EAGLE EYE TECHNICAL NOTE

Title	**Battery Room Ventilation Requirements**
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Revision History

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Introduction.

Lead-Acid (LA) and Nickel Cadmium (NiCd) vent hydrogen and oxygen when they are being charged. In the case of Valve-Regulated designs, the hydrogen is recombined with the oxygen within the battery back into water until the gassing volume/pressure exceeds the opening setting of the pressure relief valve. Hence the name "Valve-Regulated."

Oxygen gas is harmless, and our atmosphere consists of 21% oxygen. Hydrogen; however, is dangerous. It is the lightest element, and is colorless, odorless, tasteless, and highly combustible. Hydrogen has a very broad flammability range between 4% - 74% in air. Consequently, preventing hydrogen mixing with air in a confined space is very important. The various mitigation levels, codes, and methods are discussed below.

The National Fire Protection Association (NFPA) 704*, Standard System for the Identification of the Hazards of Materials for Emergency Responders*, lists hydrogen at their highest rating of 4 on their flammability scale because it is flammable when mixed with even small amounts of air, as low as 4%. (NFPA 704 produces a simple and readily recognizable and understood system of markings called the NFPA hazard diamond.)

Hydrogen Mitigation

One of the key factors in hydrogen mitigation is to have a means of preventing it reaching the Lower Flammability Level (LFL). Although the NFPA states this is 4%, other codes have more stringent levels.

According to the National Electrical Code, (NEC) the battery room should be ventilated, as required by NFPA 70 480.10 (A). "Ventilation. Provisions appropriate to the battery technology shall be made for sufficient diffusion and ventilation of gases from the battery --- to prevent the accumulation of an explosive mixture." It then has some Informational Notes which refer the reader to NFPA 1, Fire Code and IEEE Std 1635-2012/ASHRAE Guideline 21-2012 *Guide for the Ventilation and Thermal Management of Stationary Application*. The current (2020) edition of the NFPA 70 does not mention what the accumulation of hydrogen (Lower Explosive Level (LEL) is in order to create an explosive mixture. The problem with identifying the LEL is that the hydrogen concentration is dependent upon which code or standard is used. There is a saying that "the nice thing about codes and standards is that there are so many to choose from."

NFPA 70 – 2020 Article 708.20 under the heading Ventilation states that "Adequate ventilation shall be provided for the alternative power source for continued operation under maximum anticipated maximum temperature."

Hydrogen is the lightest element and it diffuses faster than any other gas because the molecular weight of hydrogen is lower than any other gas. Hydrogen molecules can react with many elements and compounds but at room temperature this reaction rate is extremely low. Bearing in mind that because the hydrogen atom is so light, it will accumulate at the highest point in an enclosure or room. Consequently, hydrogen detectors must be located at these locations. The ventilation system should be alarmed so that a failure of the system would annunciate this fact. It is recommended that hydrogen detectors be installed in the battery room.

Below is an excerpt from a joint Institute of Electrical and Electronics Engineers (IEEE) and the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE,) ASHRAE/IEEE Std 1635-2012 / ASHRAE Guideline 21-2012. *IEEE/ASHRAE Guide for the Ventilation and Thermal Management of Batteries for Stationary Applications*.

> **"Annex C**
>
> (Informative)
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> **Existing U.S. codes and standards.**
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> There are multiple codes and standards relating to batteries, but most of them only have limited information regarding ventilation. The general guidelines call for limiting the buildup of explosive and toxic gases to certain levels (see Annex D). Some codes call for taking measures that will limit abnormal conditions (such as measures that will mitigate the possibility of thermal runaway or fire). Other IEEE practices (including this document) acknowledge additional methods of thermal management of batteries that will also mitigate the possibility of thermal runaway.
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> The National Electrical Code (NEC) (NFPA 70®, 2011 Edition), Article 480, and the National Electrical Safety Code® (NESC®) (Accredited Standards Committee C2-2012) require ventilation that will avoid buildup of gases to an explosive level. This is the least stringent guideline, since the lower explosive limit (LEL) of hydrogen, as defined in the codes, is 4%. NOTE that the actual explosive level of hydrogen is generally considered to be approximately 15% to 18% concentration, but most fire codes consider the lower flammability limit (LFL), which is approximately 4% and the LEL to be the same.) Other codes are more stringent, so generally, this will not be the governing code for ventilation. The NEC Handbook provides further useful guidance in noting that forced ventilation systems are not always needed to meet the requirement. It also notes that VRLA batteries still need ventilation (refer to Clause 7 for the gassing rates of different types of batteries under different operating conditions). Failure of continuously operated or automatically powered ventilation systems should be annunciated."

Underwriters Laboratories UL 1778 [B37] requires that hydrogen buildup be limited to 2% volume in the space (a safety margin is built in). IEEE recommended practices also specify this level.

NFPA 1 (Fire Code) and the International Fire Code (IFC) (Articles 608 and/or 609, depending on which version is referenced/enforced) require that hydrogen buildup be limited to 1%. Where these codes are adopted, this will be the general design criteria.

OSHA (29CFR1910 [B15] and 29CFR1926 [B16]) has special requirements for the buildup of explosive gases in "confined spaces." Confined spaces where batteries are used are generally limited to vaults. The Federal requirement is that personnel not enter these spaces until testing shows that explosive gases are less than 10% of the LEL (0.4% hydrogen).

"Annex D

(Informative)

Explosive and toxic gas allowance considerations

D.1 Permissible hydrogen concentrations. As noted in Annex C, various standards and codes in the U.S. cite at least four different levels of maximum allowable hydrogen concentrations: 4%, 2%, 1%, and 0.4%. Which one is correct?

From a scientific perspective, the lower flammability level (LFL) of hydrogen is approximately 4% (refer to the CRC Handbook of Chemistry and Physics. Regardless of codes and standards, for personnel and equipment safety, hydrogen pockets should not be allowed to exceed 4% (the LFL). Good engineering practice dictates the use of a safety factor. It is acceptable practice that a 50% margin of safety is reasonable, therefore a 2% maximum concentration is recommended. As described in Annex C, some fire and building codes set the threshold at only 25% of the LFL, or a 1% concentration.

A decision on whether or not to design the ventilation system to prevent buildup to less than 2% should consider several factors. If the installation is subject (or might ever be subject) to a fire code, then the code dictates the design requirements. If the installation could be considered to be a *confined space*, then OSHA's 0.4% limit should be the criteria. In the absence of code requirements, economic factors can be considered. Each point of reduction in the threshold requires a significant effort and cost to achieve it. The risk should be weighed against the cost. Risk is inversely proportionate to the volume of the space to be ventilated, but mitigation costs can increase exponentially."

Conclusion.

First of all, it should be determined what code or requirement is applicable. If it is unknown, then it is advisable to use the most stringent requirement of 1% concentration. Remembering that hydrogen migrates to the highest point in the cabinet or room, the hydrogen detector should be placed at that point. If installed, the detector should be regularly calibrated in accordance with the manufacturer's instructions. Where extraction fans are employed in the battery location, they should be sized to remove the volume of air to keep the calculated hydrogen evolution below the required LEL. If this has not been provided, then it is usual that four complete room air volume exchanges per hour is adequate. Hydrogen evolution should always be calculated using the worst case scenario, i.e. when the battery is being charged at the highest set voltage which is normally the boost or equalize setting. Remember, batteries only gas when they are being charged.

Eagle Eye Power Solutions' "Gassing Calculator" can be used to determine battery gassing quantities and the amount of ventilation required. Hydrogen concentration can be determined at levels of 2% or 1%.

Further Information.

International Codes Council (ICC) – International Fire Code (IFC)

Chapter 6. Section 608 Stationary Storage Battery Systems.

U.S. Department of Labor. Occupational Safety and Health Administration (OSHA).

Code of Federal Regulations (CFR) 29CFR 1926.441