H2scan
ADVANCED HYDROGEN SENSING

Navigating the Complex Landscape of Battery Room Safety in Europe

Jeff Donato

Making Hydrogen Safe For a Cleaner World

Jeff Donato Bio



Jeff Donato is the VP of Safety Systems at H2scan. Jeff has over 30 years of experience in sales and management within the industrial battery industry, representing safety and compliance products in data centers, utilities, and telecommunications applications.

Jeff is an active member of the IEEE Power & Energy Society and is the current chair of Working Group 1578 in the Energy Storage and Stationary Battery Committee (ESSB). Jeff is also a member of several other IEEE working groups, including those focused on alternative energy storage technologies and the nuclear working group.

He has provided Environmental Health & Safety training on standby power systems to engineering, architecture, and OEM manufacturing companies, as well as delivered solutions training to end-users and specifying engineers.

Incident Case Studies

- Sodium-Sulfur Battery Fire (Japan, 2011)
- Lead Acid Battery Fire (Oahu, Hawaii, USA, 2012)
- Lithium-ion batteries fire (PORT ANGELES, WA, USA, 2013)
- Lithium-ion batteries fire (Franklin, WI, USA, 2016)
- Lithium-ion Battery Fire (Belgium, 2017)
- Twenty-three Fires at different Lithium-ion stationary storage battery systems (South Korea, 2017-2018)
- Lithium-Ion Batteries Fire/Explosion (Arizona, USA 2019)

Battery Incidents

1997 Sacramento VLA Battery Explosion:

Incident: Hydrogen gas ignition in a UPS battery room

Location: 3rd floor, building containing vented batteries

Cause:

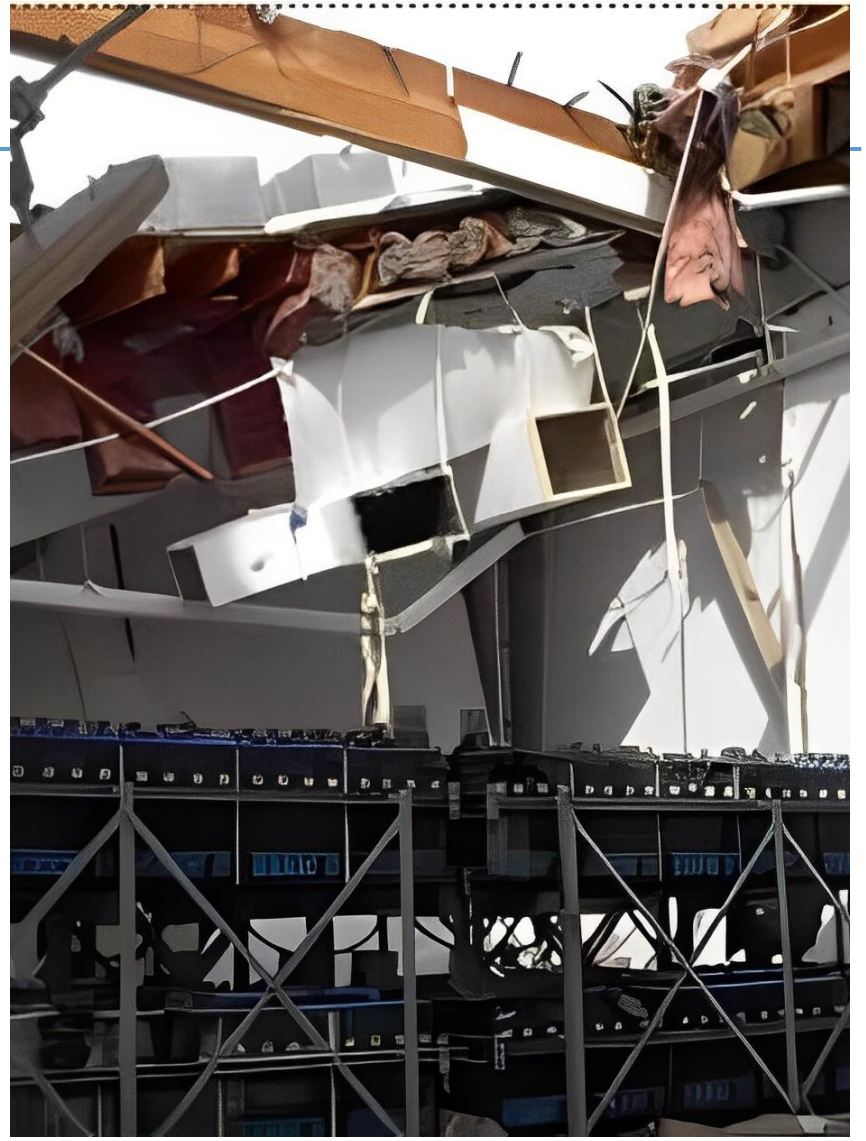
- Unattended equalize charge for 3 days. Batteries beyond expected lifespan for UPS use (16 years old)

Missed Warnings:

- Hydrogen monitoring system alarm (possibly due to disabled ventilation)
- Local alarms have been sounding (not connected to the fire panel)

Outcome:

- The explosion created a 37 square meter hole in the ceiling



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Standby & BESS Battery Safety

As the demand for energy storage systems continues to grow, ensuring the safety of these systems is paramount to protect both people and property.



Best practice standards: Exploring industry-recommended best practices



Regulations: Identifying the latest national, regional, and local regulations



Information sources: Staying informed about regulatory changes.



Adopted codes: Understanding the specific codes and standards adopted in different European jurisdictions.



Subsidiarity: Decisions should be made at the lowest possible level of government

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IEC Standards

Standard	Description	Last Revision Date
IEC 60086-1	General requirements for primary cells and batteries.	2019-11
IEC 60086-2	General requirements for secondary cells and batteries.	2019-11
IEC 62133	Battery safety performance requirements for various battery types.	2021-03
IEC 61960	Performance and safety requirements for secondary batteries, including BMS.	2021-03
IEC 60086-5	Safety requirements for stationary lead-acid batteries.	2019-11
IEC 62485-2	Safety requirements for stationary secondary batteries, including protection against electricity, gas emission, and electrolyte leakage.	2018-06

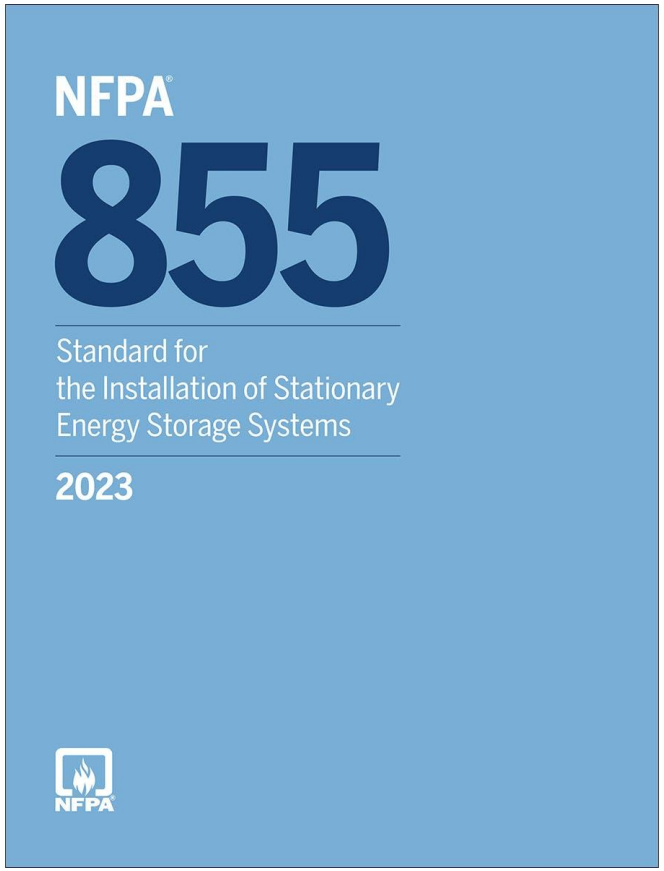
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New Standard for Stationary Energy Storage Systems

NFPA 855 Energy Storage & Stationary Batteries

NFPA 855 is a standard developed by the National Fire Protection Association that provides safety guidelines for the installation and maintenance of energy storage systems and stationary batteries. Its primary goal is to minimize fire and electrical hazards associated with these systems by establishing safety standards, risk management procedures, and best practices for design, installation, inspection, and maintenance.

- Hydrogen needs to be kept below 1% of room volume
- 2-hour backup on safety systems
- Spacing requirements for lithium batteries
- Hazardous Mitigation Plan (HMP)



Abnormal Conditions



Ventilation system failure: The ventilation system does not remove hydrogen gas from the battery compartment, allowing it to accumulate to dangerous levels.



Battery left on equalization charge: Equalization charging is a high-voltage charging process that is used to balance the voltage of all cells in a lead-acid battery. If the battery is left on equalization charge for too long, it can overheat and produce excessive hydrogen gas.



Thermal runaway: Thermal runaway is a condition in which the temperature of a lead-acid battery rises uncontrollably, causing it to produce large amounts of hydrogen gas. This can be caused by several factors, including overcharging, high ambient temperature, and internal shorts.



Charger runaway: Charger runaway is a condition in which a battery charger malfunctions and outputs a voltage that is too high for the battery. This can cause the battery to overheat and produce excessive hydrogen gas.

Hazardous Mitigation Plans: Assess the risk and develop the contingency plan.

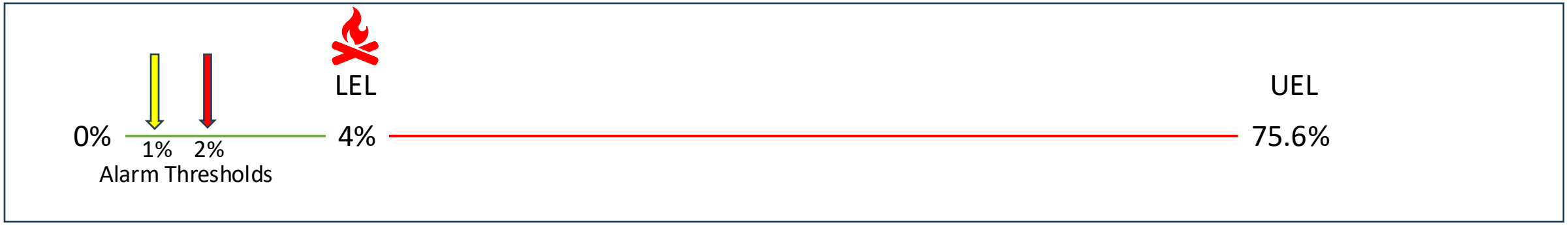
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Hazardous Mitigation Analysis/Plan

- **Monitor hydrogen concentrations:**
  - Hydrogen gas monitors should be used to detect hydrogen leaks in industrial and commercial settings.
  - Properly ventilate areas per the standards.
  - Alarm systems should notify building management or fire panels.
  - Since hydrogen is lighter than air, it will tend to rise to the ceiling. Prepare for both best- and worst-case scenarios.
- **Use proper equipment and procedures:**
  - Well-designed detection and purge systems, as well as safe operating procedures.
  - Employees working around hydrogen must be trained on its properties, hazards, and proper handling of equipment.
  - Create a plan in case of fan or sensor failure. Will it create a maintenance alarm?
  - Put safety systems on backup power – Example: 2 hours backup for standby power, 24 hours backup for BESS

Gas Generation and Ventilation

IEC 62485-2 Section 7.4/ IEEE 1635 ASHRE 21



- IEC Hydrogen levels are to be kept below 4% of volume. The ventilation requirement accounts for the hydrogen produced from the maximum current available from the charger.
- If natural ventilation is insufficient based on calculations and testing, forced ventilation must be implemented, interlocked with the charger, or create an alarm.
- Gas detection may be used in coordination with gas purge fans
- Recommended to maintain levels below 1% of room volume or 10,000 ppm (NFPA 855)

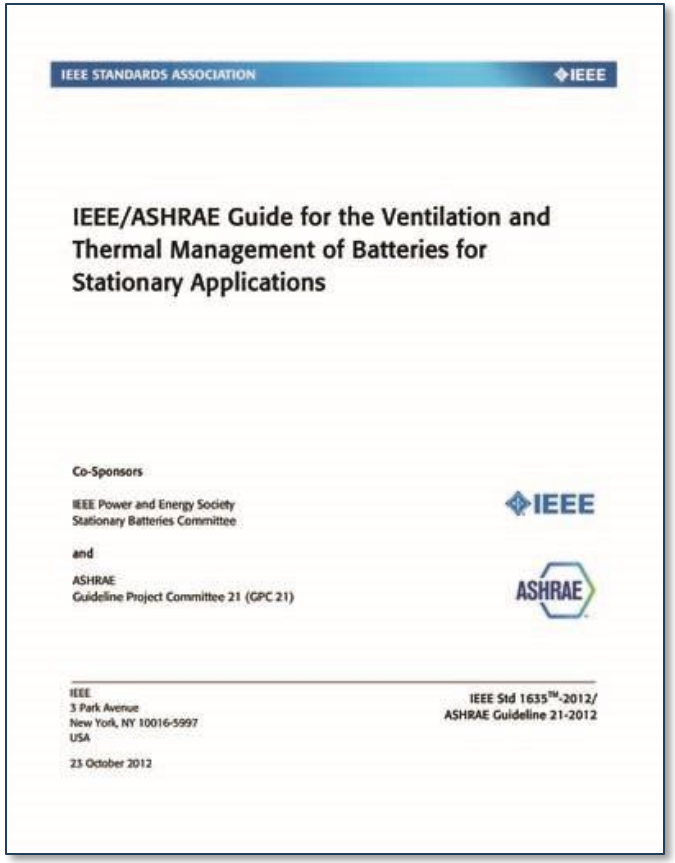
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IEEE 1635/ASHRAE 21 - VLA Example

Calculation example that demonstrates the necessary ventilation requirement for 2 strings of a 23 plate, 240 cell lead-calcium battery.

Room size: 15.24 meters by 12.192 meters

Gas Modes	Exchange Required to Maintain 1% m3/h	Time to 1% without ventilation	Time to 4% without ventilation
Float Charge	5.40282	6 days	23 days
Boost Equalize/Finish Charge	18.0094	41 hours	164 hours
Initial Charge	28.5432	26 hours	103 hours
Charger Runaway	103.2032	7 hours	28 hours



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Lithium Batteries

- Not Normally Gassing
- Gases Under Thermal Runaway Conditions
- 30-40% of the gas is hydrogen





LiFePO4 – UL 9540A Test

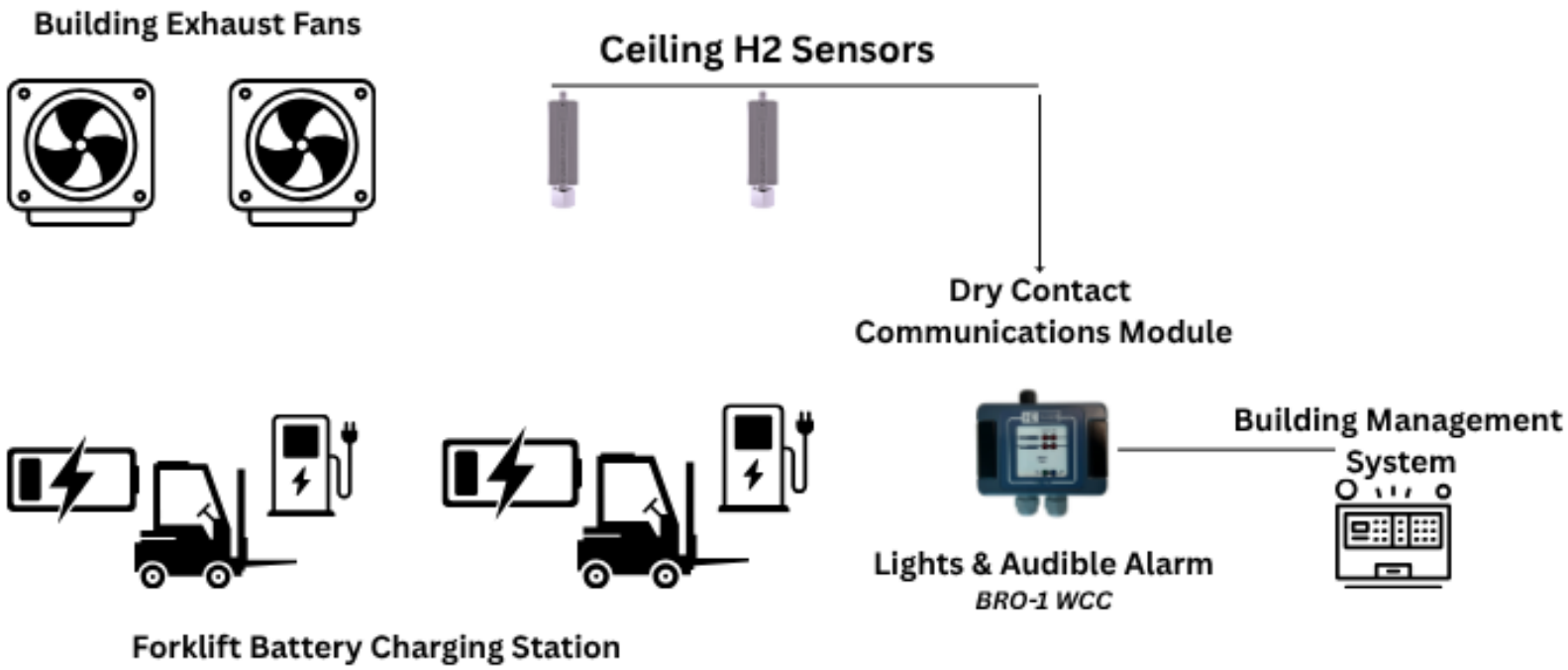
Temperature in the vessel before the test (°C)	23.8
Temperature in the vessel after the test (°C)	24.5
Atmospheric pressure in the vessel before the test (kPa)	107.2
Atmospheric pressure in the vessel after the test (kPa)	376.2
Initial oxygen content by volume (%)	0.08
Total vent gas volume (L)	50.03

Measured gas components and concentration was shown in tables below

Vent gas components (including O_2 and N_2)	
Gas component	Concentration % (v/v)
CO_2	20.39
CO	5.39
N_2	27.06
O_2	0.02
H_2	34.35
CH_4	4.50
C_2H_4	3.58
C_2H_6	1.06
C_3H_6	0.93
C_3H_8	0.29
C_4H_8	0.37
C_4H_{10}	0.12

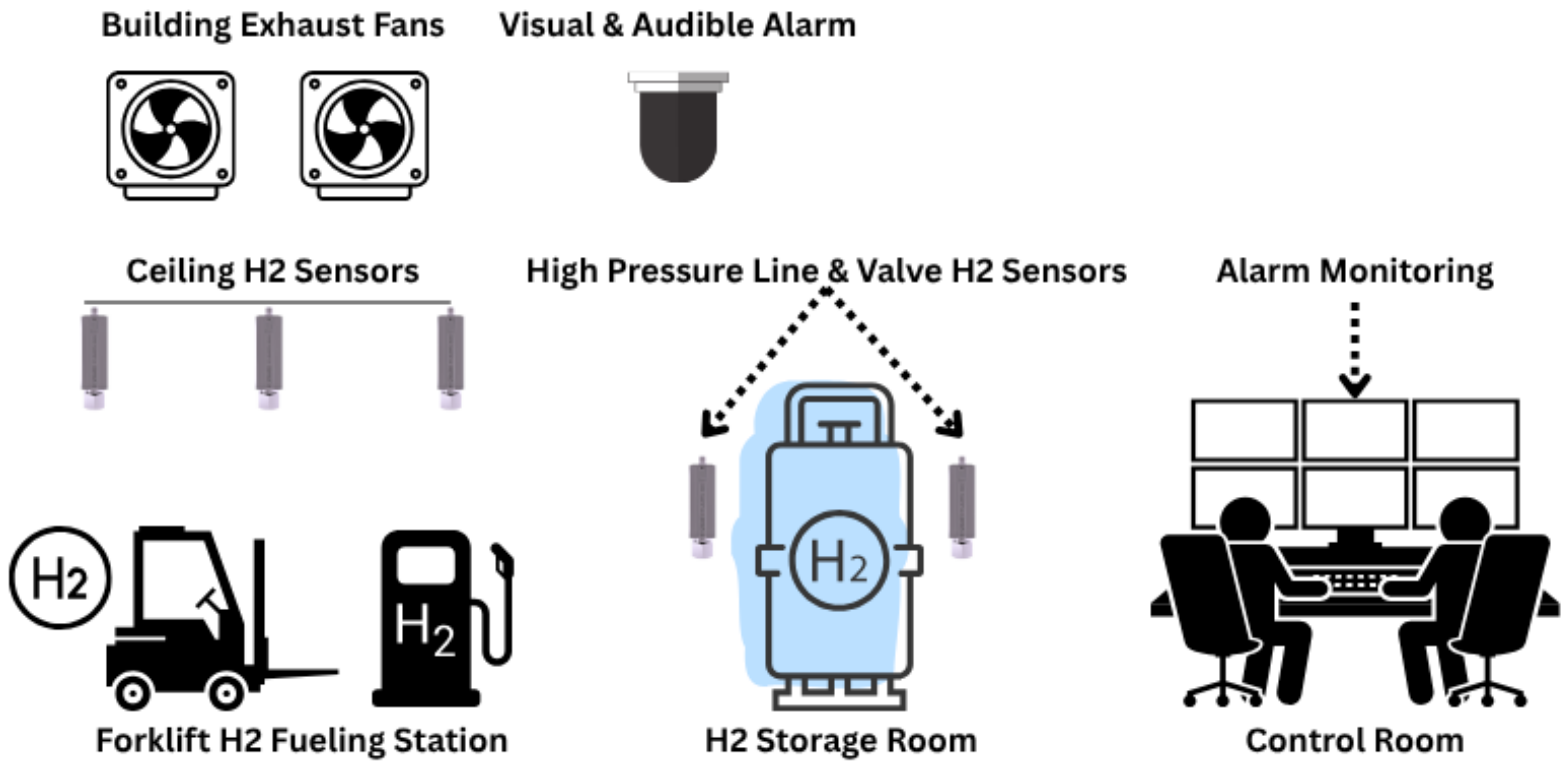
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Lead-Acid Powered Forklifts



- Monitor Safe Levels of Hydrogen in the air
- Distinguish between H2 and CO
- Activate ventilation systems
- Use in Emergency Management Plan (HMP)

Fuel Cell Powered Forklifts



- Monitor Safe Levels of Hydrogen in the air
- Distinguish between H2 and CO
- Activate ventilation systems
- Use in Emergency Management Plan (HMP)

Hydrogen Detection Technologies in the Market Place

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TCD hydrogen sensor (Created around 1913):

- Measures hydrogen concentration in a gas mixture by assessing the mixture's thermal conductivity
- Different gases have varying thermal conductivities, and the thermal conductivity of a gas mixture is a weighted average of the thermal conductivities of the individual gases.

Catalytic bead hydrogen sensor (Created around 1927):

- This device gauges hydrogen concentration in a gas mixture by sensing the heat generated when hydrogen interacts with a catalyst. Typically, this catalyst is a metal oxide.

Metal Oxide sensor (Created in the 1990's):

- Metal oxide sensors are chemical sensors that rely on the change in electrical resistance of a metal oxide material (typically a semiconductor like tin oxide, zinc oxide, or tungsten oxide) when interacting with certain gases.

Solid State Precious Metal Sensors (Created 2002):

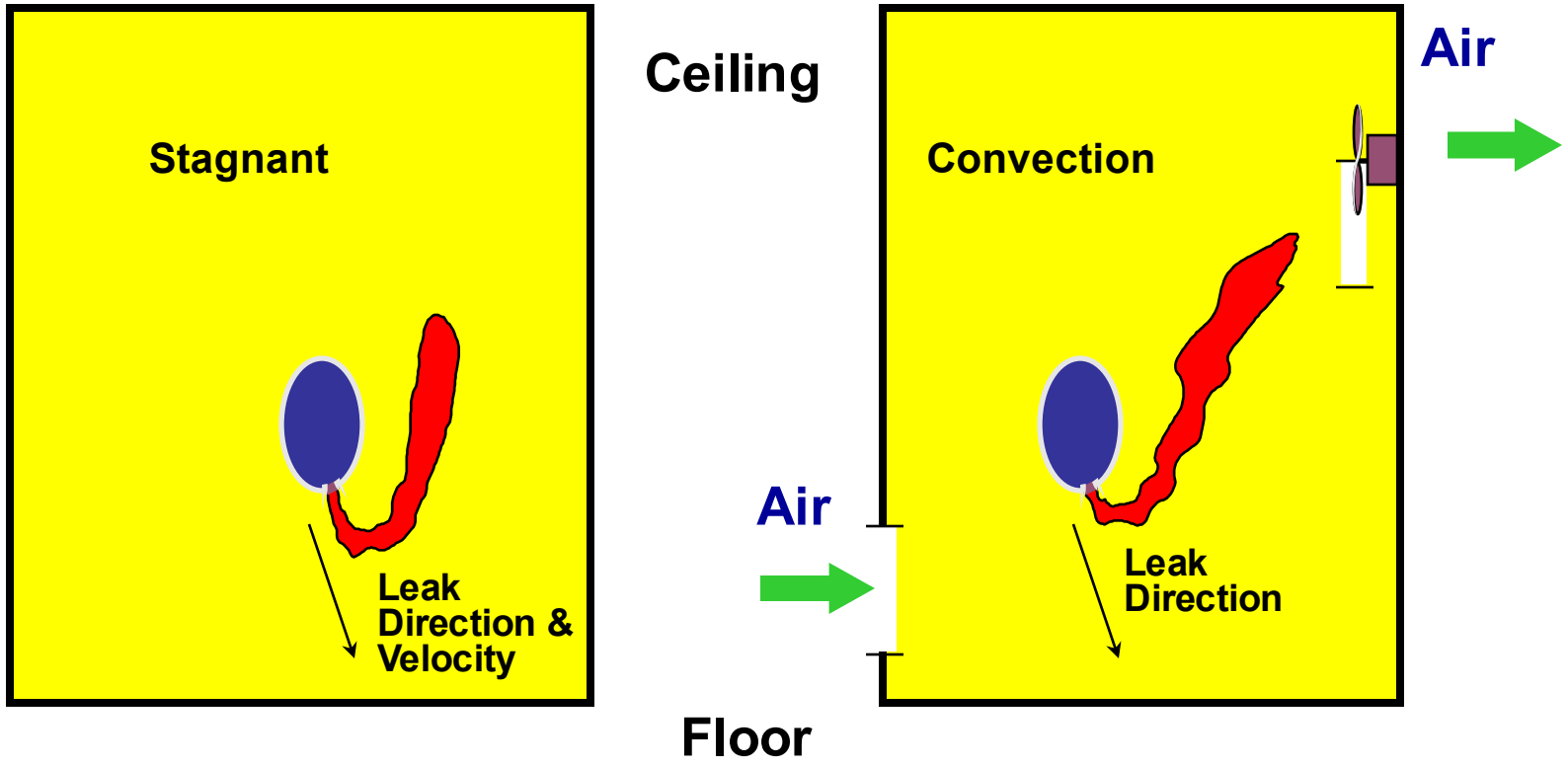
- It uses the catalytic properties of precious metals to detect hydrogen gas.
- They are also relatively fast responding and can typically detect hydrogen within a few seconds.
- They are relatively durable and have a long lifespan.

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Understanding Maintenance Requirements

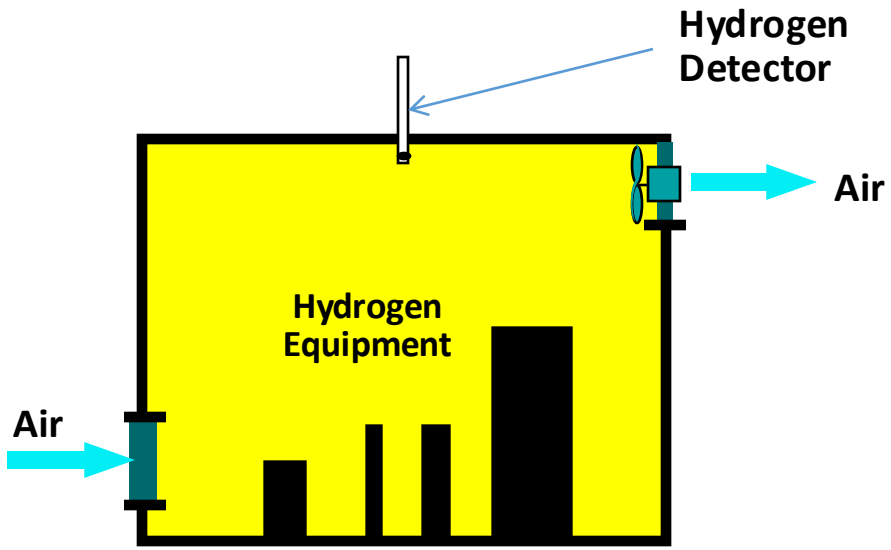
Type of sensor	Maintenance requirements
Metal Oxide (MOS)	Regular calibration, cleaning, or replacement. Lifespan is typically 2-5 years.
TCD hydrogen sensor	Regular calibration, cleaning, or replacement of the TCD filament. Lifespan is typically 5-10 years.
Catalytic bead hydrogen sensor	Regular calibration, cleaning, or replacement of the catalytic bead. Lifespan is typically 3-5 years.
Solid state precious metal hydrogen sensor	New systems require no Calibration—They Auto-Calibrate. The lifespan of legacy systems is typically 10-15 years.

Hydrogen Buoyancy



Hydrogen ventilation should always take advantage of the buoyancy effect.

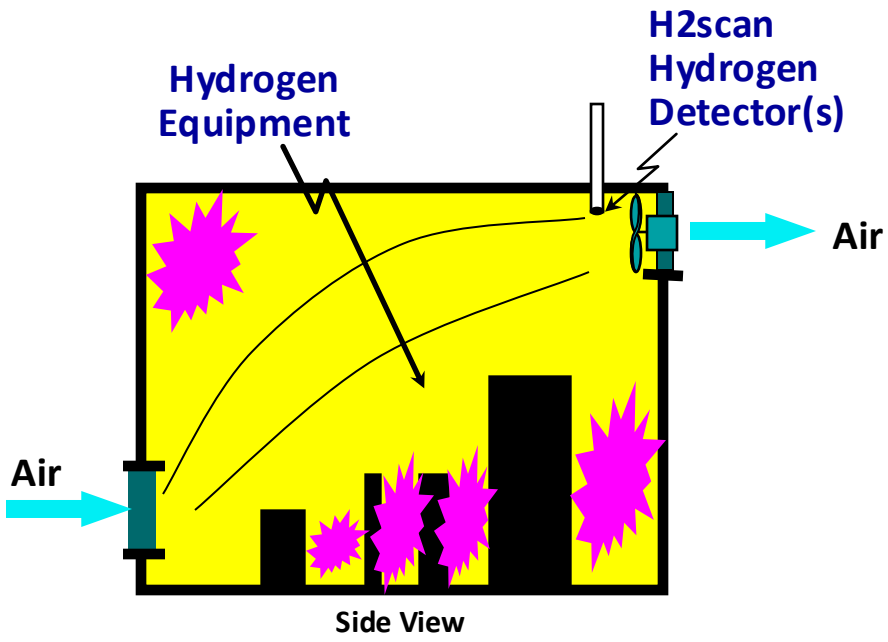
Fixed Area Monitor Placement



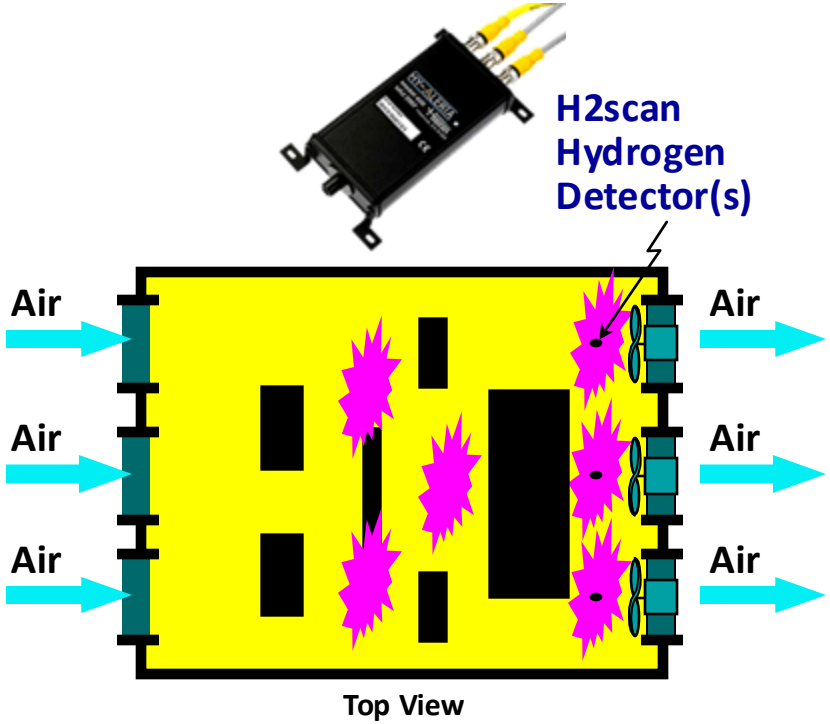
Elevation View

This placement of a sensor is not correct.

Proper Area Monitor Placement



Side View



Top View

Pink areas are regions of stagnant air, or localized eddy currents.

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Thank you for your time …
What questions can I answer for you?

Jeff Donato, Vice President – Safety Systems

+1 614 390 4626
jdonato@h2scan.com

27215 Turnberry Lane
Valencia
California, 91355

www.h2scan.com

H2scan Patented Solid-State Technology Provides Industrialized Hydrogen Sensing

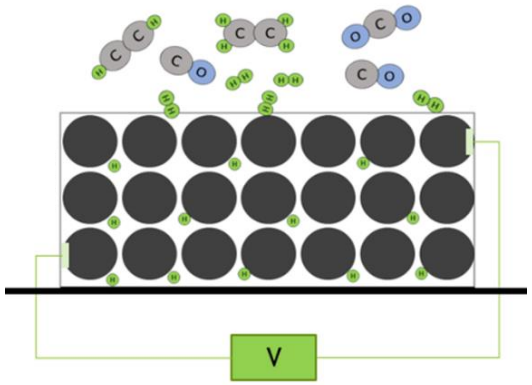
Technology Development

- Solid State Sensor Technology developed by Sandia National Lab and exclusively licensed to H2scan
- Over the last 20 years H2scan commercialized technology and patented new technologies to improve accuracy and eliminate cross gas sensitivities

Outcomes

- Hydrogen specific solid-state sensor that can measure from 5 PPM to 100% H2
- Operates in liquids and gases (oxygen free, multi-component gases streams, and requires no reference or carrier gas)
- Maintains accuracy without periodic calibration
- Industrial temperature range (-40°C to +105°C)
- Life expectancy 10+ years

Hydrogen Specific Resistive Sensor Technology



Device resistance changes as a function of H_2 concentration as it permeates the proprietary solid-state substrate

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H2scan Battery Products

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Battery Hydrogen Sensing Solutions

Durable and reliable hydrogen sensing is crucial for safety in standby power and energy storage batteries as it detects potentially explosive gas buildup. Early detection allows ventilation and other safety measures to be initiated, preventing catastrophic failures thereby protecting personnel and assets.


Lithium Battery Rooms/Containers


Lead-Acid & Ni-Cad Rooms/Containers


All Battery Rooms/Containers

Model	HY-ALERTA® 5020 General Location	HY-ALERTA 5021 General Location	HY-ALERTA 5320 Intrinsically Safe
Hydrogen Range	0.1% - 5%	0.1% - 5%	0.1% - 5%
Operating Temperature	-10°C to 60°C (14°F to 140° F)	-10°C to 60°C (14°F to 140° F)	-10°C to 60°C (14°F to 140° F)
Response Time	T90[1] @ <60 seconds	T90 @ <5 minutes	T90 @ <60 seconds
Intervals	Modbus RTU	Modbus RTU	Modbus RTU, 4-20 mA Digital Contact

[1] The time taken for the sensor to ensure 90% of the full scale of measurement.

Advantages

- Self-calibrating - Maintenance free
- Modbus equipped - Display is optional
- Run fans only when hydrogen is present
- 15+ year service life

Hydrogen Sensor Accessories


HYView® Modbus Display
Displays Percentage H2 or ppm
Know your H2 risk. Check the Hydrogen level before entering battery rooms


BR-01
Modbus to Dry Contact Converter
Potential-free contacts trigger 1% and 2% H2 gas alarms for four sensors


HYAO-1
Modbus to 4-20 mA Converter
Converts Modbus sensor data to a standard 4-20 mA current signal


Sensor Mount & Cap
Series 5000
Versatile mounting solution for 5000 series sensors and protective contaminant shield caps


Connectivity Options
Cables & Connectors
Modular cabling system for connecting and daisy-chaining up to four sensors

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27215 Turnberry Lane, Unit A, Valencia, CA 91355, USA | +1 661-775-9575 | hello@h2scan.com | www.h2scan.com

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