BS EN 61056-1:2012

BSI Standards Publication

General purpose lead-acid batteries (valve-regulated types)

Part 1: General requirements, functional characteristics — Methods of test

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National foreword

This British Standard is the UK implementation of EN 61056-1:2012. It is identical to IEC 61056-1:2012. It supersedes BS EN 61056-1:2003 which is withdrawn.

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

A list of organizations represented on this committee 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.

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(IEC 61056-1:2012)

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Bleibatterien für allgemeine Anwendungen (verschlossen) - Teil 1: Allgemeine Anforderungen, Eigenschaften - Prüfverfahren
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CENELEC

European Committee for Electrotechnical Standardization
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Management Centre: Avenue Marnix 17, B - 1000 Brussels

Foreword

The text of document 21/768/FDIS, future edition 3 of IEC 61056-1, prepared by IEC/TC 21 "Secondary cells and batteries" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 61056-1:2012.

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)	2013-06-14
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2015-03-28

This document supersedes EN 61056-1:2003.

The main changes consist in adding new battery designations and an update of the requirements like the one concerning the marking.

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 61056-1:2012 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60051-1	NOTE	Harmonized as EN 60051-1.
IEC 60051-2	NOTE	Harmonized as EN 60051-2.
IEC 60095 series	NOTE	Harmonized in EN 60095 series.
IEC 60254 series	NOTE	Harmonized in EN 60254 series.
IEC 60359	NOTE	Harmonized as EN 60359.
IEC 60896 series	NOTE	Harmonized in EN 60896 series.
IEC 61429	NOTE	Harmonized as EN 61429.

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 60417	Data-base	Graphical symbols for use on equipment	-	-
IEC 60445	-	Basic and safety principles for man-machine interface, marking and identification - Identification of equipment terminals, conductor terminations and conductors	EN 60445	-
IEC 61056-2	2012	General purpose lead-acid batteries (valve-regulated types) - Part 2: Dimensions, terminals and marking	EN 61056-2	2012

CONTENTS

GENERAL PURPOSE LEAD-ACID BATTERIES (VALVE-REGULATED TYPES) –

Part 1: General requirements, functional characteristics – Methods of test

1 Scope

This Part of IEC 61056 specifies the general requirements, functional characteristics and methods of test for all general purpose lead-acid cells and batteries of the valve-regulated type :

- for either cyclic or float charge application;
- in portable equipment, for instance, incorporated in tools, toys, or in static emergency, or uninterruptible power supply and general power supplies.

The cells of this kind of lead-acid battery may either have flat-plate electrodes in prismatic containers or have spirally wound pairs of electrodes in cylindrical containers. The sulphuric acid in these cells is immobilized between the electrodes either by absorption in a micro-porous structure or in a gelled form.

NOTE The dimensions, terminals and marking of the lead-acid cells and batteries which are applied by this standard are given in IEC 61056-2.

This part of IEC 61056 does not apply for example to lead-acid cells and batteries used for

- vehicle engine starting applications (IEC 60095 series),
- traction applications (IEC 60254 series), or
- stationary applications (IEC 60896 series).

Conformance to this standard requires that statements and claims of basic performance data by the manufacturer correspond to these test procedures. The tests may also be used for type qualification.

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 60417*, Graphical symbols for use on equipment*

IEC 60445, *Basic and safety principles for man-machine interface, marking and identification – Identification of equipment terminals, conductor terminations and conductors*

IEC 61056-2:2012, *General purpose lead-acid batteries (valve-regulated types) – Part 2: Dimensions, terminals and marking*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
general purpose lead-acid cells and batteries of the valve-regulated type
cells and batteries which provide the valve mechanism that opens when the internal pressure of the battery rises and has a function to absorb oxygen at its negative plates

3.2
cell
basic functional unit, consisting of an assembly of electrodes, electrolyte, container, terminals and usually separators, that is a source of electric energy obtained by direct conversion of chemical energy

3.3
monobloc battery
battery with multiple separate but electrically connected cell compartments each of which is designed to house an assembly of electrodes, electrolyte, terminals or interconnections and possible separators

3.4
nominal voltage
suitable approximate value of the voltage used to designate or identify a cell, a battery or an electrochemical system

3.5
final voltage
specified voltage of a battery at which the battery discharge is terminated

3.6
discharge current
I_{20}
discharge current for which the duration of discharge under the specified conditions is 20 h to a final voltage of 1,75 V/cell

Note 1 to entry The unit of I_{20} shall be ampere (A).

3.7
discharge current
I_1
discharge current for which the duration of discharge under the specified conditions is 1 h to a final voltage of 1,60 V/cell

Note 1 to entry The unit of I_1 shall be ampere (A).

3.8
rated capacity
C_{20}
quantity of electricity, declared by the manufacturer, which under the specified conditions can be discharged from the battery at a rate of I_{20} to a final voltage of 1,75 V/cell

Note 1 to entry The unit of C_{20} shall be ampere hour (Ah).

3.9
rated capacity
C_1
quantity of electricity, declared by the manufacturer, which under the specified conditions can be discharged from the battery at a rate of I_1 to a final voltage of 1,60 V/cell

Note 1 to entry The unit of C_1 shall be ampere hour (Ah).

3.10
actual capacity
C_a
quantity of electricity, which can be discharged from the battery at a specified rate of discharge to a specified final voltage

Note 1 to entry The unit of C_a shall be ampere hour (Ah).

3.11
DOD
depth of discharge

measure of a battery´s state of discharge, expressed in percent as the ratio between the discharged capacity and the battery´s rated capacity

3.12
high-rate discharge characteristic
the discharge characteristics of a battery when discharged at a comparatively large current relative to its capacity

3.13
gas recombination efficiency
the ratio between gas emitted from the cell and the amount of gas produced inside the cell by the float current

Note 1 to entry Amount of gas = 0,63 L/Ah*cell at normal temperature pressure.

3.14
regulating valve
a valve which operates at a certain internal pressure to exhaust gas but prevents external air from entering into the battery

3.15
charge retention
ability of a cell or battery to retain capacity on open circuit under specified conditions

3.16
deep discharge
discharge equivalent to the most portion of capacity of a battery

3.17
cyclic application
battery operation characterized by regular discharge followed by recharge

3.18
float application
battery operation where the battery is permanently connected to a d.c. constant voltage source, keeping the battery fully charged

Note 1 to entry In the case of power outage or surge loads, the battery takes over or supports the load.

4 General requirements

4.1 Construction

4.1.1 Batteries of this kind are composed of one or more cells. Multicell-batteries may be supplied either as monobloc batteries (see IEC 60050-482) or as mechanically and electrically interconnected single cells.

The number of cells connected in series in a battery is designated by the letter "n" throughout this standard.

4.1.2 Batteries shall be fitted with valves. The valve shall not allow gas (air) to enter into the cell but shall allow gas to escape from the cell at a certain internal pressure which does not lead to deformation or other damage of the cell or battery container.

4.1.3 Batteries or cells shall be designed so that neither water nor electrolyte can be added. They shall be suitable for storage and discharge in any orientation (for example, upside down) without leakage of liquid from valves and/or terminal seals. They shall also withstand storage at 20 °C ± 5 K and maximum 80 % relative humidity for one year in inverted orientation without leakage.

4.1.4 All battery components, for example, terminals, intercell connectors, containers, etc. shall be designed for current rates as specified in 5.4.

4.1.5 For charging, batteries or cells shall not be installed in any direction beyond 90 ° from the upright position.

4.2 Mechanical strength

Batteries shall be designed to withstand mechanical stresses, vibrations and shocks occurring in normal transportation, handling and use.

4.3 Designation

The batteries shall be identified by at least the following information on the surface in durable printing:

– supplier's or manufacturer's name or trade mark;
– type designation or product name;
– nominal voltage ($n \times 2{,}0$ V);
– rated capacity C_{20} (see 5.1.2);
– polarity;
– date of manufacture, its abbreviation or code;
– safety symbols according to national or international standards;
– recycling symbols (see IEC 61429).

If the values of functional characteristics or specific requirements are different from the values specified in Clause 5 below, these values shall be supplied with the battery or mentioned in the battery instructions.

Additional data such as recommended charging voltage U_c or charging current I_c, capacity at other discharge rates, battery weight, etc. shall be supplied with the battery in a suitable way.

4.4 Marking of polarity

The battery shall carry a marking of polarity of both terminals by the plus symbol + (60417-5005: Positive polarity) and the minus symbol – (60417-5006: Negative polarity) on the lid adjacent to the terminals. In the case where the battery carries a marking of polarity of both terminals by colour it shall be as specified in IEC 60446.The positive terminal shall be identified with red and the negative terminal with black/blue colour.

5 Functional characteristics and specific requirements

5.1 Capacity

5.1.1 The essential characteristic of a cell or battery is its capacity for the storage of electric energy. This capacity, expressed in ampere-hours (Ah), varies with the conditions of use (discharge current, end of discharge voltage, temperature).

5.1.2 The rated capacity C_{20} is a reference value, to be declared by the manufacturer, which is valid for the discharge of a new battery at the reference temperature of 25 °C and a discharge current:

$$I_{20} = \frac{C_{20}}{20} \quad (1)$$

in which discharge time is 20 h, to a final voltage U_f = $n \times$ 1,75 V and

where

I_{20} is expressed in amperes, and

C_{20} is expressed in ampere-hours.

5.1.3 The rated capacity C_1 is a reference value, optionally to be declared by the manufacturer, valid for the discharge at 25 °C and a discharge current:

$$I_1 = \frac{C_1}{1} \quad (2)$$

in which discharge time is 1 h, to a final voltage U_f = $n \times$ 1,60 V and

where

I_1 is expressed in amperes, and

C_1 is expressed in ampere-hours.

5.1.4 The actual capacity C_a shall be determined by discharging a fully charged battery (see 6.1.3) with constant current I_{20} in accordance with 7.2. The resultant value shall be used for comparison with the reference value C_{20} or for control of the state of a battery after long periods of service.

5.1.5 The determination of the actual capacity C_a in accordance with 7.2 may also be used for comparison with particular performance data (for example, C_1) indicated by the supplier. In this case, the current I_{20} shall be substituted by the particular current corresponding to the relevant performance data.

5.2 Endurance

5.2.1 Cycle service endurance

The cycle service endurance represents the ability of a battery to perform repeated discharge/recharge cycles. This performance shall be tested by a series of cycles under specified conditions with 50 % DOD at I = 3,4 × I_{20} or at I = 5 × I_{20} after which the actual capacity of the battery shall be not less than 50 % of the nominal capacity in ampere-hours (see 7.4). The number of cycles shall be not less than 200.

5.2.2 Float service endurance

The float service endurance represents the life performance of a battery in float application. The endurance determined in the test 7.5 and 7.6 shall not be less than two years at 25 °C or 260 days at 40 °C.

5.3 Charge retention

The charge retention is defined as that part of the actual capacity C_a on discharge with I_{20}, expressed as a percentage, which can be discharged with the same current I_{20} after storage on open circuit under specified conditions of temperature and time (see 7.7). Those conditions provided, the retained charge shall be not less than 75 % of C_a.

5.4 Maximum permissible current

Batteries shall be suitable to maintain a current of I_m = 40 × I_{20} for 300 s and of I_h = 300 × I_{20} for 5 s, unless otherwise specified by the manufacturer, without distortion or other damage to the battery (see 7.8).

5.5 Charge acceptance after deep discharge

Batteries according to this part may be subject to very deep discharge by an unintentional connection to a load over long periods of time. They shall then be rechargeable with constant voltage U_c (for U_c see 6.1.3) within a period of 48 h (see 7.9).

5.6 High-rate discharge characteristics

The high-rate discharge characteristic of a bettery is its capability to be discharged with high current relative to its capacity. During discharge with 20 × I_{20}, the discharge time shall reach 27 min or more within 5 cycles of charging and discharging.

5.7 Gas emission intensity

This value quantifies the escape of gas from the battery during charge with the manufacturer's recommended charging method.

When the gas emission intensity is determined during constant voltage float charging (see 7.10.1), the value G_e shall not be greater than 0,05 ml × cell^{-1} × h^{-1} × Ah^{-1}. When the

gas emission intensity is determined during constant current charging (see 7.10.2) the gas recombination efficiency shall not be less than 90 %.

5.8 Operation of regulating valve and over pressure resistance

The two following characteristics shall be checked:

a) Operation of regulating valve: when the test is performed in accordance with 7.11.1, the operating pressure of vent valve shall be 0,98 kPa to 196,1 kPa.

b) Over pressure resistance: when the test is performed in accordance with 7.11.2, the battery shall be free from deformations, cracks or liquid leakage, which exceeds the range of dimensions given in Tables 1 and 2 of IEC 61056-2:2011.

5.9 Vibration resistant characteristics

During the test according to 7.12, terminal voltage shall be not less than nominal voltage. The battery shall be free from cracks and liquid leakage when inspected visually. The deformations shall not exceed the range of dimensions given in Table 1 and Table 2 of IEC 61056-2:2011.

5.10 Shock resistant characteristics

During the test according to 7.13, terminal voltage shall be not less than nominal voltage. The battery shall be free from cracks and liquid leakage when inspected visually. The deformations shall not exceed the range of dimensions given in Table 1 and Table 2 of IEC 61056-2:2011.

6 General test conditions

6.1 Sampling and preparation of batteries for testing

6.1.1 All tests shall be carried out on new, fully charged samples, except when the tests are used for re-determination of the actual capacity to assess degradation after long periods of service.

6.1.2 Samples shall be considered as new not later than six months after the date of manufacture.

6.1.3 Unless otherwise recommended by the manufacturer, the batteries are considered as fully charged for test purposes after the following procedure.

Batteries shall be charged at an ambient temperature of 25 °C ± 2 K

1) constant voltage charge
   - either for a period of 16 h,
   - or until the current does not change by more than 0,1 × I_{20} within two consecutive hours.

   The constant voltage charge shall take place either

   a) from constant voltage, advised by the manufacturer, or, if not available, from U_c = n × 2,35 V,

   or

   b) from modified constant voltage (U_c as in a)) with an initial charging current limitation of I_{max} = 6 × I_{20}.
2) constant current charge

– charge at least 110 % but not more than 150 % of the discharged amperehours,

or

– charge to a charging voltage of 2,4 V per cell, then continue charging with the same current until at least 0,25 × C_{20} but not more than 0,5 × C_{20} amperehours have been added.

The constant current charge shall be carried out according to the recommendation of the manufacturer or if not available, with the current in the range of I = 2 × I_{20} to 4 × I_{20}.

6.2 Measuring instruments

6.2.1 Electrical measuring instruments

6.2.1.1 Range of measuring instruments

The instruments used shall enable the values of voltage and current to be measured. The caliber of these instruments and the measuring methods shall be chosen so as to ensure the accuracy specified for each test.

For analogue instruments this implies that readings shall be taken in the last third of the graduated scale.

Any other measuring instruments may be used provided they give an equivalent accuracy.

6.2.1.2 Voltage measurement

The instruments used for voltage measurement shall be voltmeters of an accuracy class equal to 0,5 or better. The internal resistance of the voltmeters used shall be at least 10 kΩ/V.

6.2.1.3 Current measurement

The instruments used for current measurement shall be ammeters of an accuracy class equal to 0,5 or better. The entire assembly of ammeter, shunt and leads shall be of an accuracy class of 0,5 or better.

6.2.2 Temperature measurement

The instruments used shall have a resolution of 1 K. The absolute accuracy of the instruments shall be 1 K or better.

6.2.3 Time measurement

For measurement of time, the instrument's accuracy shall be ± 1 % or better.

6.2.4 Dimension measurement

The instruments used for dimension measurement shall have an accuracy of ± 0,1 % or better.

6.2.5 Gas-volume measurement

For measurement of gas volume the instrument's accuracy shall be ± 2 % or better.

6.2.6 Pressure measurement

For measurement of pressure, the instrument's accuracy shall be ± 1 % or better.

7 Test methods

7.1 Test conditions

If not otherwise specified, the tests shall be carried out on batteries in the upright position at an ambient temperature from 15 °C to 35 °C, relative humidity of 25 % to 85 % and atmospheric pressure of 86 kPa to 106 kPa.

7.2 Capacity C_a (actual capacity at the 20 h discharge rate)

7.2.1 After charging according to 6.1.3, the battery shall be kept on open circuit for 5 h to 24 h.

7.2.2 Throughout the whole test period the battery shall be kept at an ambient temperature of 25 °C ± 2 K.

7.2.3 The battery shall then be discharged at the same ambient temperature with the current I_{20} (see 5.1.2). This current shall be kept constant to within ± 2 % until the terminal voltage reaches $U_f = n \times 1{,}75$ V. The duration t, of the discharge in hours, shall be recorded.

The actual capacity is $C_a = t \times I_{20}$.

7.2.4 C_a shall be equal to, or higher than, C_{20}. If not, the procedure should be repeated. The rated value shall be reached at or before the fifth discharge.

7.3 High rate capacity

7.3.1 After charging according to 6.1.3 the battery shall be kept on open circuit for 5 h to 24 h.

7.3.2 Throughout the whole test period the battery shall be kept at an ambient temperature of 25 °C ± 2 K.

7.3.3 The battery shall then be discharged with $I = 20 \times I_{20}$ until the terminal voltage reaches $U_f = n \times 1{,}60$ V.

7.4 Endurance in cycles

7.4.1 The test shall be carried out on at least three units (monoblocs or single cells) having met the requirements of 7.2.4.

7.4.2 Throughout the whole test period the battery shall be kept at an ambient temperature of 25 °C ± 2 K.

7.4.3 The battery shall be connected to a device where it undergoes a continuous series of cycles, each cycle comprising

– a discharge for 3 h at a current $I = 3{,}4 \times I_{20,}$ or a discharge for 2 h at a current $I = 5 \times I_{20}$ immediately followed by

– a recharge

- for 9 h in case of discharge for 3 h at $I = 3{,}4 \times I_{20}$ or
- for 6 h in case of discharge for 2 h at $I = 5 \times I_{20}$

at constant voltage U_c or with constant current I_c (see 6.1.3)

At the end of each 3 h or 2 h discharge period the on-load voltage U'_f shall be recorded automatically or be otherwise measured by suitable means.

7.4.4 After a series of (50 ± 5) cycles the battery shall be recharged according to 6.1.3. Then the capacity shall be determined by discharging with $I = 3{,}4 \times I_{20}$ or $5 \times I_{20}$ until $U_f = n \times 1{,}70$ V. If the discharge time is greater than 3 h or 2 h respectively, then the battery shall undergo another series of (50 ± 5) cycles according to 7.4.3.

7.4.5 If in the course of this cycling the voltage U'_f (see 7.4.3) falls below $n \times 1{,}70$ V, then cycling shall be interrupted and the battery shall be recharged according to 6.1.3. The capacity C_a shall then be determined according to 7.4.4. If the discharge time is less than 3 h or 2 h respectively, then the test shall be terminated.

7.4.6 The endurance is expressed as the total number of cycles according to 7.4.3 to which the battery can be submitted until the discharge time with $I = 3{,}4 \times I_{20}$ is less than 3 h or discharge time with $I = 5 \times I_{20}$ is less than 2 h.

7.5 Float service endurance

7.5.1 The test shall be carried out on at least three units (monobloc batteries or single cells).

7.5.2 Throughout the whole test period, the battery shall be kept at an ambient temperature of 20 °C ± 2 K, or 25 °C ± 2 K. Humidity is not defined.

7.5.3 The battery shall be charged with constant float charge voltage between $n \times 2{,}25$ V and $n \times 2{,}3$ V specified by the manufacturer. The initial current shall be limited to $I = 4 \times I_{20}$.

7.5.4 Capacity check: every six months the capacity shall be checked by discharging with $I = 3{,}4 \times I_{20}$ or $5 \times I_{20}$ until the final voltage of $U = n \times 1{,}70$ V.

7.5.5 The end of life is reached when the remaining capacity has decreased to $C < 0{,}6 \times C_{20}$ tested at $I = 3{,}4 \times I_{20}$, or $C < 0{,}5 \times C_{20}$ tested at $I = 5 \times I_{20}$

7.6 Float service endurance at 40 °C

7.6.1 The test shall be carried out on at least three units (monobloc batteries or single cells).

7.6.2 The test units shall be checked, before starting the test, an actual capacity C_a of at least C_{rt} (3 h –1,75 V/cell) and be fully charged. The initial current shall be limited to $I = 4 \times I_{20}$.

7.6.3 The units shall be placed in a hot air enclosure with the average air temperature such that the units are held at 40 °C ± 2 K. The air of the chamber shall be no higher than 36 % RH.

7.6.4 The charging condition shall be as specified by the manufacturer. This normally corresponds to charging at a constant voltage of 2,25 V/cell to 2,30 V/cell and charging current limitation to $4 \times I_{20}$.

7.6.5 Capacity check: every two months the capacity shall be checked by discharging with $I = 3{,}4 \times I_{20}$ or $I = 5 \times I_{20}$ until the terminal voltage of $U_f = n \times 1{,}70$ V. The capacity check shall be at 20 °C ± 2 K, or 25 °C ± 2 K.

7.6.6 The end of life is reached when the remaining capacity has decreased to $C < 0{,}6 \times C_{20}$, when discharged with $I = 3{,}4 \times I_{20}$ or $C < 0{,}5 \times C_{20}$ when discharged with $I = 5 \times I_{20}$.

7.7 Charge retention

A battery which has met the requirements of 7.2.4 shall be charged according to 6.1.3. The surface shall be cleaned and dried. It shall then be stored on an open circuit for 120 days at an ambient temperature of 20 °C ± 2 K, or 25 °C ± 2 K.

The battery shall then be discharged according to 7.2.3 with the discharge current I_{20}.

The duration t of the discharge to $U_f = n \times 1{,}75$ V shall be equal to, or higher than, 15 h.

7.8 Maximum permissible current

7.8.1 A fully charged battery (6.1.3) shall be kept on open circuit for 5 h to 24 h.

7.8.2 It shall then be discharged with the current $I_m = 40 \times I_{20}$ for 300 s.

7.8.3 The battery shall be recharged according to 6.1.3 and shall be left on open circuit at 25 °C ± 2 K for 16 h to 24 h.

7.8.4 It shall then be discharged with the current $I_h = 300 \times I_{20}$ for 5 s.

7.8.5 Upon inspection, no apparent physical damage from these discharges shall be observable.

7.8.6 The battery shall be recharged according to 6.1.3 and shall then be discharged with the current I_m (see 5.4). The duration t of the discharge to $U_f = n \times 1{,}34$ V shall be equal to, or higher than, 150 s.

7.8.7 If the manufacturer has declared values of I_m and I_h other than those in 5.4, the test currents of 7.8.2 and 7.8.4 shall be amended accordingly.

7.9 Charge acceptance after deep discharge

7.9.1 The test shall be carried out on at least three units (monobloc batteries or single cells). The battery shall have met the requirements of 7.2.4.

7.9.2 A load resistor is selected so that, from a voltage of $n \times 2$ V, a current of $I = 40 \times I_{20} \pm 10$ % results. The resistor shall be connected to the terminals of the battery, which shall then be stored for 360 h at an ambient temperature of 20 °C ± 2 K or 25 °C ± 2 K.

7.9.3 The load resistor shall then be disconnected from the terminals and the battery shall be recharged at a constant voltage U_c (see 6.1.3) for a period of 48 h with an available current between $6 \times I_{20}$ and $10 \times I_{20}$.

7.9.4 At the end of the charging period, the battery shall remain on open circuit at 25 °C ± 5 K for 16 h to 24 h. It shall then be discharged according to 7.2.3.

7.9.5 The resulting capacity in ampere-hours shall be $\geq 0{,}75 \times C_{20}$ (Ah).

7.10 Gas emission intensity

7.10.1 Gas emission intensity with constant voltage

7.10.1.1 The test shall be carried out with six cells or three monobloc batteries connected in series having undergone no conditioning treatment.

7.10.1.2 The units shall be maintained at a temperature between 20 °C and 25 °C and fitted with a gas collection device so that the emitted gas can be collected over several days.

7.10.1.3 The gas collection shall be carried out, for example, with a gas collection device similar to that shown in Figure 1 with an attention to a leak-free gas transport from the units to the collection device, an adequate sample volume for long unattended operation and a maximum hydrostatic head of 20 mm as given by the difference in collection vessel immersion depth and water level.

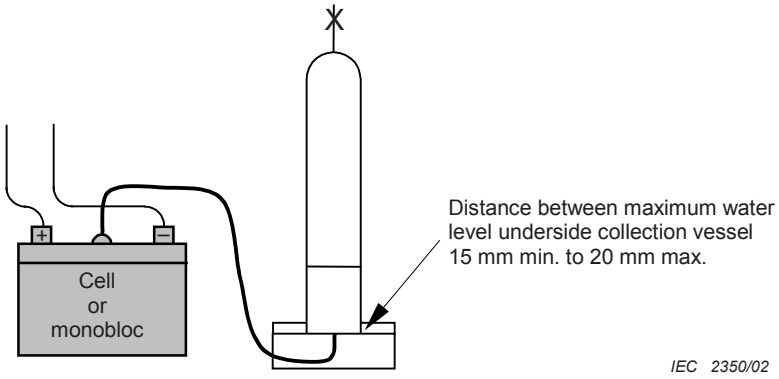

Figure 1 – Example of gas collection device

7.10.1.4 The units shall have a demonstrated capacity C_a equal to, or higher than, rated capacity C_{20}, be fully charged and float-charged for (72 ± 1) h with the manufacturer's specified float voltage U_{flo}.

7.10.1.5 After (72 ± 1) h of float charge, commence the gas collection and continue collecting gas for further (192 ± 1) h. Record the cumulative total actual gas volume collected V_a over the period of (192 ± 1) h, noting the ambient temperature T_a and the ambient pressure P_a at which the determination of the gas volumes were made.

7.10.1.6 Calculate the normalized volume of gas V_n emitted by each unit at 20 °C and 101,3 kPa reference pressure or 25 °C and 101,3 kPa reference pressure. Water vapour pressure shall be disregarded.

$$V_n = \frac{V_a \times T_r}{T_a} \times \frac{P_a}{P_r} \quad (3)$$

where

V_n is the normalized gas emitted (ml);

V_a is the cumulative total gas collected (ml);

T_r is the reference temperature (K): 20 °C = 293 K, 25 °C = 298 K;

T_a is the ambient temperature (K): T_a = 273 + T in °C;

P_a is the ambient atmospheric pressure (kPa);

P_r is the normalized pressure (kPa): P_r = 101,3 kPa.

7.10.1.7 Calculate the specific gas emission G_e per cell at normal float voltage conditions with the formula below:

$$G_e = V_n / (n \times t \times C_{rt}) \quad (4)$$

where

n is the number of cells from which the gas was collected in the collection vessel;

t is the number of hours during which the gas was collected;

C_{rt} is the rated 20 h capacity to 1,75 V_{pc} of the units from which the gas was collected.

7.10.2 Gas emission intensity with constant current (gas recombination efficiency test)

If constant current charging is recommended, gas emission intensity has to be carried out with constant current.

7.10.2.1 The test shall be carried out with six cells or three monobloc batteries connected in series having undergone no conditioning treatment.

7.10.2.2 The units shall be maintained at a temperature of 25 °C ± 5 K. and fitted with a gas collection device so that the emitted gas can be collected over several days.

7.10.2.3 The gas collection shall be carried out, for example, with a gas collection device similar to that shown in Figure 1 with an attention to a leak-free gas transport from the units to the collection device, an adequate sample volume for long unattended operation and a maximum hydrostatic head of 20 mm as given by the difference in collection vessel immersion depth and water level.

7.10.2.4 The units shall have a demonstrated capacity C_a equal to or higher than, rated capacity C_{20}, be fully charged and then charged with constant current of $2 \times I_{20}$ for (48 ± 1) h.

7.10.2.5 After 24 h constant current charge collect the gas emitted during charging for 5 h at a current of $I = 0{,}1 \times I_{20}$. Record the cumulative total actual gas volume collected (V_a in ml) noting the ambient temperature T_a and the ambient pressure P_a at which the determination of the gas volumes were made.

7.10.2.6 The gas recombination efficiency can be calculated by Formulas (5) and (6). The quantity of released gas converted to 101,3 kPa at 25 ° per charged ampere-hour is defined by Formula (5). Water vapour pressure shall be disregarded.

$$\upsilon = P_a / P_r \times 298 / (T_a + 273) \times V_a / Q \times 1 / n \quad (5)$$

where

υ is the amount of gas emission per single cell converted into amount of gas emission at ambient temperature of 25 °C and atmospheric pressure of 101,3 kPa per 1 Ah of quantity of electricity energized (ml/Ah);

P_a is the atmospheric pressure at the time of measurement (kPa);

P_r is equal to 101,3 (kPa);

T_a is the ambient temperature for burette or graduated cylinder (°C);

V_a is the quantity of the released gas collected (ml);

Q is the quantity of ampere-hours loaded during gas collection;

n is the number of cells.

The gas recombination efficiency is

$$\eta = (1 - \upsilon / 684) \times 100 \quad [\%] \quad (6)$$

where

684 is the theoretical quantity of the released gas with 101,3 kPa at 25 °C per Ah (ml/Ah).

7.11 Operation of regulating valve and over pressure resistance

7.11.1 Operation of regulating valve

Pneumatic pressure shall be gradually applied to the vent valve, the pressure when the valve is opened shall be measured, in succession the pneumatic pressure is decreased from that pressure, then the pressure when the valve is closed shall be measured. These pressures shall be taken as the operational pressure of vent valve.

7.11.2 Over pressure resistance

The liquid leakage resistance characteristics test shall be as follows:

a) the battery charged in accordance with 6.1.3 shall be used;

b) the battery shall be charged at a current of $4 \times I_{20}$ for 5 h;

c) the existence of cracks or liquid leakage shall be checked visually, and the size shall be measured with vernier callipers.

7.12 Vibration resistant characteristics

7.12.1 Fully charge a battery according to 6.1.3.

7.12.2 The test shall be conducted in accordance with the following conditions:

a) axis of vibration: X, Y, Z;

b) continuously vibrate with a sinusoidal wave having an amplitude of 4 mm and a frequency of 16,7 Hz for 1 h in each direction. After the application of vibration, the existence of cracks or liquid leakage shall be checked visually, and the size shall be measured with vernier callipers. Also, the voltage of the battery shall be measured with the voltmeter.

7.13 Shock resistant characteristics

7.13.1 Fully charge a battery according to 6.1.3.

7.13.2 The test shall be conducted in accordance with the following conditions:

a) drop a battery three times, with the bottom downward from a height of 20 cm onto a flat hardwood at least 10 mm thick;

b) after the drops, the existence of cracks or liquid leakage shall be checked visually, and the outside dimension of the battery shall be measured with vernier callipers. Also, the voltage of the battery shall be measured with the voltmeter.

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