BS EN 61427-1:2013

BSI Standards Publication

Secondary cells and batteries for renewable energy storage — General requirements and methods of test -

Part 1: Photovoltaic off-grid application

...making excellence a habit.™

National foreword

This British Standard is the UK implementation of EN 61427-1:2013. It is identical to IEC 61427-1:2013. Together with BS EN 61427-2, it supersedes BS EN 61427:2005 which will be withdrawn upon publication of all parts of this series.

The UK participation in its preparation was entrusted to Technical Committee PEL/21, Secondary cells and batteries.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Published by BSI Standards Limited 2014

ISBN 978 0 580 74813 4

ICS 27.160; 29.220.20

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 January 2014.

Amendments/corrigenda issued since publication

Date	Text affected

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 61427-1

July 2013

ICS 27.160; 29.220.20

Supersedes EN 61427:2005

English version

Secondary cells and batteries for renewable energy storage - General requirements and methods of test - Part 1: Photovoltaic off-grid application

(IEC 61427-1:2013)

Accumulateurs pour le stockage de l'énergie renouvelable -
Exigences générales et méthodes d'essais -
Partie 1: Applications photovoltaïques hors réseaux
(CEI 61427-1:2013)

Wiederaufladbare Zellen und Batterien für die Speicherung erneuerbarer Energien -
Allgemeine Anforderungen und Prüfverfahren -
Teil 1: Photovoltaische netzunabhängige Anwendung
(IEC 61427-1:2013)

This European Standard was approved by CENELEC on 2013-05-28. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Management Centre: Avenue Marnix 17, B - 1000 Brussels

Ref. No. EN 61427-1:2013 E

Foreword

The text of document 21/793/FDIS, future edition 1 of IEC 61427-1, prepared by IEC/TC 21 "Secondary cells and batteries" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 61427-1:2013.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2014-02-28
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2016-05-28

This document supersedes EN 61427:2005.

EN 61427-1:2013 includes the following significant technical changes with respect to EN 61427:2005:

a) a restructuration of the previous edition of the document;

b) a clarification of the different clauses with regard to conditions of use, general requirements, functional characteristics, general tests conditions, test method and recommended use of tests, the aim being to ensure a better understanding by the end user;

c) a clear distinction between on-grid and off-grid applications for future markets needs.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

Endorsement notice

The text of the International Standard IEC 61427-1:2013 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following note has to be added for the standard indicated:

IEC 60721-1 NOTE Harmonised as EN 60721-1.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60050	Series	International Electrotechnical vocabulary (IEV)	-	-
IEC 60622	-	Secondary cells and batteries containing alkaline or other non-acid electrolytes - Sealed nickel-cadmium prismatic rechargeable single cells	EN 60622	-
IEC 60623	-	Secondary cells and batteries containing alkaline or other non-acid electrolytes - Vented nickel-cadmium prismatic rechargeable single cells	EN 60623	-
IEC 60896-11	-	Stationary lead-acid batteries - Part 11: Vented types - General requirements and methods of tests	EN 60896-11	-
IEC 60896-21	-	Stationary lead-acid batteries - Part 21: Valve regulated types - Methods of test	EN 60896-21	-
IEC 61056-1	-	General purpose lead-acid batteries (valve-regulated types) - Part 1: General requirements, functional characteristics - Methods of test	EN 61056-1	-
IEC 61836	-	Solar photovoltaic energy systems - Terms, definitions and symbols	-	-
IEC 61951-1	-	Secondary cells and batteries containing alkaline or other non-acid electrolytes - Portable sealed rechargeable single cells - Part 1: Nickel-cadmium	EN 61951-1	-
IEC 61951-2	-	Secondary cells and batteries containing alkaline or other non-acid electrolytes - Portable sealed rechargeable single cells - Part 2: Nickel-metal hydride	EN 61951-2	-
IEC 61960	-	Secondary cells and batteries containing alkaline or other non-acid electrolytes - Secondary lithium cells and batteries for portable applications	EN 61960	-
IEC 62259	-	Secondary cells and batteries containing alkaline or other non-acid electrolytes - Nickel-cadmium prismatic secondary single cells with partial gas recombination	EN 62259	-

CONTENTS

1 Scope ... 6
2 Normative references ... 6
3 Terms and definitions ... 7
4 Conditions of use ... 7
4.1 General ... 7
4.2 Photovoltaic energy system ... 7
4.3 Secondary cells and batteries ... 7
4.4 General operating conditions ... 8
4.4.1 General ... 8
4.4.2 Autonomy time ... 8
4.4.3 Typical charge and discharge currents ... 8
4.4.4 Daily cycle ... 8
4.4.5 Seasonal cycle ... 8
4.4.6 Period of high state of charge ... 9
4.4.7 Period of sustained low state of charge ... 9
4.4.8 Electrolyte stratification ... 9
4.4.9 Storage ... 9
4.4.10 Operating temperature ... 10
4.4.11 Charge control ... 11
4.4.12 Physical protection ... 11
5 General requirements ... 11
5.1 Mechanical endurance ... 11
5.2 Charge efficiency ... 12
5.3 Deep discharge protection ... 12
5.4 Marking ... 12
5.5 Safety ... 12
5.6 Documentation ... 12
6 Functional characteristics ... 13
7 General test conditions ... 13
7.1 Accuracy of measuring instruments ... 13
7.2 Preparation and maintenance of test batteries ... 13
8 Test method ... 13
8.1 Capacity test ... 13
8.2 Generic cycling endurance test ... 14
8.3 Charge retention test ... 14
8.4 Cycling endurance test in photovoltaic applications (extreme conditions) ... 14
8.4.1 General ... 14
8.4.2 Phase A: shallow cycling at low state of charge (see Table 5) ... 15
8.4.3 Phase B: shallow cycling at high state of charge (see Table 6) ... 15
8.4.4 Residual capacity determination ... 16
8.4.5 Test termination ... 16
8.4.6 Water consumption of flooded battery types and cells with partial gas recombination ... 16
8.4.7 Requirements ... 16
9 Recommended use of tests ... 17

9.1 Type test 17
9.2 Acceptance test 17
9.2.1 Factory test 17
9.2.2 Commissioning test 17
Bibliography 18

Table 1 – Limit values for storage conditions of batteries for photovoltaic applications 10
Table 2 – Limit values for operating conditions of batteries for photovoltaic applications 10
Table 3 – Battery Ah-efficiency at different states of charge at the reference temperature and a daily depth of discharge of less than 20 % of the rated capacity 12
Table 4 – Typical capacity ratings of batteries in photovoltaic applications 14
Table 5 – Phase A – Shallow cycling at low state of charge 15
Table 6 – Phase B – Shallow cycling at high state of charge 16

SECONDARY CELLS AND BATTERIES FOR RENEWABLE ENERGY STORAGE – GENERAL REQUIREMENTS AND METHODS OF TEST –

Part 1: Photovoltaic off-grid application

1 Scope

This part of the IEC 61427 series gives general information relating to the requirements for the secondary batteries used in photovoltaic energy systems (PVES) and to the typical methods of test used for the verification of battery performances. This part deals with cells and batteries used in photovoltaic off-grid applications.

NOTE The part 2 of this series will cover cells and batteries used in “renewable energy storage in on-grid applications”.

This International Standard does not include specific information relating to battery sizing, method of charge or PVES design.

This standard is applicable to all types of secondary batteries.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050 (all parts), *International Electrotechnical Vocabulary (IEV)* (available at <www.electropedia.org>)

IEC 60622, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Sealed nickel-cadmium prismatic rechargeable single cells*

IEC 60623, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Vented nickel-cadmium prismatic rechargeable single cells*

IEC 60896-11, *Stationary lead-acid batteries – Part 11: Vented types – General requirements and methods of test*

IEC 60896-21, *Stationary lead-acid batteries – Part 21: Valve regulated types – Methods of test*

IEC 61056-1, *General purpose lead-acid batteries (valve-regulated types) – Part 1: General requirements, functional characteristics – Methods of test*

IEC 61836, *Solar photovoltaic energy systems – Terms, definitions and symbols*

IEC 61951-1, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Portable sealed rechargeable single cells – Part 1: Nickel-cadmium*

IEC 61951-2, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Portable sealed rechargeable single cells – Part 2: Nickel-metal hydride*

IEC 61960, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Secondary lithium cells and batteries for portable applications*

IEC 62259, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Nickel-cadmium prismatic secondary single cells with partial gas recombination*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-482 concerning secondary cells and batteries, and those given in IEC 61836 concerning photovoltaic generator systems apply.

4 Conditions of use

4.1 General

This clause specifies the particular operating conditions experienced by secondary batteries during their use in photovoltaic applications.

4.2 Photovoltaic energy system

The photovoltaic energy system with secondary batteries referred to in this standard can supply a constant, variable, or intermittent energy to the connected equipment (pumps, refrigerators, lighting systems, communication systems, etc.).

4.3 Secondary cells and batteries

Secondary cells and batteries mainly used in photovoltaic energy systems are of the following types:

a) vented (flooded);
b) valve-regulated, including those with partial gas recombination;
c) gastight sealed.

The cells and batteries are normally delivered in the following state of charge:

d) discharged and drained (vented nickel-cadmium batteries only);
e) charged and filled;
f) dry charged and unfilled (vented lead-acid batteries only);
g) discharged and filled (nickel-cadmium batteries only).

For optimum service life, the battery manufacturer's instructions for initial charge of the battery shall be followed.

Other secondary cells and batteries such as based on sodium or vanadium electrochemical systems can be potentially used for such an application. Due to the fact that they are in a phase of adaptation for a possible use in PV systems, it is recommended that their respective supplier be contacted for the necessary planning, test and operation details.

4.4 General operating conditions

4.4.1 General

Batteries in a typical PV system operating under average site weather conditions may be subjected to the following conditions.

4.4.2 Autonomy time

The battery is designed to supply energy under specified conditions for a period of time, typically from 3 days to 15 days without solar irradiation.

When selecting the required battery capacity, the following items should be considered, e.g.:

- required daily/seasonal cycle (there may be restrictions on the maximum depth of discharge);
- time required to access the site;
- ageing;
- operating temperature;
- future expansion of the load.

4.4.3 Typical charge and discharge currents

The typical charge and discharge currents are the following:

– maximum charge current: I_{20} (A)
– average charge current: I_{50} (A)
– average discharge current as determined by the load: I_{120} (A)

Depending on the system design, the charge and the discharge current may vary in a wider range.

In some systems the load current must be supplied at the same time as the battery charging current.

NOTE 1 The following abbreviations are used:

- C_{rt} is the rated capacity declared by the manufacturer in ampere-hours (Ah)
- t is the time base in hours (h) for which the rated capacity is declared
- $I_{rt} = C_{rt}/t$

For Nickel Cadmium, Nickel Metal Hydride and Lithium battery systems

- $I_{rt} = C_{rt}/1$h in this document corresponds to $I_t = C_5/1$h

4.4.4 Daily cycle

The battery is normally exposed to a daily cycle as follows:

a) charging during daylight hours;
b) discharging during night-time hours.

A typical daily usage results in a discharge between 2 % to 20 % of the battery capacity.

4.4.5 Seasonal cycle

The battery may be exposed to a seasonal cycle of its state of charge. This arises from varying average-charging conditions as follows:

- periods with low solar irradiation, for instance during winter causing low energy production. The state of charge of the battery (available capacity) can go down to 20 % of the rated capacity or less;
- periods with high solar irradiation, e.g. in summer, which will bring the battery up to the fully charged condition, with the possibility that the battery could be overcharged.

4.4.6 Period of high state of charge

During summer for example, the battery will be operated at a high state of charge (SOC), typically between 80 % and 100 % of rated capacity.

A voltage regulator system normally limits the maximum battery voltage during the recharge period.

NOTE In a "self-regulated" PV system, the battery voltage is not limited by a charge controller but by the characteristics of the PV generator.

The system designer normally chooses the maximum charge voltage of the battery as a compromise allowing to recover to a maximum state of charge (SOC) as early as possible in the summer season but without substantially overcharging the battery.

The overcharge increases the gas production resulting in water consumption in vented cells. In valve-regulated lead-acid cells, the overcharge will cause less water consumption and gas emission but more heat generation.

Typically the maximum charge voltage is 2,4 V per cell for lead-acid batteries and 1,55 V per cell for vented nickel-cadmium batteries at the reference temperature specified by the manufacturer. Some regulators allow the battery voltage to exceed these values for a short period as an equalizing or boost charge. For the other batteries the battery manufacturers shall give the most adapted charge voltage values. Charge voltage compensation shall be used according to the battery manufacturer instructions if the battery operating temperature deviates significantly from the reference temperature.

The expected lifetime of a battery in a PV system, even kept regularly at a high state of charge, may be considerably less than the published life of the battery used under continuous float charge conditions.

4.4.7 Period of sustained low state of charge

During periods of low solar irradiation, the energy produced by the photovoltaic array may not be sufficient to fully recharge the battery. The state of charge will then decrease and cycling will take place at a low state of charge. The low solar irradiation yield of the photovoltaic array may be a result of the geographical location combined with the winter periods, heavy clouds, rains or accumulation of dust on the photovoltaic array.

4.4.8 Electrolyte stratification

Electrolyte stratification may occur in lead-acid batteries. In vented lead-acid batteries, electrolyte stratification can be avoided by electrolyte agitation/recirculation or by periodic overcharge whilst in service. In valve regulated lead-acid (VRLA) batteries, electrolyte stratification can be avoided by design or by operating them according to the manufacturer’s instructions.

4.4.9 Storage

Manufacturers’ recommendations for storage shall be observed. In the absence of such information, the storage period may be estimated according to the climatic conditions as shown in Table 1 as below.

Table 1 – Limit values for storage conditions of batteries for photovoltaic applications

Battery type	Temperature range °C	Humidity %	Storage period for batteries	
			With electrolyte	Without electrolyte
Lead-acid	-20 to +40	< 90	Up to 12 months (depending of the design)	1-2 years (dry charged)
Nickel-cadmium	-20 to +50 (standard electrolyte) -40 to +50 (high density electrolyte)	< 90	Up to 6 months	1-3 years (fully discharged, drained and sealed)
Nickel metal hydride	-40 to +50	< 90	Up to 6 months	N/A
Lithium Ion	-20 to +50	< 90	Up to 12 months	N/A

The exact limits of storage conditions are to be verified with the manufacturer.

Lead-acid or nickel-cadmium batteries with electrolyte shall be stored starting from a state at full charge.

A loss of capacity may result from exposure of a battery to high temperature and humidity during storage.

The temperature of a battery stored in a shipping container in direct sunlight, can rise to +60 °C or more in daytime. Choice of a shaded location or cooling should avoid this risk.

4.4.10 Operating temperature

The temperature range during operation experienced by the battery at the site is an important factor for the battery selection and the expected lifetime (see IEC 60721-1 for definitions of climatic conditions).

Manufacturers' recommendations for operating temperatures and humidity shall be observed.

In the absence of such information, operating temperatures and humidity may be those shown in Table 2.

Table 2 – Limit values for operating conditions of batteries for photovoltaic applications

Battery type	Temperature range °C	Humidity %
Lead-acid	-15 to +40	< 90
Nickel-cadmium (standard electrolyte)	-20 to +45	< 90
Nickel-cadmium (high density electrolyte)	-40 to +45	< 90
Nickel-metal hydride	-20 to +45	< 90
Lithium-ion and other electro chemistries	To be verified with the battery manufacturer	To be verified with the battery manufacturer

The manufacturer should be consulted for operation at temperatures outside this range. Typically the life expectancy of batteries will decrease with increasing operating temperature.

Low temperature will reduce the discharge performance and the capacity of the batteries. For details, the manufacturer should be consulted.

4.4.11 Charge control

Excessive overcharge does not increase the energy stored in the battery. Instead, overcharge affects the water consumption in vented batteries and consequently the service interval. In addition, valve-regulated lead-acid batteries may dry out resulting in a loss of capacity and / or overheating.

Overcharge can be controlled by the use of proper charge controllers. Most non-aqueous systems, such as lithium-ion batteries and similar, will not accept any overcharge without damage or safety problems. Such batteries are normally supplied with a BMS (battery management system) that prevents, independently from its charge controller, that such overcharge happens.

The parameters of the regulator shall take into account the effects of the PV generator design, the load, the temperature and the limiting values for the battery as recommended by the manufacturer.

Vented lead-acid or nickel-cadmium batteries including those with partial gas recombination shall have sufficient electrolyte to cover at least the period between planned service visits. Overcharge in valve-regulated lead-acid batteries shall be carefully controlled to be able to reach the expected service life.

The water consumption is measured during the cycle test (see 8.4.6) and can be used together with the system's design information to estimate the electrolyte service intervals.

4.4.12 Physical protection

Physical protection shall be provided against consequences of adverse site conditions, for example, against the effects of:

- uneven distribution and extremes of temperature;
- exposure to direct sun light (UV radiation);
- air-borne dust or sand;
- explosive atmospheres;
- flooding, water vapour condensation and sea water spray;
- earthquakes;
- shock and vibration (particularly during transportation).

5 General requirements

5.1 Mechanical endurance

Batteries for photovoltaic application shall be designed to withstand mechanical stresses during transportation and handling taking in account that PVES installations may be accessed via unpaved roads and installed by less qualified personnel. Additional packing or protection shall be provided for off-road conditions.

Particular care shall be taken while handling unpacked batteries. Manufacturer's instructions shall be observed.

In case of specific requirements regarding mechanical stresses, such as earthquakes, shock and vibration, these shall be individually specified or referred to in a relevant standard.

5.2 Charge efficiency

The charge efficiency is the ratio between the quantity of electricity delivered during the discharge of a cell or battery and the quantity of electricity necessary to restore the initial state of charge under specified conditions (see IEC 60050-482:2004, 482-05-39).

NOTE The quantity of electricity is expressed in amperes-hours (Ah).

Where no data are available from the battery manufacturer, the following efficiencies as given in Table 3 may be assumed.

Table 3 – Battery Ah-efficiency at different states of charge at the reference temperature and a daily depth of discharge of less than 20 % of the rated capacity

State of charge (SOC) %	**Efficiency Lead-acid cells** %	**Efficiency Nickel-cadmium and Ni-MH cells** %	**Efficiency Li-Ion cells**
90	> 85	> 80	>> 95 %
75	> 90	> 90	>> 95 %
< 50	> 95	> 95	>> 95 %

5.3 Deep discharge protection

Lead-acid batteries shall be protected against deep discharge so to avoid capacity loss due to irreversible sulphation or passivation effect. This could be achieved by using a system that monitors the battery voltage and automatically disconnects the battery before it reaches its maximum depth of discharge (see manufacturer’s recommendations).

Vented and partial gas recombination Nickel-cadmium batteries do not normally require this type of protection.

For the other types of batteries, the manufacturer’s recommendations shall be followed.

5.4 Marking

The marking of the cells or monobloc batteries shall comply with the applicable standards listed in 7.2.

5.5 Safety

The applicable local regulations and the manufacturer’s instructions shall be observed during transport, installation, commissioning, operation, maintenance, decommissioning and disposal.

5.6 Documentation

The manufacturer shall provide documentation for transport, installation, commissioning, operation, maintenance, decommissioning and disposal of such cells and batteries for photovoltaic applications.

The manufacturer shall advise if there are special considerations to be observed for the initial charging of batteries when only the photovoltaic array is available as the power source.

6 Functional characteristics

The batteries shall be characterized by their:

- rated capacity (see 8.1);
- endurance in cycling (see 8.2);
- charge retention (see 8.3);
- endurance in cycling in photovoltaic application (extreme conditions) (see 8.4).

7 General test conditions

7.1 Accuracy of measuring instruments

The accuracy of the measuring instruments shall be in compliance with the relevant requirements of the applicable standards listed in 7.2.

The parameters and accuracy values shall be in accordance with relevant clauses of the applicable standards listed in 7.2.

7.2 Preparation and maintenance of test batteries

The test batteries shall be prepared according to the procedures defined in the following standards or, in their absence, according to the manufacturer's instructions:

- IEC 60896-11 for stationary lead-acid batteries (vented types);
- IEC 60896-21 for stationary lead-acid batteries (valve-regulated types);
- IEC 61056-1 for portable lead-acid batteries (valve-regulated types);
- IEC 60622 for sealed nickel-cadmium batteries;
- IEC 60623 for vented nickel-cadmium batteries;
- IEC 62259 for nickel cadmium prismatic rechargeable single cells with partial gas recombination;
- IEC 61951-1 for portable nickel-cadmium batteries;
- IEC 61951-2 for portable nickel metal hydride batteries;
- IEC 61960 for portable lithium batteries.

NOTE The IEC 62620 for lithium batteries for use in industrial applications is under development.

8 Test method

8.1 Capacity test

Test batteries shall be selected, prepared, installed and tested according to the applicable standards listed in 7.2.

The verification of the rated capacity shall be performed by using a current of I_{10} (A) for lead-acid batteries, 0,2 I_t(A) for nickel-cadmium, Ni-MH, and Lithium batteries and I_{10}(A) for other batteries according to Table 4 and the relevant clauses of the applicable standards listed in 7.2.

The verification of the long duration capacity shall be performed according to Table 4, by using a current of I_{120} (A) and the relevant clauses of the applicable standards listed in 7.2.

The charging shall be carried out according to the relevant clauses of the applicable standards listed in 7.2.

Table 4 – Typical capacity ratings of batteries in photovoltaic applications

Capacity Ah	**Current** A		**Discharge duration** h	**Final voltage** V/cell	
	Lead-acid	**Nickel-cadmium Ni-MH and lithium**		**Lead-acid**	**Nickel-cadmium and Ni-MH**
C_{120}	I_{120}	I_{120}	120	1,85	1,00
C_{10}	I_{10}	-	10	1,80	-
C_5	-	0,2 I_t	5	-	1,00

NOTE For definitions, see Table 1.

For other batteries the battery manufacturer shall give at least the C_{120} rated capacity and the corresponding end voltage.

8.2 Generic cycling endurance test

The batteries shall be tested for generic cycling endurance according to the clauses, if any, of the applicable standards listed in 7.2.

8.3 Charge retention test

The batteries shall be tested for charge retention according to the clauses, if any, of the applicable standards listed in 7.2.

8.4 Cycling endurance test in photovoltaic applications (extreme conditions)

8.4.1 General

In photovoltaic applications the battery will be exposed to a large number of shallow cycles but at different states of charge. The test below is designed to simulate such service under extreme conditions by submitting the batteries at +40 °C, to several aggregates of discharge/charge cycles each comprising 50 cycles at low state of charge (phase A) and 100 cycles at high state of charge (phase B).

NOTE One set of 150 aggregate cycles is approximately equivalent to 1 year service in a PV energy storage application.

The cells or batteries shall therefore comply with the requirements of the test below, which is a simulation of the photovoltaic energy system operation:

a) the test battery shall be selected, prepared and installed according to the applicable standards listed in 7.2;
b) the test shall be carried out with a battery composed of such a number of cells that its open circuit voltage is > 12 V;
c) the test battery shall meet or exceed the rated capacity value when tested for capacity according to 8.1;
d) the test shall be started with the battery fully charged;
e) the test battery shall be brought to a temperature of +40 °C ± 3 K and stabilized at this temperature for 16 h;
f) the test battery shall be maintained at +40 °C ± 3 K throughout the test phase a) and b).

8.4.2 Phase A: shallow cycling at low state of charge (see Table 5)

8.4.2.1 Lead-acid batteries and other batteries

a) Discharge the battery for 9 h with a current I_{10} (A)

b) Recharge for 3 h with a current 1,03 I_{10} (A)

c) Discharge for 3 h with a current I_{10} (A).

8.4.2.2 Nickel-cadmium, Ni-MH and Lithium batteries

a) Discharge the battery for 9 h with a current 0,1 I_t (A)

b) Recharge for 3 h with a current 0,103 I_t (A)

c) Discharge for 3 h with a current 0,1 I_t (A).

The steps b) and c) shall be repeated 49 times

At the termination of the 49th execution of step c) the test batteries, still at +40 °C ± 3 K, shall be fully charged according to the manufacturers recommendations and then cycling as specified for phase B shall be continued.

Table 5 – Phase A – Shallow cycling at low state of charge

	Discharge duration h	Charge duration h	Lead-acid and other batteries current A	Nickel-cadmium, Ni-MH and Lithium batteries current A
a)	9		I_{10} (A)	0,1 I_t (A)
b)		3	1,03 I_{10} (A)	0,103 I_t (A)
c)	3		I_{10} (A)	0,1 I_t (A)
Repeat b) to c) 49 times and continue to phase B.				

8.4.3 Phase B: shallow cycling at high state of charge (see Table 6)

- **<u>Lead-acid batteries and other batteries</u>**
  a) Discharge the battery for 2 h with a current 1,25 I_{10}
  b) Recharge for 6 h with a current I_{10} (A) until for lead-acid batteries a voltage of 2,40 V/cell is reached, unless otherwise specified by the manufacturer, and then continue charging at 2,40 V/cell until a total charging time of 6 h is reached. For other batteries the charge voltage shall be limited to a safe level as specified by the manufacturer
- **<u>Nickel-cadmium, Ni-MH and lithium batteries</u>**
  a) Discharge the battery for 2 h with a current de 0,125 I_t (A)
  b) Recharge for 6 h with a current 0,1 I_t (A) until, for vented Ni-Cd batteries, a voltage of 1,55 V/cell is reached unless otherwise specified by the manufacturer, then continue charging at 1,55 V/cell until a total charging time of 6 h is reached.

  For Ni-MH and lithium batteries the charge voltage shall be limited to a safe level as specified by the manufacturer.

  The steps a) and b) shall be repeated 99 times.

  At the termination of the 99th execution of step b) the test battery shall be submitted to a capacity test according to 8.4.4.

Table 6 – Phase B – Shallow cycling at high state of charge

	Discharging time h	Charging time h	Lead-acid and other batteries current A	Nickel-cadmium, Ni-MH and lithium batteries current A
a)	2		1,25 I_{10} (A)	0,125 I_t (A)
b)		6	I_{10} (A) (For lead acid batteries charge voltage limited to 2,40 V/cell unless otherwise specified by the manufacturer)	0,1 I_t (A) (For vented nickel cadmium batteries charge voltage limited to 1,55 V/cell unless otherwise specified by the manufacturer)
Repeat a) to b) 99 times				

8.4.4 Residual capacity determination

a) At the conclusion of phase B, the battery shall be cooled down, under continued charge, to the temperature defined for a capacity test in the applicable standards as listed in 7.2, and then stabilized at this temperature for 16h.

b) The residual capacity test for lead acid and other batteries shall be carried out with the I_{10} current to 1,80 V × n cells for lead acid batteries and at the 0,2 I_t current to 1,00 V × n cells for nickel-cadmium, and Ni-MH batteries. For lithium batteries and other batteries the end voltages are defined by the battery manufacturer

c) At the completion of the residual capacity test, and if no condition for test termination is encountered (see below), the batteries shall be recharged according to the manufacturer's specifications and a new set of phase A) cycles initiated.

d) When the residual capacity is found in b) below 80 %, then the fully recharged batteries shall be submitted also to a determination of the C_{120} capacity according to the relevant standards and data of Table 4.

8.4.5 Test termination

The cycling endurance test in photovoltaic applications shall be considered terminated when one of the conditions below is fulfilled:

a) When during the discharge c) of phase A, a battery with n cells showed a voltage of n × 1,5 V/cell for lead acid batteries, n × 0,8 V/cell for nickel cadmium or Ni-MH batteries or n × XYZ V/cell i.e. the manufacturer's recommended minimum safe cell voltage for Lithium and other batteries.

b) When during the residual capacity determination according to 8.4.4, the determined capacity was found lower than 80 % of the rated capacity.

c) The cycling endurance in photovoltaic applications shall be expressed in terms of completed aggregate phase A+B cycles before a limit, as specified in a) or b) above, was encountered together with the value of C_{120} capacity, expressed in per cent of the rated one, as determined at the conclusion of the test.

8.4.6 Water consumption of flooded battery types and cells with partial gas recombination

During the cycle endurance test, vented type batteries may be topped up with water to the level indicated and with a quality specified by the manufacturer. The amount of water added shall be measured and reported.

8.4.7 Requirements

The minimum number of completed A+B phase cycle sequences (150 cycles each) shall be not less than 3.

9 Recommended use of tests

9.1 Type test

Type tests are:

- the rated capacity test and the charge retention test;
- the generic cycling endurance test;
- the cycling endurance test in photovoltaic application (extreme conditions).

The minimum number of cell or monobloc batteries shall be as specified in the applicable standards listed in 7.2 or in 8.4 above.

9.2 Acceptance test

9.2.1 Factory test

The acceptance test shall be agreed between the customer and the supplier. Compliance to marking, labelling or to the rated capacity shall be verified.

9.2.2 Commissioning test

At commissioning a capacity test is recommended to demonstrate the integrity of the installed battery system.

Bibliography

IEC 60721-1, *Classification of environmental conditions – Part 1: Environmental parameters and their severities*

IEC 62620, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Large format secondary lithium cells and batteries for use in industrial applications*[1]

---

[1] Under development.

This page deliberately left blank

British Standards Institution (BSI)

BSI is the national body responsible for preparing British Standards and other standards-related publications, information and services.

BSI is incorporated by Royal Charter. British Standards and other standardization products are published by BSI Standards Limited.

About us

We bring together business, industry, government, consumers, innovators and others to shape their combined experience and expertise into standards -based solutions.

The knowledge embodied in our standards has been carefully assembled in a dependable format and refined through our open consultation process. Organizations of all sizes and across all sectors choose standards to help them achieve their goals.

Information on standards

We can provide you with the knowledge that your organization needs to succeed. Find out more about British Standards by visiting our website at bsigroup.com/standards or contacting our Customer Services team or Knowledge Centre.

Buying standards

You can buy and download PDF versions of BSI publications, including British and adopted European and international standards, through our website at bsigroup.com/shop, where hard copies can also be purchased.

If you need international and foreign standards from other Standards Development Organizations, hard copies can be ordered from our Customer Services team.

Subscriptions

Our range of subscription services are designed to make using standards easier for you. For further information on our subscription products go to bsigroup.com/subscriptions.

With **British Standards Online (BSOL)** you'll have instant access to over 55,000 British and adopted European and international standards from your desktop. It's available 24/7 and is refreshed daily so you'll always be up to date.

You can keep in touch with standards developments and receive substantial discounts on the purchase price of standards, both in single copy and subscription format, by becoming a **BSI Subscribing Member**.

PLUS is an updating service exclusive to BSI Subscribing Members. You will automatically receive the latest hard copy of your standards when they're revised or replaced.

To find out more about becoming a BSI Subscribing Member and the benefits of membership, please visit bsigroup.com/shop.

With a **Multi-User Network Licence (MUNL)** you are able to host standards publications on your intranet. Licences can cover as few or as many users as you wish. With updates supplied as soon as they're available, you can be sure your documentation is current. For further information, email bsmusales@bsigroup.com.

Revisions

Our British Standards and other publications are updated by amendment or revision.

We continually improve the quality of our products and services to benefit your business. If you find an inaccuracy or ambiguity within a British Standard or other BSI publication please inform the Knowledge Centre.

Copyright

Useful Contacts:

Customer Services
Tel: +44 845 086 9001
Email (orders): orders@bsigroup.com
Email (enquiries): cservices@bsigroup.com

Subscriptions
Tel: +44 845 086 9001
Email: subscriptions@bsigroup.com

Knowledge Centre
Tel: +44 20 8996 7004
Email: knowledgecentre@bsigroup.com

Copyright & Licensing
Tel: +44 20 8996 7070
Email: copyright@bsigroup.com

BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK

...making excellence a habit.™