



SURFACE VEHICLE RECOMMENDED PRACTICE	J2380™	DEC2021
	Issued	1998-01
	Revised	2021-12
Superseding J2380 DEC2013		
Vibration Testing of Electric Vehicle Batteries		

RATIONALE

Revisions were made to this document to be consistent with information in the Cooperative Research Program SAE/NHTSA DOT HS 812 717 report. Vibration tables and figures were enhanced for accuracy. Test equipment and instrumentation sections were updated.

FOREWORD

This document provides a test procedure for characterizing the effect of long-term, road-induced vibration and shock on the performance and service life of electric vehicle batteries. For mature, production-ready batteries, the intent of the procedure is to qualify the vibration durability of the battery. Either swept sine wave vibration or random vibration is typically used for the performance of such testing. Random vibration is the focus of this document.

The vibration tests defined in this procedure are based on rough-road measurements at locations likely to be appropriate for mounting of traction batteries in electric vehicles. The data were analyzed to determine an appropriate cumulative number of occurrences of shock pulses at various given G-levels over the life of the vehicle. The vibration envelopes shown in Figure 1 correspond to approximately 100000 miles of usage at the 90th percentile. The vibration spectra contained in this procedure have been designed to approximate this cumulative exposure envelope. For testing efficiency, a time-compressed vibration regime is specified to allow completion of the test procedure in a minimum of 13.6 hours and a maximum of 92.6 hours of testing, depending on the type of shaker table available and the choice of acceleration levels.

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Cumulative Exposure to Vibration

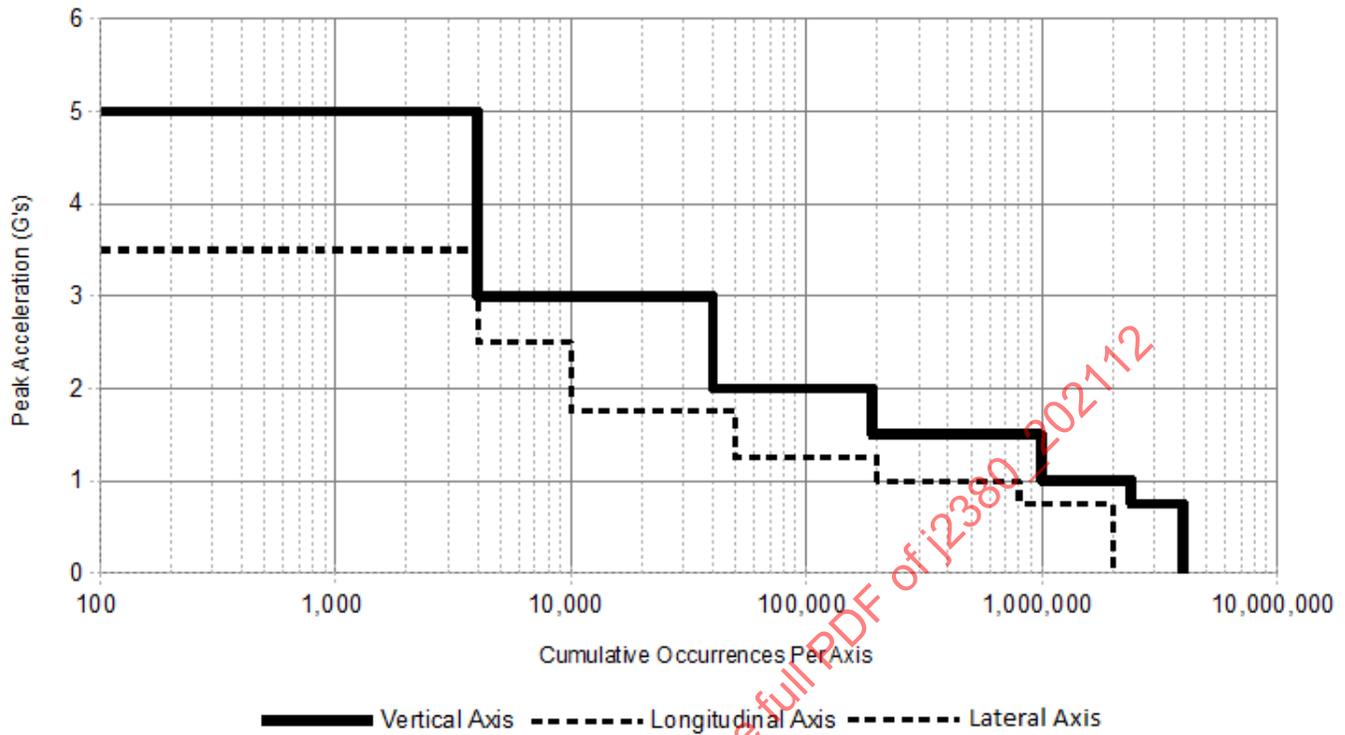


Figure 1 - Cumulative vibration envelopes

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1. SCOPE

This SAE Recommended Practice describes the vibration durability testing of a single battery (test unit) consisting of either an electric vehicle battery module or an electric vehicle battery pack that is typically greater than 200 kg in mass and structurally integrated as part of the vehicle. For statistical purposes, multiple samples would normally be subjected to such testing. Additionally, some test units may be subjected to life cycle testing (either after or during vibration testing) to determine the effects of vibration on battery life. Such life testing is not described in this procedure; SAE J2288 may be used for this purpose as applicable. Finally, impact testing, such as crash and pothole, are not included in this procedure. SAE 2464 describes abusive/safety shock tests.

Preferably, a specific vibration durability profile should be developed based on actual vehicle measurements for the specific electric vehicle application.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE J1715	Hybrid Electric Vehicle (HEV) and Electric Vehicle (EV) Terminology
SAE J1715/2	Battery Terminology
SAE J1766	Recommended Practice for Electric, Fuel Cell and Hybrid Electric Vehicle Crash Integrity Testing
SAE J1798	Recommended Practice for Performance Rating of Electric Vehicle Battery Modules
SAE J2288	Life Cycle Testing of Electric Vehicle Battery Modules
SAE J2464	Electric and Hybrid Vehicle Rechargeable Energy Storage System (RESS) Safety and Abuse Testing
SAE J2929	Safety Standard for Electric and Hybrid Vehicle Propulsion Battery Systems Utilizing Lithium-based Rechargeable Cells

2.2 Related Publication

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.2.1 IEC Publications

Available from IEC Central Office, 3, rue de Varembe, P.O. Box 131, CH-1211 Geneva 20, Switzerland, Tel: +41 22 919 02 11, www.iec.ch.

IEC 60068-2-6 Environmental Testing- Part 2 Test-Test Fc Vibration (Sinusoidal)

2.2.2 USABC Publication

Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161, Tel: 703-605-6000, www.ntis.gov.

USABC Electric Vehicle Battery Test Procedures Manual, Revision 2, January 1996. Obtainable by mail order as Report No. DOE/ID-10479, Rev. 2. http://avt.inl.gov/energy_storage_lib.shtml.

2.2.3 U.S. Department of Transportation Publications

U.S. DOT HS 812 717 Safety Performance of Rechargeable Energy Storage Systems May 2019. Section: Vibration and Thermal Cycling Test

3. DEFINITIONS

Except as specifically noted in this section, the definitions of SAE J1715 shall apply to this document.

DEPTH OF DISCHARGE: The number of A•h withdrawn from a battery divided by its rated capacity at the test current and temperature and expressed as a percentage.

DOD: Depth of Discharge where:

0% DOD is a fully charged battery according to the battery manufacture suggested charging recommendations.

80% DOD is 80% of the rated capacity removed via a C/3 discharge rate from a 0% DOD start.

4. TECHNICAL REQUIREMENTS

4.1 Prerequisites

A battery test plan or other test requirements document is normally required for testing using this procedure. The test plan specifies the appropriate test conditions for the Reference Performance Tests (see 4.4.1) and certain vibration frequencies to be used, along with testing precautions and any special handling/testing instructions specified for the battery by the manufacturer and/or the test sponsor.

Performance of certain Reference Performance Tests specified in SAE J1798 is normally required before and after the conduct of vibration testing. For completeness, these are itemized within the procedure steps in 4.4.

Unless otherwise specified in a test plan document, the test unit shall be tested early in its life (i.e., prior to the performance of any life cycle testing.)

4.2 Test Equipment

4.2.1 Equipment

Performance of this procedure requires a one- to three-axis (one axis excited at a time) table capable of producing accelerations up to 1.9 G over the vibration spectra detailed in Table 3 and Figure 2, extending from 10 to approximately 200 Hz. If the unit to be tested can only be vibrated while in a particular physical orientation, a multi-axis table will be required. Additional equipment should include shielding, spill tank, and/or explosion proof chambers where applicable.

4.2.2 Fixtures

Test fixtures are required to properly secure the test unit to the shaker table. The exact nature of these fixtures depends on the type of table used, the test unit itself, and any restrictions on physical orientation of the test unit. The device under test (DUT) mounting and support structure (fixture) shall be as similar as possible to the manufacturer's recommended installation requirements.

The fixture shall not have any detrimental resonance in the testing frequency range. The fixture shall hold the DUT from direct contact with any point on the platform of the vibration exciter other than fixtures.

4.2.3 Instrumentation

4.2.3.1 Special instrumentation hookups capable of withstanding the vibration are required so that important battery conditions can be monitored during testing. The DUT shall be instrumented with appropriate sensors to monitor voltage, State of Charge (SOC), temperature and resonances. It shall be instrumented to measure any loss of electrical isolation for both battery positive and negative to the case or equipment ground, if appropriate.

For all measured data, unless more specific requirements are provided in a device specific test plan, the measurement tolerances in Table 1 shall be considered acceptable.

Table 1 - Measurement tolerances

Temperature	±5 °C of reading
Voltage, Current	±1% of reading
Vibration	±4% of reading

Voltage, current, isolation detection and temperature sensor locations shall be recorded and photographed to facilitate test repeatability.

4.2.3.2 During testing, the vibration shall be monitored through the use of accelerometers. Sizes and types of accelerometers can be determined by the test facility based on the size of the DUT. There should be a minimum of three accelerometers utilized for control and measurement at locations defined below.

4.2.3.2.1 Control Point – A control point shall be an accelerometer placed at or as near as possible to a fixed mounting point of the sample. If the DUT does not have any mounting points, such as with an internal module for example, the control point should be at or near the base of the DUT to the base fixture. A minimum of one control point is required, but best practice is to have two or more and use the average control as described in 4.2.3.2.3. Selection of control points shall be the responsibility of the test requestor.

4.2.3.2.2 Reference Point – A reference point shall be an accelerometer placed at the discretion of the test requestor as a means to gather information about the responses of the DUT. Reference points shall not be utilized in the control of the test.

4.2.3.2.3 Average Control – Best practice for the control of the vibration parameters is to have two accelerometers utilized at opposing mounting points and the responses from these devices averaged. Selection of control shall be the responsibility of the test requestor. If no direction is given by the requestor, two accelerometers with the farthest distance across the DUT from one another should be selected.

4.2.3.3 Acceptable guidelines for the accelerometer and vibration controller parameters is shown in Table 2.

Table 2- Accelerometer and vibration controller parameters

Parameter	Value
System Startup Rate	20%
Filtering Window	Hanning
Slew Rate	200 V/μs
Signal Clipping	None
Data Recording Rate	1/minute

4.3 Determination of Test Conditions and Test Termination Criteria

4.3.1 Electrical Test Conditions

Electrical test conditions are determined according to the procedures in SAE J1798 which are specified in 4.4.1.

4.3.2 Vibration Frequencies

Vibration test conditions are as specified in the procedure steps in 4.4.

4.3.3 Test Termination

Vibration testing shall be suspended or terminated if any observed component degradation produces conditions which are abnormal or outside the operating ranges of the battery as specified by the manufacturer. Conditions to be monitored are defined in 4.5.

4.4 Test Procedure

- 4.4.1 Perform a sequence of Reference Performance Tests consisting of a C/3 Constant Current discharge, a Dynamic Capacity Test discharge to 100% of rated capacity, and a Peak Power discharge, as defined in SAE J1798. A visual inspection is to be conducted to note any existing defects or abnormalities. The default ambient temperature shall be 23 °C ± 5 °C.
- 4.4.2 Charge the battery fully using the manufacturer's recommended charge method. The DUT shall be unpowered with all safety disconnects in place during testing.
- 4.4.3 For each of the vertical, longitudinal, and lateral axes of the battery, select either the normal or alternative G-levels from Table 3 and program the shaker table appropriately. This choice will determine the vibration time required for each axis, also in accordance with Table 3. (The vibration spectra, shown in Figure 2, are expressed in G²/Hz, so they can be scaled for either set of G-levels.)

Table 3 - Vibration schedule for random vibration test

TEST CONDITIONS			NORMAL TEST			ALTERNATIVE TEST		
VIBRATION SPECTRUM		DOD (%)	Accel (g rms)	Time (h)	Cumul Time, h	Accel (g rms)	Time (h)	Cumul Time (h)
Vertical Axis Vibration:								
Vertical 1	spectrum	0	1.9	0.15	0.15	1.9	0.15	0.15
Vertical 1	spectrum	0	0.75	5.25	5.4	0.95	3.5	3.65
Vertical 2	spectrum	0	1.9	0.15	5.55	1.9	0.15	3.8
Vertical 2	spectrum	0	0.75	5.25	10.8	0.95	3.5	7.3
Vertical 3	spectrum	80	1.9	0.15	10.95	1.9	0.15	7.45
Vertical 3	spectrum	80	0.75	5.25	16.2	0.95	3.5	10.95
Longitudinal Axis Vibration:								
Longitudinal	spectrum	40	1.5	0.09	16.29	1.5	0.09	11.04
Longitudinal	spectrum	40	0.4	19	35.29	0.75	6.7	17.74
Longitudinal	spectrum	40	1.5	0.09	35.38	1.5	0.09	17.83
Longitudinal	spectrum	40	0.4	19	54.38	0.75	6.7	24.53
Lateral Axis Vibration:								
Lateral	spectrum	40	1.5	0.09	54.47	1.5	0.09	24.621
Lateral	spectrum	40	0.4	19	73.47	0.75	6.7	31.321
Lateral	spectrum	40	1.5	0.09	73.56	1.5	0.09	31.411
Lateral	spectrum	40	0.4	19	92.56	0.75	6.7	38.111

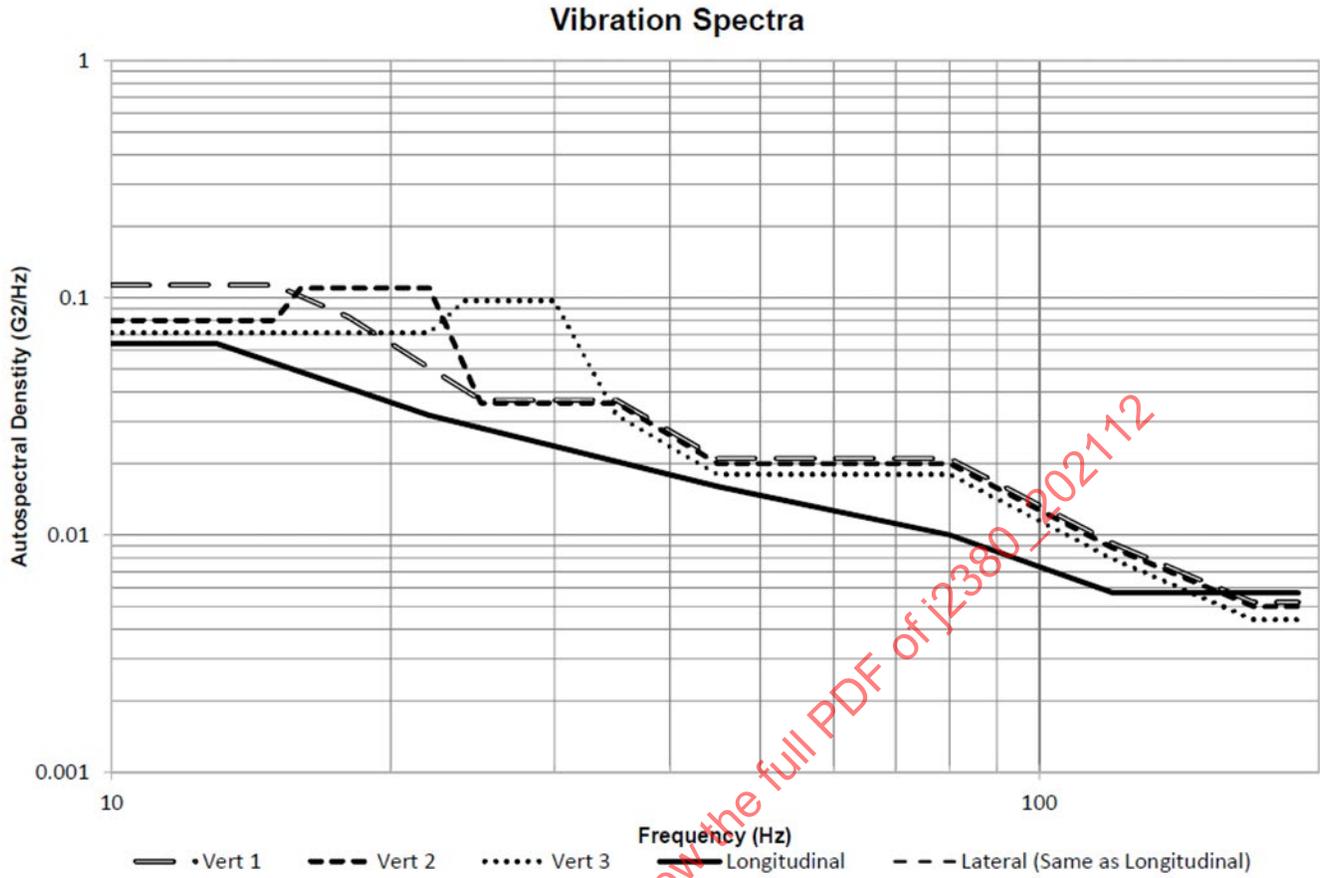


Figure 2 - Vibration spectra for random vibration test

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