



SURFACE VEHICLE RECOMMENDED PRACTICE

ISO/SAE 12906™

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Test Procedures for Electric Vehicles to Determine Charging Performance

RATIONALE

This document is to mirror ISO 12906. The document was developed by a joint ISO and SAE working group. This document replaces SAE J2953/4.

The differences between this document and ISO 12906 are limited to:

- This informational rationale.
- Formatting changes as required by the respective organizations (SAE and ISO).
 - Additions to the “Applicable Documents” section and likewise non-normative references in the document to aid the reader in finding additional information.
 - Replacement of “,” with “.” for representing decimal place in numbers.

The test procedures presented in this document are identical to ISO12906. However, the following adjustments are specified for the North American market:

- The test case “Test procedure for test case Normal Charging” is superseded by the recharge test in SAE J1634, which is incorporated by reference into 40 CFR 600.311-12(k).
- Air temperature indicated in 6.3.2.3 and Appendix A for soaking and “ambient” testing should be changed from “23 °C” to “20 to 30 °C per SAE J1634 requirements” to account for North American testing standards. Reporting of metrics for “Test procedure for test case Fast Charging” (and similar) should be reported in miles added (as opposed to kilometers added) using the conversion factor of 1 mile = 1.61 km.
- When selecting the DC energy consumption (EC_{DC}) per mile to be used in 6.2.5(b), the value should be the same EC_{DC} used in the calculation of the reported total vehicle range and any associated correction factors such as those used for 5-cycle corrections. For example: A vehicle range test is performed per SAE J1634 MCT, the city range, R_{city} , and highway range, $R_{highway}$, are calculated then combined per 40 CFR 600.311-12(j)(2) with a 0.45 and 0.55 weighting. The result is then multiplied by a 5-cycle correction factor of 0.7 (per 40 CFR 600.210-12(d)(3)) to obtain the total vehicle range that is reported on the label. In this case, the EC_{DC} used for calculating recharged range should also be weighted 0.45 and 0.55 with the correction factor 0.7 included.
- If multiple values of total vehicle range are computed (i.e., city range and highway range), it is recommended to calculate and communicate a charge rate corresponding to each range individually (i.e. miles per 10 minutes of city driving and miles per 10 minutes of highway driving). In such cases, the EC_{DC} used for each calculation should be specific to the driving cycle to which it is referencing.

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FOREWORD

The test procedures were derived from typical use cases, whereas both test procedures and use cases were established based on the following premises:

- **Comparability:** The charging performance determined according to this document enables a comparison of the performance of different electrically propelled vehicles (EVs) in realistic scenarios. The application of specific optimizing features to improve the charging performance (e.g., battery thermal preconditioning based on navigation systems) is taken into account.
- **Imitability and plausibility:** The possibility to retrace the determined charging performance in principle.
- **Reproducibility:** The specified test conditions, test methods, and test processes ensure reproducibility within common measurement tolerances. It was important to leave as little space as possible for inadvertent deviations or manipulations.

The test results serve for information purposes (e.g., for vehicle operator interfaces) or manufacturer specifications.

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1. SCOPE

This document specifies test procedures to determine the charging performance of electric vehicles. This document facilitates clear and consistent comparisons of realistic charging capabilities of electrically propelled vehicles (EVs) via commercially available electric vehicle supply equipment. It provides details about test conditions, test methods, and test processes derived from typical use cases. Furthermore, it specifies requirements regarding the information for the vehicle operator.

This document is applicable to EVs, including plug-in hybrid EVs.

This document does not provide requirements for mopeds and motorcycles.

Unless specified otherwise, all test procedures can be applied to AC, DC, or wireless charging methods.

NOTE: Specifications for reverse power transfer are under consideration.

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 J2953/4 Plug-In Electrical Vehicle Charge Rate Reporting and Test Procedures

SAE J2954 Wireless Power Transfer for Light-Duty Plug-In/ Electric Vehicles and Alignment Methodology

2.1.2 ISO Publications

Copies of these documents are available online at <https://webstore.ansi.org/>.

ISO 5474-4 Electrically propelled road vehicles - Functional and safety requirements for power transfer between vehicle and external electric circuit - Part 4: Magnetic field wireless power transfer

ISO 6469-1 Electrically propelled road vehicles - Safety specifications - Part 1: Rechargeable energy storage system (RESS)

ISO 6469-3 Electrically propelled road vehicles - Safety specifications - Part 3: Electrical safety

ISO 12906 Road vehicles - Test procedures for electric vehicles to determine charging performance

ISO/TR 11954 Fuel cell road vehicles - Performance measurement - Vehicles fuelled with compressed hydrogen

2.1.3 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 61851-1 Electric vehicle conductive charging system - Part 1: General requirements

IEC 62053-21 Electricity metering equipment - Particular requirements - Part 21: Static meters for AC active energy (classes 0,5, 1 and 2)

3. DEFINITIONS

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

ISO Online Browsing Platform is available at <https://www.iso.org/obp>.

IEC Electropedia is available at <https://www.electropedia.org/>.

3.1 APPLICABLE DRIVING TEST (ADT)

Driving test provision including test procedure and requirements for homologation in the intended market.

EXAMPLE: Worldwide harmonized light vehicles test procedure; refer to SAE J1634.

3.2 ADT SCHEDULE

Collection of one or more driving cycle(s).

EXAMPLE: Worldwide light-duty test cycle; urban dynamometer driving schedule.

3.3 DC ELECTRIC ENERGY CONSUMPTION (EC_{DC} , $R_{EC,DC}$)

Energy withdrawn per unit of distance from the *RESS* (see [3.9](#)) for operating the *EV* (see [3.5](#)) as measured by the combined test procedure defined in the *ADT* (see [3.1](#)).

NOTE 1: Charging losses due to AC charging are excluded.

NOTE 2: The unit of the distance referred to depends on the specification in the *ADT*.

NOTE 3: In the worldwide light-duty test cycle, the consumption of the combined test procedure is called $EC_{DC,WLTC}$.

3.4 discharged battery energy (DBE, E_{rUBE})

Energy removed from the *RESS* ([3.9](#)) during the *ADT schedule* ([3.2](#))

NOTE: At the end of the *ADT schedule* (see [3.2](#)), the DBE equals the usable battery energy.

3.5 ELECTRICALLY PROPELLED VEHICLE (EV)

Vehicle with one or more electric drive(s) for vehicle propulsion. (Refer to ISO 6469-3, 3.1; the abbreviated term “EV” has been added.)

3.6 EV SUPPLY EQUIPMENT (EVSE)

Equipment or combination of equipment that provides dedicated functions to supply electric energy from a fixed electrical installation or supply network to an EV (see [3.5](#)) for the purpose of charging. (Refer to IEC 61851-1, 3.1.1; Modified: Examples were deleted.)

3.7 INDICATED STATE OF CHARGE (INDICATED SOC)

Residual capacity of *rechargeable energy storage system* (see [3.9](#)) available to be discharged as indicated to the vehicle operator.

NOTE: Indicated SOCE is normally expressed as a percentage of full charge.

(Refer to ISO/TR 11954, 3.11; Modified: The term was originally RESS state of charge, and “as indicated to the vehicle operator” has been added.)

3.8 OPTIMIZING FEATURES

All vehicle functions that positively impact the test results when activated either automatically or by the vehicle operator.

EXAMPLE: Battery thermal preconditioning functions activated by navigation systems; specific charging modes selected by the vehicle operator.

3.9 RECHARGEABLE ENERGY STORAGE SYSTEM (RESS)

Rechargeable system that stores energy for delivery of electric energy for the electric drive.

EXAMPLE: Battery, capacitor.

(Refer to ISO 6469-1, 3.22; Modified: “Flywheel” has been deleted from the examples.)

3.10 RECHARGED USABLE BATTERY ENERGY (r_{UBE} , E_{rUBE})

Calculated share of *UBE* (see [3.13](#)) that is recharged within a certain period.

3.11 REMAINING ELECTRIC RANGE

Range calculated based on the battery capacity remaining for driving and the EC_{DC} (see [3.3](#)) of the *EV* (see [3.5](#)) as determined in the *ADT* (see [3.1](#)).

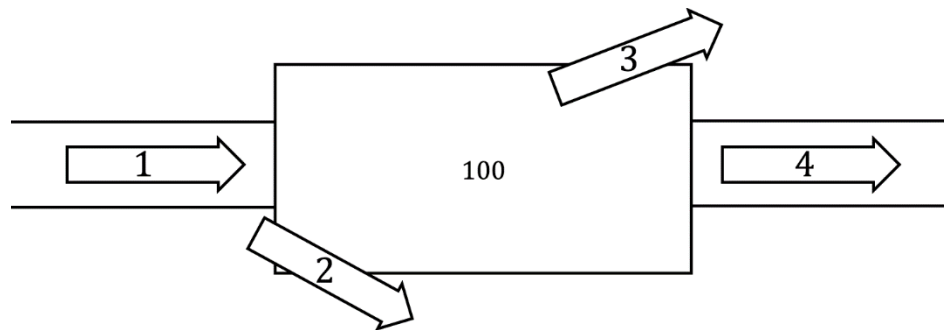
3.12 SOAKING

Establishing a targeted steady state by exposing the *EV* (see [3.5](#)) to defined environmental conditions.

3.13 USABLE BATTERY ENERGY (UBE)

Usable *RESS* (see [3.9](#)) energy determined according to *ADT* (see [3.1](#)).

Note: See [Figure 1](#).

**Key:**

- 1 Energy entering the RESS during charging (see MP3 in [Figure 4](#))
- 2 Q_{loss} for recharging (e.g., loss due to cell chemistry, heating in RESS)
- 3 Q_{loss} for discharging (e.g., loss due to cell chemistry, heating in RESS)
- 4 UBE (see MP4 in [Figure 4](#))
- 100 RESS

Figure 1 - Relationship between energies and losses at the RESS

4. ABBREVIATIONS

AC	alternating current
DC	direct current
GPS	global positioning system
PER	pure electric vehicle
RMS	root mean square
WLTC	worldwide light-duty test cycle
WLTP	worldwide harmonized light vehicles test procedure

5. GENERAL

The test procedures specified in this document serve to determine the charging performance of an EV.

NOTE: It is not necessary to perform all test procedures.

This document does not address bundling or the classification of vehicle configurations. Therefore, it does not specify for which changes in vehicle configurations the test procedures shall be repeated. The manufacturer may apply test results to other vehicle configurations than the vehicle configuration tested. In this case, the vehicle manufacturer shall ensure that the values stated in the vehicle operator information (see [Section 7](#)) are also possible with the corresponding vehicle configurations.

The vehicle manufacturer may specify values in the vehicle operator information that are worse than the test results achieved (e.g., to add some margin).

The vehicle manufacturer may specify a range of values in the vehicle operator information for bundling or the classification of vehicle configurations.

NOTE: The vehicle operator can be the owner or driver of the vehicle or a test engineer.

6. TEST CASES AND GENERAL REQUIREMENTS

6.1 Overview of Test Cases

[Table 1](#) gives an overview of the test cases to determine the charging performance. Implementation details on how to perform the corresponding test procedures are given in [6.3](#).

Table 1 - Overview of test cases

Test case	Charging power	Start condition	End condition	Test result
Normal Charging ⁽⁴⁾	Charging power applied in ADT ⁽¹⁾	Start and end conditions apply according to the ADT		- Charging duration - Charging efficiency - Maximum charging power
		Start conditions apply according to the ADT	60 minutes	Electric range obtained within 60 minutes of normal charging
Fast Charging	Charging power up to the maximum charging power supported by the EV	15 to 60 km remaining electric range ⁽²⁾	10 minutes	Electric range obtained within 10 minutes of fast charging
		10% indicated SOC ⁽³⁾	80% indicated SOC	- Charging duration - Charging efficiency - Maximum charging power

⁽¹⁾ Europe 11 kW (16 A at 230 V 3-phase), U.S. 9.6 kW (40 A at 240 V), China 7 kW (32 A at 220 V), Japan 6 kW (30 A at 200 V).

⁽²⁾ See [6.3.2.5](#) for specifications related to the starting condition.

⁽³⁾ See [6.2.4](#) for determination of indicated SOC.

⁽⁴⁾ Typically AC unless unavailable on the EV.

The fast charging test case is only applicable to EVs that support a maximum charging power >22 kW.

[Appendix A](#) specifies the test procedure to determine the charging performance at low ambient temperatures. [Appendix B](#) provides a test procedure for heavy-duty vehicles.

6.2 General Requirements

6.2.1 Vehicle Manufacturer Specifications

The vehicle manufacturer shall specify the required current and voltage ranges to be covered by the EVSE for each test procedure.

For AC charging, the vehicle manufacturer shall additionally specify the number of phases and the charging cable applied.

The vehicle manufacturer specifications should take region-specific availabilities (e.g., supply network connections) into account.

The EVSE applied in the testing shall support the specifications of the vehicle manufacturer to allow the maximum charging performance of the EV under test.

If applicable, the vehicle manufacturer shall explain how to activate optimizing features (e.g., specific charging modes, GPS navigation, activation via diagnostic function).

6.2.2 EV Run-In

The EV under test shall have been run-in according to the specifications of the ADT. If the ADT does not specify run-in requirements, the EV shall have been run-in at least 300 km or one full charge distance, whichever is longer.

NOTE: The EV run-in time can differ between battery electric vehicles and externally chargeable electric hybrid vehicles in the ADTs.

6.2.3 Measurement Tolerances and Accuracies

The vehicle manufacturer shall take measurement tolerances and accuracies into account in the determination of the test result. External measuring tools and/or onboard measurement data from the EV may be used in the tests.

[Table 2](#) provides sample rate, accuracy, and resolution for different parameters that shall be applied in the measurements described in this document.

Table 2 - Measurement sample rates, accuracies, and resolutions

Measured parameter	Sample rate	Accuracy	Resolution
Time(s)	--	±1 s	≤ 1 s
Indicated SOC (%)	1 Hz	As provided by the EV	≤ 1%
Energy (kWh) during discharge to measure the DBE (see 6.2.5)	20 Hz for the voltage and current measurements	±1% of reading, or 0.3% of full scale of measurement device, whichever is greater	≤ 1 kWh
Energy (kWh) to identify the charging efficiency (see 6.2.6)	Watt-hour meter, Class 1 in accordance with IEC 62053-21 or equivalent		
Electrical power (kW) (see 6.2.7)	1 Hz	±1% of reading	≤ 10 W when charging power < 10 kW and ≤ 100 W when charging power ≥ 10 kW

The full scale of the measurement device should not exceed the maximum measured parameter to the extent that it significantly impacts the test result.

NOTE: A wideband meter (power analyzer) or wideband ampere-hour meter for pulsed power electronics can be used for the DBE measurement.

6.2.4 Determination of Indicated SOC

The indicated SOC shall be obtained from the onboard measurement from the EV or from the onboard indication.

NOTE: The indicated SOC at any other interface available can be used for plausibility checks but can be subject to certain latencies.

6.2.5 Determination of Recharged ADT Range by Recharged Energy

In ADTs, the vehicle's EC_{DC} is usually determined using a measurement at the RESS terminal.

During fast charging, a large share of energy is typically transferred to heat just inside the RESS because of heat generated by electric resistances at high charging current (see Figure 1, Key 2).