Test Specification – APU Efficiency Testing

Center for Evaluation of Clean Energy Technology (CECET)

An Intertek Company

430 S. 2nd Avenue

Phoenix, Arizona 85003-2418

Phone: (480) 525-5885

http://www.intertek.com/automotive
http://www.intertek.com/automotive/field-performance
http://www.cecet.com

Revision History Log

Revision No.	Revisions Description	Effective Date	Revised/Reviewed By	Approved By
0	Initial release	11/23/2015	Jeffrey Wishart	Jeremy Diez

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1 Objective

The objective of this Test Specification is to provide methods for testing the efficiency of an auxiliary power unit (APU) on board a vehicle as well as to evaluate the capacity of the on-board APU to act as a generator to off-board electrical appliances of vehicles participating in the Advanced Vehicle Testing and Evaluation (AVTE) program or in other advanced vehicle testing. This Test Specification outlines the requirements for experimental conduct. The actual specific steps for the test conduct are listed and described in the associated Center for Evaluation of Clean Energy Technology (CECET) internal Work Instruction document.

2 Test Conduct

Documentation resulting from usage of this Test Specification shall be consistent, easy to understand, easy to read, and readily reproducible. All documentation required to complete testing shall be completed, approved, and ready for issue prior to commencing the testing it addresses. The following will abide by company policy:

- Review and approval of test results
- Storage and retention of records during and following testing activities
- Recording of any deviation from the outlined procedures and the reason for the deviation

3 Initial Conditions & 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.

3.1 Personnel

Personnel conducting testing under this Test Specification, i.e., the Test or Project Engineer(s), shall be familiar with the requirements of this Test Specification, shall be trained in accordance with company policy, and shall be certified by a Mandated Reviewer prior to commencing any testing activities. This requirement includes training in all aspects of the Test Specification, including its automatic shutdowns and safety procedures.

3.2 Vehicle Modes

Vehicles shall be tested in the modes that allow for the APU to power external loads. The applicable vehicle modes shall be determined by the Mandated Reviewer prior to testing.

3.3 Environmental Conditions

Ambient temperature during road testing shall be within the range of 41 °F (5 °C) to 100 °F (38 °C).

3.4 Vehicle Conditions

3.4.1 Vehicles should have accumulated a minimum of 4000 miles (6450 km) prior to this testing. Actual mileage shall be recorded prior to starting testing.

3.4.2 Vehicle Supplier's recommended tires and lubricants shall be used. Tires should have accumulated a minimum of 100 miles (160 km) and shall have at least 75% of the original tread depth remaining. All tire break-ins shall be performed on the test vehicle. Tread depth will be recorded in 1/32 inch increments prior to start of test.

3.4.3 Vehicle tires shall be inflated to the Vehicle Supplier's recommended cold inflation pressure as specified on the tire placard, corrected for the difference between ambient temperature and tire temperature. [Tire pressures will be increased 1 psi for each 13 °F; the preparation area is higher than the test area (or 1 kPa for each 1 °C)].

NOTE: Tire sizes and inflation pressures shall be in accordance with the requirements of the placard. At no time shall the tire's cold inflation pressure exceed the maximum pressure imprinted upon the tire's sidewall.

3.4.4 ESS temperatures throughout the testing shall be within Vehicle Supplier specifications.

3.4.5 Accessories shall not be used during testing.

3.5 Instrumentation

3.5.1 All instrumentation used during testing shall be calibrated. The calibration shall be performed and documented in accordance with company policy.

3.5.2 All instrumentation shall have the accuracies and resolutions noted. Unless specific exceptions have been made by a Mandated Reviewer, the following identifies the minimum instrumentation specification that shall be installed and employed during the testing.

3.5.2.1 Time

a) Accuracy ± 0.1%
b) Resolution of 0.1s

3.5.2.2 Speed

a) Accuracy of ± 0.25 mph (0.4km/h)
b) Resolution of 0.1 mph (0.2 km/h)

3.5.2.3 Temperature

The temperature indicating devices must have a resolution of 2 °F (1 °C) and an accuracy of ± 2 °F (± 1 °C). The sensing element shall be shielded from radiant heat sources.

3.5.2.4 Atmospheric Pressure

A barometer with an accuracy of ± 0.2 inches Hg (± 0.7 kPa) is necessary.

3.5.2.5 Tire Pressure

Accuracy requirement is ± 0.5 psi (± 4 kPa).

3.5.2.6 Engine RPM (if applicable)

Accuracy requirement is ± 50 RPM

3.5.2.7 Battery Current (if applicable)

Accuracy requirement is ± 1 A

3.5.2.8 Battery Voltage (if applicable)

Accuracy requirement is ± 1 V

3.5.2.9 Motor Current (if applicable)

Accuracy requirement is ± 1 A

4 Test Activity Requirements

This section addresses the activities required to meet the stated purpose and objectives of this Test Specification.

4.1 Collected Test Data

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, or as specifically excepted elsewhere.

4.1.1 Electric energy supplied by the generator

4.1.2 Fuel consumption

4.1.3 Starting and ending ambient temperature

4.1.4 The range of ambient temperature during the testing shall be recorded.

4.1.5 The date, starting and ending times shall be recorded.

4.1.6 The volume of liquid fuels consumed when testing shall be determined by a weight method. The test vehicle shall be supplied from an external fuel tank. The tank shall be weighed before and immediately after testing. The quantity of fuel consumed shall be calculated using the density of the fuel and the weight of the fuel consumed during testing. The scale used for this measurement shall have an accuracy of at least 2% of the weight of the fuel tank after testing.

4.2 Equations

The following equations will be used to calculate the Energy Efficiency and Energy Capacity of the vehicle APU from the data taken during testing. The calculation results shall be input to the appropriate locations.

$$Fuel\ Consumed = \frac{Fuel\ Weight(lb)}{Fuel\ Density\left(\frac{lb}{gal}\right)} \quad (1)$$

$$Energy\ Efficiency = \frac{Average\ Power\ (kW) \times Test\ Time\ (h)}{Fuel\ Consumed\ (gal)} \quad (2)$$

$$Energy\ Capacity = Energy\ Efficiency\ \left(\frac{kWh}{gal}\right) \times Fuel\ Tank\ Size\ (gal) \quad (3)$$

5 Glossary

APU: Auxiliary power unit. This is an engine coupled to a generator for the purpose of producing electricity. The electricity is normally used for propulsion purposes; however, in certain vehicles, the electricity can be used by off-board devices. If the latter capability exists, the testing described in this document is conducted

AVTE: Advanced Vehicle Testing and Evaluation

CECET: Center for Evaluation of Clean Energy Technology (CECET)

Charge-Depleting (CD) Mode: An operating mode in which the energy storage system (ESS) state of charge (SOC) is depleted (not continuously, but the trend is depletion) while the vehicle is driven. May be ESS-Only (i.e., the vehicle operates solely on energy from the ESS) or Blended CD (i.e., the vehicle operates on energy from both the ESS and the consumable fuel energy converter (CFEC)).

Charge-Sustaining (CS) Mode: An operating mode in which the energy storage system (ESS) state of charge (SOC) is maintained within a prescribed range by operation of a consumable fuel energy converter (CFEC).

Consumable Fuel Energy Converter (CFEC): An engine which consumes fuel to produce work (either electrical or mechanical).

Curb Weight: The total weight of the vehicle including batteries, lubricants, and other expendable supplies but excluding the driver, passengers, and other payloads.

Effective Date: After a document has been reviewed and approved, the first date the procedure can be utilized in an official capacity.

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

ESS-Only Mode: An operator selectable vehicle operating mode in which the CEFC is disabled and the vehicle operates solely on energy from the ESS.

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.

Initial Conditions: Conditions that must exist prior to an event occurring.

Initial State of Charge (SOC): ESS SOC at the beginning of a test.

Mandated Reviewer: The individual(s) responsible for the implementation of the AVTE program and of other advanced vehicle testing activities.

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

SAE: Society of Automotive Engineers

Shall: This word is used to indicate an item which requires adherence without deviation. ‘Shall’ is used to identify the binding requirements in a statement. A go or no-go criterion.

Should: This word is used to identify an item, which requires adherence if at all possible. 'Should' statements identify preferred conditions.

State of Charge (SOC): The ESS SOC is defined as the present capacity, (ampere-hours or watt-hours or miles), expressed as a percentage of the total available.

Test or Project Engineer: The individual(s) assigned responsibility for the conduct of any given test.

Test Mass (Weight): The mass [weight] of the vehicle as tested, including driver and all instrumentation

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

Vehicle Manufacturer: Entity that manufactured the test vehicle.

6 References

SAE J1666 (OCT., 2002). "Electric Vehicle Acceleration, Gradeability, and Deceleration Test Procedure"