SAE International™

SURFACE VEHICLE RECOMMENDED PRACTICE

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Measurement of Hydrogen Gas Emission from Battery-Powered Passenger Cars and Light Trucks During Battery Charging

1. ***Scope***—This SAE Recommended Practice describes a procedure for measuring gaseous hydrogen emissions from the aqueous battery system of a battery-powered passenger car or light truck. The purpose of this procedure is to determine what concentrations of hydrogen gas an electric vehicle together with its charger will generate while being charged in a residential garage. Gaseous emissions are measured during a sequence of vehicle tests and laboratory tests that simulate normal and abnormal conditions during operational use. The results of this test may be used to determine whether or not forced air ventilation is required when a particular electric vehicle and its associated battery and charging system are used in a residential garage.

a. Gaseous emissions are measured in an enclosure during charging cycles at temperature extremes simulating garage charging at the manufacturer's recommended upper and lower operating limits of the battery under test.
b. To prevent damage of the battery under normal operating conditions due to ignition of gases within the battery by an external spark or flame, battery systems that are vented shall be equipped with a suitable flame arresting system. A flame arrestor may be provided either for each individual cell or at the outlet of a battery venting system.
c. Because certain failures in the charging system could cause gassing to be many times the normal rate, the measurement of hydrogen during the test should include appropriate abnormal conditions such as single point failures in the charging control subsystem.

These are tests of the charging system which may involve components both on and off the vehicle. It is also expected that there will be a wide variety of designs to accomplish battery charging. It is therefore required that great care be exercised in the detailed execution of these tests so that their intent is preserved.

The Scope of this document is intended to cover all battery conditions which may maximize gassing. However, it does not include the testing of batteries at their end of life. It is generally accepted that aged batteries will emit more gas while charging and the achievement of the aged condition by accelerated means would be difficult to control and the test results would not be reproducible.

1.1 Rationale—This Recommended Practice defines a procedure for measuring gaseous hydrogen emissions from the aqueous battery system of a battery-powered passenger car or light truck. The purpose of this procedure is to determine what concentrations of hydrogen gas an electric vehicle together with its charger will generate while being charged in a residential garage. Hydrogen is generated from aqueous batteries during charge. Today's use of aqueous batteries is limited to Neighborhood Electric Vehicles or special military vehicles.

SAE J1718 is not relevant to the new fleet of general purpose electric or hybrid electric vehicles that are being developed with advanced battery technology, which are sealed battery systems with a different chemistry that does not produce hydrogen on charge. Aqueous batteries don't have sufficiently high energy density or specific energy to be competitive with today's advanced battery technologies that will be used in the new vehicles under development. Furthermore, procedures that address hydrogen safety in fuel cell vehicles are addressed elsewhere.

2. References

2.1 Applicable Documents—The following publications form a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J1634—Electric Vehicle Energy Consumption and Range Test Procedure
SAE J1715—Electric Vehicle Terminology

2.1.2 NFPA PUBLICATION—Available from National Fire Protection Association, Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 30—Flammable and Combustible Liquids Code

2.1.3 UL PUBLICATION—Available from Underwriters Laboratories, 333 Pfingsten Road, Northbrook, IL 60062-2096.

UL 1989—Standard for Standby Batteries

3. Definitions—The following definitions apply to the terms used:

3.1 Flame Arrestors—Devices located at the outlet(s) of a battery venting system designed to prevent damage of the battery system from an external spark or flame that could ignite gases within the battery system under normal operating conditions. A Flame Arrestor must prevent propagation of an external flame into the battery system when tested in accordance with the Flame Arrestor Vent Cap Tests described in UL 1989 or comparable procedures. It is accepted that flame arrestors may also be incorporated within a battery system to prevent internal propagation of explosions. However, their testing lies outside the scope of this procedure.

3.2 Adequate Ventilation—As defined in NFPA 30, ventilation is considered adequate if it is sufficient to prevent accumulation of vapor-air mixtures in concentrations over one-fourth of the lower flammable limit (LFL).

4. Power Control and Charger

4.1 The vehicle and off-board equipment involved in charge control are to be either supplied by the manufacturer or the equipment must be as specified by the vehicle manufacturer.

5. Test Facilities and Equipment

5.1 Provisions must be made for controlling the environment of the vehicle, cooling the vehicle, and charging and discharging the battery system. All temperatures have tolerances of ±5 °C unless otherwise stated.

5.2 Environment—Appropriate controls must be provided to maintain ambient test temperatures at 43 °C (110 °F) and –18 °C (0 °F).

5.3 Energy Dissipation—A means of dissipating the energy from the battery system must be provided. This could take various forms such as a chassis dynamometer or electrical load.

5.4 Vehicle Powertrain Cooling—A fan of adequate capacity may be needed to maintain vehicle powertrain cooling if the vehicle is running on the chassis dynamometer.

5.5 Battery Operating Temperatures—Batteries are intended to be tested at the extremes of their recommended operating temperatures. It may be necessary to provide a means of achieving the maximum and minimum battery operating temperatures specified by the manufacturer, such as soaking, discharging, or heating or cooling elements as agreed to by the manufacturer.

5.6 DC Current, Voltage, and Temperature Measurement—Instrumentation to measure DC current, voltage, and temperature of the battery system must be provided. If it is not available on board the vehicle, it must be provided externally. The required degree of accuracy shall be as specified in SAE J1634.

5.7 Test Enclosure—An enclosure with internal dimensions of 3 x 6 x 2.6 m (10 x 20 x 8.5 ft) high will accommodate vehicles with up to 3300 mm (130 in) wheelbase, and has been found convenient for testing most U.S. passenger cars. The foregoing dimensions may be adjusted to accommodate different size vehicles without significantly affecting the test results. The enclosure door must allow entry of the maximum size vehicle. Door sealing may be accomplished by a resilient gasket, an inflatable seal, or a pressure sealing zipper if a flexible door is used.

Care must be taken to limit the permeation of hydrogen (see Appendix A for leak check). Permeable materials may be covered with polyvinyl fluoride sheet of approximately 0.15 mm (0.006 in) thickness. One wall, door, or ceiling should be of flexible material such as 0.15 mm (0.006 in) polyvinyl fluoride sheet to provide a safety "blow-out" panel, and to allow for minor temperature changes of the contained gas without excessive "breathing."

A mixing blower is needed for Appendix A tests but is optional for Section 8 tests.

5.8 Gas Monitoring Equipment—The enclosure must be equipped with a combustible gas monitoring system capable of measuring hydrogen concentrations reliably in the range of 400 to 40 000 ppm.

5.9 The following calibration gases are required:

a. Industrial-grade hydrogen gas
b. 2.00% hydrogen by volume in air (nominal)

The sample should be withdrawn from the enclosure through a tube of 6.4 mm (1/4 in) ID, terminating 50.8 to 305 mm (2 to 12 in) inside the wall and located on the geometric center of the wall opposite the door or on one of the sides or below the center of the ceiling. The tubing connecting this tube to the analyzer should be of 6.4 mm (1/4 in) OD stainless steel or similar inert material and should be as short as possible.

5.10 Purge Blower—A blower of adequate capacity is required for purging the enclosure between tests.

5.11 Temperature Measuring Device—Two temperature measuring devices for monitoring the enclosure temperature should be installed 76 cm (30 in) above the floor and 10 cm (4 in) in from either side, both midway along the length of the enclosure.

6. Test Overview—The test method provides for sealing the vehicle in an enclosure during the test. Hydrogen emissions are determined from the changes in the hydrogen concentrations in the enclosure. The complete enclosure measurement system should be checked initially and periodically for calibration, hydrogen retention (leakage), and self emission. Appendix A gives details.

Prior to testing, the battery must be conditioned by charging completely and then discharging to 80% depth of discharge (DOD) as recommended by the manufacturer. The test must be run with the battery at its lowest and highest operating temperatures to ensure that the vehicle is tested under the conditions most likely to produce the maximum amount of hydrogen venting. The test will also be repeated with single point failures induced in the charging control circuitry. These single point failures should be induced at the operating temperature shown to produce the greatest amount of hydrogen. Use of a mixing blower inside the chamber during these tests is optional.

7. Preparation of Test Vehicle—Preparation of test vehicles should be done at nominal room ambient conditions, 23 °C ± 5 °C.

7.1 Vehicle manufacturers shall supply vehicles which are ready for stable operation.

7.2 Bring battery to 100% state-of-charge by charging battery according to manufacturer's recommendations.

7.3 Discharge batteries using the C/3 rate to the cut-off voltage as defined by the manufacturer prior to conducting tests. Record the discharge current and the elapsed time required to reach the cut-off voltage. This will be the basis for determining 80% DOD for the battery system.

7.4 Repeat step 7.2.

7.5 Discharge batteries to 80% DOD using the C/3 rate. Discharge the battery for 80% of the time needed to reach the cut-off voltage as described in 7.3.

8. Test Procedure—The test procedure consists of three phases intended to simulate vehicle usage at the maximum ambient and maximum recommended battery operating temperature, the minimum ambient and minimum recommended battery operating temperature, and under abnormal conditions arising from single point failures in the vehicle or charger charging control. The intent is to obtain the charging conditions which will cause the battery system to produce the greatest amount of hydrogen gas.

Before beginning tests, the complete system should be checked and equipment calibrated as described in Appendix A.

If at any time during the course of a test the hydrogen concentration exceeds 50% of the LFL, the test should be discontinued immediately.

8.1 Prepare test vehicle as described in Section 6.

8.2 Bring environment to 43 °C or the highest charging temperature to produce maximum gassing but not higher than 43 °C. Maintain throughout test run.

8.3 Bring battery to the temperature of 8.2 by soaking for 16 h before the start of test. Thermal management systems can be used only if supplied as standard equipment.

8.4 Position vehicle in the enclosure and connect all sensors.

8.5 Zero and calibrate gas analyzer.

8.6 Close and seal enclosure door. Activate the hydrogen measurement equipment. Wait until a stable hydrogen reading is obtained before beginning the test. Record enclosure interior air temperature, battery temperature, barometric pressure, and background hydrogen concentration.

8.7 Begin charging vehicle. This is to be done using the manufacturer's supplied or specified equipment and is to be conducted in a manner recommended by the manufacturer.

8.8 Record enclosure hydrogen concentration, enclosure interior air temperature, and vehicle data (battery temperature, current, and voltage) at 1 min intervals.

8.9 Continue charging the vehicle until the charging is complete as determined by the vehicle charging system. Once charging is complete, the batteries may continue to vent hydrogen. Monitoring the hydrogen concentration should continue for an additional 1 h or until the hydrogen level has stopped increasing.

8.10 Record hydrogen concentration at the end of the test run and subtract initial from maximum reading to determine the net concentration of hydrogen. Check the analyzer zero and calibration points to insure that they have not drifted.

8.11 Open enclosure and activate purge blower. The purging of the enclosure should be continued until the hydrogen concentration returns to its pretest value.

8.12 Return vehicle and enclosure to nominal room ambient conditions.

8.13 Discharge vehicle to 80% DOD.

8.14 Bring environment to –18 °C or the lowest charging temperature to produce maximum gassing but not lower than –18 °C. Maintain throughout test run.

8.15 Bring battery to the temperature of 8.14 by soaking for 16 h before start of test. Thermal management systems can be used only if supplied as standard equipment.

8.16 Repeat Steps 8.4 through 8.13.

8.17 Repeat tests under Single Point Failure (SPF) conditions. The intent is to produce the charging condition that will cause the battery system to emit the greatest amount of hydrogen gas. Induce SPFs (based on manufacturer's guidance) which could include denying feedback of voltage, current, and temperature during maximum gassing phase. SPFs can include failures in the vehicle or charger as explained in Appendix C. Perform the SPF tests at the appropriate temperature for the environment and batteries through repeating steps 8.4 through 8.13.

OPTION—If shut-down occurs reintialize and then induce next single point failure.

9. Information and Data Recorded—Details are listed on the sample data sheets (Figures B1 to B4) in Appendix B.

9.1 Information

a. Test identification
b. Tests performed and description
c. Vehicle description
d. Battery description
e. Charging system description

9.2 Data to be Collected

a. Temperatures
b. Barometric pressure
c. Hydrogen concentrations
d. Car enclosure method records

9.3 Presentation of Data

a. Objective of test
b. Description of system under test
c. Conclusion from the test
d. Discussion of the test and system
e. Test tabulation or plots

PREPARED BY THE SAE ELECTRIC VEHICLE BATTERY SYSTEMS STANDARDS COMMITTEE
AND THE SAE ELECTRIC VEHICLE FORUM COMMITTEE

CANCELLED BY THE SAE HYBRID COMMITTEE

APPENDIX A

VEHICLE ENCLOSURE SYSTEM CHECKOUT

A.1 Calibration—Use hydrogen calibration gas to calibrate the gas monitoring equipment.

A.2 Hydrogen Retention (Leak Check)—Inject adequate hydrogen into the enclosure to obtain approximately 30% LFL. Record enclosure hydrogen concentration.

Allow the enclosure to remain sealed for 4 h without sampling interior gases. The mixing blower should continue to operate throughout this period.

Read final hydrogen concentration. The difference between initial and final concentrations should indicate less than 4% mass "leakage".

A.3 Emission Check—It should be demonstrated that a new enclosure structure does not contain materials which will themselves emit hydrogen.

Seal the enclosure after thoroughly purging. Read hydrogen concentration at the beginning and end of a 1 h period without sampling during the interim. Change in hydrogen concentration should be negligible, but in any case should be less than 400 ppm to be considered acceptable.

APPENDIX B

SAMPLE DATA SHEETS

B.1 This Appendix contains sample data sheets for:

a. Preparation of Test Vehicle (Figure B1)
b. High-Temperature Test (Figure B2)
c. Low-Temperature Test (Figure B3)
d. Single Point Failure Test (Figure B4)

Date .... Tested by ....

Electric Vehicle Type ....

Battery Type ....

Battery Capacity ....

Recommended Charging Conditions ....

Cut-off Voltage ....

....

Charge Battery

Charge battery to 100% state of charge according to manufacturer's recommendations.

Charge Current .... Charging Time ....

Final Battery Voltage ....

....

Begin Discharging Battery

Time	_____	_____	_____	_____	_____	_____	_____
Battery Voltage	_____	_____	_____	_____	_____	_____	_____

Time to Reach Cut-off Voltage ....

....

Recharge Battery

Recharge battery to 100% state of charge according to manufacturer's recommendations.

Charge Current .... Charging Time ....

Final Battery Voltage ....

....

Discharge Battery to 80% DOD

Discharge battery for 80% of the time used to reach the cut-off voltage.

Time .... Discharge Current ....

Time	_____	_____	_____	_____	_____	_____	_____
Battery Voltage	_____	_____	_____	_____	_____	_____	_____

FIGURE B1—PREPARATION OF TEST VEHICLE

Date .... Tested by ....

Electric Vehicle Type ....

Battery Type ....

Battery High Temperature Operating Limit ....

....

Initial Hydrogen Concentration ....

Time	____	____	____	____	____	____	____
Enclosure Air Temperature	____	____	____	____	____	____	____
Battery Temp.	____	____	____	____	____	____	____
Current	____	____	____	____	____	____	____
Voltage	____	____	____	____	____	____	____
Hydrogen Concentration	____	____	____	____	____	____	____

....

Time	____	____	____	____	____	____	____
Enclosure Air Temperature	____	____	____	____	____	____	____
Battery Temp.	____	____	____	____	____	____	____
Current	____	____	____	____	____	____	____
Voltage	____	____	____	____	____	____	____
Hydrogen Concentration	____	____	____	____	____	____	____

....

Time	____	____	____	____	____	____	____
Enclosure Air Temperature	____	____	____	____	____	____	____
Battery Temp.	____	____	____	____	____	____	____
Current	____	____	____	____	____	____	____
Voltage	____	____	____	____	____	____	____
Hydrogen Concentration	____	____	____	____	____	____	____

....

Maximum Hydrogen Concentration ....

FIGURE B2—HIGH-TEMPERATURE TESTS