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Road vehicles — Test procedures for electric vehicles to determine charging performance

Véhicules routiers — Procédures d'essai des véhicules électriques pour déterminer les performances de charge

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Foreword

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This document was jointly prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 37, *Electrically propelled vehicles* and SAE Hybrid – EV Committee.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html. Alternatively, to provide feedback on this document, please visit http://standards.sae.org/PRODCODE.

Introduction

The test procedures were derived from typical use cases. 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 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.

Road vehicles — Test procedures for electric vehicles to determine charging performance

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 Normative references

There are no normative references in this document.

3 Terms and 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: available at https://www.iso.org/obp

— IEC Electropedia: 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; 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* (3.9) for operating the *EV* (3.5) as measured by the combined test procedure defined in the *ADT* (3.1)

Note 1 to entry: Charging losses due to AC charging are excluded.

Note 2 to entry: The unit of the distance referred to depends on the specification in the ADT.

Note 3 to entry: 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_{DBE}
energy removed from the *RESS* (3.9) during the *ADT schedule* (3.2)

Note 1 to entry: At the end of the ADT schedule the DBE equals the usable battery energy.

3.5
electrically propelled vehicle
EV
vehicle with one or more electric drive(s) for vehicle propulsion

[SOURCE: ISO 6469-3:2021, 3.15 — 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 *electrically propelled vehicle* (3.5) for the purpose of charging

[SOURCE: IEC 61851-1:2017, 3.1.1, modified – Examples were deleted.]

3.7
indicated state of charge
indicated SOC
residual capacity of *rechargeable energy storage system* (3.9) available to be discharged as indicated to the vehicle operator

Note 1 to entry: Indicated state of charge is normally expressed as a percentage of full charge.

[SOURCE: ISO/TR 11954:2024, 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.

[SOURCE: ISO 6469-1:2019, 3.22, modified — "Flywheel" has been deleted from the examples.]

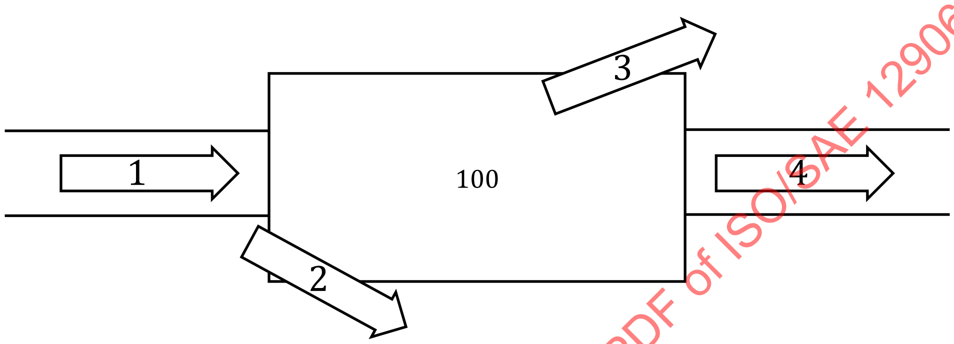
3.10
recharged usable battery energy
rUBE
E_{rUBE}
calculated share of *UBE* (3.13) that is recharged within a certain period

3.11
remaining electric range
range calculated based on the battery capacity remaining for driving and the EC_{DC} (3.3) of the *EV* (3.5) as determined in the *ADT* (3.1)

3.12
soaking
establishing a targeted steady state by exposing the *EV* (3.5) to defined environmental conditions

3.13
usable battery energy
UBE
usable *RESS* (3.9) energy determined according to *ADT* (3.1)

Note 1 to entry: See Figure 1.



Key
1 energy entering the RESS (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/rUBE (see MP4 in Figure 4)
100 RESS

Figure 1 — Relationship between energies and losses at the RESS

4 Abbreviated terms

AC	alternating current
DC	direct current
GPS	global positioning system
PER	pure electric range
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. It therefore 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 Clause 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, e.g. 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 Charge[d]	charging power applied in ADT[a]	start and end conditions apply according to the ADT		— charging duration — charging efficiency — max. charging power
		start conditions apply according to the ADT	60 min	— recharged electric range obtained within 60 min of Normal Charge
Fast Charge	charging power up to the max. charging power supported by the EV	15 km to 60 km remaining electric range[b]	10 min	— recharged electric range obtained within 10 min of Fast Charge
		10 % indicated SOC[c]	80 % indicated SOC	— charging duration — charging efficiency — max. charging power

a E.g. Europe 11 kW (16 A at 230 V 3-phase), US 9,6 kW (40 A at 240 V), China 7 kW (32 A at 220 V), Japan 6 kW (30 A at 200 V).

b See 6.3.2.5 for specifications related to the starting condition.

c See 6.2.4 for determination of indicated SOC.

d Typically AC unless unavailable on the EV.

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

Annex A specifies the test procedure to determine the charging performance at low ambient temperatures. Annex 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 on-board 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 Wh
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 analyser) 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 on-board measurement data of the EV or from the on-board 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 electric range by recharged energy

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

During Fast Charge, 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 (Figure 1, key 2).

Therefore, the measurement of the electric energy added to the RESS (Figure 1, key 1) is higher than the energy stored in the RESS.

Consequently, the measurement of the electric energy added to the RESS (Figure 1, key 1) is not suitable to determine the effectively delivered rUBE inside the RESS (Figure 1, key 4). The method specified in the clause solves this problem and determines the rUBE in good approximation.

a) Determination of rUBE

1) Required measurements during ADT schedule

During the ADT schedule the DBE of all RESSs and the indicated SOC shall be synchronously recorded. The measurements shall allow the association of the DBE to an indicated SOC interval.

Care shall be taken to calculate the net energy for the appropriate SOC interval including both, RESS discharge during vehicle operation and RESS charging during regenerative braking events during ADT schedule.

2) Required measurements during charging phase

During the charging phase, the indicated SOC and the time shall be synchronously recorded.

The time measurement shall start with the first change of the indicated SOC (=SOC_start).

NOTE The first change of the indicated SOC (=SOC_start) can be positive or negative, e.g. due to functions before the beginning of the actual charging process.

The indicated SOC (=SOC_end) shall be recorded after t_{ref}. In addition, the time t_{SOC_end} from the start of the time measurement until the indicated SOC changes to SOC_end shall be recorded. Charging shall continue until the SOC_end changes to the next indicated SOC (=SOC_end+1) and the time t_{SOC_end+1} shall be recorded until the indicated SOC changes to SOC_end+1.

3) Calculation of rUBE within the reference time t_{ref}

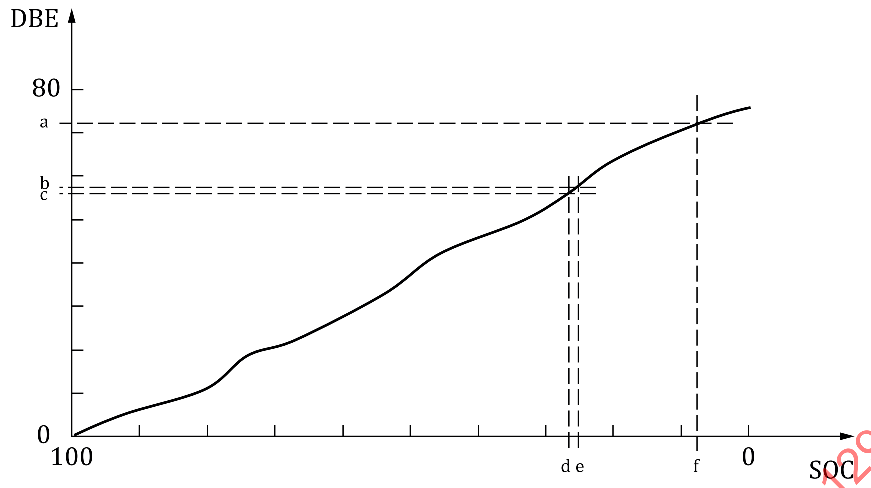
Using the data from 1) and 2), the rUBE within t_{ref} shall be calculated by subtracting the DBE associated to the SOC_end (=E_{DBE,SOC_end}) from the DBE associated to the SOC_start (E_{DBE,SOC_start}), taking the last uncompleted SOC_end proportionally (linearly interpolated) into account as per Formula (1):

$$E_{rUBE}(t_{ref}) = E_{DBE,SOC\_start} - E_{DBE,SOC\_end} + \frac{t_{ref} - t_{SOC\_end}}{t_{SOC\_end+1} - t_{SOC\_end}} \times \left(E_{DBE,SOC\_end} - E_{DBE,SOC\_end+1}\right) \quad (1)$$

where

E_{rUBE}	is the recharged usable battery energy (rUBE) within the specified time span of t_{ref};
t_{ref}	is the reference time for recharged electric range calculation (e.g. 10 min);
E_{DBE,SOC_start}	is the DBE associated with the SOC_start;
E_{DBE,SOC_end}	is the DBE associated with the SOC_end;
E_{DBE,SOC_end+1}	is the DBE associated with the SOC_end+1;
t_{SOC_end}	is the measured time until the indicated SOC changes to SOC_end;
t_{SOC_end+1}	is the measured time until the indicated SOC changes to SOC_end+1.

Figure 2 and Figure 3 illustrate the determination of the rUBE with example values for the parameters of Formula (1).



a $E_{DBE,SOC\_start} = 72,362$

b $E_{DBE,SOC\_end} = 57,819$

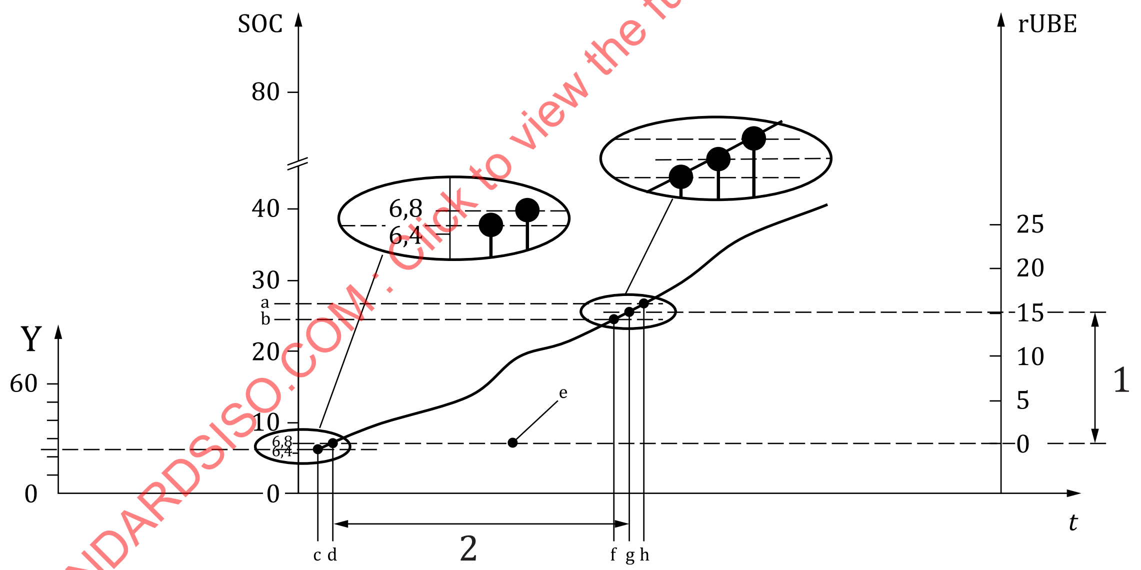
c $E_{DBE,SOC\_end+1} = 56,138$

d SOC_end+1=27,1

e SOC_end=26,4

f SOC_start=6,8

Figure 2 — Determination of DBE during ADT schedule (example)



Key

Y remaining electric range [km]

1 rUBE after 10 min

2 rUBE measuring duration (10 min)

a SOC_end+1=27,1

b SOC_end=26,4

c beginning of charging

d beginning of time and SOC measurement

e SOC_start = 6,8

f $t_{SOC\_end} = 9\ \text{min}\ 48\ \text{s}$

g $t_{ref} = 10\ \text{min}$

h $t_{SOC\_end+1} = 10\ \text{min}\ 21\ \text{s}$

Figure 3 — Determination of rUBE during charging (example)

With the example values from Figure 2 and Figure 3, Formula (1) leads to the following result:

$$E_{\mathrm{rUBE}}\left(10\,\mathrm{min}\right)=72{,}362\,\mathrm{kWh}-57{,}819\,\mathrm{kWh}+\frac{10\,\mathrm{min}-9\,\mathrm{min}\,48\,\mathrm{s}}{10\,\mathrm{min}\,21\,\mathrm{s}-9\,\mathrm{min}\,48\,\mathrm{s}}\times\left(57{,}819\,\mathrm{kWh}-56{,}138\,\mathrm{kWh}\right)=15{,}154\,\mathrm{kWh}$$

SOC_start, SOC_end, and SOC_end+1 shall be selected from the recorded data during the charging phase. If any of these values do not align with the indicated SOC values recorded during the ADT schedule, a linear interpolation using the next lowest indicated SOC and the next highest indicated SOC recorded during the ADT schedule shall be used to identify the $E_{\mathrm{DBE,SOC\_start}}$, $E_{\mathrm{DBE,SOC\_end}}$, or $E_{\mathrm{DBE,SOC\_end+1}}$ values as necessary.

EXAMPLE 1 During discharge, the measurement indicates the DBE of 57,589 kWh when the vehicle reports an SOC step to 26,8 %, and the DBE of 58,125 kWh when the vehicle reports an SOC step to 26,1 %. However, during charging, the final SOC step recorded from the vehicle before the end of test, SOC_end, is 26,4 %. This recorded SOC value was not provided by the vehicle during discharge but was provided during charge. The $E_{\mathrm{DBE,SOC\_end}}$ between 26,1 % and 26,8 % is identified by linear interpolation: $E_{\mathrm{DBE,SOC\_end}}$ = (58,125 kWh − 57,589 kWh) / (26,8 % − 26,1 %) × (26,4 % − 26,1 %) + 57,589 = 57,819 kWh.

b) Determination of recharged electric range

The recharged electric range during a charging phase shall be calculated from the $\mathrm{EC_{DC}}$ according to Formula (2). The result of the calculation of the recharged electric range shall be rounded down to integer numbers.

$$r_{\mathrm{rPER}}\left(t_{\mathrm{ref}}\right)=\frac{E_{\mathrm{rUBE}}\left(t_{\mathrm{ref}}\right)}{R_{\mathrm{EC,DC}}} \qquad (2)$$

where

$r_{\mathrm{rPER}}(t_{\mathrm{ref}})$	is the recharged pure electric range within the specified time span of t_{ref};
$E_{\mathrm{rUBE}}(t_{\mathrm{ref}})$	is the recharged usable battery energy (rUBE) within the specified time span of t_{ref};
$R_{\mathrm{EC,DC}}$	is the DC electric energy consumption ($\mathrm{EC_{DC}}$);
t_{ref}	is the reference time for recharged electric range calculation (e.g. 10 min).

EXAMPLE 2 The rUBE within the time period of 10 min is 15,154 kWh. The vehicle's $\mathrm{EC_{DC}}$ is 0,15 kWh/km. The result for the recharged electric range within 10 min of charging is (15,154 kWh / 0,15 kWh/km) = 101 km.

6.2.6 Determination of charging efficiency

Charging efficiency shall be calculated as the relationship between rUBE and the energy provided to the EV according to Formula (3). The rUBE shall be determined according to 6.2.5, where t_{ref} is the measured charging duration from the Normal Charge test procedure respectively from the Fast Charge test procedure.

$$\eta_{\text{charge}} = \frac{E_{\text{rUBE}}}{E_{\text{MP}}} \times 100 \tag{3}$$

where

η_{charge} is the charging efficiency of the charging phase;

E_{rUBE} is the recharged usable battery energy (rUBE) determined according to 6.2.5;

E_{MP} is the provided energy at the corresponding measurement point.

The relationship shall be expressed in percentage, rounded to one decimal place.

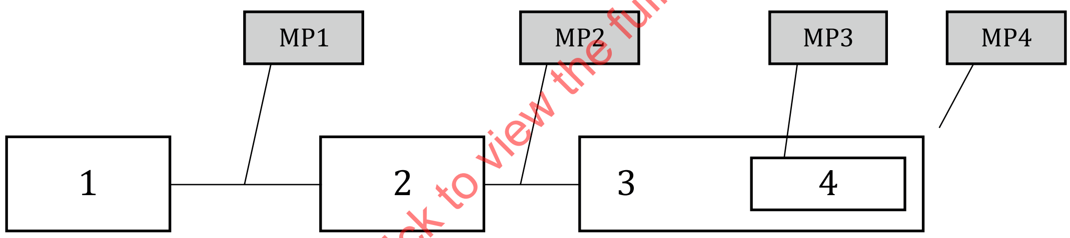
NOTE 1 The charging duration for Normal Charge is measured according to 6.3.1.2 or 6.3.1.3. The charging duration for Fast Charge is measured according to 6.3.2.5 (10 % to 80 % indicated SOC).

For AC charging, the provided energy (E_{MP}) shall be measured at MP1 (see Figure 4) or at MP2 (see Figure 4) for the same period of time as the measurement of the rUBE.

For DC charging, the provided energy (E_{MP}) shall be measured at MP2 (see Figure 4) for the same period of time as the measurement of the rUBE.

For wireless charging, this subclause does not apply.

NOTE 2 Product standards for wireless charging systems (e.g. ISO 5474-4 and SAE J2954) have a specific procedure for determining the charging efficiency.



Key

1 supply network (mains)
2 EVSE
3 EV
4 RESS
MP1 voltage and current between utility and EVSE (typ. AC; 50 Hz or 60 Hz)
MP2 voltage and current between EVSE and vehicle (AC or DC)
MP3 voltage and current into cells of the RESS (DC)
MP4 calculation of rUBE

Figure 4 — Visual description of measurement points (MP) used in the document

6.2.7 Determination of maximum charging power

To determine the maximum charging power supported by the EV, the power provided to the EV shall be recorded during the charging duration.

For AC charging, the provided power shall be measured at MP1 or at MP2 (see Figure 4).

For DC charging, the provided power shall be measured at MP2 (see Figure 4).

For wireless charging, this subclause does not apply.

NOTE Product standards for wireless charging systems (e.g. ISO 5474-4 and SAE J2954) have a specific procedure for determining the charging power.

The maximum charging power is the highest averaged power within a 30 s interval during the charging duration.

For AC charging, the maximum charging power shall be expressed in kW, rounded to one decimal place in the case of maximum charging power < 10 kW, or rounded to an integer in the case of maximum charging power ≥ 10 kW.

For DC charging, the maximum charging power shall be expressed in kW, rounded to integer numbers.

6.3 Test procedures

6.3.1 Test procedure for test case Normal Charge

6.3.1.1 General

To assess multiple vehicle properties, an EV must execute the ADT. As part of the ADT, any EV under test executes a charging phase until full charge to assess the recharged electric energy E_{AC}. If the ADT does not specify such a charging phase, the charging phase shall be executed according to WLTP.

To determine the performance of Normal Charge, the charging duration of this charging phase until full charge shall be measured during the execution of the ADT.

6.3.1.2 Normal Charge AC

The charging duration shall be measured from the point in time the charging current exceeds 1 A (RMS) at any phase until the end-of-charge criterion is reached according to the ADT.

For AC charging, the charging current shall be measured at MP1 (see Figure 4) or at MP2 (see Figure 4).

For wireless charging, the charging current shall be measured at MP1 (see Figure 4).

The charging phase shall be executed by applying the corresponding specifications of the vehicle manufacturer according to 6.2.1. The supply network (mains) voltage shall not exceed 101 % of its nominal voltage during the entire charging phase. Conformance is demonstrated by at least one measurement of the voltage at MP2 (see Figure 4) under full load conditions.

EXAMPLE 1 In case of a nominal voltage of 240 V, the supply network voltage does not exceed 242,4 V.

The time measured shall be rounded up to the next 5 min interval for charging durations ≤ 2 h and up to the next 15 min interval for charging durations > 2 h.

EXAMPLE 2 For a measured time of 6 h 33 min, the test result is 6 h 45 min.

In addition, and from the same test, the recharged electric range shall be calculated according to 6.2.5 after a t_{ref} of 60 min.

NOTE The test procedure for the North American market is defined by SAE J1634.

6.3.1.3 Normal Charge DC

If an EV does not support AC charging, the test procedure shall be executed applying a DC charging power as applied in the corresponding ADT. When the DC charging power in the corresponding ADT is > 20 kW or not defined, up to 20 kW at the output of the EVSE shall be applied.

The charging duration shall be measured from when the charging current exceeds 1 A until the end-of-charge criterion is reached according to the ADT.

For DC charging, the charging current shall be measured at MP2 (see Figure 4).

The charging phase shall be executed by applying the corresponding specifications of the vehicle manufacturer according to 6.2.1.

The time measured shall be rounded up to the next 5 min interval for charging durations ≤ 2 h and up to the next 15 min interval for charging durations > 2 h.

EXAMPLE For a measured time of 6 h 33 min, the test result is 6 h 45 min.

In addition, and from the same test, the obtained range shall be calculated according to 6.2.5 after t_{ref} of 60 min.

6.3.1.4 Charging efficiency and charging power for Normal Charge

In addition to charging duration, charging efficiency and maximum charging power shall be determined for Normal Charge.

During the determination of the charging duration according to 6.3.1.2 or 6.3.1.3, the charging efficiency shall be determined according to 6.2.6 and the charging power shall be determined according to 6.2.7.

6.3.2 Test procedure for test case Fast Charge

6.3.2.1 Overview of process phases

The test procedure for the test case Fast Charge shall be executed by applying the following process phases in the indicated sequence:

1) soaking phase;

2) preparation phase (optional);

3) charging phase.

Further details on each phase are given in 6.3.2.2 to 6.3.2.6.

6.3.2.2 Relocations

The EV may be relocated between the phases of the test procedure, e.g. to a chassis dynamometer or an EVSE.

For relocations, the following applies:

— the vehicle shall be passively moved and shall not be actively driven or actively charged or discharged;

— optimizing features shall not be activated during relocations. If they cannot be deactivated, relocations are not permitted;

— relocations shall be undertaken as quickly as possible, without any unjustified delay for a maximum of 30 min. For EVs with a UBE of the RESS > 25 kWh according to ADT, relocations shall be undertaken as quickly as possible, without any unjustified delay for a maximum of 45 min;

NOTE Larger RESSs are thermodynamically more stable. There is no impact on the test results due to the allowance for an extended relocation time.

— the ambient temperature during relocations shall be ≤ 30 °C.

6.3.2.3 Soaking phase

The vehicle shall be soaked for a minimum of 12 h.

The soak area shall have a temperature set point of 23 °C. The tolerance of the actual value shall be within ±3 °C on a 5 min running arithmetic average and shall not show a systematic deviation from the set point.

The temperature of the EV, especially the RESS, should be achieved in a homogeneous manner.

The indicated SOC or remaining electric range at the beginning or during the soaking phase, is up to the discretion of the vehicle manufacturer but shall ensure that the requirements for the starting condition of the charging phase in 6.3.2.5 can be met.

Optimizing features shall not be activated during the soaking phase.

6.3.2.4 Preparation phase (optional)

The EV shall be operated within a speed range of 25 km/h to 30 km/h for a maximum of 30 min at an ambient temperature range of 0 °C to 30 °C.

Alternatively, the EV may be soaked for maximum 30 min at an ambient temperature range of 0 °C to 30 °C.

Optimizing features may be activated.

6.3.2.5 Charging phase

During the charging phase, the EV shall be in the following conditions:

— parked;

— doors closed, unoccupied;

— key removed from the vehicle, but vehicle in a state that allows charging;

— vehicle loads (e. g. chiller, pumps, lights) controlled by vehicle;

— any on-board equipment that can be switched off by the vehicle operator may be switched off during testing;

— power shall not be simultaneously transferred via different interfaces (e.g. solar panels, inductive charging, multiple vehicle inlets) during the test.

During the charging phase, the EV should stand in an environment with the following attributes:

— no sun load;

— wind less than 10 km/h;

— minimum 1 m clearance around the vehicle to allow air flow for radiators and condensers, see Figure 5.

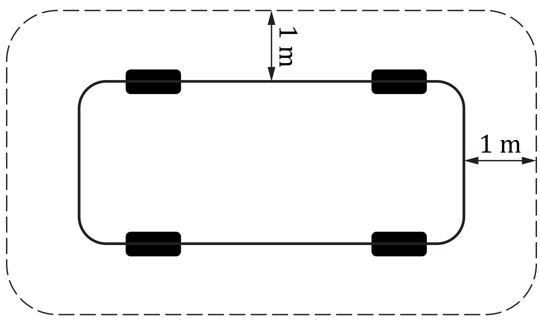


Figure 5 — Clearance space around vehicle

NOTE 1 Not all vehicles have these components located in the front.

The charging phase shall be executed with the following start conditions:

— any value of remaining electric range ≥ 15 km and ≤ 60 km and an indicated SOC ≤ 9 %, or

— an indicated SOC ≤ 9 % and a remaining electric range of < 15 km, in case a remaining electric range of 15 km corresponds to an indicated SOC > 9 %.

The starting condition of the remaining electric range ≥ 15 km and ≤ 60 km shall be set according to one of the following options:

a) Any remaining electric range ≥ 15 km and ≤ 60 km is indicated.

NOTE 2 The electric remaining range refers to the combined consumption, which is not impacted by previous drive cycles.

b) The indicated SOC corresponds to a remaining electric range of ≥ 15 km and ≤ 60 km. The remaining electric range and indicated SOC shall be calculated using the DBE and indicated SOC as synchronously recorded during the ADT [see 6.2.5 a) 1)]. The following principles apply:

— when the DBE of the indicated SOC point "0 %" equals more than 60 km of range, the charging phase shall start with an indicated SOC of 1 %;

— when the DBE of one indicated SOC point other than "0 %" completely covers the remaining electric range of ≥ 15 km and ≤ 60 km, the charging phase shall start with this indicated SOC;

EXAMPLE 1 When 2,3 % indicated SOC equals 15 km of remaining electric range and 2,9 % indicated SOC equals 60 km of remaining electric range, the charging phase starts with an indicated SOC of 2 %.

— when the indicated SOC changes once within the remaining electric range equivalent ≥ 15 km and ≤ 60 km, the charging phase shall start with the indicated SOC point with the larger share of the window. When the shares of both indicated SOC points are equal (rounded to one decimal place), both may be used;

EXAMPLE 2 When 1,8 % indicated SOC equals 15 km of remaining electric range and 2,4 % indicated SOC equals 60 km of remaining electric range, the charging phase starts with an indicated SOC of 2 %.

— when the indicated SOC changes two or more times within the remaining electric range equivalent ≥ 15 km and ≤ 60 km, the charging phase shall start with any of the indicated SOC points that falls completely inside the remaining electric range equivalent ≥ 15 km and ≤ 60 km.

EXAMPLE 3 When 1,7 % indicated SOC equals 15 km of remaining electric range and 6,3 % indicated SOC equals 60 km of remaining electric range, the charging phase starts with an indicated SOC of 2 %, 3 %, 4 % or 5 %.

The charging phase shall be executed by applying the specifications of the manufacturer according to 6.2.1.

The charging phase shall not be executed at ambient temperatures that significantly impact the measurement. During the charging phase, the ambient temperature shall be within 0 °C to 30 °C. An ambient temperature of 23 °C ± 3 °C is recommended.

The recharged electric range shall be calculated according to 6.2.5 after t_{ref} of 10 min. At the discretion of the vehicle manufacturer, additional durations may be reported with the following guidance:

— t_{ref} of 5 min and 20 min are recommended;

— t_{ref} shall be ≥ 5 min;

— all recharged electric ranges, including that for the required 10 min duration, shall be measured from the same test.

EXAMPLE 4 A recharged electric range for 5 min is desired. A charging test is run for a minimum of 10 min and the calculation according from Formula (1) is performed twice, once for a t_{ref} = 5 min and again for t_{ref} = 10 min.

In addition, and from the same test, the charging duration shall be measured from when the indicated SOC changes to 10 % until the indicated SOC changes to 80 %. The resulting value shall only be valid when the DBE for this indicated SOC interval (see 6.2.5) corresponds to at least 69 % of the UBE of the RESS according to the ADT.

The time measured shall be rounded up to the next 1 min interval.

EXAMPLE 5 For a measured time of 20 min 16 s, the test result is 21 min.

6.3.2.6 Charging efficiency and charging power for Fast Charge

In addition to the charging duration and the recharged electric range(s), the charging efficiency and the maximum charging power shall be determined for Fast Charge.

During the determination of the charging duration according to 6.3.2.5, the charging efficiency shall be determined according to 6.2.6 and charging power shall be determined according to 6.2.7.

7 Vehicle operator information

The test procedures have been developed to enable the comparison of the charging performance of different EVs and to reproduce the achieved results. Table 3 gives an overview for illustration purposes.

Table 3 — Overview of results of test procedures given in this document

Test procedure	Charging duration	Charging efficiency	Max. charging power	Recharged electric range
Normal Charge (full charge)	xx h xx min	xx, x %	xx, x kW	xxx km after 60 min
Fast Charge (10 % to 80 %)	xx h xx min	xx, x %	xxx kW	xxx km after 10 min

NOTE 1 Charging efficiency and maximum charging power are determined during the charging duration.

NOTE 2 Losses of the EVSE are not included for DC charging.

The terms for the test cases, including the additional information in brackets, should be given in the vehicle operator information as expressed in Table 3. If optimizing features that are directly or indirectly activated by the vehicle operator are applied, the vehicle manufacturer shall indicate this for each test result.

EXAMPLE Battery thermal preconditioning functions, or specific charging modes directly activated in the user interface. Battery thermal preconditioning functions indirectly activated by navigation systems.

Annex A
(informative)

Fast Charge at low ambient temperature

A.1 General

Low ambient temperatures can have a significant impact on the charging performance of an EV. Due to several physical and procedural effects, the test procedures given in Clause 6 cannot simply be executed at lower ambient temperatures without further adaptations.

At the time of publication of this document, little experience with the effects of low ambient temperature on the charging behaviour was available. For this reason, the low ambient temperature test procedure is described in this annex and is not part of the main body of the document.

A.2 Options for low ambient temperature test procedure

The overall test consists of two separate test procedures: one at low ambient temperature (−7 °C ± 3 °C) and one at normal ambient temperature (23 °C ± 3 °C). The result of the test is the calculated ratio of the charging durations of the charging phases in the two test procedures.

There are two equivalent options to execute the test. An overview of these options is given in Figure A.1. Both options have in common the initial adjustment of the indicated SOC, the soaking phase and the charging phase but differ in the phase before the charging phase. As indicated in Figure A.1, that preparation phase shall be executed the same way in the test procedure at low ambient temperature and at normal ambient temperature, by either:

— continuing the soaking phase and applying optimizing features, or

— executing a drive cycle.

Details on the dedicated phases of the test procedure and for relocations in between are given in A.3.

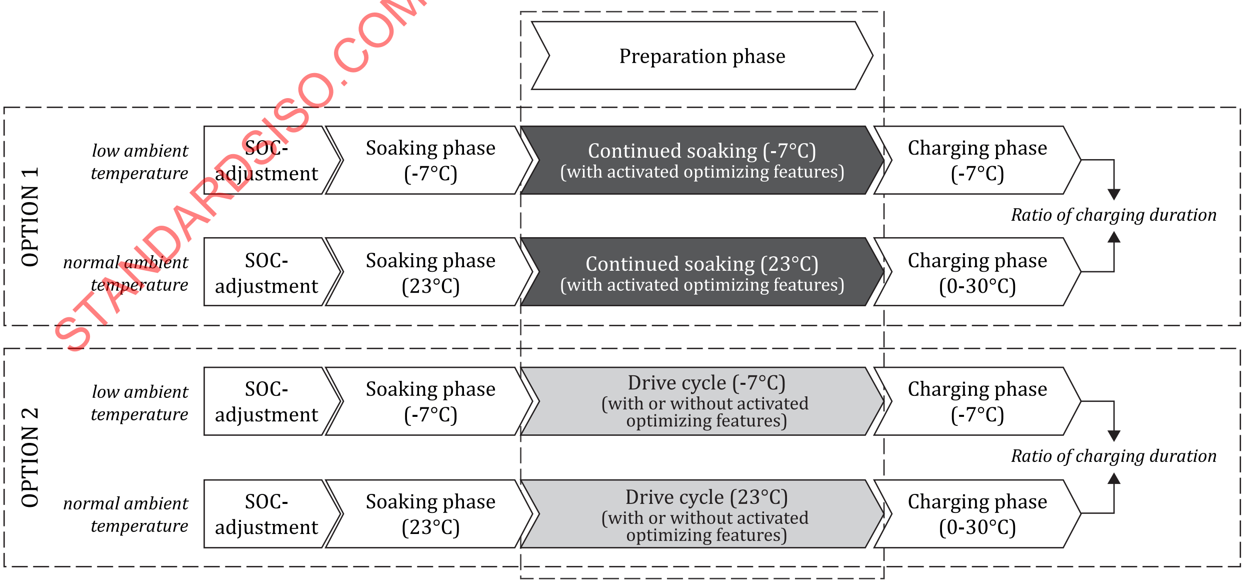


Figure A.1 — Options for low ambient temperature test procedure

A.3 Process phases of low ambient test procedure

A.3.1 Relocations

A.3.1.1 General

The EV may be relocated between the phases of the test procedure, e.g. to a chassis dynamometer or a soaking area. For a relocation between SOC-adjustment and the soaking phase, no specific requirements apply.

For relocations between the other phases of the procedure, the following applies:

— the vehicle shall be passively moved and shall not be actively driven or actively charged or discharged;

— optimizing features shall not be activated during relocations. If they cannot be deactivated, relocations are not permitted;

— relocations shall be undertaken as quickly as possible, without any unjustified delay.

As relocations are specified to not impact the result of the test, relocations at normal ambient temperatures may be different from relocations at low ambient temperatures during the test procedure.

EXAMPLE The vehicle is relocated after the drive cycle at −7 °C, but is not relocated after the drive cycle at 23 °C.

A.3.1.2 Relocations in normal ambient temperature test procedure

Relocations during the normal ambient temperature test procedure shall be limited in time to a maximum of 30 min. For EVs with a UBE of the RESS > 25 kWh according to ADT, relocations shall be undertaken as quickly as possible, without any unjustified delay for a maximum of 45 min. Thus, the following phase shall not start later than 30 min for RESS ≤ 25 kWh, or 45 min for RESS > 25 kWh, after the end of the phase before the relocation.

The ambient temperature during relocations shall be between 0 °C and 30 °C.

A.3.1.3 Relocations in low ambient temperature test procedure

If the vehicle is exposed to an ambient temperature higher than −4 °C during the transfer from the soak area to the test cell:

— the transfer shall be undertaken as quickly as possible, without any unjustified delay;

— the transfer shall be no longer than 20 min;

— the vehicle shall be restabilised by holding it at an ambient temperature of −7 °C ± 3 °C for at least six times as long as the vehicle was exposed to the ambient temperature higher than −4 °C.

A.3.2 Adjustment of indicated SOC

The goal of this phase is to set the same DBE at the beginning of the soaking phase in both test procedures (low ambient temperature and normal ambient temperature). Therefore, the following phases shall be executed:

1) The indicated SOC shall be set to 10 % ± 5 %. How this indicated SOC is reached is up to the discretion of the manufacturer and may vary between the low ambient temperature and the normal ambient temperature test procedure.

2) The vehicle shall be soaked for a minimum of 12 h. The soak area shall have a temperature set point between 10 °C and 30 °C. The tolerance of the actual value shall be within ±3 °C on a 5 min running arithmetic average and shall not show a systematic deviation from the set point. The temperature set point shall be the same for the test procedure at low ambient temperature and at normal ambient temperature.

EXAMPLE When the temperature set point in the test procedure at low ambient temperature is 25 °C the temperature set point in the test procedure at normal ambient temperature is also 25 °C.

The temperature of the EV, especially the RESS, should be achieved in a homogeneous manner.

3) The RESS shall be charged until the indicated SOC changes to 25 %, with a maximum charge rate of 0,5 C. The charging power applied shall be constant and shall deviate by a maximum of 1 kW between the test procedure at low ambient temperature and at normal ambient temperature. This charging phase shall be executed at a temperature set point between 10 °C and 30 °C. The tolerance of the actual value shall be within ±3 °C on a 5 min running arithmetic average and shall not show a systematic deviation from the set point. The temperature set point shall be the same for the test procedure at low ambient temperature and at normal ambient temperature.

A.3.3 Soaking phase

The vehicle shall be soaked for a minimum of 12 h.

The soak area shall have a temperature set point of 23 °C or −7 °C respectively. The tolerance of the actual value shall be within ±3 °C on a 5 min running arithmetic average and shall not show a systematic deviation from the set point.

The temperature of the EV, especially the RESS, should be achieved in a homogeneous manner.

NOTE The soaking phase can take significantly longer at −7 °C than at 23 °C.

Optimizing features shall not be activated during the soaking phase.

A.3.4 Preparation phase (optional)

A.3.4.1 Option 1: Continued soaking phase

In this option, the soaking phase according to A.3.3 may be extended for a maximum of 30 min. The duration of the extension shall be the same in both test procedures (at low ambient temperature and normal ambient temperature) with a tolerance of ±1 min.

Optimizing features may be activated for the duration of this continued soaking phase. Optimizing features shall either:

— be activated during both, the normal ambient temperature test procedure and the low ambient temperature test procedure, or

— be deactivated during both, the normal ambient temperature test procedure and the low ambient temperature test procedure.

The time the optimizing features are activated may include a time these optimizing features are not running, e.g. because the target conditions are already reached.

A.3.4.2 Option 2: Drive cycle

The EV shall be operated within a speed range of 25 km/h to 30 km/h run for a maximum of 30 min. The drive cycle and the duration of the drive cycle shall be the same in both test procedures (at low ambient temperature and normal ambient temperature).

The ambient temperature during the drive cycle shall be 23 °C or −7 °C respectively. The tolerance of the actual value shall be within ±3 °C on a 5 min running arithmetic average and shall not show a systematic deviation from the set point.

Optimizing features may be activated during this drive cycle. Optimizing features shall either:

— be activated during both, the normal ambient temperature test procedure and the low ambient temperature test procedure, or

— be deactivated during both, the normal ambient temperature test procedure and the low ambient temperature test procedure.

A.3.5 Charging phase

The charging phase shall be executed by applying the specifications of the manufacturer according to 6.2.1.

During the normal ambient temperature test procedure, the charging phase shall not be executed at ambient temperatures that significantly impact the measurement. During the charging phase, an ambient temperature of 23 °C ± 3 °C is recommended, and the ambient temperature shall be within 0 °C to 30 °C.

During the low ambient temperature test procedure, the ambient temperature shall be ≤ −4 °C.

In both test procedures, the charging duration shall be measured from when the charging current exceeds 1 A until the indicated SOC changes to 80 %. The time measured shall be rounded up to the next 1 min interval.

For AC charging, the charging current shall be measured at MP1 (see Figure 4) or at MP2 (see Figure 4).

For DC charging, the charging current shall be measured at MP2 (see Figure 4).

For wireless charging, the charging current shall be measured at MP1 (see Figure 4).

If the vehicle has different settings for the charging power, the setting that is optimized for the shortest charging duration to achieve an indicated SOC of 80 % at 23 °C shall be applied in both test procedures.

NOTE The conditions of this test make it impossible to reuse the results for charge duration determined in 6.3.2.5. Also, the optimized setting can be different.

A.3.6 Determination of ratio

The test result is calculated as the ratio between the charging durations of the two test procedures according to Formula (A.1).

$$R_{\text{cold}} = \frac{t_{\text{cold}}}{t_{\text{normal}}} \tag{A.1}$$

where

R_{cold} is the low ambient temperature charging duration ratio;

t_{cold} is the charging duration at low ambient temperature, expressed in minutes;

t_{normal} is the charging duration at normal ambient temperature, expressed in minutes.

The ratio calculated according to Formula (A.1) shall be rounded to 1 decimal place.