



Installation, maintenance, testing and replacement of secondary batteries in buildings

Part 1: Vented cells



AS 2676.1:2020

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- CSIRO
- Electrical Compliance Testing Association of Australia
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- Energy Networks Australia
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Installation, maintenance, testing and replacement of secondary batteries in buildings

Part 1: Vented cells

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Preface

This Standard was prepared by the Standards Australia Committee EL-005 Secondary Batteries, to supersede AS 2676.1—1992, *Guide to the installation, maintenance, testing and replacement of secondary batteries in building, Part 1: Vented cells*.

The objective of this Standard is to set out minimum requirements for the installation, maintenance, testing and replacement of vented secondary batteries permanently installed in buildings, structures or premises.

It also provides guidance to determine when batteries should be replaced.

This Standard covers secondary batteries with a nominal voltage of 24 V or greater, and a capacity exceeding 10 A.h at the 1 h rate and includes batteries comprising vented lead-acid cells and alkaline batteries comprising vented cells (such as nickel-cadmium cells).

This Standard covers requirements for components of the d.c. system of which the battery is a part, where these components comprise an essential part of the d.c. system.

This Standard covers vented cells only. The installation and maintenance of sealed cells are covered by AS 3011.2 and AS 2676.2.

The major changes in this edition are as follows:

- (a) Scope aligned to complement AS/NZS 5139.
- (b) Important requirements established in text.
- (c) Battery terminal connection requirements aligned with AS 3011.1.
- (d) Battery protection requirements aligned with AS 3011.1.
- (e) Layout, location and ventilation requirements aligned with AS 3011.1.

The terms “normative” and “informative” are used in Standards to define the application of the appendices to which they apply. A “normative” appendix is an integral part of a Standard, whereas an “informative” appendix is only for information and guidance.

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Introduction

Both the ampere-hour capacity and voltage of battery installations have increased to the point where some voltages now border on the medium and high voltage range. Even in extra-low voltage installations, the low internal resistances of batteries under short-circuit conditions can cause severe injuries to staff working on a battery or cell, or cause fire and explosion.

Tests have shown that batteries of 24 V d.c. and above may present problems in breaking fault currents and that additional precautions need to be taken to reduce the possibility of accidental short-circuits.

In preparing this Standard, the Committee considered the requirements of both vented lead-acid cells and vented alkaline cells.

Australian Standard®

Installation, maintenance, testing and replacement of secondary batteries in buildings

Part 1: Vented cells

Section 1 Scope and general

1.1 Scope

This Standard sets out requirements and provides guidance for the installation, maintenance, testing and replacement of vented secondary batteries permanently installed in buildings, structures or premises.

This Standard covers secondary batteries with a nominal voltage of 24 V or greater, and a capacity exceeding 10 A.h at the 1 h rate. It includes batteries comprising vented lead-acid cells and alkaline batteries comprising vented cells (such as nickel-cadmium cells).

This Standard covers requirements for components of the d.c. system of which the battery is a part, where these components comprise an essential part of the d.c. system.

This Standard covers vented cells only. The installation and maintenance of sealed cells are covered by AS 3011.2 and AS 2676.2.

NOTE 1 Requirements specifically applicable to the design and installation of extra-low voltage (d.c.) power supplies that are used by telecommunications carriers in the provision of public telecommunications networks are given in AS/NZS 3015.

NOTE 2 General installation and safety requirements for battery energy storage systems (BESSs) are given in AS/NZS 5139.

1.2 Application

This Standard is to be read in conjunction with AS 3011.1.

1.3 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document.

NOTE Documents for informative purposes are listed in the Bibliography.

AS 1170.4, *Structural design actions, Part 4: Earthquake actions in Australia*

AS 1319, *Safety signs for the occupational environment*

AS 2668, *Water for use in secondary batteries*

AS 2669, *Sulphuric acid for use in lead-acid batteries*

AS 3011.1, *Electrical installations — Secondary batteries installed in buildings, Part 1: Vented cells*

AS/NZS 3000, *Electrical installations (known as the Australian/New Zealand Wiring Rules)*

AS/NZS 61439.1, *Low-voltage switchgear and controlgear assemblies, Part 1: General rules (IEC 61439-1, Ed. 2.0 (2011), MOD)*

1.4 Terms and definitions

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

1.4.1

accessible, readily

capable of being reached quickly and without climbing over or removing obstructions, mounting upon a chair, or using a movable ladder, and in any case not more than 2 m above the ground, floor or platform

1.4.2

authorized personnel

person in charge of the premises, or other person appointed or selected by the person in charge of the premises, to perform certain duties associated with the battery installation on the premises

Note 1 to entry: There may be additional regulatory requirements that work on low or medium voltage equipment be undertaken by licensed personnel.

1.4.3

battery

unit consisting of one or more cells connected in a series, parallel or series-parallel arrangement, to supply the voltage and current requirements of a connected load

1.4.4

battery enclosure

enclosure containing batteries for use in an area other than a battery room or an area restricted to appropriately qualified personnel

Note 1 to entry: A battery enclosure may also be used in a battery room

1.4.5

battery room

room specifically intended for the installation of batteries

1.4.6

battery stand

1.4.6.1

stepped

stand on which containers are placed in rows, the rows being placed at different levels to form a stepped arrangement

1.4.6.2

tiered

stand on which rows of containers are placed above containers of the same or another battery

1.4.7

boost charge

partial charge generally at a high rate for a short period

1.4.8

capacity

C

quantity of electricity which a fully charged battery can deliver under specified conditions, measured in ampere hours (A.h.)

Note 1 to entry: The capacity of a cell or battery is denoted by the symbol *C*. As the capacity varies with rate of discharge, the symbol *C* is followed by a numerical suffix giving the rate of discharge. Thus *C*₁₀ is the capacity in ampere hours at the 10 h rate of discharge. The specified temperature is usually 25 °C. The final voltage depends on battery type and conditions of service.

1.4.8.1**actual capacity**

quantity of electricity in ampere hours that can be withdrawn from a cell or battery for a specific set of operating conditions including discharge rate, temperature, initial state of charge, age, and final voltage

1.4.8.2**rated capacity**

quantity of electricity in ampere hours, declared by the manufacturer, a battery can deliver after a full charge under specified conditions

Note 1 to entry: The specified conditions are rate of discharge, final voltage and temperature.

1.4.9**capacity test**

discharge of a battery to a designated terminal voltage whilst measuring time

1.4.10**cell**

assembly of electrodes and electrolyte which constitute the basic unit of a battery

1.4.11**charge/discharge rate**

current at which a battery is charged or discharged, expressed in either amperes or as a multiple of the rated capacity (see [Clause 1.4.8](#)) of the battery

Note 1 to entry: If a battery is rated at 500 A.h at the 10 h rate of discharge and is being discharged at a current of 50 A, its discharge rate can be expressed as $0.1C_{10}$.

1.4.12**charging**

operation during which a battery receives electric energy, which is converted to chemical energy, from an external circuit

Note 1 to entry: The quantity of electric energy is known as the charge, and is usually measured in ampere hours.

1.4.13**constant current charge**

charge during which the current is maintained at a constant value

1.4.14**constant voltage charge**

charge during which the voltage across the battery terminals is maintained at a constant value

1.4.15**container**

container for the plate pack and electrolyte of a cell constructed of a material impervious to attack by the electrolyte

1.4.16**discharging**

operation during which a battery delivers current to an external circuit by the conversion of chemical energy to electric energy

1.4.17**duty cycle**

specified output of voltage or current to be achieved by the battery for a given period followed by a charge current to restore the battery charge to an acceptable level

1.4.18**electrolyte**

liquid or solid substance containing mobile ions which will render the substance ionically conductive

Note 1 to entry: Sulfuric acid (H₂SO₄) in lead-acid batteries and sodium hydroxide (NaOH) in nickel-cadmium batteries are examples.

1.4.19**electrolyte density**

density of the electrolyte measured in kilograms per cubic metre at a specific temperature (the density of pure water = 1 000 kg/m³ at 4 °C)

Note 1 to entry: The density of an electrolyte was formerly indicated by its specific gravity. Specific gravity is the ratio of the density of the electrolyte to the density of pure water, shown as the following equation:

$$\text{S.G.} = \frac{\text{electrolyte density (in kilograms per cubic metre)}}{1\,000}$$

1.4.20**equalizing charge**

extended charge to ensure complete charging of all the cells in a battery

1.4.21**final voltage****cutoff voltage****end voltage**

prescribed voltage at which a discharge is considered finished

1.4.22**float charge**

permanent connection of a battery to a voltage-regulated d.c. system so that the battery is maintained fully charged and able to supply power to the system, if the normal charging source fails

1.4.23**gassing**

formation of gas produced by electrolysis

1.4.24**inter-cell connections**

connections made between consecutive cells or monoblocs in a battery

Note 1 to entry: This includes connections made between cells or monoblocs located on different rows or tiers, commonly referred to as inter-row connections

1.4.25**may**

indicates the existence of an option

1.4.26**monobloc battery**

secondary battery in which two or more cells are fitted in a multi-compartment container

1.4.27**performance test**

test of the capacity of a battery carried out in order to compare the capacity of a battery with its rated value, or a previously measured value

1.4.28**pilot cell**

selected cell of a battery which is considered to be representative of the average state of the battery or part of the battery

1.4.29**prospective fault current**

highest level of fault current that can occur at a point in a circuit

Note 1 to entry: This is the fault current that can flow in the event of a zero impedance short-circuit and if no protective devices operate.

1.4.30**service life**

period of useful life of a battery under specified conditions

1.4.31**service test**

special test of the ability of a battery to satisfy the design requirements (battery duty cycle) of the d.c. system

1.4.32**shall**

indicates that a statement is mandatory

1.4.33**should**

indicates a recommendation

1.4.34**shroud**

insulated cover to protect the terminals and inter-cell connectors from inadvertent contact by personnel, and accidental short-circuiting, and to provide protection against corrosion

1.4.35**terminal post**

part provided for the connection of a cell or a battery to external conductors

1.4.36**transit plug**

special plug fitted to the cells for transit

1.4.37**vent plug**

part closing the filling hole which is also employed to permit the escape of gas

Section 2 Design considerations for direct current systems using batteries

2.1 General

The major considerations in the design of a battery installation are the —

- (a) size and type of battery; and
- (b) ratings and types of switchgear and conductors.

The size and type of battery depend upon the requirements and function of the d.c. system of which the battery is a part.

The major considerations in switchgear and conductor selection are as follows:

- (i) Rated operational voltage.
- (ii) Rated continuous current of switchgear.
- (iii) Rated short-time withstand current.
- (iv) Rated making and breaking current of switchgear.

2.2 Battery size (nominal voltage and rated capacity)

The following d.c. system requirements are basic to the selection of battery size:

- (a) The minimum system voltage.
- (b) The maximum system voltage.
- (c) The duty cycle.
- (d) The design life of the battery.
- (e) Environmental conditions.

2.3 Method of connection

Batteries typically consist of a number of identical cells connected in series. The voltage of a series connection of cells is the voltage of a single cell multiplied by the number of cells. Cells of unequal capacity shall not be connected in series.

If cells with capacity great enough to meet the design load and duration requirements of the installation are not available, then two or more series-connected strings of equal numbers of cells may be connected in parallel to achieve the desired rated capacity.

The rated capacity of such a battery is the sum of the capacities of a group of cells comprising a single cell from each of the parallel branches. Cells of unequal capacity should not be connected in parallel unless this arrangement is recommended by the manufacturer.

2.4 Operating conditions

The conditions under which a battery is operated affect the capacity of a battery.

Important factors that reduce the capacity of a battery below the rated capacity are as follows:

- (a) Low temperatures reduce the actual capacity of a battery below its rated capacity, see [Appendix A](#).
- (b) A higher rate of discharge than the rate used in specifying rated capacity reduces its capacity.

- (c) Maintaining a higher final cell voltage than that used by the manufacturer to determine rated capacity will result in a decrease in actual capacity.

NOTE Operation of a battery in ambient temperatures above that used by the manufacturer to specify the life of the battery may result in reduced battery life.

2.5 Battery short-circuit current

The need for a high discharge current for short periods has resulted in the development of cells with low internal resistance and high discharge current capability. A typical vented lead-acid stationary battery with a nominal capacity of 200 A.h is capable of delivering a short-circuit current of 2 000 A.

Batteries should be accompanied by manufacturer information regarding the applicable sizing of battery short-circuit protection. If such information regarding the short-circuit protection of a battery is not available, the prospective fault level at the battery terminals should be considered to be 20 times the nominal battery capacity at the 3 h rate.

NOTE 1 The internal resistance of a cell can be measured by the method provided in [Appendix B](#). The cell short-circuit current can then be calculated from the following [Equation 2.1](#):

$$I_{sc} = \frac{V_{oc}}{R_i} \quad 2.1$$

where

- I_{sc} = cell short-circuit current, in amperes
 V_{oc} = cell open-circuit voltage
 R_i = cell internal resistance at full charge, in ohms

The short-circuit current rating of a battery consisting of strings of cells in parallel is the sum of the short-circuit current ratings of a group of cells comprising a single cell from each of the parallel branches.

NOTE 2 A monobloc battery consisting of a number of cells in series can be treated as a single cell for the purpose of determining short-circuit current rating.

2.6 Voltage drop

The required maximum voltage drop between the battery terminals and the d.c. load, rather than current-carrying capacity, will determine the size of the conductors for some installations.

The smallest conductor that will satisfy a maximum voltage drop requirement is the smallest that will satisfy [Equation 2.2](#):

$$V_c = \frac{1\,000V_h}{L \times I_f} \quad 2.2$$

where

- V_c = voltage drop over the route length of the circuit as shown in manufacturers' tables for various conductors, in millivolts per ampere metre (mV/A.m)
 V_h = maximum voltage drop, in millivolts per ampere metre
 L = route length of the circuit, in metres
 I_f = full load current, in amperes

2.7 Connection between battery and direct current switchboard

2.7.1 General

Any cable, busway or busbar forming the connection between a battery terminal and a d.c. switchboard shall be rated to withstand the prospective short-circuit current which the battery is able to deliver for a period of at least 1 s.

AS 3011.1 provides requirements for the insulation and identification of cables and busbars.

2.7.2 Cables

Cables should be effectively clamped and sufficient support provided throughout the length of cables to minimize sag, and prevent undue strain from being imposed on the cable. Cables shall not be bent through a radius less than the minimum bending radius specified by the cable manufacturer.

2.7.3 Busbars

Busbars should be insulated throughout their length by an insulating material not affected by the corrosive fumes that are present in a battery room. Steelwork supporting the busbar system shall be installed so as not to restrict access to the battery for the purpose of maintenance.

2.7.4 Busways

Busways are recommended for larger installations because of their modular construction and ease of installation. They can be suspended from the ceiling of the battery room, leaving greater access area around the battery.

Busways should be fully enclosed and shall be able to withstand the prospective fault current without damage.

2.8 Direct current switchboards

Because of the high prospective fault current of batteries, d.c. switchboards used in conjunction with a battery shall be designed in accordance with the following:

- (a) All switchgear (e.g. combination fuse-switch units, moulded case circuit-breakers and isolators) shall be of such design that the occurrence of an internal arc fault is minimized.
- (b) Direct current switchboards of rated current greater than 100 A or prospective short-circuit current greater than 5 kA shall be in accordance with AS/NZS 61439.1.

NOTE Direct current switchboards with prospective fault levels in excess of 20 kA should be designed for increased security against the occurrence of or the effects of internal arcing faults. Refer to the guidelines provided in AS/NZS 61439.1.

2.9 Terminals and connectors

AS 3011.1 provides requirements for connections for batteries and busbars.

Inter-cell and battery terminal connections should be constructed of materials either intrinsically resistant to corrosion or suitably protected by surface finish against corrosion. The joining of materials that are incompatible with a corrosive atmosphere should be avoided.

2.10 Direct current systems — earthing and earth-fault detection

There are four basic installation schemes for d.c. systems using batteries. These are as follows:

- (a) The unearthed d.c. system in which neither pole of the battery is connected to earth.

A non-galvanically isolated, i.e. transformerless, unearthed d.c. system, when supplied from a mains supply earthed by the MEN system in accordance with AS/NZS 3000, will have one terminal of the battery referenced at half nominal voltage to the installation earth. Work on a battery in such a system should be carried out with the battery isolated from the battery charger.

- (b) The solidly earthed d.c. system, where either the positive or negative pole of the battery is connected directly to earth.

NOTE 1 See [Appendix C, Figures C.1 and C.2](#).

- (c) The resistance earthed d.c. system, where the battery is connected to earth through a resistance. The resistance is used to permit operation of a current relay which in turn initiates an alarm.

NOTE 2 See [Appendix C, Figure C.3](#).

- (d) A tapped solid earth, either at the centre point (Edison system) or at another point to suit the load system.

NOTE 3 See [Appendix C, Figure C.4](#).

The advantage of an unearthed floating system is that it is not necessary to disconnect supply in the event of a single earth-fault. It is only after the occurrence of a second earth-fault that a dangerous situation may arise and supply shall be disconnected. An unearthed system should be fitted with an alarm to indicate the presence of an earth-fault.

Typical earth-fault relay operating currents are as follows in [Table 2.1](#).

Table 2.1 — Earth-fault relay operating currents

Direct current system voltage V	Earth-fault relay operating current mA
50	5
110	10
240	30

2.11 Earth-fault location

Where an earth-fault has occurred on a circuit employing an earth-leakage relay and alarm, each d.c. distribution circuit should be isolated in turn until all faults have been isolated.

2.12 Protection of batteries and direct current circuits

Requirements for protection of output conductors against overcurrent are specified in AS 3011.1.

Protective devices should be selected from the following:

- (a) Fuses, refer to AS/NZS IEC 60947.3.
- (b) Combination fuse switch units incorporating HRC fuses, refer to AS/NZS IEC 60947.3.
- (c) Miniature circuit-breakers (MCBs), refer to AS/NZS 3111 or moulded case circuit-breakers (MCCBs), refer to AS 2184.

MCBs and some MCCBs have limited short-circuit current ratings and may need to be backed up by HRC fuses.

The installation should be arranged so that it is possible to completely isolate the battery.

2.13 Alarms

AS 3011.1 provides requirements for alarms for overcurrent or overvoltage conditions.

It is desirable to receive early warning of high or low battery voltage for the following reasons:

- (a) An indication of low battery voltage warns against —
 - (i) discharging the battery to an extent that is unsuitable for normal operation of the load; and
 - (ii) maintaining the battery in a discharged condition.

Either of the above will shorten the life of cells, particularly cells of lead-acid batteries.

- (b) An indication of high battery voltage warns against overcharging the battery and reduces the risk of damage to battery-charging equipment.

When a battery is receiving a charge (other than a float charge), suitable detectors should monitor the battery voltage so that when the battery reaches full charge either the charge rate is reduced automatically, or an alarm is initiated.

When a battery is receiving a float charge, suitable detectors should monitor the battery voltage and initiate an alarm if the voltage exceeds or falls below the normal operating voltage limits of the rectifier or generator which is permanently connected in parallel with the battery.

Detection devices should incorporate a short delay to avoid spurious operation of alarms by transient voltages.

The alarm system should provide an audible alarm and visual indication at the system installation. If provision is made for the adjustment of an alarm setpoint, the adjusting device should be located behind a cover that cannot be removed without the use of a tool.

2.14 Dual battery system

Where the requirement for continuous supply makes the disconnection of a battery for service difficult, a dual battery system may be warranted.

NOTE [Appendix E, Figure E.1](#) illustrates a typical dual battery system.

Section 3 Battery accommodation

3.1 General

Installations using secondary batteries vary considerably in size, from large public utility installations to small emergency lighting installations. AS 3011.1 provides requirements for battery accommodation.

3.2 Layout and location

AS 3011.1 contains requirements for the layout of battery rooms and enclosures.

Equipment with exposed arcing contacts shall not be located in areas where hydrogen pockets are likely to form if ventilation were to fail.

The following recommendations apply to battery room layout and location:

- (a) The location should be as free from vibration as possible.
- (b) Extreme ambient temperatures should be avoided because low temperatures decrease battery capacity and prolonged high temperatures shorten battery life.
- (c) A battery-servicing equipment locker should be installed in or adjacent to the battery installations.

3.3 Ventilation

3.3.1 Gas evolution

All vented battery installations shall be supplied with either natural or forced ventilation depending on the amount of hydrogen gas generated.

All vented secondary cells generate hydrogen and oxygen gases during charging. The major release of hydrogen gas occurs after a cell has achieved 95 % of charge, or during any boost charging or overcharging of the battery. Significant gas evolution does not occur when a battery is on float charge.

3.3.2 Rate of ventilation

AS 3011.1 provides requirements for ventilation.

To calculate the minimum exhaust ventilation rate required to maintain hydrogen concentration below 2 %, apply [Equation 3.1](#):

$$q_v = 0.006nI \quad 3.1$$

where

q_v = the minimum exhaust ventilation rate, in litres per second

n the number of battery cells

I the charging rate, in amperes, see [Clause 3.3.3](#)

If there is more than one battery in a room or enclosure then the total exhaust ventilation rate is the sum of the rates of all the batteries.

3.3.3 Charging rate

The charging rate (I) in [Equation 3.1](#) is determined for two conditions as follows:

- (a) *Condition I* — If the charger does not have an automatic overvoltage cutoff, the charging current is the maximum output rating of the charger or the rating of the output fuse or circuit-breaker of the charger.
- (b) *Condition II* — If the charger has an automatic overvoltage cutoff set at the battery manufacturer's recommended level, the charging rate is —
 - (i) 0.5 A for 100 A.h at the 3 h rate of discharge of battery capacity for lead-acid batteries; and
 - (ii) 1.5 A for 100 A.h at the 3 h rate of discharge of battery capacity for nickel-cadmium batteries.

NOTE These charging rates are based on a float voltage of 2.27 V per cell for lead-acid batteries and 1.45 V per cell for nickel-cadmium batteries, which have been selected to provide a safe level of ventilation for all types of battery construction.

3.3.4 Method of ventilation

3.3.4.1 General

Where possible, natural ventilation should be used for battery rooms and enclosures because of the fault potential of mechanical ventilation.

3.3.4.2 Natural ventilation

If natural ventilation is used, determine the minimum size of inlet and outlet apertures by using [Equation 3.2](#):

$$A = 100q_v \quad 3.2$$

where

A = the minimum area of the apertures, in square centimetres

q_v = the minimum exhaust ventilation rate, in litres per second, see [Clause 3.1](#)

With natural ventilation, an air velocity of at least 0.1 m/s is assumed to flow through the apertures.

3.3.4.3 Mechanical ventilation

If mechanical ventilation is used, determine the minimum flow rate by using [Equation 3.2](#).

3.3.4.4 Arrangement of ventilation

The following apply to the arrangement and layout of the ventilation system:

- (a) Exhaust air shall not pass over other electrical equipment.
- (b) Battery rooms and enclosures shall be provided with ventilation by means of holes, grilles or vents so that air sweeps across the battery. To avoid stratification of the airflow, it is recommended that ventilation inlets and outlets consist of —
 - (i) a number of holes spaced evenly along the side of the room or enclosure; or