Battery Technology for Data Centers and Network Rooms: Ventilation

White Paper #34

APC
Legendary Reliability™

Revision 1

Executive Summary

Lead-acid batteries are the most widely used method of energy reserve. Ventilation systems must address health and safety as well as performance of the battery and other equipment in a room. Valve Regulated Lead Acid (VRLA) batteries and modular battery cartridges (MBC) do not require special battery rooms and are suitable for use in an office environment. Air changes designed for human occupancy normally exceed the requirements for VRLA and MBC ventilation. Vented (flooded) batteries, which release hydrogen gas continuously, require a dedicated battery room with ventilation separate from the rest of the building. This paper summarizes some of the factors and codes to consider when selecting and sizing a ventilation system for a facility in which stationary batteries are installed.

Introduction

The main objectives of any ventilation system are management of environmental air temperature, humidity and air quality. In a data center, or any facility in which electrical equipment and battery systems are installed, the ventilation system must address:

- Health safety - The air must be free of pollutants that could be toxic, corrosive, poisonous, or carcinogenic
- Fire safety - The system must prevent and safely remove the accumulation of gasses or aerosols that could be flammable or explosive.
- Equipment reliability and safety - The system must provide an environment that optimizes the performance of equipment (including both batteries and electronic equipment) and maximizes their life expectancy
- Human comfort

Stationary lead-acid batteries are the most widely used method of energy reserve for information technology rooms (data centers, network rooms). Selecting and sizing ventilation for battery systems must balance and trade off many variables. These could include different battery technologies, installation methods, operating modes, and failure modes.

Terminology

Battery technologies are described in detail in other White Papers (see “Related Documents”). The following brief overview describes different lead-acid battery technologies and how they would interact with a ventilation system.

Battery Types

Vented Lead Acid Batteries are commonly called “flooded” or “wet cell” batteries because of their conspicuous use of liquid electrolyte. As the name implies, this type of battery “vents” hydrogen continuously during normal float operation. The electrolyte is sulfuric acid diluted in water. Vented batteries are usually installed on open racks in dedicated battery rooms that have dedicated ventilation systems to prevent mixing with ventilation systems for the rest of the building

Valve Regulated Lead Acid (VRLA) Batteries are the most widely used battery type because of their high power density and ease of use. VRLA batteries are considered to be “sealed” because they normally do not allow for the addition or loss of liquid. A vented battery gives off sixty times more gas than a VRLA battery in normal use. The term VRLA derives from the use of safety valves that allow pressure to be released when a fault condition causes internal gas to build up faster than it can be recombined. VRLA batteries can be mounted on open racks (rarely), or in cabinets (most common). Small power systems (such as single-phase UPS systems) integrate VRLA batteries inside their own enclosures. VRLA batteries can use the ventilation provided for human occupancy.

Modular Battery Cartridges (MBC) are actually strings of VRLA batteries packaged into cartridges that can be swiftly plugged into a power system that has the appropriate mating connections. MBCs are designed for use in a data center, network room or office environment and can use the ventilation provided for human occupancy.

Modes of Operation

All battery types work on the principle of chemical reactions between positive and negative plates. Because they have different technologies, they have different considerations for ventilation under the same operating mode.

Storage – Stored lead-acid batteries create no heat. High ambient temperatures will shorten the storage life of all lead-acid batteries.

Vented (flooded) – With shipping plugs removed, flooded batteries can give off minor amounts of hydrogen and oxygen due to normal evaporation of water (depending upon the amount of ambient heat and air humidity).

VLRA and MBC – create no off-gassing

Normal Mode – In back-up applications the batteries are kept at a constant state of maximum potential (called float voltage) in order to ensure maximum power reserve. The constant presence of voltage causes batteries to continuously create hydrogen and oxygen. Optimum ambient temperature is defined by the battery manufacturer, but is usually between 20°C and 25°C (68-77°F). Higher room temperatures increase off gassing and shorten battery life. When float charged at the manufacturer's recommended voltage and room temperature, a battery can generate heat roughly in the magnitude of 0.1% of the full load operating power of the batteries.

Vented (flooded) – Some of the hydrogen gas is released into the room. Flooded lead acid batteries vent approximately 60 times more hydrogen than comparably rated VRLA batteries.

VRLA and MBC – Hydrogen recombines into water inside the battery.

Discharge – Batteries vent little or no gas during a discharge. High ambient temperature will cause more chemical reaction and longer run times, whereas low ambient temperature does the opposite. The battery generates little heat. However, the power electronics supported by the battery might run slightly hotter during a discharge.

Vented (flooded) – Little or no gas vented during discharge.

VRLA and MBC – Little or no gas vented during discharge.

Recharge – Higher charging voltage following a discharge causes the battery to heat up and release some measure of hydrogen gas. More voltage means more gas release.

Vented (flooded) – Release the most hydrogen into a room during recharge.

VRLA and MBC – Vulnerable to overheating if voltage and/or ambient temperature exceed recommended levels.

Failure Mode – A rare but serious battery failure mechanism in lead acid batteries is a condition known as "thermal runaway." Thermal runaway is preventable.

Vented (flooded) – Flooded batteries are largely immune to thermal run-away.

VRLA and MBC – Only a tiny percentage of VRLA battery systems ever experience thermal runaway. It is most likely to occur on inexpensive systems without appropriate protective circuits. This condition can be triggered by a cell failure, improper float voltage settings, charger failure, high ambient temperature around the batteries, excess charger capacity, or a combination of these conditions. Charger over-voltage is the most common cause. In thermal runaway heat generates inside the battery faster than it can be dissipated. The safety valves open and the battery vents hydrogen until temperature and/or voltage are reduced, or else the battery melts or dries out. A well-designed UPS system will have circuits to detect battery over-temperature and/or excess float current. Corrective action to prevent thermal runaway is to reduce charger voltage or to shut down a failed charger.

Hazardous Gasses

One should consult the material safety data sheets provided with the battery for complete details of hazardous materials. In general, battery installations could potentially be exposed to the following types of gasses to some degree:

Explosive gas is hydrogen (H_2), which can be emitted by all lead-acid batteries.

Vented (flooded) –Continuously release small amounts of hydrogen.

VRLA and MBC – Recombine the hydrogen to form water inside the battery and release hydrogen only when overheated and/or overcharged.

Toxic gas emissions are miniscule, but can include arsine, stibine, and hydrogen sulfide. These gasses appear only during severe failure events such as thermal runaway, and are not always present during such events.

Aerosols and corrosive vapor that can be emitted during a severe venting event include electrolyte vapor. Reports of problems associated with aerosols are rare. Long term consequences are usually limited to equipment reliability. Aerosols generally pose little personnel risk.

Environmental Design Considerations

Most building and fire codes have separate articles specifically for batteries in order to distinguish battery rooms from classified (hazardous) locations. For example, the Uniform Building Code [1] specifically exempts rooms or structures containing stationary lead-acid batteries from being classified as Class H, Division 1 occupancy. The International Fire Code [2] states "Batteries shall be permitted in the same room as the equipment that they support." Special fire or explosion-proof equipment should not be required.

Vented (flooded) Lead-Acid Battery Requirements

Because they continuously vent hydrogen gas, vented batteries are usually installed in dedicated battery rooms. They are sometimes co-located with the UPS or other electronic equipment with which they are associated, although this practice is not recommended. Dedicated flooded battery rooms must be physically separated from other areas, avoid localized heat sources, and have doors and partitions designed to meet the required fire resistance rating for the application. For more information on battery safety codes and environmental regulations see APC White Paper #31: "Battery Technology for Data Centers and Network Rooms: Safety Codes" and APC White Paper #32: "Battery Technology for Data Centers and Network Rooms: Environmental Regulations".

VRLA (sealed) Battery and MBC Requirements

VRLA batteries and modular battery cartridges can be used in the same room as the equipment they support. If the room has controlled access (i.e., accessible only by trained and authorized personnel), the batteries can be installed in open racks; otherwise the batteries should be in cabinets with doors. Rooms and cabinets should be designed to prevent the accumulation of hydrogen as described below.

Ventilation

The requirements of a ventilation system must be coordinated with the requirements of a fire prevention and suppression system.

Cleanliness of Air – All battery manufacturers and all best practices [3,4,5] recommend that batteries be clean.

Vented (flooded) – Vented batteries are more vulnerable than VRLA batteries to build-up of oils and dust. In rare situations, accumulation of water-soluble salts in fine particles can accumulate on equipment surfaces where they can lead to increased corrosion levels, surface leakage, and potential arcing problems, particularly when the relative humidity is above 40%. In most cases, coarse-mode particles do not cause surface leakage or corrosion unless the dust is metallic (and therefore conductive) or contains large amounts of chloride.[6] Typically, medium efficiency filters are recommended to filter outside air supply for rooms with vented batteries.

VRLA and MBC – Filters for rooms with electronic equipment, where VRLA batteries and MBC are often used, will typically have an ASHRAE Standard 52 dust spot efficiency between 30 to 60 percent… far in excess of the battery's requirements.

Air Changes

Vented (flooded) – ASHRAE[7] and NFPA-111[8] recommend a minimum of two air changes per hour to remove gases generated by vented batteries during charging or caused by equipment malfunction.

VRLA and MBC – Sealed or valve regulated batteries are typically used in occupied environments. The National Electric Code (NEC) [9] and NFPA-75 [10] define specific requirements for ventilation under raised floors or above ceilings for Information Technology (IT) equipment rooms. Special rules apply if the space is used to re-circulate computer room/computer area environmental air. In order to qualify as an IT space, air in the under-floor area cannot be shared with non-IT spaces. No additional air changes are required because of the presence of VRLA batteries or modular battery cartridges.

Hydrogen Accumulation - In any space, hydrogen should not be allowed to accumulate to greater than two percent concentration. Most regulations stipulate a maximum concentration of only one percent. The lower explosive level of hydrogen [i.e. the point at which hydrogen can combust] is four percent. (By comparison, the natural concentration of hydrogen in the atmosphere is 0.01%). Battery manufacturers should be able to provide exact gassing rate, charging voltage and charging currents for the type of battery installed. (Note that gassing rates can vary significantly depending upon voltage applied to the battery, temperature, and atmospheric pressure.)

Vented (flooded) – The Institute of Electrical and Electronics Engineers (IEEE) provides formulae for calculating the maximum hydrogen evolution in vented (flooded) batteries when precise information is known about the battery and charger characteristics.[3]

VRLA and MBC – VRLA batteries and MBC do not vent unless they are forced into a failure mode. Contact the supplier for the gassing rate of a particular model.

When precise data is not practical or possible, Fire Codes[2, 12] require continuous ventilation at a rate not less than one cubic foot per minute per square foot of floor area for a VRLA battery system, or per square foot of the entire room for a vented battery system. The following tables give some rough comparisons.

Table 1 *– Ventilation requirements for a typical 80 kW UPS battery system*

	Vented (Flooded)	VRLA	MBC
Necessary Ventilation Air Flow	12 cubic meters / hr	1.2 cubic meters / hr	1.2 cubic meters / hr
Outdoor (Fresh) Air Requirements for Office Space per Person	36 cubic meters / hr	36 cubic meters / hr	36 cubic meters / hr
Ratio	3 to 1	30 to 1	30 to 1
Special ventilation required	Yes	No	No

Table 2 *– Ventilation requirements for a typical 400 kW UPS battery system*

	Vented (Flooded)	VRLA	MBC
Necessary Ventilation Air Flow	60 cubic meters / hr	6 cubic meters / hr	6 cubic meters / hr
Outdoor (Fresh) Air Requirements for Office Space per Person	36 cubic meters / hr	36 cubic meters / hr	36 cubic meters / hr
Ratio	0.6 to 1	6 to 1	6 to 1
Special ventilation required	Yes	No	No

The NEC 2002 Handbook [13] says that mechanical ventilation is not required for enclosures of battery systems. Convection ventilation is permitted. Hydrogen disperses rapidly and requires little air movement to prevent accumulations. Unrestricted natural air movement in the vicinity of the battery, together with normal air changes for occupied spaces or heat removal, will normally suffice. If the space is confined, mechanical ventilation may be required in the vicinity of the battery. Hydrogen is lighter than air and will tend to concentrate at ceiling-level, so some form of ventilation should be provided at the upper portion of the structure. Ventilation can be a fan, roof ridge vent, or louvered area.

Temperature – While all batteries will operate within a fairly wide temperature range, the life expectancy of a battery can be severely shortened at high temperatures. For example, continuous operation at 33°C (91°F) would cut the life expectancy of a VRLA battery by ½ and a vented battery by about ¼. The optimum temperature for air around a stationary battery is 22° ± 5°C (72 ± 9°F). [Note: this includes the air inside a battery cabinet, which may be warmer than the rest of the room.]

Table 3 *– Effect of temperature on battery life*

	Vented Cells	VRLA & MBC
Design temperature	25°C (77°F)	25°C (77°F)
Reduction in battery life from heat above design temperature	2.5 % per °C (1.8°F)	5 % per °C (1.8°F)
Other effects of heat	More frequent watering and maintenance	Venting & dry-out Bulging, cracking

Humidity - Battery environments should be kept dry and free of static electricity. The optimum relative humidity is in the range of 35% to 55%.

Battery Placement - Open racks for flooded and VRLA batteries allow heat to dissipate into the room. VRLA batteries in a cabinet should allow airflow around each battery container to allow removal of heat by convection or fan cooling. Avoid placing battery racks and/or cabinets near heat-generating sources.

Monitoring & Instrumentation - Where mechanical ventilation is used, monitors are recommended to detect and sound an audible alarm upon loss of air movement, fan failure and/or closure of fire/smoke dampers. Any alarm system should be monitored twenty-four hours per day. Alarm functions and use of automatic controls (such as switching to backup ventilation methods or disconnecting the battery) will depend upon operator availability, component redundancy, battery charging cycle duration and frequency, and ventilation dilution rate margins. Local codes usually do not require hydrogen and other gas detectors to be installed in dedicated battery rooms. If used, hydrogen detectors should be set to alarm at a maximum of two percent concentration. Requirements are typically vague about the quantity and placement of sensors. Careful consideration must be given to where pockets are likely to form. Nuisance alarms can be generated if the sensor is too close to battery vents.

Conclusions

Ventilation systems for stationary batteries must address human health and safety, fire safety, equipment reliability/ safety, and human comfort. Vented (flooded) batteries should be installed in dedicated battery rooms, but may share the same room as the equipment they support (such as a UPS system). VRLA batteries and modular battery cartridges can be used in an office environment. The amount of heat generated by a battery system is insignificant compared to the total IT system. However, batteries need cool, clean air for optimum performance and long life. Vented batteries must have a dedicated ventilation system that exhausts to the outside and prevents circulation of air in other parts of the building. For VRLA and MBC systems, the ventilation required for human occupancy is normally sufficient to remove heat and gases that might be generated. A minimum of two room air changes per hour and a temperature in the range of 20 – 24° C (68 – 75° F) are recommended. The ventilation system must prevent the accumulation of hydrogen pockets in greater than 1 – 2% concentration.

For vented batteries, it is recommended to enlist the services of an engineering firm experienced in battery room design, including ventilation, fire protection, hazardous material reporting and disposal, and spill control.

For VLRA and MBC battery systems, the ventilation requirements for human occupancy and electronic equipment operation in a data center or network room well exceed the requirements for the batteries. No additional engineering should be necessary for VRLA battery ventilation.

Related Documents

APC White Paper #30: “Battery Technology for Data Centers and Network Rooms: Battery Options”

APC White Paper #31: “Battery Technology for Data Centers and Network Rooms: Safety Codes”

APC White Paper #32: “Battery Technology for Data Centers and Network Rooms: Environmental Regulations”

APC White Paper #33: “Battery Technology for Data Centers and Network Rooms: Site Planning”

APC White Paper #34: “Battery Technology for Data Centers and Network Rooms: VRLA Reliability and Safety”

References

[1] *1997 Uniform Building Code, Vol. 1***,** Section 307.1.1, International Conference of Building Officials,

[2] *International Fire Code*, Article 608, International Code Council, Inc.

[3] IEEE P1184, *IEEE Guide for Batteries for Uninterruptible Power Supply Systems [Draft 09/2001],* para 3.1.1 and 5.1.1.1, Institute of Electrical and Electronics Engineers

[4] IEEE P1188, *IEEE Recommended Practice for Maintenance, Testing & Replacement of Valve Regulated Lead-Acid Batteries for Stationary Applications [Balloted 10/2002*], para. 5.3.1 c and 5.2.1.e.(2)

[5] IEEE P450, *IEEE Recommended Practice for Maintenance, Testing & Replacement of Vented Lead-Acid Batteries for Stationary Applications*, para. 5.2.1.b and 5.3.1.e

[6] ATIS T1E1.5/2002, *Battery Rooms and Enclosures Standard,* para. 5.4.1

[7] ANSI/ASHRAE Standard 62-2001, *Ventilation for Acceptable Indoor Air Quality,* Table 2.1, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

[8] NFPA 111, *Standard on Stored Electrical Energy, Emergency and Standby Power Systems, 2001 ed*., para 5.3.2

9 NFPA 70, *National Electric Code 2002*, Article 645, National Fire Protection Association

10 NFPA 75, Standard for the Protection of Electronic Computer/Data Processing Equipment, 1999, National Fire Protection Association

11 *1997 Uniform Fire Code,* Article 64, Uniform Fire Code Association

12 NFPA 1, 2003 Uniform Fire Code (Draft), Chapter 52, National Fire Protection Association

13 NFPA 70HB02, *NEC 2002 Handbook,* National Fire Protection Association