UL 1989

STANDARD FOR SAFETY

Valve Regulated or Vented Batteries with Aqueous Electrolytes

UL Standard for Safety for Valve Regulated or Vented Batteries with Aqueous Electrolytes, UL 1989

Sixth Edition, Dated September 21, 2023

Summary of Topics

This Sixth Edition of ANSI/UL 1989 dated September 21, 2023 has been issued with a new Standard title of "Valve Regulated or Vented Batteries with Aqueous Electrolytes" and scope expansion to cover valve regulated or vented batteries for mobile application, and reflects the latest ANSI approval date.

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated July 28, 2023.

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UL 1989

Standard for Valve Regulated or Vented Batteries with Aqueous Electrolytes

First Edition – November, 1992
Second Edition – December, 1996
Third Edition – December, 2006
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Sixth Edition

September 21, 2023

This ANSI/UL Standard for Safety consists of the Sixth Edition.

The most recent designation of ANSI/UL 1989 as an American National Standard (ANSI) occurred on September 21, 2023. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

Comments or proposals for revisions on any part of the Standard may be submitted to ULSE at any time. Proposals should be submitted via a Proposal Request in the Collaborative Standards Development System (CSDS) at https://csds.ul.com.

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INTRODUCTION

1 Scope

1.1 These requirements cover valve regulated or vented batteries with aqueous electrolytes that can be used in various applications including stationary applications such as instrument batteries, enclosed batteries, emergency lighting batteries, emergency power batteries and uninterruptible power supply batteries, portable applications such as portable power tool batteries, and mobile applications such as industrial truck batteries.

1.2 These requirements only address potential risks unique to the utilization of a battery supply in a product. Products employing a battery supply shall comply with the basic requirements contained in this Standard applicable to the type of product and its intended use.

1.3 These requirements are intended to address aqueous electrolyte valve regulated or vented batteries such as lead acid, nickel-metal hydride, nickel zinc, or nickel cadmium, etc., and do not cover risks that may be unique to certain chemistries, such as the fire and explosion risks of lithium batteries. Lithium batteries are outside the scope of this Standard.

1.4 A battery system composed of vented or valve regulated types with battery management controls and other battery system components, and other chemistries or battery types used in stationary and motive auxiliary power applications are covered by the Standard for Batteries for Use in Stationary and Motive Auxiliary Power Applications, UL 1973.

2 Components

2.1 A component of a product covered by this Standard shall:

a) Comply with the requirements for that component as specified in this Standard;

b) Be used in accordance with its rating(s) established for the intended conditions of use; and

c) Be used within its established use limitations or conditions of acceptability.

2.2 A component of a product covered by this Standard is not required to comply with a specific component requirement that:

a) Involves a feature or characteristic not required in the application of the component in the product;

b) Is superseded by a requirement in this Standard; or

c) Is separately evaluated when forming part of another component, provided the component is used within its established ratings and limitations.

2.3 Specific components are incomplete in construction features or restricted in performance capabilities. Such components are intended for use only under limited conditions, such as certain temperatures not exceeding specified limits, and shall be used only under those specific conditions.

2.4 A component that is also intended to perform other functions such as overcurrent protection, ground-fault circuit-interruption, surge suppression, any other similar functions, or any combination thereof, shall comply additionally with the requirements of the applicable standard(s) that cover devices that provide those functions.

3 Units of Measurement

3.1 Values stated without parentheses are the requirement. Values in parentheses are explanatory or approximate information.

4 Referenced Publications

4.1 Any undated reference to a code or standard appearing in the requirements of this Standard shall be interpreted as referring to the latest edition of that code or standard.

4.2 The following publications are referenced in this Standard:

UL 94, *Tests for Flammability of Plastic Materials for Parts in Devices and Appliances*

UL 746C, *Polymeric Materials – Use in Electrical Equipment Evaluations*

UL 1973, *Batteries for Use in Stationary and Motive Auxiliary Power Applications*

5 Glossary

5.1 The following definitions apply for the purpose of this Standard.

5.2 BATTERY APPLICATIONS:

a) MOBILE APPLICATION – A secondary battery, used in a vehicle or a device which is capable of moving from place to place, such as battery used in an electric truck or a scooter, etc.

b) PORTABLE APPLICATION – A secondary battery, used in a device that is not fixed and can be moved by a single person without mechanical aids, such as battery used in a portable power tool or a portable power pack, etc.

c) STATIONARY APPLICATION – A secondary battery, used in a device that is either fixed or normally not moved due to its physical characteristics, such as instrument batteries, enclosed batteries, emergency lighting batteries, and emergency power batteries and uninterruptible power supply batteries, etc.

5.3 BATTERY, ENCLOSED – A secondary battery, up to 27.2 kg (60 lbs) in weight and up to 60 V in voltage, contained within telephone equipment on customers premises.

5.4 BATTERY, INSTRUMENT – A small primary or secondary battery, up to 4.54 kg (10 lbs) in weight, used within telephone instruments. Typical types are:

a) Primary (dry) cells such as (1) carbon zinc cells (LeClanche and zinc chloride cells), or (2) alkaline (manganese-dioxide) cells.

b) Secondary (rechargeable) cells such as nickel-cadmium.

5.5 BATTERY, LEAD ACID:

a) VALVE REGULATED – A storage battery, the electrodes of which are made of lead (negative electrode) and lead dioxide (positive electrode) and the electrolyte consists of a solution of sulfuric acid in which the venting of the products of electrolysis is controlled by a reclosing pressure-sensitive valve. These batteries have commonly been referred to as maintenance-free, starved electrolyte.

b) VENTED – A storage battery the electrodes of which are made of lead and the electrolyte consists of a solution of sulfuric acid in which the products of electrolysis and evaporation are allowed to escape freely to the atmosphere. These batteries have commonly been referred to as flooded or wet batteries.

5.6 BATTERY, NICKEL-CADMIUM:

a) VALVE REGULATED – An alkaline storage battery in which the positive active material is nickel oxyhydroxide and the negative contains cadmium and the venting of the products of electrolysis is controlled by a reclosing pressure sensitive valve.

b) VENTED – An alkaline storage battery in which the positive active material is nickel oxyhydroxide and the negative contains cadmium and the products of electrolysis and evaporation are allowed to escape freely to the atmosphere. These batteries are commonly referred to as flooded or wet batteries.

5.7 BATTERY, NICKEL-METAL HYDRIDE – An alkaline storage battery in which the positive active material is nickel oxyhydroxide and the negative contains a metal hydride alloy, and the venting of the products of electrolysis is controlled by a reclosing pressure sensitive valve.

5.8 BATTERY GROUP – A group or family of battery types that exhibit similar physical characteristics with respect to cell chemistry, cell construction, cell structure, and case (enclosure), and that are rated such that all batteries in the group demonstrate equivalent performance characteristics. Batteries belonging to the same group or family differ only in capacity or physical dimensions, or both.

5.9 BATTERY SUPPLY – One or more unit cell or multicell batteries that together supply power to a battery-operated product. A battery supply may consist of a collection of individual and separately replaceable unit cell or multicell batteries in a series and/or parallel array of permanently interconnected and not separately replaceable unit cell or multicell batteries (for example, a "battery pack").

5.10 BATTERY SUPPLY ENCLOSURE – A surrounding case or housing used to protect the battery supply and prevent personnel from accidently contacting live parts. The battery supply enclosure may be part of the battery-operated product, or in the case of an external battery supply a separate structure housing the battery supply.

5.11 CAPACITY – Generally, the total number of ampere-hours that can be withdrawn from a fully charged battery at a specific discharge rate and electrolyte temperature, and to a specific cutoff voltage.

5.12 CELL – The basic electrochemical unit, characterized by an anode and a cathode used to receive, store, and deliver electrical energy.

5.13 CHARGE AND DISCHARGE RATE (CHARGE AND DISCHARGE CURRENT) – The rate, in amperes, at which current is delivered to (charge) or by (discharge) a battery expressed in multiples of the value C, which is the rated capacity of the cell or battery in ampere-hours as stated by the manufacturer. For example, 0.1C A designates that the value of the charge or discharge current in amperes is 0.1 times the numerical value of the rated capacity in amperes-hours. In terms of charge and discharge rates, 0.1C A corresponds to a 10 h (charge or discharge) rate (C/10 = 0.1C A).

5.14 CHARGING – The conversion of electrical energy into chemical energy within the cell or battery.

NOTE: This restoration of the active materials is accomplished by maintaining an unidirectional current in the cell or battery in the opposition direction to that during discharge; a cell or battery that is stated to be charged is understood to be fully charged.

5.15 CONTROLLED CURRENT CHARGE – A method of charging a battery by controlling the charger current to the battery; that is, constant current, taper current, trickle current, and the like.

5.16 CONTROLLED VOLTAGE CHARGE – A method of charging a battery by controlling the charger voltage to the battery; that is, constant voltage, multilevel voltage, float voltage, and the like.

5.17 CURRENT RATING – The discharge capacity in amperes obtainable from a battery for 1-1/2 h at a constant discharge rate. The current rating is specified by the battery manufacturer.

5.18 DISCHARGE – Withdrawal of electrical energy from a cell or battery.

5.19 DRY CELL (OR DRY BATTERY) – A cell (or battery) in which the electrolyte is immobilized.

5.20 ELECTROLYTE – A conducting medium in which the flow of electric current takes place by migration of ions.

NOTE: Many physical chemists define electrolyte as a substance that when dissolved in a specific solvent, usually water, produces an ionically conducting solution.

5.21 END-OF-DISCHARGE VOLTAGE (EODV) – The voltage, under load, of the cell or battery at the end of discharge. The EODV may be specified, as in the case of a voltage terminated discharge, or simply measured in the case of a time-controlled discharge.

5.22 JAR (OR CASE) – The container that directly encloses and confines the electrolyte, anode and cathode of a cell or battery.

5.23 MULTICELL BATTERY – A battery consisting, internally, of a series and/or parallel array of two or more cells.

5.24 PRIMARY CELL (OR PRIMARY BATTERY) – A cell (or battery) that produces electric current by electrochemical reactions without regard to the reversibility of those reactions. Some primary cells are reversible to a limited extent.

5.25 RATED CAPACITY – The ampere-hour capacity assigned to a storage cell by its manufacturer for a given discharge time, at a specified electrolyte temperature and specific gravity, to a given end-of-discharge voltage.

5.26 RATED VOLTAGE – The nominal terminal voltage delivered by the cell or battery during normal discharge, and normally marked on the battery jacket.

5.27 SECONDARY CELL (OR SECONDARY BATTERY) – A cell (or battery) that produces electric current by reversible electrochemical reactions.

5.28 UNIT (SINGLE) CELL BATTERY – A battery consisting of a single cell. For example, size N, AAA, AA, C, and D "flashlight" batteries.

5.29 WET CELL (OR WET BATTERY) – A cell (or battery) whose electrolyte is in liquid form.

CONSTRUCTION

6 General

6.1 Batteries shall have transparent or translucent jackets unless they are of the maintenance free type.

6.2 A vented cell or battery shall be equipped with a flame arrester(s) designed to prevent an external flame from propagating into the cell or battery when the by-products of electrolysis (which are vented through the arrester) are ignited. See Flame Arrester Vent Cap Tests, Section 9.

6.3 A sealed cell or battery shall be equipped with a pressure-release vent(s) to prevent excessive accumulation of gas pressure, or the battery/cell shall be constructed to prevent scatter of battery/cell parts in the event of a battery/cell explosion. See Pressure Release Test, Section 8.

6.4 The case material of batteries used in an uninterruptible power supply, portable applications or mobile applications shall be classed as V-2, HF-2, or less flammable in accordance with the requirements in UL 94.

Exception: Materials need not be classed as V-2, HF-2, or less flammable if they comply with the enclosure flammability – 19-mm (3/4-in) flame test described in UL 746C.

PERFORMANCE

7 General

7.1 A battery shall be tested as described in Sections 8 – 13 to determine if any fire or explosion is obtained under these test conditions. If a fire or explosion is obtained, the use of these batteries in products shall be restricted to applications in which the batteries will not be exposed to, or will be protected from, any conditions shown to cause a fire or explosion. See Table 7.1.

Table 7.1
Tests for Battery Application/Type

Test	Section	Battery application/type
Pressure Release Test	8	UPS, emergency lighting batteries, emergency power batteries, batteries for portable and mobile applications (with pressure release valves)
Flame Arrester Vent Cap Tests	9	UPS, emergency lighting batteries, emergency power batteries, batteries for mobile applications (with flame arresters)
Back Pressure Test	9.4	UPS, emergency lighting batteries, emergency power batteries, batteries for mobile applications (with flame arresters)
Test for Sustained Burning	9.5	UPS, emergency lighting batteries, emergency power batteries, batteries for mobile applications (with flame arresters)
Test for Flame Propagation	9.6	UPS, emergency lighting batteries, emergency power batteries, batteries for mobile applications (with flame arresters)
Capacity Rating Tests	10	Emergency lighting batteries, emergency power batteries
Battery Enclosure Flammability Tests	11	UPS Batteries, batteries for portable and mobile applications
Overcharge and Discharge Test	12	Instrument and enclosed batteries
Battery Enclosure Tests	13	Instrument and enclosed batteries
Drop Impact Test	13.2	Instrument and enclosed batteries (types per Table 13.1)
Ball Impact Test	13.3	Instrument and enclosed batteries (types per Table 13.1)
Crush Test	13.4	Instrument and enclosed batteries (types per Table 13.1)
Rod Pressure Test	13.5	Instrument and enclosed batteries (types per Table 13.1)
High Temperature Conditioning Test	13.6	Instrument and enclosed batteries (types per Table 13.1)

7.2 The evaluation of a battery group may be based on the evaluation of batteries representative of the group.

8 Pressure Release Test

8.1 A sample of the battery/cell is to be submerged in a container of mineral oil. For large batteries only the vents need to be submerged. A charging current shall be caused to flow at an increased rate (to be specified by the manufacturer) until bubbles are observed to rise from the pressure release device openings. Results are acceptable if battery gas is released normally and the battery/cell case is not ruptured.

Exception: Rupture of the battery/cell case is acceptable if the rupture closely follows the design contours of a non-resealable single operation release device.

9 Flame Arrester Vent Cap Tests

9.1 General

9.1.1 After the various exposures as described in 9.2.2 there shall be no evidence of impairment or damaging effects to any of the samples and no evidence of a vent cap popping out of the simulated battery cover.

9.1.2 At least six vent caps (three sets of two each) and six simulated battery covers, to which the vent caps are intended to be attached, are to be provided for the conditioning procedure and vent cap tests as described in 9.2.1 – 9.6.3.

9.2 Conditioning

9.2.1 The conditioning apparatus is to consist of:

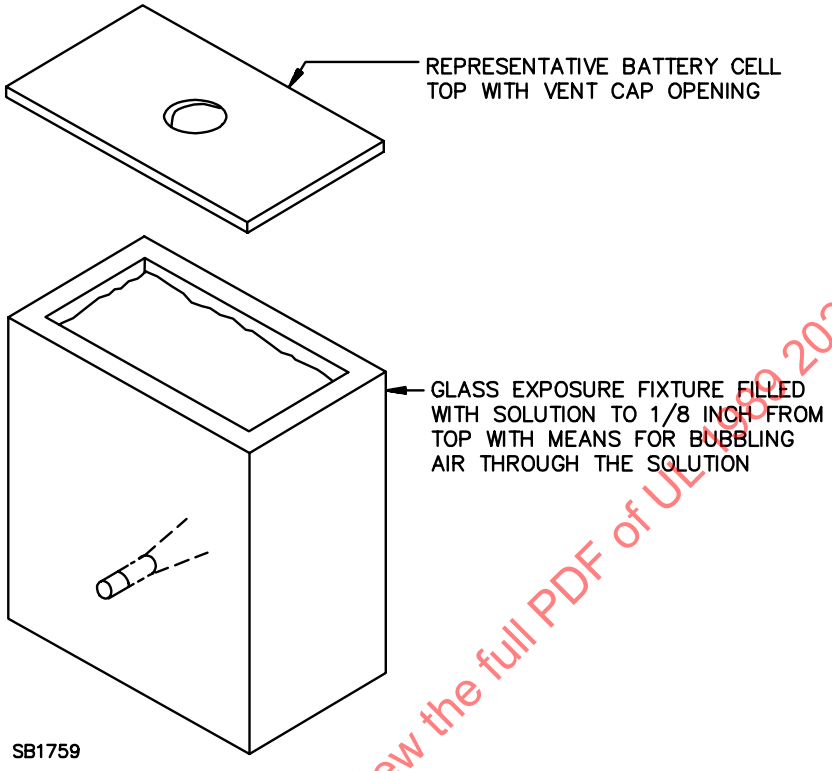
a) A circulating-air oven;

b) A humidity conditioning chamber; and

c) A wetting-exposure fixture as shown in Figure 9.1.

Figure 9.1

Wetting Exposure Fixture



9.2.2 Prior to testing, two vent caps are to be exposed to each of the following conditions:

a) 48 h at 23 ±2 °C (73 ±3.6 °F) and 50 ±5 % relative humidity;

b) 168 h at 70 °C (158 °F) in a circulating-air oven; and

c) While attached to simulated battery covers that are assembled on the top of the wetting fixture, one set of two vent caps is to be exposed for 24 h to an airflow of twice the maximum total flow (H_2 and O_2 combined) indicated by the four sets of flow rates in Table 9.1 for the appropriate battery capacity rating. If the vent cap is intended for use with a lead acid battery the airflow is to be bubbled through a 50 % aqueous solution of sulfuric acid and vented through the cap. If the vent cap is intended for use with a nickel cadmium battery the airflow is to be bubbled through a 30 % aqueous solution of potassium hydroxide and vented through the cap.

Table 9.1
Gas Flow Rates for Battery Vent Caps

Battery capacity (Ah)	Flow rate for hydrogen and oxygen, cc/min							
	Flow rate number 1		Flow rate number 2		Flow rate number 3		Flow rate number 4	
	H_2	O_2	H_2	O_2	H_2	O_2	H_2	O_2
50	27	14	21	10.5	14	7	7	3.5
100	56	28	49	24.5	28	14	14	7

Table 9.1 Continued on Next Page

Table 9.1 Continued

Battery capacity (Ah)	Flow rate for hydrogen and oxygen, cc/min							
	Flow rate number 1		Flow rate number 2		Flow rate number 3		Flow rate number 4	
	H_2	O_2	H_2	O_2	H_2	O_2	H_2	O_2
150	84	42	49	24.5	28	14	14	7
200	112	56	105	52.5	49	24.5	21	10.5
C[a]	C/1.8	C/3.6	C/2.5	C/5.0	C/5.0	C/10	C/10	C/20

[a] C is the capacity of the battery in ampere-hours (use this row if C is greater than 200).

9.3 Vent cap tests

9.3.1 The conditioned samples are to be tested as described in 9.4.1 – 9.6.3.

9.3.2 The test apparatus is to consist of the following:

a) A heavy wall plexiglass hydrogen test fixture as shown in Figure 9.2.

b) Equipment capable of supplying, monitoring and mixing hydrogen and oxygen in stoichiometric proportions.

c) A spark ignition source produced across a 6.4-mm (1/4-in) gap in the 60 kV, 23 mA secondary of a transformer.

d) A test enclosure cover as shown in Figure 9.3. This test enclosure cover is to be fitted over the hydrogen test fixture as shown in Figure 9.4 for the test as described in 9.6.

e) A protective test room or chamber is to be used as needed for safety.

Figure 9.2

Hydrogen Test Fixture

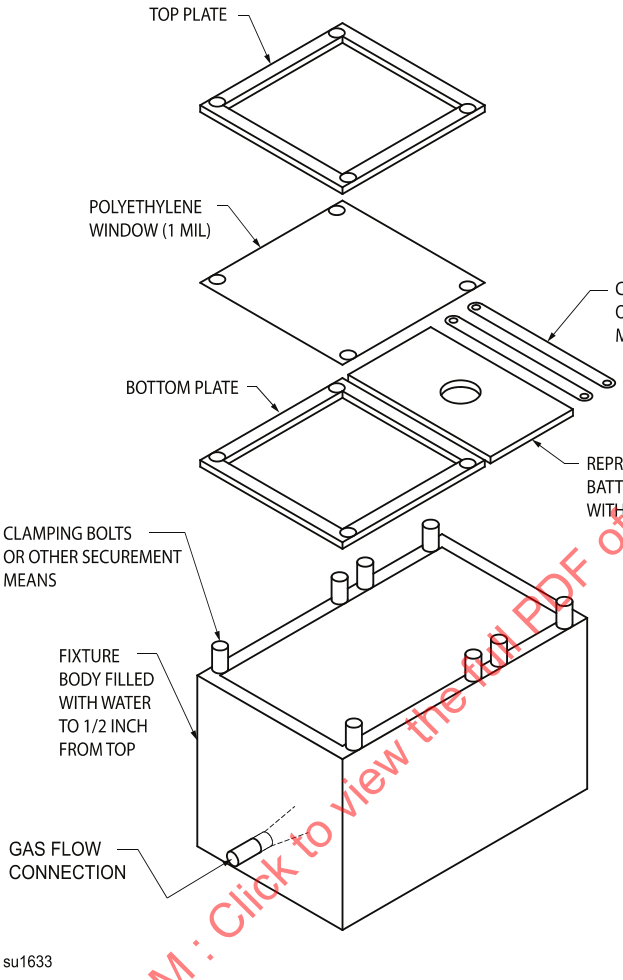


Figure 9.3

Test Enclosure Cover
Clear Plastic with Ventilation Openings Shown (1 in^2 Opening Area/500 in^3 Volume)

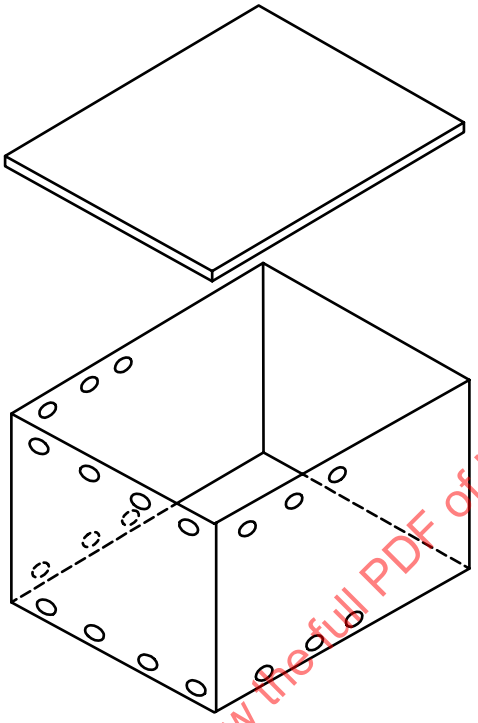


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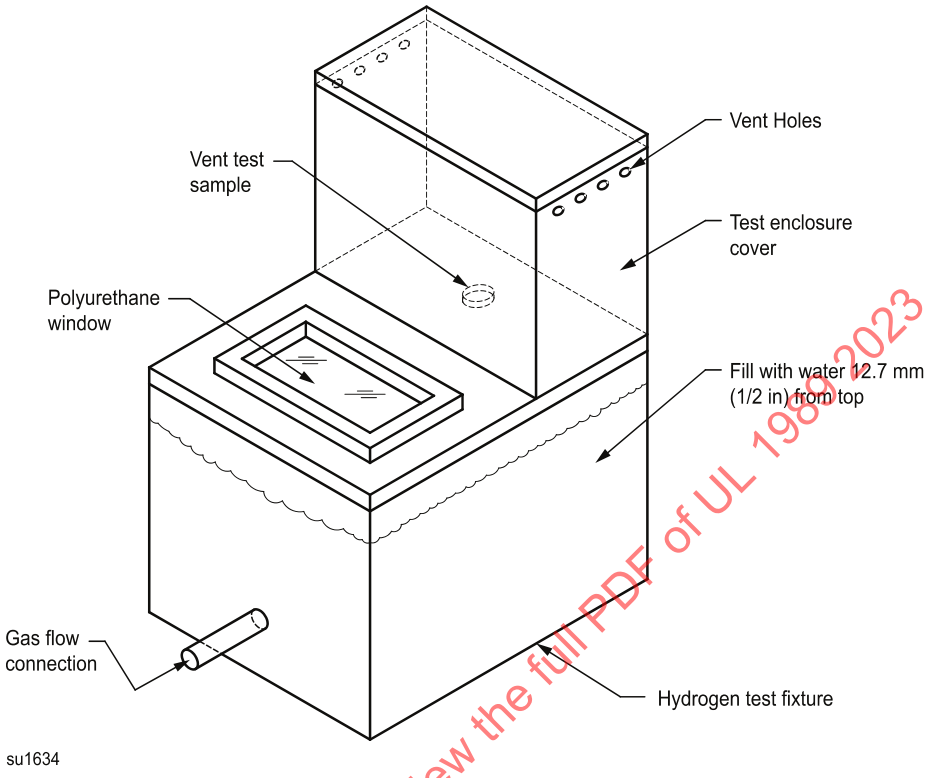
Figure 9.4

Hydrogen Test Fixture with Test Enclosure Cover Assembled



9.4 Back pressure test

9.4.1 Air shall be vented through a flame arrester vent at a rate equal in cubic centimeters per minute to the ampere-hour capacity of the battery divided by 13.5. The back pressure obtained shall be 15 mm of water (0.59 in of water) or less.

9.5 Test for sustained burning

9.5.1 As a result of the testing described in 9.5.2 there shall be no sustained burning of vented gas that results in impairment to the vent cap.

9.5.2 One each of the conditioned samples are to be installed in the hydrogen test fixture, described in Figure 9.2, without the test enclosure cover, described in Figure 9.3, in place. The hydrogen test fixture is to be located in a protective room or test chamber as considered necessary for safety purposes. A mixture of hydrogen and oxygen gas is to be caused to flow through the fixture and vent cap and is to be adjusted to the appropriate maximum value as indicated in Table 9.1 and allowed to flow for at least 1 min before ignition attempts are made. As the gas flow continues, six attempts are to be made to ignite the gas mixture venting from the cap using the spark ignition source. Each attempt to ignite the gas is to consist of a single spark, and there is to be a 10-s interval between each ignition attempt. The gas lines should be cleared after each sample is tested. Since hydrogen gas can burn without visible flame, sustained burning is to be determined by using paper as an indicator.

9.6 Test for flame propagation

9.6.1 After the test described in 9.5.2 for sustained burning, one of each of the conditioned vent caps is to be installed as described in 9.5.2 with the test enclosure cover shown in Figure 9.3, in place as shown in

Figure 9.4. The gas mixture is to be allowed to flow into the test fixture for at least 1 min before ignition attempts are made. As the gas flow continues, six attempts are to be made to ignite the gas venting from the cap, approximately 12.7 mm (1/2 in) from the vent cap opening, using the spark ignition source located in the path of the gas flow. Each attempt to ignite the gas is to consist of a single spark, and there is to be a 10-s interval between each ignition attempt.

9.6.2 The test described in 9.6.1 is to be repeated for each of the samples at each of the appropriate gas mixture flow rates as indicated in Table 9.1. The gas lines should be cleared after each sample is tested.

9.6.3 The results are not acceptable if there is evidence of flame propagation through the vent cap to within the fixture, as determined by rupture of the 0.025 mm (1 mil) polyethylene-film window in the top of the hydrogen test fixture.

10 Capacity Rating Tests

10.1 A storage battery shall be capable of supplying and maintaining the maximum total load, at the specific temperature range, for a period not less than that indicated in the marking, but in no case for less than 1-1/2 h and the final open circuit battery voltage shall not be less than 87.5 % rated battery voltage.

10.2 The following data is to be supplied by the battery manufacturer:

a) Battery type and rated voltage.

b) Charging system to be used, either:

1) Controlled voltage;

2) Controlled current; or

3) A combination controlled voltage and controlled current.

c) Range of charging rates:

1) Voltage (maximum and minimum); or

2) Current (maximum and minimum), or both.

d) Current rating is to be a 1-1/2 h constant discharge current, resulting in an end-of-discharge voltage no less than 87.5 % and no greater than 100 % of rated voltage.

e) Whether the battery is to be used at room temperature, 25 ±5 °C (77 ±9 °F) or within an expanded temperature range.

f) Electrolyte maintenance instructions, if needed.

10.3 The charging and discharging tests are described in Table 10.1. Depending on the difference in the charging system specified by the manufacturer, a battery sample is subjected to one of the test sequences as follows:

a) Controlled current charge test: I, II, III, IV, I, V, I, II. This test method applies to batteries having controlled current charging systems.

b) Controlled voltage charge test: VI, II, VII, IV, VI, V, VI, II. This test method applies to batteries having controlled voltage charging systems.

c) Combination controlled current charge and controlled voltage charge test: I, II, III, IV, VII, IV, VI, V, I, V, VI, II. This test method applies to batteries with charging systems with a combination of controlled current and controlled voltage.

Table 10.1
Charge/Discharge Tests

Test	Test mode	Duration of test (h)	Load current	Measurements to be taken[d]
I	Charge @ I (controlled current)	168[a]	–	I_1, T_c, V_1
II	Discharge (constant current)	1-1/2	I_2	I_2, T_d, V_2
III	Charge @ I (controlled current)	24[b]	–	I_c, I_1, T_c, V_c, V_1
IV	Discharge (constant current)	1	I_2	I_2, T_d, V_2
V	Discharge (constant current)	24[c]	I_2	I_2, T_d
VI	Charge @ V (controlled voltage)	168[a]	–	I_1, T_c, V_1
VII	Charge @ V (controlled voltage)	24[b]	–	I_1, T_c, V_1

[a] The charge period may be less than 168 h if requested by the manufacturer.

[b] The charge period may be less than 24 h if requested by the manufacturer.

[c] The 24-h discharge period may be reduced if a sensing circuit is provided that disconnects the battery in a shorter time. The discharge period may be no less than 1-1/2 h in any case.

[d] The measurements symbolized are:

I_c – Specified charge current range (maximum and minimum).

I_1 – Battery charger current during battery charge cycle.

I_2 – Battery current rating.

T_c – Temperature on battery case during charge cycle.

T_d – Temperature on battery case during discharge cycle.

V_c – Specified charger voltage range (maximum and minimum).

V_1 – Battery terminal voltage during charge cycle.

V_2 – Closed circuit voltage at battery terminals at end of discharge cycle.

10.4 The battery may be subjected to a conditioning program specified by the manufacturer prior to the charging and discharging tests described in 10.3 and Table 10.1. The program may not:

a) Exceed 168 h; or

b) Recharge the battery outside the manufacturer's recommended minimum or maximum rates.

10.5 The manufacturer has the option of having the battery tested for use at room temperature or within an expanded temperature range. Batteries shall be rated for the ambient temperature or temperature range in which the equipment they are to be installed in is intended to operate. For batteries intended to operate at temperatures other than 25 ±5 °C (77 ±9 °F) the lower limit of the range shall be 10 °C (50 °F) or a lower temperature than 10 °C in 10 °C (18 °F) increments. The upper limit of the range shall be 40 °C (104 °F) or a higher temperature than 40 °C in 10 °C (18 °F) increments. Room temperature test conditions are specified in 10.6 and temperature range test conditions are given in 10.7.

10.6 All tests are to be conducted at an ambient temperature of 25 ±5 °C (77 ±9 °F).

10.7 Each test is to be conducted after 24 h of either condition A or B and while maintained at the specified condition. The total time of exposure to the environmental conditions will depend on the specified initial charge and recharge times for the Capacity Rating Test. The manufacturer has the option of using