IEC 60095-1

Edition 8.0 2018-11
REDLINE VERSION

INTERNATIONAL STANDARD

colour inside

Lead-acid starter batteries –
Part 1: General requirements and methods of test

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IEC 60095-1:2018-11 RLV(en)

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IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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Lead-acid starter batteries –
Part 1: General requirements and methods of test

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LEAD-ACID STARTER BATTERIES –

Part 1: General requirements and methods of test

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 60095-1 has been prepared by IEC technical committee 21: Secondary cells and batteries.

This eighth edition cancels and replaces the seventh edition published in 2006. This edition constitutes a technical revision.

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

a) charge acceptance test;
b) cranking performance test;
c) charge retention test; and
d) endurance test added.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
21/974/FDIS	21/987/RVD

Full information on the voting for the approval of this International Standard 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 in the IEC 60095 series, published under the general title *Lead-acid starter batteries*, 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.

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LEAD-ACID STARTER BATTERIES –

Part 1: General requirements and methods of test

1 Scope

This part of IEC 60095 is applicable to lead-acid batteries with a nominal voltage of 12 V, used primarily as a power source for the starting of internal combustion engines, lighting, and for auxiliary equipment of internal combustion engine vehicles. These batteries are commonly called "starter batteries".

This document is applicable to batteries for the following purposes:

- batteries for passenger cars;
- batteries for commercial and industrial vehicles.

This document is not applicable to batteries for other purposes, such as the starting of railcar internal combustion engines or for motorcycles and other power sport vehicles.

This document defines many general properties of lead-acid batteries. Single sections can be referenced in other parts of the IEC 60095 series even if the application is excluded in the scope of this document.

This document specifies the:

- general requirements;
- essential functional characteristics, relevant test methods and results required,

for several classes of starter batteries:

- according to the general type of application;
- according to the type of product.

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, *International Electrotechnical Vocabulary – Chapter 482: Primary and secondary cells and batteries*

IEC 60095-2, *Lead-acid starter batteries – Part 2: Dimensions of batteries and dimensions and marking of terminals*

IEC 60095-4, *Lead-acid starter batteries – Part 4: Dimensions of batteries for heavy ~~trucks~~ vehicles*

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3 Terms and definitions

For the purposes of this document, the terms and definitions 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
flooded battery
lead-acid battery having a cover provided with one or more openings through which gaseous products may escape

3.2
enhanced flooded battery
EFB battery
flooded lead-acid battery with additional special design features to significantly improve the cycling capability compared to standard flooded batteries

3.3
valve regulated lead-acid battery
VRLA battery
lead-acid battery which is closed under normal conditions but which has an arrangement that allows the escape of gas if the internal pressure exceeds a predetermined value

Note 1 to entry: The VRLA battery cannot receive addition to the electrolyte and after activation of dry-charged VRLA.

Note 2 to entry: In VRLA batteries the electrolyte is immobilized.

3.4
absorbent glass mat battery
AGM battery
VRLA battery in which the electrolyte is immobilized by absorption in a glass mat

3.5
gel battery
VRLA battery in which the electrolyte is immobilized by fixing as a gel

4 ~~Classification and~~ Designation of starter batteries – Electrolyte density and open circuit voltage

~~**4.1 Battery classification according to application**~~

~~Three classes of batteries are defined according to their application, as follows:~~

~~– Class A: batteries for starter applications with usual cycling capability and normal mechanical resistance;~~

~~– Class B: batteries for starter applications which have an important higher requirement in cycling ability and /or mechanical resistance;~~

~~– Class C: batteries for starter applications and high temperature duty.~~

4.1 ~~Battery~~ Designation according to type

Batteries are designated according to their type, as follows:

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~~– Vented (flooded) battery: a vented battery is a secondary battery having a cover provided with one or more openings through which gaseous products may escape.~~

~~– Valve-regulated (with gas recombination) battery: a valve-regulated battery is a secondary battery that is closed under normal conditions and has an arrangement that allows the escape of gas if the internal pressure exceeds a predetermined value. The battery cannot normally receive an addition of water or electrolyte. In this type of battery, the electrolyte is immobilised.~~

- flooded batteries (vented);
- enhanced flooded batteries, EFB;
- valve regulated lead-acid batteries, VRLA;
  - absorbent glass mat batteries, AGM;
  - gel batteries.

4.2 Dry-charged batteries

Lead-acid batteries may be supplied in a dry-charged state. Dry-charged batteries can be activated by filling with the defined electrolyte indicated by internal or external marks or according to the manufacturer's activation instructions. After activation, these batteries are ready to use.

4.3 Electrolyte density and open circuit voltage

The density of the electrolyte in all fully charged vented batteries shall be in the range of 1,27 kg/l to 1,30 kg/l at 25 °C unless otherwise specified by the manufacturer.

NOTE For valve-regulated batteries, the electrolyte is not accessible and, therefore, its density cannot be checked.

The open circuit voltage (OCV) at 25 °C, of fully charged batteries after a minimum 24 h stand on open circuit, shall be in the range of 12,70 V to 12,90 V for vented types and 12,80 V ~~minimum~~ to 13,10 V for valve regulated types unless otherwise specified by the manufacturer.

The manufacturer shall specify the value and tolerance of the electrolyte density or OCV. If such information is not available, vented battery testing shall be carried out with a density of 1,28 kg/l ± 0,01 kg/l at 25 °C or an OCV of 12,76 V ± 0,06 V at 25 °C and valve regulated battery testing shall be carried out with a minimum OCV of 12,80 V.

5 Condition on delivery

New vented batteries may be supplied either:

- in a state ready for use, or
- in a dry-charged (or charge-conserved) state not filled with electrolyte. The density of the electrolyte to fill these batteries before use (unless otherwise recommended by the manufacturer) shall be:
  - 1,28 kg/l ± 0,01 kg/l at 25 °C;

Valve-regulated batteries are normally supplied in a state ready for use.

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6 General requirements

6.1 Identification, labelling

6.1.1 General

Batteries ~~according to~~ complying with this document shall bear the following characteristics on at least the top or one of their four sides.

6.1.2 The identification of manufacturer or supplier

The name of the manufacturer or supplier shall be indicated.

~~**6.1.2 Class of battery: (IEC) A, B or C (see 4.1)**~~

~~NOTE In some countries, the class is indicated by the battery numbering system. In these cases, there is no need to include the class on the label.~~

6.1.3 Nominal voltage: 12 V

The nominal voltage of 12 V shall be indicated.

~~**6.1.4 Capacity: (see 7.1.2)**~~

~~– either 20 hour capacity C_n (Ah),~~

~~– or reserve capacity C_{rn} (min).~~

~~NOTE In some countries, the capacity is indicated by the battery numbering system. In these cases, there is no need to include the capacity on the label.~~

~~**6.1.5 Nominal cranking current: I_{cc} (A) (see 7.1.1)**~~

6.1.4 Capacity or reserve capacity (see 7.1.2) and nominal cranking current (see 7.1.1)

Three options are possible for the identification and labelling of capacity (or reserve capacity) and nominal cranking current:

Option 1:

- 20 h capacity C_{20} (Ah);
- with nominal cranking current I_{cc} (A) (see 7.1.1 and 9.3.1) defined at −18 °C with $U_{10s} \geq 7{,}5$ V and $U_{90s} \geq 6{,}0$ V (under $I_{cc}/0{,}6$).

Option 2:

- reserve capacity RC (minutes);
- with nominal cranking current I_{cc} (A) (see 7.1.1 and 9.3.1) defined at −18 °C with $U_{30\,s} \geq 7{,}20$ V.

Option 3:

- 20 h capacity C_{20} (Ah);
- with nominal cranking current I_{cc} (A) (see 7.1.1 and 9.3.1) defined at −18 °C with $U_{30\,s} > 7{,}20$ V.

NOTE These three options are in accordance with the present use in the different areas in the world.

The preferred version is Option 1.

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6.1.5 Production date code

Batteries shall be marked with the date of production. This can be part of a more complex code.

6.1.6 Safety labelling

~~Batteries shall be marked with the six coloured symbols as described in part 1 of Annex B.~~

If under national regulations, coloured safety symbols are required to be used, they should follow the design as set out in Annex C, Clause C.1.

However, to be in compliance with some national regulations, additional wording or special labelling can be used (for example, the safety label for North America area shown in Annex C, Clause C.2).

6.1.7 Recycling labelling

Batteries shall be marked for separate collection and recycling, if required by local area regulations.

6.1.8 Valve-regulated batteries

VRLA batteries shall be marked using the term "VRLA". In addition it is recommended that ~~Valve regulated~~ VRLA batteries shall bear special indication ~~mentioning~~ that the battery shall not be opened.

EXAMPLE: "VRLA – Do not open"

6.2 Marking of the polarity

The terminals shall be identified according to the requirements of IEC 60095-2 or of IEC 60095-4.

~~6.3 Water loss designation~~

~~Vented starter batteries may be designated as "Low water loss" or "Very low water loss" according to IEC 60095-1, if they comply with the requirements of 9.5 and 9.7. If they do not comply, they are designated as "Normal".~~

~~This additional designation shall be indicated either on the battery label or in the catalogue.~~

~~NOTE Starter batteries are subject to a wide variety of operating conditions, for example temperature, overcharge voltage, etc., that have an influence on the decomposition of water from the electrolyte, regardless of internal design features. Thus, the terms "low water loss" or "very low water loss" in the sense of this standard are linked to well-defined conditions in 9.7 that do not cover the complete range of practical operating conditions.~~

6.3 Fastening of the battery

Where batteries are fastened to the vehicle by means of integral parts (for example, bottom ledges), these shall be in compliance with the requirements of IEC 60095-2 and of IEC 60095-4.

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7 Functional characteristics

7.1 Electrical characteristics

7.1.1 The cranking performance is the discharge current I_{cc}, as indicated by the manufacturer according to the option chosen (Option 1 or Option 2), which a battery can supply according to 9.3.

7.1.2 The *capacity* of a starter battery is defined for a temperature of 25 °C ± 2 °C.

It may be indicated by the manufacturer as either:

- nominal 20 h capacity ~~C_n~~ C_{20}, or
- nominal reserve capacity ~~$C_{r,n}$~~ RC_n.

The nominal 20 h capacity C_n is the electric charge in ampere hours (Ah) that a battery can supply with a current:

$$I_n = C_n / 20\ \text{h} \quad \text{(A)}$$

until the terminal voltage falls to U_f = 10,50 V.

The effective 20 h capacity C_e shall be determined by discharging a battery with constant current I_n to U_f = 10,50 V (see 9.1). The resultant discharge time, in hours, is used for the verification of C_n.

The nominal reserve capacity ~~$C_{r,n}$~~ RC_n is the period of time (in minutes) for which a battery can maintain a discharge current of 25 A to a cut-off voltage U_f = 10,50 V.

The effective reserve capacity ~~$C_{r,e}$~~ RC_e shall be determined by discharging a battery with the constant current I = 25 A to U_f = 10,50 V (see 9.2). The resultant discharge time, in minutes, is used for the verification of ~~$C_{r,n}$~~ RC_n.

NOTE For the correlation (relationship) of C_n and ~~$C_{r,n}$~~ RC_n, see Annex A.

7.1.3 The *charge acceptance* is expressed as the current I_{ca} which a partially discharged battery accepts at 0 °C and a constant charging voltage of 14,40 V.

7.1.4 The *charge retention* is ~~defined as~~ rated by the cold cranking performance of the charged and filled battery after storage on open circuit under defined conditions of temperature and time (see 9.5).

7.1.5 *The endurance test consists of two parts:*

~~**7.1.5.1**~~ • the corrosion test represents the ability of a battery to perform repeated overcharge/storage periods (see 9.6.1.1).

~~**7.1.5.2**~~ • the *cycling test* represents the ability of a battery to perform repeated discharge/recharge cycles and long rest periods on open circuit. This ability shall be tested by a series of cycles and rest periods under specified conditions after which the cold cranking or the capacity performances shall be determined (see 9.6.1.2 or 9.6.2).

~~**7.1.6** *Water consumption*: maintenance-free service of a battery requires a low rate of water decomposition through overcharge (see 9.7).~~

~~Valve regulated batteries have a very low water consumption and are not intended to receive additional water.~~

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The water consumption test checks if the battery can keep its performance under extended exposure to heat and overcharge conditions. It is measured as loss of weight during overcharge of a fully charged battery and is defined as g/Ah C_e (see 9.7).

~~**7.1.7** *Dry charged battery (or conserved charge battery)*: a new battery may be designated as dry charged (or conserved charge) if it can be activated ready for service just by filling it with the appropriate electrolyte and if it then conforms to the requirements of 9.10.~~

7.2 Mechanical characteristics

7.2.1 *Vibration resistance* represents the ability of a battery to maintain service under periodic or irregular acceleration forces. Minimum requirements shall be verified by a test (see 9.8).

7.2.2 *Electrolyte retention* is the ability of a battery to retain the electrolyte under specified physical conditions (see 9.9).

8 General test conditions

8.1 Sampling of batteries

~~All tests shall be carried out on new battery samples. Samples shall be considered as "new" not later than:~~

~~– 30 days after shipment date of the manufacturer in the case of filled batteries;~~

~~– 60 days after shipment date of the manufacturer in the case of dry-charged or charge-conserved batteries.~~

Samples shall be tested not later than:

- 45 days after the production date of the manufacturer in the case of filled batteries;
- 60 days after the production date of the manufacturer in the case of dry-charged batteries.

8.2 ~~Preparation of batteries prior to test~~ Charging method – Definition of a fully charged battery

~~All tests, except that in 9.10, shall commence with fully-charged batteries.~~

~~Vented batteries shall be considered as fully-charged if they have undergone one of the two charging procedures of 8.2.1 or 8.2.2 carried out at 25 °C ± 10 °C. If necessary, an appropriate temperature control system, for example a water bath, shall be used.~~

~~Valve regulated batteries shall be considered as fully-charged if they have undergone one of the two charging procedures of 8.2.3 or 8.2.4 carried out at 25 °C ± 10 °C. If necessary, an appropriate temperature control system, for example a water bath, shall be used.~~

~~8.2.1 Charging of vented batteries at constant current~~

~~The battery shall be charged:~~

~~– at a constant current of 2 I_n (see 7.1.2), until voltage stabilisation is established when three consecutive voltage or specific density measurements, corrected for the battery temperature, taken at 15 min intervals, remain constant.~~

~~8.2.2 Charging of vented batteries at constant voltage and constant current~~ (two step method)

~~The battery shall be charged:~~

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~~– at a constant voltage of *U* Volt for 20 h with the maximum current limited to 5 In (see 7.1.2)~~

~~where *U* is related to the battery water loss level (as for cycling tests):~~

~~Normal water loss *U* = 14,80 V ± 0,10 V~~

~~Low water loss *U* = 15,20 V ± 0,10 V~~

~~Very low water loss *U* = 16,00 V ± 0,10 V~~

~~– then with a constant current charge of In for 4 h.~~

~~In the case of recharging after a test for cranking performance (according to 9.3) the charging time at constant voltage may be limited to 10 h.~~

~~NOTE If neither complete knowledge of the battery construction nor a specification from the manufacturer is available, then charging according to the present subclause (8.2.2) with U = 14,8V is recommended.~~

~~8.2.3 Charging of valve regulated batteries at constant current (two step method)~~

~~The battery shall be charged:~~

~~– at a constant current of 2 I_n (see 7.1.2), until the voltage reaches 14,40 V;~~

~~– then at a constant current of I_n for 4h.~~

~~8.2.4 Charging of valve regulated batteries at constant voltage and constant current (two step method)~~

~~The battery shall be charged:~~

~~– at a constant voltage of 14,40V ± 0,10 V for 20 h with the maximum current limited to 5 I_n (see 7.1.2),~~

~~– then with a constant current of 0,5 I_n for 4 h.~~

~~NOTE If neither complete knowledge of the battery construction nor a specification from the manufacturer is available, then charging according to the present subclause (8.2.4), is recommended.~~

Batteries shall be considered as fully charged if they have undergone the charging procedures. Prior to the first capacity test, the battery charge shall be limited to 16 h.

If not specified differently by the battery manufacturer, the batteries that will be tested according to this document shall be charged according to Table 1.

Table 1 – Charging method

Battery type	Voltage U_C	Current	Time	Remarks
Flooded batteries with size in accordance with IEC 60095-2	16,00 V ± 0,05 V	5 I_n	24 h (16 h)[a]	
Flooded batteries with size in accordance with IEC 60095-4	16,00 V ± 0,05 V	5 I_n	20 h (16 h)[a]	Step 1
	no limitation	I_n	4 h	Step 2
Valve-regulated batteries VRLA	14,80 V ± 0,05 V	5 I_n	24 h (16 h)[a]	

[a] A charging time of 16 h is sufficient after a cranking performance test and prior to the first capacity check.

All charges shall be performed with batteries in a water bath at 25 °C ± 2 °C.

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~~8.3 Activation of dry-charged or charge-conserved batteries~~

~~Dry charged batteries shall be filled with the appropriate electrolyte (according to 4.3) to the maximum level indicated by internal or external marks of the battery or according to the manufacturer's instructions.~~

8.3 Test equipment

8.3.1 Measuring instruments

~~8.4.1 Electrical measuring instruments~~

~~The range of instruments used shall be appropriate for the magnitude of the voltage or current to be measured.~~

~~– Voltage measurement:~~

~~The instruments used for measuring voltages shall be digital voltmeters having an accuracy of ±0,04V or better.~~

~~– Current measurement:~~

~~The instruments used for current measurement shall be digital ammeters having an accuracy of 1,0 % or better. The assembly of ammeter, shunt and leads shall have an overall accuracy of 1,0 % or better.~~

~~8.4.2 Temperature measurement~~

~~The thermometers used for measuring temperature shall have an appropriate range, and the value of each scale division shall not be greater than 1 K. The accuracy of the calibration of the instruments shall be not less than 0,5 K.~~

~~8.4.3 Density measurement~~

~~The density of the electrolyte shall be measured with hydrometers having either graduated scale or digital displays that are able to register increments of 0,005 kg/l.~~

~~8.4.4 Time measurement~~

~~The instruments used for measuring time shall be graduated in hours, minutes or seconds. They shall have an accuracy within ±0,1 % in all cases with the exception of cranking performance tests where the times measured in seconds shall have an accuracy within ±1,0 %.~~

The range of instruments used shall be appropriate for the magnitude of the parameters to be measured. The minimum accuracy of test equipment is given in Table 2.

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Table 2 – Accuracy of test equipment

Parameter	Accuracy of test equipment
Current for cold cranking tests	0,5 %
Current for other tests	1 % full-scale with a minimum accuracy of ±30 mA
Voltage	± 0,04 V
Temperature	± 1 °C
Time	± 1 s
Density of electrolyte	≤ 0,005 kg/l
Weight of battery	± 1 g below 30 kg ± 5 g above 30 kg

The instruments used for measuring time shall be graduated in hours, minutes and seconds.

8.3.2 Water bath

If a test needs to be carried out in a water bath, the following conditions shall be fulfilled. The terminal base of the battery shall be at least 15 mm but not more than 25 mm above the water surface level. If several batteries are in the same water bath then the distance between them and also the distance to the walls of the bath shall be at least 25 mm.

Minimum soak time for batteries in the water bath is 4 h.

If not stated differently in the individual test description, the tolerance for the temperature of the water bath is ±2 °C.

It is recommended to cover the surface of the water with floating elements using testing temperatures of 40 °C or more. This improves the thermal isolation against air and avoids evaporation of water.

8.3.3 Environmental chamber

If a test needs to be carried out in an environmental chamber, the batteries are placed in an air gaseous phase at the requested temperature and tolerance; the wind velocity near the battery shall not be more than 2,0 m/s.

Minimum time for batteries in the environmental chamber before the test beginning is 8 h.

8.4 Test sequence

8.4.1 Batteries filled and charged

a) Initially, the batteries are subjected to the following series of tests:

- first C_e or ~~$C_{r,e}$~~RC_e check;
- first cranking performance test;
- second C_e or ~~$C_{r,e}$~~RC_e check;
- second cranking performance test;
- third C_e or ~~$C_{r,e}$~~RC_e check;
- third cranking performance test.

For C_e or RC_e and the cranking performance, the specified values shall be met in at least one of the relevant discharges above.

It is not necessary to complete the sequence if the specified values are achieved on the first or second test.

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NOTE The choice between testing C_e or RC_e is the decision of the customer or user.

b) The tests according to Table 3 shall be carried out only if batteries have complied with the previous tests, and not later than one week after completion of the first part.

Table 3 – Test/~~Battery~~ sequence

~~Test~~		~~Battery~~					
		~~1~~	~~2~~	~~3~~	~~4~~	~~5~~	~~6~~
~~1st 20 h capacity~~	~~1st reserve capacity~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~
~~1st cranking performance~~		~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~
~~2nd 20 h capacity~~	~~2nd reserve capacity~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~
~~2nd cranking performance~~		~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~
~~3rd 20 h capacity~~	~~3rd reserve capacity~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~
~~3rd cranking performance~~		~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~
~~Endurance tests (9.6)~~	~~Corrosion test~~ ~~Cycling test~~	~~X~~	~~X~~				
~~Charge retention (9.5)~~					~~X~~		
~~Charge acceptance (9.4)~~				~~X~~			
~~Electrolyte retention (9.9)~~					~~X~~		
~~Vibration resistance (9.8)~~						~~X~~	
~~Water consumption (9.7)~~							~~X~~
~~NOTE The test for water consumption should be applied only to vented "low water loss" or "very low water loss" batteries according to 6.3.~~							

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Step	Test	Reference	Battery					
			No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
0	Cranking performance for dry charged batteries	8.4.2 and 9.10	✓	✓	✓	✓	✓	✓
1	Initial charge prior to test	8.2	✓	✓	✓	✓	✓	✓
2	First 20 h capacity or First reserve capacity	9.1 or 9.2	✓	✓	✓ C_{20}	✓	✓	✓
3	First cranking performance according to Option 1 or Option 2	9.3.1	✓	✓	✓	✓	✓	✓
4	Second 20 h capacity Second reserve capacity	9.1 or 9.2	(✓)	(✓)	✓ C_{20}	(✓)	(✓)	(✓)
5	Second cranking performance according to Option 1 or Option 2	9.3.1	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)
6	Third 20 h capacity Third reserve capacity	9.1 or 9.2	(✓)	(✓)	✓ C_{20}	(✓)	(✓)	(✓)
7	Third cranking performance according to Option 1 or Option 2	9.3.1	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)
8	Cranking performance – very cold climate	9.3.2	✓					
9	Corrosion test	9.6.1.1	✓					
10	Endurance in cycle test	9.6.1.2 or 9.6.2		✓				
11	Charge retention	9.5				✓		
12	Charge acceptance	9.4			✓			
13	Electrolyte retention	9.9				✓		
14	Vibration resistance	9.8					✓	
15	Water consumption	9.7						✓

Key

– ✓: test to be fulfilled.

– (✓): test to be fulfilled only if the previous identical test carried out failed.

Battery no. 3 shall perform the full sequence of 3 tests with 20 h capacity before the charge acceptance test in 9.4.

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8.4.2 Dry-charged or conserved-charge batteries

a) Initially, the batteries are subjected to:
   – initial cranking performance after filling with electrolyte (see 9.10).

b) The tests according to Table 3 shall be carried out only if the batteries have complied with the ~~previous~~ test mentioned in a) and no more than one weekafter the said test.

9 Tests methods

9.1 20 h capacity check C_e

~~9.1.1~~ Throughout the duration of the tests, the battery shall be placed in a water bath at a temperature of 25 °C ± 2 °C, in accordance with 8.3.2. ~~The terminal base of the battery shall be at least 15 mm but no more than 25 mm above the level of the water. If several batteries are in the same water bath then the distance between them and also the distance to the walls of the bath shall be at least 25 mm.~~

~~9.1.2~~ The battery shall be discharged with the current I_n (calculated according to 7.1.2) kept constant at ±2 % of the nominal value until the terminal voltage falls to 10,50 V ± 0,05 V. The duration t (h) of the discharge shall be recorded. The beginning of the discharge shall take place between 1 h to 5 h after the completion of charging according to 8.2.

The battery temperature, measured in one of the middle cells, if applicable, shall be 25 °C ± 2 °C before the discharge begins.

~~9.1.3~~ The capacity C_e is as follows:

$$C_e = t \times I_n \quad \text{(Ah)}$$

~~If the final battery temperature is different from 25 °C ± 2 °C the following temperature correction formula shall be used:~~

~~$C_{e25\,°C} = C_{eT}\,[1 - 0{,}01(T - 25)]$~~

9.2 Reserve capacity check ~~$C_{r,e}$~~ RC_e

~~9.2.1~~ Throughout the duration of the tests, the battery shall be placed in a water bath at a temperature of 25 °C ± 2 °C, in accordance with 8.3.2. ~~The terminal base of the battery shall be at least 15 mm but no more than 25 mm above the level of the water. If several batteries are in the same water bath then the distance between them and also the distance to the walls of the bath shall be at least 25 mm.~~

~~9.2.2~~ The battery shall be discharged with a current (25 ± 0,25) A ~~± 1 %~~ until the terminal voltage falls to 10,50 V ± 0,05 V. The duration t (in minutes) of the discharge shall be recorded. The beginning of the discharge shall take place between 1 h to 5 h after the completion of charging according to 8.2.

~~NOTE~~ The battery temperature, measured in one of the middle cells, if applicable, shall be 25 °C ± 2 °C before the discharge begins.

$$\text{~~$C_{r,e}$~~}\ RC_e = t \text{ (min)}$$

~~If the final battery temperature is different from 25 °C ± 2 °C the following temperature correction formula shall be used:~~

~~$C_{r,e25\,°C} = C_{r,eT}[1 - 0{,}009(T - 25)]$~~

9.3 Cranking performance test

9.3.1 Cranking performance test – Standard temperature (−18 °C)

~~9.3.1.1 After a rest period of up to 24h after preparation according to 6.2, the battery shall be placed in a cooling chamber with (forced) air circulation at a temperature of −18 °C ± 1 °C until the temperature in one of the middle cells has reached −18 °C ± 1 °C.~~

~~NOTE It is generally accepted that the required temperature will be achieved after a minimum period of 24h in the cooling chamber.~~

~~9.3.1.2 The battery shall then be discharged, either within or outside the cooling chamber, within 2 min after the end of the cooling period with a current I_{cc} (see 7.1.1). This current shall be kept constant to within ±0,5 % during the discharge.~~

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~~**9.3.1.3** After 10 s discharge, the terminal voltage U_{f10s} shall be recorded. After 30 s discharge, the terminal voltage U_{f30s} shall also be recorded and the current shall be cut off.~~

~~NOTE Subclauses 9.3.1.1 to 9.3.1.3 comprise stage 1 of the cranking performance test.~~

~~**9.3.1.4** The test shall be continued after a rest time of 20 s ± 1s.~~

~~**9.3.1.5** The battery shall then be discharged at 0,6 I_{cc}. The current shall be kept constant to within ± 0,5 % during the discharge. The discharge shall be terminated when the battery voltage reaches 6V.~~

~~**9.3.1.6** The discharge time (t_{6v}), in seconds, at 0,6 I_{cc} to 6V shall be recorded.~~

~~NOTE Subclauses 9.3.1.4 to 9.3.1.6 comprise stage 2 of the cranking performance test.~~

Option 1:

After a rest period of 24 h up to 72 h after preparation according to 8.2, the battery shall be placed in a cooling environmental chamber with (forced) air circulation at a temperature of −18 °C ± 1 °C until the temperature of the middle cells has reached −18 °C ± 1 °C.

It is generally accepted that the required temperature will be achieved after a minimum period of 24 h in the cooling environmental chamber.

The battery shall then be discharged, either within or outside the cooling chamber, within 2 min after the end of the cooling period with a current I_{cc} (see 7.1.1). This current shall be kept constant to within ± 0,5 % during the discharge.

After 10 s discharge, the terminal voltage U_f shall be recorded and the current shall be cut off.

The voltage U_f shall be not less than 7,50 V.

After a rest period of 10 s ± 1 s, the test shall be continued as follows:

The battery shall then be discharged at 0,6 I_{cc}. The current shall be kept constant to within ± 0,5 % during the discharge. The discharge shall be terminated when the battery voltage reaches 6 V. The discharge time ($t'_{6\,V}$) at 0,6 I_{cc} to 6 V shall be recorded in seconds. $t_{6\,V}$ is defined as the duration of the second stage ($t'_{6\,V}$) plus the equivalent duration of the first stage discharge if run at 0,6 I_{cc}, i.e. it is given, in seconds, by the following equation:

$$t_{6\,V} = t'_{6\,V} + \frac{10\ \text{s}}{0{,}6} = t'_{6\,V} + 17\ \text{s}$$

Requirements: the battery shall comply with the following requirement: $t_{6\,V} \geq 90$ s.

Option 2:

After a rest period of 24 h up to 72 h after preparation according to 8.2, the battery shall be placed in a cooling environmental chamber with (forced) air circulation at a temperature of −18 °C ± 1 °C until the temperature in one of the middle cells has reached −18 °C ± 1 °C.

It is generally accepted that the required temperature will be achieved after a minimum period of 24 h in the cooling chamber.

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The battery shall then be discharged, either within or outside the cooling environmental chamber, within 2 min after the end of the cooling period with a current I_{cc} (see 7.1.1). This current shall be kept constant to within ± 0,5 % during the discharge.

After 30 s discharge, the terminal voltage $U_{f30\ s}$ shall also be recorded and the current shall be cut off.

Requirements: the battery shall comply with the following requirement: $U_{f30\ s} \geq 7{,}2$ V.

9.3.2 Cranking performance test – Very cold climates

This test shall be performed only if the battery is specified for very cold climate application by the manufacturer.

The test method is the same as defined above in Option 2 for standard temperatures with:

- cooling environmental chamber temperature = −29 °C ± 1 °C;
- I_{cc} for very cold climate ~~rated on the battery label~~ specified by the manufacturer.

9.3.3 High current discharge test at low temperature

After a rest period of up to 72 h, the battery shall be placed in a cooling environmental chamber with (forced) air circulation at a temperature of −18 °C ± 1 °C until the temperature of the middle cells has reached −18 °C ± 1 °C.

It is generally accepted that the required temperature will be achieved after a minimum period of 24 h in the cooling environmental chamber.

The battery shall then be discharged, either within or outside the cooling environmental chamber within 2 min after the end of the cooling period with a current 0,6 I_{cc} (see I_{cc} definition in 7.1.1, Option 1). This current shall be kept constant to within ±0,5 % during the discharge.

After 30 s discharge, the terminal voltage $U_{30\ s}$ shall be recorded and the current shall be cut off.

Requirements: if not stated differently in the previous test, the voltage $U_{30\ s}$ shall be not less than 7,20 V.

9.4 Charge acceptance test

~~9.4.1~~ The test shall be carried out on batteries which have been charged in accordance with 8.2.~~2 (vented batteries) or 8.2.4 (VRLA batteries).~~

~~9.4.2~~ The battery shall be placed in a water bath at a temperature of 25 °C ± 2 °C, according to 8.3.2. ~~The terminal base of the battery shall be at least 15 mm but no more than 25 mm above the level of the water. If several batteries are in the same water bath then the distance between them and also the distance to the walls of the bath shall be at least 25 mm.~~

~~9.4.3~~ The battery shall be discharged at a current I_0:

$$I_0 = C_{e20} / 10\ \text{h (A) for 5 h.}$$

The value C_e shall be taken as the maximum value C_e of the three previous discharges in accordance with 9.1.

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~~**9.4.4**~~ Immediately after the discharge, the battery shall be cooled at a temperature of 0 °C ± 1 °C for a minimum of 20 h or until the temperature of one of the middle cells has reached 0 ºC ± 1 ºC.

~~**9.4.5**~~ At this temperature of 0 °C ± 1 °C, the battery shall be charged at a constant voltage of 14,40 V ± 0,10 V.

After 10 min, the charging current I_{ca} shall be recorded.

9.5 Charge retention test

~~**9.5.1** A fully-charged battery (according to 8.2), with its vent plugs firmly in place and a clean dry surface, shall be stored at 40 °C ± 2 °C on open circuit for a time (*t*) defined in 9.5.3. No connecting clamps or cables shall be attached to the terminals.~~

~~**9.5.2** After this storage period, the battery shall be submitted, without recharge, to a cranking performance test at −18 °C and a current $I = 0{,}6\ I_{cc}$. The voltage after 30 s (U_{30s}) shall be recorded.~~

~~**9.5.3 Storage time**~~

- ~~Normal water loss batteries (N) t = 10 days~~
- ~~Low water loss batteries (L) : t = 14 days~~
- ~~Very low water loss batteries (VL) : t = 49 days~~
- ~~Valve regulated batteries (VRLA) : t = 49 days~~

A fully charged battery (according to 8.2), with its vent plugs firmly in place and a clean dry surface, shall be stored at 40 °C ± 2 °C on open circuit for 21 days. No connecting clamps or cables shall be attached to the terminals.

After this storage period, the battery shall be submitted, without recharge, to a cranking performance test at −18 °C and a current $I = 0{,}6\ I_{cc}$. The voltage after 30 s ($U_{30\ s}$) shall be recorded.

Requirements:

- normal batteries (N) and low water loss batteries (L): $U_{30\ s} \geq 8$ V;
- very low water loss batteries (VL): $U_{30\ s} \geq 8{,}5$ V.

9.6 Endurance test for batteries

9.6.1 Corrosion test

9.6.1.1 General

The corrosion test unit is as follows.

~~**9.6.1.1**~~ • The test shall be carried out on fully charged batteries in accordance with 8.2~~.2 (vented batteries) or 8.2.4 (VRLA), but with the times of the constant voltage charge being limited to 10 h~~.

~~**9.6.1.2**~~ • The battery shall be placed in a water bath maintained at a temperature of 60 °C ± 2 °C, according to the installation described in 8.3.2~~. The terminal base of the battery shall be at least 15 mm but not more than 25 mm above the level of the water. If several batteries are in the same water bath then the distance between them and also the distance to the walls of the bath shall be at least 25 mm.~~

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9.6.1.3 • The battery, maintained at 60 °C ± 2 °C, shall be charged at a constant voltage of 14,00 V ± 0,10 V, for a period of 13 days.

9.6.1.4 • The battery shall be stored on open circuit, still at 60 °C ± 2 °C, for a period of 13 days. No connecting clamps or cables shall be attached to the terminals.

9.6.1.5 • The battery shall be cooled to reach 25 °C ± 2 °C. Purified water shall be added, if possible, to maintain the electrolyte level in accordance with the manufacturer's recommendations (this does not apply to VRLA batteries).

9.6.1.6 • The battery shall then be recharged in accordance with 8.2.2 (vented batteries) or 8.2.4 (VRLA) but with the times of the constant voltage charge being limited to for 6 h.

9.6.1.7 • The battery, maintained at 25 °C ± 2 °C, shall be stored for a rest period of 20 h.

9.6.1.8 • The battery shall be discharged with a current of 0,6 I_{cc} at 25 °C ± 2 °C for 30 s. The 30 s voltage shall be recorded.

9.6.1.9 The sequence 9.6.1.1 to 9.6.1.8 constitutes one corrosion test unit.

9.6.1.10 The whole sequence 9.6.1.1 to 9.6.1.8 This corrosion test unit shall be repeated and the test shall be terminated when the battery voltage reaches less than 7,2 V at 30 s with a current of 0,6 I_{cc} in cranking test at 25 °C ± 2 °C (see 9.6.1.8).

The number of corrosion test units to apply is mentioned in Table 6.

9.6.1.11 Requirements: number of units, see Clause 10.

9.6.2 Cycling test 1

9.6.2.1 Tests shall be carried out on fully charged batteries in accordance with 8.2.

9.6.2.2 Throughout the whole test period, with the exception of the rapid discharge test at the temperature of - 18 °C ± 1 °C, the battery shall be placed in a water bath at a temperature of 25° C ± 2 °C. The terminal base of the battery shall be at least 15 mm but not more than 25 mm above the level of the water. If several batteries are in the same water bath then the distance between them and also the distance to the walls of the bath shall be at least 25 mm.

9.6.2.3 Purified water shall be added to the battery as necessary during the test to maintain the electrolyte level in accordance with the manufacturer's recommendations except for "low water loss", "very low water loss" and VRLA batteries.

9.6.2.4 The batteries shall be connected to a device where they undergo a series of discharge/charge cycles for a required number of cycles, each cycle comprising:

a) a discharge for 1 hour at a current, in amperes, of $I = 5\ I_n$;

b) immediately followed

- by a recharge for 2 h and 55 min at a voltage depending on the battery technology with its related water loss level (see Table 2) with a maximum current in amperes being limited to $I_{max} = 10\ I_n$ (see 7.1.2), and
- for 5 min at a constant current, in amperes, of $I = 2{,}5\ I_n$ (N,L,VL),
- for 5 min at a constant current, in amperes, of $I = 0{,}5\ I_n$ (VRLA).

9.6.2.5 The test shall be terminated if the battery voltage drops below 10,50 V during the discharge prior to completion of the required number of cycles (see Clause 10).

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9.6.2.6 When the cycling is over, the battery shall be placed in a cooling chamber with (forced) air circulation at a temperature of −18 °C ± 1 °C for a minimum of 20 h or until the temperature in one of the middle cells has reached −18 °C ± 1 °C.

9.6.2.7 The battery shall then be discharged after the end of the cooling period with a current 0,6 I_{cc}.

9.6.2.8 After 30 s of discharge, the voltage across the battery terminals shall be measured. It shall not be less than 7,20 V. The discharge shall then be terminated.

9.6.2.9 Charging conditions

Charging voltage depends on the battery technology and is, therefore, related to the battery water loss level (see Table 2) or battery type. The water loss level used should be the value that is declared by the manufacturer. If this is not available, then it should be determined by tests according to 9.5 and 9.7.

Table 2 – Charging voltage

Water loss	Voltage
Very low (VL)	16,00 V ± 0,10 V
Low (L)	15,20 V ± 0,10 V
Normal (N)	14,80 V ± 0,10 V
Valve regulated (VRLA)	14,40 V ± 0,10 V or 14,80 V ± 0,10 V (according to manufacturer recommendation)

9.6.2.10 Requirements: number of cycles, see Clause 10

9.6.3 Cycling test 2

9.6.3.1 The test shall be carried out on batteries that have been charged in accordance with 8.2.2. (vented batteries) or 8.2.4 (VRLA batteries).

9.6.3.2 Throughout the whole test period, with the exception of the rapid discharge test at the temperature of -18 °C ± 1 °C, the battery shall be placed in a water bath at a temperature of 25° C ± 2 °C. The terminal base of the battery shall be at least 15 mm but not more than 25 mm above the level of the water. If several batteries are in the same water bath then the distance between them and also the distance to the walls of the bath shall be at least 25 mm.

9.6.3.3 Purified water shall be added to the battery as necessary during the test to maintain the electrolyte level in accordance with the manufacturer's recommendations except for "low water loss", "very low water loss" and VRLA batteries.

9.6.3.4 The batteries shall be connected to a device where they undergo a series of 18 cycles, each cycle comprising:

a) a discharge for 2 h at a current, in amperes, of $I = 5\ I_n$;

b) immediately followed:

- by a recharge for 4 h and 45 min at a voltage depending on the battery technology with its related water loss level (see Table 2) with a maximum current in amperes being limited to $I_{max} = 5\ I_n$ (see 7.1.2), and
- for 15 min at a constant current in amperes of $I = 2{,}5\ I_n$ (N,L,VL),
- for 15 min at a constant current in amperes of $I = 0{,}5\ I_n$ (VRLA).

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9.6.3.5 The battery, maintained at 25 °C ± 2 °C, shall be charged in accordance with 8.2.2 (vented batteries) or 8.2.4 (VRLA) but with the times at constant voltage charge being limited to 6 h.

9.6.3.6 The battery shall be stored on open circuit, still at 25 °C ± 2 °C, for 5 h.

9.6.3.7 The battery shall then be discharged at $I = 5\ I_n$ down to 10,00 V ± 0,05 V (Capacity: C).

9.6.3.8 The battery shall then be recharged in accordance with 8.2.2 or 8.2.4.

9.6.3.9 The sequence 9.6.3.2 to 9.6.3.8 constitutes one cycling test unit.

9.6.3.10 The whole sequence 9.6.3.2 to 9.6.3.8 shall be repeated to the required number of units. The actual capacity at the end of the last unit shall be $C \geq 0{,}5\ C_n$.

9.6.3.11 If the criteria $C \geq 0{,}5\ C_n$ is achieved, the battery shall be placed in a cooling chamber with (forced) air circulation at a temperature of –18 °C ± 1 °C for a minimum of 20 h or until the temperature in one of the middle cells has reached –18 °C ± 1 °C.

9.6.3.12 The battery shall then be discharged after the end of the cooling period with a current of $0{,}6\ I_{cc}$.

9.6.3.13 After 30 s of discharge, the voltage across the battery terminals shall be measured. It shall not be less than 7,20 V. The discharge shall then be terminated.

9.6.3.14 Requirements: number of units, see Clause 10.

9.6.4 Cycling test 3 (applicable to vented Batteries only with C_{20} from 60 Ah to 220 Ah)

9.6.4.1 The test shall be carried out on batteries that have been charged in accordance with 8.2.2 (vented batteries)

9.6.4.2 Throughout the whole test period, the battery shall be placed in a water bath at a temperature of 40° C ± 2 °C. The terminal base of the battery shall be at least 15 mm but not more than 25 mm above the level of the water. If several batteries are in the same water bath then the distance between them and also the distance to the walls of the bath shall be at least 25 mm.

9.6.4.3 Purified water shall be added to the battery as necessary during the test to maintain the electrolyte level in accordance with the manufacturer's recommendations.

9.6.4.4 The batteries shall be connected to a device where they undergo a series of cycles, each cycle comprising:

a) a discharge for 1 h at the discharge current, in amperes, as specified in Table 3.

b) immediately followed by a charge for 5 h at the charge current, in amperes, as specified in Table 3.

The cycle of this discharge and charge constitutes one endurance cycle.

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Table 3 – Discharge current and charge current

Capacity of battery (20 h rate)	Over 60 Ah up to and including 90 Ah	Over 90 Ah up to and including 220 Ah
Discharge current (A)	20	40
Charge current (A)	5	10

9.6.4.5 During the test, a continuous discharge is made after each 25 endurance cycles, at the discharge current specified in Table 3, until the terminal voltage of the battery falls to 10,2 V. The duration of discharge, in hours, shall be recorded.

9.6.4.6 The battery shall then be charged at the charge current specified in Table 3 until the terminal voltage of battery or the specific gravity of the electrolyte (corrected to 20 °C), measured every 15 min, remains constant for three consecutive readings.

9.6.4.7 The battery capacity obtained as the product of the discharge current and the duration of the discharges of tests carried out in line with clause 9.6.4.5 should be recorded and plotted on a graph of the number of endurance cycles against the battery capacity. When the battery capacity falls to 40 % or less of the battery's 20 hour capacity C_e, the cycling test has been completed and should be discontinued. The actual total number of endurance cycles can be obtained from the graph described above.

9.6.4.8 The required number of endurance cycles is defined as the number achieved when the capacity becomes 40 % of the 20 h capacity C_e and is obtained from Clause 10 which shows the required number as a relationship of the battery's 20h capacity.

9.6.5 Cycling test 4 (applicable to batteries with C_f from 40 min to 150 min)

9.6.5.1 The test shall be carried out on batteries that have been charged in accordance with 8.2.2. (vented batteries) or 8.2.4 (VRLA batteries).

9.6.5.2 Throughout the whole test period, the battery shall be placed in a water bath at a temperature of 40 °C ± 2 °C (or 75 °C ± 3 °C). The terminal base of the battery shall be at least 15 mm but not more than 25 mm above the level of the water. If several batteries are in the same water bath then the distance between them and also the distance to the walls of the bath shall be at least 25 mm.

9.6.5.3 Purified water should be added to the electrolyte as required during the cycling portion of the test with the exception of those batteries described as "low water loss ", " very low water loss" or VRLA.

9.6.5.4 The batteries shall be connected to a device where they undergo a continuous series of cycles, each cycle comprising:

a) a discharge for 240 s ± 1s at 25 A ± 0,1 A

b) followed, within 10 s, by a charge for 600 s ± 1 s at the maximum charge current of 25 A ± 0,1 A with a maximum charge voltage of 14,80 V ± 0,03 V,

with the interval between the charge and the discharge periods not exceeding 10 s, for 100 h $^{+12}_{-0}$ h.

9.6.5.5 The battery, maintained at the temperature chosen in clause 9.6.5.2, shall be stored on open circuit for between 65 h – 70 h.

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9.6.5.6 With the battery at the temperature selected in 9.6.5.2 , discharge at I_{cc} cranking amps for 30 s. The terminal voltage at 30 s (U_{30s}) shall be recorded together with the number of cycles described in 9.6.5.4.

9.6.5.7 The battery should be replaced on the cycling test without a separate charge, starting on the "charge" portion 'b)' of the cycle.

9.6.5.8 The cycling test should be considered complete when the terminal voltage at 30 s (U_{30s}) of 9.6.5.6 falls to below 7,20 V.The number of cycles shall be determined by plotting the 30s (U_{30s}) voltage values versus the cycle values. The point where the line crosses 7,20 V shall be the cycle reported for that battery.

9.6.5.9 Requirements: number of cycles, see Clause 10.

9.6.6 Endurance test sequence

According to their classification, batteries are submitted to the test sequence defined in Tables 4 and 5.

Table 4 – Endurance test sequence vented batteries

Battery class / Test	A [a]	B [b]	C
Corrosion	X	X	X
Cycling 1 or 4 (40 °C)	X		
Cycling 2 or 3		X	
Cycling 4 (75 °C)			X

a) Cycling test for class A batteries:

Batteries have to comply with either cycling test 1 or cycling test 4 (40° C). The choice between cycling test 1 and cycling test 4 has to be made by the battery manufacturer.

b) Cycling test for class B batteries:

Batteries have to comply with either cycling test 2 (preferred) or cycling test 3. The choice between cycling test 2 and cycling test 3 has to be made by the battery manufacturer.

Table 5 – Endurance test sequence VRLA batteries

Battery class / Test	A	B
Corrosion	X	X
Cycling 1 or 4 (40 °C)	X	
Cycling 2		X

9.6.1.2 Endurance in cycle test

The tests shall be carried out on fully charged batteries in accordance with 8.2.

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Table 4 – Parameters cycle test

Battery size according to:	Test temperature	Charging voltage U	Constant current I	Charging ratio CR
IEC 60095-2	+40 °C ± 2 °C	14,4 V for VRLA 15,6 V for flooded	I_n	1,08
IEC 60095-4	+25 °C ± 2 °C	15,6 V	2,5 I_n	1,10

The battery shall be placed in a water bath as defined in 8.3.2 and maintained at a temperature as stated in Table 4.

The charging voltage U and charging ratio CR defined as:

$$CR = \frac{2C_{rch}}{C_n}$$

stated in Table 4 shall be used if not otherwise specified by the manufacturer of the battery to be tested.

Only for batteries having a normal water loss requirement, purified water shall be added to the battery as necessary during the test to maintain the electrolyte level in accordance with the manufacturer's recommendations.

The batteries shall be connected to a test device where they undergo a series of cycles. Each cycle consists of the following steps.

Step 1: discharge the battery for 2 h with a constant current of I = 5 I_n. The cut-off criterion for this test is the voltage during the discharge. If it drops below 10,5 V the test shall be terminated.

Step 2: recharge the battery for maximum 5 h with a constant voltage and a current limitation of 5 I_n. Record the recharged capacity C_{rch} (Ah) during the charging.

Once the charging ratio CR reaches the specified value of Table 4, stop the charging.

Step 3: if the charging ratio CR is lower than specified in Table 4 after completion of Step 2, continue to recharge the battery in a second step with a constant current as specified in Table 4 until the charging ratio CR reaches the required value or until the maximum duration of 1 h for this step is reached.

Perform Steps 1 to 3 as long as the voltage during discharge is above the limit or until the number of cycles of the requirement level is reached as defined in Table 6.

A following high current discharge test in accordance with 9.3.3 shall be performed without any preceding recharge of the battery.

The number of cycles to apply is mentioned in Table 6.

The requirement for the capacity test (with a preceding charging according to 8.2) is:

$$C_e \geq 0{,}5\ C_{20}$$

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9.6.2 Optional endurance cycle test for passenger car batteries – Maximum capacity 100 Ah

The test shall be carried out on batteries that have been charged in accordance with 8.2.

Throughout the whole test period, the battery shall be placed in a water bath according to 8.3.2 at a temperature of 40 °C ± 2 °C.

Purified water should be added to the electrolyte as required during the cycling portion of the test with the exception of those batteries described as "low water loss", "very low water loss", or VRLA.

The batteries shall be connected to a device where they undergo a continuous series of cycles, with each cycle comprising:

a) a discharge for 240 s ± 1 s at 25 A ± 0,1 A;

b) followed, within 10 s, by a charge for 600 s ± 1 s at the maximum charge current of 25 A ± 0,1 A with a maximum charge voltage of 14,80 V ± 0,03 V;

with the interval between the charge and the discharge periods not exceeding 10 s, for 100 h $^{+12}_{0}$ h.

The battery, maintained at the temperature of 40 °C, shall be stored on open circuit for between 65 h to 70 h.

With the battery at the temperature selected 40 °C, discharge at I_{cc} cranking amps for 30 s. The terminal voltage at 30 s ($U_{30\ s}$) shall be recorded together with the number of cycles described.

The battery should be replaced on the cycling test without a separate charge, starting on the "charge" portion "b)" of the cycle.

The cycling test should be considered complete when the terminal voltage at 30 s ($U_{30\ s}$) of the cranking test falls to below 7,20 V. The number of cycles shall be determined by plotting the 30 s ($U_{30\ s}$) voltage values versus the cycle values. The point where the line crosses 7,20 V shall be the cycle reported for that battery.

The number of cycles to apply is mentioned in Table 6.

9.7 Water consumption test

This test applies only to vented batteries.

~~9.7.1~~ The battery, after being charged according to 8.2, shall be cleaned, dried and weighed to an accuracy of ± 0,05 % (W1).

~~9.7.2~~ The battery shall be placed in a water bath maintained at a temperature of 40 °C ± 2 °C according to the ~~same conditions as in 9.6.1~~ provisions of 8.3.2.

~~9.7.3~~ The battery shall be charged at a constant voltage of 14,40 V ± 0,05 V (measured across the battery terminals) for a period of 500 h.

~~9.7.4~~ Immediately after this overcharge period, the battery shall be weighed under the same conditions as ~~in 9.7.1~~ initially, with the same scales (W2).

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~~9.7.5~~ The ratio (W1-W2)/~~C_n~~C_{20} shall be calculated and compared against the requirements listed in ~~Clause 10~~ Table 6.

NOTE It is possible to carry out this test with a different temperature than 40 °C (for example 60 °C); see the correlation formula between temperatures in Annex B.

9.8 Vibration resistance test

~~9.8.1~~ After charging according to 8.2, the battery shall be stored for 24 h at a temperature of 25 °C ± 2 °C.

~~9.8.2~~ The battery shall be fastened rigidly to the table of the vibration tester. The fastening shall be of the same type as that used on a vehicle and secured by either:

- the bottom hold-downs or ledges on the lower part of the container and suitable hold-down clamps and bolts with M8 thread, tightened to a torque of between 15 Nm and 25 Nm, or
- an angle-iron frame covering the upper edges of the battery case/cover assembly for a minimum width of ~~*X* mm (see table 5)~~ 15 mm for batteries according to IEC 60095-2 and of 33 mm for batteries according to IEC 60095-4, connected to the vibration table by four screwed rods with M8 thread, tightened to a torque of between 8 Nm and 12 Nm.

~~9.8.3~~ The battery shall be subjected for a period of T (h) (see Table ~~6~~ 5) to a vertical vibration of a frequency of 30 Hz ± 2 Hz, these vibrations being as nearly sinusoidal as possible.

The maximum acceleration on the battery shall reach the value Z (see Table ~~6~~ 5).

~~NOTE~~ The battery temperature throughout the vibration shall be between 20 °C and 30 °C.

~~9.8.4~~ After a maximum of 4 h after the end of the vibration, the battery shall be subjected, without recharge, to a discharge at a temperature of 25 °C ± 2 °C with a current $I = I_{cc}$.

The terminal voltage after 30 s ($U_{30\ s}$) discharge shall be recorded. The discharge shall then be terminated.

~~**Table 6 – Values for vibration resistance test**~~

	~~Battery class~~	
	~~A, C~~	~~B~~
~~*X*~~	~~15 mm~~	~~33 mm~~
~~*T*~~	~~2 h~~	~~8 h~~
~~*Z*~~	~~30 ms^{-2} ± 1 ms^{-2}~~	~~50 ms^{-2} ± 1 ms^{-2}~~

Table 5 – Vibration resistance – Levels V1 to V3

Parameter	Requirement level		
	V1	V2	V3
Period of vibration, T	2 h	2 h	20 h
Maximum acceleration on the battery, Z	30 ms^{-2}	60 ms^{-2}	60 ms^{-2}

The requirement level V1 to V3 should be chosen according to customer application needs; however V3 is limited to applications that need extremely high vibration resistance.

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9.9 Electrolyte retention test

~~9.9.1~~ After charging according to 8.2, the battery shall be stored for 4 h on open circuit at a temperature of 25 °C ± 2 °C.

~~9.9.2~~ If necessary, the electrolyte level of each cell shall be adjusted to the maximum with purified water. The external surfaces of the battery shall be cleaned and dried.

~~9.9.3~~ The battery shall then be tilted in each of the four directions at intervals of not less than 30 s between each tilting as follows:

a) the battery shall be tilted through 45° from the vertical in a maximum period of 1 s;

b) the battery shall be maintained in this position for 3 s;

c) the battery shall be returned to the vertical position in a maximum period of 1 s.

~~9.9.4~~ Throughout the tests described above, the battery ~~must~~ shall be examined for any sign of electrolyte leaking from the battery. The observations shall be recorded.

9.10 Cranking performance for dry-charged (or conserved-charge) batteries after activation

~~9.10.1~~ The dry-charged battery and a sufficient amount of electrolyte supplied by the manufacturer, or according to the manufacturer's specifications, shall be stored at 25 °C ± 2 °C for at least 12 h (before filling).

~~9.10.2~~ The battery shall be filled with its electrolyte up to the level indicated by the manufacturer. After a rest period of 20 min at the same ambient temperature, the battery shall be discharged at a current $I = I_{cc}$ for 30 s.

The voltage after a discharge period of 30 s ($U_{30\ s}$) shall be recorded. The discharge shall then be terminated.

10 Requirements

The requirements applicable to essential functional characteristics are summarized in Table 6.

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Table 6 – Summary of requirements

Functional characteristics		Requirements	Comments
20 h capacity	(9.1)	$C_e \geq C_n$	For batteries rated in Ah
Reserve capacity	(9.2)	$C_{re} \geq C_{rn}$	For batteries rated in Reserve Capacity
Cranking performance test -18 °C or -29 °C (if specified)	(9.3)	$U_{10\ s} \geq 7{,}5$ V $U_{30\ s} \geq 7{,}2$ V $t_{6\ V} \geq 40$ s total time $\geq$ 90 s =(30/0,6 s + 40 s)	Compulsory Compulsory Optional
Charge acceptance	(9.4)	$I_{ca} \geq 2I_e$	
Charge retention	(9.5)	$U_{30\ s} \geq 8{,}0$ V	
Endurance	(9.6)		
Corrosion test	(9.6.1)	Number of units = 4	
Cycling test 1	(9.6.2)	Number of cycles = 120	Or higher if specified
Cycling test 2	(9.6.3)	Number of units = 5	Or higher if specified
Cycling test 3	(9.6.4)	Number of cycles = 2,8*Cn + 82 [a]	Or higher if specified
Cycling test 4 (40 °C & 75 °C)	(9.6.5)	Number of cycles = 34*Cr,n – 581 [b]	Or higher if specified
Water Consumption Normal batteries (N) Low water loss batteries (L) Very low water loss batteries (VL)	(9.7)	 no requirement < 4 g/Ah < 1 g/Ah	
Vibration	(9.8)	$U_{30\ s} \geq 7{,}2$ V	
Electrolyte retention	(9.9)	No evidence of liquid on the vent plugs. (Or from the single point vent outlet)	
Cranking performance after activation	(9.10)	$U_{30\ s} \geq 7{,}2$ V	
For both C_e or $C_{r,e}$ and the cranking performance, the specified values shall be met in at least one of the three relevant discharges above (see 9.1, 9.2, and 9.3).			
[a] This formula applies for C_{20} from 60 Ah to 220 Ah [b] This formula applies for C_r from 40 min to 150 min			

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Functional characteristics	See paragraph	Requirements	Comments
20 h capacity	9.1	$C_e \geq C_{20}$	For batteries rated in Ah
Reserve capacity	9.2	$RC_e \geq RC_n$	For batteries rated in reserve capacity
Cranking performance test −18 °C	9.3.1	Option 1 (for batteries rated in Ah) $U_{10\ s} \geq 7{,}50$ V $t_{6\ V} \geq 90$ s Option 2 (for batteries rated in reserve capacity) $U_{30\ s} \geq 7{,}20$ V	
Cranking performance test −29 °C	9.3.2	$U_{30\ s} \geq 7{,}20$ V	Optional
Charge acceptance	9.4	$I_{ca} \geq 2I_0$	
Charge retention Normal batteries (N) and Low water loss batteries (L)	9.5	$U_{30\ s} \geq 8{,}0$ V	
Charge retention Very low water loss batteries (VL)	9.5	$U_{30\ s} \geq 8{,}5$ V	
Corrosion test	9.6.1.1	Number of units ≥ 4	
Endurance in cycle test	9.6.1.2	Flooded (vented) ≥ 60 cycles VRLA ≥ 250 cycles	
Optional endurance in cycle test	9.6.2	Number of cycles = 34 × RC_n – 581	Optional
Water consumption Normal batteries (N)	9.7	No requirement	
Water consumption Low water loss batteries (L)	9.7	Maximum 4 g/Ah	
Water consumption Very low water loss batteries (VL)	9.7	Maximum 1 g/Ah	
Vibration	9.8	$U_{30\ s} \geq 7{,}2$ V	
Electrolyte retention	9.9	No evidence of liquid on the vent plugs (or from the single point vent outlet)	
Cranking performance after activation	9.10	$U_{30\ s} \geq 7{,}2$ V	
For both C_e or RC_e and the cranking performance, the specified values shall be met in at least one of the three relevant discharges above (see 9.1, 9.2, and 9.3).			

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Annex A
(normative)

Correlation between C_n and ~~$C_{r,n}$~~ RC_n

The value of ~~$C_{r,n}$~~ RC_n (in minutes) may be estimated from C_n (in ampere hours) using the following equation:

$$\text{~~}C_{r,n}\text{~~}\, RC_n = \beta\,(C_n)^{\alpha}$$

where

α = 1,182 8 for flooded batteries, or 1,120 1 for valve-regulated batteries;

β = 0,773 2 for flooded batteries, or 1,133 9 for valve-regulated batteries.

Reciprocal equation:

$$C_n = \delta\,(\text{~~}C_{r,n}\text{~~}\, RC_n)^{\gamma}$$

where

γ = 0,845 5 for flooded batteries, and 0,892 8 for valve-regulated batteries;

δ = 1,242 9 for flooded batteries, and 0,893 9 for valve-regulated batteries.

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Annex B
(informative)

Water consumption test – Conversion of test temperatures and test durations

B.1 General

This document recommends that the water consumption test be performed according to 9.7 at 40 °C. Other regional standards request a test temperature of 60 °C. If the same charging voltage of 14,4 V is used it is possible to convert the results from the 60 °C test to 40 °C conditions following Arrhenius law and a compensation reflecting possible differences in test duration.

B.2 Conversion formula

$$WL_{40} = \frac{500\,\text{h}}{d} \times \frac{1}{4} \times WL_{60}$$

where

WL_{40} is the water loss result according to IEC 60095-1 after 500 h charging with 14,4 V at 40 °C;

WL_{60} is the water loss result according to regional standard after d hours charging with 14,4 V at 60 °C;

d is the duration of 60 °C test procedure in hours.

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Annex C
(~~normative~~ informative)

Safety labelling

C.1 Definition of the six coloured symbols

~~The symbols mentioned in 6.1.5 are shown in Figure B.1:~~

IEC 2515/2000

~~**Figure B.1 – Symbols for safety labelling**~~

If coloured safety symbols are required to be used by national regulations, they should refer to the designs in accordance with ISO 7010.

Table C.1 – Definition of safety symbols according to ISO 7010

Reference	Description	Graphical symbol
ISO 7010 P003:2011-05	No open flame; Fire, open ignition source and smoking prohibited	
ISO 7010 M004:2011-05	Wear eye protection	
ISO 7010 P036:2012-06	No children allowed	
ISO 7010 W023:2011-05	Warning; Corrosive substance	
ISO 7010 M002:2011-05	Refer to instruction manual/booklet	
ISO 7010 W002:2011-05	Warning; Explosive material	

IEC 2516/2000

The individual symbols shall have common dimensions, as shown in Figure C.1, with ~~a~~ minimum dimensions of 10 mm.

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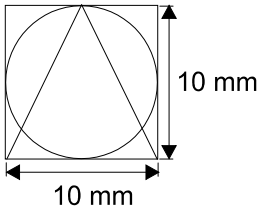

Figure C.1 – Symbol dimensions ~~for symbols in safety labelling~~

~~The symbols shall be located in a group on the top of the battery (as shown for example in Figure B.1).~~

~~No text in any language shall be included with the 6 symbol block.~~

~~The meaning of the 6 symbols is given by ISO standards~~

~~The meanings of the symbols are as follows:~~

~~(RED) No smoking, no naked flames, no sparks~~
~~(BLUE) Shield eyes~~
~~(RED) Keep away from children~~
~~(YELLOW) Battery acid~~
~~(BLUE) Note operating instructions~~
~~(YELLOW) Explosive gas~~

C.2 Safety labelling – Label for North America area

For information, specific safety labelling is used in North America: see Figures C.2 and C.3.

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Figure C.2 – Safety labelling – Label for North America area, former version (still valid)

Figure C.3 – Safety labelling – Label for North America area, new version

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Bibliography

ISO 7010, *Graphical symbols – Safety colours and safety signs – Registered safety signs*

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IEC 60095-1

Edition 8.0 2018-11

INTERNATIONAL STANDARD

colour inside

Lead-acid starter batteries –
Part 1: General requirements and methods of test

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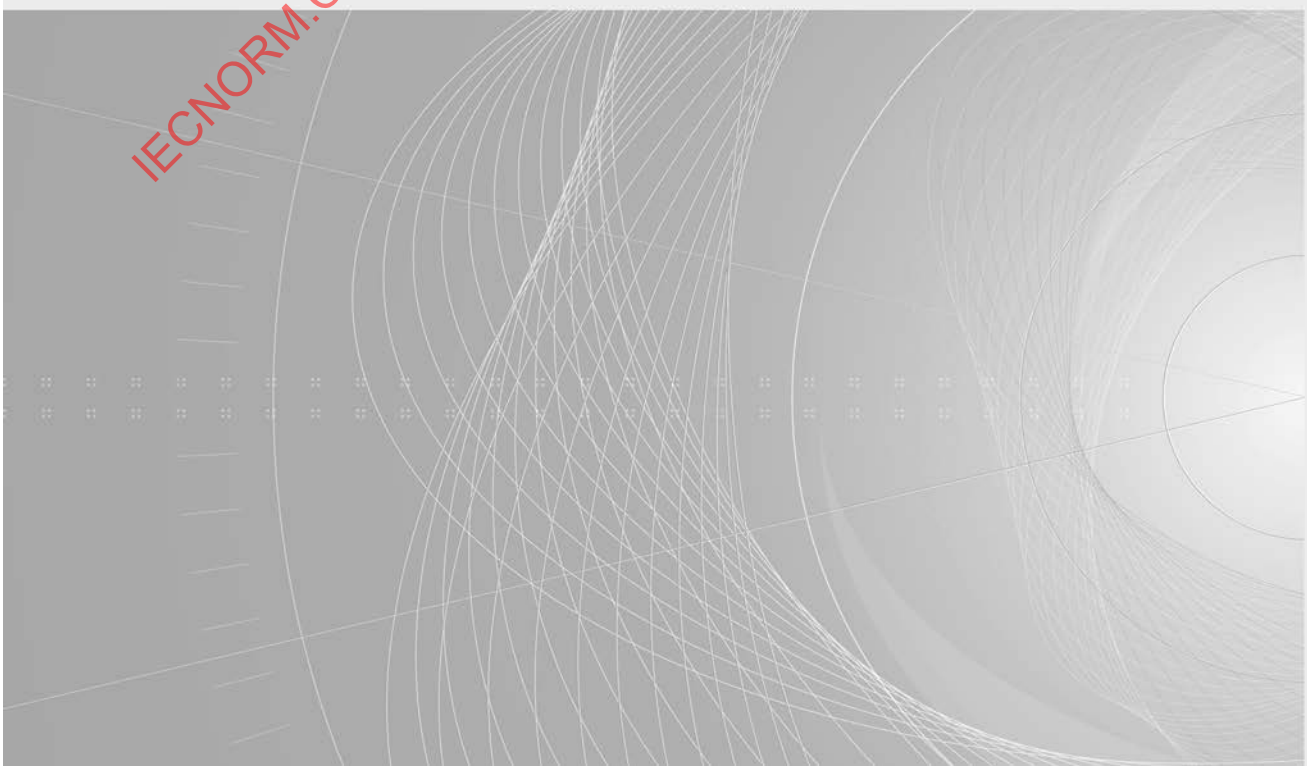

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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LEAD-ACID STARTER BATTERIES –

Part 1: General requirements and methods of test

FOREWORD

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International Standard IEC 60095-1 has been prepared by IEC technical committee 21: Secondary cells and batteries.

This eighth edition cancels and replaces the seventh edition published in 2006. This edition constitutes a technical revision.

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

a) charge acceptance test;
b) cranking performance test;
c) charge retention test; and
d) endurance test added.

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The text of this International Standard is based on the following documents:

FDIS	Report on voting
21/974/FDIS	21/987/RVD

Full information on the voting for the approval of this International Standard 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 in the IEC 60095 series, published under the general title *Lead-acid starter batteries*, 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.

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LEAD-ACID STARTER BATTERIES –

Part 1: General requirements and methods of test

1 Scope

This part of IEC 60095 is applicable to lead-acid batteries with a nominal voltage of 12 V, used primarily as a power source for the starting of internal combustion engines, lighting, and for auxiliary equipment of internal combustion engine vehicles. These batteries are commonly called "starter batteries".

This document is applicable to batteries for the following purposes:

- batteries for passenger cars;
- batteries for commercial and industrial vehicles.

This document is not applicable to batteries for other purposes, such as the starting of railcar internal combustion engines or for motorcycles and other power sport vehicles.

This document defines many general properties of lead-acid batteries. Single sections can be referenced in other parts of the IEC 60095 series even if the application is excluded in the scope of this document.

This document specifies the:

- general requirements;
- essential functional characteristics, relevant test methods and results required,

for several classes of starter batteries:

- according to the general type of application;
- according to the type of product.

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, *International Electrotechnical Vocabulary – Chapter 482: Primary and secondary cells and batteries*

IEC 60095-2, *Lead-acid starter batteries – Part 2: Dimensions of batteries and dimensions and marking of terminals*

IEC 60095-4, *Lead-acid starter batteries – Part 4: Dimensions of batteries for heavy vehicles*

3 Terms and definitions

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

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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
flooded battery
lead-acid battery having a cover provided with one or more openings through which gaseous products may escape

3.2
enhanced flooded battery
EFB battery
flooded lead-acid battery with additional special design features to significantly improve the cycling capability compared to standard flooded batteries

3.3
valve regulated lead-acid battery
VRLA battery
lead-acid battery which is closed under normal conditions but which has an arrangement that allows the escape of gas if the internal pressure exceeds a predetermined value

Note 1 to entry: The VRLA battery cannot receive addition to the electrolyte and after activation of dry-charged VRLA.

Note 2 to entry: In VRLA batteries the electrolyte is immobilized.

3.4
absorbent glass mat battery
AGM battery
VRLA battery in which the electrolyte is immobilized by absorption in a glass mat

3.5
gel battery
VRLA battery in which the electrolyte is immobilized by fixing as a gel

4 Designation of starter batteries – Electrolyte density and open circuit voltage

4.1 Designation according to type

Batteries are designated according to their type, as follows:

- flooded batteries (vented);
- enhanced flooded batteries, EFB;
- valve regulated lead-acid batteries, VRLA;
  - absorbent glass mat batteries, AGM;
  - gel batteries.

4.2 Dry-charged batteries

Lead-acid batteries may be supplied in a dry-charged state. Dry-charged batteries can be activated by filling with the defined electrolyte indicated by internal or external marks or according to the manufacturer's activation instructions. After activation, these batteries are ready to use.

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4.3 Electrolyte density and open circuit voltage

The density of the electrolyte in all fully charged vented batteries shall be in the range of 1,27 kg/l to 1,30 kg/l at 25 °C unless otherwise specified by the manufacturer.

NOTE For valve-regulated batteries, the electrolyte is not accessible and, therefore, its density cannot be checked.

The open circuit voltage (OCV) at 25 °C, of fully charged batteries after a minimum 24 h stand on open circuit, shall be in the range of 12,70 V to 12,90 V for vented types and 12,80 V to 13,10 V for valve regulated types unless otherwise specified by the manufacturer.

The manufacturer shall specify the value and tolerance of the electrolyte density or OCV. If such information is not available, vented battery testing shall be carried out with a density of 1,28 kg/l ± 0,01 kg/l at 25 °C or an OCV of 12,76 V ± 0,06 V at 25 °C and valve regulated battery testing shall be carried out with a minimum OCV of 12,80 V.

5 Condition on delivery

New vented batteries may be supplied either:

- in a state ready for use, or
- in a dry-charged (or charge-conserved) state not filled with electrolyte. The density of the electrolyte to fill these batteries before use (unless otherwise recommended by the manufacturer) shall be:
  - 1,28 kg/l ± 0,01 kg/l at 25 °C;

Valve-regulated batteries are normally supplied in a state ready for use.

6 General requirements

6.1 Identification, labelling

6.1.1 General

Batteries complying with this document shall bear the following characteristics on at least the top or one of their four sides.

6.1.2 The identification of manufacturer or supplier

The name of the manufacturer or supplier shall be indicated.

6.1.3 Nominal voltage: 12 V

The nominal voltage of 12 V shall be indicated.

6.1.4 Capacity or reserve capacity (see 7.1.2) and nominal cranking current (see 7.1.1)

Three options are possible for the identification and labelling of capacity (or reserve capacity) and nominal cranking current:

Option 1:

- 20 h capacity C_{20} (Ah);
- with nominal cranking current I_{cc} (A) (see 7.1.1 and 9.3.1) defined at −18 °C with U_{10s} ≥ 7,5 V and U_{90s} ≥ 6,0 V (under I_{cc}/0,6).

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Option 2:

- reserve capacity RC (minutes);
- with nominal cranking current I_{cc} (A) (see 7.1.1 and 9.3.1) defined at −18 °C with $U_{30\ s} \geq 7{,}20$ V.

Option 3:

- 20 h capacity C_{20} (Ah);
- with nominal cranking current I_{cc} (A) (see 7.1.1 and 9.3.1) defined at −18 °C with $U_{30\ s} > 7{,}20$ V.

NOTE These three options are in accordance with the present use in the different areas in the world.

The preferred version is Option 1.

6.1.5 Production date code

Batteries shall be marked with the date of production. This can be part of a more complex code.

6.1.6 Safety labelling

If under national regulations, coloured safety symbols are required to be used, they should follow the design as set out in Annex C, Clause C.1.

However, to be in compliance with some national regulations, additional wording or special labelling can be used (for example, the safety label for North America area shown in Annex C, Clause C.2).

6.1.7 Recycling labelling

Batteries shall be marked for separate collection and recycling, if required by local area regulations.

6.1.8 Valve-regulated batteries

VRLA batteries shall be marked using the term "VRLA". In addition it is recommended that VRLA batteries shall bear special indication that the battery shall not be opened.

EXAMPLE: "VRLA – Do not open"

6.2 Marking of the polarity

The terminals shall be identified according to the requirements of IEC 60095-2 or of IEC 60095-4.

6.3 Fastening of the battery

Where batteries are fastened to the vehicle by means of integral parts (for example, bottom ledges), these shall be in compliance with the requirements of IEC 60095-2 and of IEC 60095-4.

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7 Functional characteristics

7.1 Electrical characteristics

7.1.1 The cranking performance is the discharge current I_{cc}, as indicated by the manufacturer according to the option chosen (Option 1 or Option 2), which a battery can supply according to 9.3.

7.1.2 The capacity of a starter battery is defined for a temperature of 25 °C ± 2 °C.

It may be indicated by the manufacturer as either:

- nominal 20 h capacity C_{20}, or
- nominal reserve capacity RC_n.

The nominal 20 h capacity C_n is the electric charge in ampere hours (Ah) that a battery can supply with a current:

$$I_n = C_n / 20\ \text{h} \quad \text{(A)}$$

until the terminal voltage falls to U_f = 10,50 V.

The effective 20 h capacity C_e shall be determined by discharging a battery with constant current I_n to U_f = 10,50 V (see 9.1). The resultant discharge time, in hours, is used for the verification of C_n.

The nominal reserve capacity RC_n is the period of time (in minutes) for which a battery can maintain a discharge current of 25 A to a cut-off voltage U_f = 10,50 V.

The effective reserve capacity RC_e shall be determined by discharging a battery with the constant current I = 25 A to U_f = 10,50 V (see 9.2). The resultant discharge time, in minutes, is used for the verification of RC_n.

NOTE For the correlation (relationship) of C_n and RC_n, see Annex A.

7.1.3 The charge acceptance is expressed as the current I_{ca} which a partially discharged battery accepts at 0 °C and a constant charging voltage of 14,40 V.

7.1.4 The charge retention is rated by the cold cranking performance of the charged and filled battery after storage on open circuit under defined conditions of temperature and time (see 9.5).

7.1.5 The endurance test consists of two parts:

- the corrosion test represents the ability of a battery to perform repeated overcharge/storage periods (see 9.6.1.1).
- the cycling test represents the ability of a battery to perform repeated discharge/recharge cycles and long rest periods on open circuit. This ability shall be tested by a series of cycles and rest periods under specified conditions after which the cold cranking or the capacity performances shall be determined (see 9.6.1.2 or 9.6.2).

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7.1.6 The water consumption test checks if the battery can keep its performance under extended exposure to heat and overcharge conditions. It is measured as loss of weight during overcharge of a fully charged battery and is defined as g/Ah C_e (see 9.7).

7.2 Mechanical characteristics

7.2.1 Vibration resistance represents the ability of a battery to maintain service under periodic or irregular acceleration forces. Minimum requirements shall be verified by a test (see 9.8).

7.2.2 Electrolyte retention is the ability of a battery to retain the electrolyte under specified physical conditions (see 9.9).

8 General test conditions

8.1 Sampling of batteries

Samples shall be tested not later than:

- 45 days after the production date of the manufacturer in the case of filled batteries;
- 60 days after the production date of the manufacturer in the case of dry-charged batteries.

8.2 Charging method – Definition of a fully charged battery

Batteries shall be considered as fully charged if they have undergone the charging procedures. Prior to the first capacity test, the battery charge shall be limited to 16 h.

If not specified differently by the battery manufacturer, the batteries that will be tested according to this document shall be charged according to Table 1.

Table 1 – Charging method

Battery type	Voltage U_C	Current	Time	Remarks
Flooded batteries with size in accordance with IEC 60095-2	16,00 V ± 0,05 V	5 I_n	24 h (16 h)[a]	
Flooded batteries with size in accordance with IEC 60095-4	16,00 V ± 0,05 V	5 I_n	20 h (16 h)[a]	Step 1
	no limitation	I_n	4 h	Step 2
Valve-regulated batteries VRLA	14,80 V ± 0,05 V	5 I_n	24 h (16 h)[a]	
[a] A charging time of 16 h is sufficient after a cranking performance test and prior to the first capacity check.				

All charges shall be performed with batteries in a water bath at 25 °C ± 2 °C.

8.3 Test equipment

8.3.1 Measuring instruments

The range of instruments used shall be appropriate for the magnitude of the parameters to be measured. The minimum accuracy of test equipment is given in Table 2.

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Table 2 – Accuracy of test equipment

Parameter	Accuracy of test equipment
Current for cold cranking tests	0,5 %
Current for other tests	1 % full-scale with a minimum accuracy of ±30 mA
Voltage	± 0,04 V
Temperature	± 1 °C
Time	± 1 s
Density of electrolyte	≤ 0,005 kg/l
Weight of battery	± 1 g below 30 kg ± 5 g above 30 kg

The instruments used for measuring time shall be graduated in hours, minutes and seconds.

8.3.2 Water bath

If a test needs to be carried out in a water bath, the following conditions shall be fulfilled. The terminal base of the battery shall be at least 15 mm but not more than 25 mm above the water surface level. If several batteries are in the same water bath then the distance between them and also the distance to the walls of the bath shall be at least 25 mm.

Minimum soak time for batteries in the water bath is 4 h.

If not stated differently in the individual test description, the tolerance for the temperature of the water bath is ±2 °C.

It is recommended to cover the surface of the water with floating elements using testing temperatures of 40 °C or more. This improves the thermal isolation against air and avoids evaporation of water.

8.3.3 Environmental chamber

If a test needs to be carried out in an environmental chamber, the batteries are placed in an air gaseous phase at the requested temperature and tolerance; the wind velocity near the battery shall not be more than 2,0 m/s.

Minimum time for batteries in the environmental chamber before the test beginning is 8 h.

8.4 Test sequence

8.4.1 Batteries filled and charged

a) Initially, the batteries are subjected to the following series of tests:

- first C_e or RC_e check;
- first cranking performance test;
- second C_e or RC_e check;
- second cranking performance test;
- third C_e or RC_e check;
- third cranking performance test.

For C_e or RC_e and the cranking performance, the specified values shall be met in at least one of the relevant discharges above.

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It is not necessary to complete the sequence if the specified values are achieved on the first or second test.

NOTE The choice between testing C_e or RC_e is the decision of the customer or user.

b) The tests according to Table 3 shall be carried out only if batteries have complied with the previous tests, and not later than one week after completion of the first part.

Table 3 – Test sequence

Step	Test	Reference	Battery					
			No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
0	Cranking performance for dry charged batteries	8.4.2 and 9.10	✓	✓	✓	✓	✓	✓
1	Initial charge prior to test	8.2	✓	✓	✓	✓	✓	✓
2	First 20 h capacity or First reserve capacity	9.1 or 9.2	✓	✓	✓ C_{20}	✓	✓	✓
3	First cranking performance according to Option 1 or Option 2	9.3.1	✓	✓	✓	✓	✓	✓
4	Second 20 h capacity Second reserve capacity	9.1 or 9.2	(✓)	(✓)	✓ C_{20}	(✓)	(✓)	(✓)
5	Second cranking performance according to Option 1 or Option 2	9.3.1	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)
6	Third 20 h capacity Third reserve capacity	9.1 or 9.2	(✓)	(✓)	✓ C_{20}	(✓)	(✓)	(✓)
7	Third cranking performance according to Option 1 or Option 2	9.3.1	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)
8	Cranking performance – very cold climate	9.3.2	✓					
9	Corrosion test	9.6.1.1	✓					
10	Endurance in cycle test	9.6.1.2 or 9.6.2		✓				
11	Charge retention	9.5				✓		
12	Charge acceptance	9.4			✓			
13	Electrolyte retention	9.9				✓		
14	Vibration resistance	9.8					✓	
15	Water consumption	9.7						✓

Key

– ✓: test to be fulfilled.

– (✓): test to be fulfilled only if the previous identical test carried out failed.

Battery no. 3 shall perform the full sequence of 3 tests with 20 h capacity before the charge acceptance test in 9.4.

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8.4.2 Dry-charged or conserved-charge batteries

a) Initially, the batteries are subjected to:

– initial cranking performance after filling with electrolyte (see 9.10).

b) The tests according to Table 3 shall be carried out only if the batteries have complied with the test mentioned in a) and no more than one week after the said test.

9 Tests methods

9.1 20 h capacity check C_e

Throughout the duration of the tests, the battery shall be placed in a water bath at a temperature of 25 °C ± 2 °C, in accordance with 8.3.2.

The battery shall be discharged with the current I_n (calculated according to 7.1.2) kept constant at ±2 % of the nominal value until the terminal voltage falls to 10,50 V ± 0,05 V. The duration t (h) of the discharge shall be recorded. The beginning of the discharge shall take place between 1 h to 5 h after the completion of charging according to 8.2.

The battery temperature, measured in one of the middle cells, if applicable, shall be 25 °C ± 2 °C before the discharge begins.

The capacity C_e is as follows:

$$C_e = t \times I_n \quad \text{(Ah)}$$

9.2 Reserve capacity check RC_e

Throughout the duration of the tests, the battery shall be placed in a water bath at a temperature of 25 °C ± 2 °C, in accordance with 8.3.2.

The battery shall be discharged with a current (25 ± 0,25) A until the terminal voltage falls to 10,50 V ± 0,05 V. The duration t (in minutes) of the discharge shall be recorded. The beginning of the discharge shall take place between 1 h to 5 h after the completion of charging according to 8.2.

The battery temperature, measured in one of the middle cells, if applicable, shall be 25 °C ± 2 °C before the discharge begins.

$$RC_e = t \text{ (min)}$$

9.3 Cranking performance test

9.3.1 Cranking performance test – Standard temperature (−18 °C)

Option 1:

After a rest period of 24 h up to 72 h after preparation according to 8.2, the battery shall be placed in a cooling environmental chamber with (forced) air circulation at a temperature of −18 °C ± 1 °C until the temperature of the middle cells has reached −18 °C ± 1 °C.

It is generally accepted that the required temperature will be achieved after a minimum period of 24 h in the cooling environmental chamber.

The battery shall then be discharged, either within or outside the cooling chamber, within 2 min after the end of the cooling period with a current I_{cc} (see 7.1.1). This current shall be kept constant to within ± 0,5 % during the discharge.

After 10 s discharge, the terminal voltage U_f shall be recorded and the current shall be cut off.

The voltage U_f shall be not less than 7,50 V.

After a rest period of 10 s ± 1 s, the test shall be continued as follows:

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