BS 6290-4:1997
Incorporating Amendment No. 1

Lead-acid stationary cells and batteries —

Part 4: Specification for classifying valve regulated types

ICS 29.220.20

British Standards

Committees responsible for this British Standard

The preparation of this British Standard was entrusted to Technical Committee PEL/21, Secondary cells and batteries, upon which the following bodies were represented:

Association of Manufacturers Allied to the Electrical and Electronic Industry (BEAMA Ltd.)
British Industrial Truck Association
British Railways Board
British Telecommunications plc
Electric Vehicle Association of Great Britain
Electricity Association
Health and Safety Executive
Lighting Industry Federation Ltd.
London Regional Transport
Ministry of Defence
Society of British Battery Manufacturers
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Contents

Foreword

This British Standard has been prepared by Technical Committee PEL/21. It supersedes BS 6290-4:1987 which is withdrawn.

The start and finish of text introduced or altered by Amendment No. 1 is indicated in the text by tags [A1⟩ ⟨A1].

BS 6290 was initially published in four parts. Part 1 specified the general requirements and methods of test and was a common reference to Parts 2, 3 and 4 which were product standards specifying the design and performance requirements respectively for Planté, flat plate and valve regulated lead-acid stationary cells and batteries.

The publication of BS EN 60896-1:1992 partially superseded BS 6290-1:1983 which was declared obsolescent. The relevant provisions of BS 6290-1:1983 which are not given in BS EN 60896-1:1992 are contained in this revision of BS 6290-4 and BS 6290-1:1983 is therefore withdrawn. Information on life at various temperatures, operational recommendations, general applications, acceptance tests and contractual information, have been transferred to Annex A of this standard.

The title of this revised standard has been changed to *Lead-acid stationary cells and batteries: Part 4. Specification for classifying valve regulated types*. This more accurately reflects the scope of the standard and will avoid confusion with Part 2 of BS EN 60896 which will carry a title similar to that of BS 6290-4:1987.

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

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 29 and a back cover.

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1 Scope

This Part of BS 6290 specifies the criteria for classifying lead-acid units (cells or monoblocs) of the valve regulated type.

The system of classification relates to electrical performance, durability and safety. Information that can be used to estimate battery lives is shown.

NOTE The titles of the publications referred to in this standard are listed on the inside back cover.

2 References

2.1 Normative references

This Part of BS 6290 incorporates, by dated or undated reference, provisions from other publications. These normative references are made at the appropriate places in the text and the cited publications are listed on the inside back cover. For dated references, only the edition cited applies; any subsequent amendments to, or revisions of, the cited publication apply to this Part of BS 6290 only when incorporated in the reference by updating or revision. For undated references, the latest edition of the cited publication applies, together with any amendments.

2.2 Informative references

This Part of BS 6290 refers to other publications that provide information or guidance. Editions of these publications current at the time of issue of this standard are listed on the inside back cover, but reference should be made to the latest editions.

3 Definitions

For the purposes of this Part of BS 6290, the definitions given in BS 6133 apply, together with the following.

3.1
unit
a cell or monobloc

3.2
monobloc
a secondary battery in which the cells are fitted in a multi-compartment container

3.3
valve regulated cell
a secondary cell which is closed under normal conditions but which has a valve arrangement which allows the escape of gas if the internal pressure exceeds a predetermined value. The cell cannot normally receive addition to the electrolyte

3.4
thermal runaway
a critical condition arising during constant voltage charging in which the current and the temperature of the battery produce a cumulative, mutually reinforcing effect which further increases them, and which may lead to the destruction of the battery

4 Measuring instruments

4.1 Electrical measuring instruments

4.1.1 *Ranges of measuring devices*

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

NOTE 1 For analogue instruments this implies that readings should be taken in the last third of the graduated scale.

NOTE 2 Any other measuring instruments may be used provided they give an equivalent accuracy.

4.1.2 *Voltage measurement*

The instruments used for voltage measurement shall be voltmeters of an accuracy class equal to 0.5 or better. The resistance of the voltmeter used shall be at least 1 000 Ω/V (see BS 89-2).

4.1.3 *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 0.5 or better.

4.2 Temperature measurement

For measuring temperature, thermometers shall be used having a suitable measuring range in which the value of each graduated division does not exceed 1 °C. The absolute accuracy of the instruments shall be ±0.5 °C or better.

4.3 Time measurement

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

4.4 Gas pressure measurement

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

4.5 Gas volume measurement

For measurement of volume, the instrument accuracy shall be ±1 % of full scale or better.

5 Capacity

5.1 Cell or unit capacity

5.1.1 The rated capacity C_{rt} (in A·h) is a reference figure, stated by the manufacturer, which is valid for a new unit, at a reference temperature of 20 °C, which has a discharge time of t hours to the final voltage U_f.

NOTE 1 Recommended values of t (in h) are t = 20, 10, 8, 5, 3, 2, 1, 0.5, 0.25. Of those various C_{rt} values, one value may be selected and declared as the nominal capacity C_{nom}. The most commonly used rated values of t (in h) are between 10 and 1, and the final discharge voltage U_f may be obtained from **B.3**.

5.1.2 For the purposes of this standard the rated values shall be $t = 3$; $U_f = 1.80$ V per cell, $C_{rt} = C_3$, and $I_{rt} = I_3$.

5.1.3 The discharge current I_{rt} (in A) that will flow from a unit of rated capacity C_{rt} (in A·h) at a temperature of 20 °C for a time t (in h) to a final voltage U_f (in V) is given by:

$$I_{rt} = \frac{C_{rt}}{t}$$

5.1.4 The actual capacity C_a shall be determined by discharging a fully charged unit in accordance with the test specified in **B.1**.

5.2 Verification of battery capacity

5.2.1 *General*

Battery capacity shall either be verified by consulting Table 1, which gives expected battery performance, supported by Table 3 and Table 4 which give unit performance and classification, or by performing a site test in accordance with **5.2.2**.

5.2.2 *Battery acceptance by site test*

If a site test is required, the test shall be conducted in accordance with **B.2**.

NOTE 1 The test in **B.2** may be used for alternative rates of discharge in which case the criteria specified in **B.3** apply.

The following requirements apply:

a) the temperature corrected battery capacity, C_T, shall be greater than C_3; and

b) the temperature corrected unit capacity shall meet the requirements for the appropriate performance class given in Table 4.

NOTE 2 In the case of marginal non-conforming units (i.e. where C_T meets the class performance less 2 %), a retest should always be considered as a precautionary measure against incomplete site charging.

NOTE 3 Table 1 can help the specifier to select the required performance stated in Table 2.

6 Safety features

6.1 Terminal pillars

The terminal pillars shall be cast in lead or lead alloy and [A1⟩ connect to ⟨A1] a threaded insert (male or female) to which mechanical connections can be made. The insert shall be prepared so that a sound electrical and mechanical bond is made with the pillar. The primary current path shall be between a flat surface on the pillar assembly and any connector and not via any threaded parts. The covering of lead [A1⟩ , or other electrolyte impermeable material ⟨A1], round the insert within the unit shall be not less than 2 mm.

[A1⟩ Where the manufacturer has added an adaptor to the main female or male terminal as an extension of that terminal (e.g. front terminal adaptors), the adaptor shall sustain a 1h rate constant current discharge for 1h, and during this time the temperature rise of the adaptor shall not exceed 20 °C. The maximum current capability of such an adaptor shall be calculated and specified by the manufacturer. ⟨A1]

6.2 Containers and lids

6.2.1 *Flammability of containers, lids and covers*

The containers, lids, and covers shall be made of flame retardant plastics materials. When tested in accordance with **C.1**, the materials shall be assigned to the category index rating stated in the test report (see **C.1.3**). The manufacturer shall state the level of rating (FV0, FV1, or FV2) achieved in the type test certificate.

[A1⟩ *Note deleted.* ⟨A1]

6.2.2 *Container integrity*

The containers and lids shall be so designed as to minimize flexing of the surfaces under normal internal operating pressures, and operating temperatures up to 40 °C.

The lid shall be welded or bonded to the container, and the complete assembly, which includes the pillar to lid seal, shall be able to withstand without fracture for 5 h at 20 °C an internal pressure of five times the mean venting pressure declared by the manufacturer. The complete assembly shall be designed to be gas-tight and electrolyte-tight.

Table 1 — Performance class

Performance class (see Table 4)	Unit conformity %	Temperature corrected capacity performance (48 V battery) 3 h rate	
		Unit performance	**Battery performance**
1	99.9 % > C_3	All units C_T > 0.99 C_3	100 % batteries C_T > C_3
2	99 % > C_3	All units C_T > 0.97 C_3	100 % batteries C_T > C_3
3	99 % > C_3	All units C_T > 0.95 C_3	75 % batteries C_T > C_3
4	90 % > C_3	All units C_T > 0.93 C_3	0 % batteries C_T > C_3
The values for battery performance are based upon the 3 h rate of discharge and assume a battery size of 48 V. The battery performance for classes 3 and 4 will be different for larger battery sizes.			

6.3 Gas emission

The gas emission (G_E) in the overcharge float condition shall be measured by the gas emission test specified in **C.2**. The manufacturer shall state the gas emission value for new units in the type test certificate.

NOTE 1 The overcharge float condition is defined at 2.4 V per cell.

NOTE 2 The value of G_E may be used in Annex A of BS 6133 to calculate the ventilation requirements for racks, cabinets, and battery rooms. This can be achieved by converting the gas emission value G_E into an equivalent current I_E. The value of G_E has been referenced to an atmospheric pressure of 1 bar[1)] and an ambient temperature of 20 °C. To convert G_E into the equivalent current I_E the value of G_E has to be referenced to 0 °C. The equivalent current value I_E is given by the following formula.

$$I_E = \frac{G_E \times C_3 \times 273}{418 \times 293}$$

NOTE 3 The value of I_E is that equivalent current flowing through the battery at 2.4 V per cell and at 20 °C. If an estimate of the current flowing at higher temperatures is required, the value of I_E should be doubled for every 10 °C rise in temperature.

1) 1 bar = 10^5 N/m^2 = 100 kPa.

6.4 High current endurance

6.4.1 Units claiming suitability for high current endurance shall be tested in accordance with **C.3** and shall satisfy the following requirements.

a) During the test, the units shall show no indication of combustion and shall not explode as a result of self-ignition.

b) The actual capacities of the units, C_a, after the high current test shall be not less than C_3. The subsequent examination of the unit group bars and monobloc internal intercell connections shall show no sign of melting.

6.4.2 If the requirements of **6.4.1** are satisfied, the manufacturer shall state "H" (high current endurance) in the type test certificate. For those units not claiming suitability for high current endurance, the manufacturer shall state "L" (low current endurance) in the type test certificate.

NOTE 1 The test method in **C.3** indicates the safe operation of the battery and does not imply its longer term continued fitness for purpose.

7 Performance

NOTE This clause addresses product characteristics of an applications nature. It is not intended to state criteria to which the product should conform, but provides standardized test methods by which essential performance characteristics can be determined should they be required for the engineering or operation of battery systems.

Electromagnetic compatibility is addressed in Annex F.

7.1 Capacity conformity level

7.1.1 The manufacturer shall rate the capacity of the VRLA unit for periods of discharge between 5 min and 10 h. This may be achieved either by the capacity conformity level test specified in **D.1**, or by use of the manufacturer's own equivalent techniques.

7.1.2 The manufacturer shall calculate the level of conformity in accordance with **D.1.8**, at the following rates of discharge: 5 min; 15 min; 1 h; 3 h; 8 h and 10 h.

7.1.3 The manufacturer shall state the calculated levels of conformity in the type test certificate.

7.2 Cyclic endurance

Values for cyclic endurance shall be determined by the test method specified in **D.2**, and the manufacturer shall state the [A1⟩ minimum and maximum ⟨A1] cyclic endurance value in the type test certificate. A minimum of 50 cycles is required.

7.3 Charge retention

Values of the charge retained C_R, expressed as a percentage, shall be determined by the test method specified in **D.3** and the manufacturer shall state in the type test certificate the value of C_R achieved.

7.4 Internal resistance

Values of unit internal resistance (R_i) shall be determined by the test method specified in **D.4**.

The manufacturer shall state the internal resistance values of the unit in the type test certificate.

NOTE 1 This test method provides information on the d.c. resistance from stabilized test conditions, and does not indicate dynamic reactions, for example those occurring during the first milliseconds of a short circuit. The results of this test have an accuracy which is of the order ±10 %.

NOTE 2 For a.c. impedance values which may be required for converter applications, reference should be made to the battery manufacturer.

8 Durability

8.1 Life at elevated temperatures

[A1] 8.1.1 *Standard life test at the 8 h rate of discharge*

For the purposes of this standard, life shall be determined, at an elevated temperature of 55 °C, by the test specified in **E.1**. The manufacturer shall state the following in the type test certificate:

a) the life in terms of the average endurance at the 8 h rate of discharge to 1.84 V per cell, and

b) the float voltage at which the test was conducted.

For test certificate purposes this performance shall be presented as follows:

average endurance (in days) /rate of discharge (in h) /float voltage (in V).

Thus the performance of a product at the 8 h rate giving an average endurance of 330 days at a float voltage of 2.27 V per cell would be:

330/8/2.27.

NOTE 1 A conversion guide estimating lives at normal ambient temperatures is given in **A.1.1**.

NOTE 2 A method for estimating life at temperatures of between 20 °C and 40 °C is given in **A.1.2**. [A1] *Text deleted* [A1]

8.1.2 *Additional, applications-dependent life tests at the 1 h and 0.25 h rates*

For comparison purposes by either user or manufacturer and according to the demands for application, life tests at these additional rates shall be performed.

These tests shall be performed using the end voltages in Table B.1 and Table B.2 in accordance with the procedure in **8.1.1** and the test method specified in **E.1**. Note 1 and Note 2 of **8.1.1** do not apply. The resultant values for the average endurance shall be stated in 15a) and 15b) of the type test certificate shown in Table 3.

NOTE In order to save resources and testing time, laboratories may wish to perform all the discharge rates at the same time within one single programme. Whilst this is permitted within the test procedure, it is not recommended, as the consequences could be detrimental to the results obtained. [A1]

8.2 Float voltage characteristics

8.2.1 When testing in accordance with **E.2**, the manufacturer shall state in the type test certificate the value of float voltage, U_{flo}, used in the test.

8.2.2 The unit float voltage measurements, $U_{1\text{-}6}$, prior to the discharges 1, 3 and 4 shall be treated as one population. The maximum float voltage measurement, U_{MAX}, and the minimum float voltage measurement, U_{MIN}, shall be within the range (U_{flo} ± 3 %).

If U_{MAX} < (U_{flo} ± 3 %) < U_{MIN}, "PASS" shall be recorded in the type test certificate.

8.2.3 The unit capacities for day 8, day 91, and day 183 shall be plotted against the day number of the test, and the maximum unit reduction in capacity from the initial discharge, C_{IA}, to the final discharge, C_{FA}, shall be expressed as a % of C_{IA} in the type test certificate.

8.2.4 [A1] The unit capacities C_a following the second discharge on day 11, shall be greater than the rated capacity C_3. If Day 11 $C_a > C_3$ for each unit, "PASS" shall be recorded in the type test certificate. [A1]

8.3 Pillar seal assembly

After testing in accordance with **E.3**, the manufacturer shall state in the test certificate which test was used, **E.3.1** or **E.3.2**, and the number of days on test before the seals started to leak. This shall be taken as the number of days until the first recorded instance of a leaking seal in the sample tested.

8.4 Mechanical strength

Valve regulated stationary lead-acid units shall be designed to withstand the mechanical stresses met during normal transportation, handling, and climatic changes.

When tested in accordance with **E.4**, the [A1] three [A1] units shall remain gas and liquid tight, and in the 5 min rate discharge, performance of the three units subjected to the mechanical test shall be at least 90 % of the original value.

The manufacturer shall state in the type test certificate whether the units have passed or failed this test.

NOTE Resistance to earthquakes, shocks and vibration, if required, should be individually specified.

9 Classification

9.1 Type testing

NOTE Where cells and batteries employ the same materials, manufacturing process and plate/element design, as defined by the manufacturer's quality system, over a range of product sizes or product types, it is not necessary to test fully each individual design in the classification to obtain qualification, provided that manufacture is in the same factory.

9.1.1 Tests shall be undertaken according to the schedule given in Table 2.

9.1.2 Modifications to, or departures from, the tested design shall invalidate the qualification.

9.1.3 The manufacturer shall indicate the level of conformity of the product in the type test certificate.

NOTE The type test certificate is arranged into three groups of characteristics: safety, durability and performance. The format of the type test certificate is shown in Table 3.

9.2 Classification procedure

9.2.1 The classification of the product shall be established by reading the values in the status column of the type test certificate (Table 3) across to the corresponding row in the appropriate class column of the classification table (Table 4).

9.2.2 If in any one group of characteristics the product is represented in classes 1, 2 and 3, its overall classification shall be 3.

9.2.3 There is a requirement, irrespective of class, to indicate in the classification table whether the high current endurance test is applicable. To prevent misapplication of products, the status of the product in this respect shall be added to the classification (see Table 3 and **6.4.2**).

9.2.4 The type test certificate and classification table shall be made available on request together with supporting test data.

Table 2 — Schedule of classification tests

Factor	Testing requirement	Clause reference
Flammability of containers lids and covers	Test the compounded materials	**6.2.1**
Container integrity	Test the assembly with the largest unsupported surface area	**6.2.2**
Internal resistance	Test each cell and battery	**7.4**
High current endurance	Test each cell and battery	**6.4**
Rated capacity/conformity level	Test the largest configuration of capacity and voltage within each product range (see note)	**7.1**
Pillar seal assembly	Test the largest configuration of capacity and voltage within each product range (see note)	**8.3**
Mechanical strength	Test the largest configuration of capacity and voltage within each product range (see note)	**8.4**
Life at elevated temperature	Test the largest configuration of capacity and voltage within each product range (see note)	**8.1**
Cyclic endurance	Test the largest configuration of capacity and voltage within each product range (see note)	**7.2**
Charge retention	Test the largest configuration of capacity and voltage within each product range (see note)	**7.3**
Float voltage characteristic	Test the largest configuration of capacity and voltage within each product range (see note)	**8.2**
Gas emission	Test the largest configuration of capacity and voltage within each product range (see note)	**6.3**

NOTE A product range is defined as those types using the same materials, manufacturing processes, quality systems and design of positive plates and negative plates, and elements.

The largest configuration refers to:

the maximum outside dimensions;

the maximum capacity contained in one compartment;

the maximum voltage.

If the largest dimensional configuration appears as either 2 × compartments (90 A·h each) at 4 V, or 3 × compartments (60 A·h each) at 6 V, the 4 V configuration is the preferred type for group qualification purposes.

10 Marking

10.1 Polarity

Valve regulated stationary lead-acid units shall carry the polarity marking of at least the positive terminal. Symbols used for the marking of the polarity shall be in accordance with BS 6217:1981, the marking of the positive terminal being in accordance with symbol 417-IEC-5005: positive polarity, which shall be indented or in relief on the lid adjacent to the positive terminal.

Where used, the marking of the negative terminal shall be according to the symbol 417-IEC-5006: negative polarity, and shall be indented or in relief on the lid adjacent to the negative terminal. The value of dimension *a* of the symbols shall be not less than 5 mm, which corresponds to a minimum total length of 6 mm for each arm of the symbol.

10.2 Information marks

The following information shall be permanently marked on the unit:

a) nominal voltage;

b) name of manufacturer or supplier and manufacturer's or supplier's type reference;

c) rated or nominal capacity expressed (in A·h), with an indication of the rating expressed either as current or as time, together with the relevant final voltage of 1.80 V per cell;

d) voltage for float operation at 20 °C with tolerance of ±1 % (see **8.2.1**);

e) date of manufacture, for example (month and year) or (week and year) as defined in BS EN 28601;

f) environmental and safety provisions required by national or European regulations shall be included on the product.

g) product label (see **6.4.2** and **10.3**).

10.3 Product label

10.3.1 The product classification shall be declared on a product label.

10.3.2 The content of the product label shall be as illustrated in Figure 1.

The overall classification of the product shall be described by the sequence of class numbers in the order presented in the label. Therefore a product which is safety class 1 with high current endurance, performance class 2 and durability class 3, shall have the overall classification of 1H23.

NOTE Where the higher product classifications are being claimed, the manufacturer is encouraged to obtain independent audited certification of the claims made in the type test certificate and classification.

The index marked (+) is a safety index obtained from the type test certificate and shall be either "L" for low current endurance or "H" for high current endurance.

The indices shall be obtained from the type test certificate in conjunction with the classification table.

[A1) Classification according to BS 6290-4:1997 (A1]			
Group	Safety	Performance	Durability
Class	.... (+)	....	....

Figure 1 — Product label

Table 3 — Type test certificate

A1⟩ Type test certificate: BS 6290-4:1997 ⟨A1			
Characteristic	**Clause reference**	**Requirement**	**Status**
Safety			
Flammability of container	**6.2.1**	1) State the rating achieved	FV.........
Container integrity	**6.2.2**	2) State whether pass or fail	....
Gas emission	**6.3**	3) State emission value (G_E) A1⟩ (ml/cell A·h/h) ⟨A1	....
High current endurance	**6.4**	4) State whether pass A1⟩ at ⟨A1 (H) or (L)	....
Performance			
Rated capacity conformity level	**7.1**	5) State % conformity at 5 min	...........%
	7.1	6) State % conformity at 15 min	...........%
	7.1	7) State % conformity at 1 hour	...........%
	7.1	8) State % conformity at 3 hours	...........%
	7.1	9) State % conformity at 8 hours	...........%
	7.1	10) State % conformity at 10 hours	...........%
Cyclic endurance	**7.2**	A1⟩ 11) State minimum/maximum ⟨A1 value	.....cycles
Charge retention	**7.3**	12) State value (C_R)	...........%
Internal resistance	**7.4**	13) State value (R_i)	...........Ω
A1⟩ *Durability*			
Standard life test at the 8 h rate of discharge	**8.1.1**	14) State endurance/discharge rate/float volts	...../8/......
Additional applications-dependent life tests	**8.1.2**	15a) State endurance/discharge rate/float volts	...../1/......
Additional applications-dependent life tests	**8.1.2**	15b) State endurance/discharge rate/float volts	.../0.25/...
	8.2.1	16) State float volts value used (U_{flo})	V
	8.2.3	17) State maximum unit capacity reduction	...........%
	8.2.2	18) $U_{Max} < (U_{flo} \pm 3\ \%) < U_{Min}$	....
	8.2.4	19) $C_{2A} > C_3$	....
Pillar seal assembly	**8.3**	20) State which test: **E.3.1** or **E.3.2**	**E.3**........
	8.3	21) State number of days on test	.......days
Mechanical strength	**8.4**	22) State whether pass or fail	.... ⟨A1
Manufacturer:			
Address:			
Product:			
Range:			
Types:			

Table 4 — Classification table

Requirement number (see Table 2)	Safety class			Performance class				Durability class				
	1	2	3	1	2	3	4	1	2	3	4	5
1	FV0	FV1	FV2									
2	Pass	Pass	Pass									
3	[a]	[a]	[a]									
4	[a]	[a]	[a]									
5				≥ 99.9	≥ 99	≥ 95	≥ 90					
6				≥ 99.9	≥ 99	[A1⟩ ≥ 95	≥ 90					
7				≥ 99.9	≥ 99	≥ 95	≥ 90					
8				≥ 99.9	≥ 99	≥ 95	≥ 90					
9				≥ 99.9	≥ 99	≥ 95	≥ 90					
10				≥ 99.9	≥ 99	≥ 95 ⟨A1]	≥ 90					
11				50	50	50	50					
12				[a]	[a]	[a]	[a]					
13				[a]	[a]	[a]	[a]					
14								>648	>518	>389	>259	>130
[A1⟩ 15a								[a]	[a]	[a]	[a]	[a]
15b								[a]	[a]	[a]	[a]	[a] ⟨A1]
16								[a]	[a]	[a]	[a]	[a]
17								<3 %	<3 %	<4 %	<4 %	<5 %
18								Pass	Pass	Pass	Pass	Pass
19								Pass	Pass	Pass	Pass	Pass
20								[a]	[a]	[a]	[a]	[a]
21								[a]	[a]	[a]	[a]	[a]
22								[a]	[a]	[a]	[a]	[a]
Manufacturer:												
Address:												
Product:												
Range:												
Types:												

[a] These values do not affect the classification, but may be obtained from the "status" column of Table 3.

Annex A (informative) Applications and contractual recommendations

A.1 Product lives at various temperatures

A.1.1 *Ambient temperatures*

Where temperature is used to accelerate product life endurance, an approximate relationship exists whereby for every 10 °C increase in temperature the life is reduced by a factor of two. Conversely every 10 °C reduction in temperature extends the life by a factor of two. Thus the average durations identified in **E.1** and **8.1** can be expressed in durations at 20 °C by the following equation:

average duration (at 20 °C) = average duration (at 55 °C) × 11.31.

[A1] NOTE 1 [A1] Because there is usually more than one failure mechanism taking place at the same time, the technique only gives an indication of life and may be used for comparison purposes only.

[A1] NOTE 2 Because the high rate performance has the least correlation between room temperate and the accelerated life condition, the life estimation factor given in **A.1.1** should only apply to the endurance at the 8h rate of discharge. [A1]

A.1.2 *Temperatures of between 20 °C and 40 °C*

Estimates of product lives at temperatures of between 20 °C and 40 °C may be obtained from the values listed in Table A.1.

Table A.1 — Temperature and service life

Temperature °C	**Life** %
20	100
21	93
22	87
23	82
24	76
25	71
26	66
27	62
28	57
29	53
30	50
31	47
32	44
33	41
34	38
35	35
36	33
37	31
38	29
39	27
40	25

A.2 Operational recommendations

A.2.1 *Rated capacity*

Where the operating temperatures specified are outside the range 10 °C to 30 °C, the capacity should be declared by the manufacturer.

A.2.2 *Conservation of charge*

Where a battery is likely to become isolated from its normal charging arrangements for any length of time, the manufacturer should recommend the charging procedures needed to restore the battery to a healthy condition and to maintain that condition. The recommendations should include provision for any load that might be imposed on a battery in such circumstances.

A.2.3 *Environmental conditions*

The manufacturer should be consulted if a stationary battery is to be located where the ambient temperature range is outside the range +5 °C to +40 °C, or where the relative humidity exceeds 95 % for long periods.

A.2.4 *Thermal management*

To minimize circumstances giving rise to the thermal runaway condition, the following recommendations are made.

a) The cell or monobloc should be designed to provide sufficient ventilation to dissipate the heat generated by the float charge energy. Ideally, the ventilation should be capable of dissipating the heat generated under fault/abuse conditions however they may be defined. Where batteries are in enclosed accommodation an air flow distance of at least 10 mm between the cells or monobloc is recommended.

b) Where the ambient air temperature exceeds 25 °C, consideration should be given to reducing the float charge energy passing through the cell or monobloc by lowering the float voltage. In such circumstances, reference should be made to the battery manufacturer's recommendations.

c) If recommended by the manufacturer, constant current trickle charging could be considered as an alternative to constant voltage float charging.

d) In order to prevent the temperature of the battery rising beyond the safe limit recommended by the manufacturer, a thermal cut out could be used to interrupt the charge to the battery.

NOTE Additional information is contained in BS 6133.

A.3 General application

VRLA stationary batteries specified in this standard are suitable for use in standby power applications. The applications include central battery room configurations, enclosed equipment racks, and office compatible systems. Their suitability for use in offices and equipment can be determined by reference to BS 6133. It should be noted that the gases released from units specified in this standard are measured under boost charge conditions.

A.4 Acceptance tests

The tests in this standard that are suitable for acceptance tests are as follows:

a) the capacity test specified in **B.1** (for laboratory acceptance testing);

b) the battery capacity test specified in **B.2** (for site acceptance testing).

A.5 Contractual information

Enquiries or orders for stationary cells or batteries specified in this British Standard should contain the following information:

a) the number of this British Standard;

b) number of identical batteries required;

c) operating voltage range or voltage ranges of the battery, or alternatively, the number of cells;

d) discharge loads and durations required, or capacity (in A·h) at the 3 h rate;

e) mode of operation, e.g. storage charge/discharge, float/trickle charge, etc.;

f) whether stands or cubicles are required or not, together with layout or space available and, if applicable, the floor loading;

g) accessories, notices and spares required (if any);

h) any special conditions, e.g. storage, operational, environmental, statutory, etc.;

i) schedules of technical and test data required to be submitted with the tender;

j) whether additional capacity tests as described in are required;

k) the required performance class as described in Table 1 and Table 4;

l) the method of battery capacity verification as described in **B.2**.

Annex B (normative) Capacity tests

B.1 Capacity test (laboratory)

B.1.1 Charge units for testing in accordance with the manufacturer's instructions. All tests shall be carried out on new and fully charged units. The tests shall take place with units in an upright position, unless they are intended for use in a different orientation approved by the manufacturer.

NOTE Unless otherwise stated by the manufacturer, the units are considered to be fully charged when, during charging at the constant voltage recommended by the manufacturer, the observed current shows no appreciable change during a period of 2 h, taking into account changes in the surface temperature of the cell or monobloc battery.

Measuring instruments used in test procedures shall conform to clause **4** of this standard.

B.1.2 In order to take temperature readings of a battery, choose one pilot unit per group of six units for batteries of 100 units or fewer, and one pilot unit per group of 12 units for batteries of more than 100 cells.

B.1.3 Measure the surface temperature at the centre of the container wall, parallel to the plates, immediately prior to the discharge test. The individual readings shall be between 10 °C and 35 °C. The mean temperature of the selected units shall be considered as representative of the average temperature of the battery.

NOTE It is desirable that the average initial surface temperature and the ambient temperature are as near to the reference temperature of 20 °C as is practicably possible.

B.1.4 Within 1 h to 24 h after the end of charging, subject the units to a discharge current I_{rt} (see **5.1.3**).

Maintain this current within ±1 % throughout the whole discharge time. Deviations during manual adjustments of the current shall be permitted, provided they are within ±5 % of the specified value.

B.1.5 The voltage between the terminals of the units, including one inter-unit connector, shall be either recorded automatically against time or taken by readings from a voltmeter (see **4.1.2**). Voltmeter readings shall be made at least at 25 %, 50 % and 80 % of the discharge time given by:

$$t = \frac{C_{rt}}{I_{rt}}$$

and at suitable time intervals to enable detection of the final discharge voltage U_f.

B.1.6 Discontinue the discharge when the voltage has reached the value $n \times U_f$ (see **5.1.2**), where n is the number of cells. Note the discharge time.

NOTE 1 In a test on a single unit, the discharge voltage is measured across the terminals including one inter-cell connector arrangement.

NOTE 2 By agreement between manufacturer and user, additional limitations may be applied to the unit voltage for the capacity test.

B.1.7 The uncorrected capacity, C (in A·h), at the initial average temperature θ shall be calculated as the product of the discharge current (in A) and the discharge time (in h).

B.1.8 When the initial average temperature θ is different from the reference temperature (20 °C), the uncorrected capacity, C, shall be corrected by means of the following equation to obtain the actual capacity, C_a, at the reference temperature:

$$C_a = \frac{C}{1 + \lambda\ (\theta - 20)}$$

The coefficient, λ, shall be taken as 0.006 unless otherwise specified by the manufacturer.

B.2 Battery capacity test (on site)

B.2.1 Prepare the battery for service by charging in accordance with the manufacturer's instructions.

B.2.2 Commence the discharge test to determine the capacity between 1 h and 24 h after the end of the charge.

B.2.3 Perform the discharge at a unit temperature, θ, measured as the mean of every sixth unit (for batteries < 100 units) or every twelfth unit (for batteries $\geq$ 100 units) of the battery under test between 10 °C and 35 °C. Calculate the mean temperature, θ (in °C), as follows:

$$\theta = \frac{1}{n}(\theta_1 + \theta_2 + \theta_3 .....\theta_n)$$

where

θ_1, θ_2 etc. are the initial unit temperatures (in °C);

n is the number of test units.

Measure the temperature at the centre of the container wall, parallel to the plates, immediately prior to the discharge test.

B.2.4 In order to determine the actual capacity at the 3 h rate, discharge the battery at a constant current, I (in A), of 0.33 $C_3 \pm 5$ % for the whole of the discharge, until the voltage at the battery terminals has fallen to 1.80 V, multiplied by the number of cells in the battery.

NOTE The test discharge should be the first discharge after the completion of the erection of the battery.

B.2.5 During the discharge, check the following values:

a) the voltage of the battery terminals;

b) the individual voltages across each unit plus one of its interconnectors;

c) the discharge current, I (in A);

d) the duration time of the discharge, h (in h).

Record the values at 30 min intervals. To prevent damage to the battery complete the final measurement of individual unit voltages before the voltage at the battery terminals has fallen to 1.80 V multiplied by the number of cells in the battery.

B.2.6 The duration of the discharge is the period of time, h (in h), from the commencement of discharge until the voltage at the battery terminals has fallen to 1.80 V per cell.

B.2.7 The capacity, C_θ, (in A·h), at the average temperature of the units, θ (in °C), is given by:

$$C_\theta = I \cdot h$$

B.2.8 If the average temperature, θ (in °C), differs from the reference temperature, $T = 20$ °C, correct the measured capacity, C_θ, to the capacity at the referenced temperature, C_T using the following equation:

$$C_T = \frac{C_\theta}{1 + \lambda(\theta - T)}$$

where λ is the temperature coefficient of capacity variation, per degree Celsius difference between the average temperature, θ, of the units and the reference temperature, $T = 20$ °C. λ may be taken as 0.006 unless otherwise specified by the manufacturer.

B.3 Additional capacity tests

If an additional test for capacity is required at a rate between the 1 h and 10 h rates of discharge, the discharge shall be terminated at the final voltages given in Table B.1. If an additional capacity test is required at rates in excess of 1 h, the discharge shall be terminated at the final voltages given in Table 2.

Table B.1 — Final voltages at discharge durations of between 1 h and 10 h

Discharge duration h	Final voltage per cell V
1	1.75
2	1.78
3	1.80
4	1.81
5	1.82
6	1.83
7	1.83
8	1.84
9	1.84
10	1.85

Table B.2 — Final voltage at discharge durations of less than 1 h

Discharge duration Min	Final voltage per cell V
1	1.60
5	1.62
15	1.65
30	1.69

Annex C (normative) Methods of test (safety features)

C.1 Flammability test

C.1.1 The samples of containers, lids and covers shall be tested in accordance with Method F; (Flame-Vertical specimen) given in BS 6334:1983.

C.1.2 For the purposes of this standard the test specimens shall be manufactured by the moulding method used to manufacture the plastic components.

C.1.3 For the purposes of this standard the test shall be completed on the issue of the test report prescribed in BS 6334:1983.

C.2 Gas emission test

C.2.1 This test determines the gas emission from new valve regulated stationary lead-acid units when operated in the overcharge float condition.

C.2.2 The test shall be carried out on a number of new units, equivalent to 12 cells, which have undergone the capacity test specified in **B.1** and have been found to have a capacity, C_a, of at least C_3.

C.2.3 The units shall be maintained at an ambient temperature between 20 °C and 25 °C. Each unit valve shall be fitted with a gas collection device so that the emitted gas can be collected over several days and the volume determined to an accuracy of ±1 %.

NOTE 1 The emission of gas from the units occurs at irregular intervals so that provision for long unattended quantitative gas collection is needed. The emitted gas should be accumulated in a simple gas collection and measurement device as shown in Figure C.1.

C.2.4 Float charge the units as a series string at a voltage equivalent to 2.4 volts per cell for 72 h.

C.2.5 On completion of 72 h of float charge, commence gas collection and continue collecting gas for a further 96 h. Record the cumulative total actual volume of gas collected [A1] (V_a in ml) [/A1] over the period of 96 h, noting the ambient temperature, T_a (in °C), and pressure, P_a (in bar), at which the collections were made.

C.2.6 Calculate the normalized volume of gas, V_N, emitted by the new units at 20 °C and 1 bar pressure, where:

$$V_N = \left[\frac{V_a \cdot T_R}{T_A}\right]\left[\frac{P_a}{P_r}\right]$$

where:

- V_a is the cumulative total of gas collected, in [A1] ml [/A1];
- T_R is the reference temperature, in °K (at 20 °C T_R = 293 °K);
- T_A is the ambient temperature, in °K ($T_A = 273 + T_a$K);
- P_a is the ambient pressure, in bar;
- P_r is the normalized pressure, in bar (at 1 bar, P_r = 1 bar).

Therefore the above equation becomes

$$V_N = \left[\frac{293\ V_a}{273 + T_a}\right]\left[\frac{P_a}{1}\right]$$

The normalized rate of gas emission, G_E at 2.4 volts per cell, is given by:

$$G_E = \frac{V_N}{n \times C_3 \times t}$$

where:

- n the number of cells in the test (12, as given in **C.2.2**);
- C_3 the rated capacity in A·h at 20 °C (see **5.1.1** and **5.1.2**);
- t the test duration, in h (96 h, as given in **C.2.5**);

therefore

G_E = [A1) ml (A1] per cell, per A·h, per h.

The above expression therefore becomes

$$G_E = \frac{V_N}{12 \times C_3 \times 96}$$

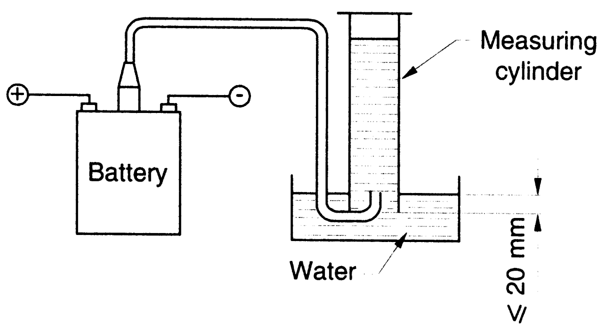

Figure C.1 — Gas collection and measurement

C.3 High current endurance test

C.3.1 The three units used in this test shall be capable of giving their rated capacity, C_3, and shall be fully charged in accordance with **B.1.1**.

C.3.2 Discharge each unit for 1 min at a constant current equal to 3.5 times the 5 min current specified in Table B.2. Charge each unit in accordance with **B.1.1**, and then perform a capacity test in accordance with **B.1** at the C_3 rate. Record the value of the actual capacity C_a. Following the capacity test, examine the units internally for the integrity of the group bars and current carrying parts of the top lead.

Record any indication of melting. During the test make observations to detect the absence of combustion or self-ignition.

CAUTION. There is the risk of an explosion of the internal gas mixture with this test and it should take place in an enclosure capable of containing explosion debris.

Annex D (normative) Methods of test (performance)

D.1 Capacity conformity level test

D.1.1 *Introduction*

The capacity conformity level test requires data at five conditions and ideally the sample size at each condition should be as large as possible. Inevitably the procedure requires a considerable number of expensive test pieces and the first part of this test method maximizes the data obtained from the 20 units subjected to the test. This is achieved by subjecting the same group of units to three test discharge conditions and correcting the measured data back to the first discharge level, as required by the standard. Ultimately the conformity level is determined on eight pieces of standardized corrected discharge data obtained at five conditions.

Manipulation of the test data is critical to the test procedure and this is explained by reference to the programme of discharge tests shown in Table D.1.

D.1.2 *Test procedure*

Subject a group of 20 units to the capacity test specified in **B.1**, programmed as given in Table D.1 The current I_{rt} shall be the value rI, to be estimated by the manufacturer, approximating to the discharge rate r given in Table D.1. Record the values of rI in a matrix as shown in Table D.1.

The final end voltage, U_f shall be 1.70 V per cell for r = 10 h, 8 h and 3 h rates, and 1.60 V per cell for r = 1 h, 0.25 h and 0.08 h rates. Measure and record the voltage against time for the discharges and the discharge temperatures θ_t.

Plot all the voltage/time curves from the recorded data.

NOTE In practice this is most efficiently achieved by plotting curves by each subgroup $rt_{y,z}$.

At the point where the plot intersects the value of U_f, determine the measured time rt and record this value in a matrix as shown in Table D.1.

The measured durations rt have now to be converted to standardized durations rt_s to standard final end voltages U_{fs}.

D.1.3 *Calculation of the standardized durations* rt_s *to standard final end voltages* U_{fs}

From the measured durations rt calculate the mean duration $rt_{m(y, z)}$ for each subgroup. Refer the mean duration values to Table D.2. and determine the standard final end voltage $U_{fs(y,z)}$ for each subgroup $rt_{m(y,z)}$.

Refer back to the original individual voltage/time curves prepared in **D.1.2** and attach the relevant standard final end voltage value $U_{fs(y, z)}$, and determine the standard voltage duration $rt_{s(x, y, z)}$ for each discharge current, rI, given in the matrix shown in Table D.1.

The Table D.1. matrix now contains standardized voltage durations $rt_{s(x, y, z)}$ at discharge currents rI to the standard final end voltages U_{fs}.

This data $rt_{s(x, y, z)}$ has now to be corrected for the following variables:

a) test temperature θ_t. To be corrected to the reference temperature 20 °C.

b) discharge number z. Data where z = 2 and z = 4 to be corrected to the equivalent z = 1.

c) variation between main group performance rt_{s1} and subgroup performance $rt_{s(y, 1)}$.

Table D.1 — Programme of discharge tests

Unit allocation		**Discharge number, *z***																			
		1				2				3				4				5			
		Data reference		**Measured data**		**Data reference**		**Measured data**		**Data reference**		**Measured data**		**Data reference**		**Measured data**		**Data reference**		**Measured data**	
Unit number, *x*	**Subgroup (*y*)**	*r*	*x, y, z.*	*rI*	*rt*	*r*	*x, y, z.*	*rI*	*rt*	*r*	*x, y, z.*	*rI*	*rt*	*r*	*x, y, z.*	*rI*	*rt*	*r*	*x, y, z.*	*rI*	*rt*
1	1	3	1.1.1			10	1.1.2			3	1.1.3			0.08	1.1.4			3	1.1.5		
2		3	2.1.1			10	2.1.2			3	2.1.3			0.08	2.1.4			3	2.1.5		
3		3	3.1.1			10	3.1.2			3	3.1.3			0.08	3.1.4			3	3.1.5		
4		3	4.1.1			10	4.1.2			3	4.1.3			0.08	4.1.4			3	4.1.5		
5	2	3	5.2.1			8	5.2.2			3	5.2.3			0.25	5.2.4			3	5.2.5		
6		3	6.2.1			8	6.2.2			3	6.2.3			0.25	6.2.4			3	6.2.5		
7		3	7.2.1			8	7.2.2			3	7.2.3			0.25	7.2.4			3	7.2.5		
8		3	8.2.1			8	8.2.2			3	8.2.3			0.25	8.2.4			3	8.2.5		
9	3	3	9.3.1			1	9.3.2			3	9.3.3			1	9.3.4			3	9.3.5		
10		3	10.3.1			1	10.3.2			3	10.3.3			1	10.3.4			3	10.3.5		
11		3	11.3.1			1	11.3.2			3	11.3.3			1	11.3.4			3	11.3.5		
12		3	12.3.1			1	12.3.2			3	12.3.3			1	12.3.4			3	12.3.5		
13	4	3	13.4.1			0.25	13.4.2			3	13.4.3			8	13.4.4			3	13.4.5		
14		3	14.4.1			0.25	14.4.2			3	14.4.3			8	14.4.4			3	14.4.5		
15		3	15.4.1			0.25	15.4.2			3	15.4.3			8	15.4.4			3	15.4.5		
16		3	16.4.1			0.25	16.4.2			3	16.4.3			8	16.4.4			3	16.4.5		
17	5	3	17.5.1			0.08	17.5.2			3	17.5.3			10	17.5.4			3	17.5.5		
18		3	18.5.1			0.08	18.5.2			3	18.5.3			10	18.5.4			3	18.5.5		
19		3	19.5.1			0.08	19.5.2			3	19.5.3			10	19.5.4			3	19.5.5		
20		3	20.5.1			0.08	20.5.2			3	20.5.3			10	20.5.4			3	20.5.5		

NOTE r is the discharge rate, and at the 8 hour rate of discharge ($r = 8$) the discharge current $rI = 8I$.
Each measured time period rt is uniquely described $rt_{x.y.z}$,
where
r is the discharge rate;
x is the unit number;
y is the subgroup number;
z is the discharge number.
Each subgroup of data can be described as $rt_{y.z}$. The main group of data can be described as rt_z. In practice, however, this can only apply to z = 1, 3, or 5.

Table D.2 — Standard final end voltage (see **B.3**)

Mean duration, $rt_{m(y,z)}$ h	**Standard final end voltage,** U_{fs} V	**Mean duration,** $rt_{m(y,z)}$ h	**Standard final end voltage,** U_{fs} V
0.025	1.60	0.833	1.73
0.058	1.61	0.950	1.74
0.100	1.62	1.117	1.75
0.142	1.63	1.500	1.76
0.208	1.64	1.750	1.77
0.267	1.65	2.250	1.78
0.325	1.66	2.750	1.79
0.383	1.67	3.500	1.80
0.458	1.68	4.500	1.81
0.533	1.69	5.500	1.81
0.600	1.70	7.500	1.83
0.667	1.71	9.500	1.84
0.750	1.72	>9.500	1.85

NOTE If a mean value $rt_{m(y, z)}$ falls between two values of standard mean duration or is equal to the upper value, the upper value is used to determine the standard final end voltage.

D.1.4 *Correction factors*

D.1.4.1 *Temperature (θ_t) corrections to durations rt_s*

Correct the standardized durations rt_s using the following formula

$$rt_{s(\theta t)} = \frac{rt_s}{1 + (\lambda\theta_t - 20)}$$

where

$rt_{s(\theta t)}$	is the standardized voltage duration corrected for temperature;
θ_t	is the temperature measured during the test;
λ	is the value 0.006 unless otherwise specified by the manufacturer.

This correction procedure applies to all standardized durations $rt_{s(x, y, z)}$ in the matrix shown in Table D.1.

D.1.4.2 *Correction of $z = 2$ & $z = 4$ duration data to equivalent values at $z = 1$*

Calculate the mean durations $r_{ms}\theta_t t_z$ for z =1,3,5, and plot the values of $r_{ms}\theta_t t_z$ against z. If $r_{ms}\theta_t t_z$ increases in value against z then deduce and apply the values of the factors to convert the $z = 2$ and $z = 4$ data to their equivalent at $z = 1$.

If $r_{ms}\theta_t t_z$ does not change with z, a correction factor is not necessary. If, however, $r_{ms}\theta_t t_z$ decreases in value against z, and a problem does not exist with the product or the charging regime in the test procedure, the value of $r_{ms}\theta_t t_z$ where $z = 5$ shall be taken as being equivalent to the $z = 1$ values, and factors to correct $z = 2$ and $z = 4$ values shall be applied accordingly.

At this stage, the matrix data given in Table D.1. for discharges $z = 3$ and $z = 5$ is now redundant, and the data in discharges $z = 2$ and $z = 4$ are all now equivalent to $z = 1$. The data $z = 2$ and $z = 4$ does have to be corrected for variation in subgroup performance y.

D.1.4.3 *Correction of z = 2 and z = 4 duration data for subgroup performance y*

Calculate mean duration value $r_{ms}\theta_t t_z$ for $z = 1$. Similarly, calculate the mean duration values $r_{ms}\theta_t t_{y,z}$ for $y = 1$ to 5 and $z = 1$.

$$\text{This subgroup correction factor} = \frac{r_{ms}\theta_t t_z}{r_{ms}\theta_t t_{y,z}}$$

This subgroup correction factor is applied to the Table D.1 matrix data $r_s\theta_t t_{y,z}$ corrected for the discharge number, but remaining in subgroups $y = 1$ to 5, $z = 2$ and $z = 4$.

The remaining duration data given in the Table D.1 matrix for $z = 1$, 2 and 4 has all been standardized to final standard end voltages, corrected for temperature, corrected where necessary for discharge number z, and corrected where necessary for subgroup performance y.

If the t data corrected for s, θ_t, y and z becomes T, the data available for capacity conformity calculations in matrix Table D.1 is summarized in Table D.3.

Table D.3 — Summary of standardized, corrected duration data

Estimated rate, r	Estimated current, rI	Corrected, standardized duration values of rT	Sample size, n
10	$10I$	$[10T_{y,z}$ where $y = 1, z = 2] +$ $[10T_{y,z}$ where $y = 5, z = 4]$	8
8	$8I$	$[8T_{y,z}$ where $y = 2, z = 2] +$ $[8T_{y,z}$ where $y = 4, z = 4]$	8
3	$3I$	$3T_z$ where $z = 1$	20
1	$1I$	$[1T_{y,z}$ where $y = 3, z = 2] +$ $[1T_{y,z}$ where $y = 3, z = 4]$	8
0.25	$0.25I$	$[0.25T_{y,z}$ where $y = 4, z = 2] +$ $[0.25T_{y,z}$ where $y = 2, z = 4]$	8
0.08	$0.08I$	$[0.08T_{y,z}$ where $y = 5, z = 2] +$ $[0.08T_{y,z}$ where $y = 1, z = 4]$	8

D.1.5 ***Calculation of maximum, minimum and mean values for capacity C and duration standard deviation σ***

D.1.5.1 From Table D.3 calculate the mean of rT (r_mT) for all values of r.

D.1.5.2 From Table D.3 calculate the standard deviation of r_mT ($r\sigma$) for all values of r.

D.1.5.3 Calculate the variation of r_mt (r_mt_{var}) for all values of r, where

$$r_mT_{var} = \frac{r\sigma \times 1.96}{\sqrt{n}}$$

and where n is the subgroup sample size given in Table D.3.

D.1.5.4 Calculate the maximum mean duration r_mT_{MAX} and the minimum mean duration r_mT_{MIN}, where

r_mT_{MAX} = r_mT (see **D.1.5.1**) + r_mT_{var} (see **D.1.5.3**); and
r_mT_{MIN} = r_mT (see **D.1.5.1**) – r_mT_{var} (see **D.1.5.3**).

D.1.5.5 From the values in **D.1.5.4**, calculate the maximum, minimum and mean capacities r_mC_{MAX}, rC_{MIN} and r_mC where $r_mC = r_mT$ (see **D.1.5.1**) × rI (see Table D.3).

D.1.5.6 Using Table D.4, calculate the maximum values of $r\sigma_{MAX}$ and the minimum value $r\sigma_{MIN}$ of the duration standard deviations $r\sigma$ against the sample n given in Table D.3.

Table D.4 — Standard deviation maximum and minimum factors

Sample size n	Factor for maximum value	Factor for minimum value
4	1.732	0.791
5	1.549	0.816
6	1.483	0.816
8	1.342	0.845
10	1.304	0.877
20	1.183	0.913
40	1.095	0.953
60	1.095	0.953

D.1.6 ***Determination of characterized values capacity C_R at standard rates R***

Plot the capacity values $r_m C$, $r_m C_{MAX}$, $r_m C_{MIN}$ (see **D.1.5.5**) against the logarithm of the mean duration $r_m T$ (see **D.1.5.1**). For all values of r see Table D.3.

Draw the "best fit" for the mean curve which wholly or mainly lies between the maximum and minimum values.

From the "best fit" capacity/mean duration plot, determine the characterized capacity values C_R at discharge rates R where $R = r_m T = 0.08$ (5 min), 0.25 (15 min), 1 h, 3 h, 8 h and 10 h.

Calculate the characterized discharge current I_R where $I_R = C_R/R$.

D.1.7 ***Determination of characterized values of capacity standard deviation σ_R at standard rates R***

Plot the standard deviation values $r\sigma$ (see **D.1.5.2**), $r\sigma_{MAX}$, $r\sigma_{MIN}$ (see **D.1.5.6**) against the logarithm of the mean duration $r_m T$ (see **D.1.5.1**) and draw the "best fit" curve for the standard deviation which wholly or mainly lies between the maximum and minimum values.

From the "best fit" standard deviation/mean duration plot, determine the characterized capacity values σ_R at discharge rates R, where $R = r_m T = 0.08$ (5 min), 0.25 (15 min), 1 h, 3 h, 8 h and 10 h.

Convert the characterized standard deviation duration values σ_R into equivalent values for capacity σ_{CR} where

$\sigma_{CR} = \sigma_R \times I_R$ (see **D.1.6**).

D.1.8 ***Calculation of conformity***

Calculate the minimum capacity values $C_{R(MIN)}$ for $R = 0.08$ (5 min), 0.25 (15 min), 1 h, 3 h, 8 h and 10 h where

$C_{R(MIN)} = C_R - (3 \times \sigma_{CR})$ (see **D.1.6** and **D.1.7**).

Determine the conformity factor F at the same values of R, where

$$F = 3 + \frac{C_{R(MIN)} - C_{RM}}{\sigma_{CR}}$$

where

C_{RM} is the manufacturer's claimed capacity at the rate R; and

σ_{CR} $= \sigma_R \times I_R$.

The conformity factors F are converted into percentage conformity values by reference to the data in Table D.5.

The percentage conformity values shall be stated at the 5 min, 15 min, 1 h, 3 h, 8 h and 10 h rates of discharge.

D.2 Cyclic endurance test

Perform the test on six units which, when tested in accordance with **B.1** were found to have a capacity, C_a, of at least C_3.

Connect the units to a device whereby they undergo a continuous series of cycles throughout the test, each cycle comprising:

a) a discharge for 3 h at a current of $I = 0.75\ I_3$ maintained constant within ±1 %, where $I_3 = C_3/3$; and

b) a charge for 21 h immediately following the discharge, at a voltage recommended by the manufacturer but not exceeding 2.40 V ± 0.01 V per cell, the current at the beginning of the charge being limited to $I_{MAX} = 1.5\ I_3$ unless otherwise recommended by the manufacturer.

Perform the endurance test at the rate of one cycle per day.

Maintain the units at an ambient temperature of between 15 °C and 25 °C. The average ambient temperature shall be as close to the reference temperature 20 °C as is practicably possible.

D.2.1 After 50 cycles, remove the units from the cycling device, and recharge them at 2.4 V per cell for the period recommended by the manufacturer. On completion of the recharge, subject the units to a capacity test in accordance with **B.1**. Record the actual capacity, C_a, achieved.

Subject the units to another series of 50 cycles, and repeat the procedure until the actual capacity, C_a, has fallen to less than 0.8 C_3.

D.2.2 When the performance is stated as the number of cycles to a residual capacity, $C_a = 0.8\ C_3$, the recorded values of actual capacity, C_a, shall be plotted against the cycle endurance in 50 cycle increments. The cycle endurance at any actual capacity level, C_a, is derived from the intersection of the 0.8 C_3 value with the graph of actual capacity against cycle endurance.

Table D.5 — Percentage conformity values

Factor value *F*	Conformity %	Table 4 classification	
		Conformity %	Performance class
≥ 3	≥ 99.87	≥ 99.9	1
<3 to ≥ 2.326	<99.87 to ≥ 99	≥ 99	2
<2.326 to ≥ 1.645	<99 to ≥ 95	≥ 95	3
<1.645 to ≥ 1.282	<95 to ≥ 90	≥ 90	4
<1.282	<90	N/A[a]	N/A[a]

[a] N/A is excluded from the classification.

D.3 Charge retention test

D.3.1 Prepare, in accordance with **B.1.1**, six units which have undergone the rated capacity test in accordance with **B.1** and have obtained a capacity, C_a, of at least C_3. Ensure that the upper surface of the cells (lids) are kept clean and dry throughout the test.

Allow the units to remain without a connected circuit for a period of 90 days, during which time the average ambient temperature shall be (20 ± 2) °C.

D.3.2 After 90 days of storage without a connected circuit, subject the units to a capacity test in accordance with **B.1.2** to **B.1.8**. Correct the measured capacity, C_a, in accordance with the equation in **B.1.8** to obtain the 90 day capacity value, C'_a.

D.3.3 The charge retained, C_R, expressed as a percentage, is equal to

$$\frac{100\ C'_a}{C_a}$$

D.4 Internal resistance test

D.4.1 The values of internal resistance obtained in this test refer to a single unit. However, the resistance of intercell connections shall be taken into account when calculating the internal resistance for a complete battery.

D.4.2 Perform the test on six units which, after being submitted to the capacity test in accordance with **B.1**, have been found to have a capacity, C_a, of at least C_{r3}

D.4.3 After preparation in accordance with **B.1.1** place the units in a chamber at the appropriate ambient temperature until the surface temperature of the cells or monobloc batteries reaches (20 ± 2) °C.

Establish the discharge characteristic $U = f(I)$ by determining two of its points in the following way.

a) first point, (U_1, I_1)

After 20 s of discharge at the current $I_1 = 3\ I_3 \pm 10\ \%$, record the voltage and current to give the first point. Interrupt the discharge after a maximum period of 25 s. Without recharging and after an open circuit stand of between 2 min and 5 min, determine the second point.

b) second point, (U_2, I_2)

After 5 s of discharge at a current of $I_2 = 9\ I_3 \pm 10\ \%$ record the voltage and current to give the second point.

The slope of the characteristic $U = f(I)$ determines the value of the internal resistance (R_i).

From Figure D.1, it follows that

$$R_i = \frac{U_1 - U_2}{I_2 - I_1}\Omega$$

Measure the voltage at the terminals of each unit in order to ensure that no external voltage drop interferes with the test. A suitable circuit is given in Figure D.2.

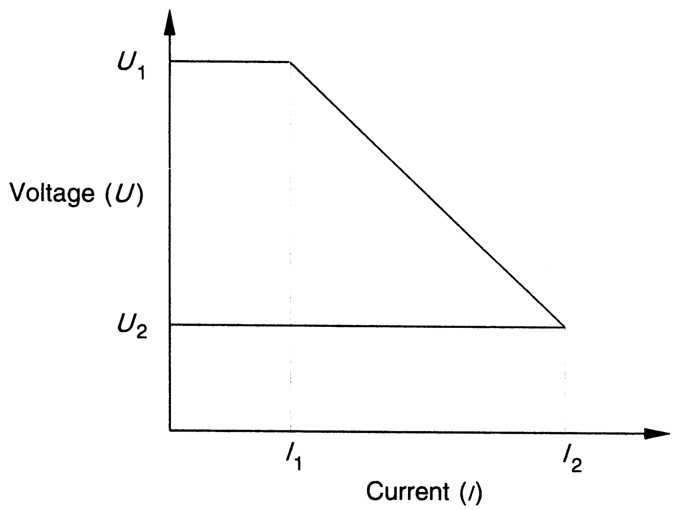

Figure D.1 — Discharge characteristic $U = f(I)$

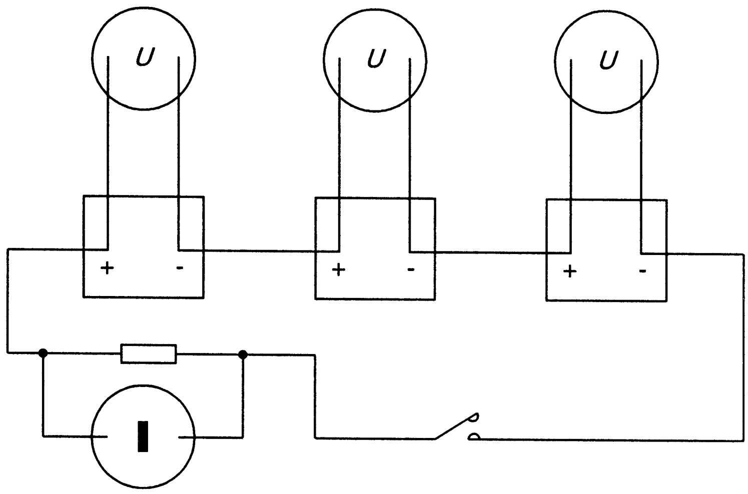

Figure D.2 — Typical test circuit

Annex E (normative) Methods of test (durability)

E.1 Elevated temperature tests

E.1.1 ***Selection of test pieces***

Choose at random four sample test pieces which are typical products of the current manufacture.

E.1.2 ***Preparation of the test pieces***

Charge the selected units at the float voltage specified in **8.2.1**. This float voltage shall be stated in the test certificate. Subject the four units to the capacity test in accordance with **B.1**. Note the actual capacities at the 3 h rate, C_{a3}, which shall be not less than C_3, the rated capacity claimed at the 3 h rate.

If a unit does not achieve the claimed 3 h capacity, select four new test pieces in accordance with **E.1.1**. If a second selection fails this criterion, the whole test shall be terminated.

Fully recharge the selected units.

E.1.3 ***Test***

E.1.3.1 Support the four test pieces individually by clamps on the opposing faces of the cell or monobloc. At no time during the test may water or electrolyte be added to units.

E.1.3.2 [A1⟩ *Text deleted* ⟨A1]

[A1⟩ Subject the four test pieces ⟨A1] to a capacity test at the 8 h rate to 1.84 V per cell in accordance with **B.1**. Record the actual capacities at the 8 h rate, C_{a8}, which shall be not less than C_8, the rated capacity claimed at the 8 h rate. Fully recharge the test pieces.

E.1.3.3 Place the test pieces in hot air enclosures. Maintain the average air temperature surrounding the pieces at 55 ± 2 °C for a period of 42 days. During this period, float charge the test pieces at the float voltage specified in **8.2.1**.

NOTE The test pieces can be configured as a parallel or series circuit.

On completion of the elevated temperature period, withdraw the test pieces from the heated enclosures and, whilst remaining on float, allow them to cool to normal ambient conditions. Fully recharge the test pieces in accordance with **B.1.1**.

E.1.3.4 Repeat the procedures specified in **E.1.3.2**.

Continue this cycle of testing until the actual capacities, C_a recorded in **E.1.3.2**, are less than 0.8 C_r, the claimed rated capacity at the appropriate rate of discharge.

By plotting C_a against the accumulated number of days at 55 °C, the endurance at each rate of discharge can be determined for each test piece to a failure level of 0.8 C_r. Calculate the average endurance at both rates of discharge.

E.2 Float voltage test

E.2.1 Perform the test on a string of at least six units, which have been prepared for testing in accordance with **B.1.1**. Maintain the units at an ambient temperature of (20 ± 1) °C. The upper surfaces of the units (lids) shall be kept clean and dry throughout the test.

E.2.2 Subject the units to a permanent floating charge at a voltage U_{flo}, where U_{flo} is the manufacturer's recommended float voltage at 20 °C operation; its value should typically be in the range of (2.23 to 2.30) × nV, n being the number of cells. Periodically interrupt the permanent floating charge by a discharge test in accordance with **B.1.2** to **B.1.8**.

The programme for the test shall be as follows:

day 1: place the units on permanent floating charge;

day 8: discharge the units in accordance with **B.1.2** to **B.1.8**, and return them immediately to permanent floating charge;

day 11: discharge the units in accordance with **B.1.2** to **B.1.8**, and return them immediately to permanent floating charge;

day 91: discharge the units in accordance with **B.1.2** to **B.1.8**, and return them immediately to permanent floating charge;

day 183: discharge the units in accordance with **B.1.2** to **B.1.8**.

Take measurements of ambient test temperature and the six unit float voltages $U_{1\text{-}6}$ just before the discharge tests on days 8, 11, 91 and 183. Calculate the actual capacities, C_a, corrected for temperature, of each of the units for the discharge tests on days 8, 11, 91 and 183.

E.3 Pillar seal assembly test

E.3.1 *Adhesive seals*

Perform tests on four units which have been charged in accordance with **B.1.1**. Connect the four units to a constant current power supply at a charging current of 0.033 C_3. Subject the four units to 24 h cycles of the temperature and humidity conditions shown in Figure E.1.

Perform this cycle 10 times and then inspect the external surface of the positive and negative terminal pillars for the presence of acid. To detect acid, place drops of Congo Red indicator solution to just cover the surface of the terminal pillar and sealing device. If no acid is detected, wash away the indicator solution and repeat the 10 days' cycle eight times.

E.3.2 *Compression seals*

The performance of the compression seal is determined during the elevated temperature test specified in **E.1** At the end of each 42 day cycle, (see **E.1.3.3**) examine the pillars for any witness marks indicating electrolyte leakage. Record the time at which the leakage was observed, and continue the test until the elevated temperature programme is concluded.

At the conclusion of the test, subject all the pillar seals to the positive pressure test specified in **E.4.2**.

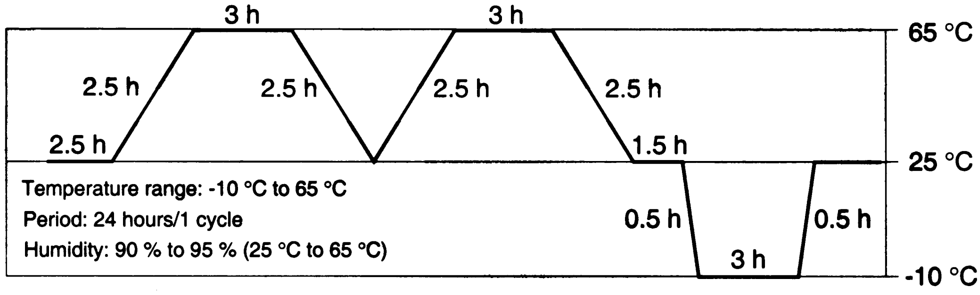

Figure E.1 — Temperature-time cycle

E.4 Mechanical stresses

E.4.1 *General*

Perform the tests on three units incorporating sensitive design features common to the product range under test, and which have been charged in accordance with **B.1.1**. Check that all units are leak proof, both before and after the tests, to a positive pressure recommended by the manufacturer. In the absence of a recommendation from the manufacturer 30 kPa shall be used as the positive pressure.

Discharge test the three units in accordance with **B.1**, both before and after the mechanical test. Perform the discharge test at the 5 min rate claimed by the manufacturer (see Table B.2).

E.4.2 *Mechanical tests*

Perform the tests at an ambient temperature between 15 °C and 35 °C on three units, testing one in accordance with each of three parts of BS EN 60068, as follows.

BS EN 60068-2-6

Maintaining the unit in an upright position, vibrate it at 19.6 ms $^{-2}$ (2 *g*) at an amplitude of 6 mm (peak to peak) in three phases through 5 Hz to 150 Hz, with crossover frequency 13 Hz at one octave per min for 30 min in each plane.

BS EN 60068-2-29

Perform the test in the vertical plane subjecting the unit to 1000 continuous bumps of 6 ms duration:

- at 245 ms^{-2} (25 *g*) for units weighing up to 50 kg;
- at 118 ms^{-2} (12 *g*) for units weighing between 50 kg and 100 kg;
- at 59 ms^{-2} (6 *g*) for units weighing between 100 kg and 250 kg.

BS EN 60068-2-32

Drop the unit twice on its base, onto a solid floor:

- from a height of 100 mm for units weighing up to 50 kg;
- from a height of 50 mm for units weighing between 50 kg and 100 kg;
- from a height of 25 mm for units weighing between 100 kg and 250 kg.

Annex F (informative)
Electromagnetic compatibility

Rechargeable cells or batteries within the scope of this standard are not sensitive to normal electromagnetic disturbances, and therefore no immunity tests shall be required. Free-standing rechargeable cells or batteries electrically isolated from any associated electrical system are for all practical purposes electromagnetically inert, and therefore any requirements for electromagnetic compatibility shall be deemed to be satisfied.

NOTE Rechargeable cells or batteries are part of an electrical system, and the manner in which they are used could involve considerations of electromagnetic compatibility. In such cases, requirements for electromagnetic compatibility should be accommodated by the design of the system.

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List of references

Normative references

BSI publications

BRITISH STANDARDS INSTITUTION, London

BS 6133:1995, *Code of practice for safe operation of lead-acid stationary cells and batteries.*

BS 6217:1981, *Guide to graphical symbols for use on electrical equipment.*

BS 6334:1983, *Methods of test for the determination of the flammability of solid electrical insulating materials when exposed to an ignition source.*

BS EN ISO 9001:1994, *Quality systems. Model for quality assurance in design, development, production, installation and servicing.*

BS EN 28601:1992, *Specification for representation of dates and times in information interchange.*

BS EN 60068, *Environmental testing.*

BS EN 60068-2-6:1996, *Test Fc. Vibration (sinusoidal).*

BS EN 60068-2-29:1993, *Tests. Test Eb and guidance. Bump.*

BS EN 60068-2-32:1993, *Test Ed. Free fall.*

Informative reference

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BRITISH STANDARDS INSTITUTION, London

BS EN 60896, *Stationary lead-acid batteries. General requirements and methods of test.*

BS EN 60896-1:1992, *Vented types.*

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