SURFACE VEHICLE RECOMMENDED PRACTICE

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Recommended Practice for Measuring Fuel Consumption and Range of Fuel Cell and Hybrid Fuel Cell Vehicles Fueled by Compressed Gaseous Hydrogen

RATIONALE

This document is being stabilized to incorporate changes reflecting progress both the fuel cell and automotive industries have made in the extending the range and improving the fuel consumption of their latest generation of compressed hydrogen gas fueled light duty vehicles. SAE J1711 has supplanted SAE J2572 as the SAE Recommended Practice used to calculate emissions and fuel economy for this class of vehicles. SAE J2572 provided procedures for measuring fuel consumption, emissions, and range using only two major test cycle procedures (UDDS and HFEDS) based on the U.S. Federal Emission Test Procedures. SAE J1711 uses an expanded testing process to include all five recognized test cycle procedures (UDDS, HFEDS, US06, SC03, and cold FTP). Because of this expanded test process, SAE J1711 is the current industry preferred document for the purpose of measuring fuel consumption and range across a broader range of test scenarios.

STABILIZED NOTICE

This document has been declared “STABILIZED” by SAE Fuel Cell Standards Committee and will no longer be subjected to periodic reviews for currency. Users are responsible for verifying references and continued suitability of technical requirements. Newer technology may exist.

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1. SCOPE

This SAE Recommended Practice establishes uniform procedures for testing fuel cell and hybrid fuel cell electric vehicles, excluding low speed vehicles, designed primarily for operation on the public streets, roads and highways. The procedure addresses those vehicles under test using compressed hydrogen gas supplied by an off-board source or stored and supplied as a compressed gas onboard.

This practice provides standard tests that will allow for determination of fuel consumption and range based on the US Federal Emission Test Procedures, using the Urban Dynamometer Driving Schedule (UDDS) and the Highway Fuel Economy Driving Schedule (HFEDS).

Chassis dynamometer test procedures are specified in this document to eliminate the test-to-test variations inherent with track testing, and to adhere to standard industry practice for fuel consumption and range testing.

Communication between vehicle manufacturer and the governing authority is essential when starting official manufacturer in-house and official government confirmatory testing that incorporates this practice.

2. REFERENCES

2.1 Applicable Documents

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 International, 400 Commonwealth Drive, Warrendale, PA15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE J2263 Road Load Measurement Using Onboard Anemometry and Coastdown Techniques

SAE J2264 Chassis Dynamometer Simulation of Road Load Using Coastdown Techniques

SAE J2574 Fuel Cell Vehicle Technology

2.1.2 CFR Publications

Available from the Superintendent of Documents, U.S. Government Printing Office, Mail Stop: SSOP, Washington, DC20402-9320.

40 CFR Part 86 EPA; Control of Air Pollution from New and In-Use Motor Vehicles and New and In-Use Motor Vehicle Engines; Certification and Test Procedures

40 CFR Part 600 EPA; Fuel Economy of Motor Vehicles

2.1.3 United States Department of Commerce, National Institute of Standards and Technology Publication

Available from NIST, 100 Bureau Drive, Stop 1070, Gaithersburg, MD20899-1070, Tel: 301-975-6478,http://physics.nist.gov/cuu/Uncertainty/bibliography.html.

NIST Technical Note 1297, 1994 Edition, “Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results”

3. DEFINITIONS

3.1 CURB WEIGHT

The total weight of the vehicle with all standard equipment and including batteries/capacitors, lubricants at nominal capacity, and the weight of optional equipment that is expected to be installed on more than 33% of the vehicle line, but excluding the driver, passengers, and other payloads. Incomplete light-duty trucks shall have the curb weight specified by the manufacturer.

3.2 BATTERY

A device that stores chemical energy and releases (or receives) electrical energy (only chemical batteries are considered in this Recommended Practice).

3.3 PROPULSION BATTERY

A device that provides electrical power that is used to propel the vehicle.

3.4 AUXILIARY BATTERY

A battery provided separately from the primary energy source for operating an instrument such as a vehicle control device (peripheral devices).

3.5 RATED AMPERE-HOUR CAPACITY

The manufacturer-rated capacity of a battery in ampere-hours, obtained from a battery discharged at the manufacturer's recommended discharge rate such that a specified minimum cut-off terminal voltage is reached.

3.6 CAPACITOR

A device that stores energy electrostatically and releases (or receives) electrical energy. High power capacitors used in hybrid vehicles are frequently called “ultracapacitors.”

3.7 CAPACITOR RATED CAPACITY

The measured capacity of a capacitor, expressed in farads (F).

3.8 FUEL CELL

An electrochemical energy conversion device in which fuel and an oxidant react to generate electricity without any consumption, physically or chemically, of its electrodes or electrolyte.

3.9 FUEL CELL VEHICLE (FCV)

A vehicle that receives propulsion energy from an onboard fuel cell power system.

3.10 HYBRID FUEL CELL VEHICLE (HFCV)

A vehicle that receives propulsion energy from both an onboard fuel cell power system and another energy source (only batteries and capacitors are covered in this Recommended Practice).

3.11 RECHARGEABLE ENERGY STORAGE SYSTEM (RESS)

A component or system of components that stores energy, for the purpose of propelling the vehicle, and for which its supply of energy is rechargeable by an on-vehicle electric motor-generator system, an off-vehicle electric energy source, or both. Examples of RESS's for HEV's include batteries, capacitors, and electro-mechanical flywheels.

3.12 REGENERATIVE BRAKING

Deceleration of the vehicle caused by operating an electric motor-generator system, thereby providing charge to the battery or capacitor.

3.13 START-OF-TEST

The point during a test at which the vehicle key switch is first placed in the “on” position.

3.14 END-OF-TEST

The point (in time and distance) at which the vehicle has been decelerated to a rest (zero velocity) condition after the appropriate test termination criteria have been met, the key switch is placed in the “off” position, and the fuel cell and propulsion battery or capacitor (if equipped) are stabilized (manufacturer automatic shutdown procedure: Hydrogen fuel flow stops and the electrical energy storage device reaches a stable condition).

3.15 TOTAL FUEL CAPACITY (kg)

The total mass of gaseous hydrogen contained in the fuel tank when it is filled to its nominal working pressure at a stabilized temperature of 15 °C.

3.16 UNUSABLE FUEL AMOUNT (kg)

The total mass of gaseous hydrogen remaining in the fuel tank at the point of Run-Out, where the pressure in the tank no longer supports stable Fuel Cell System function or where the vehicle control system no longer allows fuel to be extracted.

3.17 USABLE FUEL AMOUNT (kg)

The difference in mass between the Total Fuel Capacity and the Unusable Fuel Amount.

3.18 TOTAL TANK VOLUME (Liters)

The total water volume, at 1 atmosphere and 15 °C, of the entire space within the fuel tank system that can contain high-pressure hydrogen upstream of any isolation valve or pressure regulator.

3.19 Nominal Working Pressure (NWP)

The NWP is the gauge pressure that characterizes typical operation of a pressure vessel, container, or system. For compressed hydrogen gas containers, NWP is the container pressure, as specified by the manufacturer, at a uniform gas temperature of 15 °C (59 °F) and full gas content.

NOTES: NWP is also called Service Pressure.

4. TEST CONDITIONS AND INSTRUMENTATION

The following conditions shall apply to all tests defined in this document unless otherwise stated in specific test procedures.

4.1 Condition of Vehicle

4.1.1 Vehicles shall be stabilized as determined by the manufacturer and shall have accumulated a minimum of 1600 km (1000 miles), but no more than 9978 km (6200 miles) on the Durability Driving Schedule as defined in 40 CFR Part 86, Appendix IV, Section (a) or an equivalent driving schedule. Fuel conforming to specifications given in 4.7.2 shall be used for mileage accumulation.

4.1.2 Vehicles shall be tested with normal appendages (mirrors, bumpers, hub caps, etc.) for all testing. For the case where an off-board fuel source is used for the test, the vehicle under test may include a connector to receive the fuel from that off-board source, as mutually agreed to with the testing agency. Certain items (e.g., hub caps) may be removed where necessary for safety on the chassis dynamometer. If any appendages are removed, the fact shall be noted.

4.1.3 All accessories shall be turned off.

4.1.4 The vehicle shall be tested at loaded vehicle weight [curb weight plus 136 kg (300 lb)].

4.1.5 Manufacturer's recommended tires shall be used. Tires shall be conditioned as recommended by the vehicle manufacturer and shall have accumulated a minimum of 100 km (62 miles) and have at least 50% of the original usable tread depth remaining. For chassis dynamometer testing, tire pressures shall be set to the manufacturer recommended pressure used to establish the Dynamometer Road Target Coefficients (see SAE J2263) and shall not exceed levels necessary for safe operation.

4.1.6 The lubricants normally specified by the manufacturer shall be used.

4.1.7 If the vehicle has regenerative braking, the regenerative braking system shall be enabled for all chassis dynamometer testing, with the exception of track coastdown testing. For dynamometer testing, if the regenerative braking level is adjustable, it shall be set according to the manufacturer's specification prior to the commencement of the test. The driving schedule speed and time tolerances specified in this procedure shall not be exceeded due to the operation of the regenerative braking system.

NOTE: Adjustment of the regenerative braking system may be necessary to represent the net effect of four-wheel-drive regenerative braking mode on a two-wheel-drive chassis dynamometer.

4.1.8 The FCV or HFCV shall be able to drive the UDDS and HFEDS cycles (within the required drive schedule speed and distance tolerances).

4.2 Condition of Fuel Cell Stack

4.2.1 The fuel cell stack shall have been aged with the vehicle as defined in 4.1.1, or equivalent conditioning.

4.3 Condition of Propulsion Battery/Capacitor

4.3.1 The propulsion battery or capacitor shall have been aged with the vehicle as defined in 4.1.1, or equivalent conditioning.

4.3.2 The vehicle shall provide a point of access such that a measurement of current readings into and out of the energy storage device (e.g., battery, capacitor) is available. This point of access must be compatible with the DC Wideband Ampere-Hour Meter specified in this procedure. Readings from a vehicle onboard current measurement system can be used provided that ±1% NIST traceability can be demonstrated.

4.4 Environmental Conditions

4.4.1 Ambient temperature during the entire test sequence shall be within the range of 20 °C to 30 °C (68 °F to 86 °F).

4.5 Dynamometer

4.5.1 Use of an electric single roll chassis dynamometer, 1.2192 m (48 in.) in diameter, or equivalent, is required for FCV and HFCV testing. Electric dynamometers shall have the capability of road load simulation at an appropriate vehicle test weight and with vehicle speeds ranging from 113 to 16 km/h (70 to 10 miles per hour).

4.5.2 The dynamometer $Dyno_{set}$ coefficients shall be determined using test procedure SAE J2264.

4.5.3 Four-wheel drive or all-wheel drive vehicles, when using two independent power sources, shall be tested on a four-wheel-drive 48-inch roll chassis dynamometer, if both sets of wheels are powered. Otherwise, four-wheel or all-wheel drive vehicles may be tested in a two-wheel-drive mode of operation per 40 CFR 86.135-90 (i).

4.5.4 For a two-wheel-drive chassis dynamometer, inertia weight shall be set to 1.015 times the loaded vehicle weight. The addition of the 1.5% is to account for rotating inertia not accounted for under static conditions. The value of 1.015 may not be suitable for all vehicles. If an actual or estimated value for rotating inertia is known for the particular vehicle being tested, the more accurate value should be documented and used.

4.5.5 For four-wheel or all-wheel drive vehicles tested on a four-wheel drive dynamometer, the dynamometer inertia weight shall be set to loaded vehicle weight [curb weight plus136 kg (300 lb)].

4.5.6 During chassis dynamometer operation, a fixed speed or proportional speed cooling fan shall be positioned so as to direct cooling air to the vehicle in a manner consistent with the accepted practices for simulating road conditions. The fixed speed fan capacity in general shall not exceed 2.5 m^3/s (5300 ft^3/min). The type of fan used must be noted.

4.5.7 If the chassis dynamometer has not been operated for a period of 2 hours immediately preceding the test, it shall be warmed up as recommended by the dynamometer manufacturer.

4.6 Test Instrumentation

This section provides a list of instruments, which are required to perform the tests specified in this Recommended Practice.

4.6.1 The overall accuracy goal of measuring the mass of hydrogen fuel consumed during a test cycle shall be ±1.0% of reading. See reference NIST Technical Note 1297 for "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results." Three methods for the measurement of hydrogen consumption have been reviewed and found to be acceptable (see 7.2): (1) net mass change, based on a fuel cylinder's pressure, volume, and temperature; (2) net mass change, based on a weigh scale method; and (3) cumulative integrated mass, based on a Mass Flow Meter.

4.6.2 The chassis dynamometer shall measure vehicle speed to within 0.5% of maximum vehicle speed and integrate distance traveled within 0.5% of actual distance. The coastdown measurement instrument accuracy and process, for determining $Dyno_{set}$ coefficients, is described in SAE J2263/SAE 2264, and can be used as applicable.

4.7 General Instrumentation

All instrumentation calibration must be National Institute of Standards and Technology (NIST) traceable to within ±1.0% of full scale of the appropriate range. The following classes of instruments are typical of those required for the tests outlined in this procedure. Instruments used shall meet the minimum or equivalent requirements provided in this Section.

4.7.1 Gaseous hydrogen fuel consumption mass measurement.

4.7.2 Vehicle speed versus time recorder.

4.7.3 Distance versus time recorder.

4.7.4 Ambient temperature versus time recorder.

4.7.5 DC Wideband Ampere-Hour Meter using an integration technique shall have an integration period of less than 0.05 second so that abrupt changes of current can be accommodated without introducing significant integration errors. Sign Convention: "+" = Discharge, "–" = Charge. The ammeter shall be capable of totaling the current, and the required current resolution shall be ±1% of the expected totalized value.

4.7.6 A voltmeter and ammeter for as-needed usage (recommended).

4.7.7 Wideband instruments (bandwidth of at least 10 times that of the maximum fundamental frequency) are required where pulsed power electronics are implemented.

4.8 Test Vehicle Fuel Source

4.8.1 Vehicles may be tested using the fuel in the vehicle fuel tank(s) or a separate fuel source. In either case, a method of accurately measuring the fuel used in each of the city and highway tests is required.

4.8.2 Hydrogen complying with the appropriate SAE or appropriate U.S.A. government agency-specified fuel shall be used for all testing. To minimize performance degradation of the fuel cell stack, this fuel shall also comply with fuel quality guidance specified within SAE J2719.

4.8.3 For the case where a separate off-board fuel source is used, good engineering judgment shall be applied to consider the maximum delivery pressure.

5. REQUIRED DATA

5.1 General

5.1.1 Vehicle identification (manufacturer, model, year, etc.) and configuration (description of any nonstandard vehicle features; e.g., sunroof and oversize exterior mirrors).

5.1.2 Vehicle accumulated mileage at the start and end of each portion of the test sequence.

5.1.3 Curb weight and test weight.

5.1.4 Vehicle History

Previous history of the fuel cell, including chronological age, and a brief description of known adverse usage conditions.

5.1.5 Fuel Tank:

Manufacturer
Type
Usable Fuel Amount (kg).
Total Tank Volume (Liters)
Nominal Working Pressure (NWP) (Bars/PSIA)

5.1.6 Fuel Cell:

Manufacturer
Type
Power rating (kW)

5.1.7 Propulsion Battery or Capacitor:

Manufacturer
Type
Maximum Rated Ampere-Hour Capacity

5.1.8 Electric Propulsion Motor:

Type
Peak Power Rating (kW)

5.1.9 Overall drive train ratio(s) used during test and vehicle speed shift points for manual transmission vehicles.

5.1.10 Tire manufacturer, design, size, and pressures at start of test.

5.1.11 The range and average temperature of the ambient during test.

5.1.12 Soak duration and range of temperatures during soak.

5.1.13 Date, starting and ending times of test.

5.1.14 The type of instrumentation and methodology used to measure the energy/power flow to and from the propulsion battery/capacitor.

5.1.15 Mass of hydrogen fuel consumed during the test, the measurement method, and a description of the instrumentation used to make the measurement, including its accuracy.

5.1.16 Any deviation from this test procedure and the reason for deviation.

5.2 Dynamometer Data

5.2.1 Description of dynamometer used (including roll diameter, number of rolls, distance between roll axes, if applicable) and method of vehicle restraint.

5.2.2 Dynamometer Dynoset and Dynotarget coefficients.

5.2.3 Dynamometer inertia weight setting.

5.2.4 Actual distance driven (roll revolutions) for each test cycle, shall be reported to 3 decimal places. For example the 1372 second UDDS drive cycle is theoretically 6.278 kilometers (3.902 miles)

5.2.5 Time versus speed trace.

6. DRIVING SCHEDULES

The driving schedules provided are the United States Environmental Protection Agency (EPA) Urban Dynamometer Driving Schedule and the Highway Fuel Economy Driving Schedule.

6.1 City Fuel Economy Test

The driving cycle to be utilized for the city fuel economy test represents US city driving and consists of a series of non-repetitive idle, acceleration, cruise, and deceleration modes of various time sequences throughout an interval of 1372 seconds, as detailed in the EPA Urban Dynamometer Driving Schedule (UDDS). The Test is conducted by following the UDDS driving cycle (1372 seconds), then immediately initiating a 600-second soak period with the vehicle shut-off, followed by a repeat of the UDDS driving cycle. The distance traveled in one UDDS cycle is 12 km (7.45 miles) with an average speed of 31.5 km/h (19.6 mph) and a maximum speed of 91.2 km/h (56.7 mph). The driving cycle as described by the UDDS is in Appendix I of 40 CFR Part 86.

6.2 Highway Fuel Economy Test

The driving cycle to be utilized for the highway fuel economy test represents US highway driving and consists of a series of non-repetitive acceleration, cruise and deceleration modes of various time sequences throughout an interval of 765 seconds, as detailed in the EPA Highway Fuel Economy Driving Schedule (HFEDS). The test is conducted by performing a warm-up drive using the HFEDS driving cycle (765 seconds), followed immediately by a repeat of the HFEDS driving cycle during which fuel consumption is measured and recorded. The distance traveled for each 765-second drive is 16.4 km (10.2 miles). The average speed is 77.8 km/h (48.3 mph) with a maximum speed of 96.4 km/h (59.9 mph). The driving cycle as described by the HFEDS is in 40 CFR, Section 600.109(b).

6.3 Speed Tolerance

The speed tolerance at any given time on the UDDS and HFEDS driving schedules is defined by the upper and lower limits as described in 40 CFR part 86.115-78 and Appendix 1. The upper limit is 3.2 km/h (2 mi/h) higher than the highest point on the trace within 1 second of the given time. The lower limit is 3.2 km/h (2 mi/h) lower than the lowest point on the trace within 1 second of the given time. Speed variations greater than the tolerances (which may occur during gear changes) are acceptable provided they occur for less than 2 seconds on any occasion.

6.4 Fuel Consumption Tests

If either the UDDS or HFEDS driving schedules cannot be completed within the tolerances of 6.3, the point(s) in question for the driving schedule shall be noted and the test continued with the vehicle operating under "best effort" conditions.

7. VEHICLE FUEL CONSUMPTION DETERMINATION

7.1 Purpose of Test

The purpose of this test is to determine the fuel consumed by a test vehicle when operated on a dynamometer over prescribed driving cycles. It is the intent of this section to provide standard procedures for testing FCVs and HFCVs so that the performance can be compared when operated over fixed driving patterns. Two test types can be performed: a "city" fuel consumption measurement using the UDDS drive cycle, and a "highway" fuel consumption measurement using the HFEDS driving cycle. Both test types can be performed in a sequence, with the city test followed by the highway test, or as an option, each test type can be run separately.

7.2 Methods of Fuel Consumption Determination

Fuel consumption is reported as the mass quantity of hydrogen consumed per distance traveled, kilograms/kilometer (kg/km). The following methods have been investigated and found to be acceptable for determining the net mass of hydrogen consumed during testing:

7.2.1 Stabilized Pressure and Temperature for a Fixed Volume Pressure Vessel

Determine the hydrogen mass in the fuel tank, using stabilized pressure and temperature measurements for any hydrogen storage vessel for which the actual water volume of the vessel is known. The instrumentation used for temperature and pressure measurement must meet the accuracy requirements of 4.6.1.

Hydrogen consumption is measured by comparing the difference in tank fuel temperature and pressure before and after each test. The initial measurements and the after test measurements of temperature and pressure must be made after the vehicle, including fuel tank, reach stabilization at standard soak conditions. The functional relationship and equation to measure hydrogen consumption is:

$$n2 = f(T1,P1 ,Vt) = n1f (T2,P2 ,Vt) \quad \text{(Eq. 1)}$$

where:

P = Pressure (psig), of the gas in vehicle fuel tank
T = Temperature (°F), of the gas in vehicle fuel tank
V_t= Total tank volume
n = Moles of hydrogen
(n_2-n_1) = Moles of hydrogen consumed over a test cycle

Non-measured values can be obtained from the specific pressure and temperature data from the US NIST using the website below:

http://webbook.nist.gov/chemistry/fluid/

7.2.2 Gravimetric Method for Weighing Auxiliary Fuel Tank(s)

The quantity of hydrogen consumed during a test may also be determined by weighing the auxiliary hydrogen fuel tank(s) (used only for emissions and fuel consumption testing) at the start and at the end of each test cycle. The precision and accuracy of the scale used for weighing the auxiliary fuel tanks must support the overall fuel measurement accuracy requirements listed in 4.6.1.

7.2.3 Fuel Flow Meter

A mass flow meter may also be used to determine the quantity of hydrogen used during the test cycle. The precision and accuracy of the flow meter measurements must support the overall fuel measurement accuracy requirements listed in 4.6.1.

7.3 Calculation and Reporting of Vehicle Fuel Consumption

The fuel consumption for a given test type is expressed in kg/km and is determined from the mass of hydrogen measured in grams, divided by the measured driving distance of the test in kilometers. The equations below provide the general calculations for City and Highway Fuel Consumption.

$$\text{City Fuel Consumption} = 0.43 * \{M_{UDDS(1)} / D_{UDDS(1)}\} + 0.57 * \{M_{UDDS(2)} / D_{UDDS(2)}\} \quad \text{(Eq. 2)}$$

where:

$M_{UDDS(1)}$ = Hydrogen mass consumed during the first UDDS, in g
$M_{UDDS(2)}$ = Hydrogen mass consumed during the second UDDS, in g
$D_{UDDS(1)}$ = The measured driving distance during the first UDDS,km
$D_{UDDS(2)}$ = The measured driving distance during the second UDDS, km

$$\text{Highway Fuel Consumption} = 0.0 * \{M_{HFEDS(1)} / D_{HFEDS(1)}\} + 1.0 * \{M_{HFEDS(2)} / D_{HFEDS(2)}\} \quad \text{(Eq. 3)}$$

where:

$M_{HFEDS(1)}$ = Hydrogen mass consumed during the first HFEDS, in g
$M_{HFEDS(2)}$ = Hydrogen mass consumed during the second HFEDS, in g
$D_{HFEDS(1)}$ = The measured driving distance during the first HFEDS, km
$D_{HFEDS(2)}$ = The measured driving distance during the second HFEDS, km

All mass values are reported to the nearest 0.1 gram.
All distance values are reported to the 3rd decimal place, 0.001 km
All fuel consumption values are reported to the nearest 0.0001 kg/km

NOTE: 1kg H2 = 423.3 SCF H2 gas. This conversion is listed in the BOC Industrial Gases Data Book © 1994, The BOC Group Inc.

7.4 Track Determination of Dynamometer Target Coefficients

SAE J2263 shall be used to determine the Dynamometer Target Coefficients.

NOTE: The SAE procedure J2263 assumes a "true neutral" gear is available. If the powertrain design of a fuel cell vehicle does not employ such a "true neutral," unique coast down methods may need to be developed.

7.5 Dynamometer Test Procedure for City Fuel Consumption Measurement

7.5.1 Initial State of the Vehicle

Prior to testing, the vehicle may be brought to nominal operating condition (including RESS state-of-charge) using good engineering judgment and appropriate preconditioning procedures.

7.5.2 Fueling

Either the vehicle's on-board fuel tank, or an auxiliary fuel tank, may be used. If the vehicle and tank fuel are not stabilized at laboratory ambient temperatures, soak the vehicle for 6 to 36 hours. Omit this step if auxiliary fuel is used and the vehicle was maintained at laboratory ambient temperatures. Auxiliary fuel tank(s) shall be stabilized at laboratory ambient temperatures.

7.5.3 Vehicle Set-Up

Set drive wheel tire pressure, properly secure the vehicle on the dynamometer, raise the vehicle hood, and place the auxiliary cooling fan in front of the vehicle.

7.5.4 Preconditioning

Conduct one UDDS prep cycle (additional as needed) to condition the vehicle.

7.5.5 Vehicle Soak

The vehicle shall be soaked at laboratory ambient temperature between 12 and 36 hours.

7.5.6 If the dynamometer has not been used within two hours of testing, warm up the dynamometer per 4.5.7.

7.5.7 The vehicle shall be moved (pushed or towed – not driven) into position on the dynamometer. Laboratory ambient temperature must be maintained at all times.

7.5.8 If the vehicle has a manual transmission, gears shall be shifted at predefined shift points reasonably expected to be followed by vehicles in use.

7.5.9 Regenerative Braking

If the vehicle has regenerative braking, the regenerative braking system shall be enabled for all dynamometer testing. An accurate way to account for the effect of regenerative braking is to test the vehicle on a four-wheel drive electric dynamometer. Operating a hybrid vehicle with regenerative braking on a two-wheel drive dynamometer could overstate the effect of regenerative braking by artificially forcing all braking to occur on the driven axle.

If a vehicle is equipped with an Antilock Braking System (ABS) or a Traction Control System (TCS) and is tested on a two-wheel dynamometer, the vehicle's ABS or TCS may inadvertently interpret the non-movement of the set of wheels that are off the dynamometer as a malfunctioning system. If so, then modifications to the ABS or TCS shall be made to achieve normal operation of the remaining vehicle systems, including the regenerative braking system.

7.5.10 Connect the auxiliary fuel line to the vehicle if required. Ensure fuel-metering device (pressure and temperature to determine fuel consumed during test) is properly and safely set up.

7.5.11 For HFCVs

Prior to turning vehicle key to "on" position, initialize auxiliary instrumentation (Wideband Ampere-hour Meter) and begin the process of measuring and recording the net change in the rechargeable energy storage system (RESS). Begin fuel measurement, turn vehicle key to the "on" position and start auxiliary cooling fan (36-hour soak time shall not be exceeded).

7.5.12 Conduct two UDDS drive cycles (ref Step 6.1), with a 10 min ± 1 min vehicle soak between them. During the soak period the following conditions shall exist: the ignition key switch in the "off" position, the hood closed, test cell fan(s) off, and the brake pedal not depressed. Turn vehicle key to "off" position and turn off auxiliary cooling fan upon completion of test.

7.5.13 For HFCVs

End fuel measurement, terminate the auxiliary test instrumentation (Wideband Ampere-Hour Meter) measurement, and save the appropriate Ampere-hour readings from the rechargeable energy storage system, and the hydrogen fuel meter (if applicable).

7.6 Dynamometer Test Procedure for Highway Fuel Economy Measurement

7.6.1 If the highway test follows the city test within the 3 hours, steps 7.5.1 through 7.5.8 may be omitted as appropriate.

7.6.2 Fueling

Either the vehicle's on-board fuel tank or an auxiliary fuel tank may be used.

7.6.3 If the vehicle and tank fuel are not stabilized at laboratory ambient temperatures, soak the vehicle for 6 to 36 hours. Omit this step if auxiliary fuel is used and the vehicle was maintained at laboratory ambient temperatures. Auxiliary fuel tank(s) shall be stabilized at laboratory ambient temperatures.

7.6.4 If the dynamometer has not been used within two hours of testing, warm up the dynamometer per 4.5.7.

7.6.5 The vehicle shall be moved into position on the dynamometer. Laboratory ambient temperatures must be maintained at all times.

7.6.6 If the vehicle has a manual transmission, gears shall be shifted at predetermined shift points reasonably expected to be followed by vehicles in use.

7.6.7 Vehicle Set-Up

Set drive wheel tire pressure, properly secure the vehicle on the dynamometer, raise the vehicle hood, and place the auxiliary cooling fan in front of the vehicle.

7.6.8 Connect the auxiliary fuel line to the vehicle if required. Ensure fuel metering device (to measure fuel consumed during test) is properly set up.

7.6.9 Turn vehicle ignition key to the "on" position and start auxiliary cooling system.

7.6.10 Vehicle Warm-up

Drive the vehicle over one HFEDS driving cycle.

7.6.11 For HFCVs begin auxiliary instrumentation measurement at time 0 of 2nd HFEDS driving cycle.

7.6.12 Conduct the highway test (ref 6.2) with 10 seconds between the HFEDS driving cycles.

7.6.13 For HFCVs terminate the auxiliary test instrumentation (Wideband Ampere-Hour Meter) measurement and save the appropriate Ampere-hour readings from the cell, the electrical energy storage device, and the hydrogen fuel meter (if applicable). Terminate the auxiliary test instrumentation (Power Meter) measurement and record net Power/Energy reading.

7.7 Fuel Consumption Corrections to Account for Battery/Capacitor Effect

Currently, many HFCVs are designed in a hybrid electric vehicle configuration, one with an energy storage system (battery or capacitor) supplementing the fuel cell stack energy during various modes of operation. This type of hybrid design makes the accurate measurement of hydrogen consumption of the vehicle difficult, because of the effect a change in the electrical energy storage system can have on hydrogen consumption over a given drive cycle. For example, the RESS could have net depletion during the course of a test as the energy management system uses this energy to supplement the power of the vehicle, thereby reducing the hydrogen consumed by the vehicle. This would give an indication of greater fuel economy than would actually be the case, because the test cycle did not provide the full opportunity for the energy management system to recharge the RESS.

To more accurately report hydrogen fuel consumption during a test and provide flexibility to the design of the vehicle's power control strategy, one would like to have a test method that provides an unbiased fuel consumption test result in a standardized manner. This method would correct for the battery/capacitor influence on vehicle fuel consumption, should the energy storage system state-of-charge significantly change during the course of a test. The following procedure addresses the methodology for determining such an unbiased result and the criterion for applying or not applying the method.