LEAD ACID BATTERIES

1. Introduction

Lead acid batteries are the most common large-capacity rechargeable batteries. They are very popular because they are dependable and inexpensive on a cost-per-watt base. There are few other batteries that deliver bulk power as cheaply as lead acid, and this makes the battery cost-effective for automobiles, electrical vehicles, forklifts, marine and uninterruptible power supplies (UPS).

Lead acid batteries are built with a number of individual cells containing layers of lead alloy plates immersed in an electrolyte solution, typically made of 35% sulphuric acid (H_2SO_4) and 65% water (Figure 1). Pure lead (Pb) is too soft and would not support itself, so small quantities of other metals are added to get the mechanical strength and improve electrical properties. The most common additives are antimony (Sb), calcium (Ca), tin (Sn) and selenium (Se). When the sulphuric acid comes into contact with the lead plate, a chemical reaction is occurring and energy is produced.

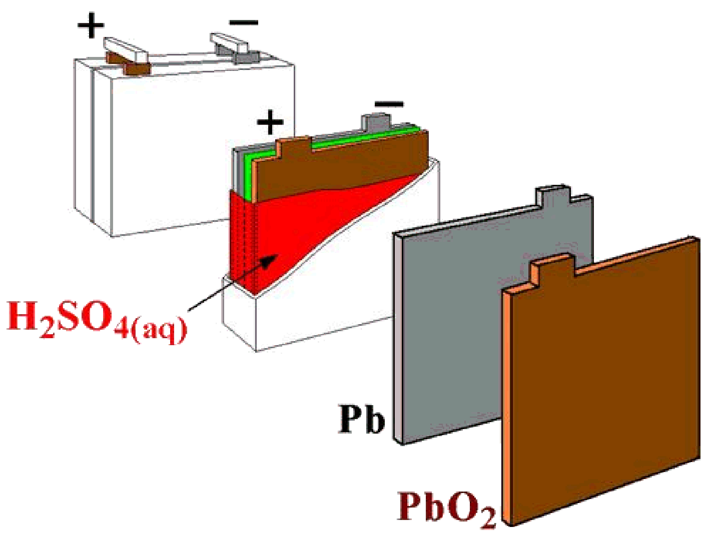


Figure 1: Typical lead acid battery schematic

Lead acid batteries are heavy and less durable than nickel (Ni) and lithium (Li) based systems when deep cycled or discharged (using most of their capacity). Lead acid batteries have a moderate life span and the charge retention is best among rechargeable batteries. The lead acid battery works well at cold temperatures and is superior to lithium-ion when operating in sub-zero conditions. Lead acid batteries can be divided into two main classes: vented lead acid batteries (spillable) and valve regulated lead acid (VRLA) batteries (sealed or non-spillable).

2. Vented Lead Acid Batteries

2.1 Hazards

Vented lead acid batteries are commonly called “flooded”, “spillable” or “wet cell” batteries because of their conspicuous use of liquid electrolyte (Figure 2). These batteries have a negative and a positive terminal on their top or sides along with vent caps on their top. The purpose of the vent caps is to allow for the escape of gases formed, hydrogen and oxygen, when the battery is charging. During normal operation, water is lost due to evaporation. In addition, the vent caps allow water and acid levels of the battery to be checked during maintenance.

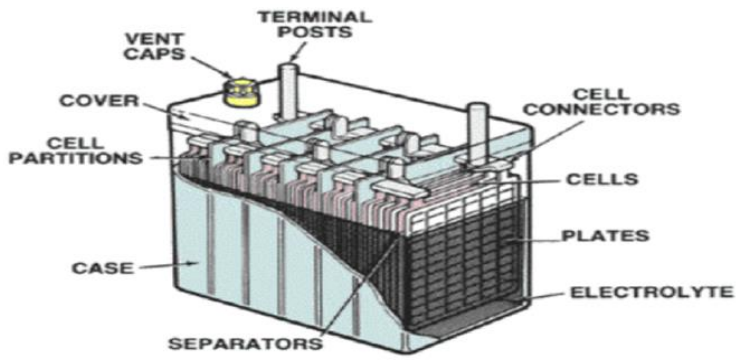


Figure 2: Typical vented lead acid battery schematic

The main hazards associated with lead acid batteries are:

1) Chemical (corrosive) hazards
2) Risk of fire or explosion
3) Electrical shocks
4) Ergonomic hazards related to their heavy weight
5) Transportation hazards

Acid burns to the face and eyes comprise about 50% of injuries related to the use of lead acid batteries. The remaining injuries were mostly due to lifting or dropping batteries as they are quite heavy.

2.2 Chemical Hazards

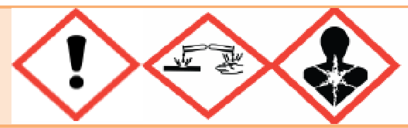
2.2.1 Sulphuric Acid

Lead acid batteries are usually filled with an electrolyte solution containing sulphuric acid. This is a very corrosive chemical (pH<2) which can permanently damage the eyes and produce serious chemical burns to the skin. Sulphuric acid is also poisonous, if swallowed. The lead alloys found in batteries are also harmful to humans and can also seriously damage the environment.

When working with battery acid, the following precautions must be taken:

- Wear the proper personal protective equipment (PPE), specifically splash-proof goggles, acid-resistant lab coat or apron, safety shoes and rubber gloves. A face shield must also be worn when refilling batteries with electrolytes.
- Know where the emergency showers and emergency eyewash stations are located; they must be located near lead acid battery storage and charging areas.
- Slowly pour concentrated acid into water; do not add water to acid. (warning: electrolyte will become hot; do not close battery vents until electrolyte has cooled down)
- Use non-metallic containers and funnels.
- Ensure neutralizers (e.g. baking soda) are available for immediate use.
- Use extreme care to avoid spilling or splashing the sulphuric acid solution

Table 1: Characteristics lead acid battery electrolyte (35% H_2SO_4 / 65% water)

Health Risks (WHMIS 2015)	
color	clear
odor	sharp, pungent
pH	1 to 2
Boiling point	95-115°C
LC_{50} (rat)	375 mg/m^3
LD_{50} (oral, rat)	2140 mg/kg

2.2.2 Electrolyte Spill

In the event of a minor electrolyte spill (Figure 3), consult the appropriate Safety Data Sheet (SDS) for electrolyte spill containment, clean-up and disposal details. Always ensure to wear adequate protective clothing (goggles, closed shoes and gloves) during clean-up of spills.

In case of a small electrolyte spilled, you should:

- Contain the spill with absorbents such as universal pads, hazmat pads, sand, earth or vermiculite.
- Remove the absorbents once it has soaked up the acid/electrolyte.
- Clean up spilled acid safely with an acid neutralizer and then with large volumes of water to rinse the area.
- Safely dispose of any contaminated material as chemical waste by contacting hazardouswaste@concordia.ca
- Advise your supervisor and complete an Injury / Near-Miss Report (**EHS-FORM-042)**.

In the event of a large acid electrolyte spill:

1. Advise and warn co-workers.
2. Evacuate the area immediately.
3. Restrict the access to the area.
4. Notify Security at **X3717** or (**514) 848-3717**, providing them with the following information:

   a. Location of the spill
   b. Name of hazardous material
   c. Quantity involved
   d. Related health risks and precautions to be taken
5. Provide the Safety Data Sheets (SDS) or appropriate documentation.

Figure 3: Picking up a small battery electrolyte spill

2.2.3 First-Aid Measures

In the event of exposure with sulphuric acid, Security must be immediately contacted at **X3717**. Following an exposure, an Injury/Near-Miss Report (**EHS-FORM-042**) must be sent to EHS.

i. Contact with skin

- Flush the contaminated area, as quickly as possible, with gently flowing lukewarm water for at least 30 minutes; if any irritation persists, repeat flushing
- Under running water, remove contaminated clothing, shoes and other leather goods (e.g., watchbands, belts); discard any contaminated clothing, shoes, etc.
- Seek medical treatment if required.

ii. Contact with eyes

- Immediately flush the contaminated eye(s) with gently flowing lukewarm water for at least 30 minutes while holding the eyelid(s) open.
- If any irritation persists, repeat flushing and seek medical treatment immediately

2.2.4 Bad Odors

Over-charging a vented lead acid battery can produce hydrogen sulfide (H_2S). The gas is colorless, very poisonous, flammable and has the odor of rotten eggs. Being heavier than air, the gas accumulates at the bottom of poorly ventilated spaces. Although noticeable at first (olfactory detection between 0.001-0.13 ppm), the sense of smell deadens the sensation with time and potential victims may be unaware of its presence. When the odor is detected, one must turn off the charger, vent the facility and stay outside until the odor disappears. Refer to **Section 2.4.2** for proper charging safety tips.

2.3 Fire & Explosion Hazards

2.3.1 Hydrogen Gas

Vented lead acid batteries vent little or no gas during discharge. However, when they are being charged, they can produce explosive mixtures of hydrogen (H_2) and oxygen (O_2) gases, which often contain a mist of sulphuric acid. Hydrogen gas is colorless, odorless, lighter than air and highly flammable. Oxygen is an oxidizer than can promote the burning or explosion of flammable and combustible materials. The mixture of two parts hydrogen to one part oxygen produced is perfect for an explosion.

If area ventilation is poor or the charging batteries enclosed, the escaping hydrogen creates an explosive atmosphere around the battery. In sealed rooms with poor ventilation, hydrogen may accumulate near the ceiling. Hydrogen must not be allowed to accumulate in concentrations greater than 1% of the volume of air in a space (the lower explosive limit [LEL] for hydrogen is 4% and the upper explosive limit [UEL] is 75%). A hydrogen (H_2) detector (Figure 4) at ceiling level must be installed in rooms where vented acid lead batteries are being charged.

Figure 4: Different types of hydrogen detectors

2.3.2 Storage

Stored lead acid batteries create no heat. High ambient temperatures will shorten the storage life of all lead acid batteries. Vented lead acid batteries would normally be stored with shipping (protecting) plugs installed, in which case they release no gas. With shipping plugs removed, vented lead acid batteries can give off minor amounts of hydrogen and oxygen due to normal evaporation of water, depending upon the amount of ambient heat and air humidity.

Vented lead acid batteries should be installed in dedicated battery rooms, but may share the same room as the equipment they support (such as a UPS system). Such rooms must be physically separated from other areas, devoid of localized heat sources and have doors and/or partitions designed to meet the required fire resistance rating for the application. Vented lead-acid storage and charging areas should be posted with appropriate signage (Figure 5), such as:

- the room contains energized battery systems;

- the room contains energized electrical circuits;
- the battery electrolyte solutions are corrosive liquids;
- hydrogen gas is generated.

Figure 5: Examples of lead-acid battery danger signs (ANSI and OSHA respectively)

Storage of vented lead acid batteries is covered under the National Fire Protection Association (NFPA) 1 Fire Code (section 52) and the International Fire Code (IFC, section 608). However, the IFC applies only to battery systems with more than 50 gallons (189.3L) of electrolyte, while the NFPA 1 applies to battery systems with more than 50 gallons (189.3L) of electrolyte in a room without sprinklers or 100 gallons (378.5L) of electrolyte in a room with sprinklers.

The NFPA 1 and IFC state that, for vented lead acid and VRLA batteries, the ventilation system shall be designed to limit the maximum concentration of hydrogen to 1% of the total volume of the room or that a continuous ventilation shall be provided at a rate of not less than 1 cubic foot per minute per square foot [$1ft^3/min/ft^2$ or $0.0051\ m^3/(s\ .\ m^2)$] of floor area of the room. Other standards that are often used to determine proper ventilation include, but are not limited to:

- National Fire Protection Association (NFPA) 76: suggests that any battery room exhaust fan capacity in Cubic Feet Minute (CFM) should be in the room area (in sq. ft.).
- American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 62: recommends 1 CFM per charging ampere to be provided, but not less than 6 air changes per hour.

While all batteries will operate within a fairly wide temperature range, the life expectancy of a battery can be severely shortened at high temperatures. The optimum temperature for air around a stationary battery is 22° +/- 5°C. The reduction of a vented lead acid battery life from heat above the recommended temperature is about 2.5% per each 1°C.

As these batteries contain an electrolyte in the liquid form, special spill containment systems (e.g. spill tray) (Figure 6) and the presence of an acid-neutralizing spill kit are required (NFPA 1 and IFC). An ABC-type fire extinguisher must also be present in these rooms.

Figure 6: Lead acid battery spill tray

2.4 Electrical Hazards

2.4.1 Electrical Shocks

Exposed terminals, even on disconnected batteries, present an electrical shock hazard. Batteries contain a lot of stored energy. Some battery systems are capable of discharging at extremely high rates of current. Accidental shorting of terminals or cables can result in severe electrical arcing, causing burns and electric shock to nearby personnel. Most batteries produce quite low voltages, and so there is little risk of electric shock. However, some large batteries produce more than 120 volts DC.

Strictly follow all manufacturer's instructions when installing or maintaining battery systems. Mainly:

- Do not allow conductive material to touch battery terminals. A dangerous short circuit may occur and cause battery failure and fire. If installed batteries are at risk of metal tools or other conductive materials touching terminals, then the terminals should be insulated.
- When batteries are stacked or palletized, cardboards must be placed between layers of stacked batteries to avoid damage and short circuits (Figure 7).

Figure 7: Stacked lead acid batteries

- Tools or cables should not be placed on batteries or in an area where they can fall onto the terminals.
- Only insulated tools should be used.

- When working on batteries, workers must not wear items of jewellery (e.g. watches, rings) as they may short out the terminals.
- Use an appropriate strap or cradle to carry batteries. Never carry them by their terminal posts.

2.4.2 Charging Batteries

The following precautions shall be taken when charging or recharging vented lead acid batteries:

- Make sure that you have been trained how to charge the battery; check battery manufacturer's specifications on recommended charging voltage thresholds. Avoid excessive charging which electrolyses some of the water, emitting hydrogen and oxygen (outgassing).
- Check that the battery ventilation holes are clean to allow the hydrogen gas to escape and prevent the battery from exploding. If the battery is not maintenance-free, remove the filler caps to vent hydrogen gas. Stand at arm's length when removing battery caps.
- Before recharging a battery, check the electrolyte level; if the electrolyte is covering the top of the plates, do not add more water. If the plates are not fully covered, fill to the designated level before charging and top up after charging if necessary. Never add electrolyte during charging.
- Fill batteries with distilled or deionized water, not tap water.
- Wear safety gloves, chemical apron, goggles and face shield while removing caps and filling up batteries with water.
- Make sure the power is shut off at the charger before connecting or removing the cable clamps. Connect the charger's positive (+) lead to the battery's positive terminal and the negative (-) lead to the negative terminal.
- Charge batteries in a properly ventilated area.
- Do not smoke, carry out hot work (e.g. welding, brazing, grinding), or use a mobile phone in the charging area.
- Ensure there is an ABC-type fire extinguisher nearby
- Do not allow batteries to freeze. A discharged battery freezes sooner than one that is fully charged. Never charge a frozen battery. If the battery has been outside in cold weather, let it warm up to room temperature before charging.
- Do not charge at temperatures above 49°C (120°F).
- Formation of gas bubbles in a flooded lead acid cell indicates that the battery is reaching full state-of-charge (hydrogen on negative plate and oxygen on positive plate).
- Allow a vented battery to stand for at least 20 minutes after disconnecting it from the charger. Carefully top up the electrolyte with distilled or deionized water to the manufacturer's recommended level.

2.5 Ergonomic Hazards

Most lead acid batteries are heavy; the average weight for a car battery is 17 kg (39 lbs) and more than half of the weight is lead. Industrial batteries used to power mobile equipment can weigh upwards of 680 kg (1,500 lbs). Due to the heavy weight of these types of batteries, correct lifting, handling and transportation procedures should be followed to avoid any injuries:

- Get your body as close as possible to the battery before lifting or lowering it.
- Bend your knees slightly before lifting or lowering the battery.
- Do not lift a heavy battery alone – ask for help from a co-worker or use a lifting device.
- Use the battery carry straps to lift or carry a battery; battery carrier straps can be purchased from battery suppliers (Figure 8).

Figure 8: Carrier strap for lead acid battery

- Carry the battery close to your body and at the centre of your body.
- Do not twist; first lift the battery and then move your feet to move the battery.
- Watch for slippery floors and obstructions as you move.
- When carrying the battery, avoid tilting it and wear appropriate protecting clothing (lab coat, smock or apron).

2.6 Battery Powered Equipment

2.6.1 Types of Lead Acid Batteries

Lead acid batteries are the most often used to power vehicles and other motorized equipment. Lead acid batteries with a conventional charger are the predominant technology option, due to their low cost, reliability and well-established supply chain.

The battery most common to everyone is the engine starting battery. The **starter battery** is designed to crank an engine with a momentary high-power load lasting a second or so. These batteries are most commonly 12 volt but can be found in 6 volt in older equipment and 24 volt in aircraft starting applications. These batteries are of different shapes and sizes but the rule of thumb is, the bigger the battery, the more power it will deliver.

The other type of lead acid batteries found within motorized equipment is known as **deep cycle and/or traction** batteries. Marine applications, golf carts, fork lift trucks, ice resurfacers and other electric vehicles use deep cycle batteries which are designed to be completely discharged before recharging (Figure 9).

Figure 9: Examples of vented lead acid powered equipment or vehicles; from left to right: forklift, scissor lift and ice resurfacer

Thicker and stronger or solid plate grids are used for deep cycling applications (Figure 10) because charging causes excessive heat which can warp the plates. Thicker plates increase the longevity and cycle life of deep-cycle batteries as each time the battery is discharged and recharged, a small amount of active material is shed from the plates. A starter battery cannot be swapped with a deep-cycle battery or vice versa.

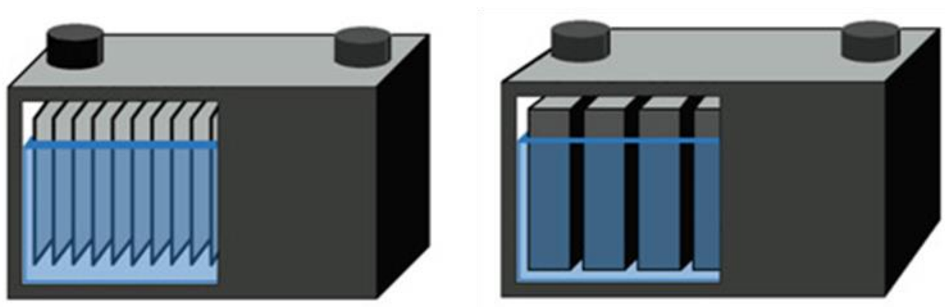


Figure 10: Typical plates found in starting (left) and deep-cycle (right) batteries

2.6.2 Facilities Requirements

Facilities that are considering switching from fossil fuels to battery powered equipment must consider a variety of construction and operational issues beyond equipment selection. There is no direct legislative obligation that clearly guides indoor battery use or charging for electrical equipment. It is left with each owner to ensure compliance specific to their battery type and equipment design.

However, as indicated in previous sections, vented lead acid batteries may produce flammable and toxic gases during recharging process that require to be vented. Recharging equipment powered by such batteries in areas like basements or other places where ventilation is poor or recirculated into living quarters should be forbidden. For both new and retrofit construction, areas designated to recharge vented lead acid battery-powered vehicles or equipment must have the followings:

- ventilation system must be designed to provide removal of fumes and excess heat from area directly above charging batteries;

- ventilation equipment should be of explosion proof design;
- ceilings in battery charging rooms be flat as to not allow pockets of gas to accumulate;
- lighting be fixed to the wall or suspended at more than 50cm from the ceiling, but not above the charging unit;
- all fixtures should be closed so that gas cannot accumulate;
- to avoid water contact chargers should be mounted off of the floor 1.2m;
- equipment and other matter should be kept 1.2m from charger;
- depending on the size of battery, an emergency eye wash station may be required.

Equipment manufacturers will usually provide guidelines and ways to determine room ventilation requirements for their equipment. The following serves as an example of calculations used for an ice resurfacer room design; this may not be valid for all vented lead acid powered equipment:

Determining hydrogen production (H):

H = .00027 x F x C
F = finish charging rate
C = number of cells being recharged

Determining ventilation (V) requirement:

V = R X P / H X 60
V = Ventilation required
R = Room in cu. feet
P = Maximum % of hydrogen allowed = .01
H = Total hydrogen produced per hour

Determining fan requirement:

Fan size = R / V
R = Room in cu. feet
V = Ventilation required

Precautions must be taken even when using vented lead acid battery-powered equipment, mainly when recharging them. Facilities have to be aware of these potential risks when purchasing this type of battery-powered equipment. Equipment powered by other types of batteries (e.g. lithium or sealed lead acid), which may be more expensive on purchase but require less maintenance and facility operation issues, should be considered at the time of purchase.

2.7 Transportation

Vented lead acid batteries cannot be shipped as limited quantities or consumer commodities. Therefore, they must be shipped in full compliance with the *Transportation of Dangerous Goods (TGD) Act*. Full compliance requires:

1. Proper documentation includes UN number, shipping name, class and packing group (no packing group for lead-acid batteries). In the case of vented lead acid batteries, the information is as followed:

   - UN2794, BATTERIES, WET, FILLED WITH ACID, class 8

2. Safety marks on packages (Figure 11) and vehicles (if required);
3. TDG training;
4. Proper packaging and containment during transportation of the batteries.

If unsure or untrained, please contact the EHS office at ehs@concordia.ca for more details concerning lead acid battery shipments. Furthermore, some ground and air carriers may not accept vented lead acid batteries for their small package services and may only ship them by freight services. Make sure to contact the shipping company prior to any shipment.

Another requirement when shipping almost any types of battery is to protect all terminals against short circuits that can result in fires. Terminals must be protected by completely covering them with an insulating, non-conductive material (e.g. using electrical tape or enclosing each battery separately in a plastic bag), or packing each battery in fully enclosed inner packaging to ensure exposed terminals are protected.

Figure 11: Safety marks on a vented lead acid battery

When transporting waste vented lead acid batteries domestically, all the same requirements apply. Provided the batteries are not damaged or leaking, waste batteries are treated the same as new batteries. This means you still require a shipping document, labels, placards, etc. Essentially, waste batteries should be in good physical condition and free from any visual damage.

Different rules apply when shipping damaged batteries. A lead acid battery is considered damaged if there is a possibility of leakage due to a crack or if one or more caps are missing. Transportation companies and air carriers may require that the batteries be drained of all acid prior to transport. Also, it’s possible that a damaged battery is no longer a dangerous good. For example, a vented lead acid battery (UN2794) may no longer be regulated if all the acid has leaked out due to a crack in the case.

2.8 Waste Vented Lead Acid Batteries

Heavy metals found in lead acid batteries are toxic to wildlife and can contaminate food and water supplies. Sulphuric acid electrolyte spilled from lead acid batteries is corrosive to skin, affects plant survival and leaches metals from other landfilled garbage. Therefore, lead acid batteries are considered as hazardous waste and shall not be placed into regular garbage. Even though the battery components are recyclable, vented lead acid batteries shall not be placed into regular battery recycling boxes (Call2Recycle). Please contact EHS at hazardouswaste@concordia.ca for more information concerning vented lead acid battery disposal and recycling.

3. Valve Regulated Lead Acid Batteries (VRLA)

3.1 Types of VRLA

Valve regulated lead acid (VRLA) batteries, also known as “sealed lead acid (SLA)”, “gel cell”, or “maintenance free” batteries, are low maintenance rechargeable sealed lead acid batteries. They limit inflow and outflow of gas to the cell, thus the term “valve regulated”.

VRLA batteries are the most widely used battery type because of their high power density and ease of use. These batteries come in all shapes, voltages, amperages and sizes. VRLA batteries are considered to be “sealed” because they normally do not allow for the addition or loss of liquid. The term VRLA derives from the use of safety valves that allow pressure to be released when a fault condition causes internal gas to build up faster than it can be recombined.

There are three primary types of VRLA batteries (Figure 12):

- **Sealed valve regulated wet cell (non-spillable)**: this battery type contains acid in the liquid form similarly to a vented lead acid battery but the wet cell VRLA battery case is better sealed.
- **Absorbed Glass Mat (AGM)**: AGM batteries differ from flooded lead acid batteries in that the electrolyte is held in the glass mats, as opposed to freely flooding the plates. The fibers that compose the fine glass mat do not absorb nor are they affected by the acidic electrolyte.
- **Gel**: gel cells add silica dust to the electrolyte, forming a thick putty-like gel. These are sometimes referred to as "silicone batteries". Unlike a flooded lead-acid battery, these batteries do not need to be kept upright. Gel batteries reduce the electrolyte evaporation, spillage (and subsequent corrosion problems) common to the wet-cell battery and boast greater resistance to shock and vibration.

Figure 12: From left to right: Sealed lead acid battery; AGM battery; Gel type battery

VRLA batteries offer a lot of advantages over other types of batteries, such as:

- Maintenance-free
- Moderate life
- High rate capacity
- High charge efficiency
- No "memory effect" as observed with nickel-cadmium (NiCad) or nickel-metal hydride (NiMH) rechargeable batteries that causes them to hold less charge
- State of charge can be determined by measuring voltage
- Relatively low cost
- Available in a variety of sizes and voltages

However, some disadvantages are:

- Cannot be stored in discharged condition
- Relatively low-energy density
- Lower cycle than NiCad batteries
- Thermal runaway can occur with incorrect charging or improper thermal management
- More sensitive to temperatures than conventional vented lead acid batteries

3.2 Chemical Hazards

VRLA batteries contain sulphuric acid which is usually held in suspension and will not normally flow if the case is damaged. VRLA batteries are exempted from the IFC spill control and neutralization procedures. In the unlikely event of contact with the electrolyte or electrolyte spill, follow the spill procedures (section 2.2.2) and first aid measures (section 2.2.3) described for the vented lead acid batteries.

3.3 Fire and Explosion Hazards

3.3.1 Flammable Gases

In VRLA batteries, any hydrogen and oxygen produced during charging does not escape but is converted back into water. Gas can only escape when internal pressure exceeds the rating of the pressure valve.

Therefore, VRLA batteries are much less likely to release hydrogen than vented batteries. A vented battery can give off sixty times more gas than a VRLA battery in normal use.

Water cannot be added to these batteries as they do not need topping up. However, it is still important to take care when charging them. Gas pressure may build up inside the battery if it is charged too quickly or for too long. If this happens, the pressure relief valves in the battery may open and let the gases escape. An explosion is likely if this happens close to an ignition source.

3.3.2 Storage

VLRA batteries are also subject to the same NFPA 1 and IFC storage requirements, however they release little or no gas until the battery is recharged to approximately 80% of its capacity. They create no off-gassing unless stored in extreme heat. They are vulnerable to overheating if voltage and/or ambient temperature exceed recommended levels, so normal charging regimen of any UPS is to reduce the charging rate during the last 20% of its charging.

VRLA batteries are typically used in occupied environments; the ventilation requirements for human occupancy and electronic equipment operation (e.g. in a data center or network room) well exceed the requirements for the batteries meaning that usually, no additional engineering is necessary for VRLA battery ventilation.

The life expectancy of a VRLA battery can be severely shortened at high temperatures. The optimum temperature for air around a stationary battery is 22° +/- 5°C. The reduction of battery life from heat above the recommended temperature is about 5% per each 1°C. In general, a VRLA battery can last between 300-500 cycles. Typically, VLRA batteries self-discharge 3% every month.

3.4 Electrical Hazards

3.4.1 Charging VRLA Batteries

Electrical hazards encountered with VRLA batteries are similar than those observed with vented lead acid batteries; please refer to **Section 2.4** for electrical hazards and precautions.

Some machines systematically charge VRLA batteries, for example some home alarm or backup systems. If VRLA batteries need to be charged with a battery tender, selecting the correct battery charger will impact its performance and service life. As a general rule of thumb when selecting a charger for a VRLA battery is to use one that is no more than 20% of the capacity rating of the battery (at a 20hr rate). Example; to charge a 12 volt/7.5 Ah battery, a charger with a maximum charge rate of 1.5 Amps (7.5 x 0.20 = 1.5) shall be used.

A capacity miss-match will result in a charge that may be harder on a battery than it should be, shortening the battery's life. A battery may become swollen as a result of overcharging. Excessive current will flow into the battery after the battery has reached a full charge. The constant current will cause decomposition of the water in the electrolyte to gases. At high rates of overcharge a battery will progressively heat up. As it gets hotter it will accept more current, heating up even further and accumulating gases.

Typically, a battery's vents will expel any gas pressure that builds up faster than the gas can re-combine. In certain cases, the battery may collect gases faster than the vents could remove them, allowing pressure to build up internally. The generated heat enables the battery to expand.

Additional safety features in the battery can limit the damage to the battery only, sparing the charger and the charging environment. The malleable plastic design of most VRLA batteries allow them to balloon without breaking (Figure 13), and an internal shorting design ceases the collection of gases.

Figure 13: Swollen batteries due to excessive charging

3.5 Ergonomic Hazards

Ergonomic hazards encountered with VRLA batteries are similar than those observed with vented lead acid batteries; please refer to **Section 2.5** for ergonomic hazards and precautions.

3.6 Transportation

VRLA batteries are considered as non-spillable wet electric storage batteries and are regulated by Transport Canada under the *Transportation of Dangerous Goods Act (TDG)*. However, exemptions are made if certain criteria can be met.

Indeed, most of the manufacturers meet the Transport Canada test requirements for "batteries, wet, non-spillable", as specified in the TDGR Schedule 2, special provision #39 (2), and are therefore exempt and non-regulated by Transport Canada for ground transportation when:

- at a temperature of 55°C, electrolyte will not flow from a ruptured or cracked battery case and there is no free liquid to flow;
- the battery's terminals are protected from short circuits;
- the outer battery packaging must be plainly and durably labeled with "NON-SPILLABLE" or "NON-SPILLABLE BATTERY";

- The battery is not intended for disposal / recycling.

As mentioned above, the exemption does not apply to spent batteries being transported for reclamation or recycling. Therefore, when shipping spent batteries, the shipment must be compliant the TDGR and the following information must be present:

- UN2800, BATTERY, WET, NON-SPILLABLE, Class 8

Battery terminals must also be protected when shipping them for disposal (Figure 14).

Figure 14: Protecting battery terminals

VRLA batteries of the GEL cell type (no free liquid and unable to leak even if the battery is damaged) are not regulated by Transport Canada. If unsure or untrained, please contact the EHS office at ehs@concordia.ca for more details concerning battery shipments.

Air shipments of VRLA (non-spillable acid batteries) performed under the *IATA Dangerous Goods Regulations* must be fully declared and conform to the requirements of *Packing Instruction 872* (vibrational and differential pressure testing). Furthermore, VRLA batteries that comply with certain additional testing (as mentioned above for ground transportation) are not subject to any regulations.

3.7 Waste VRLA Batteries

As for vented lead acid batteries, VRLA batteries content (metals and electrolyte) are toxic and corrosive. Therefore, VRLA batteries are considered as hazardous waste and shall not be placed into regular garbage. Small sealed lead acid battery (up to 5 kg) can be placed into regular battery recycling boxes (Call2Recycle) (Figure 15), as long as they first placed into a sealed plastic bag. Please contact EHS at hazardouswaste@concordia.ca for more information concerning VRLA battery disposal and recycling.

Figure 15: Call2Recylce battery recycling box

If you have any concerns about lead acid batteries at Concordia University, please email EHS at ehs@concordia.ca

Prepared: December 2016

References:

- *Batteries and Battery Fluids by Road, Government of Alberta, 2012*
- *Battery Safety, Health & Safety Ontario, 2011*
- *Battery Technology for Data Centers and Network Rooms: U.S. Fire Safety Codes Related to Lead Acid Batteries, Schneider Electric – Data Center Science Center, White Paper 31, 2012*
- *Battery Technology for Data Centers and Network Rooms: Ventilation of Lead-Acid Batteries, Schneider Electric – Data Center Science Center, White Paper 34, 2012*
- *How to safely pack and ship batteries, UPS, 2015*
- *International Fire Code (IFC) – Chapter 608*
- *Interstate Batteries, Safety Data Sheet: Battery, Wet, Non-Spillable / Absorbed Glass Mat (AGM) battery / Sealed Lead-Acid (SLA) Battery; revision date 2013*
- *National Fire Protection Association (NFPA) Code 1: Uniform Fire Code, section 52*
- *Safeguard: Dangerous Substances: Lead acid batteries, Government of South Australia, SafeWork SA, 2015*
- *Safe Ice Resurfacer Room Battery Charging Unit Installation and Use Guidelines, Ontario Recreation Facilities Association Inc., July 2014*
- *The Battery University website: www.BatteryUniversity.com*
- *Transport Canada website: www.tc.gc.ca*
- *Using electric storage batteries safely, Health and Safety Executive, 2011*
- *ZBattery website: www.ZBattery.com*