Title: **Battery Explosion Risk Analysis**

Student: Alejandro Solé Gamell

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Supervisor/s: Dr. Jaume Gimenez Farreras
Departament of Chemical Engineering and Analytical Chemistry
Cristina Sacristán Gallurt
TÜV SÜD IBERA S.A.U.

Batteries are commonly used by people today but also in the industry. For this reason, research is continuously being conducted in this field aimed at increasing the service life of batteries, make them last longer before they need to be charged and increase their safety in addition to other aspects.

Many different types of batteries are available on the market. Of all the types batteries that are available, the most commonly used in the industry have been selected: Lead-acid (open, GEL and AGM), nickel metal hydride. These batteries are used in emergency systems (UPSs, electrical generator sets, etc.) but also for drive systems on forklifts, dollies, lift machines, etc. Lithium and lithium polymer batteries with an improved performance are also used on the newest equipment but at a higher cost.

Nickel-cadmium batteries are being phased out because they are having them replaced with nickel-metal hydride batteries.

This document also describes molten salt batteries because their use is very promising and the industry is transitioning towards using solid-state batteries.

As is well known, lead-acid, nickel-cadmium and nickel-metal hydride batteries release hydrogen when they are being charged and especially when they overheat due to the electro-chemical reaction that occurs during the battery charging process or due to the type of electrolyte, which is comprised of an aqueous solutions that can produce electrolysis in the water. This possible releasing of hydrogen could create an explosive atmosphere in the battery charging area or in the room where equipment with stationary batteries.

In cases where explosive atmospheres could form, suitable prevention and protection measures shall be implemented in compliance with Directive 1999/92/CE of 16 December 1999, transposed in accordance with Royal Decree 681/2003 of 12 June 2003, which establishes the minimum requirements for protecting the health and safety of employees that could be exposed to explosive atmospheres at the workplace.

With the aim of establishing the minimum requirements for protecting the health and safety of employees, the following UNE standards are used:

General explosive atmosphere standards: UNE 202007:2006 IN and UNE-EN 60079-10-1:2016. Also, standards on explosive atmospheres generated by batteries are used: UNE-EN 50272-1:2011, UNE-EN 50272-2:2002, UNE-EN 62485-3:2015. The guide is also used: IALA Guideline 1044: 2005.

Using these six standards we can estimate the safety distance and minimum ventilation flow required for preventing hydrogen from accumulating and establishing the minimum distance at which an ignition source may be located.

The following ranges of results have been obtained for open lead-acid batteries with a capacity of 620 Ah and 40 cells and 270 Ah and 12 cells.

- UNE 202007:2006 IN: Leak rate: $1.26 \cdot 10^{-5}$ kg/s in both cases. Minimum ventilation flow: 51.67 m^3/h in both cases. Safety distance: from 1 cm to 123 cm.
- UNE-EN 60079-10-1:2016: Leak rate: $1.29 \cdot 10^{-4}$ kg/s in both cases. Minimum ventilation flow: 55.40 m^3/h in both cases. Safety distance: 165 cm in both cases regardless of the location and the type of ventilation. The estimated level of dilution is from medium to high.
- UNE-EN 50272-2:2002: Leak rate: from $6.09 \cdot 10^{-6}$ to $1.99 \cdot 10^{-7}$ kg/s. Minimum ventilation flow: from 0.82 to 25 m^3/h. Safety distance: from 22 cm to 126 cm.
- UNE-EN 62485-3:2015: Leak rate: from $8.7 \cdot 10^{-7}$ to $1.66 \cdot 10^{-5}$ kg/s. Minimum ventilation flow: from 3.53 to 94.55 m^3/h. Safety distance: from 50 cm to 197 cm.
- IALA Guideline 1044:2005: Leak rate: from $1.03 \cdot 10^{-6}$ to $7.90 \cdot 10^{-6}$ kg/s. Minimum ventilation flow: from 4.23 to 32.40 m^3/h. The safety distance cannot be estimated using this standard.

In all cases, problems are encountered when determining the different parameters because it is not easy to determine the leak rate and from here, the ventilation flow and the safety distances. Among other things, standards are used to estimate the safety distance while supposing that the ventilation is routed directed onto the battery terminals; therefore, the calculated safety distance will be shorter than what is actually required. Henceforth, this work has also pointed out some deficiencies in the methods proposed in the standards when certain parameters are evaluated. Therefore, work aimed at gradually improving these estimations is ongoing.

Finally, based on the results that are obtained and the deficiencies observed, some prevention measures and good practices have been established to reduce the possibility of explosive atmospheres from forming when the batteries are being charged.