Hydrogen Gas Management For Flooded Lead Acid Batteries

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The Problem: Gas Evolution

- All Lead acid batteries vent hydrogen & oxygen gas
  - Flooded batteries vent continuously, under all states
  - storage (self discharge)
  - float and charge/recharge (normal)
  - equalize & over voltage (abnormal)
- Flooded batteries vent significantly more gas than VRLA (can be 50 times or more greater; even VRLA's can vent significant gas volumes in rare cases of thermal runaway)
- Under float, rectifier 'overcharges' due to chemical inefficiencies of electrolyte & internal resistance of cells; excess charge electrolyzes sulfuric acid & water which causes free hydrogen & oxygen to vent
- Increasing the voltage/current and higher ambient temperatures accelerate this outgassing

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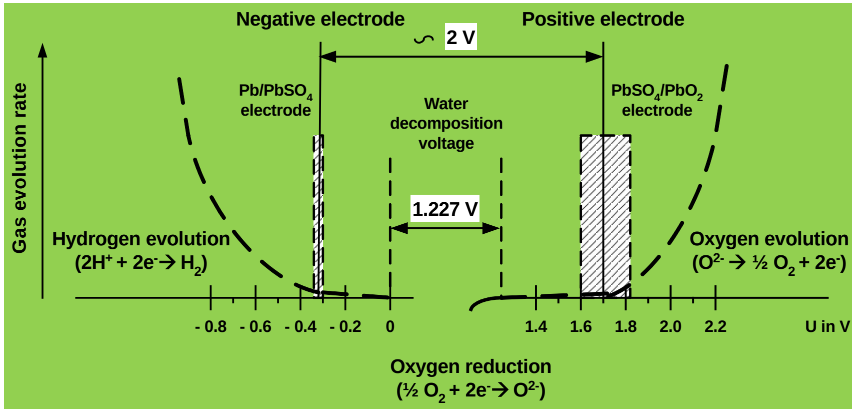
Objectives

- Provide an overview of hydrogen gas evolution, and it's impact on battery system design, operation & maintenance
- Review primary methodologies for managing & mitigating battery outgassing
- Introduce & discuss the external recombinant catalyst: how it works, critical design criteria, and it's demonstrated impact on facility planning, battery performance, & maintenance

Open Circuit (equilibrium) potentials: positive & negative electrodes (lead-acid)



- Hydrogen Evolution = Outgassing = “Water Decomposition”
- As input voltage/current charge increases, the potential difference between the positive & negative electrodes increases, accelerating outgassing
- Hydrogen gas at the negative electrode, Oxygen gas at the positive

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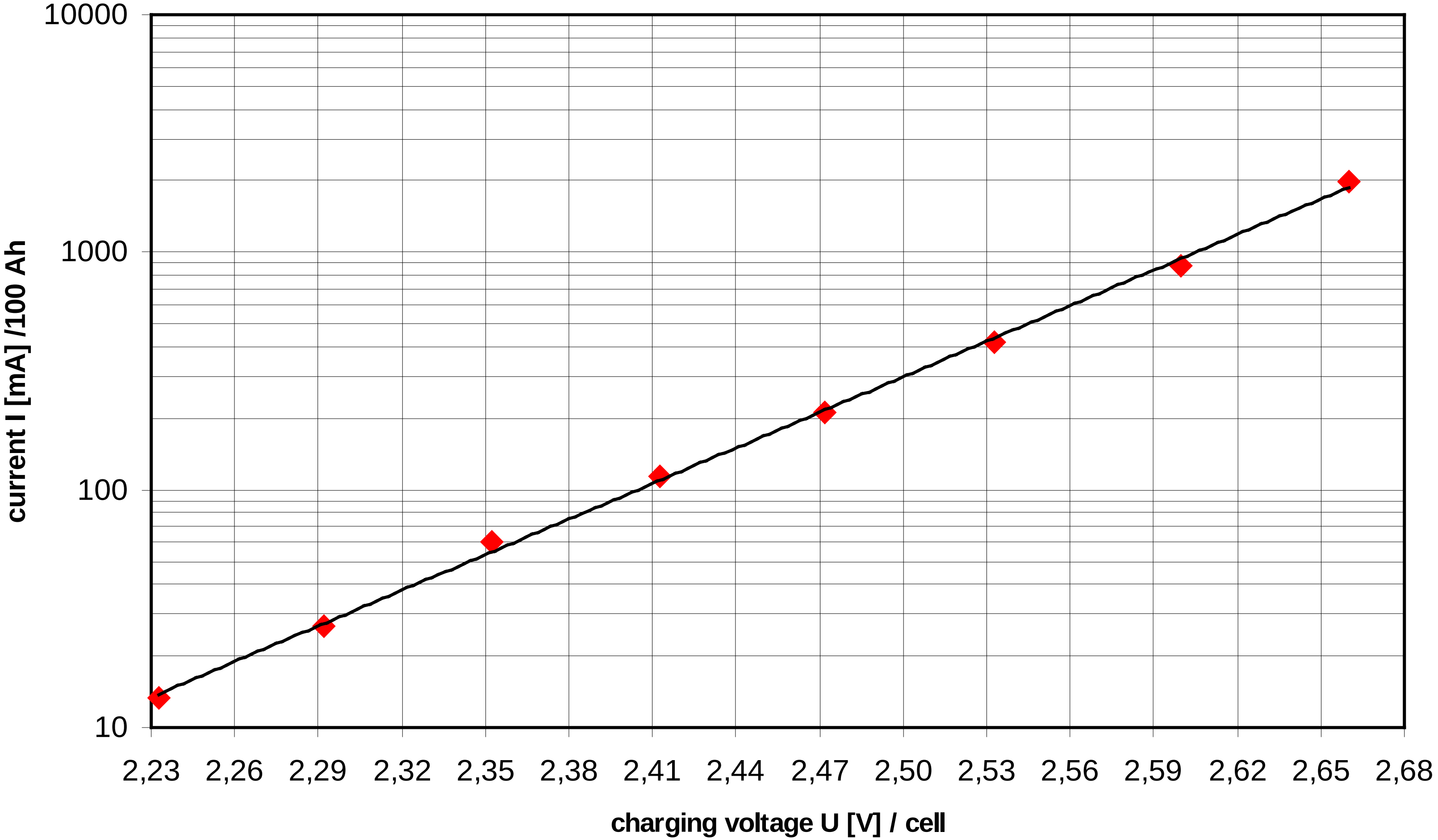
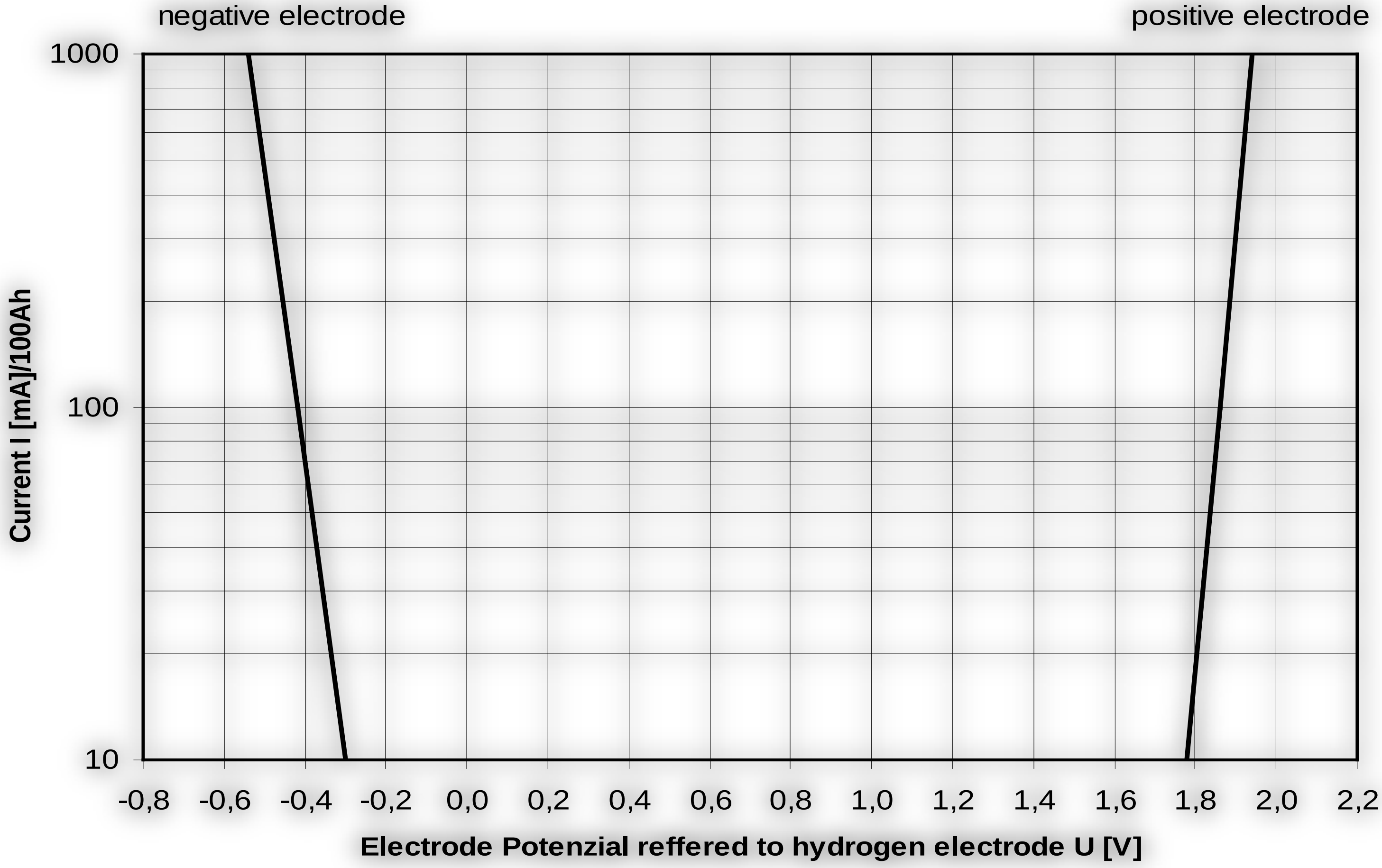
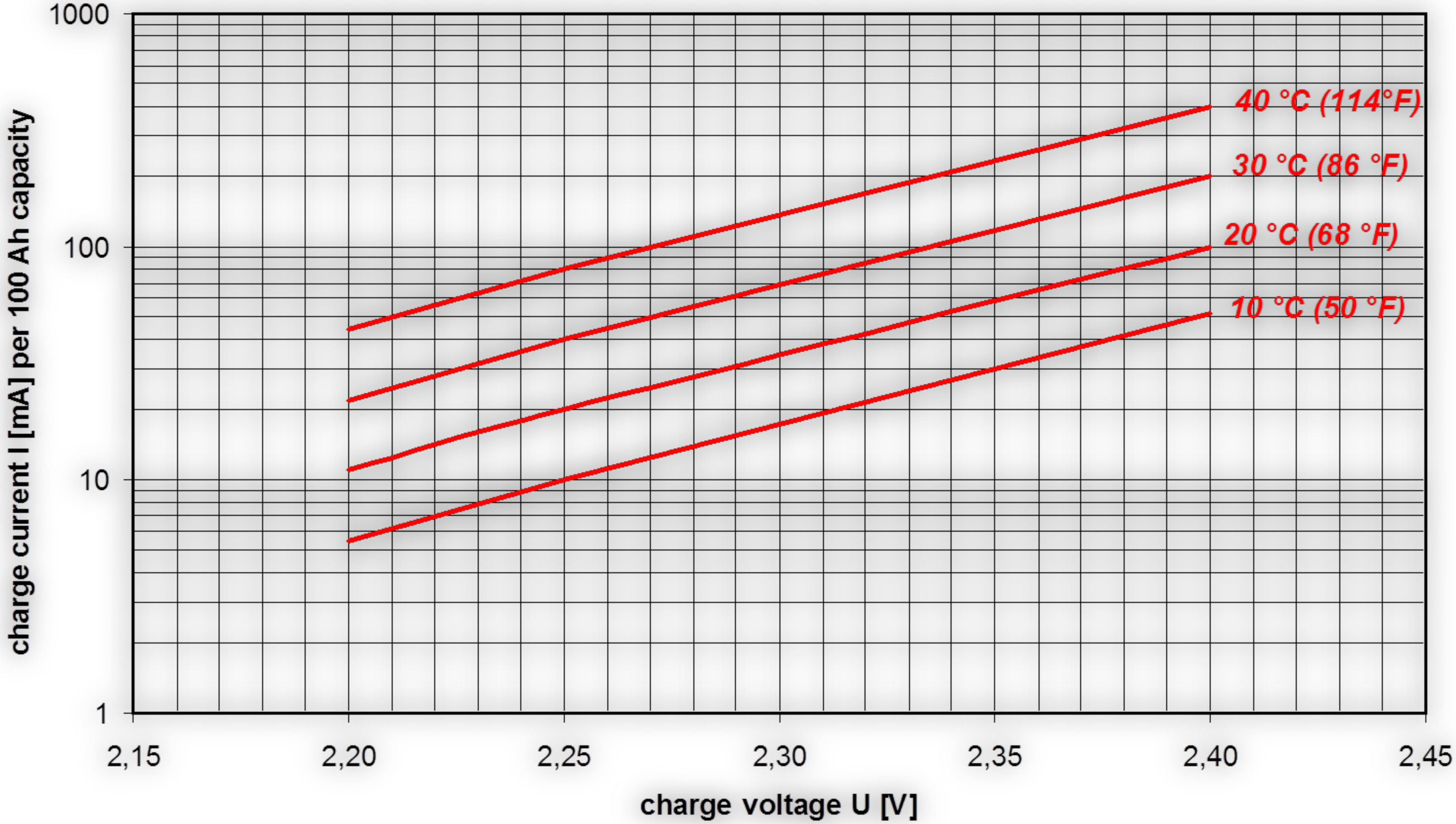
Impact of Charging Voltage on Gas Development Rate: New Lead Selenium Cells



Impact of Charging Current & Over-Voltage (New Lead Selenium Cells)



Impact of Temperature on Charging Current & Voltage: (New Lead Selenium Cells- Lead Acid)



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Primary Effects & Impact of Gas Evolution

- Fire & Explosion: Human, System & Facility Safety
  - Hydrogen combusts at 4% (LEL); vs. 0.01%
  - While rare, can be caused by abnormal conditions, e.g. malfunctioning charger, HVAC failure, cell failure (shorts, high resistance)
- Battery self-discharge
  - lead-acid batteries will vent gas & discharge even in storage
  - shelf-life will vary by grid alloy type
  - batteries in storage require periodic refreshers for the equalizing of corrosion and to correct self-discharge
- Watering Maintenance
  - high levels of outgassing (water decomposition) will increase watering maintenance & costs
  - watering rate is dependant on grid alloy, ambient temperatures,
  - voltage charging levels, & battery age

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Primary Strategies for Mitigating Gas Evolution

- Dedicated Rooms for Flooded Batteries
  - Codes require flooded batteries to be installed in separate rooms
  - Co-locating electrical loads w/ batteries not recommended
  - Flooded batteries typically in open, step/tier racks for access & airflow
  - Also recommended for large VRLA battery systems (2V 8x3 config's)
- Proper Ventilation System Design
  - Well defined standards & formulas – OSHA, ANSI/ASHRAE, IEEE; EN
  - Need to consider air movement & cooling (rule of thumb is to change room air 2x per hour; maintain ambient of 68° F)
  - Though Hydrogen LEL is 4%, universal guidelines specify a system design absolute maximum of 2%, with 1% being typical max. concentration levels
  - Proper system design requires precise Manfg's data (MSDS sheets); competent airflow engineering
  - Even a good idea to have MSDS gas evolution data for VRLA installs (in the absence of MSDS, some Codes will then require minimum airflow of 1 CFM/sq. ft for VRLA battery)

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Primary Strategies for Mitigating Gas Evolution

- Hydrogen Gas Detection Systems
  - No specific OSHA requirement
  - Increasingly cost effective means of monitoring environment
  - Typical threshold is to initiate alarm at 1% concentration, primary alarm at 2% for direct response (evacuation & max ventilation)
  - Can monitor multiple types of potentially hazardous gas/conditions

- Minimize/Avoid Static & Electrical Discharge
  - Flooded batteries require good maintenance practices to avoid static electrical discharge; enough energy to ignite hydrogen/oxygen gas
  - Static electrical potential dependant on humidity, material types
  - Electrical discharge from non-insulated tools, inadvertent contact
  - Avoid high static mat'ls (plastic vinyl sheets), synthetic cloths
  - Use personal grounding straps; <u>always use insulated tools</u>

Primary Strategies for Mitigating Gas Evolution: External Recombinant Catalysts (ERC)

- Relatively new technology based on an old idea (e.g. Thomas Edison patent in 1912)
- A lot of design & research on ERC in Europe (large base of older antimony and huge base of lead selenium batteries)
- ERC designs now have 25+ years of laboratory and empiric field data

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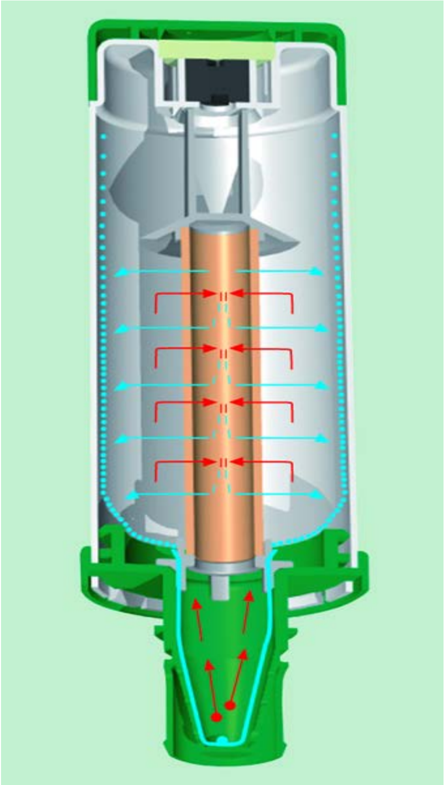
External Recombinant Catalyst: Concept

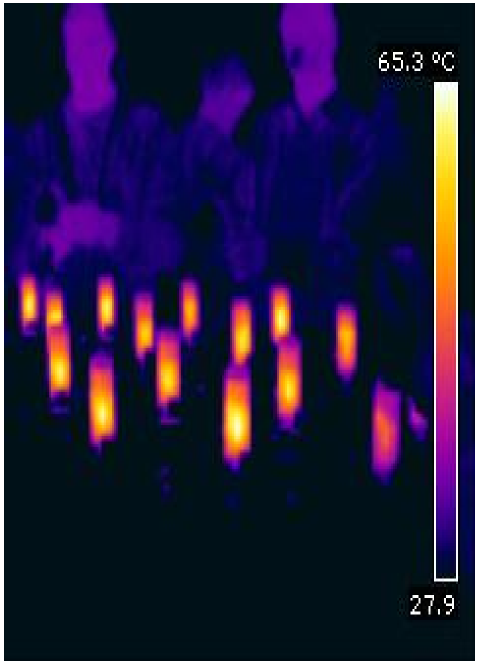


- Installed externally to flooded battery
- Captures the bulk of hydrogen gas that escapes under normal float & charge/recharge conditions, and recombines hydrogen with free oxygen to form water (returned to battery)
- Catalyst for this recombination is typically palladium (noble metal) to promote chemical recombination of hydrogen & oxygen
- Entire assembly encased in a plastic plug, to capture gas, promote recombination, and direct water back to the battery

External Recombinant Catalyst: Critical Design Considerations

- Must incorporate spark/flame arrestor (installed over battery vent)
- Self-limiting design to ensure safe operation under abnormal, high-gassing conditions (e.g. overvoltage); prevent overpressure
- Easy installation & access; mounted right on top of battery
- No maintenance or adjustments; should have life expectancy equal or better than flooded battery
- Ensure complete encapsulation of palladium to prevent potential of palladium poisoning

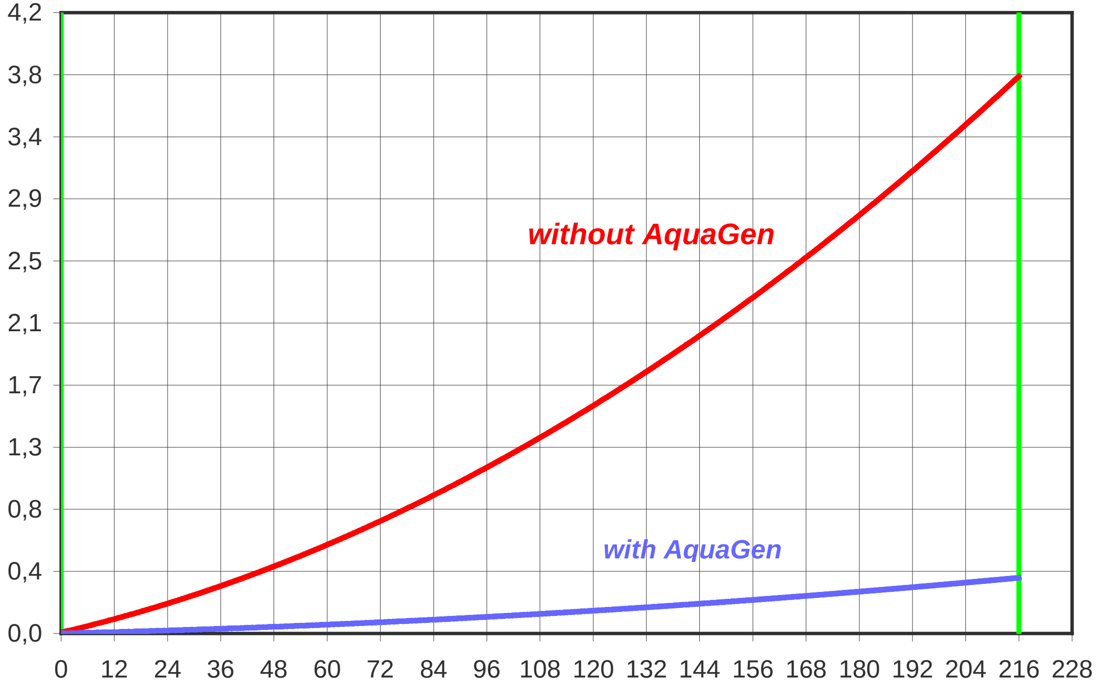
External Recombinant Catalyst: Critical Design Considerations



- Designing the ERC to be external was a carefully considered choice
- Chemical recombination is an 'exothermic' process: heat as a by-product
- Early experience with VRLA internal recombinant catalysts demonstrated a number of potentially battery life reducing impacts due to increased heat generation inside the battery
- External design separates recombination from active internal process of flooded battery

External Recombinant Catalysts: Maintenance

Water consumption (liter) per 100 AH battery capacity



Watering Maintenance is significantly reduced with the use of ERC's

External Recombinant Catalysts

- Properly designed ERC systems should have a life expectancy of more than 20 years without maintenance or adjustments
- European ERC design now has an installed base of over 3.5 million units going back almost 25 years
- NO recorded design failures, NO cases of palladium poisoning problems over past 25 years

Photo shows recent battery replaced, originally installed with ERC in 1984

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ERC: Recombinant Efficiency

- 85% + efficiencies typical in the past for stationary applications; new designs indicate efficiencies up to 99% (!!) for recombining out gassed hydrogen under normal float and charge/recharge conditions
- EN now officially recognizes impact of ERC technology in reducing impacts of outgassing; now allow a 50% reduction in ventilation requirements for flooded battery systems using ERC technology
- Efficiency also directly impacts watering maintenance & economics (primary end user consideration); reductions in watering maintenance are significant (often dramatic)
- Goal is to achieve a flooded battery with the maintenance profile of a VRLA battery

Summary

- Gas evolution (outgassing) is an inherent characteristic of lead-acid batteries, particularly flooded designs.
- Battery outgassing presents challenges to users and impacts facility, system, and maintenance planning & cost considerations.
- There are a number of well established methodologies for mitigating the potential impacts of outgassing.

Summary

- ERC is now a proven technology; almost 25 years of history, 3.5 million units installed worldwide.
- Field results confirm increases in both battery performance & lifecycle extension that translates into the real economic benefits as well as reduced maintenance, reduced HVAC and improved safety.
- ERC exploits many of the positive design and maintenance characteristics of a VRLA battery module with the superior service life of flooded batteries.

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