Introduction: Risk—monitored and unmonitored

From lead acid to LiOn to NiCad, all batteries produce flammable hydrogen gas during normal charging. Overcharging, excessive heat and many other factors can quickly cause batteries to produce even more hydrogen. As hydrogen builds up, the risk of fire, explosion and material degradation increases.

This white paper explores the types of hazards presented by hydrogen, how hydrogen can build up, and the changing building regulations and codes that address battery installations. A discussion follows of monitoring solutions to meet those regulations and prevent danger. To begin with, some real world cases illustrate the need and effectiveness of direct monitoring.

H_2 battery explosion reported by the Sacramento Fire Department.

Real-world cases

Direct hit

A few years ago, a hydrogen explosion occurred in an Uninterruptible Power Supply (UPS) battery room. The explosion created a 400 ft^2 hole in the roof of the computer and data center, collapsed numerous walls and ceilings throughout the building and significantly damaged a large portion of the 50,000 ft^2 building. It was extremely fortunate that the facility was vacant at the time, and no injuries were sustained.

The ventilation for the battery room was not in operation. Given the rate at which batteries generate H_2 (1.3 x 10-7m/s per amp-cell), it appears as though batteries were charging for a long period of time with no ventilation. Hydrogen continued to build up until it found an ignition source. On-site personnel assumed that the ignition occurred at or near a grounding strap on the battery racks, but in a room full of batteries and electrical equipment, ignition sources are plentiful.

Near miss

In 2009 a hydrogen alarm sounded when hydrogen buildup occurred in an unmanned switching room containing backup lead acid batteries after the exhaust ventilation fans failed to start at the 1% hydrogen trigger level. Failure of the ventilation fans to vent the normal off-gassing hydrogen from the lead acid batteries resulted in the hydrogen concentration in the room increasing to 2%, which triggered the hydrogen alarm. The alarm monitoring company alerted the fire department and company personnel, and the concentration of hydrogen gas was lowered before it became a potential problem. No injury of personnel or property damage occurred from this event.

The hazards of hydrogen

Hydrogen is classified among the "extremely flammable" substances.
Compare its properties with methane and petrol in the table below:

Properties	Measurement	Hydrogen	Methane	Petroleum
Ignition limits in air	(vol. %)	4 - 75	5.3 - 15	1.0 - 7.6
Detonation limits in air	(vol. %)	13 - 65	6.3 - 13.5	1.1 - 3.3
Heat of combustion	(kJ/g)	120	50	44.5
Self-ignition temperature	(°C)	585	540	228 - 501
Flame temperature	(°C)	2,045	1,875	2,200
Theoretical explosion energy	(kg TNT/m^3 gaz)	2.02	7.03	44.22

The hazards of hydrogen explained

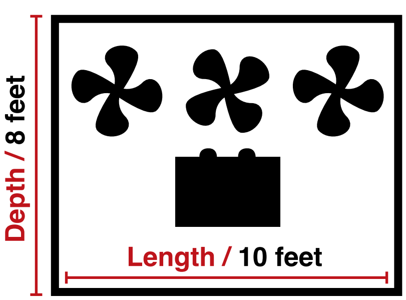
Alkaline metals (lithium, sodium, potassium, etc.) and to a lesser extent alkaline earth metals (magnesium, calcium, etc.), all metals commonly used in batteries, react violently with water and generate hydrogen. This generated hydrogen can subsequently ignite or explode depending on the exothermicity of the reaction. So the higher the temperature, the more explosive the reaction.

Hydrogen buildup from battery installations is extremely flammable, and it actually begins to accelerate the degradation of materials in the area. Not only do batteries begin to degrade, shortening their life span, but it also causes degradation of all of the other components and hardware. Even a small increase in H_2 production can quickly become dangerous.

Various types of degradation caused by hydrogen

- ***Hydrogen blistering:*** absorption of atomic hydrogen on the surface of low resistance materials resulting in blisters
- ***Hydrogen embrittlement:*** absorption of atomic hydrogen on the surface of high resistance materials resulting in low ductility and increased internal stress
- ***Hydrogen induced cracking and hydrogen stress cracking:*** blister formation that may affect the integrity of materials especially when stressed

Combined, this means that in any facility that has a battery installation, the chance of buildup and ignition is significant. For example, under the right conditions, a typical room found at the base of a cell tower can take just 7 hours to reach a high enough concentration of hydrogen to cause an explosion.



Example of buildup time if ventilation system fails or is obstructed

- ***Facility size:*** 10' x 10' x 8' room
  (typical size found at a cell tower base)
- ***Battery system:*** 15 year old 100Ah battery system
- ***Charging current:*** 2.5 amps
- ***Explosive threshold:*** 4% H_2 in just 7 hours
  (a 90°F, buildup rate would be reached much faster)

Regulations and codes

To address the risks hydrogen buildup presents, regulations on battery systems have been put in place with the help of the National Fire Protection Association (NFPA). More and more, fire marshals and inspectors are requiring H_2 monitoring systems even in small battery installations. These regulations impact both unmanned battery installations such as cell-towers, power substations and telecommunications buildings as well as manned applications such as data centers, server closets and other applications requiring banks of batteries. As battery installations are becoming increasingly common, states such as Florida, California, Texas and Illinois are also revising their building codes to address the increased risk for unmonitored hydrogen. These regulations and their enforcement are fitting considering the risk of danger inherent to hydrogen.

NFPA®

NFPA 75

Standard for the fire protection of information technology equipment:

- Covers life safety aspects
- Discusses fire threat of the installation to occupants or exposed property
- Covers economic loss from the loss of function, loss of records and loss of value of the equipment
- Regulatory and reputation impact

NFPA 76

Standard for the fire protection of telecommunications facilities:

- Details support of public safety through emergency communications (such as 911), national defense communications requirements, video transmission of critical medical operations, and other vital data.
- Describes viability of service during and after an event or replacement or restoration within a reasonable period post-event.
- Deals with service disruptions or factors that inhibit the ability of the service provider to restore service in a timely manner post-event.

NFPA 90A

Standard for the installation of air-conditioning and ventilating systems:

- Details when battery systems need to be ventilated
- Details when equipment and systems require cooling as well as the proper levels

NFPA 111

Standard on stored electrical energy emergency and standby power systems:

- Details performance requirements for stored electric energy systems providing an alternate source of electrical power in buildings and facilities during an interruption of the normal power source
- Covers power sources, transfer equipment, controls, supervisory equipment and accessory equipment needed to supply electrical power to selected circuits
- Covers installation, maintenance, operation and testing requirements as they pertain to the performance of the stored emergency power supply system (SEPSS)

For full descriptions of these regulations, visit the NFPA website. http://www.nfpa.org/aboutthecodes/List_of_Codes_and_Standards.asp?cookie_test=1

Portable vs. full installation solutions

Portable and integrated hydrogen monitoring solutions are two monitoring options often used for battery installations. Portable monitors are handheld units that give information the moment the readings are taken, but provide no protection between readings. In between readings, if fans fail, ventilation systems get blocked or obstructed, power to cooling systems fails or nature sends temperatures soaring; the danger can be catastrophic. Use of portable monitors to periodically check integrated monitoring solutions is an excellent way to ensure proper operation of an integrated monitoring system.

Permanent (life of the battery system) integrated hydrogen monitoring solutions continuously monitor the levels of hydrogen. Integrated solutions typically meet all of the regulations and can be tied in with alarm/SCADA monitoring systems to provide early warning and maximum protection. Some hydrogen detectors can also operate a battery room's exhaust system in order to dissipate hydrogen when it is first detected.

Conclusion

In best practices, H_2 monitoring systems should be linked to an auxiliary ventilation system and to fire and building monitoring control systems. This is due to the fact that, at any time, primary and/or secondary ventilation systems can fail causing the heat to rise along with the risk of an H_2 explosion. An easily integrated hydrogen detection system minimizes the risks, provides a warning and allows time to prevent catastrophe.

If you have any type of battery system installed or are planning a modification, redesign or new installation, installing a hydrogen monitoring system will not only help to prevent disaster, it is likely the only way to be compliant with current and future building codes.

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