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Edition 2.0 2018-02

TECHNICAL SPECIFICATION

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Recommendations for renewable energy and hybrid systems for rural electrification –
Part 8-1: Selection of batteries and battery management systems for stand-alone electrification systems – Specific case of automotive flooded lead-acid batteries available in developing countries

IEC TS 62257-8-1:2018-02(en)

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Recommendations for renewable energy and hybrid systems for rural electrification –
Part 8-1: Selection of batteries and battery management systems for stand-alone electrification systems – Specific case of automotive flooded lead-acid batteries available in developing countries

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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Part 8-1: Selection of batteries and battery management systems for stand-alone electrification systems – Specific case of automotive flooded lead-acid batteries available in developing countries

FOREWORD

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- the required support cannot be obtained for the publication of an International Standard, despite repeated efforts, or
- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC 62257-8-1, which is a technical specification, has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

This second edition cancels and replaces the first edition published in 2007. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) increase of the applicable voltage levels and removal of the 100 kW power limit;
b) removal of the word "small" from the description of these systems.

This technical specification is to be used in conjunction with the future parts of this series as and when they are published.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
82/1330/DTS	82/1384/RVDTS

Full information on the voting for the approval of this technical specification can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the IEC 62257 series, under the general title: *Recommendations for renewable energy and hybrid systems for rural electrification,* can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

The IEC 62257 series of documents intends to provide to different players involved in rural electrification projects (such as project implementers, project contractors, project supervisors, installers) with documents for the setting up of renewable energy and hybrid systems with AC voltage below 1 000 V and DC voltage below 1 500 V.

These documents are recommendations:

- to choose the right system for the right place;
- to design the system;
- to operate and maintain the system.

These documents are focused only on rural electrification concentrating on, but not specific to, developing countries. They are not considered as all-inclusive to rural electrification. The documents try to promote the use of renewable energies in rural electrification; they do not deal with clean mechanisms developments at this time (CO_2 emissions, carbon credit, etc.). Further developments in this field could be introduced in future steps.

This consistent set of documents is best considered as a whole with different parts corresponding to items for safety, sustainability of systems and at the lowest life cycle cost possible. One of the main objectives is to provide the minimum sufficient requirements relevant to the field of application that is: small renewable energy and hybrid off-grid systems.

For rural electrification projects using PV systems, it is recommended to use solar batteries defined in IEC 61427.

Nevertheless in many situations, it is a fact that most of the rural electrification projects are implemented using locally made automotive flooded lead-acid batteries. But these products are not designed for photovoltaic systems applications. There is presently no test to discriminate, in a panel of models of such batteries, which one could provide the best service as close as possible to the requirement of the general specification as a storage application for small PV individual electrification systems (see IEC TS 62257-2) in an economically viable way.

The purpose of IEC TS 62257-8-1 is to propose tests for automotive lead-acid batteries and battery management systems used in small PV individual electrification systems.

RECOMMENDATIONS FOR RENEWABLE ENERGY AND HYBRID SYSTEMS FOR RURAL ELECTRIFICATION –

Part 8-1: Selection of batteries and battery management systems for stand-alone electrification systems – Specific case of automotive flooded lead-acid batteries available in developing countries

1 Scope

This part of IEC 62257 proposes simple, cheap, comparative tests in order to discriminate easily, in a panel of automotive flooded lead-acid batteries, the most acceptable model for PV individual electrification systems.

It could be particularly useful for project implementers to test in laboratories of developing countries, the capability of locally made car or truck batteries to be used for their project.

Furthermore, battery-testing specifications usually need test equipment that is too costly and too sophisticated to be applied in developing countries' laboratories.

The tests provided in this document allow assessment of the batteries' performances according to the general specification of the project (see IEC TS 62257-2) and batteries associated with their battery management system (BMS) in a short time and with common technical means. They can be performed locally, as close as possible to the operating conditions of the real site.

The document provides also regulations and installation conditions to be complied with in order to ensure the life and proper operation of the installations as well as the safety of people living in proximity to the installation.

This document is not a type approval standard. It is a technical specification to be used as guidelines and does not replace any existing IEC standard on batteries.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-482:2004, *International Electrotechnical Vocabulary – Part 482: Primary and secondary cells and* batteries
IEC 60050-482:2004/AMD1:2016

IEC TS 62257-6, *Recommendations for renewable energy and hybrid systems for rural electrification – Part 6: Acceptance, operation, maintenance and replacement*

3 Terms and definitions

For the purposes of this document, the terms and definitions for secondary cells and batteries given in IEC 60050-482 and the following apply.

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

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
secondary cell
cell that is designed to be electrically recharged

Note 1 to entry: The recharge is accomplished by way of a reversible chemical reaction.

[SOURCE: IEC 60050-482:2004, 482-01-03]

3.2
storage battery
secondary battery
two or more secondary cells connected together and used as a source of electric energy

3.3
lead-acid battery
storage battery in which the electrodes are made mainly from lead and the electrolyte is a sulphuric acid solution

3.4
terminal
pole
conductive part provided for the connection of a cell or battery to external conductors

3.5
density
commonly considered as the volumic mass, in kg/dm^3

Note 1 to entry: Density is also defined as a dimensionless magnitude expressing the ratio of the electrolyte mass to the water mass occupying the same volume at 4 °C.

3.6
electrolyte
liquid or solid substance containing mobile ions that render it ionically conductive

Note 1 to entry: The electrolyte may be liquid, solid or a gel.

[SOURCE: IEC 60050-482:2004, 482-02-29]

3.7
dry charged battery
state of delivery of some types of secondary battery where the cells contain no electrolyte and the plates are dry and in a charged state

[SOURCE: IEC 60050-482:2004, 482-05-30]

3.8
self-discharge
phenomenon by which a cell or battery loses energy in other ways than by discharge into and external circuit

[SOURCE: IEC 60050-482:2004, 482-03-27]

3.9
nominal capacity
suitable approximate quantity of electricity, used to identify the capacity of a cell or a battery

Note 1 to entry: This value is usually expressed in ampere-hours (Ah).

3.10
rated capacity
<of a cell or a battery> quantity of electricity, declared by the manufacturer, that a cell or a battery can deliver under specified conditions after a full charge

Note 1 to entry: The rated capacity shown on the battery label is given for a discharge period, which depends on the technology used in the battery.

Note 2 to entry: The capacity of a battery is higher when it is discharged slowly. For example, variations are in the order of 10 % to 20 % between a capacity measured over 5 h and a capacity measured over 100 h.

3.11
ambient temperature
temperature of the medium in the immediate vicinity of a battery

3.12
initial charge
commissioning charge given to a new battery to bring it to the fully charged state

3.13
cycling
<of a cell or battery> set of operations that is carried out on a secondary cell or battery and is repeated regularly in the same sequence

Note 1 to entry: In a secondary battery these operations may consist of a sequence of a discharge followed by a charge of a charge followed by a discharge under specified conditions. This sequence may include rest periods.

[SOURCE: IEC 60050-482:2004, 482-05-28]

4 Batteries and battery management system selection

4.1 Battery technical characteristics

4.1.1 Battery cases

Battery cases shall be made of suitable materials capable of withstanding impacts and shocks and resistant to acid.

4.1.2 Battery terminals

Terminals shall be protected against accidental short circuits. Positive and negative polarities shall be identified.

4.1.3 Electrolyte

The electrolyte for lead acid batteries is prepared from special sulphuric acid for storage batteries. It shall be colourless, odourless and free of all insoluble material deposits. As there is no standard for such an electrolyte, impurity levels shall follow the battery manufacturer's requirements.

The electrolyte level checking interval varies depending on:

- the type of battery;
- the temperature;

- the use;
- the regulation algorithms of the charge controller;
- the battery's age;
- the quality of the distilled water;
- the PV resource.

The service interval would be determined from the above parameters and the electrolyte reservoir size, which is a specification of the specific battery used. Care should be used to ensure that the service interval is within the capability of the maintenance organization.

The batteries shall be designed so that electrolyte levels are able to be checked and so that distilled water can be added.

NOTE 1 Faradic water consumption for vented batteries:

When a battery reaches its fully charged state, water electrolysis occurs according to Faraday's law.

Under standard conditions:

1 Ah decomposes H_2O into 0,42 dm^3 H_2 + 0,21 dm^3 O_2.

Decomposition of 1 cm^3 (1 g) H_2O requires 3 Ah.

An estimation of water consumption of a battery is given by:

Battery H_2O (g) consumption = (X Ah charged – Y Ah discharged) × number of cells in battery / 3.

NOTE 2 The number of cells for a 12 V lead acid battery is 6.

4.2 Comparative tests

4.2.1 General

The proposed comparative tests are designed to discriminate the most appropriate batteries taking into consideration the techno-economic context of the project.

These comparative tests include a sequence of three tests as indicated in Table 1.

IMPORTANT: all the batteries shall be tested simultaneously in order to ensure that they are tested in the same conditions (insulation, temperature, etc.).

Table 1 – Testing procedure

Test 1: the most durable batteries are first selected with a **battery endurance test** **See 4.2.3**	**Test 2:** the couple **battery-BMS** is selected with another **endurance test** **See 4.2.4**
	Test 3: in parallel to test 2, the selected batteries are subjected to a **storability test** **See 4.2.5**

The installation rules for batteries provided in Clause 6 are also applicable to test installations.

4.2.2 Evaluation of the charge and discharge current for testing (I_{test})

Automotive lead acid batteries are typically rated at C_{20}.

The proposed test uses a C_{10} I_{test}. The C_{10} capacity of any battery can be obtained from its manufacturer.

If not, Table 2 gives an assessment of the C_{10} I_{test} value for a 100 Ah C_{20} battery.

Table 2 – Evaluation of charge and discharge current (I_{test})

Nominal C_{20} capacity Ah	Evaluation of C_{10} capacity Ah	Value of I_{test} (C_{10} × 0,1) A
100	87	8,7

For another nominal capacity, I_{test} varies proportionally to the nominal capacity and is intended to be equivalent to a nominal C_{10} value.

4.2.3 Test 1: battery endurance test

4.2.3.1 General

This test aims to compare the capability of the batteries to maintain their first observed capacity.

NOTE This test is dedicated to batteries for PV systems. But a battery that performs best in this test is likely to perform best in other applications (such as wind systems, pico hydro systems) when compared to other batteries of similar types.

For each type of battery, the test is performed by subjecting 3 samples to a 2-phase procedure. The test is carried out at ambient temperature. All the samples shall be tested simultaneously.

The test is proposed for 12 V batteries.

For 24 V batteries, voltage thresholds shall be multiplied by 2.

Charge voltage limitations are given for an ambient temperature of 20 °C. The rule proposed to calculate the voltage limitation in accordance with the variation of the temperature is as follows:

For an ambient temperature different from 20 °C, voltage limitation shall be set according to: −21 mV/°C for a 12 V lead-acid bloc. Voltage limitation threshold is calculated according to the usual average value of the local ambient temperature of the season when the test is performed.

Some examples of the application of this rule are given in Table 3.

Table 3 – Voltage regulation variation with temperature (examples)

Ambient temperature °C	Voltage regulation variation/value at 20 °C	Voltage regulation V
15	−0,021 V/°C × [15 °C – 20 °C] = +0,11 V	14,51
20		14,40
35	−0,021 V/°C × [35 °C – 20 °C] = −0,31 V	14,09

4.2.3.2 Test 1 procedure

4.2.3.2.1 General

The endurance test simulates the use of a battery in a photovoltaic system. The charge and discharge are based on one cycle per day, i.e. 12 h charge and 12 h discharge. This kind of cycle is as close as possible to the field conditions.

The test is performed as presented in Figure 1.

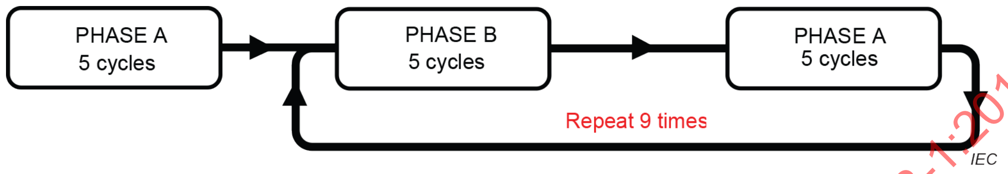

Figure 1 – Test 1 phases

Phase A is a discharge/charge cycle including an additional charge ensuring that the battery is on a high state of charge (see 4.2.3.2.2).

Phase B does not include this additional charge (see 4.2.3.2.3).

The initial Phase A is performed to prepare the batteries. This assesses the initial observed capacity of the batteries and ensures that the test is performed with batteries on a high state of charge.

The sequence of Phase A and Phase B intends to reproduce the operating mode of the battery simulating a sequence of charges and discharges with or without an overcharge period.

After the preparation of the battery, a series of Phase B + Phase A is performed 9 times (as shown in Figure 1).

During each discharge, observed capacity is assessed as explained in 4.2.3.2.2.4.

After each Phase A an average observed capacity is calculated.

When the complete test 1 process is finished, 10 values of observed capacity are available. Interpretation of results is given in 4.2.3.4.

A curve showing the change in capacity during the complete testing period could be used to understand differences between different battery models and the variability of performance of batteries of the same model.

After 90 cycles, this test will show the relative performance of the different batteries being considered.

4.2.3.2.2 Phase A

4.2.3.2.2.1 General

Phase A cycle is performed 5 times as presented in Figure 2.

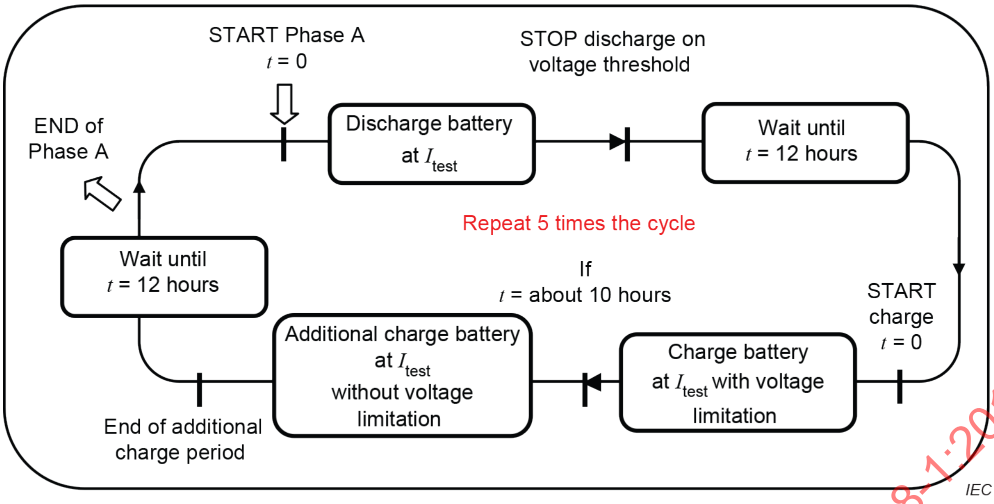

Figure 2 – Phase A battery endurance test

4.2.3.2.2.2 Operating procedure

- Discharge the battery at I_{test} to 10,8 V (± 0,1 V).
- Wait 12 h from the beginning of the discharge before starting the charge.
- Charge with an initial current equal to I_{test} during 10 h with a voltage limitation set at 14,1 V (± 0,1 V).
- Charge (additional charge), with no voltage limitation, during 2 h at I_{test}.
- Wait 12 h from the beginning of the charge before starting the next discharge.

4.2.3.2.2.3 Measurement of the Ah discharged

For each discharge:

- Measure the duration of the discharge t_d (from the start of discharge until the stop of the discharge at the low-voltage threshold).
- Calculate the Ah discharged: $C = I_{test}$ (A) × t_d (h).

4.2.3.2.2.4 Assessment of the observed capacity of each battery during Phases A

- Record the Ah discharged during each of the 5 cycles of a Phase A.
- Calculate the average value of the 5 records. This average value is taken as the observed capacity of the battery.

NOTE If one of the recorded values differs from the average value by more than 20 %, this value is excluded from the panel and the average is re-calculated on the remaining values. It could occur, for example, if there is a shut off of the charging device or of the grid.

4.2.3.2.2.5 Assessment of the initial observed capacity of each battery

For the assessment of the initial observed capacity of the battery, the average value is calculated only on the 4 last records, each of which shall be not less than −20 % of the average value.

If one or more batteries is not able to provide 4 records within the 20 % limit during the 5 first cycles, additional cycles shall be performed for all the samples of all the models, limited to a total of 10 cycles.

At the end of the initial Phase A, limited to a maximum of 10 cycles, at least two samples of the same model shall allow the calculation of the initial observed capacity. If not, the model shall be rejected.

4.2.3.2.3 Phase B

4.2.3.2.3.1 General

Phase B cycle is performed 5 times as presented in Figure 3.

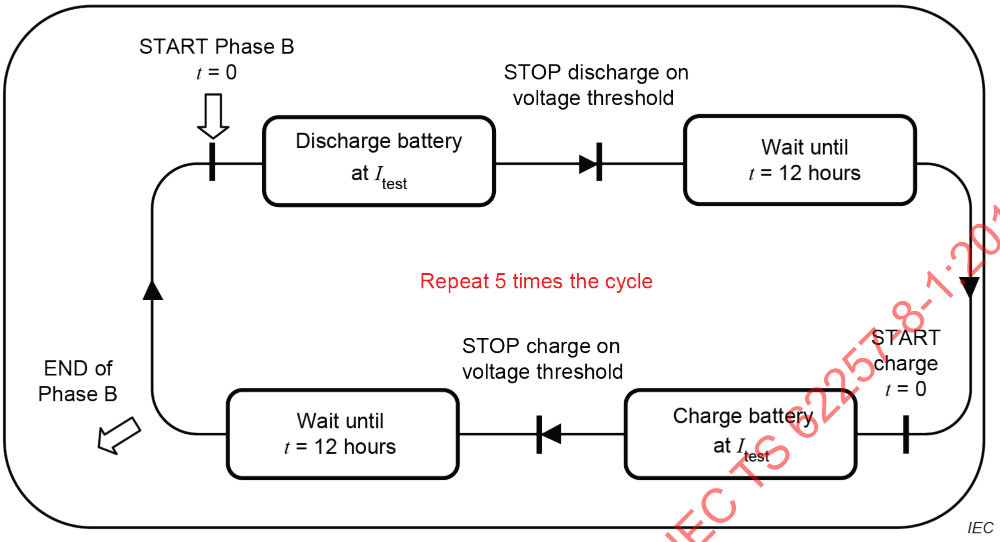

Figure 3 – Phase B battery endurance test

4.2.3.2.3.2 Operating procedure

- Discharge the battery at I_{test} to 10,8 V (± 0,1 V).
- Wait 12 h from the beginning of the discharge before starting the charge.
- Charge the battery at I_{test} to a voltage threshold of 14,1 V (± 0,1 V).
- Wait 12 h from the beginning of the charge before starting the discharge.

4.2.3.3 Test 1 equipment

To perform test 1, the equipment needed is:

- A time measurement device (clock/ watch) providing an alarm every 12 h.
- A current-generating device able to provide a stable I_{test} current (± 0,05 A) including an automatic switch-off at predetermined voltage thresholds and complying with the requirements of the relevant IEC standard concerning the ripple current rate.
- A resistive load allowing the discharge of the batteries; determine the required resistance based on 12 V and the I_{test} current (± 0,05 A).
- An ammeter and a voltmeter.

All the batteries shall be tested with the same equipment of the same class.

4.2.3.4 Interpreting the results of test 1: battery selection

Three criteria shall be used:

– remaining average observed capacity at the end of the test;
– capacity variation within the same model samples;
– capacity variation with different models.

Models of batteries not having at least two samples having a remaining observed capacity of 70 % or more of the initial observed capacity should be avoided.

Models of batteries with large variations (more than 20 %) in observed capacity within the samples should be avoided.

The battery model with the smallest change in observed capacity over the test period is likely to be more durable.

The previous 3 criteria are technical criteria and have to be considered with economic criteria to complete the choice of the battery model.

4.2.3.5 Assumption of the water consumption

The weight of each battery is measured at the beginning and after 30, 60 and 90 cycles in order to assess the water consumption. The water is added after the weight measurement.

Another way is to check the level of the electrolyte: the level can be assessed by using a small floating device equipped with a graduated gauge. The initial level is recorded and for each top-up of the battery. The quantity of distilled water needed to retrieve the initial level is measured.

When not used, floating devices should be stored in an electrolyte-resistant container.

4.2.4 Test 2: endurance test for battery and BMS

4.2.4.1 General

This test 2 simulates the use of the whole battery and BMS combination in a photovoltaic system and determines the compatibility between the battery and the battery management system (BMS), which is a critical point to extend battery lifetime. The main requirements for battery management systems are appropriate battery protection and sufficient energy delivery to the users.

The recommendations for a good battery management system are:

– adequately sized to withstand high currents provided by PV array;
– easy to use (installation, information for the user);
– having a low self-consumption (< 15 mA under 12 V).

For each type of BMS, the test is performed by subjecting two batteries and BMS combinations to a 3-phase procedure.

Test 2 is performed with new samples of models of batteries that have successfully passed Test 1.

Test 2 is performed by subjecting two samples of each combination of model of BMS + model of battery. The number of combinations to be tested is determined by the project developer/implementer according to the size of the project and the cost of the testing.

Test 2 shall be performed according to the following formula:

$$(\text{Number of models of BMS} \times \text{Number of models of selected batteries}) \times 2$$

For example, if 2 models of batteries were selected after Test 1, and 2 models of BMS are pre-selected, 8 lots of Test 2 shall be performed.

For economic reasons, it is sensible neither to select more than two models of batteries after test 1 nor to test them in test 2 with more than two models of BMS.

4.2.4.2 Test 2 procedure

4.2.4.2.1 General

The test is conducted at ambient temperature and performed as shown in Figure 4.

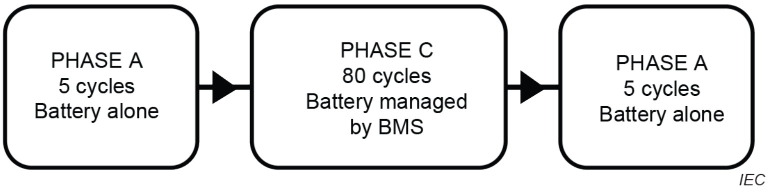

Figure 4 – Test 2 phases

For Phase A, see 4.2.3.2.2.

For Phase C, see 4.2.4.2.2.

The complete test 2 shown in Figure 4 corresponds to 90 discharge/charge cycles for the battery.

The water consumption is assessed according to 4.2.3.5.

4.2.4.2.2 Phase C

4.2.4.2.2.1 General

Phase C cycle is performed 80 times as presented in Figure 5.

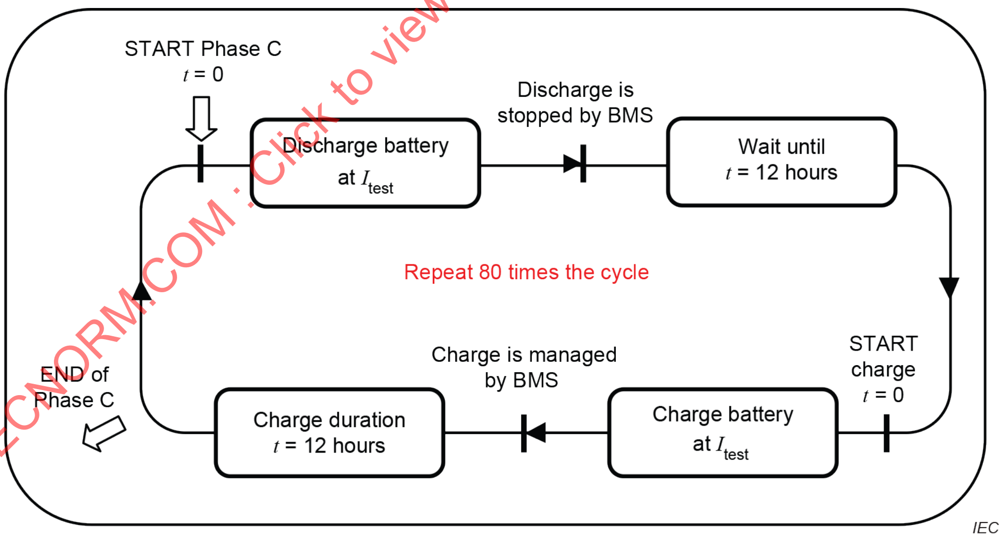

Figure 5 – Phase C battery – BMS endurance test

4.2.4.2.2.2 Operating procedure

- Discharge the battery at I_{test} up to the load disconnection managed by BMS.
- Wait 12 h from the beginning of the discharge before starting the next charge.
- Charge the battery at I_{test} to the end of charge managed by BMS.
- Wait 12 h from the beginning of the charge before starting the next discharge.

The duration of charge and discharge shall be recorded.

4.2.4.3 Interpreting the results of test 2

The observed capacity of the batteries is assessed as the average value of the five discharged capacities measured in each Phase A. Then these two values are compared to assess the loss of capacity of the battery over the test period.

The BMS selection is based first on the performance of battery after 90 cycles: the battery shall not have a capacity under 70 % of the initial observed capacity.

Then the purchaser could select the association (battery + BMS) regarding energy delivered by the system to the user, water consumption, and cost.

4.2.5 Test 3: Battery storability test

4.2.5.1 General

A fully charged battery in storage, even with no connected load circuit, discharges spontaneously. This slow discharge is called self-discharge. It should be as low as possible. When the batteries are stored full of electrolyte, it is best that their charge state remains close to the charged state.

This test is dedicated to assess the capability of batteries to recover their initial capacity after a storage period without any charge or discharge. The aim is not to measure a loss of capacity during the storage period, but the ability of the battery to recover the initial performances. In the field, batteries are never fully charged before the storage period.

NOTE 1 This test is not relevant for dry charged batteries.

NOTE 2 For temperature having a high impact on the performances of the batteries, it is all the more important for this particular test that all the samples be tested simultaneously, in the same temperature conditions.

4.2.5.2 Test 3 procedure

4.2.5.2.1 General

This test could be performed simultaneously with test 2 described above.

For example, the current sources could be used to perform the initial Phase D on batteries subjected to test 3 and then be used on the batteries subjected to test 2 as the batteries subjected to test 3 have to rest for 3 months (no current source needed).

The test 3 is performed according to Figure 6.

Figure 6 – Test 3 phases

4.2.5.2.2 Phase D

4.2.5.2.2.1 General

Phase D cycle is performed as presented in Figure 7.

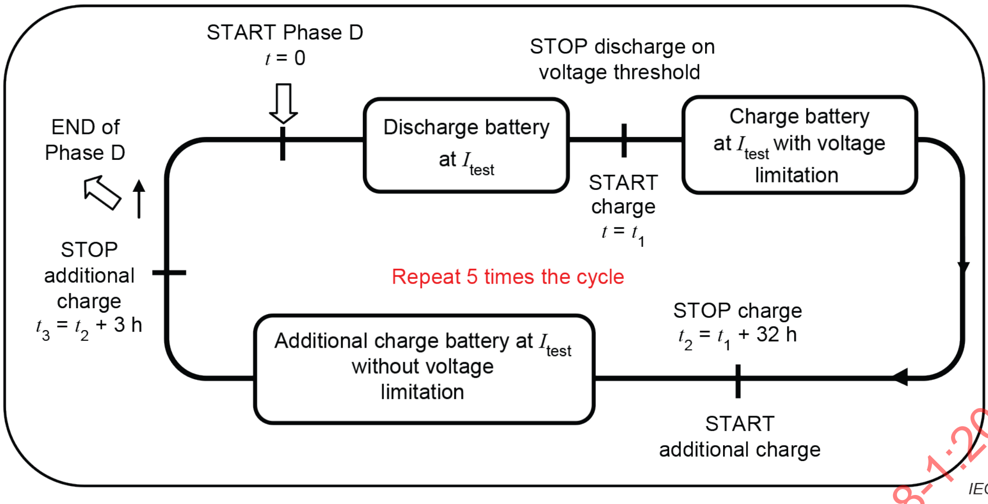

Figure 7 – Phase D storability test

4.2.5.2.2.2 Operating procedure

- Discharge the battery at I_{test} to 10,8 V (± 0,1 V).
- Charge the battery at I_{test} with 14,1 V (± 0,1 V) voltage limitation during the first 32 h.
- Charge 3 h at I_{test} with no voltage limitation.

4.2.5.2.3 Storage period

The storage period is 3 months.

The storage period conditions shall be as close as possible as they will be in the field conditions of the project.

4.2.5.3 Interpreting the results of test 3

The observed capacity is measured for Phases D as explained for Phases A in 4.2.3.2.2.4.

The capacity loss is assessed by comparison between the capacity measured at the end of the first Phase D and the capacity measured at the end of the second Phase D.

The storage battery shall be able to withstand storage for 3 months with no irreversible alteration to the initial characteristics (voltage, capacity) after completion of test 3.

The selected batteries after the test are those that have the best ability to recover their initial performances.

5 Documentation

The battery documentation shall include the following information:

- rated capacity of the battery and rated capacity at C_{10} (if available);
- nominal battery voltage;
- electrolyte density required for filling;
- maximum storage duration from manufacturing date;
- manufacturing date;
- return address of spent batteries;

- procedures for installation, initial charge and maintenance;
- recommended charging strategies (values of end of charge/discharge voltage, overcharge voltage).

6 Installation rules

6.1 Packing and shipping

The batteries shall be supplied charged or dry charged with the appropriate container of electrolyte.

All measures shall be taken by the supplier for the batteries to reach their destination in perfect condition.

Batteries for stand-alone electrification systems will possibly experience abusive conditions of transport and storage. This shall be recognized and appropriate measures to minimize damages shall be implemented.

Battery electrolyte is harmful. Electrolyte spillage shall be prevented by marking on the shipping container as illustrated by the following Figure 8 and by appropriate packaging.

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Figure 8 – Marking for spillage prevention

Apart from the recipient's address and the usual markings for fragile and dangerous equipment, each packaging shall bear the following markings in indelible letters:

- supplier's name;
- product reference;
- label to indicate chemical hazards, national or international dangerous labelling code;
- handling/storage instructions.

6.2 Environment

Temperature has a high impact on the batteries' performances.

Appropriate measures shall be implemented to operate batteries at their optimum appropriate range: +5 °C, +35 °C:

- high temperature accelerates ageing so it is recommended to implement technical means able to protect batteries from direct irradiance and heating;
- low temperature may induce a lower observed capacity.

6.3 Battery accommodation, housing

6.3.1 General

Batteries shall be housed in protected accommodation. If required, electrical accommodation or locked electrical accommodation shall be provided.

The following factors shall be taken into consideration when selecting the accommodation:

- protection from external hazard: fire, water, shock, vibration, vermin;
- protection from hazards generated by the battery: high voltage, explosion hazard, electrolyte hazard, corrosion;
- protection from access of unauthorized personnel;
- adequate natural ventilation.

6.3.2 Provision against electrolyte hazard

6.3.2.1 Electrolyte and water

Electrolyte used is an aqueous solution of sulphuric acid. Only distilled or demineralised water is used for topping up the cells.

6.3.2.2 Protective clothing

In order to avoid personal injury from electrolyte splashes when handling electrolyte and/or vented cells or batteries, protective clothing shall be worn, such as:

- protective glasses or masks for eyes or face;
- protective gloves and aprons for skin protection.

6.3.2.3 Accidental contact, first aid

6.3.2.3.1 General

Electrolyte creates burns on eyes and skin. A source of water (tap or reservoir) shall be provided in the vicinity of the battery for cleaning away splashed electrolyte.

6.3.2.3.2 Eye contact

In the event of accidental contact with electrolyte, immediately flood the eyes with large quantities of water for an extended period of time of at least 15 min. In all cases, obtain immediate medical attention.

6.3.2.3.3 Skin contact

In the event of accidental contact with electrolyte, wash the affected parts with large quantities of water. If irritation of the skin persists, obtain medical attention.

6.3.2.4 Battery accessories and maintenance tools

Materials used for battery accessories, battery stands or enclosures, and components inside battery rooms shall be resistant to or protected from the chemical effects of the electrolyte.

In the event of electrolyte spillage, remove the liquids with absorbing material; neutralizing material is preferred.

Maintenance tools, such as funnels, hydrometers, thermometers, that are in contact with electrolyte shall be separately dedicated to the batteries and shall not be used for any other purpose.