TECHNICAL SPECIFICATION

IEC TS 62257-8-1

First edition
2007-06

Recommendations for small 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

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FOREWORD

The main task of IEC technical committees is to prepare International Standards. In exceptional circumstances, a technical committee may propose the publication of a technical specification when

- 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 document is based on IEC/PAS 62111 (1999); it cancels and replaces the relevant parts of IEC/PAS 62111.

This part of IEC 62257 is to be used in conjunction with the IEC 62257 series.

It is also to be used with 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
82/457/DTS	82/476/RVC

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

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

- transformed into an International Standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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

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, etc.) documents for the setting up of renewable energy and hybrid systems with a.c. voltage below 500 V, d.c. voltage below 750 V and power below 100 kVA.

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 must not be 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 emission, 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 as 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 project 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 application. 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 62257-2) in an economically viable way.

The purpose of Part 8-1 of IEC 62257 is to propose tests for automotive lead acid batteries and batteries management systems used in small PV Individual Electrification Systems

This document and the others in the IEC 62257 series are only guidance and so cannot be international standards. Additionally, their subject is still under technical development and so they shall be published as Technical Specifications.

NOTE The IEC 62257 series of Technical Specifications is based on IEC/PAS 62111 (1999-07) and is developed in accordance with the PAS procedure.

RECOMMENDATIONS FOR SMALL 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 Technical Specification 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 too costly and too much sophisticated test equipment to be applied in developing countries laboratories.

The tests provided in this document allow to assess batteries performances according to the general specification of the project (see IEC 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 real site operating conditions.

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 referenced documents are indispensable for the application 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, *International Electrotechnical Vocabulary (IEV) – Part 482: Primary and secondary cells and batteries*

IEC 61427, *Secondary cells and batteries for photovoltaic energy systems (PVES) – General requirements and methods of test*

IEC 62257 (all parts), *Recommendations for small renewable energy and hybrid systems for rural electrification*

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.

3.1
electrochemical cell or battery
electrochemical system capable of storing in chemical form the electric energy received and which can give it back by conversion

3.2
secondary cell
cell which is designed to be electrically recharged

NOTE The recharge is accomplished by way of a reversible chemical reaction.

[IEV 482-01-03]

3.3
storage battery (secondary battery)
two or more secondary cells connected together and used as a source of electric energy

3.4
lead-acid battery
storage battery in which the electrodes are made mainly from lead and the electrolyte is a sulphuric acid solution

3.5
terminal (pole)
conductive part provided for the connection of a cell or battery to external conductors

3.6
density
commonly considered as the volumic mass, in kg / dm^3

NOTE 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.

3.7
electrolyte
liquid or solid substance containing mobile ions which render it ionically conductive

NOTE The electrolyte may be liquid, solid or a gel.

[IEV 482-02-29]

3.8
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

[IEV 482-05-30]

3.9
self-discharge
phenomenon by which a cell or battery loses energy in other ways than by discharge into and external circuit

[IEV 482-03-27]

3.10
observed battery capacity
quantity of electricity or electrical charge that a battery in high state of charge can deliver under the proposed test conditions. In practice, battery capacity is expressed in Ampere-hours(Ah)

3.11
nominal capacity
suitable approximate quantity of electricity, used to identify the capacity of a cell or a battery

NOTE This value is usually expressed in Ampere-hours (Ah).

3.12
rated capacity (of a cell or a battery)
quantity of electricity, declared by the manufacturer, which a cell or a battery can deliver under specified conditions after a full charge

NOTE 1 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 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 hours and a capacity measured over 100 hours.

3.13
short-circuit current
maximum current given by a battery into a circuit of a very low resistance compared with that of the battery, under specified conditions

3.14
charge rate
electric current at which a secondary cell or battery is charged

NOTE The charge rate is expressed as the reference current $I_t = C_r/n$ where C_r is the rated capacity declared by the manufacturer and n is the time base in hours for which the rated capacity is declared.

[IEV 482-05-45]

3.15
ambient temperature
temperature of the medium in the immediate vicinity of a battery

3.16
gassing of a cell
evolution of a gas resulting from electrolysis of the water in the electrolyte of a cell

[IEV 482-05-51]

3.17
constant current charge
charge during which the electric current is maintained at a constant value regardless of the battery voltage or temperature

[IEV 482-05-38]

3.18
initial charge
commissioning charge given to a new battery to bring it to the fully charged state

3.19
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 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.

[IEV 482-05-28]

3.20
commissioning
final checking of installation and operation of a battery on site.

3.21
BMS
battery management system (or battery charge/discharge controller)

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 colorless, odorless and free of all insoluble material deposits. As there is no standard for such an electrolyte, impurity levels shall follow the battery manufacturer 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 age;
- the quality of distilled water;
- the PV resource.

The service interval would be determined by the above parameters and 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 in order to be able to check the electrolyte levels and to add distilled water.

NOTE 1 Faradic water consumption for vented batteries:

when a battery reaches its fully state of charge, water electrolysis occurs according to the 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

The proposed comparative tests are designed to discriminate the most appropriate batteries taking in 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

<table>
<tr><td rowspan="2">Test 1: most durable batteries are first selected with a battery endurance test
See 4.2.2</td><td>Test 2: the couple battery-BMS is selected with another endurance test
See 4.2.3</td></tr>
<tr><td>Test 3: in parallel to test 2, the selected batteries are subjected to a storability test
See 4.2.4</td></tr>
</table>

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

4.2.1 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 may 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} ($C_{10} \times 0{,}1$) (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.

4.2.2 Test 1: Battery endurance test

4.2.2.1 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 phases procedure. The test is realized 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	Voltage regulation variation/value at 20 °C	Voltage regulation
15 °C	−0,021 V/°C × [15 °C – 20 °C] = +0,11 V	14,51 V
20 °C		**14,40 V**
35 °C	−0,021 V/°C × [35 °C – 20 °C] = −0,31 V	14,09 V

4.2.2.2 Test 1 procedure

4.2.2.2.1 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.

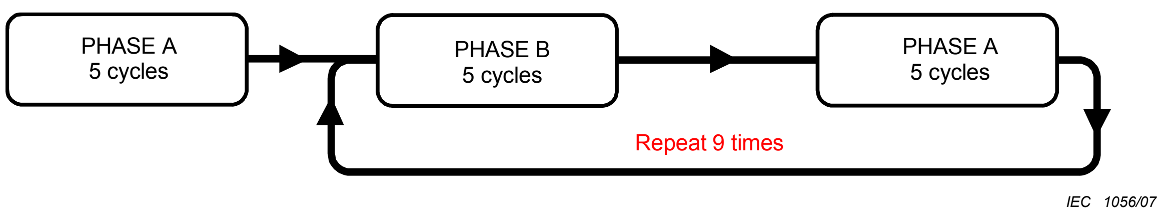

Figure 1 – Test 1 phases

Phase A is a discharge/charge cycle including an additional charge ensuring that the battery is on a high state of charge (see 4.2.2.2.2).

Phase B does not include this additional charge (see 4.2.2.2.3).

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 overcharge period.

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

During each discharge, observed capacity is assessed as explained in 4.2.2.2.2.4.

After each Phase A an average observed capacity is calculated.

When the complete test 1 process is achieved, 10 values of observed capacity are available. Interpretation of results is given in 4.2.2.4.

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.

4.2.2.2.2 Phase A

4.2.2.2.2.1 General

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

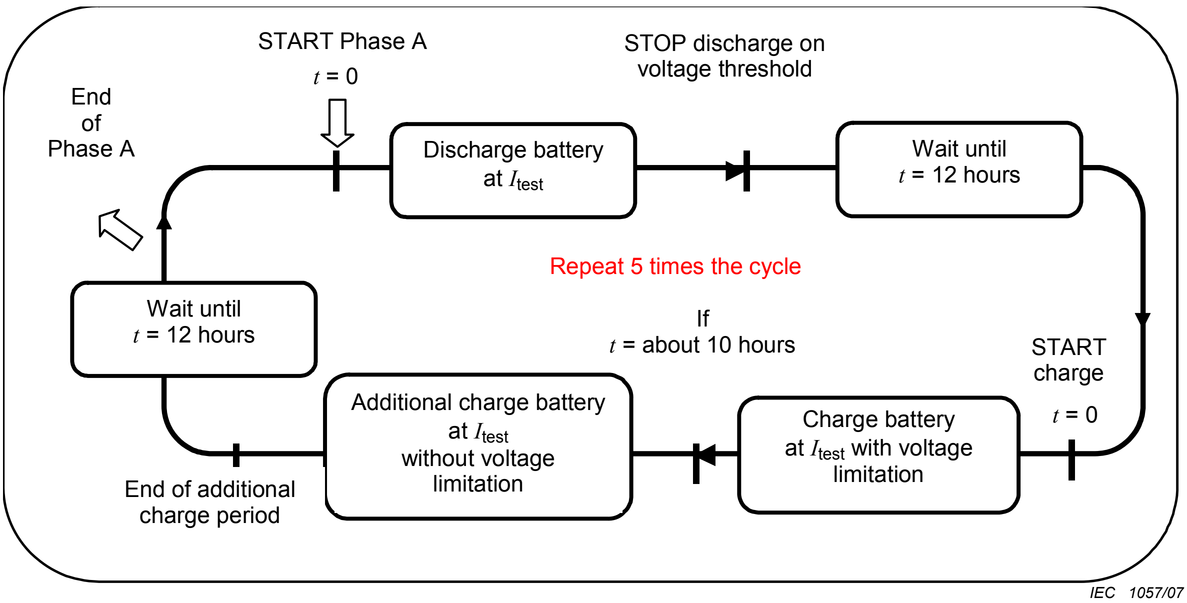

Figure 2 – Phase A battery endurance test

4.2.2.2.2.2 Operating procedure

- **Discharge** the battery at I_{test} to **10,8 V** (± 0,1 V).
- **Wait until 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** until 12 h from the beginning of the charge before starting the next discharge.

4.2.2.2.2.3 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).

4.2.2.2.2.4 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 value differs from the average value of 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.

4.2.2.2.2.5 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.

4.2.2.2.3 Phase B

4.2.2.2.3.1 General

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

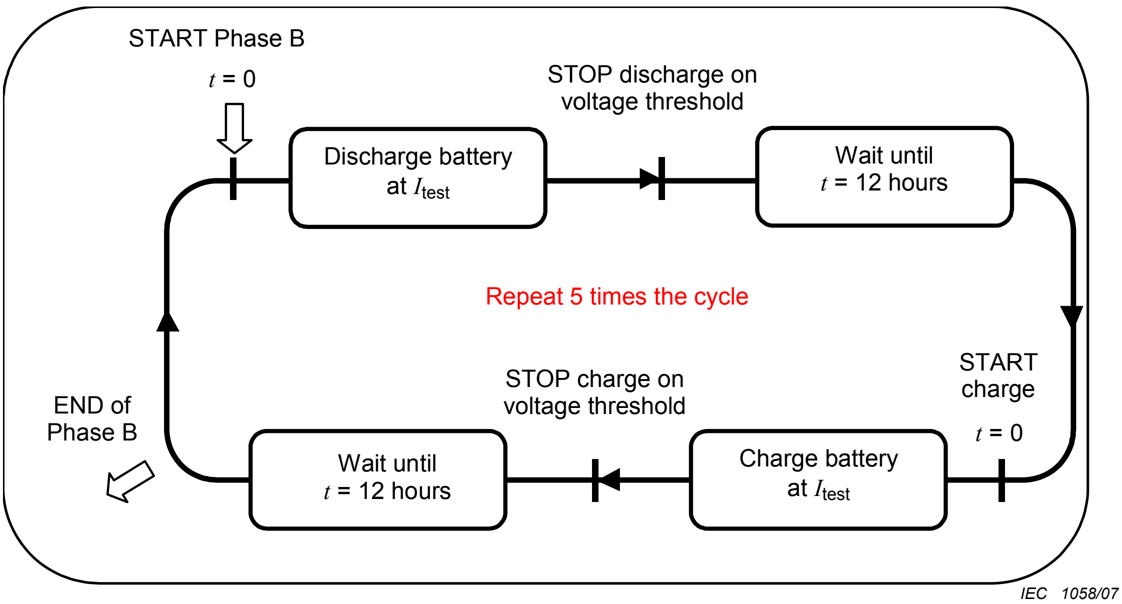

Figure 3 – Phase B battery endurance test

4.2.2.2.3.2 Operating procedure

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

4.2.2.3 Test 1 equipment

To perform the 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 IEC requirements 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.

4.2.2.4 Interpreting the results of Test 1: battery selection

3 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.

4.2.2.5 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.

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

4.2.3 Test 2: Endurance test for battery+BMS

4.2.3.1 General

This test 2 simulates the use of the whole battery and BMS combination in a photovoltaic system and determines the compatibility between battery and 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 which 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 formula:

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

For example if 2 models of batteries were selected after Test 1, and 2 models of BMS are pre-selected, 8 Test 2’s 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.

4.2.3.2 Test 2 procedure

4.2.3.2.1 General

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

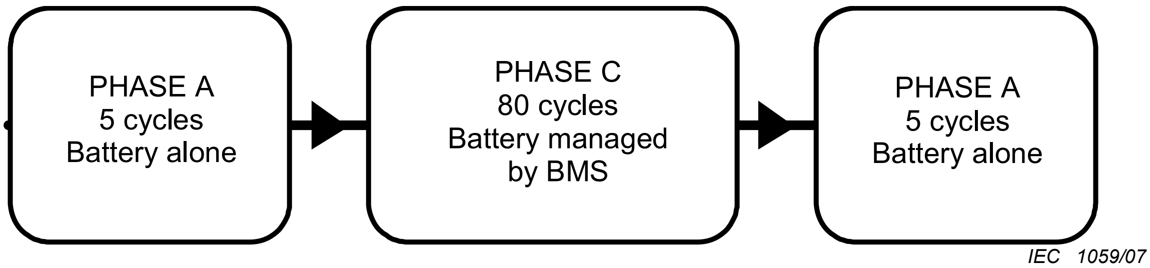

Figure 4 – Test 2 phases

For Phase A, see 4.2.2.2.2.

For Phase C, see 4.2.3.2.2.

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

The water consumption is assessed according to 4.2.2.5.

4.2.3.2.2 Phase C

4.2.3.2.2.1 General

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

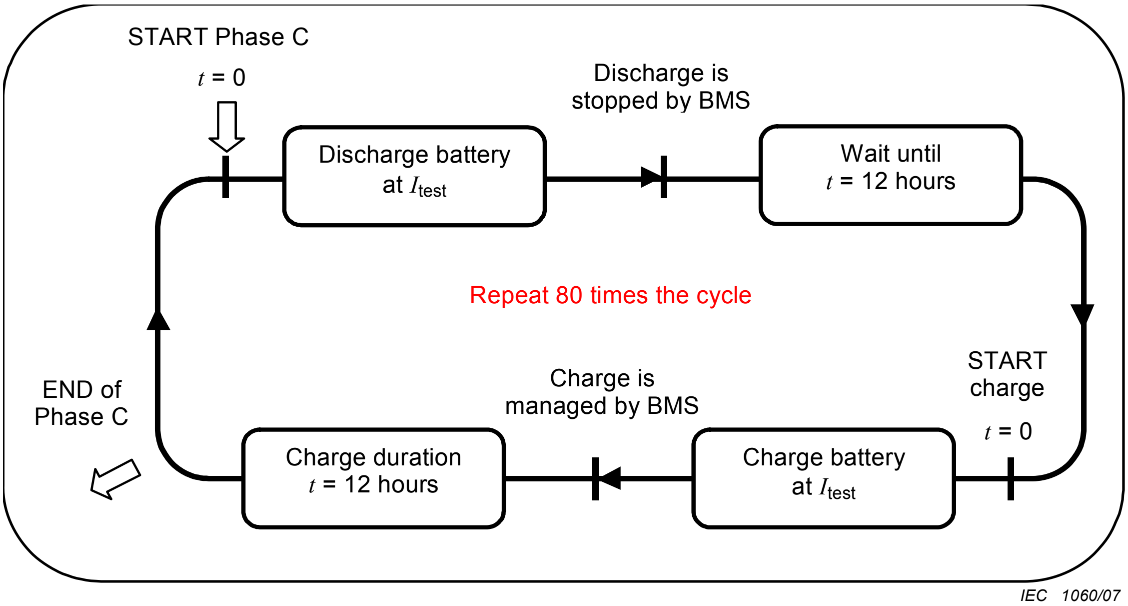

Figure 5 – Phase C battery-BMS endurance test

4.2.3.2.2.2 Operating procedure

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

The duration of charge and discharge shall be recorded.

4.2.3.3 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.

4.2.4 Test 3: Battery storability test

4.2.4.1 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.

4.2.4.2 Test 3 procedure

4.2.4.2.1 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

4.2.4.2.2 Phase D

4.2.4.2.2.1 General

Phase D cycle is performed as presented in Figure 7.

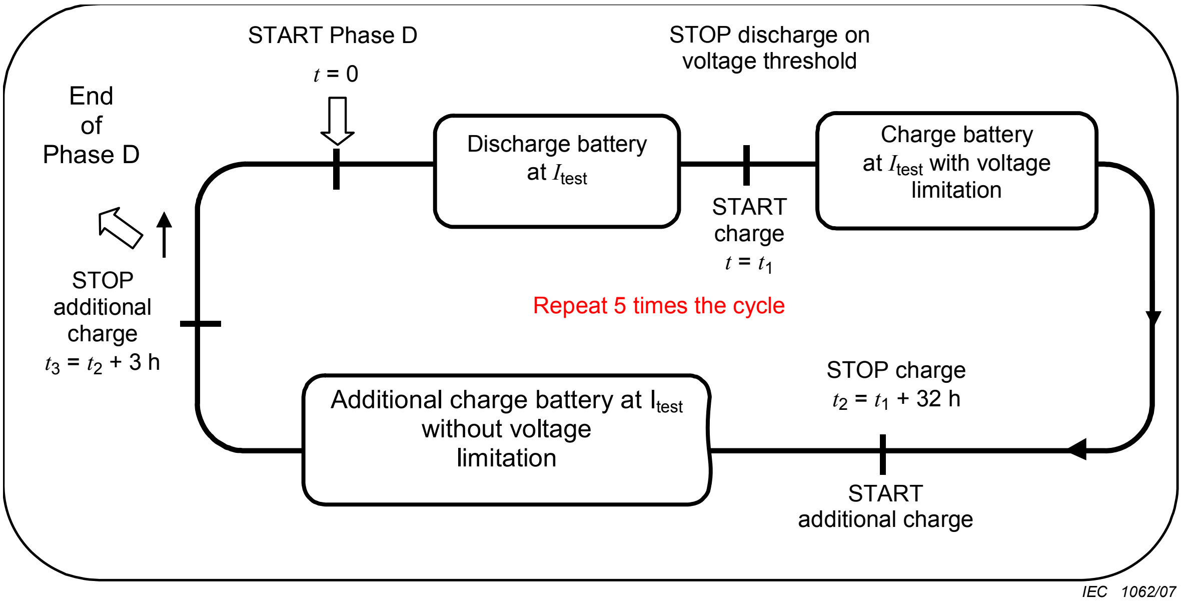

Figure 7 – Phase D storability test

4.2.4.2.2.2 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.

4.2.4.2.3 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.

4.2.4.3 Interpreting the results of test 3

The observed capacity is measured for Phases D as explained for Phases A in clause 4.2.2.2.2.4.

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 which 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 packing.

Figure 8 – Marking for spillage prevention

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

- supplier's name;
- product reference;
- label to indicate chemical hazards National or international dangerous labeling 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

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 battery: high voltage, explosion hazard; electrolyte hazard, corrosion;
- protection from access of unauthorized personnel;
- adequate natural ventilation.

6.3.1 Provision against electrolyte hazard

6.3.1.1 Electrolyte and water

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

6.3.1.2 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.

6.3.1.3 Accidental contact, first aid

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.

6.3.1.3.1 Eye contact

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

6.3.1.3.2 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.

6.3.1.4 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, like funnels, hydrometers, thermometers, which are in contact with electrolyte shall be separately dedicated to the batteries and shall not be used for any other purpose.

6.3.2 Prevention of short circuits and protection from other effects of electric current

6.3.2.1 General

In addition to the hazard of electric shock, the current flow in battery systems can cause other hazards. This is because very high currents may flow under fault conditions, and the voltage at the battery terminals cannot be switched off.

6.3.2.2 Short circuits

The electric energy stored in cells or batteries may be released in an inadvertent and uncontrolled manner due to short-circuiting of the terminals. Because of the considerable energy, the heat generated by the high current can produce molten metal, sparks, explosion and vaporization of electrolyte.

The main connections from the battery terminals shall be designed to withstand the electromagnetic forces experienced during a short circuit.

All battery connections up to the battery fuse shall be installed so that a short circuit shall not occur under all feasible conditions.

NOTE The insulation should be resistant against the effects of ambient influences like temperature, dampness, dust, gasses, steam, and mechanical stress. Where terminals and conductors are not insulated, by design or for maintenance purposes, only insulated tools are used in that area.

When working on live equipment, the use of appropriate working procedures will reduce the risk of injury. Only insulated tools shall be used.

6.3.2.3 Protective measures during maintenance

During maintenance operation people may work close to the battery system. Personnel involved in work on or close to a battery shall be competent to carry out such work, and shall be trained in any special procedures necessary.

To minimize the risk of injury, the battery system shall be designed with

- battery terminal covers which allow routine maintenance whilst minimizing exposure of live parts;
- fuse carriers which prevent contact with live parts.

All metallic personal objects shall be removed from the hands, wrists and neck before starting work.

Batteries shall be neither connected nor disconnected when current is flowing. Isolate the circuit elsewhere first.

6.3.2.4 Leakage currents

To avoid the risk of fire or corrosion, keep batteries clean and dry. To be resistant against effects of ambient influences like temperature, dampness, dust, gasses, steam, and mechanical stress the minimum insulation resistance between the battery circuit and other local conductive parts should be greater than 100 Ω per volt (of battery nominal voltage) corresponding to a leakage current < 10 mA.

6.3.3 Battery enclosures

A battery enclosure may be selected for the following reasons:

- to provide a functionally complete item of equipment in one enclosure;

- for protection against external hazards;
- for protection from hazards generated by the battery;
- for protection from access of unauthorized personnel;
- for protection from external environmental influences.

The following requirements shall apply when housing batteries in an enclosure:

- sufficient ventilation shall be provided to prevent the formation of an explosive hydrogen concentration;
- the floor (or shelf if fitted) shall be designed to take the load of the batteries;
- partitions within the enclosure will reduce the effective ventilation, and may increase the temperature of the battery. This should be assessed during the design;
- the interior of the enclosure shall be chemically resistant to the electrolyte (including shelves if any);
- the enclosure shall prevent access to hazardous parts by anyone other than authorized people;
- the enclosure shall be designed to allow adequate access for maintenance using normal tools.

6.4 Final inspection

A final inspection shall be done, including as a minimum the following items:

- visual inspection of the cells;
- verification of tightness of connections;
- inspection of the electrolyte levels;
- measurement of the electrolyte densities;
- verification of the ventilation of the housing.

6.5 Safety

6.5.1 Safety provisions

During the installation, provisions shall be made to prevent any injury due to the weight of the batteries (handling equipment, safety shoes, etc.).

For batteries installed in a locker, devices shall be implemented to keep non-authorized people from accessing the batteries. The locker shall be free of anything preventing the access when necessary.

6.5.2 Safety Information

Information shall be given according to local regulation.

Battery accessibility is defined by the operator.

The project implementer shall ensure that the necessary actions are taken to warn users and operators of the risks related to battery use: corrosion, explosion and short-circuit. The following notices shall be posted visibly outside the room or locker.

“Access forbidden to all non-authorized persons”

and after opening:

- no smoking,

- no live flames,
- first aid for electric shock, burn, acid splashes.

A suitably located warning notice in local language and pictorial shall focus on the safety provisions. As a minimum, a symbol and oral training shall be provided.

6.6 Administrative formalities

As batteries contain potentially polluting materials such as lead, electrolyte, etc. the legal or environmental regulations for each country shall be complied with. An inventory of installations equipped with batteries shall be kept in order to avoid spreading of lead, electrolyte into the environment after their useful life.

6.7 Recycling

Disposal of dead batteries shall be included in the General Specification of any project.

At the end of their useful life, the batteries shall be recycled by the operator under the responsibility of the owner. A designated person shall be able to store the dead batteries and then submit them for recycling.

Batteries shall be recycled in an environmentally responsible and physically safe fashion referred to in IEC 62257-6.

If no local recycling system is locally managed, the minimum requirement is to store the acid of used batteries in a closed container and cases with lead plates in a dedicated storage area.

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