BENEFITS OF A BATTERY SYSTEM VENTILATION CHECK LIST

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ABSTRACT

Conditions that cause a VRLA battery system to vent hydrogen can be controlled, making additional ventilation unnecessary in most cases. Code-writing panels and engineers who design rooms and buildings where batteries will be used often base their work on a combination of limited knowledge about VRLA batteries and misperceptions drawn from anecdotal experience. Many of the codes have evolved painfully from the perception that all batteries are flooded lead-acid, and they focus strictly on the battery. A good design will consider the entire battery system, which includes not only the battery itself but also any chargers, monitoring and controls. This paper will provide a basic explanation of VRLA battery systems and alternative methods for controlling risk from hydrogen or hydrogen sulfide off-gassing. This paper explains why an expensive, isolated, separately-ventilated "battery room" is seldom necessary. A check list is proposed for assessing when additional room ventilation is or is not appropriate.

INTRODUCTION

A paper by Bruce Dick published in the May and June 2004 issues of *Battery Man magazine*, "Ventilation Requirements for VRLA Batteries in Occupied Buildings," [1] introduced the concept of using a checklist to determine if supplementary ventilation is necessary for a stationary VRLA battery installation in an occupied building. The *Battery Man* paper also went into detail to show the differences between the legacy flooded lead-acid batteries and the newer VRLA (Valve Regulated Lead Acid) Batteries. The former, vented batteries which gas continually, were the basis for many of the Fire, Building, Electrical and Mechanical Codes that exist today. The latter, in controlled conditions**,** emit only a small fraction of the hydrogen gas emitted by flooded batteries. That paper emphasized that a complete battery system includes not only the battery but the charging system, monitoring, and controls as well. In this paper we expand on the use of that check list to show how its use will allow building supervisors and regulatory officials to determine if a battery installation has the features necessary to preclude the need for supplementary ventilation. The check list also acts as a guide for system providers to design and install systems that preclude the need for the supplementary ventilation.

VRLA Battery System Ventilation Check List

	YES	NO
1. Does the system have multiple (redundant) chargers?	5	
2. Does the charger system have a HIGH VOLTAGE alarm?		
- Audible & Visual indicators?	2	
- Remote Annunciator? [e.g.., Remote panel; auto pager; web interface]	5	
3. Does the system have a HIGH BATTERY TEMPERATURE &/or FLOAT CURRENT alarm?		<10>
- Audible & Visual indicators?	2	
- Remote Annunciator? [e.g.., Remote panel; auto pager; web interface]	5	
- Temperature compensated charge voltage?	20	
- Temperature probes appropriately placed in accordance with manufacturer's instructions?		<5>
- Automatic charger interrupt?	5	
4. Does the charger system have BATTERY CHARGE CURRENT LIMIT?	10	
5. Does the charger system have a BATTERY FAULT alarm?		
- Audible & Visual indicators?	2	
- Remote Annunciator? [e.g.., Remote panel; auto pager; web interface]	5	
6. Are the batteries installed in (a) cabinet(s)?		
- Is the battery cabinet listed by a NRTL? *	5	
- Does the battery cabinet have louvers?		<-25>
7. Has the battery been installed away from heat sources?		<-10>
8. Has the battery been installed so it can take advantage of building ventilation?		<-10>
9. Has the battery system/enclosure been fitted with supplementary mechanical ventilation?	5	
10. Is the room TEMPERATURE CONTROLLED at or below 25°C (77°F) 24/7? **	5	
11. Does the room have multiple air conditioners?	5	
- Redundant air conditioners?	3	
12. Has the battery been inspected for ground faults upon installation?	3	
13. Is there a mechanism to monitor for future ground faults?		
- Ground fault monitor?	3	
- Float current monitor?	5	
14. Is there a documented, implemented and accountable maintenance procedure in place to check battery condition?	5	
15. Does the charging system meet battery requirements for AC ripple voltage/ current?	5	
TOTAL:		

* NRTL = Nationally Recognized Testing Laboratory (e.g., UL, ETL, or others)

** 24/7 = 24 hours per day, 7 days per week

Instructions for using the check list

- Check the appropriate yes/no box for each question
- Some of the boxes contain a number (score). Total all of the scores for the checked boxes (note: some of the scores in the NO column are negative)
- **If the total is 60 or greater, supplementary ventilation should not be required**

A check list is used to assure that sufficient systems are in place to preclude ventilation problem with VRLA batteries when used in occupied building environments. The original paper gave an example of a site in which, under normal operation conditions, a 240-cell, 480 volt / 400 AH VRLA battery system would produces .086 cu ft of hydrogen per day**.** In an 8x14-foot room it would take the VRLA system ***more than 104 days to reach a 1% hydrogen concentration without ventilation*** compared to only 60 hours (2.5 days) for the similarly sized flooded / vented battery in the same space**.** Because conditions that can cause a VRLA battery to emit higher levels of potentially explosive hydrogen gas can be controlled by adequate design, installation and maintenance, there should be little need for a dedicated ventilation system for the batteries.

The following discussion explains how the check list can help in the assessment of any particular VRLA battery installation.

Is the system continuously monitored?

Several items on the check list include monitoring. Alarm monitoring is critical to safe operation of any facility, but monitoring is of little use if the alarms go unnoticed. In an office-type application VRLA battery systems are frequently unattended.

As a minimum, a continuously-staffed location should have audible and visual alarms for critical events. For higher security, the system should be equipped with features such as:

- **Remote annunciation** (i.e., alarms prompt action at a location elsewhere in the building or off-site that is monitoring status 24/7. This might be a monitor panel, a Building Automation System, or even an emergency service such as a fire department.)
- **Auto pager** (i.e., a critical alarm causes the system to automatically send a text message to one or more pre-programmed pager numbers to notify key personnel of a specific hazard condition.)
- **Web interface** (i.e., a critical alarm causes the system to automatically record the event and send a message over Ethernet, Internet, or other method to a location that is monitored 24/7. Some network management systems can monitor dozens of world-wide facilities in real time, allowing personnel to query the status of a system and to receive alarm notifications.)

1. Does the system have multiple (redundant) chargers?

Some rectifier plants and UPS systems are designed with multiple chargers. If the design has redundant chargers, failure of a single charger (such as an over-voltage condition) will cause the faulted module to alarm and automatically disconnect from the DC bus while the remaining chargers remain on line and continue to operate as normal.

2. Does the charger system have a HIGH VOLTAGE alarm?

- Audible & Visual indicators?
- Remote Annunciator? [e.g., Remote panel; auto pager; web interface]

This is one of the most basic requirements for VRLA batteries. As noted in the original paper[1], high voltage and / or high temperature cause VRLA batteries to evolve hydrogen gas at an accelerated rate. Normal building air exchanges required by building codes will prevent any problems with hydrogen accumulation at the slightly elevated voltages that might occur due to boost charging. However, appropriate system design and controls prevent the conditions that could cause high voltage and / or high temperature and therefore preclude the need for dedicated ventilation systems.

The charging equipment should be set at the manufacturer's recommended float voltages, typically 2.25 to 2.27 volts per cell. When charging systems were based on controlled Ferro resonant technology, if the charge rectifier failed, it could fail in a high voltage condition, and the resultant voltage and current impressed on the battery string would only be limited by the current limit of the charger itself. The maximum time at high voltage depended on the time it took to respond to high voltage alarms. Many central office telecom power systems still use controlled ferro resonant technology battery chargers, but since many of these facilities are continuously staffed and/or monitored, it only takes minutes to react to a very rare rectifier failure.

In addition, most telecom rectifier plants - and some commercial UPS systems - have multiple chargers in parallel ("N+1 redundant"), which precludes problems of a single-point charger failure (see paragraph 1). Today most, if not all systems used with VRLA batteries, are based on switch mode technology. If the charger fails, it goes to zero voltage, precluding any high voltage problem due to the charging system. In addition, all battery charging systems have high voltage alarms, whereby even moderate increases above targeted float voltage will require action to correct the condition.

While the modern charging systems would never be expected to create a high voltage condition, it is always wise to also preclude such human error as inadvertently setting a voltage level too high. Audible / visual alarms alone may not provide the quick response desired to correct the situation. Therefore the use of a remote Annunciator will notify the responsible system supervisors to correct the voltage levels even if they are not presently in the charging room.

3. Does the system have a HIGH BATTERY TEMPERATURE &/or HIGH FLOAT CURRENT alarm?

- Audible & Visual indicators?
- Remote Annunciator? [e.g.., Remote panel; auto pager; web interface]
- Temperature compensated charge voltage?
- Temperature probes appropriately place in accordance with manufacturer's instructions?
- Automatic charger interrupt?

The original paper explained that**,** along with high voltage**,** temperature is the other big culprit that causes a VRLA battery to emit hydrogen gas at an accelerated rate. It was pointed out that no controlled environments would be expected to have any high temperature problems. However, if the air conditioning systems were to fail, ambient temperature would increase in the battery area, and the battery internal temperature would eventually increase.
- If the air failure is the result of a power outage, the batteries will be supplying critical power backup. This short term loss of air conditioning would not adversely hurt the batteries while being discharged or cause increased hydrogen generation.
- If the building AC fails without a power failure, there should still be some air ventilation. A short term temperature increases would not create a problem.
- If the air ventilation systems becomes inoperable, all building operations would be forced to shut down -including the battery charging systems.

On advanced rectifier plants and UPS systems, the float voltages are controlled by temperature compensating chargers that reduce the charging voltage as temperatures increase. It is this capability - to automatically reduce the charging voltage - that is so valuable in a charging system because it precludes any cause of high temperature that could result in increased gassing. Automatically reducing the charging voltage reduces the current being drawn by the battery and minimizes internal heating of the battery.

To be effective, temperature probes must be used and properly installed in accordance with the manufacturer's instructions. It is the temperature of the electrolyte, not the air, that creates a condition for possible build-up of internal pressure and release of hydrogen from the VRLA battery. Temperature sensors must be placed in the center of the rack or middle of the string. Multiple sensors are better than single sensors. As a general rule, cells in the middle of a string are warmer than cells on either end; strings in middle shelves of a cabinet are warmer than strings with more air ventilation; and strings near the top of a cabinet or rack tend to be warmer than strings near the bottom.

High float current is a precursor to high battery temperature and was recommended in the original paper as a way to monitor ground faults. However, monitoring float current can help preclude other potential problems with a battery installation that could lead to high temperature conditions such as internal shorts, dry out, lack of internal plate compression, or just extended age in service. Float current monitoring technology has improved to the point where it can be used as an alternative or in conjunction with temperature monitoring.

4. Does the charger system have BATTERY CHARGE CURRENT LIMIT?

High charging current can result in an increase of ≥ 10°C (18°F) in battery temperature over ambient. All battery manufacturers recommend limiting recharge current on deep discharged batteries to no more than 25% of the eight hour rating. This is easily accomplished by proper sizing of the charging equipment when the system is specified. In addition, high-rate UPS-type batteries are not really being fully discharged; they can tolerate higher initial rates because they will self limit the current being drawn. Therefore this potential cause of thermal runaway (and associated hydrogen venting) is easily prevented in occupied building applications.

5. Does the charger system have a BATTERY FAULT alarm?

- Audible & Visual indicators?
- Remote Annunciator? [e.g.., Remote panel; auto pager; web interface]

This is a "summary alarm" that indicates there is a battery fault but requires that maintenance personnel check the system to diagnose the cause of the alarm. This can also be indicative of multiple alarms.

6. Are the batteries installed in (a) cabinet(s)?

- Is the battery cabinet listed by a NRTL?
- Does the battery cabinet have louvers?

In buildings where access to equipment rooms is restricted to authorized (trained) personnel, battery systems can sit on open racks. Battery Cabinets are often desirable for smaller batteries or battery systems that are located in an office environment where individuals are not normally knowledgeable about batteries and could accidentally harm the batteries or themselves. Although cabinets provide additional safety, they can also result in additional heat or gas build up within the cabinet. It is therefore critical for cabinets to be adequately louvered to allow for fee flow of air around the battery and easy escape of any gases given off by the battery. These problems should also be minimal in occupied buildings with controlled environments and indoor battery cabinets/enclosures that are listed for the application by nationally recognized testing laboratories (NRTL). A properly designed enclosure will prevent accumulation of hydrogen pockets. A listing label from a Nationally Recognized Testing Laboratory (NRTL) indicates that the cabinet is adequately ventilated.

7. Has the battery been installed away from heat sources?

Location of a battery system can prevent the external heating of the battery. For example, install the battery away from heat sources such as a window with direct sunlight on all or part of the battery, a wall exposed to solar heating, or the exhaust fans of the system power rectifiers. This is a problem easily avoided when layout is taken into consideration during the planning phase for a new battery backup system.

8. Has the battery been installed so it can take advantage of building ventilation?

Location of a battery system can also enhance the system reliability and prevent higher than ambient battery temperatures by making sure that there is good air flow and ventilation around the battery. Again, this can be accomplished when the layout is taken into consideration during the planning phase for a new battery backup system.

9. Has the battery system/enclosure been fitted with supplementary mechanical ventilation?

In this case, does a cabinetized system have an internal fan to aid air flow and ventilation? For non-cabinetized systems, have additional ducts been provided to assure that any gases given off by the batteries will be carried off easily by the existing ventilation system?

10. Is the room TEMPERATURE CONTROLLED at or below 25°C (77°F) 24/7?

This should also be a non-issue in occupied building environments as controlled temperatures below 25°C make for a more comfortable work environment and computer facilities tend to operate at even lower temperatures to better ensure the reliability of the computing equipment.

11. Does the room have multiple air conditioners?

- Redundant air conditioners?

Systems with multiple or redundant air conditioners minimize the chance of a unit failure causing an increase in a battery room temperature. Hydrogen is extremely light and tends not to collect in pockets in the presence of any air movement.

12. Has the battery been inspected for ground faults upon installation?

A ground fault can induce excessive current and heating in a portion of a battery string and result in thermal runaway. In a VRLA battery no free liquid electrolyte can flow from a broken container. However, if there were a crack in the container, capillary action could result in the formation of a slight film of conductive electrolyte in and about the crack. If this electrolyte film were to come in contact with an un-insulated metal component that is common to either polarity of the battery, it could result in an excessive short circuit current. This "ground fault" current could result in thermal runaway of a portion of the string or even a fire.

Good maintenance practices are an important step in precluding ground faults. Signs of leakage should be investigated. Any cell or battery unit found to be leaking should be replaced as soon as possible. However, the ground faults that are most likely occur as the result of a cracked jar and a leak path to ground may not be evident. The most likely cause of such a crack is shipping damage or damage during installation. The best way to check the status of a newly installed string is with an Insulation Tester / Megohmeter. This is a very sensitive test and even a dirty cell (residual electrolyte on the case) could appear to be a leak.

13. Is there a mechanism to monitor for future ground faults?

- Ground fault monitor?
- Float current monitor?

For long term protection of installed strings, use of either a ground fault detector to detect current in the ground loop, or use a current monitoring device to detect increases in the current being drawn by the battery string will prevent ground faults from causing a problem for the batteries.

14. Is there a documented, implemented and accountable maintenance procedure in place to check battery condition?

One of the easiest but time consuming ways to preclude battery problems is to have a good and documented routine for periodic maintenance. A fine reference is available from the IEEE 1188 Recommended Practice for Maintenance, Testing, and Replacement of Valve Regulated Lead-Acid (VRLA) for Stationary Applications[2]. Good maintenance procedures will prevent problems due to internal problems with -or just the normal aging of - the VRLA batteries. One of the conditions not easily spotted by the system controls is the internal shorting of a cell or multiple cells.

Shorted cells are very rare occurrences. When they do occur, the shorted cells will fall slowly in cell voltage over time. The most probable causes of shorted cells include:

1. Long periods in the discharged condition.
2. Long term storage without a freshening charge.
3. Continuous undercharging resulting in sulfated plates.
4. Continued operation beyond a reasonable life expectation.
5. Internal mechanical damage or defect, e.g. a bent plate.

If shorted cells in a string go ignored for a long period of time (six months to a year), those cells will eventually drop to zero volts with corresponding increases in voltage to the rest of the cells in the string. For example, if two cells in a 48 volt string go to 0 volts the rest of the string will be at 2.45 volts per cell. The 2.45 volts per cell would not drive the string to thermal runaway but would result in higher gas evolution and dry out of the battery. However, a higher percentage of shorted cells could lead to thermal runaway. If cell readings are checked on a periodic basis as part of normal maintenance procedures, shorted cells should never result in more than a maintenance problem.

15. Does the charging system meet battery requirements for AC ripple voltage/current?

A somewhat less obvious but equally detrimental failure would be that of the output filtering of the battery float charger. Even though the AC ripple voltage output of the charger may be quite low (less than $0.5\%_{rms}$ of the float voltage), the internal resistance of the battery being charged could also be extremely low and a significant AC ripple current can flow through the battery. The AC ripple current from the charger could be several amperes and could cause additional heating of the battery in accordance with I^2R.

If AC ripple output voltage of the charger exceeds 4% peak-to-peak of the float voltage, this could result in actual "cycling" of the battery and a resulting additional rapid rise in temperature, DC float current, gassing etc.

To prevent heating of the battery due to AC ripple current, the AC ripple current should be limited to less than 5 amperes rms per 100 Ah of rated battery capacity. This requirement is common to most battery manufacturers operating instructions. The best way to assure this never becomes a problem for VRLA batteries is to ensure the charging systems have well filtered DC outputs.

CONCLUSION

Many codes that were created based on a legacy of vented lead-acid batteries have little relevance to VRLA batteries operating in controlled and monitored environments. Most codes are concerned with the ventilation of flammable/explosive hydrogen gas. While it is possible for a VRLA battery to be forced into venting hydrogen by abusing it, the safety margin for a VRLA system in a controlled environment can be many dozens or even hundreds of times greater than for a flooded battery when installed with appropriate monitoring / controls and when properly maintained.

This paper has proposed a check list as one method of quantifying risk. A low score indicates that many safety features are missing and the ventilation system should be much the same as for a vented battery. Conversely, a high score indicates a high degree of safety features and procedures, thereby suggesting that supplementary ventilation (i.e., more than already provided for personnel or equipment) should not be necessary. It is our recommendation that this method of quantification should be reviewed by standards organizations such as IEEE and become part of a standards document.

BIBLIOGRAPHY

[1] B Dick, Ventilation Requirements for VRLA Batteries in Occupied Buildings, Battery Man May and June 2004.

[2] IEEE 1188-1996 Recommended Practice for Maintenance, Testing, and Replacement of Valve Regulated Lead-Acid (VRLA) for Stationary Applications, Annex D.2.