ETA-TP009

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Measurement and Evaluation of Magnetic Fields Generated by Electric Vehicles

Prepared by

Electric Transportation Applications

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1.0 Objective

To provide a consistent protocol for (1) the measurement of electromagnetic fields generated by Electric Vehicles and their on-board battery chargers; (2) measurement of an electric vehicle's audible noise; 3) measurement of radiofrequency interference. These measurements will be completed during the drive cycles identified in SAE Standard J1634 and procedure ETA-TP003, "Electric Vehicle Energy Consumption and Range Test."

2.0 Purpose

The purpose of this procedure is to provide a traceable, quantifiable methodology for the collection and evaluation of data which supports the stated objectives**.** This activity is meant to quantify results obtained while the vehicle is being tested as a total system. Tests of specific subsystems or portions of individual subsystems are addressed by other Test Procedures. This testing and data acquisition meets the requirements specified in the EV America Technical Requirements.

3.0 Documentation

Documentation addressed by this procedure shall be consistent, easy to understand, easy to read, and readily reproducible. This documentation shall contain enough information to "stand alone"; that is, be self-contained to the extent that all individuals qualified to review it could be reasonably expected to reach a common conclusion, without the need to review additional documentation. Review and approval of test documentation shall be in accordance with ETA-AC004, "Review of Test Results." Storage and retention of records during and following testing activities shall be completed as described in Procedure ETA-AC001, "Control, Close-out and Storage of Documentation."

4.0 Prerequisites

4.1 Personnel conducting testing under this procedure shall be familiar with the requirements of this procedure as evidenced by Certification by the Program Manager or Test Manager, any applicable SAE Test Instructions, and the Administrative Control Procedures, prior to commencing any testing activities.

4.2 Overall error in recording or indicating instruments shall not exceed ±2% of the maximum value of the variable being measured, unless otherwise excepted. Periodic calibration shall be performed and documented to ensure compliance with this requirement. This shall be verifiable to the requirements of ETA-QA001, "Quality Audits."

4.3 A list of all instrumentation used in the test shall be identified on Appendix A, and attached to the test results. It shall include the following information:

4.3.1 Manufacturer
4.3.2 Model Number
4.3.3 Serial Number
4.3.4 Last Calibration date
4.3.5 Next Calibration date

4.4 Any deviation from the test procedure and the reason for the deviation shall be approved in advance by the Program Manager or Test Manager as provided for in procedure ETA-AC002, "Control of Test Conduct."

4.5 Necessary recording equipment shall be installed in a manner that does not hinder vehicle operation or alter the operating characteristics of the vehicle.

5.0 Magnetic Field Measurement and Evaluation

NOTE

Data shall be acquired during two different periods. Average values be obtained during the drive cycle implementation of SAE J1634 test (ETA-TP003). Specific values will be obtained during the constant speed runs done concurrently with the dynamometer calibration set-up.

5.1 Measurement Circuit and Procedure

5.1.1 Figure 1 represents the measurement circuit which is implemented to monitor the magnetic field generated by an electric vehicle in a running mode.

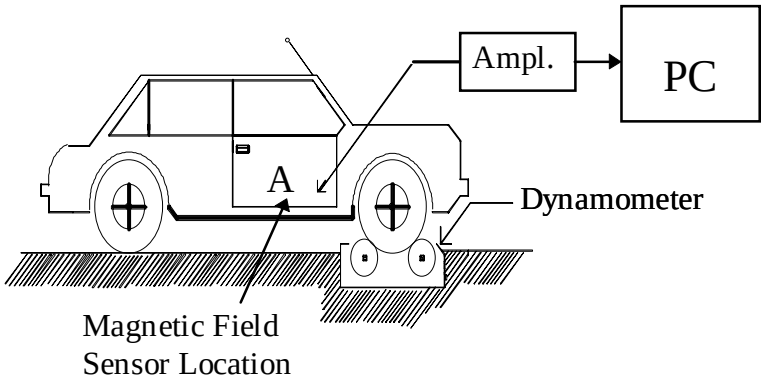

Figure 1. **Measurement circuit for monitoring the magnetic field**

5.1.2 The following instrumentation is required:

5.1.2.1 DC/AC current transformer - FLUKE Y8100 or equivalent

5.1.2.2 Three axis magnetic field sensor with a frequency range of DC to 50 kHz

5.1.2.3 LabVIEW data acquisition system and equipment

The DC/AC current probe shall have two ranges of operation - 20A and 200A. It shall also have an amplifier with an analog output of ± 2 V for each measurement range. This analog output is fed to the computer.

The magnetic field sensor shall contain three orthogonally mounted sensors. Each sensor measures a corresponding component of the magnetic field and has a built-in amplifier. Each of the amplifiers provides a ± 2V analog output signal, which is also fed to the computer. The sensor has three measurement ranges. Each axis is normally set at the 200 mG range.

Data acquisition program shall be written in LabVIEW (a virtual instrument), to take the signals from four sources (the current probe and the three components of the magnetic field) and perform the necessary computations. These data shall be taken in continuous snapshots, with the only delay between the snapshots being the time required to perform necessary calculations. Time data are sampled at a rate of 21.6 kHz (this is a time interval between samples of 0.0463 ms.) This sampling rate enables monitoring of the frequency harmonics of any parameter up to 10.8 kHz.

5.2 Evaluation Procedure

The magnetic fields shall be measured in every seat-belted position in the vehicle in the following operational modes:

- Acceleration
- Constant Speed (Cruising)
- Deceleration
- Charging Mode

However, in the charging mode, the fields shall be measured only in the close vicinity of the charger.

5.2.1 Analog signals from four sources shall be acquired by four channels. Each signal shall then be corrected for the particular current probe ratio and magnetometer amplification. The signal shall then be digitized. The rms value of current shall be calculated based on the equation:

$$I = \sqrt{\frac{1}{N}\sum i^2} \qquad Eq.\ 1$$

The calculated rms value is then stored in the computer file.

5.2.2 The analog signal from each magnetic field sensor is directly proportional to the magnetic field. The DC component of the magnetic field shall be calculated for each axis as follows:

$$bx_{dc} = mean(bx)$$

$$by_{dc} = mean(by) \qquad Eq.\ 2$$

$$bz_{dc} = mean(bz)$$

5.2.3 The AC components of the field shall be extracted as follows:

$$bx_{ac} = bx - bx_{dc}$$

$$by_{ac} = by - by_{dc} \qquad Eq. 3$$

$$bz_{ac} = bz - bz_{dc}$$

5.2.4 The following equations shall be used to calculate the rms value of each component of the AC magnetic field:

$$BX_{ac} = \sqrt{\frac{1}{N}\sum bx_{ac}{}^{2}}$$

$$BY_{ac} = \sqrt{\frac{1}{N}\sum by_{ac}{}^{2}} \qquad Eq. 4$$

$$BZ_{ac} = \sqrt{\frac{1}{N}\sum bz_{ac}{}^{2}}$$

5.2.5 The total AC and DC magnetic fields shall then be calculated as follows:

$$B_{dc} = \sqrt{bx_{dc}^2 + by_{dc}^2 + bz_{dc}^2} \qquad Eq. 5$$

$$B_{ac} = \sqrt{BX_{ac}^2 + BY_{ac}^2 + BZ_{ac}^2} \qquad Eq. 6$$

Both field components shall be continuously stored in the same file with the current.

5.2.6 The frequency spectrum of each magnetic field component shall be performed as follows:

$$FFT(bx_{ac})$$

$$FFT(by_{ac}) \qquad Eq.\ 7$$

$$FFT(bz_{ac})$$

5.2.7 The frequency spectrum of the total magnetic field shall then be calculated as follows:

$$FFT(b) = \sqrt{(FFT(bx_{ac}))^2 + (FFT(by_{ac}))^2 + (FFT(bz_{ac}))^2} \qquad Eq.\ 8$$

5.2.8 Using the first harmonic in the spectrum and the rms value of the total magnetic field, the Total Harmonic Distortion (THD) of the magnetic field is calculated:

$$THD = \sqrt{\frac{B_{ac}^2 + B1^2}{B1^2}} \qquad Eq.\ 9$$

6.0 Radio Frequency Interference

6.1 As vehicles are operated through their test program on the track and in "run-downs" (when the car is driven for the sole purpose of discharging the battery to a pre-determined SOC), drivers should conduct random checks of the AM and FM radio bands, to determine if radio stations which can normally be received in non electric vehicles can also be received in the test electric vehicles. Those comments will be noted on driver comment sheets, as appropriate, for transcription at a later date.

6.2 While operating on the dynamometer in accordance with ETA-TP003, the following devices shall be operated to determine if any interference is being generated from the vehicle:

6.2.1 Cellular telephone

6.2.2 Mobile radio scanning over the 70 cm and 2M bands

6.2.3 Citizen band radio

6.2.4 Portable compact disc player

6.2.5 Notebook computer

Devices and /or their antennae shall be located in a manner to maximize their potential for interference. [Prior to testing the initial vehicle, these devices shall be operated in the dynamometer with the dynamometer operating to verify there is no background interference.]

6.3 Device operation and any interference noted shall be recorded on Appendix B.

7.0 Electromagnetic Susceptibility

7.1 The following devices shall be operated with the vehicle on the dynamometer to determine if the any impact on the vehicle charge system can be detected:

7.1.1 A Citizen's Band Radio operating at the legal limit of 5 watts output

7.1.2 Mobile radio antennae (70 cm and 2M band frequencies) operating at 7 watts output

7.1.3 A cellular telephone

Record any impact on Appendix B.

8.0 Glossary

8.1 Audible Noise - Noise that is considered to be within the range of normal human hearing, nominally 20 Hz to 20,000 Hz.

8.2 Frequency Harmonic - A multiple of the fundamental or base frequency. May be also be a sub-harmonic.

8.3 Frequency Spectrum - The entire range of frequencies being considered.

8.4 Orthogonally - Consisting of the -*x,* -*y* and -*z* axes (three dimensional)

8.5 Program Manager - As used in this procedure, the individual within Electric Transportation Applications responsible for oversight of the EV America Performance Test Program. [Subcontract organizations may have similarly titled individuals, but they are not addressed by this procedure.]

8.6 RMS - Root Mean Squared. For sinusoidal waveforms, a value that is equal to the measured value multiplied by 1.414 (the square root of 2). Can also be determined by multiplying the peak value by 0.707.

8.7 Shall - Items which require adherence without deviation. Shall statements identify binding requirements. A go, no-go criterion.

8.8 Should - Items which require adherence if at all possible. Should statements identify preferred conditions.

8.9 Snapshot - A term given to the time frame that normally accompanies a single event or a number of concurrent events. Usually indicates a repetitive series of events is occurring or is meant to occur.

8.10 Test Director - The individual within Electric Transportation Applications responsible for all testing activities associated with the EV America Performance Test Program.

8.11 Test Director's Log - A daily diary kept by the Test Director, Program Manager, Test Manager or Test Engineer to document major activities and decisions that occur during the conduct of a Performance Test Evaluation Program. This log is normally a running commentary, utilizing timed and dated entries to document the days activities. This log is edited to develop the Daily Test Log published with the final report for each vehicle.

8.12 Test Engineer - The individual(s) assigned responsibility for the conduct of any given test. [Each contractor/subcontractor should have at least one individual filling this position. If so, they shall be responsible for adhering to the requirements of this procedure.]

8.0 Glossary (continued)

8.13 Test Manager - The individual within Electric Transportation Applications responsible for the implementation of the test program for any given vehicle(s) being evaluated to the requirements of the EV America Performance Test Program. [Subcontract organizations may have similarly titled individuals, but they are not addressed by this procedure.]

8.14 Time Stamp - The arbitrary time zero (t_o) denoting the beginning of an event.

9.0 References

9.1 EV America Technical Requirements

9.2 IEEE-450 1987, “Recommended Practices for Stationary Lead Acid Storage Batteries”

9.3 ETA-AC001, Revision 2 - “Control, Close-out and Storage of Documentation”

9.4 ETA-AC002, Revision 2 - “Control of Test Conduct”

9.5 ETA-AC004, Revision 2 - “Review of Test Results”

9.6 ETA-AC005, Revision 2 - “Training and Certification Requirements for Personnel Utilizing ETA Procedures”

9.7 ETA-AC006, Revision 2 - “Vehicle Verification”

9.8 ETA-AC007, Revision 1 - “Control of Measuring and Test Equipment”

9.9 ETA-QA001, Revision 2 - “Quality Audits”

9.11 ETA-TP003, Revision 2 - “Electric Vehicle Energy Consumption and Range Test”

9.12 ETA-TP011, Revision 1 - “Receipt Inspection”

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APPENDIX-A
Vehicle Metrology Setup Sheet
(Page 1 of 1)

Vehicle Number: _____

Instrument/Device:	Calibration Due Date:	Initials / Date:

Comments (initials/date):

Completed By:

(Printed Name) (Signature) (Date)

Reviewed By (QA):

(Printed Name) (Signature) (Date)

Approved By:

(Printed Name) (Signature) (Date)

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APPENDIX-B
Driver Interface Record
Test Data Sheet (Page 1 of 1)

Vehicle Number: _____

Radio Frequency Interference			
Procedure Step:	**Instrument/Device:**	**Interference? Yes:**	**No:**
6.2.1	Cellular Phone		
6.2.2	Mobil Radio Scanning Over the 70 cm Band		
6.2.2	Mobil Radio Scanning Over the 2M Band		
6.2.3	Citizens Band Radio		
6.2.4	Portable Compact Disk Player		
6.2.5	Notebook Computer		
Comments (initials/date):			
Electromagnetic Susceptibility			
7.1.1	A Citizen's Band Radio Operating at 5 Watts Output		
7.1.2	Mobil Radio Antennae Operating at 7 Watts Output on the 70 cm Band		
	Mobil Radio Antennae Operating at 7 Watts Output on the 2M Band		
7.1.3	A Cellular Telephone		
Comments (initials/date):			
Completed By: (Printed Name)	(Signature)	(Date)	
Reviewed By: (Printed Name)	(Signature)	(Date)	
Approved By: (Printed Name)	(Signature)	(Date)	