

Plug-in Electrical Vehicle Charge Rate Reporting and Test Procedures

RATIONALE

For the purposes of comparing charging capabilities of electric vehicles (EVs) and electric vehicle supply equipment (EVSEs), a unified methodology of reporting the charging rate is needed in the field. This document will provide common test procedures to consistently measure capabilities of vehicles and EVSEs for the consumer and media to use for clear comparisons. This document describes testing and reporting schema for direct current (DC) charging systems as applied to light duty passenger vehicles directly connected charging systems. Extensions may be added (as needed) for alternating current (AC) charge and/or wireless power transfer (WPT) systems. This document is relevant to passenger vehicles.

FOREWORD

In conventional internal combustion engine and hybrid vehicles, the time required to refill liquid- or gas-fueled vehicles is not significant and is generally not considered to be a differentiator when the vehicle is marketed, nor is it used by the consumer while comparing the capabilities of different vehicles. The longer time required for EV recharging represents a paradigm shift in customer usage which is known, but not well understood, by the general public and often results in confusion. This results in a significant difference in the way EVs are marketed and thus “charging time” remains a key concern of potential EV buyers.

Full AC charge time is currently reported on the vehicle fuel economy label. It identifies the time required for the vehicle to charge from completely empty to completely full using a best-case scenario with an AC charger. This was developed during a period when EV ranges were short and most charges were for nearly the full range. With the increase in EV ranges, the full charge time metric has become less useful as a comparison tool and generally less relevant to daily usage, though still reported and use for comparisons. This continued use results in confusion as:

- a. Full charge time is proportional to full range. Comparing different times for vehicles with different ranges causes the longer-range vehicles to appear to be slower at charging than shorter range vehicles. In reality, this is an artifact of larger batteries requiring more energy to be full, and results in a confusion point to consumers.
- b. Vehicle charging is infrequently a zero to full event. In most cases, it is the replacing of driven miles while the driver is engaged in another activity such as sleeping or working. The time it takes to replace the miles driven is not a function of “vehicle charge time,” but rather time it requires to replace the number of miles used. Therefore, using a zero to full metric is not giving the consumer a basis on which to judge the fitness of the vehicle for their daily life.

Large-capacity batteries and high-power EVSEs available in the marketplace have resulted in “charge time,” the time from empty to full battery, being less important than “charge rate.” Furthermore, an AC charge time is not useful for predicting the duration of DC charging in which the operator is waiting for the charge to end, such as when on a longer distance trip or other times when the charging is not done in parallel with other life activities (working, sleeping, etc.).

SAE Executive Standards Committee Rules provide that: “This report is published by SAE to advance the state of technical and engineering sciences. The use of this report is entirely voluntary, and its applicability and suitability for any particular use, including any patent infringement arising therefrom, is the sole responsibility of the user.”

SAE reviews each technical report at least every five years at which time it may be revised, reaffirmed, stabilized, or cancelled. SAE invites your written comments and suggestions.

Copyright © 2021 SAE International

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of SAE.

TO PLACE A DOCUMENT ORDER: Tel: 877-606-7323 (inside USA and Canada)
 Tel: +1 724-776-4970 (outside USA)
 Fax: 724-776-0790
 Email: CustomerService@sae.org
 http://www.sae.org

SAE WEB ADDRESS:

Full document details: SAE J2953_4_202106

For more information on this standard, visit
https://www.sae.org/standards/content/J2953/4_202105

Documents

Document Sharing Hub

Many corporate marketing organizations have taken note of the downside of advertising long charge times and have chosen to use DC charging times and/or rates. Historically, these efforts have been uncoordinated between manufacturers and have led to a marketplace where many different reporting paradigms are prevalent. This makes it difficult for a consumer to directly compare capabilities during the purchasing process and provides a source of confusion regarding how the vehicle will or will not fit their usage. Furthermore, lack of a common metric and test procedure leaves room for exaggeration and reporting of values that would not be seen in real-world use.

This document is intended to address that aspect with a straightforward test designed to compare different vehicles in real-world—albeit very good—conditions, which will simultaneously allow the capabilities of the vehicle to be better understood, while giving the customer a comparable metric to use when looking at different vehicles. By doing so, it will encourage better vehicle designs and infrastructure that minimizes charging rate and not on targeting the test.

This test procedure is intended to be used by all charge coupler types currently in the market.

Currently, 16 CFR 309 exists to describe the capabilities of the EVSE power measurement. This document will not attempt to rewrite that work, but does build upon it to include a duration that the EVSE is expected to deliver the rated power. This duration is coordinated with the vehicle test metric.

Future versions of this document will address AC and wireless charging rates with the intent of establishing a common rate metric that will provide a good comparison between DC, AC, and WPT. Variables that affect the rate of charge, such as temperatures, EV-EVSE pairing, starting SOC, actual drive energy, EVSE sharing, and other such real-time aspects may be addressed in future versions if the evolving marketplace warrants it. Future versions of this document may be used for recommendations for calculating and reporting to normalize what the consumer experiences, but will not impose any standards as this vehicle-driver interaction is ripe for innovation and could become be a brand-defining feature of an OEM.

TABLE OF CONTENTS

1.	SCOPE.....	4
2.	REFERENCES.....	4
2.1	Applicable Documents	4
2.1.1	SAE Publications.....	4
2.1.2	Code of Federal Regulations (CFR) Publications.....	4
3.	DEFINITIONS	4
4.	ACRONYMS	7
5.	DETERMINATION OF EV CHARGING RATE	7
5.1	Test Conditions and Instrumentation	7
5.1.1	Condition of Vehicle	7
5.1.2	Condition of Battery.....	7
5.1.3	Environmental Conditions	7
5.2	Test Instrumentation	7
5.2.1	General Instrumentation.....	7
5.2.2	Data to Be Documented for All Tests.....	8
5.2.3	Data to Be Recorded During Tests	9
5.3	Test Procedure.....	9
5.3.1	Pre-Calculations and Variables.....	9
6.	DETERMINATION OF EVSE CHARGING RATE	12
6.1	EVSE Test.....	12
6.2	Instrumentation	12
6.3	EVSE Prep	12
6.3.1	Vehicle or Vehicle Substitute	13
6.4	Test Procedure.....	13
7.	NOTES	
7.1	Revision Indicator.....	14

APPENDIX A		15
APPENDIX B		Error! Bookmark not defined.
APPENDIX C	RATIONALE ON THE NON-EXISTENCE OF A THERMAL SOAK JUST PRIOR TO THE TEST	24
Figure 1		13
Figure 2		13
Figure 3		14
Table 1	Acronyms used in this document	7
Table 2	Data to be recorded	8
Table 3	Required parameters to be recorded	9

1. SCOPE

This document facilitates clear and consistent comparisons of realistic charging capabilities of passenger vehicles via commercially available DC EVSE. Common test procedures and metrics are established for both vehicles and EVSEs operating without limitations in nominal conditions. This document does not attempt to address performance variations of EV-EVSE interactions outside of nominal conditions such as extreme temperatures, variable SOC, and so on.

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 +1 724-776-4970 (outside USA), www.sae.org.

SAE J1634 Battery Electric Vehicle Energy Consumption and Range Test Procedure

SAE J2894/2 Power Quality Test Procedures for Plug-in Electric Vehicle Chargers

2.1.2 Code of Federal Regulations (CFR) Publications

Available from the United States Government Printing Office, 732 North Capitol Street, NW, Washington, DC 20401, Tel: 202-512-1800, www.gpo.gov.

16 CFR Part 309 Labeling Requirements for Alternative Fuels and Alternative Fueled Vehicles

3. DEFINITIONS

3.1 ALTERNATING CURRENT (AC) LEVEL 2 CHARGING

A method that uses dedicated AC EV/PHEV supply equipment in either private or public locations. The vehicle shall be fitted with an on-board charger capable of accepting energy from single phase AC electric vehicle supply equipment.

3.2 AMBIENT TEMPERATURE

The air temperature outside the vehicle. Not to be confused with the temperature immediately surrounding a component (e.g., underhood or undercar temperature) or a range of temperatures (e.g., 20 to 30 °C—aka, “room temperature”).

3.3 BATTERY (RESS)

A device consisting of one or more electrochemical cells electrically connected in a series and/or parallel arrangement. Often used as shorthand for traction battery, a battery that provides power to propel a vehicle. Traction batteries are typically electrically rechargeable, with charge power supplied from the electrical grid through a charger, from energy captured from regenerative braking, and/or from power generated by a fuel-powered engine.

3.4 BATTERY AMPERE-HOUR CAPACITY

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

3.5 BATTERY ELECTRIC VEHICLE (BEV)

A vehicle that receives its power solely from batteries, unlike a hybrid vehicle that may receive a portion of its power from a separately-fueled power source, such as an internal combustion engine.

3.6 CHARGE RATE

The rate at which usable energy is returned to the vehicle battery from an offboard source expressed in miles per minute.

3.7 CHARGER

An electrical device that converts alternating current energy to regulated direct current for replenishing the energy of a rechargeable energy storage device (i.e., battery) and may also provide energy for operating other vehicle electrical systems. This may be located on-board (aka, on-board charger [OBC]) or off-board (aka, DC charger).

3.8 CONNECTOR (CHARGE PLUG)

A conductive device that by insertion into a vehicle inlet establishes an electrical connection to the electric vehicle for the purpose of transferring energy and exchanging information. This is part of the coupler.

3.9 COUPLER

A mating vehicle inlet and connector set.

3.10 DIRECT CURRENT (DC) CHARGING

A method that uses dedicated DC EV/PHEV supply equipment to provide energy from an appropriate off-board charger to the EV/PHEV in either private or public locations.

3.11 DIRECT CURRENT (DC) DISCHARGE ENERGY CONSUMPTION

Variable: ECDC. The energy withdrawn from the battery pack for operating the vehicle on a per mile basis (watt-hour per mile) as measured by the test procedure defined in SAE J1634.

3.12 ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE)

The conductors, including the ungrounded, grounded, and equipment grounding conductors and the electric vehicle connectors, attachment plugs, and all other fittings, devices, power outlets, or apparatuses installed specifically for the purpose of delivering energy from the premises wiring to the electric vehicle.

3.13 FULL CHARGE (FC)

The battery state associated with maximum off-board stored energy capacity established by using the manufacturer's recommended charging procedure and appropriate equipment. At full charge, the vehicle should indicate full charge by an easily read indicator somewhere in or on the vehicle.

3.14 HUMAN MACHINE INTERFACE (HMI)

The interface or controls that an operator may adjust, and the human readable feedback given to the operator on a piece of equipment.

3.15 JOULE LOSSES (JOULE HEATING)

The energy lost during charging or discharging the battery cells. Notable in the context of this document, during charging, the joule losses are the difference between the electrical energy entering the battery cells (integration of voltage * current) and the usable battery electrochemical energy stored in the cells.

3.16 NET BATTERY CURRENT

The sum of all currents simultaneously entering or leaving the battery cells. This may be a single measurement point or multiple measurement points depending on the electrical distribution inside the battery pack.

3.17 PREDICTED RANGE

The electric driving range remaining before the vehicle comes to a stop as predicted by a vehicle display or feedback. For the purposes of this document, the unit of “miles” is used unless otherwise noted.

3.18 PLUG IN ELECTRIC VEHICLE (PEV)

Either a PHEV or BEV or other vehicle that operates in whole or in part on electric energy and can be recharged from a grid connection

3.19 PLUG IN HYBRID ELECTRIC VEHICLE (PHEV)

A hybrid vehicle with the ability to store and use off-board electrical energy in a rechargeable energy storage device.

3.20 RECHARGED USABLE BATTERY ENERGY (rUBE)

The energy added to the battery during charging which is available for discharging at a later time. This value is equivalent to the energy added to the battery pack minus the joule losses.

3.21 SOAK

The period of a preconditioning stage that is focused on allowing the test setup to come naturally to a defined temperature. This is often accomplished through the use of a climatically controlled space.

In the context of this document, the term is used to distinguish the difference preparing the temperature of the vehicle from preparing other conditions. See Appendix C for the background of this distinction.

3.22 STATE-OF-CHARGE (SOC)

The percentage of useable energy remaining in the battery pack relative to the battery pack's full charge useable energy.

3.23 VEHICLE INLET (CHARGE INLET)

The device on the electric vehicle into which the connector is inserted for the purpose of transferring energy and exchanging information. This is part of the coupler.

3.24 VEHICLE PARKED STATE

The vehicle has been put in a state where it will may stationary for an indefinite period of time, even in loss of on-board power (e.g., dead or removed battery), using only mechanical roll-away prevention measures on-board (park pawl, parking brake, other), and the key or other device for authorization the starting system of the vehicle has been removed such that the starting system may not be operated. The end of this state is indicated when the vehicle receives a signal authorizing entry or other vehicle operation beyond information query. Guidance from the manufacturer, if supplied, should be followed to ensure a “parked” vehicle.

Note that this is the condition formerly regarded as gear selector in “P” and key removed. Changes in both gear selector and key technology, as well as after-run operations, has made a more formal definition necessary.

3.25 WIRELESS POWER TRANSFER (WPT)

Wireless charging of a plug-in vehicle utilizing an off-board component and an on-board component to transfer grid energy to and/or from the vehicle through an air gap.

4. ACRONYMS

Table 1 lists the acronyms used in this document in the order of first appearance.

Table 1 - Acronyms used in this document

Acronym	Term
AC	Alternating current
A/C	Air conditioning
BEV	Battery electric vehicles
DC	Direct current
EOT	End-of-test
EVSE	Electric vehicle supply equipment
FC	Full charge
HMI	Human machine interface
NIST	National Institute of Standards and Technology
SOC	State-of-charge
UBE	Useable battery energy
WPT	Wireless power transfer
PHEV	Plug-in hybrid electric vehicle
PEV	Plug-in vehicle
RESS	Rechargeable energy storage system

5. DETERMINATION OF EV CHARGING RATE

5.1 Test Conditions and Instrumentation

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

5.1.1 Condition of Vehicle

All accessories shall be turned off except those required by the test procedure.

5.1.2 Condition of Battery

The battery and battery management controls shall be production versions.

No requirements on the calendar age of the battery. It is recommended that the battery have less than 3000 miles of use.

All batteries shall be cycled in accordance with the vehicle manufacturer's recommendations, if any, before starting testing. Battery ampere-hour capacity shall be verified to be within acceptable limits using the manufacturer's recommended procedure as provided for SAE J1634 and should be verified at least once following the completion of vehicle testing.

5.1.3 Environmental Conditions

Ambient temperatures during vehicle and battery ambient soak (if any), test, and recharge period shall all be within the range of 20 to 30 °C (68 to 86 °F).

5.2 Test Instrumentation

This section provides a list of instruments that are required to perform the tests specified in this document.

5.2.1 General Instrumentation

All measurements shall be NIST-traceable (National Institute of Standards and Technology). The following instruments are either additionally required or recommended for as-needed usage:

Measurements in the high voltage system

- a. A DC wideband voltage, ampere-hour, and watt-hour meter (e.g., a power analyzer with integration functions for energy calculations). Sensors such as current, voltage, and/or temperature are connected to this device. Voltage of the battery pack or charge coupler are measured directly with this meter. Net battery current is summed from all applicable sensors and ampere-hour calculations are performed. The device shall have an environmental rating, including ambient temperature, that meets the rating of the test environment. Devices which record measurements or perform calculations using the assumption that the electrical frequency is a fixed 50 Hz or 60 Hz are not sufficient.
- b. Total accuracy of voltage measurements (sensor plus data collection system) shall be 1% of the reading or 0.3% of full scale required for this test, whichever is larger.
- c. Total accuracy of current measurements (sensor plus data collection system) shall be 1% of the reading or 0.3% of full scale required for this test, whichever is larger. Note: if multiple current sensors are used to sum individual paths, the total error of the calculation when summed shall be the same or better as the given above.
- d. DC wideband current measurements. It shall be installed in such a way as to measure all current leaving and entering the battery cells regardless of the number of connections on the pack. If a single sensor cannot measure the total flow, multiple sensors may be used and summed provided that the total error of the summation is within the required tolerances and the sampling rate of all sensors is the same.
- e. As the current and voltage sensors are used in long duration integration calculations, possible offset errors of sensors should be checked and corrected for prior to the test, and confirmed to have remained within tolerance after the conclusion of the test.
- f. Wideband instruments (bandwidth of at least ten times that of the maximum fundamental frequency of interest) are required where pulsed power electronics are implemented. Any watt-hour meter using an integration technique shall have a maximum integration period of 0.05 second so that short bursts of regeneration energy and current can be accommodated without causing integration errors.

As an alternative to paragraph (a), the manufacturer may use the on-board voltage measurement data. The accuracy of these data shall be demonstrated to have the required accuracy when compared to NIST-traceable instruments that would be otherwise used. As an alternative to paragraphs (a), (b), and (f), the manufacturer may use on-board RESS current measurement data. The integrated value of current (A•h) should be performed by the vehicle at 20 Hz or greater prior to communicating through CAN.

Temperature measurements: $\pm 2.5^{\circ}\text{C}$.

Delta time should be within 5 seconds of accuracy. It is recommended to use the time index of a data logging instrument or power analyzer.

5.2.2 Data to Be Documented for All Tests

The following data shall be documented for all tests. If the parameter does not apply to the test as performed (e.g., using on-board data source versus instrumented battery voltage sensor), the absence of the sensor and rationale should be documented.

Table 2 - Data to be recorded

Item	Parameter/Measurement	Description	Units
1	Current sensor(s) used	Type, serial number, calibration data	
2	Voltage sensor(s) used	Type, serial number, calibration data	
3	A•h or W•h meter (power analyzer) used	Type, serial number, calibration data, settings which are modified from factory settings	
4	EVSE rated/nameplate voltage, power and current (for vehicle test)		kW/A/V
5	EV published max charge power and current (for EVSE test)		kW/A/V



Documents

Document Sharing Hub