Valve-Regulated Lead-Acid (VRLA):
Gelled Electrolyte (Gel) and Absorbed Glass Mat (AGM) Batteries

EAST PENN Expertise and American Workmanship

I. INTRODUCTION TO VRLA

Valve-Regulated Lead-Acid or VRLA, including Gel and AGM (Absorbed Glass Mat) battery designs, can be substituted in virtually any flooded lead-acid battery application (in conjunction with well-regulated charging). Their unique features and benefits deliver an ideal solution for many applications where traditional flooded batteries would not deliver the best results.

For almost three decades, East Penn has been manufacturing valve-regulated batteries using tried and true technology backed by more than 65 years experience. East Penn produces a complete line of Gel, AGM, and conventional flooded products for hundreds of applications. This diverse product offering enables East Penn to be objective as to the advantages of each type of battery. East Penn's VRLA (Gel and AGM) products have the reputation of being the **highest quality VRLA batteries available.**

How it works

A VRLA battery utilizes a one-way, pressure-relief valve system to achieve a "recombinant" technology. This means that the oxygen normally produced on the positive plate is absorbed by the negative plate. This suppresses the production of hydrogen at the negative plate. Water (H_2O) is produced instead, retaining the moisture within the battery. **It never needs watering, and should never be opened** as this would expose the battery to excess oxygen from the air. In addition to damaging the battery, opening it also voids the warranty.

The difference between VRLA and traditional flooded batteries

Flooded electrolyte batteries do not have special one-way, pressure-relief valves, as they do not work on the recombination principle. Instead, flooded designs utilize a vent to allow gas to escape. They contain liquid electrolyte that can spill and cause corrosion if tipped or punctured. They should not be used near sensitive electronic equipment. They can only be installed "upright." Flooded batteries lose capacity and become permanently damaged if:

- Left in a discharged condition for any length of time (due to sulfation). This is especially true of designs that require water maintenance.
- Continually over-discharged (due to active material shedding). This is especially true of automotive starting types.

Ideal applications for VRLA batteries

Deep Cycle, Deep Discharge Applications

- Marine Trolling
- Sailboats
- Wheelchairs/Scooters
- Portable Power
- Personnel Carriers
- Village Power
- Marine & RV House Power
- Electronics
- Electric Vehicles
- Golf Cars
- Floor Scrubbers
- Renewable Energy (Solar, Wind)
- Commercial Deep Cycle Applications

Standby and Emergency Backup Applications

- UPS (Uninterrupted Power Systems)
- Computer Backup
- Frequency Regulation
- Telephone Switching
- Cable TV
- Emergency Lighting
- Renewable Energy (Solar, Wind)

Other Applications

- Race or High Performance Cars
- Wet Environments
- Diesel Starting
- Vehicles with Start-Stop Systems
- On-Highway Trucking
- Off-Road Vehicles
- Marine & RV Starting
- Cars and Light Trucks with Accessories

II. AGM & GEL BATTERIES

VRLA technology encompasses both gelled electrolyte or gel batteries and absorbed glass mat or AGM batteries. Both types are regulated by special one-way, pressure-relief valves and have significant advantages over flooded lead-acid products.

AGM (Absorbed Glass Mat) batteries

The electrolyte in AGM batteries is completely absorbed in separators consisting of matted glass fibers. This causes them to be spillproof, meaning they don't leak acid like a flooded design if tipped on their side. The glass mats in AGM batteries are wrapped around the positive plate, which helps prevent damage from vibration and extend cycling. The battery's groups are packed tightly in the case partitions also protecting its power producing components. AGM battery designs can have over twice the cycle life of a conventional flooded product in the right application.

Gel or Gelled Electrolyte batteries

The electrolyte in a Gel battery is permanently locked in a highly viscous gelled state instead of the traditional liquid form. Because there is no liquid-type electrolyte, it will not leak out of the battery if tipped on its side. The thick, gelled electrolyte and tightly packed groups also protect the battery's power producing components. Gel battery designs have a superior deep discharge resiliency and can deliver over two to three times the cycle life of an AGM product in the right applications.

Similarities between Gel and AGM VRLA technology

- Batteries utilize special one-way, pressure-relief valves and must never be opened.
- Requires no electrolyte maintenance unlike deep cycle flooded batteries that require frequent checking and adjustment of electrolyte levels.
- Uses a recombination reaction to prevent the escape of hydrogen and oxygen gases normally lost in a flooded lead-acid battery (particularly in deep cycle applications).
- Spillproof design enables installation in virtually any position (upside-down installation is not recommended).
- Has a higher tolerance against damage from deep discharge. These batteries have optimized amounts of electrolyte (which is also referred to as "acid-starved") so that they use the power in the acid before they use the power in the plates. This minimizes the destructive nature of ultra-deep discharges. Ultra-deep discharging is what causes plate shedding, which can destroy a battery.

Major difference between Gel and AGM battery performance

A Gel battery is better suited for super-deep discharge applications, which means it can withstand deeper discharges without damaging the battery's performance. However, due to the physical properties of the gelled electrolyte, Gel battery power declines faster than an AGM battery as the temperature drops below 32ºF (0ºC). AGM batteries excel for high current, high power applications and in extremely cold environments. AGM batteries deliver a better dual purpose solution for a combination of starting and accessory power.

Advantages of GEL and AGM battery designs

KEY BATTERY BENEFITS	GEL	AGM
Premium maintenance-free design	Yes	Yes
Air transportable	Yes (most sizes)	Yes (many sizes)
Spillproof construction, won't leak if turned sideways	Yes	Yes
Minimizes terminal corrosion	Yes	Yes
Superior deep cycle life and resiliency to deep discharge damage	Yes (Best)	Yes (Good)
Operates at severe angle or on side (won't leak or spill)	Yes	Yes
Low to no gassing	Yes	Yes
Ideal for use around sensitive electronic equipment	Yes	Yes
Extended shelf life, low self-discharge rate	Yes	Yes
Enhanced recharging efficiency	Yes	Yes
Resistance to vibration	Yes	Yes
Delivers the best combination starting, cycling, and deep cycle service	Yes (Good)	Yes (Best)
Operation in cold temperatures	Yes (Good)	Yes (Best)
Cold engine cranking	Low	Yes

III. EAST PENN'S AGM & GEL VRLA BATTERY DESIGN

Features and benefits that make our VRLA batteries unique

East Penn Expertise

East Penn builds VRLA batteries to the highest standards. Our manufacturing process features improved controls using state-of-the-art computers and the latest manufacturing technology and equipment. VRLA batteries produced by East Penn consistently meet the highest quality performance and life standards.

One-Way, Pressure-Relief Valves

A critical feature of any VRLA battery is the quality of the sealing valve. Not only must the valve safely release excessive pressure and gas, but it must also keep the cell from being contaminated by the atmosphere. Oxygen contamination will discharge and eventually ruin a VRLA battery. Our valves are UL recognized and 100% tested. The benefit is **reliable performance and long life.**

Exclusive Gel Formula & Computerized Mixing

Proper gel mixing is critical to life and performance. Our state-of-the-art gel battery manufacturing facility is one of the finest in the world with a proprietary computerized gel mixing operation. Our exclusive formula is mixed using computer control in every stage of the process. **Computer control delivers superior consistency for gel battery performance that is unequaled.** Our temperature-controlled process and specially designed equipment assures a homogenous gel. Our equipment was designed by our engineers specifically for gel mixing – even down to the contour of the tank bottoms and feed pipe locations.

Exclusive AGM Electrolyte and Filling Process

Our AGM electrolyte contains high purity sulfuric acid and pure, demineralized and deionized water. Avoiding impurities enables the battery to function at the critical performance levels necessary of the recombinant principle utilized in a valve-regulated design. This assures minimized gassing as well as water and capacity loss providing longer service life and sustained performance.

The AGM filling process assures that each cell is saturated with the maximum amount of electrolyte that can be held by the separators, without leaving excess electrolyte that could spill or leak.

Multi-Staged Filling and Vacuuming Operation

Our gel process fills and vacuums each cell several times. This multi-step process assures complete evacuation of air and complete gel-to-plate contact. Our computerized process also weighs every SLI and Stationary battery before and after filling as a check for proper gel levels. The result is a battery with more consistent and reliable performance.

Our AGM topping process assures that the maximum retainable electrolyte quantity is held within the battery separators, to produce a complete electrolyte-to-plate contact optimizing battery performance and power.

Gel Ultra-Premium, Glass Mat, Double Insulating Separators

Another critical component is the separator, which isolates the positive from the negative plate. The separator must allow maximum charge flow between the plates for maximum performance.

East Penn's Gel battery utilizes a separator with two layers:

- The first fiberglass sheet layer maintains compression force over the entire surface of the positive plate prohibiting active material shedding. The fiberglass strands from this layer also prevent shedding by embedding themselves into the surface of the plates. This acts like reinforcing rods in concrete. These extra reinforcements lock the active material to prevent capacity degradation for longer life performance.
- The second layer is a porous organic polymer. The quantity and size of the pores is optimized to balance the performance characteristics of the battery with its life characteristics. This layer has ribs on both sides to allow gel to reach the entire surface of both plates and to maintain the correct plate spacing.

Gel Polyester Element Wrap

To prevent life-shortening mossing in our gel batteries, we use a special polyester fiber sheet that is wrapped around the edge of each element, similar to the wrap in an industrial battery. The result is longer service life.

AGM Ultra-Premium Glass Mat Separators

Variations in separator properties can be detrimental to the AGM battery's functional performance. East Penn uses glass mats that are engineered to have consistency and an ideal balance of critical properties. This attention to detail results in high performance and long life.

- High absorption and retention rate holds acid securely in glass fibers to prevent uneven saturation and acid stratification (see explanation of acid stratification under Acid Stratification Prevention section).
- Thick, highly compressible mats provide padded protection around plates and absorb shock and vibration. This maintains compression force over the entire surface of the positive plate prohibiting shedding, which results in capacity degradation. An AGM separator contains no materials subject to failure from oxidation.
- Low electrical resistance from electrolyte holding fibers and micro-porous composition optimizes current flow between plates for a more efficient transfer of power.
- Durable mats are wrapped around the bottom of the plate and are wider than the plates. This inhibits failures from direct contact electrical plate shorts or shorts from the build-up of material on the battery elements.

Exclusive Alloy Compositions

Our exclusive alloy compositions provide the optimal combination of longer shelf life, more power conductance, enhanced durability, and superior corrosion resistance. By using special grain refiners, we can dramatically improve performance and life. Calcium strengthens the grid for processing in the plant so that its integrity is upheld in the battery to withstand the forces of vibration and shock in service.

Heavy-Duty Grid Style Design for Heavy-Duty Service

East Penn uses a high-performance deep cycle grid designed for durability. The thick grid wires not only lock the active material onto the grid, but also act as "bus bars" to collect and direct the energy to the terminals.

Acid Stratification Prevention

Acid stratification can occur in conventional flooded cells. During charge, acid is released at the plate surfaces. During discharge, acid is consumed at the plate surfaces. Since the concentration is not uniform, diffusion (spontaneous mixing by random molecular motions) begins. If this mixing occurred rapidly, stratification would not occur, but it is relatively slow, allowing lighter parts of electrolyte to "float" toward the surface and heavier parts to "sink" toward the bottom. The top portion of the plates do not perform as well in contact with lower concentration electrolyte. The bottom portion of the plates do not perform as well with the higher concentration and will corrode prematurely. High voltage "equalization" charging is sometimes used in flooded batteries to make gas bubbles that remix the electrolyte.

Immobilized gel or separator-absorbed electrolyte will not "float" or "sink" within itself when a non-uniform concentration exists so it cannot stratify. Therefore, no high-voltage equalizing charge is necessary. Simply recharge at the recommended recharge settings. This means longer life and consistent performance.

Proprietary Case, Cover, and One-Way, Pressure-Relief Valve

We design our own highly functional polypropylene cases, valves, and covers. Many are molded in our on-site, state-of the-art plastics molding facility. This provides ultimate control of our high performance designs, quality and delivery to our manufacturing plant, assuring you the highest quality battery and most reliable service.

East Penn's Quality Assurance Checks

Below are a few examples of the hundreds of quality checks that are performed on Gel or AGM battery types to assure total confidence in the performance and life of our batteries:

- **Extended Shelf Stand Test.** Before shipment, every battery is required to stand for a period of time and ending voltages are analyzed. This extra quality assurance step verifies that the batteries are optimized for electrical performance.
- **Computer-Enhanced Filling Controls.** During this computerized process, batteries are monitored and filled to exacting levels for precision separator absorption and complete permeation.
- **Multi-Staged Filling and Vacuuming Process.** Every battery is filled and vacuumed several times during this computerized process. Multi-staged vacuuming assures complete electrolyte-to-plate interface.
- **Computerized Polarity Check.** Every battery is checked by computer analysis for proper polarity.
- **Discharge Test.** High-precision calibrated sensors allow computers to monitor the voltage drop during this discharge to assure that every battery performs as designed.
- **Grid Casting Inspections.** Specified checks such as alloy sampling, lead pot temperatures, ladle temperatures, grid weight and thickness analysis assures patented alloy blend and precise conditions for proper grid formation and application into battery production.
- **Acid Mixing Checks.** Regulatory acid temperature and specific gravity monitoring optimizes battery performance and longevity.
- **Paste Mixing Monitoring.** Computer-assisted formula monitoring and extensive acid gravity and temperature checks provide best attributes for paste adhesion, power absorption and delivery performance.
- **Paste-to-Grid Application Monitoring.** Temperature, thickness, weight and line speed analysis assures proper adhesion and extended service life.
- **Curing Checks.** Assures proper time, temperature, and humidity to create the optimal environment to facilitate the curing process.
- **Cast-On-Strap and Assembly Audits.** Monitors lead temperatures, line speed, alloy sampling, weld quality, terminal burn depth, and leak testing all to ensure the final assembled product meets rigid specifications and standards providing a solid construction to support premium VRLA battery products.

IV. GENERAL QUESTIONS ABOUT VRLA BATTERIES

What do I need to know about VRLA battery charging?

All lead-acid batteries release hydrogen from the negative plate and oxygen from the positive plate during charging. VRLA batteries have one-way, pressure-relief valves. Without the ability to retain pressure within the cells, hydrogen and oxygen would be lost to the atmosphere, eventually drying out the electrolyte and separators.

Voltage is electrical pressure (energy per unit of charge). Charge (ampere-hours) is a quantity of electricity. Current (amperes) is electrical flow (charging speed). A battery can only store a certain quantity of electricity. The closer it gets to being fully charged, the slower it must be charged. Temperature also affects charging. If the right voltage is used for the temperature, a battery will accept charge at its ideal rate. If too much voltage is used, charge will be forced through the battery faster than it can be stored.

Reactions other than the charging reaction also occur to transport this current through the battery—mainly gassing. Hydrogen and oxygen may be given off faster than the recombination reaction. This raises the pressure until the one-way, pressure-relief valve opens. The gas lost cannot be replaced. Any VRLA battery will dry out and fail prematurely if it experiences excessive overcharging.

Note: It is too much voltage that initiates this problem, not too much charge — a battery can be "over-charged" (damaged by too much voltage) even though it is not fully "charged." **Never install any lead-acid battery in a sealed container or enclosure. Hydrogen gas must be allowed to escape.**

Can continual undercharging harm a VRLA battery?

In many respects, undercharging is as harmful as overcharging. Keeping a battery in an undercharged condition allows the positive grids to corrode and the plates to shed, dramatically shortening life. Also, an undercharged battery must work harder than a fully charged battery, which contributes to short life as well.

An undercharged battery has a greatly reduced capacity. It may easily be inadvertently over-discharged and eventually damaged.

Do VRLA batteries have a "memory" like Ni-Cad batteries?

One of the major disadvantages of nickel-cadmium (ni-cad) batteries is that after shallow discharge cycles, the unused portions of the electrodes "remember" the previous cycles and are unable to sustain the required discharge voltage beyond the depth of the previous cycles. The capacity is lost and can only be restored by slowly discharging completely (generally outside the application), and properly recharging. VRLA lead-acid batteries do not exhibit this capacity robbing effect known as memory.

What are the safety precautions for VRLA batteries?

Although all valve-regulated batteries have the electrolyte immobilized within the cell, the electrical hazard associated with batteries still exists. **Work performed on these batteries should be done with the tools and the protective equipment listed below.** Valve-regulated battery installations should be supervised by personnel familiar with batteries and battery safety precautions.

Protective Equipment

To assure safe battery handling, installation and maintenance, the following protection equipment should be used:

- Safety glasses or face shield (Consult application specific requirements)
- Acid-resistant gloves
- Protective aprons and safety shoes
- Proper lifting devices
- Properly insulated tools

Procedures

Consult user manual of specific application for safety & operating requirements. The following safety procedures should be followed during installation: **(Always wear safety glasses or face shield.)**

1. These batteries are sealed and contain no free flowing electrolyte. Under normal operating conditions, they do not present any acid danger. However, if the battery jar, case, or cover is damaged, acid could be present. **Sulfuric acid is harmful to the skin and eyes. Flush affected area with water immediately and consult a physician if splashed in the eyes. Consult MSDS for additional precautions and first aid measures.**
2. Prohibit smoking and open flames, and avoid arcing in the immediate vicinity of the battery.
3. Do not wear metallic objects, such as jewelry, while working on batteries. Do not store un-insulated tools in pockets or tool belt while working in vicinity of battery.
4. Keep the top of the battery dry and clear of all tools and other foreign objects.
5. Provide adequate ventilation as regulated by Federal, State and Local codes and follow recommended charging voltages.
6. Extinguishing media: Class ABC extinguisher. **Note: CO_2 may be used but not directly on the cells due to thermal shock and potential cracking of cases.**
7. **Never** remove or tamper with pressure-relief valves. Warranty void if vent valve is removed.

Can VRLA batteries be installed in sealed battery boxes?

NO! Never install any type of battery in a completely sealed container. Although most of the normal gasses (oxygen and hydrogen) produced in a VRLA battery will be recombined and not escape, **oxygen and hydrogen will escape from the battery in an overcharge condition** (as is typical of any type battery).

These potentially explosive gasses must be allowed to vent to the atmosphere and **must never be trapped in a sealed battery box or tightly enclosed space!**

Does depth of discharge affect cycle life?

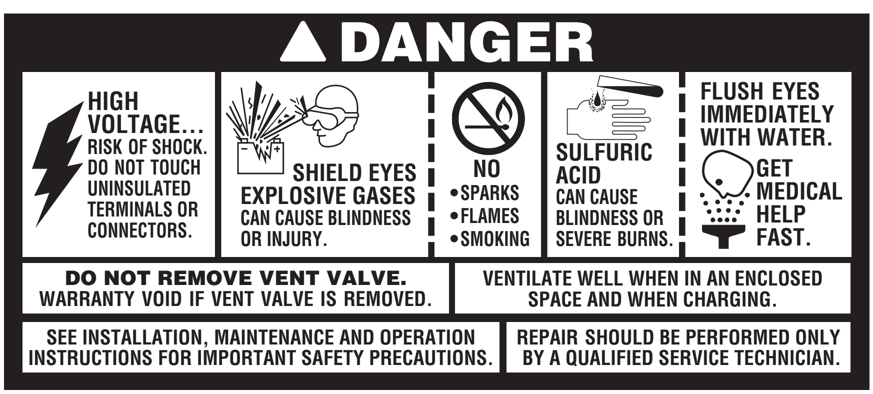
Yes! The harder any battery has to work, the sooner it will fail.

The shallower the average discharge, the longer the life. It's important to size a battery system to deliver at least twice the energy required, to assure shallow discharges.

Follow these tips for the longest life:

- Avoid ultra-deep discharges. The definition of ultra-deep discharge may vary with application and battery type.
- Don't leave a battery at a low stage of charge for an extended length of time. Charge a discharged battery as soon as possible.
- Don't cycle a battery at a low state of charge without regularly recharging fully.

Use the highest initial charging current available (up to 30% of the 20-hour capacity per hour) while staying within the proper temperature-compensated voltage range.



California Proposition 65 Warning	Batteries, battery posts, terminals and related accessories contain lead and lead compounds, and other chemicals known to the state of California to cause cancer and birth defects or other reproductive harm. **Wash hands after handling.**

What is a thermal runaway?

The appropriate charge voltage depends on the battery temperatures. A warmer battery requires a reduced voltage. If the voltage is not reduced, current accepted by the battery increases. When the current increases, the internal heating increases. This can rise to destructive levels if not taken into consideration.

Thermal runaway can be prevented with:

- Temperature compensation monitoring at the battery — not at the charger.
- Limiting charging currents to appropriate levels.
- Allowing for adequate air circulation around the batteries.
- Using timers or ampere-hour counters.
- Using smart chargers that recognize the signature of a thermal runaway event which will shut the charger down.

Why do some VRLA batteries have a concave or convex appearance?

CONCAVE APPEARANCE

The gas pressure in a VRLA battery can be lower than ambient pressure under certain circumstances. This partial vacuum will pull the container walls and cover inward. This may give the ends, sides of each cell, and tops of each cell a noticeable concave (inwardly dished) appearance. This is normal. The product is not defective. Its performance is not compromised in any way. In some situations charging will reduce or eliminate this appearance. Internal gas pressure being lower than external pressure has several potential causes that can operate alone or in combination. The recombination process continues after charging ends consuming most of the headspace oxygen — decreasing internal pressure. An increase in external pressure will result from a decrease in altitude. Cooling the battery reduces the internal gas pressure by contraction and also by causing some water vapor to return to liquid form. Severe discharging shrinks the volume of the internal materials. This leaves more volume for the gas to fill reducing the internal pressure.

CONVEX APPEARANCE

To prevent the permanent loss of gases so that recombination has time to take place, each cell can hold an internal gas pressure above external pressure before venting. Batteries with very large cells will slightly bulge as this normal pressure builds. This is especially noticeable at higher temperatures because the polypropylene case is more pliable when warm. Therefore, a certain amount of bulge is normal. If a battery bulges severely on charge, this is not normal. It is an indication of a blocked valve or an overcharge situation. Such a battery should be removed from service.

V. GLOSSARY TERMS

ACTIVE MATERIAL — The porous structure of lead compounds that produce and store electrical energy within a lead-acid battery. The active material in the positive plates is lead dioxide and that in the negative is metallic sponge lead. When an electrical circuit is created, these materials react with sulfuric acid during charging and discharging according to the following chemical reaction:

$PbO_2 + Pb + 2H_2SO_4 = 2PbSO_4 + 2H_2O$.

AGM (Absorbed Glass Mat) — A type of non-woven separator material comprised almost entirely of glass microfibers that absorbs and retains the electrolyte leaving no free electrolyte in the cell to spill. VRLA batteries made with this material are often referred to as "AGM" batteries.

AMPERE (Amp, A) — The unit of measure of the electron flow rate, or current, through a circuit.

AMPERE-HOUR (Amp-Hr, Ah) — A unit of measure for a battery's electrical storage capacity, obtained by multiplying the current in amperes by the time in hours of discharge. (Example: A battery that delivers 5 amperes for 20 hours delivers 5 amperes X 20 hours = 100 Amp-Hr of capacity.)

BOOST CHARGE — The process of ensuring that the cells and plates within a battery are charged sufficiently for the battery to perform its desired function. Boost charging is typically done for a short duration at a high current.

CAPACITY — The capacity of a battery is specified as the number of Amp-Hrs that the battery will deliver at a specific discharge rate and temperature. The capacity of a battery is not a constant value and is seen to decrease with increasing discharge rate. The capacity of a battery is affected by a number of factors such as: active material weight, density of the active material, adhesion of the active material to the grid, number, design and dimensions of plates, plate spacing, design of separators, specific gravity and quantity of available electrolyte, grid alloys, final limiting voltage, discharge rate, temperature, internal and external resistance, age, and life history of the battery.

CONTAINER AND COVER — The reservoir and lid containing the battery parts and electrolyte made from impact and acid resistant material such as polypropylene.

CELL — The basic electrochemical current-producing unit in a battery, consisting of a set of positive plates, negative plates, electrolyte, separators, and casing. In a lead-acid battery the cell has an open-circuit voltage of approximately 2-volts. There are six cells in a 12-volt lead-acid battery.

CIRCUIT — An electrical circuit is the path followed by a flow of electrons. A closed circuit is a complete path. An open circuit has a broken, or disconnected, path.

CIRCUIT (Series) — A circuit that has only one path for the flow of current. Batteries arranged in series are connected with negative of the first to positive of the second, negative of the second to positive of the third, etc. If two 12-volt batteries of 50 ampere-hours capacity each are connected in series, the circuit voltage is equal to the sum of the two battery voltages, or 24 volts, and the ampere-hour capacity of the combination is 50 ampere-hours.

CIRCUIT (Parallel) — A circuit that provides more than one path for the flow of current. A parallel arrangement of batteries (usually of like voltages and capacities) has all positive terminals connected to a conductor and all negative terminals connected to another conductor. If two 12-volt batteries of 50 ampere-hour capacity each are connected in parallel, the circuit voltage is 12 volts, and the ampere-hour capacity of the combination is 100 ampere-hours.

COLD CRANK RATING — The cold crank rating refers to number of amperes a lead-acid battery at 0°F (-17.8°C) can deliver for 30 seconds and while maintaining at least 7.2 volts (1.2 volts per cell). This is commonly referred to as CCA (Cold Cranking Amps).

CONDUCTANCE — The ability to transmit current in a circuit or battery.

CORROSION — The chemical or electrochemical reaction between a material, usually a metal, and its environment that produces a deterioration of the material and its properties. The positive lead grids in a battery gradually corrode in service often leading to battery failure. Battery terminals are subject to corrosion if they are not properly maintained.

CURRENT — The rate of flow of electricity, or the movement of electrons along a conductor. It is comparable to the flow of a stream of water. The unit of measure for current is the ampere.

CURRENT (ALTERNATING) (AC) — A current that varies periodically in magnitude and direction. A battery does not deliver alternating current (AC).

CURRENT (DIRECT) (DC) — An electrical current flowing in an electrical circuit in one direction only. A secondary battery delivers direct current (DC) and must be recharged with direct current in the opposite direction of the discharge.

CYCLE — In a battery, one discharge plus one recharge equals one cycle.

DISCHARGING — When a battery is delivering current, it is said to be discharging.

ELECTROLYTE — In a lead-acid battery, the electrolyte is sulfuric acid diluted with water. It is a conductor that supplies water and sulfate for the electrochemical reaction:

$PbO_2 + Pb + 2H_2SO_4 = 2PbSO_4 + 2H_2O$.

ELECTRONIC TESTER — An electronic device that assesses the condition of a battery through an ohmic measurement such as resistance or conductance, typically without drawing large current loads.

ELEMENT — A set of positive and negative plates assembled with separators.

EQUALIZATION CHARGE — The process of ensuring that the cells and plates within a battery are all at full charge and that the electrolyte is uniform and free of stratification. This is normally done by charging the battery under controlled conditions (charge current, time and upper voltage limits are usually specified).

FORMATION — In battery manufacturing, formation is the process of charging the battery for the first time. Electrochemically, formation changes the lead oxide paste on the positive grids into lead dioxide and the lead oxide paste on the negative grids into metallic sponge lead.

GEL — Electrolyte that has been immobilized by the addition of a chemical agent, normally fine silica, to prevent spillage. Batteries made with gelled electrolyte are often referred to as Gel batteries. Gel batteries are one typical type of VRLA battery.

GRID — A lead alloy framework that supports the active material of a battery plate and conducts current.

GROUND — The reference potential of a circuit. In automotive use, the result of attaching one battery cable to the body or frame of a vehicle that is used as a path for completing a circuit in lieu of a direct wire from a component. Today, over 99% of automotive and LTV applications, use the negative terminal of the battery as the ground.

HYDROMETER — A device used to measure the strength (i.e., the concentration of sulfuric acid in the electrolyte) of the electrolyte through specific gravity of the electrolyte.

INTERCELL CONNECTORS — Lead structures that connect adjoining cells in series, positive of one cell to the negative of the next, within a battery.

LOAD TESTER — An instrument that draws current (discharges) from a battery using an electrical load while measuring voltage. It determines the battery's ability to perform under actual discharge conditions.

LOW WATER LOSS BATTERY — A battery that requires little to no water additions under normal operating conditions; also referred to as maintenance-accessible batteries.

MAINTENANCE-FREE — A battery that normally requires no service watering during its lifetime of use.

NEGATIVE — Designating, or pertaining to, electrical potential. The negative battery terminal is the point from which electrons flow during discharge.

OHM — A unit for measuring electrical resistance or impedance within an electrical circuit.

OHM'S LAW — Expresses the relationship between volts (V) and amperes (I) in an electrical circuit with resistance (R). It can be expressed as follows:
$V = IR$
Volts (V) = Amperes (I) x Ohms (R). If any two of the three values are known, the third value can be calculated using the above equation.

OPEN CIRCUIT VOLTAGE — The voltage of a battery when it is not delivering or receiving power.

PLATES — Thin, flat structures comprised of a grid and active material. The grid supports the active material and conducts electrons out of the cell. Plates are either positive or negative, depending on the active material they hold.

POSITIVE — Designating, or pertaining to, a kind of electrical potential; opposite of negative. A point or terminal on a battery having higher relative electrical potential. The positive battery terminal is the point to which electrons flow during discharge.

PRIMARY BATTERY — A battery that can store and deliver electrical energy but cannot be recharged. A lead-acid battery is NOT a primary battery.

RESERVE CAPACITY RATING — The time in minutes that a new, fully charged battery will deliver 25 amperes at 27°C (80°F) and maintain a terminal voltage equal to, or higher than, 1.75 volts per cell. This rating represents the time the battery will continue to operate essential accessories if the alternator or generator of a vehicle fails.

RESISTANCE — The opposition to the free flow of current in a circuit or battery. It is commonly measured in Ohms.

SECONDARY BATTERY — A battery that can store and deliver electrical energy and can be recharged by passing direct current through it in a direction opposite to that of discharge. A lead-acid battery is a secondary battery.

SEPARATOR — A porous divider between the positive and negative plates in a cell that allows the flow of ionic current to pass through it, but not electronic current. Separators are made from numerous materials such as: polyethylene, polyvinyl chloride, rubber, glass fiber, cellulose, etc.

SHORT CIRCUIT — An unintended current-bypass in an electric device or wiring. Outside the battery a short circuit is established when a conductive path is established between the two terminals of a battery. Inside a battery, a cell short circuit is the result of contact between the positive and negative plates and will cause a cell to discharge and render the battery useless.

SPECIFIC GRAVITY (Sp. Gr. or SG) — Specific Gravity is a measure of the electrolyte concentration in a battery. This measurement is based on the density of the electrolyte compared to the density of water and is typically determined by the use of a hydrometer (see Hydrometer). By definition, the specific gravity of water is 1.00 and the specific gravity of the sulfuric acid electrolyte in a typical fully charged battery is 1.265-1.285. Specific gravity measurements are typically used to determine if the battery is fully charged or if the battery has a bad cell.

STATE OF CHARGE — The amount of deliverable low-rate electrical energy stored in a battery at a given time expressed as a percentage of the energy when fully charged and measured under the same discharge conditions. If the battery is fully charged the "State of Charge" is said to be 100%.

STRATIFICATION — The unequal concentration of electrolyte due to density gradients from the bottom to the top of a cell. This condition is encountered most often in batteries recharged from a deep discharge at constant voltage without a great deal of gassing. Continued deep cycling of a 'stratified' battery will result in softening of the bottoms of the positive plates. Equalization charging is a way to avoid acid stratification.

SULFATION — The generation or conversion of the lead sulfate discharge in the plates to a state that resists normal recharge. Sulfation often develops when a battery is stored or cycled in a partially discharged state at warm temperatures.

TERMINALS — The electrical structures on the battery to which the external circuit is connected. Typically, batteries have either top-terminals (posts) or side-terminals. Some batteries have both types of terminals (dual-terminal).

VENTS — Mechanisms that allow gasses to escape from the battery while retaining the electrolyte within the case. Flame arresting vents typically contain porous disks that reduce the probability of an internal explosion as a result of an external spark. Vents come in both permanently fixed and removable designs.

VOLT — The unit of measure for electrical potential or voltage.

VOLTMETER — An electronic device used to measure voltage, normally in a digital format.

VOLTAGE DROP — The net difference in the electrical potential (voltage) when measured across a resistance or impedance (ohms). Its relationship to current is described in Ohm's law.

VRLA — Valve Regulated Lead Acid battery. AGM and Gel are the two types of VRLA batteries. These batteries have no "free" liquid electrolyte and in the cell operate on the oxygen recombination cycle, which is designed to minimize water loss. VRLA batteries feature valves that have a one-way, pressure-relief design. These low-pressure valves prohibit air entering the cell while permitting gases to vent from the cell if necessary. The pressure maintained in the battery, though only very slight, is required to facilitate the oxygen recombination reaction, which converts the oxygen generated at the positive plates back into water.

WATT — The unit for measuring electrical power, i.e., the rate of doing work, in moving electrons by, or against, an electrical potential. Formula: Watts = Amperes x Volts.

WATT-HOUR (Watt-Hr, WH) — The unit of measure for electrical energy expressed as Watts x Hours.

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