear		Right Rear	
Pressure: (psi or kPa)		Pressure: (psi or kPa)	

Track/Weather Conditions

Test Track Location:	Track Grade: % (Within 1%)
Ambient Temperature (initial): (40-90°F or 5-32°C)	Ambient Temperature (final): (40-90°F or 5-32°C)
Wind Velocity (initial): (<10 mph or 16 km/h)	Wind Velocity (final): (<10 mph or 16 km/h)
Wind Direction (initial): °	Wind Direction (completion): °

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APPENDIX-C
HICEV Gradeability Limit
Test Data Sheet
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VIN Number:_____

Sequence No: 1	File No.:	Direction of Travel:
Time (initial):	Time (final):	
Odometer (initial): (miles or kilometers)	Odometer (final): (miles or kilometers)	
Comments (initials/date): Force Reading: _____ Time Duration: _____ Vehicle Speed: _____		
Completed By: (Printed Name)	(Signature)	(Date)
Reviewed By: (Printed Name)	(Signature)	(Date)
Approved By: (Printed Name)	(Signature)	(Date)

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APPENDIX-D
HICEV Gradeability at Speed Test Data Sheet (Analytical Method)
(Page 1 of 1)

VIN Number: _____

Speed Calculated for 3% Grade
General Comments (initials/date):
Speed Calculated for 6% Grade
General Comments (initials/date):
Completed By: (Printed Name) (Signature) (Date)
Reviewed By: (Printed Name) (Signature) (Date)
Approved By: (Printed Name) (Signature) (Date)

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APPENDIX-E
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: (Printed Name) (Signature) (Date)		
Reviewed By (QA): (Printed Name) (Signature) (Date)		

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