The Engineering Society For Advancing Mobility Land Sea Air and Space®
INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

SURFACE VEHICLE RECOMMENDED PRACTICE

An American National Standard

SAE J2380

ISSUED JAN1998

Issued 1998-01

Vibration Testing of Electric Vehicle Batteries

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. However, swept sine wave testing is considered somewhat more representative and is addressed in this document, which is generally based on a corresponding test for electric vehicle batteries developed by the U.S. Advanced Battery Consortium.

The procedure has been synthesized from rough-road measurements at locations likely to be appropriate for mounting of traction batteries in EVs. 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 of this procedure correspond to approximately 100 000 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 h and a maximum of 92.6 h of testing, depending on the type of shaker table available and the choice of acceleration levels.

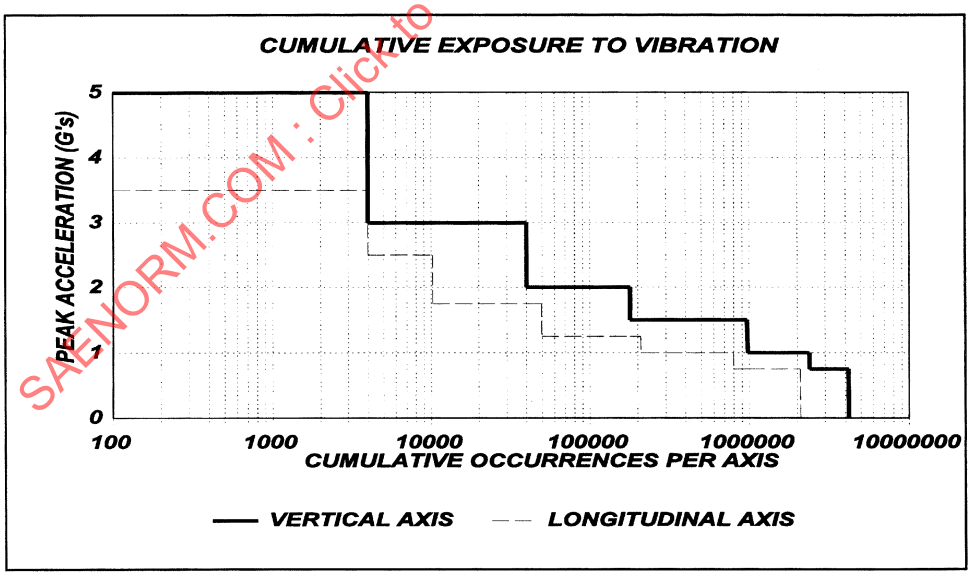

FIGURE 1—CUMULATIVE VIBRATION ENVELOPES

TABLE OF CONTENTS

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. 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.

2. ***References***

2.1 **Applicable Publications—**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, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J1715—Electric Vehicle Terminology
SAE J1798—Recommended Practice for Performance Rating of Electric Vehicle Battery Modules
SAE J2288—Recommended Practice for Life Cycle Testing of Electric Vehicle Battery Modules

2.2 **Related Publication—**The following publication is provided for information purposes only and is not a required part of this document.

2.2.1 USABC PUBLICATION—Available from NTIS, 5285 Port Royal Road, Springfield, VA 22161.

USABC Electric Vehicle Battery Test Procedures Manual, Revision 2, January 1996. Obtainable by mail order as Report No. DOE/ID-10479, Rev. 2, from NTIS, 5285 Port Royal Road, Springfield, VA 22161.

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

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 table capable of producing accelerations up to 1.9 G over the vibration spectra detailed in 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. Additionally, the time required to perform the test can be significantly reduced if the longitudinal and lateral axis vibration (or all three axes) can be performed concurrently.

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.

4.2.3 INSTRUMENTATION—Special instrumentation hookups capable of withstanding the vibration are required so that important battery conditions can be monitored during testing. (See 4.5.)

4.3 Determination of Test Conditions and Test Termination Criteria

4.3.1 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.

4.4.2 Charge the battery fully using the manufacturer's recommended charge method.

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 1 and program the shaker table appropriately. This choice will determine the vibration time required for each axis, also in accordance with Table 1. (The vibration spectra, shown in Figure 2, are expressed in G^2/Hz, so they can be scaled for either set of G-levels.)

TABLE 1—VIBRATION SCHEDULE FOR RANDOM VIBRATION TEST

TEST CONDITIONS VIBRATION SPECTRUM	TEST CONDITIONS SOC (%)	NORMAL TEST Accel (g rms)	NORMAL TEST Time (h)	NORMAL TEST Cumul Time, h	ALTERNATIVE TEST Accel (g rms)	ALTERNATIVE TEST Time (h)	ALTERNATIVE TEST Cumul Time, h
			Vertical Axis Vibration:				
Vertical 1 spectrum	100	1.9	0.15	0.15	1.9	0.15	0.15
Vertical 1 spectrum	100	0.75	5.25	5.4	0.95	3.5	3.65
Vertical 2 spectrum	100	1.9	0.15	5.55	1.9	0.15	3.8
Vertical 2 spectrum	100	0.75	5.25	10.8	0.95	3.5	7.3
Vertical 3 spectrum	20	1.9	0.15	10.95	1.9	0.15	7.45
Vertical 3 spectrum	20	0.75	5.25	16.2	0.95	3.5	10.95
			Longitudinal Axis Vibration:				
Longitudinal spectrum	60	1.5	0.09	16.29	1.5	0.09	11.04
Longitudinal spectrum	60	0.4	19.0	35.29	0.75	6.7	17.74
Longitudinal spectrum	60	1.5	0.09	35.38	1.5	0.09	17.83
Longitudinal spectrum	60	0.4	19.0	54.38	0.75	6.7	24.53
			Lateral Axis Vibration:				
Longitudinal spectrum	60	1.5	0.09	54.47(1)	1.5	0.09	24.62(1)
Longitudinal spectrum	60	0.4	19.0	73.47(1)	0.75	6.7	31.32(1)
Longitudinal spectrum	60	1.5	0.09	73.56(1)	1.5	0.09	31.41(1)
Longitudinal spectrum	60	0.4	19.0	92.56(1)	0.75	6.7	38.11(1)

1. These cumulative times apply only if all three axes are done separately.

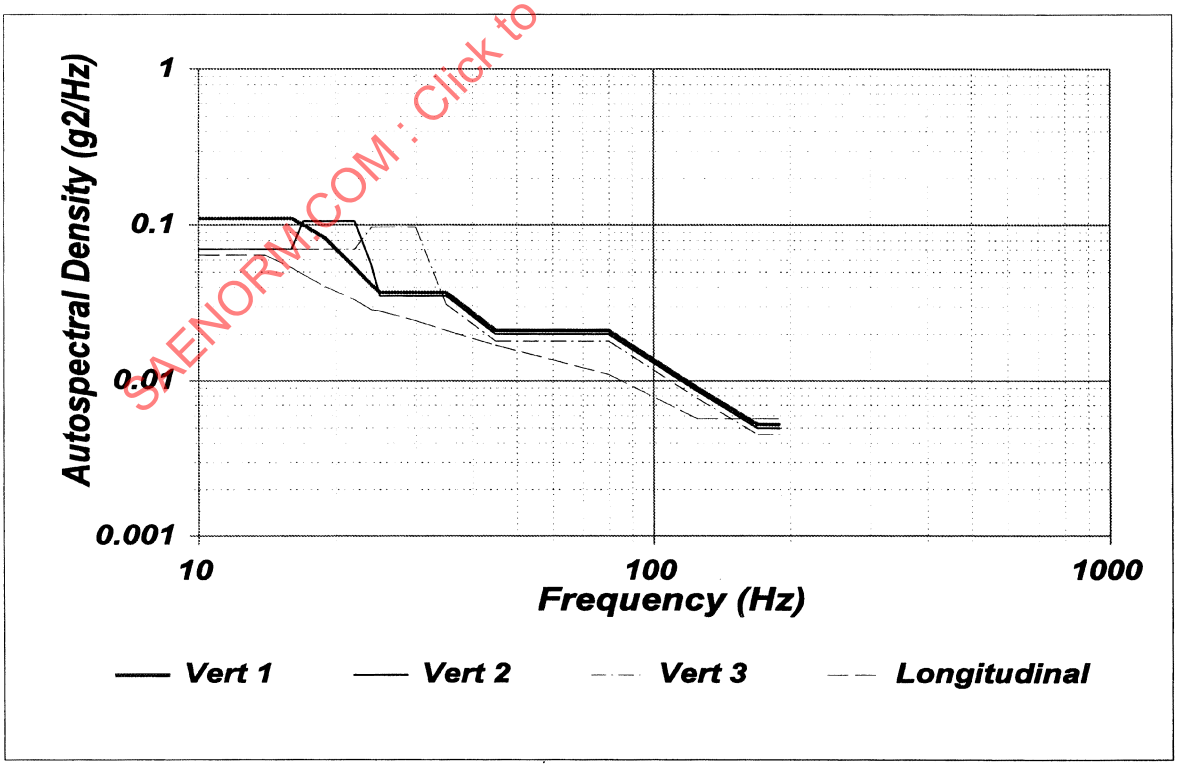

FIGURE 2—VIBRATION SPECTRA FOR RANDOM VIBRATION TEST