Innovative Battery Solutions

BATTERY 101

#4 -13511 Crestwood Place, Richmond, BC, V6V 2E9, Canada + 1.778.776.3288 info@discoverbattery.com

The information included in this document has been collected over years of experience, and from references compiled from various sources within the industry. The reader is encouraged to search for additional information that will improve their overall experience with lead-acid batteries and other related areas of interest.

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Section I – Introduction

Discover® 700 Series Dry Cell Batteries, EV Traction Dry Cell Batteries, Deep Cycle AGM Batteries and Advanced Technology Battery Power Blocks:

Discover® is a powerful force combining more than 60 years of seasoned management in the power protection, generation and energy storage industry. Discover® is bringing together our leading global position in the design, manufacture and distribution of energy storage products with emerging energy technologies and the Clean and Green Energy Movement. What makes Discover® unique is the direct linkage of the knowledge based distribution and service capabilities of select OEMs and Factory Warehouses with the battery design, battery engineering and battery manufacturing capabilities of Discover® facilities. This direct linkage, as well as our common commitment to protect, enhance and make safer our living and working environments are what makes Discover® the industry leading battery company worldwide.

We believe the 21st century will be an age of greater environmental awareness and responsibility. Discover® is acting now to enhance our coexistence in the world by creating diverse and innovative ways of utilizing the latest battery technologies. Our efforts, such as the development of non-hazardous lead-acid Deep Cycle and Traction batteries, as well as battery power blocks that utilize advanced battery chemistries for use in battery powered mobile and stationary applications, help reduce the emissions of C02 and hydrogen gas, in addition to meeting our customer's needs for increased productivity and lower total cost of ownership. Discover's Deep Cycle and Traction Dry Cell batteries and Advanced Technology Solutions allow you to:

Discover Advantages:

- Eliminates maintenance related battery failures
- No acid and hazardous material handling, reporting and shipping restrictions
- Prevents noxious smells, explosive gases, corroded equipment, voltage related electronics failures
- Provide more power per cubic in(cm) of available installation area
- Will not experience lower discharge rates when in storage
- Are non-hazardous
- Have excellent safety and reliability
- Have no shipping restrictions, are classified NON-SPILLABLE and are F.A.A, IATA and UPS approved for shipping or transportation
- Do not develop a memory and do not need to be fully discharged before recharging
- Can be used in a wide range of operating temperatures
- Are 100% recyclable
- Are UL recognized and approved
- Are manufacture controlled under recognized ISO, QS, and TUV quality assurance processes

Discover® Valve Regulated Lead-Acid (VRLA) technology, also referred to as Sealed Valve Regulated technology (SVR), encompasses Absorbed Glass Mat (AGM), and Gelled electrolyte (Gel) Deep Cycle and EV Traction Dry Cell batteries. All types are valve regulated and have significant advantages over flooded lead-acid products. The following information is provided for better understanding the wide array of benefits, features and overall advantage of the Discover® line of batteries.

General Benefits and Features of Discover® Valve Regulated Lead-Acid (VRLA) technology:

Discover® batteries are designed and engineered for dependability in commercial and industrial, public and private applications. They can be found as Original Equipment in mobility and home medical equipment (HME), broadband and cable TV (CATV) equipment, uninterruptible power supplies (UPS), telecommunication equipment, photovoltaic, solar and renewable energy installations, electronic and security equipment, marine, RV, golf and electric vehicles, aerial work platforms (AWP) and forklifts, floor machines and robotics applications.

• In Doors • Out Back • Off Shore • On Duty

Discover® Valve Regulated Deep Cycle and Traction batteries have the features and benefits that matter to your customers and you!

- Completely sealed valve regulated construction
- Clean & Green Non-Hazardous Deep Cycle, Traction Dry Cell batteries and Power Blocks
- Flame arresting pressure regulated safety sealing valves for safety, operating pressure management and protection against atmospheric contamination (excess oxygen being absorbed by negative plates)
- Computer-aided 99.994% pure heavy-duty lead calcium with high tin grid designs
- Discover® proprietary Paste Formulas and Proprietary Discover® Dry Cell processes
- Discover® separators are highly porous and have extremely low electrical resistance: hold electrolyte efficiently and deliver higher capacity and run times
- Multi step Measured and Immobilized electrolyte Vacuum filling and weighing processes
- Advanced technology for efficient gas recombination of up to 99.9% and freedom from electrolyte maintenance
- Wide range of operating temperatures (-40°F~140°F) (-40°C~60°C)
- Low self discharge rates (Approx. 1%-3% monthly at 68°F~77°F) (20°C~25°C)
- High impact reinforced copolymer polypropylene or ABS cases with flat top designed covers that are rugged and vibration resistant
- Thermally welded case to cover bonds that eliminate leakage
- Copper and stainless steel alloy terminals and hardware
- Multi-terminal options with terminal protectors
- Carry handles on nearly all batteries
- Classified as “NON-SPILLABLE BATTERY” Not restricted for Air (IATA/ICAO) Provision 67, Surface (DOT-CFR-HMR49) or Water (Non-hazardous per IMDG amendment 27) transportation
- Can be used in any orientation in float service (**Except Upside down**). To avoid premature loss of capacity (approx. 15%) and life, upright orientation is highly recommended for constant *deep discharge* applications.
- Compatible with sensitive electronic equipment
- Quality Assurance processes with ISO (4400/992579), QS and TUV Certification EMC tested, CE, ETTS Germany (G4M19906-9202-E-16)
- Recognized EN, Tellcordia & Bellcore procedural and testing compliance
- UL recognized and approved components

Section II - Working with Batteries in General

Caution:

All lead-acid batteries contain sulfuric acid which is highly corrosive and these batteries also produce excess gas during charging that may explode if exposed to an ignition source. When working with batteries, you need to have plenty of ventilation, remove your jewelry, wear protective eyewear (safety glasses) and clothing, and exercise caution. Do not allow battery electrolyte to mix with salt water. Even small quantities of this combination will produce harmful Chlorine gas.

CAUTION/DANGER:

Lead-acid batteries contain a sulfuric acid electrolyte, which can be poisonous and is highly corrosive. Flooded Lead-acid batteries will produce gasses when discharging and re-charging which can explode.

CALIFORNIA Proposition 65 Warning:

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.

Safety first:

Although Poison Danger, Safety and Caution information is dispersed throughout this battery guide, we will list the basics below.

Danger of exploding batteries:

All lead-acid batteries contain sulfuric acid. Flooded or wet lead-acid batteries produce explosive mixtures of hydrogen and oxygen when charging and discharging. Because self-discharge action can generate hydrogen gas even when the battery is not in operation, make sure batteries are stored and worked on in well ventilated areas. **ALWAYS** wear safety glasses and a face shield when working on or near batteries. Discover® Valve Regulated Deep Cycle and Traction batteries are sealed and maintenance-free and all sulfuric acid is immobilized and absorbed, and under normal operating conditions any gas produced is recombined and is not vented to the atmosphere. All lead-acid batteries, including sealed valve regulated batteries, will vent gases if over charged.

When working with batteries:

1. Always wear proper eye, face and hand protection.
2. Keep sparks flames and cigarettes away from the battery.
3. Do not remove or damage the vent caps on sealed valve regulated types.
4. Do not open in any way sealed valve regulated batteries.
5. Cover vents with a damp cloth to minimize gas seepage.
6. Make sure work area is well ventilated.
7. Never lean over battery while testing, boosting or charging.

When installing or replacing batteries:

1. Disconnect ground cable (negative cable) first.
2. Note position of **Positive** (+) and **Negative** (-) cables. Mark cables for correct connection to the new battery.
3. Remove old batteries.

4. Clean terminals and cable connections. Broken, frayed, brittle, kinked or cut cables should be replaced.
5. Clean and/or paint and repair battery compartment and hold down.
6. Install and secure the new battery. Be careful not to ground the terminals on any metal mounting, fixture or body part.
7. Connect the cables tightly. Connect the ground cable last to avoid sparks.

When charging batteries:

1. Before operating the charger make sure to read and understand the instructions that come with the charger. Never attempt to charge a battery without first reviewing and understanding the instructions of the charger that is being used. Always make sure the charger's charging curve meets the batteries' charging requirement.
2. Always charge batteries in a ventilated area.
3. Always wear protective gear for your eyes.
4. Never charge a visibly damaged battery.
5. Never charge a frozen battery.
6. Connect the charger leads to the battery; **(+) positive lead to the positive (+) terminal of the battery and the (-) negative lead to the negative (-) terminal**. If the battery is still in the vehicle, connect the negative lead to the engine block to serve as a ground. If the vehicle is positive grounded, connect the positive lead to the engine block. To be absolutely sure, make sure that the battery is completely disconnected from the equipment and hook the charger leads up accordingly.
7. Make sure that the charger lead, both at the charger and the battery side of the leads, connections are tight.
8. If the charger has a battery type selector switch (I.E. Flooded, Gel, or AGM), set it to the proper location.
9. Set the timer if it is available and turn the charger on.
10. If the battery becomes hot or if violent gassing or spewing of electrolyte (in the case of flooded battery types) occurs, reduce the charge rate or temporarily halt the charger. If these events repeat themselves even after you restart the charger and/or reduce the charge rate, take the battery to a professional to be evaluated.
11. Always **turn the charger OFF** before removing the leads from the battery to avoid dangerous sparks.

When handling battery acid:

1. Battery acid or electrolyte is a solution of sulfuric acid and water that can destroy clothing and burn skin. Use extreme caution when handling electrolyte and keep an acid neutralizing solution, such as baking soda or household ammonia mixed with water, readily available in the event of a spill.
2. Always wear eye protection.
3. If electrolyte is splashed into the eye, immediately force the eye open and flood with clean cool water. Get medical attention immediately.
4. If electrolyte is somehow taken internally, drink large amounts of water or milk. **DO NOT induce vomiting**. Get medical attention immediately.
5. Neutralize with baking soda any electrolyte that spills in the work area, rinse with water.

When booster cables are used:

1. When jump starting, always wear proper eye protection.
2. Never lean over the battery.
3. Do not jump start a damaged battery.
4. Do not jump start a frozen battery.
5. Inspect both batteries before connecting booster cables. Be sure vent caps are tight and level, place a damp cloth over the vents of both batteries.
6. Make sure the vehicles are not touching.
7. Make sure both ignition switches are turned to the **OFF** position.
8. Connect positive (+) booster cable lead to the (+) terminal of the discharged battery.
9. Connect the other end of the positive (+) booster cable to the positive (+) terminal of the boosting battery.
10. Connect the negative (-) cable to the negative (-) terminal of the boosting battery.
11. Make the final connection of the Negative (-) cable to the engine block of the stalled vehicle, away from the battery. If this is not possible be careful when connecting the negative (-) cable to the discharged battery as the electrical current may jump at the discharged terminal creating a spark.
12. Start vehicle and remove cables in the **REVERSE** order of their connection.

Section III - General Lead-acid Battery Description

General lead-acid battery types:

There are many different batteries currently in production throughout the world. Lead-acid batteries can “generally” be described first by **Type or Construction:**

- Sealed Valve Regulated Starved Electrolyte
- Sealed Maintenance-free Flooded
- Accessible Maintenance-free Flooded
- Maintenance required Flooded such as industrial batteries or golf cart batteries

Sealed valve regulated or starved electrolyte types use a solution of sulfuric acid and water suspended in a Gel or absorbed into a glass-mat. There is no excess electrolyte to leak out even if tipped or turned upside down. This Sealed “Non spillable” characteristic is a product of the construction and chemistry of the battery design.

Sealed Maintenance-free Flooded and Accessible Maintenance-free Flooded types use a solution of sulfuric acid and water that can spill out of the battery if it is tipped. Even though the Sealed Maintenance-free Flooded batteries are not accessible, electrolyte will eventually leak out through the vents if tipped.

General lead-acid battery chemistry:

A battery can be described by the **Chemistry** of the alloys used in the production of the batteries' grids or plates:

- Calcium/Calcium alloys
- Calcium/Antimony hybrid alloys
- Antimony and High Antimony alloys

Amongst other things, the alloy (chemistry) used in the production of the battery will dictate how well the battery will cycle, how long it will live when properly maintained, how much it will gas when being discharged and recharged and how much water it will use as it works. Typically, calcium/calcium alloys will use less water and will live better in heat. Batteries made with Traction Type calcium/calcium plates will have the added advantage of long life in Deep Cycle Traction applications as well as reduced or eliminated maintenance requirements. Batteries made with higher Antimony alloys will generally deliver good cycle or run times and life in cyclic applications but will use more water in the process requiring rigorous maintenance schedules. Hybrid alloys will perform somewhere in between.

General lead-acid battery applications:

Batteries can be referred to by the **Application** they were designed for. These applications will range from pure starting to pure cycling or deep cycling and many applications have needs somewhere in between.

- Starting – for engine starting applications
- Float – for UPS/Telecom or standby applications
- Cyclic – for light duty loads in RV/Marine or recreational applications
- Deep Cycle – for medium duty loads in RV/Marine and Renewable applications
- Traction – for high rate deep cycling loads in industrial and commercial applications

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Section IV - Discover® Sealed Valve Regulated Batteries

Discover® Sealed Valve Regulated Lead-acid batteries:

- Can be substituted into virtually any flooded lead-acid battery application
- Excel in applications where traditional flooded batteries are prohibited
- Excel in applications where levels of service or service intervals cannot be guaranteed
- Excel in applications where the "COST to SERVICE" makes the use of flooded batteries impractical

Because of their unique features and benefits, Discover® 700 Series, EV Traction Dry Cell and Deep Cycle batteries are particularly well suited for Deep Cycle, Deep Discharge Applications:

- Marine Trolling
- Electric Vehicles
- Portable Power
- Personnel Carriers
- Electronics
- Wheelchairs
- Floor Scrubbers
- Materials Handling
- Aerial Lifts
- Marine & RV House Power
- Sailboats
- Golf Cars
- Commercial deep cycle application
- Renewable Energy
- Mobile Work Vehicle Power Blocks
- DC Powered Air Conditioning
- Creature comfort units for Class 8 highway vehicles (See key-off legislation)

What is a Discover® 700 SERIES Dry Cell battery?

A Discover® 700 SERIES Dry Cell battery is a lead-acid electric storage system that:

- Is a Discover® CLEAN &GREEN Non-Hazardous Dry Cell battery
- Is the ULTIMATE QUALITY choice produced with every technological advancement for the longest life performance characteristics
- Is Classified as "NON-SPILLABLE BATTERY" Not restricted for Air (IATA/ICAO) Provision 67, Surface (DOT-CFR-HMR49) or Water (Non-hazardous per IMDG amendment 27) transportation
- Uses our most robust flat and tubular plate designs with extremely high active material densities per amp hour of usable power for extended cycle life
- Computer-generated grid designs to optimize high power density
- Incorporates advanced plate pasting and curing procedures
- Use tank formation processes
- Has heavier duty plate straps
- Can be discharged and charged completely many times
- Is severely acid starved and uses ultra pure refined electrolyte
- Uses a recombination reaction to prevent the escape of hydrogen and oxygen gases
- Is non-spillable, and therefore can be operated in virtually any position
- Has an extremely high active material to acid ratio

- Discover® 700 Series Gel Cell batteries contain ultra-premium poly, ribbed glass-mat, dual-insulating separators which will not break down in service. The glass mat embeds itself into the plate, which retards life-shortening shedding.
- Discover® 700 Series AGM Dry Cell batteries contain glass separators at the ideal compression and ideal saturation to achieve the best balance between capacity utilization and recombination efficiency. The dual insulating separators also help to prevent separator misalignment and treeing or shorting at the bottom and sides of the plates. The glass embeds itself into the plate, which retards shedding.
- 700 Series AGM types use Micro fibrous silicate glass mat acid absorption
- 700 Series Gel Cell types uses electrolyte that is transformed into a gelled consistency
- Is sealed using special pressure valves and should never be opened (warranty is void if opened)
- Typically uses Calcium/Calcium high tin metal alloys
- Is maintenance-free with proper change management
- Is produced in certified ISO, QS and TUV facilities
- Is an Underwriters Laboratories (UL) recognized component
- Have multiple advanced terminal design options
- Incorporates proprietary manufacturing techniques, additives and processes

* Life cycles vary by battery voltage, capacity, size and operating temperatures.

What is a Discover® EV Traction Dry Cell & Gel Cell battery?

A Discover® EV Traction Dry Cell battery is a lead-acid electric storage system that:

- Is a Discover® CLEAN &GREEN Non-Hazardous Dry Cell battery
- Is the HIGHEST QUALITY choice by leading Original Equipment Manufacturers and integrators of power blocks in Electric Vehicle, Traction and Renewable Energy applications
- Is Classified as “NON-SPILLABLE BATTERY” Not restricted for Air (IATA/ICAO) Provision 67, Surface (DOT-CFR-HMR49) or Water (Non-hazardous per IMDG amendment 27) transportation
- Has robust flat plates with very high active material densities per amp hour of usable power
- Computer-generated grid designs to optimize high power density
- Incorporates advanced plate pasting and curing procedures
- Use tank formation processes
- Has heavy duty plate straps
- Can be discharged and charged many times beyond 80%
- Is extremely acid starved and uses ultra pure refined electrolyte
- Uses a recombination reaction to prevent the escape of hydrogen and oxygen gases
- Has a very high active material to acid ratio
- Discover® EV Traction Gel Cell batteries contain ultra-premium poly, ribbed glass-mat, dual-insulating separators which will not break down in service. The glass mat embeds itself into the plate, which retards life-shortening shedding.
- Discover® EV Traction batteries contain glass separators at the ideal compression and ideal saturation to achieve the best balance between capacity utilization and recombination efficiency. The dual insulating separators also help to prevent separator misalignment and treeing or shorting at the bottom and sides of the plates. The glass embeds itself into the plate, which retards shedding.
- EV Traction AGM Dry Cell types use Micro fibrous silicate glass mat acid absorption.
- EV Traction Gel Cell batteries use electrolyte that is transformed into a gelled consistency

- Is sealed using special pressure valves and should never be opened (warranty is void if opened)
- Typically uses Calcium/Calcium high tin metal alloys
- Is maintenance-free with proper change management
- Is produced in certified ISO, QS and TUV facilities
- Is an Underwriters Laboratories (UL) recognized component
- Have multiple advanced terminal design options
- Incorporates proprietary manufacturing techniques, additives and processes

* Life cycles vary by battery voltage, capacity, size and operating temperatures.

What is a Discover® Deep Cycle AGM battery?

A Discover® Advanced AGM battery is a lead-acid electric storage battery that:

- Is a Discover® Non-Hazardous battery
- Is the QUALITY choice by leading Original Equipment Manufacturers and integrators
- Classified as "NON-SPILLABLE BATTERY" Not restricted for Air (IATA/ICAO) Provision 67, Surface (DOT-CFR-HMR49) or Water (Non-hazardous per IMDG amendment 27) transportation.
- Has thick flat plates
- Can be discharged and charged many times beyond 30%~50%
- Performs well in cyclic, starting or combination cyclic starting applications
- Is acid starved and uses ultra pure refined electrolyte
- Uses a recombination reaction to prevent the escape of hydrogen and oxygen gases
- Has a higher active material to acid ratio than standard SVR types
- Uses Micro fibrous silicate glass mat acid absorption
- Is sealed using special pressure valves and should never be opened (warranty is void if opened)
- Typically uses Calcium/Calcium metal alloys
- Is maintenance-free with proper change management
- Is produced in certified ISO, QS and TUV facilities
- Is an Underwriters Laboratories (UL) recognized component.
- Have multiple advanced terminal design options
- Incorporates proprietary manufacturing techniques, additives and processes

* Life cycles vary by battery voltage, capacity, size and operating temperatures.

Section V - Discover® Battery Advantages and Disadvantages

700 SERIES Dry Cell Advantages:

- It is a Discover® Non-Hazardous Dry Cell power block
- Classified as "NON-SPILLABLE BATTERY" Not restricted for Air (IATA/ICAO) Provision 67, Surface (DOT-CFR-HMR49) or Water (Non-hazardous per IMDG amendment 27) transportation
- Spill proof / leak proof
- No corrosion
- Severely acid starved. Extremely high active material to acid ratio for the longest life in constant deep cycle applications
- Micro fibrous silicate glass mat acid absorption along with charge control eliminate water loss
- Excellent for multiple long or short duration deep discharges
- Excellent for Long Duration BACK UP POWER and RENEWABLE ENERGY applications
- Excellent for long life UPS/TELECOM and HIGH RATE applications
- Excellent in high discharge current applications
- Superior deep cycle life and superior energy density over Deep Cycle Gel or AGM batteries
- No loss of capacity as a result of viscous degradation or voids in gelled electrolyte
- Installs upright or on side for float service (side installation may lose 10%-15% capacity and life will be affected). Upright orientation highly recommended for high rate deep discharge service to prevent loss of performance and life.
- Very low to no gassing (unless overcharged). By design 70% less than regulations require even at increased temperature and charge voltage.
- Compatible with sensitive electronic equipment
- Superior shelf life
- Superior recharge ability (from 0% to 90% in 4 hours; from 0% to 100% in 6 hours)
- Battery output efficiency in excess of 85% means less energy and timed used during recharge
- Very safe at sea with no chlorine gas in bilge (due to sulfuric acid and salt water mixing)
- May be recycled at any smelter that processes lead-acid batteries
- Operates in wet environment even under 30 feet of water
- Good in extreme temperature applications. Will not freeze to –20°F/-30°C (if fully charged)
- **Lowest Life Cost per Amp Hour or Kilowatt Hour (cost/total energy supplied)**
- **Lowest cost-per-month (cost / months of life)**
- **Lowest cost-per-cycle (cost / life cycles)** – Up to 30% more cycles than EV Traction Dry Cell types
- Up to 10 times the cyclic ability of standard AGM or Gel when discharged capacity exceeds 50%
- Up to 7 times the cyclic ability of standard AGM or Gel when discharged capacity exceeds 80%
- *> 650 cycles when discharged to 20% remaining capacity
- *> 1300 cycles when discharged to 50% remaining capacity
- *> 4000 cycles when discharged to 80% remaining capacity

* Actual results will vary depending upon application by battery, discharge rates, charging regime and temperature etc.

700 SERIES Dry Cell Disadvantages:

- Higher initial cost
- Heavier weight per Amp Hour of available power
- Water cannot be replaced if continually overcharged
- Typically cannot be used (without a 20% loss of life) to replace flooded types without verifying the applications existing chargers
- Automatic temperature-sensing, voltage-regulated chargers must be used
- Charge voltage must be limited (14.4 to 14.7 volts maximum at 25°C/77°F)

EV Traction Dry Cell & Gel Cell Advantages:

- It is a Discover® CLEAN &GREEN Non-Hazardous Dry Cell power block
- Classified as "NON-SPILLABLE BATTERY" Not restricted for Air (IATA/ICAO) Provision 67, Surface (DOT-CFR-HMR49) or Water (Non-hazardous per IMDG amendment 27) transportation
- Spill proof / leak proof
- No corrosion
- Highly acid starved. Very high active material to acid ratio for longer life in constant deep cycle applications
- Micro fibrous silicate glass mat acid absorption along with charge control eliminate water loss
- Excellent for multiple long or short duration deep discharges
- Excellent for Long Duration BACK UP POWER and RENEWABLE ENERGY applications
- Excellent for UPS/TELECOM and HIGH RATE applications
- Excellent in high discharge current applications
- Superior deep cycle life and superior energy density over Deep Cycle Gel or AGM batteries
- No loss of capacity as a result of viscous degradation or voids in gelled electrolyte
- Installs upright or on side for float service (side installation may lose 10%-15% capacity and life will be affected). Upright orientation highly recommended for high rate deep discharge service to prevent loss of performance and life.
- Very low to no gassing (unless overcharged). By design 70% less than regulations require even at increased temperature and charge voltage.
- Compatible with sensitive electronic equipment
- Superior shelf life
- Superior recharge ability (from 0% to 90% in 4 hours)
- Superior recharge ability (from 0% to 100% in 6 hours)
- Battery output efficiency in excess of 85% means less energy and timed used during recharge
- Rugged and vibration-resistant
- Very safe at sea with no chlorine gas in bilge (due to sulfuric acid and salt water mixing)
- May be recycled at any smelter that processes lead-acid batteries
- Operates in wet environments even under 30 feet of water
- Good in extreme temperature applications. Will not freeze to –20°F/-30°C (if fully charged).
- **Extremely good Life Cost per Amp Hour or Kilowatt Hour (cost/total energy supplied)**
- **Extremely good cost-per-month (cost / months of life)**
- **Extremely good cost-per-cycle (cost / life cycles)** – Up to 50% more cycles than standard deep cycle absorbed electrolyte batteries when discharged capacity exceeds 80%
- Up to 10 times the cycling ability of Deep Cycle Gel or AGM when discharged capacity exceeds 50%

- Up to 7 times the cycling ability of Deep Cycle Gel or AGM when discharged capacity exceeds 80%
- *> 500 cycles when discharged to 20% remaining capacity
- *> 1000 cycles when discharged to 50% remaining capacity
- *> 3000 cycles when discharged to 80% remaining capacity

* Actual results will vary depending upon application by battery, discharge rates, charging regime and temperature etc.

EV Traction Dry Cell & Gel Cell Disadvantages:

- Higher initial cost
- Heavier weight per Amp Hour of available power
- Water cannot be replaced if continually overcharged
- Typically cannot be used (without a 20% loss of life) to replace flooded types without verifying the applications existing chargers
- Automatic temperature-sensing, voltage-regulated chargers must be used
- Charge voltage must be limited (14.4 to 14.7 volts maximum at 25°C/77°F)

Deep Cycle AGM Advantages:

- It is a Discover® Non-Hazardous Dry Cell power block
- Classified as “NON-SPILLABLE BATTERY” Not restricted for Air (IATA/ICAO) Provision 67, Surface (DOT-CFR-HMR49) or Water (Non-hazardous per IMDG amendment 27) transportation
- Spill proof / leak proof
- No corrosion
- Severely acid starved. High active material to acid ratio for long life in cyclic applications
- Micro fibrous silicate glass mat acid absorption along with charge control eliminate water loss
- Good for multiple medium duration deep discharges
- Good for Medium Duration BACK UP POWER and RENEWABLE ENERGY applications
- Good for UPS/TELECOM and HIGH RATE applications
- Good deep cycle life with good starting ability
- Superior energy density over Gel batteries
- No loss of capacity as a result of viscous degradation or voids in gelled electrolyte
- Installs upright or on side for float service (side installation may lose 10%-15% capacity and life will be affected). Upright orientation highly recommended for deep discharge service to prevent loss of performance and life
- Very low to no gassing (unless overcharged) By design 70% less than requirements even at increased temperature and charge voltage
- Compatible with sensitive electronic equipment
- Superior shelf life
- Superior recharge ability (from 0% to 90% in 4 hours)
- Superior recharge ability (from 0% to 100% in 6 hours)
- No recharge current limitation @ 13.8~14.7 Volts
- Rugged and vibration-resistant
- Very safe at sea with no chlorine gas in bilge (due to sulfuric acid and salt water mixing)
- May be recycled at any smelter that processes lead-acid batteries
- Operates in wet environments…even under 30 feet of water
- Good in extreme temperature applications. Will not freeze to –20°F/-30°C (if fully charged).
- **Low Life Cost per Amp Hour or Kilowatt Hour (cost/total energy supplied)**
- **Low cost-per-month (cost / months of life)**

- **Low cost-per-cycle (cost / life cycles)** – Up to 40% more cycles than standard deep cycle absorbed electrolyte batteries when discharged capacity exceeds 80%
- Up to 7 times the cycling ability of standard AGM when discharged capacity exceeds 50%
- Up to 5 times the cycling ability of standard AGM when discharged capacity exceeds 80%
- *> 350 cycles when discharged to 20% remaining capacity
- *> 700 cycles when discharged to 50% remaining capacity
- *> 2000 cycles when discharged to 80% remaining capacity

* Actual results will vary depending upon application by battery, discharge rates, charging regime and temperature etc.

Deep Cycle AGM Disadvantages:

- Higher initial cost
- Heavier weight per Amp Hour of available power
- Water cannot be replaced if continually overcharged
- Typically cannot be used to replace flooded types without verifying the applications existing charger
- Automatic temperature-sensing, voltage-regulated chargers must be used and Charge voltage **must** be limited (14.4 to 14.7 volts maximum at 25°C/77°F)

Section VI – Why Discover®

Safety and productivity:

Today's purchase decisions are increasingly being made by safety supervisors, legal teams and cost accountants. Mining operations, transit companies, cities, hospitals, schools, airport authorities and manufacturing organizations – to name just a few multi-bank operator (MBOs) channels – are all required to implement rigorous risk management and environmental impact programs. These programs enable them to manage workplace hazards that may affect their employees, their communities and their environments. Failure to do so can result in injury and lead to civil or even criminal charges.

Discover® CLEAN &GREEN batteries are LEED certified and can help purchasers reduce these risks and improve their environmental performance. Discover® has responded to the needs of these industries for sealed non-spillable, and non-hazardous batteries in "DROP IN" replacement sizes. Discover® batteries meet the environmental and occupational health and safety compliance needs and, over the life of the product, save users money and time in service costs and compensation claims. The Discover® line of batteries has been designed and engineered with the footprints, performance and terminal options to respond to ALL of user's needs. From button terminals to Dual SAE / T type terminals to drop terminals for 4D and 8D types, the options are many. Matching chargers are also available. The Discover® line of batteries and chargers gives you an opportunity to develop sales and provide solutions in areas that were not available before, where the customer or user is appreciative of the unique features and benefits and where margins can be maintained and protected.

How can I manage the risks associated with batteries in my organization?

As a Multi-Station, Multi-System or Multi-Bank Operator, you are required to implement a rigorous risk management program that protects you, your employees, the community and the environment. You must be aware of the hazards associated with using batteries (particularly flooded batteries), Transportation Hazards, Community "Right to Know Acts", Environmental Compliances and more.

Discover® dealers are trained, willing and able to help you reduce the chance of

accidents. Because Discover® has the largest range of CLEAN &GREEN Sealed Valve Regulated (SVR) batteries in the world, our dealers can supply you with a battery to fit your needs. Battery options that will not gas, unless they are overcharged, reducing the chance of explosions. In fact, from as much as 1 in 1,000 for flooded batteries to as little as 1 in 1,000,000 for SVR batteries.

By using Discover® CLEAN &GREEN **non-hazardous** batteries you limit your risks associated with the Department of Transportation (DOT). Flooded batteries are considered hazardous material. Because of related dangers, your drivers must have a Commercial Driver's License with a hazardous materials endorsement. You may also be limited from carrying any other hazardous material in the vehicle at the same time (such as cleaners, petroleums, etc.) Discover® batteries are sealed non-spillable and they are labeled as such. Because they are clearly labeled and shipped with terminal protectors, they are exempt from certain restrictive DOT regulations.

If ignited in a fire the plastic, lead and acid contained in a battery can cause toxic fumes. Therefore, the Community Right to Know Act (read more on the EPCRA act of 1986 at www.epa.gov.com) requires reporting for batteries if sulfuric acid is present in quantities over 500 lbs (227 kgs.) and/or lead in quantities over 10,000 lbs. (4,545 kgs.). Storing 24 standard cable TV back up batteries or 20 standard golf cart batteries may make you liable to report as the acid content exceeds the limits. Violators are subject to fines up to $25,000.00. Discover® dealers can make just-in-time deliveries of your battery needs and help keep you updated with the information needed to comply with emergency planning in your communities.

Failure to dispose of used batteries can also lead to huge fines and criminal penalties. Used batteries not properly managed might end up in the hands of metal dealers who might dump the sulfuric acid to get at the lead. If your batteries are found in the garbage or a landfill you can be fined and held liable for cleanup costs. Discover® dealers can manage your risk associated with the environment. As professionals they collect and dispose of scrap everyday under strict transportation and reporting guidelines. By using Discover® Sealed Valve Regulated batteries from Discover® approved dealers, you can reduce many of your potential liabilities and better manage the risks associated with batteries within your organization. For more information, be sure to read the section on “How do I compare and make an informed buying decision when deciding between Flooded, AGM, Deep Cycle AGM, Series 700 and/or Gel batteries”.

CAUTION/DANGER:

Lead-acid batteries contain a sulfuric acid electrolyte, which can be poisonous and is highly corrosive. Flooded Lead-acid batteries will produce gasses when discharging and re-charging which can explode!
When working with batteries, you need to have plenty of ventilation, remove your jewelry, wear protective eyewear (safety glasses) and clothing, and exercise caution.

Do not allow battery electrolyte to mix with salt water. Even small quantities of this combination will produce harmful Chlorine gas.

Sales Channels

Air & Marine Emergency Service Centers / Navigation
Airline Equipment and Supplies
Bicycle Equipment and Sales
Boat Equipment and Supplies
Boat Manufacturing, Repair and Rigging
Business Machines
City, County, Airport Authorities
Crisis Centers
Communication Companies
Elevator Equipment and Supplies
Fire Equipment and Supplies
Gas Companies
Hospital Equipment and Supplies
Hotels and Casinos
Janitorial Supplies
Lighting
Manufacturing facilities
Materials Handling and Food Service Companies
Medical Supplies
Mining Operations
Motels
Motorcycles
Office Machines
Oilfield Equipment and Supplies
Pagers
Pet Stores
Photographers
Physician Equipment and Supplies
Police Supplies
Property Management Companies
Radio Stations
Recreational Vehicles
Rent to Own Stores
Rental Equipment
Research labs
Security Equipment and Supplies
Solar and Renewable Energy Organizations
Surveying instruments, Equipment and Supplies
Television Stations
Telecom Equipment Services and Supplies
Trailer manufacturing and Sales
Transit Authorities
Utility Boards and Companies
Vending Equipment and Supplies
Wheelchair and Mobility
X-Ray Equipment and Supplies

Industry around Batteries for the Photovoltaic (SOLAR) business

Alternative Energy Companies
Dealers networks of the Solar panel companies
Residential Grid Tie Systems
Residential Water Pumping
Residential RV and Marine
Residential Remote Home Systems
Commercial and Industrial Grid Tie Systems
Commercial and Industrial Communications
Commercial and Industrial Oil and Gas
Commercial and Industrial Traffic
Commercial and Industrial Railroad
Commercial and Industrial Lighting
Commercial and Industrial Rural Development
Commercial and Industrial Government/Military
Commercial and Industrial Greenhouses

Work Vehicle market and companies supplying solutions to the latest Key-Off legislation in the Class 8 truck industry

Section VII - Frequently asked General Questions and Answers

What is a Gel battery?

- Old mature technology that has been in use since the early 1950's
- Uses various plate thicknesses relative to application and cost requirements
- Is sealed using special pressure valves and should never be opened
- Typically uses Calcium/Calcium metal alloys
- It is maintenance-free with proper charge controls
- Uses various degrees of gelled electrolyte depending upon manufacturer
- Acid to active material ratios along with acid specific gravities may vary according to application and market costing requirements. ******* User/integrator should note and verify.
- 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)
- Is non-spillable

What is an AGM battery?

An AGM battery is a lead-acid electric storage battery that:

- Uses various plate thicknesses relative to application and cost requirements
- Is sealed using special pressure valves and should never be opened
- Typically uses Calcium/Calcium metal alloys
- With proper charge controls is maintenance-free
- Has its entire electrolyte absorbed in separators consisting of a sponge-like mass of matted glass fibers
- Acid to active material ratios along with acid specific gravities may vary according to application and market costing requirements. ******* User/integrator should note and verify.
- Uses a recombination reaction to prevent the escape of hydrogen and oxygen gases normally lost in a flooded lead-acid battery (particularly in any cycling applications)
- Is non-spillable

*** Available amounts of usable amp hours CAN BE ADJUSTED BY AS MUCH AS 30% by adjusting the acid and active material densities. Buyers should be aware that increasing acid specific gravities and acid to active material ratios will severely reduce the batteries life cycle expectancy as well as increase the available usable power per discharge cycle. For example a 75 amp hour battery can be made to deliver 100 amp hours by increasing the acid to active material ratio and the specific gravity of the acid. Both of these adjustments will severely reduce the life of the battery. Therefore, if you are quoted an unbelievable price on a 100AH battery given the current market pricing, you may now know why!

What is a Flooded battery?

A Flooded battery is a lead-acid electric storage battery that:

- Can be both sealed and open-vented
- Can use High Antimony, Low Antimony or Calcium metal alloys or a combination of Calcium and Low Antimony grids (hybrid)
- Requires maintenance in cyclic applications
- Its entire electrolyte volume is free to move within the cell with nothing to prevent the escape of hydrogen and oxygen gases normally lost during charging and discharging (particularly in deep cycle applications)
- Is considered Flooded because it has excess electrolyte which allows the plates to be completely and even over discharged while delivering the batteries usable power
- Escaping gasses in the discharge/charge cycle can be detrimental to users, sensitive electronic equipment and the environment due to its corrosive nature.

- Is spillable, and therefore, can only be operated in an upright position. This includes sealed maintenance free versions of the flooded battery type.
- Is classified as Hazardous

What are the differences between Gel batteries and Absorbed glass mat (AGM) batteries?

Both Gel and AGM batteries are recombinant batteries. Both are sealed and valve regulated and are considered non-spillable and both are considered “acid-starved.” In an AGM or Gel battery, the electrolyte does not flow like a normal liquid. In AGM batteries all liquid electrolyte is trapped in a sponge-like matted glass fiber separator material. In a Gel battery the electrolyte is mixed with an additive which changes it into a gelled consistency.

The “acid-starved” condition of Gel and AGM batteries protects the plates during heavy deep-discharges. The more acid starved the batteries are, the more protection is given to the active materials.

Due to the physical properties of the gelled electrolyte, Gel battery power declines faster than an AGM battery’s as the temperature drops below 32°F (0°C). AGM batteries excel for high current, high power applications and in extremely cold environments. Gel batteries tend to lie longer in hot climates.

Flooded batteries are more easily replaced by AGM batteries than Gel batteries as Gel batteries require different (precisely controlled) charging algorithms (mainly lower finishing voltages) to excel and ensure proper live than do either AGM or Flooded types.

Note that the difference between Gel and AGM batteries for higher current, high power applications is very small until extremely low temperatures are experienced.

What is the difference between VRLA (Gel or AGM) batteries and traditional wet or flooded batteries?

- Wet or flooded batteries do not have special pressurized sealing vents, as they do not work on the recombination principle
- Wet batteries contain excess liquid electrolyte that can spill and cause corrosion if tipped or punctured
- Wet batteries are not air transportable without special containers and they cannot be shipped via Express Courier or Parcel Post
- Wet batteries should not be used near sensitive electronic equipment
- Wet batteries can only be installed “upright”
- Because of the cost in time (man-hours), service products (distilled water etc), damaged clothing, and polluted environments when being charged and/or discharged, wet batteries may actually end up costing more money to own over the life of the battery than do high quality VRLA batteries. Some brands of wet or flooded automotive batteries are also marketed and sold as sealed or maintenance-free, but they are still flooded cell batteries - not “acid-starved” - and they DO NOT have the same pressurized venting system and will spill electrolyte if not maintained in an upright position.
- Wet 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 for High or Low Antimony and/or Hybrid types.
    - They are continually over-discharged due to active material shedding. This is especially true for automotive starting types and “so-called” marine/RV combination cycling/starting batteries that are now being sold by many manufacturers as cheap alternatives to true deep cycle batteries.

A key feature of VRLA-batteries is the process of recombination of oxygen during the charge process. The cycle starts at the positive plate. Water is broken down and gaseous oxygen is formed. The hydrogen ions remain dissolved in the electrolyte and are not released as gas, which is the case with vented wet type batteries. The electrons move away via the positive plate.

What happens now to the oxygen as it makes its way to the negative plate is different in wet vented batteries than it is in VRLA batteries.

- In wet or flooded lead-acid batteries of the vented design with excess electrolyte, it is practically impossible for the oxygen to move to the negative plate. Immediately after having left the positive plate, it bubbles up and escapes through the vent plug.
- In VRLA batteries, a densely porous medium is offered to the oxygen to facilitate its movement. The porous medium in an AGM VRLA battery is the glass mat. The porous medium in a Gel VRLA battery is the cracks in the gelled electrolyte.

Figure 1 shows a comparison between vented battery gassing and VRLA battery recombination.

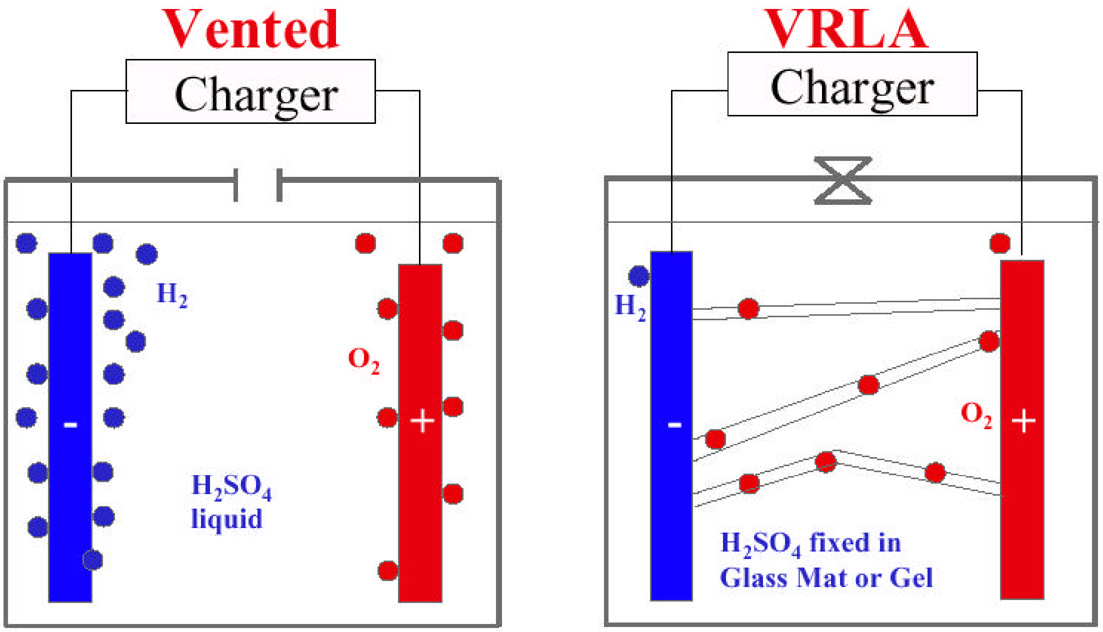

Figure 1 - Vented Battery Gassing and VRLA Battery Recombination.

How does a Discover® Gel or AGM VRLA battery work?

Discover® VRLA batteries are designed using proven gas recombination technology which removes the need for regular water addition by controlling the evolution of hydrogen and oxygen during charging. This means that the oxygen normally produced on the positive plates of all lead-acid batteries is absorbed by the negative plate through a porous medium (see Figure 1) without being vented. This suppresses the production of hydrogen at the negative plate. Water (H_20) is produced instead, retaining the moisture within the battery. **It never needs watering, and should never be opened** as this would "poison" the battery with additional oxygen from the air.

The retained oxygen produces an over-pressure within the cell. This is normal. The battery's sealing valves should not open at too low pressure because this would allow too much oxygen to escape and be irretrievably lost. If the defined opening pressure is achieved, the sealing valve will open for a short time to release over-pressure caused by the accumulated gas. Under normal operating conditions this gas consists mainly of hydrogen. Under unfavorable conditions, (high charge voltages at high temperatures, for instance) oxygen would also escape. In high quality VRLA batteries, the quantity of electrolyte as a ratio to active material (plates and oxides) is controlled in such a way as to allow the battery to attain an expected performance and design life under normal operating conditions, taking into account:

- The rate of recombination
- The corrosion of the positive electrode (oxygen consumption)
- The losses by diffusion through the cell container

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 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 batteries do not exhibit this "use it" or "lose it" capacity robbing effect known as memory. It is important to note, however, that if any lead-acid battery is left unattended and discharged for extended periods of time its ability to do its job will be diminished and eventually extinguished.

Why are calcium grids used in VRLA batteries for deep cycle applications?

The Calcium alloy used in Discover® VRLA batteries gives the grid the necessary mechanical stability it needs as well as guarantees low gassing behaviors. The tin added to the alloy provides higher corrosion resistance and increased cycle life. Discover® alloy's using calcium also allow for a very efficient battery with low resistance. In addition, Discover® pays a great deal of attention to the overall electrochemical battery design details when producing our High Quality Calcium Deep Cycle VRLA batteries including:

- Over dimensioning the negative active material to ensure the negative plate is never fully charged
- Tightly controlling the specific gravity and volume of electrolyte in such a way that the battery attains the expected design life (under normal operating conditions), taking into account:
    - The rate of recombination
    - The corrosion of the positive electrode (oxygen consumption)
    - The hydrogen diffusion rate that may occur through the cell container

Why do Discover® batteries have longer cycle life than others?

- Super pure grid alloys which incorporate proprietary additives that increase the surface area of the plate which ultimately helps to retard corrosion and extend the life of the grid
- Using thicker grids (>3.5mm) achieves more corrosion resistance than thinner grids
- Discover® VRLA batteries are protected against deep discharge because they are "acid-starved", and in the case of the Discover® 700 SERIES and the Discover® EV Traction DRY CELL types, "extremely acid starved." This means that the battery uses the power in the acid before it uses the power in the plates. Therefore, the plates are never subjected to destructive ultra-deep discharges. More technically speaking, the quantity of electrolyte must be tightly controlled in such a way that the battery attains the expected design life (under normal operating conditions), taking into account the rate of recombination and the corrosion of the positive electrode.
- Discover® uses more active material per amp hour of battery capacity, which ultimately results in a ***"more"*** acid starved reaction meaning, that even when the battery is discharged deeply (the sulfuric acid in the electrolyte is used up and absorbed by the active material in the process of discharge) the active material utilization is kept to a minimum. More technically speaking, the active material is over dimensioned to ensure that all of the active material is never completely charged or discharged in the discharge and charge cycle. Depending upon the part number, Discover® 700 Series Dry Cell and EV Traction Dry Cell batteries contain as much as:
    - 77% more active material than Flooded Deep Cycle batteries
    - 33% more active material than competitive VRLA Deep Cycle batteries
- Discover® Gel batteries contain ultra-premium poly, ribbed glass-mat, dual-insulating separators which will not break down in service. The glass mat embeds itself into the plate, which retards life-shortening shedding.
- Discover® High quality Dry Cell batteries contain glass separators at the ideal compression and ideal saturation to achieve the best balance between capacity utilization and

recombination efficiency. The dual insulating separators also help to prevent separator misalignment and treeing or shorting at the bottom and sides of the plates. The glass embeds itself into the plate, which retards shedding.

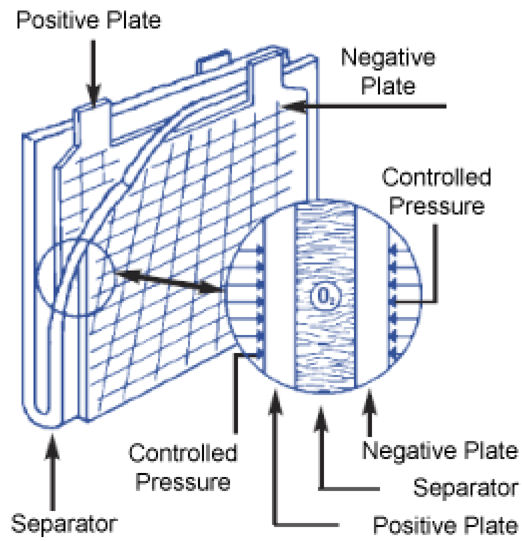

Figure 2 - Plate with AGM Separate

Why do Discover® VRLA batteries have excellent shelf life?

Discover® uses higher quality superior grids, premium separators and pure electrolyte which make the difference in preventing prematurely high self-discharge rates. Impurities in the lead alloy, separators and electrolyte cause tiny currents inside a cell which eventually discharge the battery and shorten its shelf life. Premium inter-cell welds block the slight cell-to-cell currents that cause self-discharge.

Can Discover® 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 as described above in “How does a Gel or AGM VRLA battery work”, oxygen and hydrogen will escape from the battery in an overcharge condition. For safety’s sake, these potentially explosive gasses must be allowed to vent to the atmosphere and must never be trapped in a sealed battery box or a tightly enclosed space! Under normal conditions, Gel and AGM batteries will produce little if any dangerous gas. Heat, however, can be generated during the charge and discharge process. To ensure the longest life for the battery, it is important that this heat is allowed to dissipate as quickly as possible.

Can Discover® VRLA batteries be used as starting batteries as well?

Discover® VRLA batteries will work in starting applications as long as the charging voltage is regulated appropriately. Many vehicle regulators are set too high for Gel batteries; therefore, the charging system may require adjustment to properly charge a Gel VRLA battery for best performance and life. Both Gel and AGM batteries excel as combination cranking / reserve capacity storage batteries. In low temperatures AGM batteries will perform better than gelled electrolyte batteries. As a general rule, if you are going to use a true deep cycle AGM, Traction Dry Cell, Gel or Flooded battery as a starting battery also, you should increase the reserve capacity or AH rating of the original battery by between 20 and 30%. Modern engines with

Electronic Fuel Injection (EFI) and electronic ignition generally require much less total battery power (CCA) to start. However, most have higher minimum voltage requirements that must be maintained under load for the EFI to work properly, therefore, larger ampere hour (Reserve Capacity - RC) requirements are a must. To convert AH to cranking amps you can generally multiply the batteries AH rating by 6 or 7. To convert RC to Ampere-Hours at the 25 amp rate, multiply RC by .4167.

How can I convert Reserve Capacity to amp hours at a 25 amp discharge rate?

To convert 25 amp Reserve Capacity to Ampere-Hours at the 25 amp rate, multiply RC by .4167. More ampere-hours (or RC) are better in every case when looking for a deep cycle battery. Within the same battery footprint or industry group size, the battery with higher ampere hours (or RC) will tend to deliver longer cycle lives. This conversion method will allow you to convert and compare competitive data.

Do I need to do anything special when installing batteries on or near water?

Installing batteries in marine applications (especially salt water) requires some special attention. The cable used needs to be marine approved and should be tinned copper. If you use any other type of cable, be prepared to spray and coat the cable and connections with silicone. Use silicone lined heat shrink tubing to cover terminal connections. The main concern is obviously keeping the marine atmosphere away from any exposed terminals or connections.

CAUTION/DANGER: Do not allow battery electrolyte to mix with salt water. Even small quantities of this combination will produce Chlorine gas that can KILL you!

Why can't Discover® VRLA batteries be opened?

Discover® VRLA (Valve Regulated Lead-Acid) batteries work on a recombination principle. Oxygen gas is produced at the positive plates during charge. The charged negative plates react first with this oxygen and subsequently with the electrolyte. Water is produced and the negative plates are slightly discharged. Additional charging recharges the negative plates instead of producing hydrogen gas. Since very little hydrogen and oxygen is lost and the water (H_20) is retained, we say that the gasses have recombined. To work properly, the oxygen produced must be retained in the battery until the reaction is completed. Positive pressure allows the gas to be retained. If any VRLA (gelled or absorbed electrolyte) battery is overcharged, gas will be vented from the valves. Hydrogen as well as oxygen will be released. If continued, the electrolyte will eventually dry out and the battery will fail prematurely. This is why charging limits are so critical. In a sealed battery a balance is maintained between the hydrogen, oxygen and charge. If a VRLA battery is opened:

- The negative plates are exposed to extra oxygen from the atmosphere
- This excess oxygen upsets the balance
- The negative plates become discharged
- The positive plates may be subsequently severely overcharged
- The battery will fail prematurely

Why do some Discover® VRLA batteries bulge?

To prevent the permanent loss of gases so that recombination has time to take place, each cell can hold approx. 1.6 pounds per square inch (psi) of pressure without venting. Large batteries with very large cells will bulge somewhat as this normal pressure builds. This is especially true in higher temperatures, because the polypropylene case is pliable. Therefore, a certain amount of bulge is normal. The valves only let gas out, never in. A partial vacuum can form within a sealed battery under various circumstances. Battery temperature and ambient pressure play a role, but predominantly the recombination and discharge reactions are responsible. After charging ends, the recombination reaction continues until most of the oxygen in the battery is consumed. The total volume within the battery decreases slightly during a discharge. Deeply discharged batteries often have a “sucked-in” appearance. Batteries with large cells may display this appearance even when fully charged. If a battery bulges severely on charge, it may be an indication of a blocked valve or an overcharged situation. When a battery is in this situation, it should be removed from service.

Why do some Discover® VRLA batteries appear sucked in?

A sucked-in appearance is quite normal. A sucked-in-battery should be charged, but if it remains sucked-in after charging, the appearance can safely be ignored. However, if only a single cell displays or lacks this appearance a load test would be prudent. A partial vacuum can form within a sealed battery under various circumstances. Battery temperature and ambient pressure play a role, but predominantly the recombination and discharge reactions are responsible. After charging ends, the recombination reaction continues until most of the oxygen in the battery is consumed. The total volume within the battery decreases slightly during a discharge. Deeply discharged batteries often have a “sucked-in” appearance. Batteries with large cells may display this appearance even when fully charged. To prevent the permanent loss of gases so that recombination has time to take place, each cell can hold approx. 1.6 pounds per square inch (psi) of pressure without venting.

Are Discover® Gel and AGM batteries approved for air transportation?

Yes. Discover® VRLA batteries are approved for air transport by the F.A.A., I.A.T.A. and the D.O.T. This information is stated on a label located on the battery.

How do I increase the capacity of my Discover® battery and system?

The capacity of your individual batteries cannot be increased from its original capacity. However, strings of batteries can be easily connected together to increase a system's voltage or its capacity. To increase the voltage of a system you must connect multiple batteries in Series.

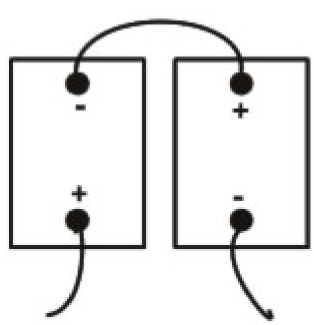

Figure 3 - Series Connections

To increase a system's capacity (amp hours, reserve capacity) connect multiple batteries in Parallel.

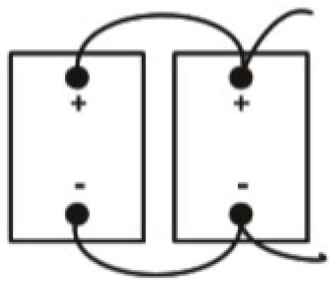

Figure 4 - Parallel Connections

To increase both the system's voltage and the capacity, connect multiple batteries in Series and in Parallel.

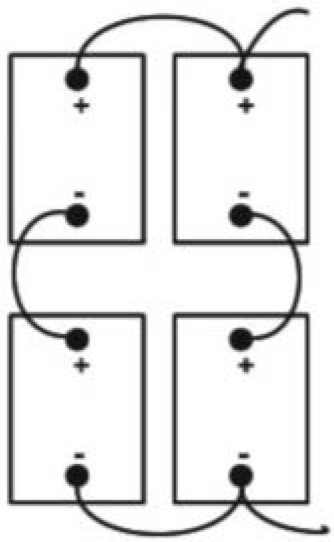

Figure 5 - Series/Parallel Connection

If more capacity is required, as mentioned above, multiple batteries can be connected in Parallel (positive terminal of Battery One to the positive terminal of Battery Two and so on).

Parallel Connections for UNSOPHISTICATED USERS and INSTALLERS:

Only use new and identical batteries. If you connect two 12-volt batteries in parallel and they are identical in type, age and capacity, you can potentially double your original capacity. If you connect two that are not the same type, you will either overcharge the smaller of the two, or you will undercharge the larger of the two. If you connect two that are identical, but one being older, you will definitely reduce the life of the new one. When connecting in series or parallel and to prevent recharging problems, do not mix old and new batteries or ones of different chemistries or performance abilities. Cable lengths should be kept short and cabling must be sized large enough to prevent significant voltage drops. There should be a maximum drop of 0.2 volts (200 milli-volts) between batteries.

Parallel Connections for SOPHISTICATED USERS and INSTALLERS:

While most manufacturers stipulate not to install more than 4 strings of paralleled batteries, It is possible to have more strings in parallel without reducing the life of the battery or the batteries getting out of balance. General conditions and features that apply for up to 10 strings in parallel are:

- The same voltage drops must be realized from each string to the end connection (load and ground) regardless if the string consists of one unit (single cell or monobloc) or several units

- This can be achieved by proper choice of cable lengths, cable diameters and arrangement for crosswise connection configurations
- The connector cables for positive and negative terminals of each battery string must have the same length
- The minimum cable size for the end connectors of a string is $25mm^2$/100 Ah of string capacity
- The end-connector cables must be placed on a copper bar with at least $100mm^2$/100 Ah of string capacity with the shortest possible distance
- It is a must to have a circuit breaker for each string
- The strings must have all the same number of cells
- Each string must be exposed to the same heat or temperature potential

If these requirements are fulfilled then paralleling of up to 10 strings is possible. The performance data of all of the batteries has to be applied to the end terminal of each string. By using this parallel string configuration, the reliability of the system is increased due to the redundancy. Neither battery life or reliability will be affected if this form of paralleling is done correctly. Parallel connection of strings with different capacities as well as different ages is possible (the age and capacity of the batteries within each string should be the same). The current during both discharge and charge will be split according to the capacity or age of the batteries, respectively. Also, the type of lead-acid batteries may differ as long as the required charging regime and voltage (Vpc) per string is guaranteed. Always connect the individual series strings first and check that the different strings are at the same potential before connecting them together.

Will a battery explode?

Recharging a flooded lead-acid battery normally produces hydrogen and oxygen gasses. Spark retarding vent caps can help prevent explosions in flooded battery types. Explosions typically occur when jumping, connecting or disconnecting battery chargers or battery cables, and under load or while starting the engine. While not fatal, battery explosions cause thousands of eye and burn injuries each year. Below are the usual sequence of events when battery explosions occur with a flooded battery in a starting application:

- One or more cells had a concentration of hydrogen gas *above 4.1%* because the vent cap was plugged or a defective valve did not release the gas. An explosion requires a concentration of hydrogen above 4.1%!
- The electrolyte levels fell below the top of the plates due to high under hood temperatures, overcharging, or poor maintenance resulting in excessive gassing
- A low resistive bridge or “treeing” formed between the top of the plates such that when the current started to flow, it caused an arc or spark in one of the cells above the electrolyte level
- A combination of the above events ignites the gas, blows the battery case cover off and spatters electrolyte all over the engine compartment

The largest number of battery explosions while starting an engine occurs in hot climates. When an explosion happens, thoroughly rinse the engine compartment with water, and then wash it with a solution of one-pound (.5Kg) of baking soda to one gallon (4L) of warm water to neutralize the residual battery acid. Then thoroughly rewash the engine compartment with water.

Using Discover® AGM or Gel batteries can significantly reduce the possibility of battery explosions.

Do batteries last longer in hot climates than in cold ones?

Batteries used in colder or moderate conditions can last between twice and three times as long as batteries used in hot climates or high heat conditions. Heat kills batteries! In the northern US states, in Canada or in Northern Europe, the life expectancy of an automotive battery is between 48 and 54 months. In more Southern Climates like the state of Florida in the USA, the average life expectancy of standard automotive batteries is about 18 to 23 months. This data is based on normal usage and very good charge and discharge conditions.

How can I tell if my battery has reached the end of its useful life?

Different types of batteries use test procedures that allow different end of life criteria. For example:

- An electric vehicle or standard deep cycle product would be considered to be at its end of life when it was not able to deliver 50% of its rated capacity
- A golf cart battery would not be determined to be at its end of life until it was not able to produce at least 1.75 volts per cell during 40 minutes of discharge at 75 amperes
- Most official tests to determine the cycle life of a battery are performed in laboratories under controlled circumstances and temperatures. For the average user, it is important to make sure that the battery is being charged properly and that the temperature during evaluation is not extreme (outside of 18°C and 28°C for example).
- As documented by Battery Council International BCIS section 6 Rev. DEC02 the measurement of the end of life cycle performance of a battery is defined, as the point at which the battery will not deliver at least 50% of the manufacturers rated capacity when discharged at the 2 hour rate.

Section VIII - Frequently asked Storage and Maintenance Questions and Answers

What do I do if I have to store my batteries outside for winter?

VRLA batteries can be stored in sub-freezing temperatures as low as -25°F ~ -35°F as long as they are fully charged prior to storage. The self-discharge rate of fully-charged batteries is very low in these conditions and they will not require charging for many months. However, if your VRLA batteries do freeze, they may not always recover. To attempt recovery bring them inside and let them sit until the temperature of the battery reaches the temperature of the room, approx. 68°F, then charge the batteries normally. You may have to cycle the battery a couple of times before making a decision on its final condition.

What is the freezing point of electrolyte?

Table 1 - Electrolyte Freezing Point

Digital Voltmeter	State of Charge	Hydrometer Reading	Electrolyte
Open Circuit Volts	Approximate	Specific Gravity	Freezing Point
12.65	100%	1.265	-75° F (-59.4° C)
12.45	75%	1.225	-55° F (-48.3° C)
12.24	50%	1.190	-34° F (-36.7° C)
12.06	25%	1.155	-16° F (-26.7° C)
11.89	Discharged	1.120	-10° F (-23.3° C)

How do I compensate for temperature in my hydrometer readings?

If you are using a non-temperature compensated hydrometer, make the adjustments shown in the table below. For example, at 30° F (-1.1° C), the specific gravity reading would be 1.245 for a 100% State-of-Charge. At 100° F (37.8° C), the specific gravity would be 1.273 for 100% State-of-Charge. This is why using a temperature compensated hydrometer is highly recommended and more accurate than other means when testing flooded battery types. For non-sealed batteries, check the specific gravity in each cell with a hydrometer and average the readings.

Table 2 - Hydrometer Temperature Compensation

Temperature	Add or Subtract to Hydrometer Reading	Add or Subtract to Voltmeter Reading
0° / -17.8°	-.032	-.192
10° / -12.2°	-.028	-.168
20° / -6.7°	-.024	-.144
30° / -1.1°	-.020	-.120
40° / 4.4°	-.016	-.096
50° / 10°	-.012	-.072
60° / 15.6°	-.008	-.048
70° / 21.1°	-.004	-.024
80° / 26.7°	0	0
90° / 32.2°	+.004	+.024
100° / 37.8°	+.008	+.048
110° / 43.3°	+.012	+.072
120° / 48.9°	+.016	+.096
130° / 54.4°	+.020	+.120
140° / 60.0°	+.024	+.144
150° / 65.6°	+.028	+.168
160° / 71.1°	+.032	+.192

How do I compensate for temperature in my voltmeter readings?

If you are using a digital voltmeter, make the adjustments indicated in the table below. For example, at 30° F (-1.1° C), the voltage reading would be 12.53 for a 100% State-of-Charge. At 100° F (37.8° C), the voltage would be 12.698 for 100% State-of-Charge. For sealed batteries, measure the Open Circuit Voltage across the battery terminals with an accurate digital voltmeter. This is the only way you can determine the State-of-Charge on sealed non-accessible batteries.

Table 3 - Voltmeter Temperature Compensation

Temperature	Add or Subtract to Hydrometers Reading	Add or Subtract to Voltmeter Reading
0° / -17.8°	-.032	-.192
10° / -12.2°	-.028	-.168
20° / -6.7°	-.024	-.144
30° / -1.1°	-.020	-.120
40° / 4.4°	-.016	-.096
50° / 10°	-.012	-.072
60° / 15.6°	-.008	-.048
70° / 21.1°	-.004	-.024
80° / 26.7°	0	0
90° / 32.2°	+.004	+.024
100° / 37.8°	+.008	+.048
110° / 43.3°	+.012	+.072
120° / 48.9°	+.016	+.096
130° / 54.4°	+.020	+.120
140° / 60.0°	+.024	+.144
150° / 65.6°	+.028	+.168
160° / 71.1°	+.032	+.192

How long will my Discover® battery last?

How long a battery will last in terms of its usable life depends completely on how often the battery is discharged and charged, how fast or at what rate it is discharged and charge, to what extent it is discharged or the depth of discharge, and how well or properly it is recharged. It is most important to make sure the battery is sized properly given the job it will be required to do, that correct low voltage cutoff voltages are used to protect the battery from constant over-discharge and that proper charging is ensured relative to the type of service. Contact your Discover® representative or Discover® engineering for assistance.

Will a battery lose its charge sitting in storage?

Depending on the battery's chemistry and type, batteries in storage will have a self-discharge or internal electrochemical "leakage" of between 1% and 15% per month. This internal or self-discharge rate will cause the battery to become sulfated and fully discharged over time. Higher temperatures accelerate this process. A battery stored at 95° F (35° C) will self-discharge twice as fast than one stored at 75° F (23.9° C). Discover® AGM or Gel batteries will naturally discharge at approximately;

- less than 2% per month when stored at 8°C/46°F
- 3% per month when stored at 20°C/68°F
- 5% per month when stored at 30°C/86°F
- 10% per month when stored at 40°C/104°F

How can I tell if my battery needs to be replaced?

You should replace the battery if one or more of the following conditions occur:

- If there is a .05 (sometimes expressed as 50 "points") or more difference in the specific gravity reading between the highest and lowest cells of a flooded battery. This means the flooded battery you are testing has a weak or dead cell(s).
- If the battery will not recharge to a 75% or more state-of-charge level.
- In an automotive battery with a built-in hydrometer that still does not indicate "good" after charge (usually the hydrometer will show green or blue which represents 65% state-of-charge or better, then the battery should be replaced).
- If a digital voltmeter indicates 0 volts on a battery, you know to have been charged properly, you have an open or short circuited cell and you should replace the battery.
- If a digital voltmeter indicates 10.45 to 10.65 volts on a battery you know to be a fully charged battery, then the battery probably has a shorted or dead cell.
- If the battery is fully charged, has a "good" built-in hydrometer indication or a good voltmeter indication then you can test the capacity of the battery by applying a known load and measuring the time it takes to discharge the battery until 20% of its originally published capacity is remaining

Note: Different types of batteries use test procedures that allow different end of life criteria. For example, Battery Council International BCIS section 6 Rev. DEC02 states that the measurement of the end of life cycle performance of a battery is defined as the point at which the battery will not deliver at least 50% of the manufacturers rated capacity when discharged at the 2 hour rate; while a golf cart battery would not be determined to be at its end of life until it was not able to produce at least 1.75 volts per cell during 40 minutes of discharge at 75 amperes.

Depending on your application, batteries that have reached a performance level of 50% or less of their original capacity will most likely not meet your operational needs. Discover® thinks that in most commercial applications where productivity is key, batteries that do not reach 80% of original capacity should be replaced. If the battery passes the load test, you should recharge it as soon as possible to restore it to peak performance and to prevent lead sulfation. Always consider the temperature when making your evaluation and that the batteries are being properly charged.

Can I store my Discover® battery in my garage during the winter or will it freeze?

Provided the batteries are maintained in a fully charged status, Discover® Sealed Valve Regulated batteries can be stored in temperatures as low as -25°F without freezing.

Can I store my Discover® battery on a concrete floor?

A hundred years ago when battery cases were made of porous materials, such as wood, storing batteries on concrete floors would accelerate their discharge. This is no longer a problem as modern battery cases, made of polypropylene or hard rubber, are sealed against external leakage which causes discharge. However, the top of the battery must be kept clean and dry. Temperature stratification within large batteries could accelerate the self-discharge if the battery is sitting on a cold floor in a warm room or is installed in a submarine.

Section IX - Frequently asked Charge/Discharge Questions and Answers

Selecting a charger

Most deep cycle applications have some sort of charging system already installed for battery charging (e.g. solar panels, inverter, golf car charger, alternator, etc.). However, there are still systems with deep cycle batteries where an individual charger must be selected. Also, when changing between Flooded, AGM and Gel type batteries, the existing charger may need to be changed and/or the voltage cutoffs reset. Chargers installed by most high quality original equipment manufacturers have selector switches built into their systems that allow the user to change between Flooded and Gel type batteries.

What follows will help in making a proper selection.

There are many types of chargers available today. They are usually rated by their voltage and their start rates, or the rate in amperes that the charger will supply at the beginning of the charge cycle. When selecting a charger, the charge rate should be between 10% and 30% of the battery's 20-hour AH capacity. For example, a battery with a 20-hour capacity rating of 100 AH should use a charger rated between approximately 10 and 30 amps (for multiple battery charging use the AH rating of the entire bank to determine the charger rating required).

We recommend using a charger from one of the high quality charger manufacturers Discover® has approved. OEM chargers with Discover® approved charge curves prolong battery life and enhance performance. Alternatively, we recommend using a 3-stage voltage compensating and temperature sensing charger. These chargers usually have three distinct charging stages: bulk, acceptance, and float. Some chargers that claim to have an equalize mode or stage should not be used on AGM or Gel batteries. Discover® approved chargers have "Balance Charge" modes included in their "single cycle" charge algorithms. Balance Charging is similar to an equalize charge but it is performed using specific temperature adjusted current, voltage and time data.

WARNING – DO NOT EQUALIZE CHARGE Gel OR AGM BATTERIES! Equalizing is an "over voltage-over charge" performed on flooded lead-acid batteries after they have been fully charged. It helps to eliminate stratification and sulfation, two of many conditions that can reduce the overall performance and life of a flooded battery. Laboratory designed, specific to Discover®, "Balance" charge algorithms have been designed and are included in all Discover® recommended Industrial Commercial charges offered for sale wherever our Discover® VRLA products are sold. Visually the Balance Charging curve is similar to a flooded equalize charge curve in its finishing voltage, but it is strictly controlled to promote active material conversion and not to prevent acid stratification. Discover®'s Balance charging algorithms are HIGHLY recommended for batteries being installed in strings, larger batteries using taller plate groups and/or with batteries constantly being subjected to high rate deep discharges.

Charging

Charging batteries properly requires administering the right amount of current at the right voltage. The original instructions for your charging equipment should be referenced for proper charging. Here is a list of helpful items to remember when charging.

1. Become familiar with and follow the instructions issued by the charger manufacturer.
2. Batteries should be charged after each period of use.
3. Lead-acid batteries do not develop a memory and does not need to be fully discharged before recharging.
4. Charge flooded batteries only in well-ventilated areas. Keep sparks or flames away from a charging battery.
5. Verify charger voltage settings are correct for the type of battery you are charging (Flooded, AGM or Gel).
6. Correct the charging voltage to compensate for temperatures above and below 25°C/77°F.

Compensation for battery temperature above or below 25°C/77°F can be made by subtracting 0.005 volts per cell for each 1°C above 25°C or by adding 0.005 volts per cell for each 1°C below 25°C (subtract .028 volt per cell for every 10° above 77° F and add .028 volt per cell for every 10° below 77° F).

7. Check water level on flooded batteries (see the Watering section).
8. Tighten all vent caps on flooded batteries before charging.
9. Prevent overcharging the batteries. Overcharging causes excessive gassing (water breakdown), heat buildup, and battery aging in flooded batteries and will dry out the electrolyte and damage VRLA batteries.
10. Prevent undercharging the batteries. Undercharging causes stratification.
11. Do not charge a frozen battery; allow it to thaw at room temperature.
12. Avoid charging at temperatures above 50°C/125°F.

General charging information for AGM and Gel batteries:

1. Only charge Gel batteries using a confirmed and reliable temperature sensing voltage regulated charger. Never use a constant current charger!
2. Charging Current or Amps is the flow of electricity. Every battery can only store, deliver or receive a certain amount of electricity. Voltage is electrical pressure. The amount of voltage dictates the rate at which the amps will be forced into the battery during the re-charge process. The temperature at which this process is taking place also affects charging. When the right pressure is used, at the right temperature, the battery will be charged at its optimal rate. If too much pressure is used, current or charge will be forced through the battery faster than it can be stored. This will cause the battery to give off hydrogen and oxygen faster than it can be recombined leading to the destruction of the battery. A warmer battery accepts re-charge easier.
3. At 25°C/77°F keep charging current in the range of 2.38 volts to 2.42 volts per cell for Gel cell batteries.
4. At 25°C/77°F keep charging voltage in the range of 2.4 volts to 2.465 volts per cell for AGM batteries.
5. Compensation for battery temperature above or below 25°C/77°F can be made by subtracting 0.005 volts per cell for each 1°C above 25°C or by adding 0.005 volts per cell for each 1°C below 25°C (add .028 volt per cell for every 10° below 77° F and subtract .028 volt per cell for every 10° above 77° F).
6. When re-charging, take into consideration that in order to replenish the ampere hours removed in the discharge process, you will need to replace 104% to 112% of the charge removed. Also, the time it will take to re-charge will depend on certain variables such as the depth of the discharge, the ambient and battery temperature, the age/condition of the battery and the charger's overall features. Typically you should expect that it will take 60% of the charge time to return the battery to within 90% of its original capacity. It will take the remaining 40% of the charge time to completely recharge the battery.
7. The process of re-charging a battery should be considered completed when the charge rate drops below or equal to the battery's self-discharge rate. For example, a 100AH battery with a 3% self discharge rate should be considered to be re-charged when the charge rate reaches and remains stable at 3 amps.

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Gel battery charging:

The first stage in a 3 or 4 stage charging algorithm is the “Bulk Stage.” Typically the Bulk Stage is a “Constant Current” (CC) charge but may also be Constant Power, Pulse Current or Taper Charge. In this stage, the optimum charge current should be limited to less than or equal to 20 amps per 100 ampere hour (20 hour rate) of battery capacity or .2C. This stage should end when the cell voltage is equal to 2.38-2.42V/Cell at 25°C/77°F. The maximum time in hours should = 1.2 times the DOD (in AH) divided by the average charge current in amps. If this time is exceeded, charging should be stopped and the battery and/or charge process should be analyzed. This stage will represent approximately 60% of the total charge time. The battery will be nearing 80%-90% charged at the end of this stage.

The second stage is the “Absorption Stage.” Typically this stage is a Constant Voltage (CV) stage where the terminal voltage is maintained at 2.38-2.42V/Cell at 25°C/77°F (adjusting for temperature). The charge current is maintained until current acceptance drops by less than .1 ampere over a 1 hour period. This stage should take the battery to 100% charged and should not take longer than 10-12 hours. If this time is exceeded, charging should be stopped and the battery and/or charge process should be analyzed.

The third stage is the “Float Stage” or maintenance and monitor stage. This step is generally not needed if no load is present when the battery's device is not in operation and the battery's device is used on a regular basis and does not sit idle for lengthy periods of time. Float voltage should be maintained at 2.25-2.30 V/Cell.

If a “Balance Mode” is included in the charging algorithm it would typically happen after the “Absorption Stage.” This would become the third stage and the “Float Stage” would then become the fourth stage. A balance mode is similar to an Equalize function for flooded batteries but is performed at a lower voltage and/or is tightly controlled against current, voltage and time.

To compensate for battery temperature not at 25°C, subtract 0.005 V/Cell for each 1°C above 25°C, and add 0.005 V/Cell for each 1°C below 25°C.

AGM battery charging

The first stage in a 3 or 4 stage charging algorithm is the “Bulk Stage.” Typically the Bulk Stage is a “Constant Current” (CC) charge but may also be Constant Power, Pulse Current or Taper Charge. In this stage the optimum charge current should be limited to less than or equal to 30 amps per 100 ampere hour (20 hour rate) of battery capacity or .3C. This stage should end when the cell voltage is equal to 2.4-2.465V/Cell at 25°C/77°F. The maximum time in hours should = 1.2 times the DOD (in AH) divided by the average charge current in amps. If this time is exceeded, charging should be stopped and the battery and/or charge process should be analyzed. This stage will represent approximately 60% of the total charge time. The battery will be nearing 80%-90% charged at the end of this stage.

The second stage is the “Absorption Stage.” Typically this stage is a Constant Voltage (CV) stage where the terminal voltage is maintained at 2.4-2.465V/Cell at 25°C/77°F (adjusting for temperature). The charge current is maintained until current acceptance drops by less than .1 ampere over a 1 hour period. This stage should take the battery to 100% charged and should not take longer than 10-12 hours. If this time is exceeded, charging should be stopped and the battery and/or charge process should be analyzed.

The third stage is the “Float Stage” or maintenance and monitor stage. This step is generally not needed if no load is present when the battery's device is not in operation and the battery's device is used on a regular basis and does not sit idle for lengthy periods of time. Float voltage should be maintained at 2.25-2.30 V/Cell.

If a “Balance Mode” is included in the charging algorithm it would typically happen after the “Absorption Stage.” This would become the third stage and the “Float Stage” would then become the fourth stage. A balance mode is similar to an Equalize function for flooded batteries but is performed against tightly controlled current, voltage and time. For example, the current should be limited to 1 amp per 100 amp hour of battery capacity and the battery should not be maintained at the balance or over voltage limit for less than 1 hour and for no longer than 4 hours.

WARNING – DO NOT EQUALIZE CHARGE Gel OR AGM BATTERIES! Equalizing is an “over voltage-over charge” performed on flooded lead-acid batteries after they have been fully charged. It helps to eliminate stratification and sulfation, two of many conditions that can reduce the overall performance and life of a flooded battery. Laboratory designed, specific to Discover®, “Balance” charge algorithms have been designed and are included in all Discover® recommended Industrial Commercial charges offered for sale wherever our Discover® VRLA products are sold. Visually the Balance Charging curve is similar to a flooded equalize charge curve in its finishing voltage, but it is strictly controlled to promote active material conversion and not to prevent acid stratification. Discover®'s Balance charging algorithms are HIGHLY recommended for batteries being installed in strings, larger batteries using taller plate groups and/or with batteries constantly being subjected to high rate deep discharge.

Equalizing (Flooded batteries only):

Many experts recommend that batteries be equalized periodically, ranging anywhere from once a month to once or twice per year. However, we only recommend equalizing when low or wide ranging specific gravity (± .015) is detected after fully charging a battery.

Equalizing is an “over voltage - overcharge” performed on flooded lead-acid batteries after they have been fully charged. It helps to eliminate stratification (the uneven distribution of acid), and sulfation (the buildup of sulfate crystals on the plates). These are two of many conditions that can reduce the overall performance and life of a flooded battery. An Equalize charge (equalizing) should only be used on flooded batteries when specific gravity readings vary from cell to cell at +/-.015 on a fully charged battery.

Equalize charging should not be performed on AGM or Gel batteries. ”Balance Charge” modes are included in all our Discover® Industrial, Commercial and Electric Vehicle charges. Balance Charging is similar to an equalize charge cycle but is performed at formulated and temperature compensated voltage, time and current data.

Step by Step Equalizing:

- Verify the batteries are flooded type
- Remove all loads from the batteries
- Connect battery charger
- Set charger to equalizing mode
- Start charging batteries
- Batteries will begin gassing and bubbling vigorously
- Take specific gravity readings every hour
- Equalization is complete when specific gravity values no longer rise during the gassing stage

NOTE: Many chargers do not have an equalization setting so this procedure can’t be carried out.

WARNING – DO NOT EQUALIZE CHARGE Gel OR AGM BATTERIES! Equalizing is an “over voltage-over charge” performed on flooded lead-acid batteries after they have been fully charged. It helps to eliminate stratification and sulfation, two of many conditions that can reduce the overall performance and life of a flooded battery. Laboratory designed, specific to Discover®, “Balance” charge algorithms have been designed and are included in all Discover® recommended Industrial Commercial charges offered for sale wherever our Discover® VRLA products are sold. Visually the Balance Charging curve is similar to a flooded equalize charge curve in its finishing voltage, but it is strictly controlled to promote active material conversion and not to prevent acid stratification. Discover®'s Balance charging algorithms are HIGHLY recommended for batteries being installed in strings, larger batteries using taller plate groups and/or with batteries constantly being subjected to high rate deep discharge.

Discharging:

Discharging batteries is a function of your application. Below is a list of helpful items:

- Shallow Depth of Discharges (DOD) will result in a longer battery life. <50% DOD is recommended
- 75-80% DOD is the maximum safe discharge for flooded and AGM batteries
- Do not discharge flooded batteries >80%. This will damage (or kill) the battery
- Recommend operating DOD for flooded batteries is 50% to 75% of capacity
- A periodic equalization charge for flooded batteries is a must
- Do not leave batteries deeply discharged for any length of time
- Lead-acid batteries do not develop a memory and need not be fully discharged before recharging
- Batteries should be charged after each period of use
- Batteries that charge up but cannot support a load are most likely bad and should be tested

How long can I discharge my Discover® battery?

How long your Discover® battery will last depends upon its capacity and the amount of power consumed by the equipment connected to it. Generally, the faster you discharge the battery the less power it will deliver, and the slower you discharge it the more power it will deliver. A 100 amp hour battery supplies a current of 5 amps for 20 hours during which time the battery's voltage remains above 1.75 volts per cell (10.5 volts for a 12 volt battery). If the same battery is discharged at 100 amps, the battery will only run for approximately 45 minutes before the voltage drops to 1.75 volts per cell, delivering only 75 amp hours of total power. Connecting a load of only 1.2 amps to the same battery until it reaches a cell voltage of 1.75 will result in the battery delivering 120 amps of usable power. This is all the result of the Peukert effect. Discover® 700 Series and EV Traction Dry Cell batteries are electrochemically designed to deliver 80% of published AH capacity above 1.9 volts per cell, thereby, ensuring that a 100 amp hour Discover® battery will deliver a higher % of the 100AH available than competitors' 100 amp hour batteries, in addition to delivering longer life at high rate discharges.

What is the Peukert Effect?

The Peukert effect describes how a battery's capacity is directly affected by the speed at which it is discharged or, in other words, the effect that different discharge rates will have on the available capacity of the battery. The Peukert value or exponent is directly related to the internal resistance of the battery. The higher the internal resistance, the higher the losses while charging and discharging, especially at higher currents. This means that the faster a battery is discharged, the lower its ampere hour capacity will be. Conversely, if it is drained slower, the AH capacity is higher.

For instance, a 100 AH battery (rated at the 20 hour rate) will deliver a steady 5 amp draw for 20 hours before the battery voltage drops to 1.75 volts per cell. However, if discharged at a current of 100 amp, this same 100AH battery will only deliver approximately 47 total amp hours.

The Peukert Effect can be described through a formula:

$$C_p = Int \tag{1}$$

Where:
Cp = available battery capacity with a given discharge current
I = the discharge current

n = the Peukert exponent and can be found with Equation 2:

$$n = \frac{t_2 - t_1}{I_1 - I_2} \qquad 2$$

where t = discharge time in hours.

The Peukert formula for a battery's capacity at a given discharge current is: Cp = I n *t,* where Cp is the capacity available with any given discharge current; I = the discharge current; n = the Peukert exponent which is a result of Time (T2 minus T1) divided by Current (I1 minus I2), which can be determined by carrying out two discharge tests and measuring the time to 1.75vpc with each being at a different discharge current (I). Each test should be dramatically different in regards to the discharge current. One high and one low is best.

Does depth of discharge affect cycle life?

Yes. Work it harder and longer and it will fail sooner. But remember if you do not work it at all or you work it too often then the life cycle will be reduced also. Discover® batteries have been designed for dependability and performance while being USED in the toughest applications.

Table 4 - Cycling Life vs. Depth of Discharge Estimates

Typical Cycling Ability vs. Depth of Discharge (DOD) Comparison **

DOD	700 Series DRY CELL	EV Traction DRY CELL	Deep Cycle AGM	Standard AGM	Deep Cycle Flooded
>80%	400~700	300~550	250~450	50~100	100~150
>50%	900~1600	700~1200	550~1000	150	200~250
>30%	>1600	>1200	>1000	350	300~500
<30%	>4000	>3000	>2000	1200	1500

** Actual results will vary depending upon battery sizing, application, charging regime, temperature, etc. For direct comparison you must pay close attention to the test temperature, the amp ours removed, and the discharge and recharge rates and times for each product being compared! *(life cycles vary by battery voltage, capacity and size)*

Why can't Discover® high quality VRLA batteries be discharged too low?

High quality VRLA batteries are designed to be "**acid-starved**." This means that the power (sulfate) in the acid is used before the power in the plates. This design protects the plates from ultra-deep discharges. Ultra-deep discharging is what causes life-shortening plate shedding and accelerated positive grid corrosion which can destroy a battery. The higher the active material % vs. the volume of electrolyte is, the more "acid starved" the battery will be!

Discover® 700 Series and EV Traction Dry Cell are tested and comply with "proof against standing deep-discharge" DIN 43 539, part 5. This means that a Discover® 700 Series and EV Traction Dry Cell battery, after being connected to a load equal to a discharge current of at least 2 x I20 and kept in this state for 30 days, will recover at least 75% of original capacity while being re-charged over a 48 hour period.

See also, "Why do Discover® batteries have longer cycle life than others" in Section VII for more detail.

How often should I equalize my Discover® Gel and AGM batteries?

Discover® VRLA batteries never need to be equalized. One reason why batteries are equalized is to combat voltage separation from cell to cell within a battery. A 12-volt battery is composed of six 2-volt cells connected in series internally. A 12-volt battery reading 12.8 volts on a voltmeter should equal 2.133 volts per cell. However, when batteries are manufactured and when activation or formation is done, then one cell may receive more or less electrolyte than the other five cells of that battery. When this happens, the battery's individual cell voltages after formation may be unequal: 2.123 - 2.133 - 2.143 - 2.113 -2.123 - 2.14…. "The total battery voltage after formation (12.80) is fine, but cell by cell they are different."

As a battery is discharged, the cells with the lower voltage will be drained further than the cells at the higher voltage. As the same battery is charged, the cells with the high voltage will be fully charged before the cells with the lower voltage. The more a battery is cycled, the more the cell separation takes place. Equalizing batteries helps to bring all the cells of a battery to the same voltage.

Discover® batteries are manufactured and formed using a specific procedure to activate the plates guaranteeing equally formed and voltage matched plates. The extra handling of the plates provides an additional inspection step in the process to verify plate quality

Equalize charging is also used to combat acid stratification. More information is given in the next section.

Do I have to equalize my Discover® batteries to prevent stratification?

When liquid electrolyte or acid stratifies, the heavier charged ions actually sink to the bottom of the cell, leaving discharged acid at the top. This oxidizes and corrodes the top of the plates, reducing performance and shortening life. The bottoms of the plates also corrode due to the strength of the acid. This can happen in stand-alone solar or telecom applications because the battery never moves.

More specifically, the term stratification describes a non-homogeneous vertical acid distribution within the cell of the battery. Stratification occurs due to insufficient charging and the gravity effect. Acid stratification occurs especially during cyclical (not float) applications. It will cause shorter battery life by increasing plate corrosion and sulphation. Acid stratification must be compensated for during each re-charge process. Concentrated sulphuric acid is generated during all re-charge processes. It has a higher specific weight compared to diluted acid, therefore, it tends to deposit in the lower parts of the cell container directly after leaving the pores of the active material. For instance, it is not uncommon in a flooded battery cell to measure acid concentration of 1.10 kg/l in the upper part of a cell whilst measuring 1.40 kg/l in the lower parts. Acid stratification in a Discover® battery is prevented due to the high absorption rate of the generated sulphuric acid as it escapes from the pores of the active material during the charging process. In the case of vented batteries with flooded electrolyte, the stratification cannot be prevented and has to be compensated for at the end of charge through an overcharge that causes gassing action witnessed with flooded type batteries (these gas bubbling helps mix the electrolyte). This re-charging process is normally expressed by what is referred to as a charge factor. The following charge factors represent typical charge coefficients for high quality VRLA and Flooded type batteries at the end of a 10 hour discharge:

- 1.04 to 1.08, typically 1.05 for a Discover® Gel battery
- 1.05 to 1.12, typically 1.08 for a Discover® AGM battery
- 1.15 to 1.30, typically 1.20 for vented batteries.

For all of the reasons mentioned above, clear differences exist between Gel, AGM and Vented or Flooded type batteries.

Due to the efficiency of the charging behavior of the positive and negative plates in Discover® VRLA batteries, less energy is needed to re-charge the battery. Acid stratification in a Discover® VRLA battery is virtually prevented due to the overall design, so 95% of the charge factor shown above for the Discover® Gel and AGM battery is used to convert the active material and not to prevent acid stratification as with vented or flooded batteries.

WARNING – DO NOT EQUALIZE CHARGE Gel OR AGM BATTERIES! Equalizing is an "over voltage-over charge" performed on flooded lead-acid batteries after they have been fully charged. It helps to eliminate stratification and sulfation, two of many conditions that can reduce the overall performance and life of a flooded battery. Laboratory designed, specific to Discover®, "Balance" charge algorithms have been designed and are included in all Discover® recommended Industrial Commercial charges offered for sale wherever our Discover® VRLA products are sold. Visually the Balance Charging curve is similar to a flooded equalize charge curve in its finishing voltage, but it is strictly controlled to promote active material conversion and not to prevent acid stratification. Discover®'s Balance charging algorithms are HIGHLY recommended for batteries being installed in strings, larger batteries using taller plate groups and/or with batteries constantly being subjected to high rate deep disharges.

Battery Council International BCIS-04 Rev. Draft Dec02 3.8.2 states that for **Flooded** batteries "An equalizing charge is allowed in conjunction with constant voltage charging to promote electrolyte mixing and to insure complete recharge. The equalizing charge must not exceed 3 hours and should be used cautiously to avoid excessive overcharge. For VRLA batteries, no equalizing charge should be used unless specifically recommended by the manufacturer."

How does a battery recharge?

The process is the same for all types of lead-acid batteries: flooded, Gel and AGM. The actions that take place during discharge are the reverse of those that occur during charge. The discharged material on both plates is lead sulfate ($PbSO_4$). When a charging voltage is applied, charge flow occurs. Electrons move in the metal parts; ions and water molecules move in the electrolyte. Chemical reactions occur at both the positive and negative plates, converting the discharged material into charged material. The material on the positive plates is converted to lead dioxide (PbO_2); the material on the negative plates is converted to lead (Pb). Sulfuric acid is produced at both plates and water is consumed at the positive plate. If the voltage is too high, other reactions will also occur; Oxygen is ripped from water molecules at the positive plates and released as a gas; Hydrogen gas is released at the negative plates – unless, oxygen gas can reach the negative plates first and "recombine" into H_20. A battery will "gas" near the end of charge because the charge rate is too high for the battery to accept. A temperature-compensating voltage-regulating charger, which automatically reduces the charge rate as the battery approaches the fully charged state, eliminates most of this gassing. **It is extremely important not to charge batteries for long periods of time at rates which cause them to gas** because they use water, which in sealed valve regulated batteries cannot be replaced. Of course, no battery should be overcharged for a long period of time even at low rates using so-called "trickle charges." In a fully charged battery, most of the sulfate is in the sulfuric acid. As the battery discharges, some of the sulfate begins to form on the plates as lead sulfate ($PbSO_4$). As this happens, the acid becomes more diluted and its specific gravity drops as water replaces more of the sulfuric acid. A fully discharged battery has more sulfates in the plates than in the electrolyte. A battery left in this discharged state or continually undercharged will prematurely fail. This failure condition is often referred to as sulfation.

How do Discover® Gel or AGM (VRLA) batteries recharge and are there any special precautions?

While VRLA batteries accept a charge extremely well due to their low internal resistance, any battery will be damaged by continual under or overcharging. Capacity is reduced and life is shortened. Overcharging is especially harmful to any VRLA battery because of the sealed design. Overcharging dries out or evaporates the electrolyte by driving the oxygen and hydrogen out of the battery through the pressure relief valves. Performance and life are reduced. If a battery is continually undercharged, a power-robbing layer of sulfate will build up on the positive plate, which acts as a barrier to recharging. Premature plate shedding can also occur. Performance is reduced and life is shortened. Therefore, **it is critical that a charger equipped with approved**

charge currents and voltages be used. The charger should be temperature-compensated to prevent under or overcharging due to ambient temperature changes.

Why are Gel and AGM batteries so charge sensitive and why is charge voltage so critical?

All lead-acid batteries give off hydrogen from the negative plate and oxygen from the positive plate during charging. VRLA batteries have pressure-sensitive 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. 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 pressure (voltage) is used for the temperature, a battery will accept charge at its ideal rate. If too much pressure is used, charge will be forced through the battery faster than it can be stored. Reactions other than the charging reaction occur to transport this current through the battery – mainly gassing. Hydrogen and oxygen are given off faster than the recombination reaction. This raises the pressure until the pressure relief valve opens. The gas lost cannot be replaced. Any VRLA battery will dry out and fail prematurely if it experiences excessive overcharge.

NOTE: It is the pressure (voltage) that initiates this problem – a battery can be "over-charged" (damaged by too much voltage) even though it is not fully "charged." This is why charging voltage must be carefully regulated and temperature compensated.

What will happen to my VRLA battery's life if the charge voltage is not controlled?

As mentioned before, VRLA batteries are voltage sensitive. In fact all batteries are voltage sensitive. If you continually charge your VRLA battery over the recommended levels you will shorten the life of your battery. Our tests have shown that you will reduce the life of your battery by between 5% and 7% for every 1/10th volt above the voltage recommended. For example, if you continually charge your battery at (depending upon the temperature) a temperature compensated value of 14.50 volts when it should be at 14.10 volts (4 tenths over), you can expect to reduce the life expectancy of your battery by 20% to 30%.

How long does it take to recharge a fully discharged Gel or AGM (VRLA) battery?

A specific time is difficult to determine because recharging depends on so many variables:

- Depth of discharge
- Temperature
- Size and efficiently of the charger
- Age and condition of the battery

The initial charging current with a Discover® battery should be at least equal to the battery's 10 hour amp hour capacity rating. For more detail on charging, refer to the data provided in the battery specific engineering data.

It will take about 60% of the total charge time to bring a VRLA battery from 0% charged to 80-90% charged. It will take the remaining 40% of the total charging time to put the last 10-20% of the charge back into the battery. Charge is a quantity of electricity equal to rate of flow (Amperes) multiplied by time (hours), and is usually expressed in Ampere-hours (Ah). Once the charger has been turned on for 1 to 2 minutes, the charge rate in amps will indicate the approximate charge time in hours.

A battery with a 0% state of charge is defined as having been discharged to a point when the terminal voltage is equal to or less than 1.75 volts per cell (10.50 Volts for a 12 volt battery) measured under a steady load at the battery's 20-hour rate at 80°F. The 20-hour rate is the battery's capacity divided by 20 hours.

Typically, the charge (capacity of the re-charge) that must be returned to a VRLA battery to achieve a 100% state of charge is from 104% to 112% of the charge removed. *For comparison purposes, the returned charge for flooded electrolyte batteries needs to be between 115% and 130% of the charge removed.*

NOTE: Variables such as the rate of charging current, ambient temperature during charge cycle and the control of the voltage during the charging cycle will impact the ability of the battery to be properly replenished and the ongoing performance of the battery.

How can undercharging harm my Discover® battery?

In many respects, undercharging is as harmful as overcharging. Keeping a battery in an undercharged condition or continually under charging a battery allows the positive grids to corrode, lead sulfate to build up, and plates to shed which can dramatically shorten life. Also, an undercharged battery must work harder than a fully charged battery, which contributes to shortened life as well. An undercharged battery has a greatly reduced capacity. It will easily be inadvertently over-discharged and eventually damaged.

Laboratory designed, specific to Discover®, “Balance” charge algorithms have been designed and are included in all Discover® recommended Industrial Commercial charges offered for sale wherever our Discover® VRLA products are sold. Visually the Balance Charging curve is similar to a flooded equalize charge curve in its finishing voltage, but it is strictly controlled to promote active material conversion and not to prevent acid stratification. Discover®’s Balance charging algorithms are HIGHLY recommended for batteries being installed in strings, larger batteries using taller plate groups and/or with batteries constantly being subjected to high rate deep disharges.

How often should I charge my wheelchair (scooter) batteries?

If you use your wheelchair on a daily basis then you should charge it daily. You do not want to get caught out with low batteries! This is especially important if you use your chair or scooter outside of your home. If you only use your chair or scooter periodically then charge before you intend to use it and charge again. The ideal recharge time would be when your gauge or voltmeter shows that the battery is about 50%. But remember, if you do not use the battery and just keep it on charge or perpetually leave it in a discharged condition, you will eventually damage its ability to meet your chair's/scooter's power needs.

How can you tell if a battery is fully charged?

The only true way to tell if a VRLA battery is fully charged is by using a good voltmeter to determine the open circuit voltage (OCV). Accessible flooded type batteries can also use a hydrometer.

Table 5 - State of Charge vs. OCV

Charge %	Open Circuit Voltage Flooded Battery	Open Circuit Voltage Gel Dry Cell Battery	Open Circuit Voltage AGM Dry Cell Battery
100%	12.60 – 12.80	12.85-12.95	12.80-12.90
75%	12.40	12.65	12.60
50%	12.20	12.35	12.30
25%	12.00	12.00	12.00
0%	11.80	11.80	11.80

Divide the above values in half for 6 volt batteries or by six to determine cell voltage. The TRUE OCV can ONLY be measured after the battery has been removed from the charge or discharge load for 24 hours.

How can you tell if a battery has been damaged by under or overcharging?

The only way is with a load test. Use the same procedure for VRLA batteries that you would use with a flooded cell battery:

1. Recharge if the open circuit voltage is below 75%.
2. If adjustable, set the load at three times the 20 hour rate.
3. Apply the load for 15 seconds. The voltage should stabilize above 9.6 volts while on load.
4. If the battery has a CCA rating you can apply a load equal to ½ the rating for 15 seconds. The voltage should stabilize above 9.6 volts while on load. To apply a more determined test, you may apply a load equal to 100% of the rated CCA for 30 seconds. The voltage should stabilize above 7.2 volts while on load.
5. If below 9.6 volts (7.2 volts for the 100% CCA test), recharge and repeat test. If below 9.6 volts (7.2 volts for the 100% CCA test) a second time, replace the battery.

How can I measure my battery's "State of Charge"?

If the battery's temperature, or electrolyte in flooded types, is above 110° F (43.3° C), allow it to cool. To determine the battery's state-of-charge with the battery's temperature at 80° F (26.7° C), use the following tables. Table 1 assumes that a 12.65 voltage reading or a 1.265 specific gravity reading represents a fully charged battery. For other battery or electrolyte temperatures, use the Temperature Compensation tables below to adjust the Open Circuit Voltage for VRLA batteries or Specific Gravity readings for flooded types.

Table 6 - Electrolyte Freezing Point

Digital Voltmeter	**State of Charge**	**Hydrometer Reading**	**Electrolyte**
Open Circuit Volts	**Approximate**	**Specific Gravity**	**Freezing Point**
12.65	100%	1.265	-75° F (-59.4° C)
12.45	75%	1.225	-55° F (-48.3° C)
12.24	50%	1.190	-34° F (-36.7° C)
12.06	25%	1.155	-16° F (-26.7° C)
11.89	Discharged	1.120	-10° F (-23.3° C)

Table 7 - Hydrometer Temperature Compensation

Temperature	Add or Subtract to Hydrometer Reading	Add or Subtract to Voltmeter Reading
0° / -17.8°	-.032	-.192
10° / -12.2°	-.028	-.168
20° / -6.7°	-.024	-.144
30° / -1.1°	-.020	-.120
40° / 4.4°	-.016	-.096
50° / 10°	-.012	-.072
60° / 15.6°	-.008	-.048
70° / 21.1°	-.004	-.024
80° / 26.7°	0	0
90° / 32.2°	+.004	+.024
100° / 37.8°	+.008	+.048
110° / 43.3°	+.012	+.072
120° / 48.9°	+.016	+.096
130° / 54.4°	+.020	+.120
140° / 60.0°	+.024	+.144
150° / 65.6°	+.028	+.168
160° / 71.1°	+.032	+.192

Table 8 - Voltmeter Temperature Compensation

Temperature	Add or Subtract to Hydrometers Reading	Add or Subtract to Voltmeter Reading
0° / -17.8°	-.032	-.192
10° / -12.2°	-.028	-.168
20° / -6.7°	-.024	-.144
30° / -1.1°	-.020	-.120
40° / 4.4°	-.016	-.096
50° / 10°	-.012	-.072
60° / 15.6°	-.008	-.048
70° / 21.1°	-.004	-.024
80° / 26.7°	0	0
90° / 32.2°	+.004	+.024
100° / 37.8°	+.008	+.048
110° / 43.3°	+.012	+.072
120° / 48.9°	+.016	+.096
130° / 54.4°	+.020	+.120
140° / 60.0°	+.024	+.144
150° / 65.6°	+.028	+.168
160° / 71.1°	+.032	+.192

How can I tell if I have a battery problem or a charging problem?

Diagnosing potential or perceived battery related issues can be complex. A voltmeter is still the most valuable tool when troubleshooting sealed batteries (see “How can you tell if a battery is fully charged?). When testing a battery, always start by checking the voltage first. In multi-12 volt systems such as a 24-volt system, we know the chances for all of the batteries being bad are very low. So what we need to determine is which battery is bad, if either battery is bad or if something else is wrong. This is accomplished by checking the voltage of each battery separately. We cannot just check the total voltage of the pack because we might incorrectly assume the bank is good, when really one has a voltage of 12.70 and the other a voltage of 12.1. Multiple 12 volt battery banks charge and discharge together almost as one when hooked in series. A wide voltage separation between two 12 volt batteries in a 24 volt system indicates that you may need to replace one or both batteries. If both batteries read a similar voltage, they should be fully charged before doing any further testing. If both batteries are below 12.0 volts, the question becomes, why? Is the battery charger working correctly? Could there be a problem with the applications wiring or other components? You can start to determine this step by step once you know the voltage of each battery.

What is a thermal runaway?

The appropriate charge voltage depends on the battery temperature. A warmer battery requires a reduced voltage. If the voltage is not reduced then the current accepted by the battery increases. When the current increases then heating within the battery increases. This can continue in a loop, feeding on itself with the battery temperature and charging current rising to destructive levels. This is thermal runaway. Batteries may become more susceptible with increasing age. Without a recombination reaction, flooded batteries convert most excess charging energy to gas, not heat. This makes them almost immune from the thermal runaway.

Thermal runaway can be prevented with:

- Temperature compensation monitoring at the battery and 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 which will shut the charger down

How do I know if a charger is “Gel friendly” or “AGM friendly”?

Unfortunately, many chargers on the market claim to be Gel “friendly” or “OK for sealed batteries”, but are not. Some overcharge the batteries, while others may not fully charge the batteries. Some chargers claim to be “smart.” Some “smart” chargers do a good job, others do not. The best choice of charger often depends on the application. Use only “voltage-regulated” or “voltage-limited” chargers if possible. **Standard constant current or taper current chargers must not be used**. Almost all applications require temperature sensing and voltage compensation. Beware, many chargers measure the ambient temperature which could be significantly different from the battery’s internal temperature. Be sure that if using a non-temperature compensated charger, that the charger's profile and charging “time-outs” recognizes this!

Low frequency current ripple (to about 333Hz) can be detrimental to sealed batteries depending on the application. On applications where the charger is connected continuously to a float voltage, especially where simultaneous charge and discharge may occur, the level of current ripple must be a consideration.

If you are not sure if a charger is performing properly, follow this procedure;

a. Using a fully discharged VRLA battery (OCV about 11.8V) and a digital voltmeter, record the initial open circuit voltage at the battery terminals.
b. Using an automatic charger as described above, set voltage if adjustable (14.2V for gel, 14.5V for AGM models).
c. Connect and start charging. Record initial on-charge voltage and current.
d. Each hour or so, check and record the on-charge voltage across the battery terminals. Except for occasional, brief “blips” or pulses, the voltage should not exceed the voltage limits noted in “b” above.
e. At the end of charge (when the current is very low or goes to zero) check and record the voltage. Note that the charger may have turned off by then.
f. The disconnected battery should be at 100% or above after a 24 hour rest.

During the charging time, the charger should not have exceeded the limit (except for occasional, brief pulses). This indicates that the charger is working properly. Keep in mind that the voltage limit is at 77°F/25°C. Charging at higher or lower temperatures will change this limit.

A temperature-sensing charger should always be used when charging VRLA batteries, as manual adjustments are never accurate and exceeding temperature limits will damage any battery.

Discover® has worked with many high quality charger manufacturers to develop a complete line of chargers specifically designed for its Discover® products, with the capability to charge all other types of lead-acid batteries as well. Please enquire with a Discover® dealer!

What is a safe charge rate or voltage setting for a battery used outdoors?

There is no fixed voltage setting or current that will work with certainty for applications with wide temperature fluctuations if a temperature-sensing charger is not available. A temperature-sensing, voltage-regulated charger must be used. Anything else will damage any battery and cause premature failure! It may be possible to limit this potential by using an ambient temperature sensing charger and assuming that the battery temperature is similar to the surrounding temperature. NOTE, however, that the temperature of the battery will fluctuate during discharge and recharge, and this fact will eventually damage the battery and cause premature failure if not controlled. If the recommended charger is not available then limiting the charge current and extending the charge time will reduce the chance of damaging the battery.

What is float charging? What float voltage is recommended?

This type of charge continually monitors and maintains a pre-set battery voltage, regardless of charge conditions. These chargers are used in stationary, emergency back-up power, emergency lighting, and other similar applications. Most high quality AGM and Gel chargers will have an alternative float cycle in its finishing charge algorithm. The frequency of discharge and temperature will dictate a more exact setting. For example, the more frequent the discharge, the higher the suggested recharge voltage should be to ensure that the recharge time is sufficient to maintain the battery's proper performance. The typical float voltage for monitoring and maintaining is between 2.25 and 2.30 volts per cell at 25°C/77°F.

Table 9 - AGM Charge and Float Voltage vs.Temperature

Temp. °F	Charge Standard	Charge Maximum	Float Standard	Float Maximum	Temp. °C
≥ 120	13.60	13.90	12.80	13.00	≥ 49
110 – 120	13.80	14.10	12.90	13.20	43 – 49
100 –110	13.90	14.20	13.00	13.30	38 – 43
90 – 100	14.00	14.30	13.10	13.40	32 – 38
80 – 90	14.10	14.40	13.20	13.50	27 – 32
70 – 80	14.30	14.60	13.40	13.70	21 – 27
60 – 80	14.45	14.75	13.55	13.85	16 – 21
50 – 60	14.60	14.90	13.70	14.00	10 – 16
40 – 50	14.80	15.10	13.90	14.20	4 – 10
≤ 40	15.10	15.40	14.20	14.50	≤ 4
Discover® AGM					
77°F	14.20	14.72	13.40	13.80	25°C

Table 10 - Gel Charge and Float Voltage vs. Temperature

Temp. °F	Charge Standard	Charge Maximum	Float Standard	Float Maximum	Temp. °C
≥ 120	13.00	13.30	12.80	13.00	≥ 49
110 – 120	13.20	13.50	12.90	13.20	44 – 48
100 –109	13.30	13.60	13.00	13.30	38 – 43
90 – 99	13.40	13.70	13.10	13.40	32 – 37
80 – 89	13.50	13.80	13.20	13.50	27 – 31
70 – 79	13.70	14.00	13.40	13.70	21 – 26
60 – 69	13.85	14.15	13.55	13.85	16 – 20
50 – 59	14.00	14.30	13.70	14.00	10 – 15
40 – 39	14.20	14.50	13.90	14.20	5 – 9
≤ 39	14.50	14.80	14.20	14.50	≤ 4
Discover® Gel					
77°F	14.10	14.50	13.35	13.75	25°C

Table 11 - Flooded Charge and Float Voltage vs. Temperature

Temp. °F	Charge Standard	Charge Maximum	Float Standard	Float Maximum	Temp. °C
≥ 120	14.10	14.40	12.80	13.00	≥ 49
110 – 120	14.20	14.50	12.90	13.20	44 – 48
100 –109	14.25	14.55	13.00	13.30	38 – 43
90 – 99	14.30	14.60	13.10	13.40	32 – 37
80 – 89	14.40	14.70	13.20	13.50	27 – 31
70 – 79	14.42	14.75	13.40	13.70	21 – 26
60 – 69	14.45	14.80	13.55	13.85	16 – 20
50 – 59	14.48	14.80	13.70	14.00	10 – 15
40 – 39	14.50	14.80	13.90	14.20	5 – 9
≤ 39	14.55	14.85	14.20	14.50	≤ 4

Equalization voltage for flooded batteries should typically be maintained at a maximum of 15.60 volts at 80°F. Make sure to correct the charging voltage to compensate for temperatures above and below 80°F. Add .028 volt per cell for every 10 degrees below 80°F and subtract .028 volt per cell for every 10 degrees above 80°F.

Will driving my car fully recharge my battery?

Some factors affecting a car charging system's ability to charge are; how much current from the alternator is diverted to the battery to charge it; how long the current is available and at what temperature the charging activity is taking place. Generally, idling the engine or on short “stop-and-go trips” during bad or hot weather or at night will not recharge a battery. A long daytime trip in warm weather should recharge a battery.

How long will a Deep Cycle battery last on a single charge?

Discharging batteries depends on a number of factors. These include, but are not limited to, the initial state-of-charge, the depth-of-discharge, the age and original capacity of the battery, the load or rate of discharge and the temperature at the time of discharge. To estimate the cycle time at 70° F (21.1° C), divide the batteries ampere hour rating by the load or discharge current in amps. For example, a new 72-ampere-hour battery with a 10-amp load should last approximately 7.2 hours. As the battery ages, this capacity will be reduced.

Why does temperature affect a battery's available capacity?

A battery's available capacity varies depending on the temperature. As the ambient temperature rises, a battery's ability to deliver current increases. As the temperature falls, so does the battery's ability to deliver current.

Temperature is a major factor in battery performance, shelf life, charging and voltage control. At higher temperatures there is dramatically more chemical activity inside a battery than at lower temperatures. Battery capacity is reduced as temperature goes down, and increased as temperature goes up. This is why your car battery has reduced performance on a cold winter morning, and why capacity needs to be taken into account when sizing your battery for use in different environments. The standard rating for batteries is at room temperature (25°C/77°F). At approximately -22°F (-27°C), battery capacity drops by 50%. At freezing capacity, it is reduced by 20%. Capacity is increased at higher temperatures. At 122°F a battery's capacity will be increased by about 10-15%. As mentioned earlier, battery charging voltage also changes with temperature. It will vary from about 2.74 volts per cell at -40°C to 2.3 volts per cell at 50°C. This is why temperature sensing and compensating chargers are so important.

The Thermal Mass of larger batteries and battery banks leads to more discussion. Because some of these batteries have so much mass, they will change the internal temperature much slower than the surrounding air temperature. A large insulated battery bank may vary as little as 10° over 24 hours internally, even though the air temperature varies from 20° to 70° degrees. In these circumstances, external thermo couples attached and insulated to one of the positive terminals are a good idea. The sensor will then read very closely to the actual internal battery temperature.

Even though the battery capacity at high temperatures is higher, battery life is shortened. High temperatures affect the battery's service life according to a common “rule of thumb” or law of “Arrhenius,” which states that the corrosion rate will be doubled per 10° C. Therefore, the lifetime will be halved per 10° C increase in temperature.

Example:

- 15 years at 20° C becomes reduced to 7.5 years at 30° C

NOTE: Even though a battery's ability to deliver current goes up as temperature rises, prolonged operation at extreme temperatures may shorten the life of the battery.

To calculate approximate capacity correlation due to temperature, add or subtract the % adjustments shown in the following table:

Discharge Time	0.C	5.C	10.C	15.C	20.C	25.C	30.C	35.C	40.C
<30 Min	-20%	-15%	-12%	-8%	-3%	0%	+5%	+8%	+10%
30-60 Min	-18%	-13%	-11%	-7%	-2%	0%	+4%	+6%	+8%
>60 Min	-16	-12%	-10%	-6%	-1%	0%	+3%	+4%	+5%

Typical self-discharge of VRLA batteries at different temperatures:

A fully charged battery's shelf life will discharge at approximately;

2% per month when stored at 8°C/46°F
3% per month when stored at 20°C/68°F
5% per month when stored at 30°C/86°F
10% per month when stored at 40°C/104°F

Typical self-discharge of high quality Deep Cycle Flooded batteries at different temperatures:

A fully charged battery's shelf life may discharge at approx;

6% per month when stored at 8°C/46°F
9% per month when stored at 20°C/68°F
15% per month when stored at 30°C/86°F
30% per month when stored at 40°C/104°F

Batteries kept in storage while discharged will not perform as intended when put into service. Battery inventories should be constantly checked and re-charged when necessary. A battery in storage should never be allowed to discharge more than 45-50% of its original capacity.

Section X –Buying Decision

How do I compare and make an informed buying decision?

Discover® has made available the LARGEST EV Traction, Deep Cycle AGM, AGM SVR and Gel product line in the world! This means that you have a number of sizes and performance options to choose from when making your purchase decision. First consider the following;

- Do you have any size restrictions (Height, total W x L area available)
- Do you have multiple areas available for batteries? If so, how far apart are they and are they similar in area?
- Is the area hard to get to or is it going to be easy to get heavy batteries installed?
- Do you have weight restrictions? Both on a per battery basis and as a total installation.
- Will the installed batteries be easy to service? **If not, DO NOT consider Flooded types!**
- Is the installation area serviced by a dedicated exhaust fan? **If not, DO NOT consider Flooded types!**
- What type of battery(s) are you using now?
- What type of charging system do you have?

With these questions answered, you are now ready to consider the options available to you. Make sure you have read and understand the sections on: **How do I increase the capacity of my battery and system.**

What should I look for when buying Deep Cycle batteries?

The most important consideration in buying a deep cycle battery is to first make sure the battery you are considering is a “True or Real” deep cycle battery. Once you have determined that the battery type is correct then make sure the Ampere-Hour or Reserve Capacity rating of the battery will meet or exceed your requirements. Most deep cycle batteries are rated in discharge rates of 100 hours, 20 hours, 10 hours, 8 hours or 5 hours, and/or reserve capacity minutes.

Reserve Capacity (RC) is the number of minutes a fully charged lead acid battery at 80° F (26.7° C) can be discharged at 25 amps before the voltage falls below 1.75 volts per cell (100% DOD). To convert RC to Ampere-Hours at the 25 amp rate, multiply RC by .4167.

It is better to have more ampere-hours (or RC) because within the same battery type, footprint or industry group size, the battery with higher ampere hours (or RC) will tend to deliver longer discharge times. It is important to also know the battery electrochemical design. A 100 ampere-hour battery of a certain dimension that is designed for UPS applications may deliver more initial run time than a Traction or Deep Cycle battery of the same dimension, but it most certainly will not provide the life or number of cycles that the Traction or Deep Cycle battery will. Contrary to popular belief battery weight (while important) is “not” the perfect indication of the quality of one battery to another. It is almost a certainty that if two batteries of the same dimension are weighed - one battery designed for UPS service and the other battery designed for Deep Cycle service- the UPS battery should weigh more. Be certain you understand what you are buying!

The “Battery Council International” manual BCIS-05 Rev. Dec02 provides some guidance with amp hour capacity relationships when comparing batteries design for the same type of service application. In it they state that “for guidance in establishing rates, ampere hour capacity relationships are approximately”:

20 hour	125%	3 hour	82%
6 hour	100%	2 hour	72%
5 hour	95%	1 hour	55%
4 hour	89%		

Finally, the available space and any weight restrictions will have to be considered when determining the appropriate deep cycle battery.

Things to question when making a battery buying decision:

Because of the growing number of performance rating schemes and/or ways to value your buying decision in the market today, it has become difficult to make a decision that doesn't come with some form of buyer's remorse at a later date. The following are some of the more obvious things to watch out for when buying;

- ☹ Some companies rate their Reserve Capacities (minutes that the battery will deliver a discharge current) at 23 amps instead of the industry standard (BCI published) way of establishing Reserve Capacity which is at 25 amps.

- Amp Hour (AH) ratings can be at 5 hour, 10 hour, 20 hour and even 100 hour rates, so make sure you are comparing the same rate.

- ? Cranking Amps (the ability of the battery to deliver a higher starting current over a shorter period for engine starting) are given at different temperatures, so make sure that you compare the published "Cranking Amps" of each battery at the same temperature. CCA or Cold Cranking Amps at 0°F/-18°C is the industry standard rating. You may see ratings published at CA, MCA, MCCA and HCA. All reputable suppliers will publish the CCA.

Some companies have invented their own rating system by recognizing that the process of comparing deep cycle batteries should be simplified. An American based manufacturer of batteries invented a new labeling system incorporating the "Lifetime Energy Unit" (LEU). This was their way of attempting to help a buyer determine the lifetime performance and value of any given battery in the market. Simply stated, and in the words of the SANTA FE SPRINGS, CA. manufacturer.

"Lifetime Energy Units signify the number of kilowatt-hours of energy a battery delivers over its lifetime. The bigger the number, the more total work the battery can perform. Before the introduction of LEUs, accurately determining battery performance and value required complex calculations. Engineers compute the true worth of a battery as the total energy it contains, measured in kilowatt-hours (KWH). To derive a number for KWH, they build a curve that profiles the relationship between run time and number of cycles. The area under the curve is the total energy the battery delivers over its lifetime. When amp-hours are multiplied by battery voltage, the result is the battery's capacity in watt-hours. The next step - comparing a battery's value - is also simplified. By dividing the LEU by the battery's price, the prospective purchaser obtains a value figure (energy units per dollar) that ensures an apples-to-apples comparison between competing products."

Discover® completely rejects this position. As with the variations in determining Reserve Capacity and Cranking Amps, mentioned earlier, this is NOT a recognized Battery Council International (BCI) method for rating or comparing batteries as suggested by the manufacturer. In fact, the manufacturer leaves out the exact method of determining LEUs, in order for an exact comparison to be done, which was their stated purpose for establishing the rating. This creates a situation where two suppliers could use two sets of methodology to determine their respective LEUs, making reasonable comparisons impossible. This implies that the LEU idea or concept in practice is simply a marketing tool with no real scientific basis for engineers as the manufacturer suggests. In fact, LEUs – as a way of helping buyers make an informed decision – would work very well if the buyer was given some additional pieces of data (data that IS available from other manufacturers and that could be used to make meaningful comparisons):

1. The exact discharge control methods (test procedures) used in determining the battery's “Cycle Time” (what discharge rate and to what depth is the battery discharged?).
2. Whether or not the batteries can be pre-conditioned before running the procedure.
3. The resulting ampere hours of power discharged per cycle
4. The re-charge control methods (test procedures) prior to the next discharge procedure.
5. The exact control methods used in determining the battery's “Life Cycles”.
6. The resulting ampere hours of power discharged over the life of the battery.

In addition to the problems listed above for making good performance comparison amongst different batteries, using the LEU marketing tool to make a serious value comparison is equally flawed. The value comparison requires more detail. Some, but certainly not all of the issues to be examined and required in determining value are:

1. Time and Supply costs associated with servicing the battery (as recommended by the manufacturer) to ensure it achieves its assumed life cycles.
2. Costs associated with Workers' Safety and Clothing needs (as recommended by the manufacturer).
3. Cost associated with Environmental Issues, Storage and Equipment Damage resulting from the emission of free hydrogen molecules during discharge and re-charge.
4. Freight/time costs and/or restrictions related to shipping.

If these data were known the buyer would then be able to determine the true energy units per dollar, or lifetime energy value as suggested by the manufacturer who introduced the LEU calculation.

What to consider when buying a Deep Cycle battery:

It is our opinion that to determine the actual best “bang for your buck” for batteries in cycling applications, you should gather the following information and perform the following calculations.

Information gathering before buying?

A. Determine the amount of energy the battery will deliver in its life using test procedures recognized by world wide manufacturers and published in the BCI technical manual. This information should be available from all manufacturers and should include:

- Discharge current used (25Amps, 75Amps, 20 hour rate, etc.)
- Discharge time (Cycle Life) to an effective 100% depth of discharge (1.75 volts per cell)
- Discharge cycles (Life Cycles) achieved before the battery could not deliver at least 50% of its original rated capacity

NOTE: Different types of batteries use test procedures that allow different end of life criteria. For example, an electric vehicle or standard deep cycle product would be considered to be at its end of life when it was not able to deliver 50% of its rated capacity while a golf cart battery would not be determined to be at its end of life until it was not able to produce at least 1.75 volts per cell during 40 minutes of discharge at 75 amperes.

Determine the number of times the battery will have to be serviced in its life time as recommended by the manufacturer. It is important to use the manufacturer's recommended service schedule. For time/cost analysis we recommend you use an average of 10 minutes per service per battery.

B. Determine the average per hour/minute labor costs in your organization.

This number varies by region and industry - should not include anything but direct labor costs. You can safely use a figure of $18.00 - $25.00 per hour ($.30 - $.42 per minute) (2003 dollars) without benefits etc. One transit authority stated that their direct labor cost associated with maintaining batteries in each of their transit buses was $180.00 per year; another stated it was as high as $550 per battery. We suggest using $22.00 as an average hourly cost ($.367 per minute).

C. Cost of service materials over the life of the battery such as; distilled or specially treated water - using a per cell fluid usage by volume of 20% on an average cell volume of 2.35l/80oz and a 75% consumption efficiency or between $.02-$.04 per oz. Battery fluid volumes are as low as 5l/169oz and as high as 16l/540oz ; cleaning and neutralizing agents at 1oz per battery or $.25 per battery per service; special clothing; repair and replacement of battery boxes and trays and more.

D. Cost Per Battery

- Purchase price of the battery
- Freight or handling charges (overland or can they be shipped via courier or air)

Calculating Cost to Own:

Estimate the cost of materials used when servicing the battery as recommended by the manufacturer. For comparison, it is reasonable to use just $1.70 each time for distilled water, cleaning and neutralizing agents and ignore the other variable costs. Multiply this amount by the number of years the manufacturer says the battery will last in the application. Multiply the result by the number of times the manufacturer says the battery should be serviced per year to achieve the published life expectancy. Our experience shows most manufacturers will recommend you service flooded batteries at least once per month. Two of the “World's” leading manufacturers and sellers of Flooded, Gel and AGM Deep Cycle batteries state the following on their web sites;

“Flooded batteries need water. More importantly, watering must be done at the right time and in the right amount or else the battery’s performance and longevity suffers. Water should always be added after fully charging the battery. Prior to charging, there should be enough water to cover the plates.”

“Batteries should be watered after charging unless plates are exposed before charging. If exposed, plates should be covered by approximately 1/8" of acid. Check acid level after charge. The acid level should be kept 1/4" below the bottom of the fill well in the cell cover. Water used to replenish batteries should be distilled or treated not to exceed 200 T.D.S. (total dissolved solids...parts per million). Particular care should be taken to avoid metallic contamination (iron).”

“As batteries age, their maintenance requirements change. This means longer charging time and/or higher finish rate (higher amperage at the end of the charge). Usually older batteries need to be watered more often. And, their capacity decreases. Periodic battery testing is an important preventative maintenance procedure. Hydrometer readings of each sell (fully charged) gives an indication of balance and true charge level. Imbalance could mean the need for equalizing, is often a sign of improper charging or a bad cell. Voltage checks (open circuit, charged and discharged) can locate a bad battery or weak battery. Load testing will pick out a bad battery when other methods fail. A weak battery will cause premature failure of companion batteries”

This would suggest that the world’s leading manufacturers of flooded deep cycle batteries recommend that service is required, particularly as the battery ages, **BEFORE** and **AFTER** *every* charge/discharge cycle. In some cases they suggest that failing to do so will void the warranty.

If you cycle the battery 2 times per week the battery will last approximately 3 years following the manufacturer's recommended service procedures (we attempt to use the manufacturers published life cycle data in the following comparisons).

This means your per battery service material costs will be at least $1.70 x 12 services per year x 3 years = $61.20. If you service as the manufacturers suggest it will be as much as $1.70 x 104 services per year x 3 years = $530.40. To achieve a 3 year life that is cycled two times per week, flooded batteries need to be serviced at least once every 4 cycles or bi-monthly. $1.70 x 3 years x 26 services = $132.60 per battery. Every user of deep cycle batteries is familiar with dried out “rotten egg” smelling batteries, the result of NOT maintaining a proper service schedule over the life of the battery. ***In all of our comparisons we calculate service costs based on the flooded batteries being service after 6 to 8 cycles. Well below that recommended by the leading manufacturers.***

NOTE: that when asked, more than 80% of equipment managers could not produce or describe a “battery service schedule” - for equipment under their supervision that use cycling batteries.

In our opinion, if you were to match a flooded battery against a Discover® 700 SERIES EV or EV Traction DRY CELL, of the same size and AH rating for use in the same application, you would find the following data to be a conservative representation of the comparable costs. Note that we have shown “cost per cycle” data for the Discover® battery at optimum, at drastically reduced and at 60% of the published life expectancy of a flooded battery. We present the results against a flooded battery that performs to its maximum as stated by its manufacturer. We do this even though we show the flooded battery being serviced after 6 or 8 charge-discharge cycles and not after every charge/discharge cycle as the manufacturer required to achieve their published results.

Discover® batteries require less service, and as a result, with proper charging methods, Discover® batteries will out-value flooded batteries. It is more likely that the standards of service for the flooded batteries will not be met in the real world, therefore, it will not meet the manufacturer's required levels to achieve maximum life.

Additionally, in the following comparisons we do not take into consideration any of the other issues, inconveniences and/or costs associated with servicing, working with or having sensitive equipment around flooded batteries. These would include, but are not limited to:

- damaged and/or special clothing
- battery compartment repairs
- air quality problems
- workers compensation claims
- occupational health issues
- hazardous materials handling requirements
- shipping restrictions
- damage to service areas from acid and corrosive by product spills

Some of the most interesting and relevant results from the following study are:

- The more competitive and demanding the channel (jobber/installer/large user/rental equipment) is the more compelling and feasible the switch to Discover® batteries becomes.
- The larger the bank of batteries used, the more important costs associated with service becomes and the more compelling and feasible the switch to Discover® batteries becomes

We think the results will surprise you and bring into focus why this is such an opportunity for Discover® users to greatly reduce their operational costs and risks to their employees, communities and the environment that the use of flooded batteries currently presents.

Single 6 volt Floor Scrubber and HD Lift battery

Type (L16)	List Price	Total Service and Material Costs	Total Costs	Average per Cycles Cost
DC Flooded	$259.99	$445.70	$705.69	$1.41
DC Advanced	$359.99	$33.03	$393.02	$.65 ($.98) ($1.31)
DC Gel	$429.99	$33.03	$463.02	$.77 ($.92) ($1.54)

DC Flooded 6 Volt 350AH / 500 cycle life (>80% DOD)battery / $304.60 in 83 services over 3 years at 10 minutes each at $.367 per minute / $141.10 in materials.

DC Advanced AGM 6 Volt 350AH / 600 (400) (300) cycle life (>80% DOD) battery / $33.03 in 18 services over 3 years at 5 minutes each at $.367 per minute / No materials

DC Gel 6 Volt 350AH / 600 (500) (300) cycle life (>80% DOD) battery / $33.03 in 18 services over 3 years at 5 minutes each at $.367 per minute / No materials

Type (L16)	Fleet/Jobber Price	Total Service and Material Costs	Total Costs	Average per Cycles Cost
DC Flooded	$155.99	$445.70	$601.69	$1.20
DC Advanced	$215.99	$33.03	$249.02	$.41 ($.62) ($.83)
DC Gel	$257.99	$33.03	$291.02	$.48 ($.58) ($.97)

12 volt Floor Scrubber and HD Lift battery

Type (L16 x 2)	List Price	Total Service and Material Costs	Total Costs	Average per Cycles Cost
DC Flooded (2)	$519.99	$501.97	$1021.96 $2.04	
DC Advanced (2)	$719.99	$33.03	$753.02	$1.25 ($1.88) ($2.51)
DC Gel (2)	$859.99	$33.03	$463.02	$1.48 ($1.78) ($2.97)

DC Flooded 12 Volt 350AH / 500 cycle life (>80% DOD) battery / $260.57 in 71 services over 3 years at 5 minutes (2 batteries) each at $.367 per minute / $241.40 (2 batteries) in materials.

DC Advanced AGM 12 Volt 350AH / 600 (400) (300) cycle life (>80% DOD) battery / $33.03 in 18 services over 3 years at 5 minutes each at $.367 per minute / No materials

DC Gel 12 Volt 350AH / 600 (500) (300) cycle life (>80% DOD) battery / $33.03 in 18 services over 3 years at 5 minutes each at $.367 per minute / No materials

Type (L16 x 2)	Fleet/Jobber Price	Total Service and Material Costs	Total Costs	Average per Cycles Cost
DC Flooded (2)	$311.99	$501.97	$813.96	$1.63
DC Advanced (2)	$431.99	$33.03	$465.02	$.77 ($1.16) ($1.55)
DC Gel (2)	$515.99	$33.03	$549.02	$.91 ($1.09) ($1.83)

Single Scrubber, HD Deep Cycle and Marine Trolling battery

Type (DC31)	List Price	Total Service and Material Costs	Total Costs	Average per Cycles Cost
DC Flooded	$129.99	$204.06	$334.05	$1.11
DC Advanced	$209.99	$33.03	$243.02	$.48 ($.81) ($1.35)
DC Gel	$219.99	$33.03	$253.02	$.50 ($.72) ($1.40)

DC Flooded 12 Volt 130AH / 300 cycle life (>80% DOD) battery / $139.46 in 38 services over 3 years at 10 minutes each at $.367 per minute / $64.60 in materials.

DC Advanced AGM 12 Volt 110AH / 500 (300) (180) cycle life (>80% DOD) battery / $33.03 in 18 services over 3 years at 5 minutes each at $.367 per minute / No materials

DC Gel 12 Volt 97AH / 500 (350) (180) cycle life (>80% DOD) battery / $33.03 in 18 services over 3 years at 5 minutes each at $.367 per minute / No materials

Type (DC31)	Fleet/Jobber Price	Total Service and Material Costs	Total Costs	Average per Cycles Cost
DC Flooded	$77.99	$204.06	$282.05	$.94
DC Advanced	$125.99	$33.03	$159.02	$.31 ($.53) ($1.06)
DC Gel	$131.99	$33.03	$165.02	$.33 ($.47) ($.1.09)

Single Scrubber, HD Deep Cycle and Marine Trolling battery

Type (DC27)	List Price	Total Service and Material Costs	Total Costs	Average per Cycles Cost
DC Flooded	$119.99	$204.06	$344.45	$1.38
DC Advanced	$179.99	$33.03	$213.02	$.42 ($.71) ($1.42)
DC Gel	$199.99	$33.03	$233.02	$.46 ($.66) ($1.55)

DC Flooded 12 Volt 115AH / 250 cycle life (>80% DOD) battery / $139.46 in 38 services over 3 years at 10 minutes each at $.367 per minute / $64.60 in materials.

DC Advanced AGM 12 Volt 96AH / 500 (300) (150) cycle life (>80% DOD) battery / $33.03 in 18 services over 3 years at 5 minutes each at $.367 per minute / No materials

DC Gel 12 Volt 87AH / 500 (350) (150) cycle life (>80% DOD) battery / $33.03 in 18 services over 3 years at 5 minutes each at $.367 per minute / No materials

Type (DC27)	Fleet/Jobber Price	Total Service and Material Costs	Total Costs	Average per Cycles Cost
DC Flooded	$71.99	$204.06	$276.05	$1.10
DC Advanced	$107.99	$33.03	$141.02	$.28 ($.47) (.94)
DC Gel	$119.99	$33.03	$153.02	$.30 ($.43) ($.1.02)

Dual 12 volt HD Deep Cycle house and Marine Trolling batteries

Type (DC24 x 2)	List Price	Total Service and Material Costs	Total Costs	Average per Cycles Cost
DC Flooded (2)	$219.99	$324.44	$544.43	$1.97
DC Advanced (2)	$319.99	$33.03	$353.02	$.70 ($1.17) ($2.13)
DC Gel (2)	$359.99	$33.03	$393.02	$.78 ($1.12) ($2.38)

DC Flooded 12 Volt 200AH / 275 cycle life (>80% DOD) battery / $195.24 in 38 services over 3 years at 7 minutes each (2 batteries) at $.367 per minute / $129.20 in (2 batteries) materials.

DC Advanced AGM 12 Volt 160AH / 500 (300) (165) cycle life (>80% DOD) battery / $33.03 in 18 services over 3 years at 5 minutes each at $.367 per minute / No materials

DC Gel 12 Volt 87AH / 500 (350) (165) cycle life (>80% DOD) battery / $33.03 in 18 services over 3 years at 5 minutes each at $.367 per minute / No materials

Type (DC24 x 2)	Fleet/Jobber Price	Total Service and Material Costs	Total Costs	Average per Cycles Cost
DC Flooded (2)	$131.99	$324.44	$456.43	$1.66
DC Advanced (2)	$191.99	$33.03	$225.02	$.45 ($.75) ($1.36)
DC Gel (2)	$215.99	$33.03	$249.02	$.49 ($.71) ($.1.51)

Single Golf Cart or Electric Vehicle battery

Type (GC)	List Price	Total Service and Material Costs	Total Costs	Average per Cycles Cost

DC Flooded	$99.99	$402.75	$502.74	$.100 ($.84)
DC Advanced	$189.99	$33.03	$223.02	$.44 ($.59) ($.67)
DC Gel	$199.99	$33.03	$233.02	$.46 ($.54) ($.70)

DC Flooded 6 Volt 210AH / 500 (600) cycle life (>80% DOD) battery / $275.25 in 75 services over 3 years at 10 minutes each at $.367 per minute / $127.50 in materials.

DC Advanced AGM 6 Volt 210AH / 500 (375) (330) cycle life (>80% DOD) battery / $33.03 in 18 services over 3 years at 5 minutes each at $.367 per minute / No materials

DC Gel 6 Volt 200AH / 500 (425) (330) cycle life (>80% DOD) battery / $33.03 in 18 services over 3 years at 5 minutes each at $.367 per minute / No materials

Type (GC)	Fleet/Jobber Price	Total Service and Material Costs	Total Costs	Average per Cycles Cost
DC Flooded	$59.99	$402.75	$462.74	$.93 ($.77)
DC Advanced	$113.99	$33.03	$147.02	$.29 ($.39) ($.45)
DC Gel	$119.99	$33.03	$153.02	$.30 ($.36) ($.46)

36 volt Golf Cart and Electric Vehicle battery bank

Type (GC x 6)	List Price	Total Service and Material Costs	Total Costs	Average per Cycles Cost
DC Flooded (6)	$599.99	$1654.38 $2254.37	$4.50	
DC Advanced (6)	$1139.99 $198.18	$1338.18	$2.67 ($3.57) ($4.05)	
DC Gel (6)	$1199.99 $198.18	$1398.18 $2.79 ($3.28) ($4.23)		

DC Flooded 36 Volt 210AH / 500 cycle life (>80% DOD) battery / $858.78 in 78 services over 3 years at 30 minutes (6 batteries) at $.367 per minute / $795.60 in (6 batteries) materials.

DC Advanced AGM 36 Volt 210AH / 500 (375) (330) cycle life (>80% DOD) battery / $198.18 in 18 services over 3 years at 30 minutes (6 batteries) at $.367 per minute / No materials

DC Gel 36 Volt 200AH / 500 (425) (330) cycle life (>80% DOD) battery / $198.18 in 18 services over 3 years at 30 minutes (6 batteries) at $.367 per minute / No materials

Type (GC x 6)	Fleet/Jobber Price	Total Service and Material Costs	Total Costs	Average per Cycles Cost
DC Flooded (6)	$359.99	$1654.38 $2014.37	$4.02	
DC Advanced (6)	$683.99	$198.18	$882.18	$1.76 ($2.35) ($2.67)
DC Gel (6)	$719.99	$198.18 $918.18	$1.83 ($2.16) ($2.78)	

48 volt Golf cart and Electric Vehicle battery bank

Type (GC8 x 6)	List Price	Total Service and Material Costs	Total Life Costs	Cycle Cost
DC Flooded (6)	$719.99	$1654.38 $2374.37	$4.74	
DC Advanced (6)	$1259.99 $198.18	$1458.17	$2.91 ($3.88) ($4.42)	
DC Gel (6)	$1319.99 $198.18	$1518.17 $3.03 ($3.57) ($4.60)		

DC Flooded 48 Volt 170AH / 500 cycle life (>80% DOD) battery / $858.78 in 78 services over 3 years at 30 minutes (6 batteries) at $.367 per minute / $795.60 in (6 batteries) materials.

DC Advanced AGM 48 Volt 170AH / 500 (375) (330) cycle life (>80% DOD) battery / $198.18 in 18 services over 3 years at 30 minutes (6 batteries) at $.367 per minute / No materials

DC Gel 48 Volt 170AH / 500 (425) (330) cycle life (>80% DOD) battery / $198.18 in 18 services over 3 years at 30 minutes (6 batteries) at $.367 per minute / No materials

Type (GC8 x 6)	Fleet/Jobber Price	Total Service and Material Costs	Total Costs	Average per Cycles Cost
DC Flooded (6)	$431.99	$1654.38 $2086.37	$4.17	

DC Advanced (6)	$683.99	$198.18	$882.18	$1.76 ($2.71) ($3.52)
DC Gel (6)	$719.99	$198.18	$918.18	$1.83 ($2.16) ($3.67)

Multiple 12 volt Marine and Photo Voltaic house bank

Type (8D x 5)	List Price	Total Service and Material Costs	Total Costs	Average per Cycles Cost
DC Flooded (5)	$1399.99	$1951.17	$3351.16	$3.35
DC Advanced (5)	$2249.99	$165.15	$2415.14	$2.41 ($3.22) ($4.02)
DC Gel (5)	$2499.99	$165.15	$2665.14	$2.66 ($3.13) ($4.44)

DC Flooded 12 Volt 1080AH / 1000 cycle life (>80% DOD) battery / $1288.17 in 78 services over 3 years at 45 minutes (5 batteries) at $.367 per minute / $663.00 in (5 batteries) materials.

DC Advanced AGM 12 Volt 1275AH / 1000 (750) (600) cycle life (>80% DOD) battery / $165.15 in 18 services (x 5 batteries) over 3 years at 5 minutes each at $.367 per minute / No materials

DC Gel 12 Volt 1175AH / 1000 (850) (600) cycle life (>80% DOD) battery / $165.15 in 18 services (x 5 batteries) over 3 years at 5 minutes each at $.367 per minute / No materials

Type (8D x 5)	Fleet/Jobber Price	Total Service and Material Costs	Total Costs	Average per Cycles Cost
DC Flooded (5)	$839.99	$1951.17	$2791.16	$2.79
DC Advanced (5)	$1349.99	$165.15	$1515.14	$1.51 ($2.02) ($3.03)
DC Gel (5)	$1499.99	$165.15	$1665.14	$1.66 ($1.95) ($3.33)

24 volt Scrubber and HD Deep Cycle battery

Type (1850 x 2)	List Price	3 Year Service and Material Costs	3 Year Total Costs	3 Year per Cycles Cost
DC Flooded (2)	$479.99	$665.96	$1145.95	$2.29
DC Advanced (2)	$919.99	$33.03	$953.02	$1.90 ($2.54) ($2.88)
DC Gel (2)	$999.99	$33.03	$1033.02	$2.06 ($2.29) ($3.13)

DC Flooded 24 Volt 200AH / 500 cycle life (>80% DOD)battery / $400.76 in 78 services over 3 years at 7 minutes each battery at $.367 per minute / $265.20 in materials.

DC Advanced AGM 24 Volt 225AH / 500 (375) (330) cycle life (>80% DOD) battery / $33.03 in 18 services over 3 years at 5 minutes each at $.367 per minute / No materials

DC Gel 24 Volt 200AH / 500 (450) (330) cycle life (>80% DOD) battery / $33.03 in 18 services over 3 years at 5 minutes each at $.367 per minute / No materials

Type (1850 x 2)	Fleet/Jobber Price	3 Year Service and Material Costs	3 Year Total Costs	3 Year per Cycles Cost
DC Flooded (2)	$287.99	$665.96	$953.95	$1.90
DC Advanced (2)	$551.99	$33.03	$585.02	$1.17 ($1.56) ($1.77)
DC Gel (2)	$599.99	$33.03	$633.02	$1.26 ($1.40) ($1.91)

Section XII - Servicing Batteries

Tools

There are many tools that may help in properly caring for and maintaining batteries. Below is a list of basic items that are recommended for this task:

- Insulated tools sized to match nuts, bolts and cables in use
- Distilled water for flooded batteries (if not available, good clean tap water is better than nothing)
- Voltmeter
- Hydrometer for flooded batteries
- Post cleaner and wire brush
- Baking Soda
- Petroleum Jelly
- Goggles, Gloves (wear polyester clothing)
- Fire extinguisher

CAUTION: Always wear protective clothing, gloves, and goggles when handling batteries, electrolyte, and charging your battery.

Batteries should be carefully inspected on a regular basis in order to detect and correct potential problems before they can do harm. It is a great idea to start this routine when the batteries are first received.

Inspection

Examine the outside appearance of the battery

- Look for cracks in the container
- Check the battery, posts and connections to make sure they are clean, free of dirt, fluids and corrosion
- Any fluids on or around the battery may be an indication that electrolyte is spilling, leaching or leaking out. Pay close attention to this if it is a flooded battery you are checking as a low electrolyte situation in the battery may cause excessive gassing and ultimately dispense fluid on or around the battery.
- All battery cables and their connections should be tight, intact, and NOT broken or frayed
- Replace any damaged batteries
- Replace any damaged cables
- Re-torque all connector bolts. See manufacturer’s recommendations for torque values.

Proper Initial and annual Maintenance Torque Values for Connection Hardware are:
Flooded:

Automotive SAE:	45 in/lbs. (5NM)
Automotive Side terminals:	70 in/lbs. (8NM)
Wing nut terminals:	95 in/lbs. (11NM)
T stud type terminals:	140 in/lbs. (15NM)
L, LT, UT terminals:	110 in/lbs. (13NM)

VRLA:

X terminals (U1) terminals:	45 in/lbs. (5NM)
Light Duty L terminals:	45 in/lbs. (5NM)
Standard Duty L terminals:	80 in/lbs. (9NM)
Heavy Duty L terminals:	95 in/lbs. (11NM)

Automotive SAE:	70 in/lbs. (8NM)
M5 Button type terminals:	45 in/lbs. (5NM)
M6 Button type terminals:	55 in/lbs. (6NM)
M8 Button type terminals:	70 in/lbs. (8NM)

WARNING: Do not over tighten terminals. Doing so can result in post breakage, post meltdown, and fire.

Always follow the manufacturer's instructions.

Testing

Visual inspection alone is not sufficient to determine the overall health of the battery. Both open-circuit voltage and specific gravity readings (for flooded batteries) can give a good indication of the battery's charge level, age, and health. Routine voltage and gravity checks will not only show the state of charge but also help spot signs of improper care, such as undercharging, overcharging and over-watering in the case of flooded batteries, and possibly even locate a bad or weak battery. The following steps outline how to properly perform routine voltage and specific gravity testing on batteries.

Specific Gravity Test

DO NOT ADD WATER BEFORE TESTING (Flooded batteries only)

1. Fill and drain the hydrometer 2 to 4 times before pulling out a sample.
2. There should be enough sample electrolyte in the hydrometer to completely support the float.
3. Take a reading, record it, and return the electrolyte back to the cell.
4. To check another cell, repeat the 3 steps above.
5. Check all cells in the battery.
6. Replace the vent caps and wipe off any electrolyte that might have been spilled.
7. Correct the readings to 80^{o} F:

    - **Add .004 to readings for every 10^{o} above 80^{o} F, (6^{o} above 26^{o} C)**
    - **Subtract .004 for every 10^{o} below 80^{o} F, (6^{o} below 26^{o} C)**

8. Compare the readings.
9. Check the state of charge using "Open Circuit Voltage" table below.

The readings should be at or above the factory specification or 1.280 ± .005. If any specific gravity readings register low, then follow the steps below:

1. Check and record voltage level(s).
2. Put battery(s) on a complete charge.
3. Take specific gravity readings again.

If any specific gravity readings still register low then follow the steps below:

1. Check voltage level(s).
2. Perform equalization charge. Refer to the Equalizing section for the proper procedure.
3. Take specific gravity readings again.

If any specific gravity reading still registers lower than the factory specification or 1.280 ± .005 then one or more of the following conditions may exist:

1. The battery is old and approaching the end of its life.
2. The battery was left in a state of discharge too long.
3. Electrolyte was lost due to spillage or overflow.
4. A weak or bad cell is developing.
5. Battery was watered excessively previous to testing.
6. Batteries in conditions 1 - 4 should be taken to a specialist for further evaluation or retired from service.

Open-Circuit Voltage Test

For accurate voltage readings, batteries must remain idle (no charging, no discharging) for at least 8 hrs, preferably 24 hrs.

1. Disconnect all loads from the batteries.
2. Measure the voltage using a DC voltmeter.
3. Check the state of charge with the Table below.
4. Charge the battery if it registers 0% to 75 % charged.

After charge, if the battery registers below the Temperature Compensated values illustrated in **"How can you tell if a battery is fully charged"** or **"How can I measure my battery's State of Charge,"** the following conditions may exist:

1. The battery was left in a state of discharge too long.
2. The battery has a bad cell.

Batteries in these conditions should be taken to a specialist for further evaluation or retired from service.

Load Testing

Use this same procedure for VRLA batteries and Flooded batteries:

1. Recharge if the open circuit voltage is below 75%.
2. If you have an adjustable load tester, set the load at 3 to 3.5 times the 20 hour rate.
3. Apply the load for 15 seconds. The voltage should stabilize above 9.6 volts while on load.
4. If the battery has a CCA rating you can apply a load equal to ½ the rating for 15 seconds. The voltage should stabilize above 9.6 volts while on load. To apply a more determined test, you may apply a load equal to 100% of the rated CCA or 3 to 3.5 times the 20 hour rate for 30 seconds. The voltage should stabilize above 7.2 volts while on load.
5. If below 9.6 volts (7.2 volts for the 100% CCA test), recharge and repeat test.
   If below 9.6 volts (7.2 volts for the 100% CCA test) again, replace the battery.

Watering (Flooded batteries only)

Flooded batteries need water. More importantly, watering must be done at the right time and in the right amount or else the battery's performance and longevity suffers. Water should always be added after fully charging the battery. Prior to charging, there should be enough water to cover the plates. If the battery has been discharged (partially or fully), the water level should also be above the plates. Keeping the water at the correct level after a full charge will prevent having to worry about the water level at a different state of charge. Depending on the local climate, charging methods, application, etc. it is recommended that batteries be checked a minimum of once a month and/or once every 7 discharge–charge cycles until you get a feel for how thirsty your batteries are. Important things to remember:

1. Do not let the plates get exposed to air. This will damage (corrode) the plates.

2. Do not fill the water level in the filling well to the cap. This most likely will cause the battery to overflow acid, consequently losing capacity and causing a corrosive mess.
3. Do not use water with a high mineral content. Use distilled or de-ionized water only.

CAUTION: The electrolyte is a solution of acid and water so skin contact should be avoided.

Step by step watering procedure: (Flooded batteries only)

1. Open the vent caps and look inside the fill wells.
2. Check electrolyte level; the minimum level is at the top of the plates.
3. If necessary add just enough water to cover the plates at this time.
4. Put batteries on a complete charge before adding any additional water (refer to the Charging section).
5. Once charging is completed, open the vent caps and look inside the fill wells.
6. Add water until the electrolyte level is 1/8" below the bottom of the fill well.
7. A piece of rubber can be used safely as a dipstick to help determine this level.
8. Clean, replace, and tighten all vent caps.

WARNING: Never add acid to a battery.

Cleaning

Batteries seem to attract dust, dirt, and grime. Keeping them clean will help you spot trouble signs if they appear and avoid associated problems.

1. Check that all vent caps are tightly in place (flooded batteries).
2. Clean the battery top with a cloth or brush and a solution of baking soda and water.
3. When cleaning, do not allow any cleaning solution, or other foreign matter to get inside the battery (flooded batteries).
4. Rinse with water and dry with a clean cloth.
5. Clean battery terminals and the inside of cable clamps using a post and clamp cleaner.
6. Clean terminals will have a bright metallic shine.
7. Reconnect the clamps to the terminals and thinly coat them with petroleum jelly (Vaseline) to prevent corrosion.
8. Keep the area around batteries clean and dry.

Storage:

Periods of inactivity can be extremely harmful to lead-acid batteries. When placing a battery into storage, follow the manufacturer's recommendations and/or the recommendations below to insure that the battery remains healthy and ready for use. The most important things to avoid:

1. Freezing. Avoid locations where freezing temperatures are expected. Keeping batteries at a high state of charge will also prevent freezing. Freezing results in irreparable damage to battery plates and containers. **NOTE** that if a battery is kept completely charged; the chances of it freezing are very small.
2. Heat. Avoid direct exposure to heat sources, such as radiators or space heaters. Temperatures above 80.F / 26.C accelerate the battery's self-discharge characteristics. **NOTE** that heat causes more damage to a battery than cold ever will, so keep your battery storage area as cool as reasonably possible.
3. **NOTE** that storing your battery on concrete will not damage your battery!

Step by step storage procedure

1. Completely charge the battery before storing.
2. Store the battery in a cool, dry location, protected from the elements.
3. During storage, monitor the specific gravity (flooded) or voltage. Batteries in storage should be given a boost charge when they show a charge of less than 75% or approximately 12.40 volts for a 12 volt battery. See "Open Circuit Voltage" table above.
4. Completely charge the battery before re-activating.

5. For optimum performance, equalize the batteries (flooded) before putting them back into service. Refer to the Equalizing section for this procedure.

WARNING: DO NOT EQUALIZE CHARGE Gel OR AGM BATTERIES!

Section XIII - Glossary

A

Advanced Battery Management

A three-stage charging system designed to prolong the service life of UPS batteries. By charging the batteries only when necessary, battery life is significantly improved. Charging stage one: quickly recharges battery to approximately 90% of capacity. Charging stage two: fully charges the battery to 100%. Charging stage three: rest mode prevents overcharging. Charging stage one is initiated after a power outage or periodic UPS self-test.

AC

Alternating Current electrical power supplied by a utility company or from an AC generator.

AC Distribution

A module in the power system that distributes AC power to other power system modules.

AC Metering

Measurement of AC power input voltage and current parameters by sampling. The results of the measurements are used to calculate the rms (Route Mean Squared) equivalents for voltage, current and power, and also calculate the power factor and frequency.

AC Utility

The electric power furnished by an electric power utility company.

Active Load Share

A current sharing scheme controlled by the supervisory module that adjusts the output voltage of individual rectifiers so that all rectifiers in a DC power system produce the same output current.

Active Voltage Control

The supervisory module adjusts the rectifier output voltages to maintain a constant DC power system voltage (measured at the output or battery) independent of load fluctuations during normal operation.

Agent

A software program that acts as a focal point for data collection and configuration of a specific network entity (hardware or software). SNMP agents provide data to management stations regarding the operation and configuration of devices on a network.

Alternating Current (AC)

Current which changes (or alternates) direction at regular intervals. Since the current flows in one direction for the same amount of time that it flows in the opposite direction, the average value of the current flow is zero.

Ampere (Amp or A)

The unit of measure for current. One ampere is the amount of electricity per second that flows through a conductor such as a wire.

AVC

Active Voltage Control

B

Bandwidth

The data a cable can carry measured in bits per second (bps).

Battery Backup

A battery or a set of batteries in a UPS system. Its purpose is to provide an alternate source of power if the main source is interrupted.

Battery Capacity

The battery ampere-hour capacity at full charge, standard temperature, and at a specified (usually C10) discharge rate.

Battery Charger

A device or a system which provides the electrical power needed to keep the battery backup fully charged.

Battery Current Limit

System voltage control that limits the battery charge current to a preset value.

Bi-Directional Converter

A device which changes (or converts) alternating-current power to direct-current power and vice versa.

Blackout

A total loss of the AC utility (commercial power).

Boost

See buck and boost.

Brownout

A reduction in the voltage of the AC utility without complete loss of power.

Buck and Boost

A proprietary voltage regulation process used when an over-voltage or under-voltage situation occurs in the UPS. Under-voltage is boosted to make the voltage greater, and over-voltage is bucked to reduce it. The result is less reliance on the UPS battery, extending overall battery life.

Bus Voltage

The actual voltage supplied to the load as measured at the bus bars.

Bypass

A circuit used to change the path of the electrical power so that it goes around (or bypasses) its normal path. In the UPS, the bypass circuit is used to route the power around the major electronics in the UPS so they can be serviced without power interruption.

C

C5

Symbol for ampere-hour capacity of a battery at the 5-hour discharge rate, to a specified end voltage.

C10

Symbol for ampere-hour capacity of a battery at the 10-hour discharge rate, to a specified end voltage.

C20

Symbol for ampere-hour capacity of a battery at the 20-hour discharge rate, to a specified end voltage.

C100

Symbol for ampere-hour capacity of a battery at the 100-hour discharge rate, to a specified end voltage.

CE

Conformite Europeene (European Conformity)

Circuit Breaker (CB)

A device for manually opening (breaking) or closing a circuit to interrupt or apply electric power to an electrical apparatus. A circuit breaker can also open a circuit automatically when it senses an overload.

Clean Power

Electrical power which has been conditioned and/or regulated to remove electrical noise from the output power.

Configuration file

The information or data loaded into and the supervisory module that controls the behavior of a power system to suit the particular requirements of a customer's site or installation.

Configurations Database

This is the total set of configurable parameters.

Conformite Europeene (European Conformity)

CE marking is used to signify that a product complies with all the applicable performance and safety standards adopted by the members of the European Union and is therefore certified for sale in European Union countries.

Converter

A device which changes electrical energy from one form to another, such as from alternating current to direct current.

Current

Amount of electricity that flows through a conductor, such as a wire.

Current Share

A process used to balance output currents between rectifiers. See Active Current Share.

D

DC

Direct Current

DC Distribution (DCD)

A module in the power solution that distributes DC power to the loads. It also provides protection for the load cables.

DC Distribution - Fused version (DCF)

A DC Distribution module that uses fuses for protection.

DC Distribution - Miniature Circuit Breaker (MCB) version (DCM)

A DC Distribution module that uses miniature circuit breakers for protection.

Delta Connection

A method of connecting a three-phase source or load in series for a closed circuit (3-wire, plus ground).

Digital Input

An input which recognizes an open-circuit and short-circuit.

Digital Output

A voltage free relay contact.

Direct Current (DC)

A type of current which never reverses its direction. Since the current flows in only one direction, the average value of the current cannot be zero unless the current has stopped flowing.

Double-Conversion

A UPS design in which the primary power path consists of a rectifier and inverter. Double-conversion isolates the output power from all input anomalies such as low voltage, surges and frequency variations by converting AC to DC to AC. See Online UPS.

Dry Contact

Isolated contacts through which the end user supplies an external circuit. Dry contact UPSs provide basic communication capabilities such as monitoring and shutdown.

E

Efficiency

The ratio of the output power from the UPS to the input power from the utility. This shows the percentage of the input power that is available as useful output power. For example, a UPS that is 95% efficient delivers 95% of the utility power it receives to the load. The remaining power takes the form of dissipated heat.

EMC

Electro Magnetic Compatibility.

Emergency Shutdown

Used to instantly or quickly shutdown all of the electrical power available to the UPS and the load. An emergency shutdown device is usually used during a crisis to prevent damage to the UPS and the load. Some computer-room installations require a Remote Emergency Power Off (REPO) capability as part of their security/safety system.

Equalize

This is the process of increasing the Float Voltage to the Equalize Voltage to recharge or equalize the batteries.

Event

An alarm activation or de-activation.

F

Fast Charge

Increasing the Operating Voltage after a battery discharge, following an AC failure, to give a rapid battery recharge. Typically at a constant current charge rate higher than .3C, (1/3 the batteries rated ampere-hour capacity).

Fault Tolerance

The ability of a system to continue operating in the event of a fault.

Filtering

A method of removing noise from the output of a UPS preventing “dirty power” from reaching connected equipment.

Float Voltage

The set output voltage of the DC power system (not including temperature compensation or other adjustments).

Frequency

The number of cycles (oscillation positive and negative) completed in one second. Defined as Hertz. In North America, utility power completes 60 cycles per second, (60 Hertz).

Full Load

The greatest load that a circuit is designed to carry under specific conditions; any additional load is considered an overload.

G

Graphic User Interface (GUI)

A computer system using graphics images on the screen rather than text to display applications information for the user.

Ground (GND)

A conductor connected between a circuit and the soil.

H

Hardware Default Voltage

The rectifier output fail-safe operating voltage used if the rectifier microprocessor fails.

Hardwired

Describes any equipment connected to its power source by hardware attached directly to terminal blocks or distribution panels.

Harmonic Distortion

The presence of harmonics that change the AC voltage waveform from a simple sinusoidal to complex waveform. Harmonic distortion can be generated by a load and fed back to the AC utility line, causing power problems to other equipment on the same circuit.

Heterogeneous Network

A network with a multitude of workstations, and operating systems, and a variety of application types from different vendors.

High Rupturing Capacity (HRC) (fuse)

A precisely rated fuse which will operate under high fault current conditions, without self-destructing.

Homogeneous Network

A network of components - workstation, server, operating system from the same vendor, or compatible equipment that can run under the same network or operating system.

Hot-Swappable Batteries

A feature which enables the user to change UPS batteries without powering down the connected load.

Hot-Swappable Power Modules

A feature which enables the user to change UPS power modules without powering down the connected load.

I

I/O

Input/Output

Input Line Cord

The covered bundle of wiring connected to the input terminals of the UPS. The end of the cord not connected to the UPS is connected, via an input plug, to an AC utility outlet supplying power to the UPS.

Input Plug

Connected to the end of the input line cord. To be plugged into an AC utility outlet receptacle.

Internal Bypass

UPS circuitry which provides a redundant power path is referred to as an Internal Bypass. If there is an internal UPS fault, the connected load will still be supplied with unconditioned utility power.

Inverter

An Inverter is a machine, device, or system that changes direct current (DC) power into alternating current (AC) power.

Isolation

The separation - often through the use of an Isolation Transformer - of one section of a system in order to avoid undesired electrical influences that may occur in another section.

Isolation Transformer

An Isolation Transformer uses isolated windings that physically separate the primary and secondary windings. Although the two windings are physically disconnected, the magnetic field in the windings of the primary creates (induces) electrical power in the secondary winding. In this way, the electrical power available at the input can be transferred to the output. An isolation transformer does not transfer unwanted noise and transients from the input circuit to the output windings. This attenuation, or reduction in amplitude, could be as high as one million to one.

L

LCD

Liquid Crystal Display

LEDs

Light Emitting Diodes that inform users of various power conditions and operations.

Line-interactive

A UPS containing an off-line inverter that must transfer on during a blackout, but provides faster transfer times than an off-line UPS and power conditioning and surge suppression functions which protect the connected load.

Load

Equipment that receives power from a UPS.

Load Bus

The bus to which the load equipment is connected.

Load Segments

Groups of receptacles on the rear panel of a UPS which can be independently controlled.

Load Shedding

The ability to selectively shut off a set of UPS output receptacles, extending the capacity of the UPS battery. Some UPS models are able to shed less critical loads by turning off selected output receptacles during an extended power failure while maintaining power to the more critical load(s) on the remaining output receptacles.

Low Voltage Disconnect (LVD)

A module in the power system that disconnects the load from the batteries from the when the battery voltage falls below a preset value. The LVD reconnects the load to the batteries when the battery voltage rises above a preset value.

M

Management Information Base (MIB)

The structure of the database in a power system.

Manual Bypass Switch (MBS)

A manually operated transfer switch used to bypass the major electronics in the UPS, so the UPS can be serviced without power interruption.

Mapping

The process of assigning physical entities to logical entities, e.g. when a particular analogue channel (internal or external) is assigned to be the channel used for measuring the bus voltage.

Maximum System Current (MSC)

The maximum current that can be supplied by or from a power system (excluding batteries) under all conditions. The MSC is normally 120% of the systems rated current.

MCB

A Miniature Circuit Breaker is a precisely rated, re-settable circuit protection device.

MDV

A Metal Oxide Varistor is a non-linear semiconductor device used for surge protection or voltage limiting.

N

National Electrical Code (NEC)

The code of standards and practices for the U.S. electrical and electronics industry. Developed by the National Fire Protection Association of Quincy, Mass. and first published in 1896.

Network Transient Protector

An in and out RJ11 jack for telephone/modem protection (120V models only) or RJ45 for 10Base-T network cable. It isolates connected equipment such as modem and fax machines from "back door" power surges.

Noise

Random, sporadic, or multi-frequency electrical signals that become part of a transmission, making the signal or information more difficult to identify.

Nominal System Voltage

The DC output voltage generally used to describe a type of system, usually 24 V or 48 V.

Nominal Value

A designated value which has been accepted for the sake of convenience. For instance, nominal voltages are values assigned to circuits so that the voltages of the circuits can be conveniently discussed as 120 Vac nominal units, or 230 Vac nominal units.

Null Modem Cable

A special cable for connecting two RS-232 ports or devices directly, in place of a modem connection.

N+X UPS Redundancy

This form of redundancy provides reliable UPS operation by eliminating any single point of failure within the UPS.

O

Off-line UPS

A UPS type which feeds power to the load directly from the utility and then transfers to the battery power via an inverter after utility drops below a specified voltage. The delay between utility power loss and inverter startup can be long enough to disrupt the operation of some sensitive loads. Also called a standby UPS.

Online UPS

A UPS in which the inverter is on during normal operating conditions supplying conditioned power to the load through an inverter or converter that constantly controls the AC output of the UPS regardless of the utility line input. In the event of a utility power failure, there is no delay or transfer time to backup power.

Outlet

Any point on a wiring system where current is taken to supply electrical power for a load.

Output Enable Delay

The delay between the start of primary side switching and the start of output current walk in. This is in two parts: a fixed hardware delay controlled by the secondary side control circuits and an adjustable delay controlled by the microprocessor. During this period the output voltage is at the minimum of approximately 40 V.

Overload

A condition in which the load wants more from the power source (such as a UPS) than the power source has been designed to supply.

Over-voltage Shutdown (OVSD)

A protection method that will shutdown any rectifier module with an output voltage over a preset maximum value.

P

Parallel Online UPS

Online UPS technology or installations that provide redundant sources of conditioned backup power so that the critical load is protected even in the event of UPS component failure.

Power Factor (PF)

The ratio of total real power, (W) to the total apparent power in volt-amperes (VA);W/VA.

Power Management Software

Provides monitoring and shutdown for UPS and connected load.

Power System

A rack module, single rack or several parallel connected racks, providing DC power to a single DC bus.

Preset Voltage

The voltage that a rectifier will default to if communications with the Supervisory Module is lost. Generally, this is set to the float voltage by the Supervisory Module.

PSTN

Public Switched Telephone Network

R

Rack mount UPS

UPS that can be mounted in a rack along with servers, hubs, and other devices.

Rated Rectifier Current

The maximum output current of a rectifier at 58 V for a 48 V (nominal) rectifier, or 29 V for a 24 V (nominal) rectifier.

Rated System Current

The sum of the rated rectifier currents in the power system.

Raw Power

Electrical power which may or may not contain unwanted electrical signals.

Receptacle

A contact device installed at an outlet designed to accept a single plug. Receptacles on the rear of a UPS accept plugs from supported system equipment such as computers or monitors.

Rectifier

A module fitted to the power system that converts AC input power to regulated DC output power.

Rectifier Bus

The bus to which the outputs of the rectifiers are connected.

Rectifier Magazine

A module in the power system used to connect the rectifiers to other modules in the power system.

Rectifier Voltage

The voltage to which the rectifiers are set. This is assumed to be the same for each rectifier and does not include current share adjustments.

Redundancy

Duplication of elements in a system or installation to enhance the reliability or continuity of operation.

Regulation

The act of limiting voltage – using various methods – to a set range.

Reserve

Battery time remaining to end of discharge.

RFI

Radio Frequency Interference

RM

Rectifier Magazine

RMS
Route Mean Squared

RS-232

Also called serial ports; a method of communicating digital information in which the data bits are transmitted sequentially over one line.

RS-232C

A common point-to-point hardware configuration for serial communications.

RS-485

A multi-drop hardware configuration for serial communications. There is no intrinsic method of bus collision detection in RS-485, so higher layers in the protocol stack must take this into account.

S

Scalable UPS

A UPS that allows for expandability; for example, enables a UPS to accommodate a larger load by purchasing additional power modules.

Simple Network Management Protocol (SNMP)

A request-response protocol that collects management information from network devices and provides a way to set and monitor configuration parameters.

Sine Wave

The sinusoidal wave form exhibited by alternating current.

Single-Phase Power (1Ø)

Power that is provided by a single source which normally includes one hot lead and a grounded (neutral) return line.

Slope Discrimination Method

A design format that causes the Over Voltage Shutdown set point to fall with increasing load.

SNMP

Simple Network Management Protocol

Square Wave

Output waveform generated by very basic, low-cost UPSs. Functions adequately for less sensitive loads, but may not provide acceptable quality input for some types of electronic equipment.

Standby Power System

See Off-Line UPS.

Start-On-Battery

Enables user to power up UPS in the absence of utility power.

Start Up Delay

The interval between power on and the start of current walk in. It is the sum of the Primary Enable Delay and the fixed and adjustable portions of the Output Enable Delay.

Status LEDs

Light Emitting Diodes (LEDs) that show the status of the UPS when they light up or turn off.

Step Wave

(Modified Sine wave) Enhanced version of square wave that provides adequate input for some more sensitive loads, but still not as high quality as a sine wave.

Supervisory Module

The module that monitors and controls the operation of the DC power system.

Surge

A transient (or momentary) wave of current, potential, or power in an electric circuit.

System Voltage

The nominal voltage of the power system, equal to the nominal voltage of the rectifier modules (48 V or 24 V).

T

Temperature Compensation

Adjustment of the rectifier output voltage to provide the optimum charging voltage for the battery. One of the components in system voltage control, calculated by the Supervisory Module calculation based on battery temperature.

Temperature Sensor

A sensor that is used to produce a variable electrical output representing the temperature of a component, typically a battery.

Terminal Block

An insulating base equipped with terminals for connecting secondary and control wiring. Used on hardwired equipment, such as a UPS, when input plugs and output receptacles are either impractical or unavailable.

Terminal

A connector for attaching a conductor to an electrical apparatus.

Three-Phase Power (3Ø)

Power that is provided by a single source with three outputs with a phase difference of 120° between any two of the three voltages and currents.

Transfer Switch

A switch which will transfer current from one circuit path to another without interrupting the flow of the current.

Transformer (T)

A device that raises or lowers the voltage of an alternating current electrical source.

Transient

The fast radical change in a smooth sine wave that occurs in both voltage and current waveforms during the transition from one steady-state operating condition to another.

Trickle Charge

With the trickle charging process, the battery receives a constant voltage feeding a low current. Constant use of this method dries the electrolyte and corrodes the plate, reducing potential battery service life by up to 50 percent.

Two-Phase Power

Power which is provided by a single source with two outputs which may be 180 degrees out of phase or 120 degrees out of phase.

U

UL

Underwriters Laboratories. An approval organization based in the United States.

Uninterruptible Power System (UPS)

A system designed to automatically provide power, without delay or transients, when the normal power supply is incapable of supplying acceptable power. Some UPSs also filter and/or regulate utility power.

UPS Topology

Overall term describing the internal circuitry of a UPS. There are three basic UPS topologies: standby (off-line), line-interactive, and online.

User-Replaceable Batteries

User replaceable batteries allow the user to easily exchange UPS batteries, once the unit has been turned off.

V

Volt (V)

The unit of measure for voltage. Voltage is the electrical pressure which forces the current to flow in a conductor such as a wire.

Volt-Ampere (VA)

Voltage (V) multiplied by the current (ampere); apparent power. For instance, a device rated at 10 amps and 120 V has a VA rating of 1200 or 1.2 kVA.

W

Walk-In-Time

The time that the rectifier takes to reach rated output current after the Start Up Delay. The slope is fixed so that a lower output current will have a shorter walk in period.

Walk-In

The process of gradually ramping up rectifier output voltage (and current) at start up to prevent a large input current surge.

Watt (W)

The unit of measure for true power. Watts = VA x Power Factor.

Wye Connection

A three-phase source of load connection, with a single common junction and three phase lines out or in.

Section XIV - Frequently asked Solar industry Q&A's

How do solar panels (cells) generate electricity?

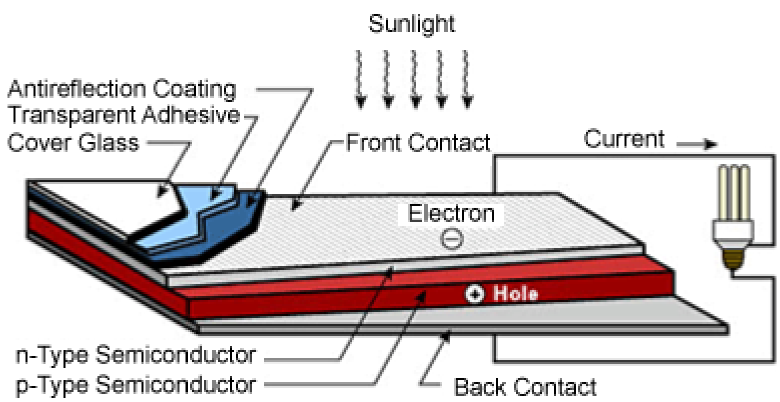

Figure 6 - Solar Panel Cutaway

Photocells (photovoltaic or "PV") can be thought of as a direct current (DC) generator or charger powered by the sun. When light photons of sufficient energy strike a solar cell, they knock electrons free in the silicon crystal structure forcing them through an external circuit (battery or direct DC load), and then returning them to the other side of the solar cell to start the process all over again. The voltage output from a single crystalline solar cell is about ½ Volt with an amp output that is directly proportional to the cell's surface area (approximately 7 amps for a 6 inch square multi-crystalline solar cell). In typical solar module there will be 30 to 36 cells connected in series. This produces a solar module with a 12V nominal output (17V peak output) that can then be wired in series and/or parallel with other solar modules to form a complete solar array capable of charging a 12, 24 or 48 volt battery bank.

Will solar work in my location?

The sun's solar activity is universal. Although some locations are better than others, solar will work anywhere. Irradiance is a measure of the sun's power available at the earth's surface. It is typically expressed in kilowatts per square meter. It averages about 1000 watts per square meter. With typical crystalline solar cell efficiency (14-16%), we can expect to generate about 140W-160W per square meter off of solar cells placed in full sun. Irradiance multiplied by time equals insulation. Insolation is a measure of the available energy from the sun and is expressed in terms of "full sun hours" (i.e. 4 full sun hours = 4 hours of sunlight at an irradiance level of 1000 watts per square meter). Obviously different parts of the world receive more sunlight than others which results in more "full sun hours" per day. The solar insolation zone map below gives you a general idea of the "full sun hours per day" for different zones. You have to extend the zones north and south for reference zones in Canada and Mexico.

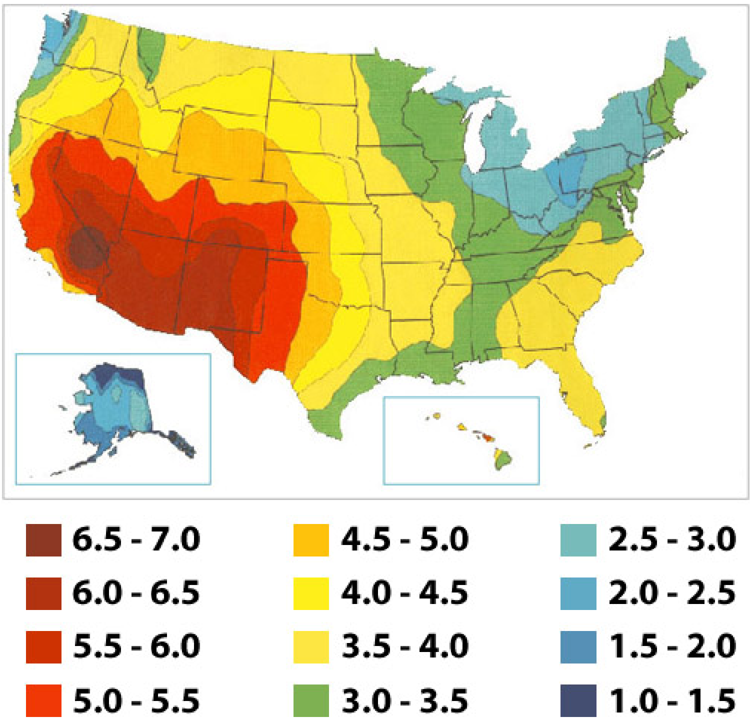

Figure 7 - USA Sun Zones

For reference purposes above zones can be extended north and south into Canada and Mexico.

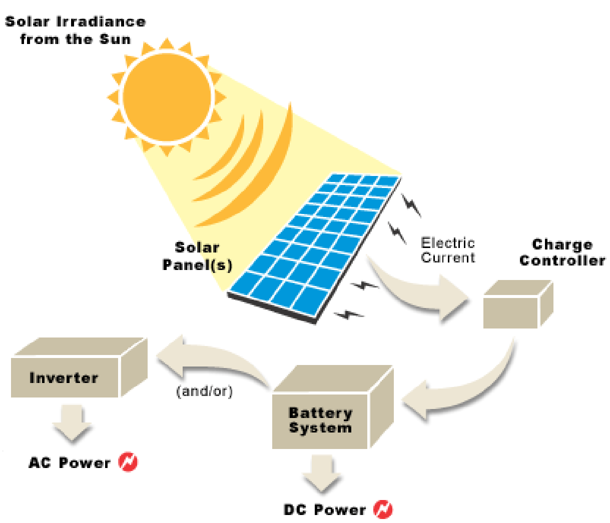

Figure 8 - Simple Solar Installation

How much will a system cost for my 2000 square foot home?

Unfortunately, there is no per square foot "average" since the cost of a system actually depends on your daily energy usage, how many full sun hours you receive per day, and if you have other sources of electricity. To accurately size a system to meet your needs, you need to know how much energy you use per day. If your home is connected to the utility grid, simply look at your monthly electric bill. You can design a system that will meet your needs using this information.

Can I use all of my normal 120/240 VAC appliances?

The simple answer is maybe but not likely. Older homes with older appliances and fixtures are less efficient. When you install a renewable energy system for your home, you become your own power company so every kilowatt hour (kwh) of energy you use means more equipment. More equipment means more cost. Appliances that operate at 240 Volts Alternating Current (VAC) are impractical loads to run on solar. Alternatives such as propane or natural gas should be considered for space and water heating and cooking. Also, along with designing a passive solar design into new construction, an evaporative cooling system should be considered instead of compressor based AC units. After electrical heating loads, refrigeration and lighting is typically the largest user of 120 VAC energy. You should make sure that you get the most energy efficient units available when purchasing refrigeration and lighting. Conservation is the law in renewable energy. For every dollar you spend replacing your inefficient appliances, you will save three dollars in the cost of a renewable energy system to run them.

What components do I need for a grid-tie system?

Grid-tie systems are inherently simpler than either grid-tie with battery back-up or stand-alone solar systems. Other than safety disconnects, mounting structures and wiring a grid-tie system is just solar modules and a grid-tie inverter! Today's sophisticated grid-tie inverters incorporate most of the components needed to convert direct current (DC) from the modules to alternating current (AC), track the maximum power point of the modules to operate the system at peak efficiencies and terminate the grid connection if grid power is interrupted form the utility.

What components do I need for a complete solar system?

There are many components that make up a complete solar system, but the 4 main items are: solar modules, charge controller(s), Discover® batteries, and inverter(s). The solar modules are physically mounted on a mount structure and the DC power they produce is run through a charge controller before it goes on to the battery bank to be stored. The two main functions of a charge controller are to prevent the battery from being overcharged and eliminate any reverse current flow from the batteries back to the solar modules at night or in reduced light. The battery bank stores the energy produced by the solar array during the day for use at anytime of day or night. Discover® batteries are available in many footprints with many storage capacities. The inverter takes the DC energy stored in the batteries and inverts it to 120 VAC to run the AC appliances.

What type of solar module mounting structure should I use?

There are four basic types of mount structures: roof/ground, top-of-pole, side-of-pole and tracking mounts, each having their own pros and cons. For example, roof mount structures typically keep the wire run distances between the solar array and battery bank to a minimum, which is good. But they also require roof penetrations in multiple locations (a potential source of leakage) and they require expensive ground fault protection (GFP) (a requirement in article 690-5 of the National Electrical Code). Ground mounted solar arrays do not require GFP but they do require fairly precise foundation setup and are more susceptible to vandalism and excessive snow accumulation at the bottom of the array. Next are pole-top mounts which are relatively easy to install. After squarely securing a pole (steal or treated wood etc.) into the ground, the solar modules are mounted and racked on top of the pole. Pole-top mounts are a better choice for cold climates because snow slides off easily however they may be hard to clean. Pole-side mounts are easy to install and are typically used for small numbers of solar modules (1-4) for remote lighting systems where a pole exists to attach them to. Last but not least are the trackers, which increase the daily number of full sun hours and are used for solar water pumping applications. Trackers are extremely effective in the summer time when water is needed the most. In northern climates (or zones further away from the equator), typical home energy usage peaks in the winter when a tracker mount will make very little difference. A less expensive fixed roof, ground or pole-top mount with more modules will perform better in the winter than fewer modules on a tracker. However, in southern climates (or areas closer to the equator) your energy usage peaks in the summer and a tracker system may be the better solution.

Where should I mount the solar modules and what direction should I face them?

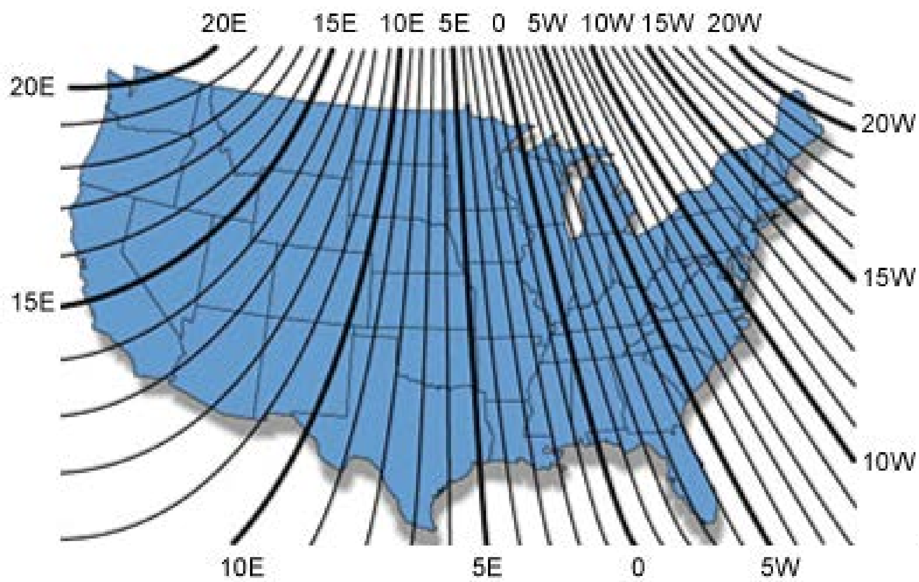

Figure 9 - Sun Declination Map

If your site is in the Northern Hemisphere you need to aim your solar modules to the true south direction (the reverse is true for locations in the Southern Hemisphere) to maximize your daily energy output. For many locations there is quite a difference between magnetic south and true south, so please consult the declination map above before you setup your mount structure. The solar modules should be tilted up from horizontal to get a better angle at the sun and help keep the modules clean by shedding rain or snow. For best year round power output with the least amount of maintenance, you should set the solar array facing true south (or north if in the southern hemisphere) at an angle to the horizon equal to the degrees of latitude of your position. If you plan to adjust your solar array tilt angle seasonally, a good rule of thumb to go by is latitude minus 15° in the summer, latitude in the spring/fall and latitude plus 15° in the winter. Most mount structures provided for a seasonal adjustment of the tilt angle are from horizontal to 65°.

Should I set my system's battery bank up at 12, 24 or 48 VDC?

The PV industry really began with the 12V recreational vehicle market. These systems were typically small (1-2 solar modules) and had all 12 VDC loads. As the solar industry matured and entered the home market, systems became much larger (16+ solar modules) and no longer used DC loads exclusively. Most home systems today are 24 or 48 VDC since the higher system voltage gives you a lot more flexibility as to how far away you can place your solar modules from the battery bank as compared to a 12 V system. For a given power output, a higher system voltage reduces your amperage flow (but not your power) which allows you to use a smaller and less expensive gauge wire for your solar to battery and battery to inverter wire runs. Of course, if you already have a lot of 12 VDC loads this may be the deciding factor in what voltage you set your system up at. Most grid-tied systems operate at 48 volts or higher.

Should I wire my home for AC or DC loads?

It depends on the size of the system and what type of loads you want to run. DC appliances are usually more efficient than AC since you don't have to worry about the loss through the inverter, but DC loads are typically more expensive and harder to find than their AC counterparts. Small cabin and RV systems are typically wired DC while most home systems are wired for AC loads exclusively. With improvements in inverter efficiency AC is the way to go for home systems. Another advantage AC has over DC is that the voltage drop for a 120 VAC circuit is much less than a 12 VDC circuit carrying the same power, which allows you to use smaller gauge wire.

Can I use PV to heat water or for space heating?

No. Photovoltaic cells convert the sun's energy into DC electricity at a relatively low efficiency level. Therefore, trying to operate a high power electric heating element on PV’s would be very inefficient and expensive. Solar thermal (or passive solar) is the direct heating of air or water from the heat of the sun and is much more efficient for heating applications than photovoltaic (a black barrel full of water kept in the sun).

Section XV - Solar industry Glossary

ABSORBER – solar photovoltaic industry

The absorber is a part of the solar thermal collector that receives the incident radiant energy and transforms it into heat energy.

ACTIVE SOLAR THERMAL SYSTEM – solar photovoltaic industry

A system that traps the sun's energy with solar collectors and uses an electromechanical subsystem to move that energy to its point of intended use for water heating, space heating, pool heating, industrial process heat, electrical generation and space cooling.

ALTERNATING CURRENT (AC) – solar photovoltaic industry

An electrical current in which the direction of electron flow reverses periodically, usually many times per second. Most U.S. household electrical systems use AC current rated at 120 volts and 60 cycles per second.

ALTERNATOR – solar photovoltaic industry

A mechanical device that generates alternating current electricity.

ALTITUDE ANGLE – solar photovoltaic industry

The angle of the sun above the horizon, measured in degrees. In winter, the sun is at a low solar altitude, and in the summer, the sun is at a high solar altitude.

AMMETER – solar photovoltaic industry

A device used for measuring the current (amperage) at any point in an electrical circuit.

AMORPHOUS SILICON – solar photovoltaic industry

A thin-film PV silicon cell having no crystalline structure.

AMPACITY – solar photovoltaic industry

Refers to the highest safe amount of electrical current through conductors, over current devices, or other electrical equipment. Ampacity is determined by the cross-sectional area and the material of the conductor, or the manufacturer’s equipment rating.

AMPERE (AMP; A, I) – solar photovoltaic industry

The rate of flow of electrical charge. Unit of electrical current. One volt across one ohm of resistance causes a current of one ampere. One ampere is equal to 6.235×10^{18} electrons (one coulomb) per second passing a given point in a circuit.

AMPERE-HOUR (AMP-HOUR; AH) – solar photovoltaic industry

A measure of electron flow over time, used to measure battery capacity and state of charge. For example, a current of 1 amp drawn from a battery for 10 hours would result in 10 amp-hours of charge cycling through the battery.

AMPERE-HOUR METER – solar photovoltaic industry

An instrument that monitors electron flow over time. Amp-hours are the product of electron flow (in amperes) and time (in hours).

AMPLITUDE

Generally refers to the maximum and minimum voltage attained by an alternating or pulsed current in each complete cycle or pulse of that current.

ANGLE OF INCIDENCE

The angle between the sun's rays and a line perpendicular to the active surface of a solar module or collector, in degrees.

ANGLE OF INCLINATION

The angle that a solar collector or PV module is positioned above horizontal.

ANODE

(Battery) The electrode within a battery cell that undergoes the chemical process of oxidation. Electrically, the anode is the cell's positive terminal.

(Water heater) An aluminum or magnesium sacrificial rod installed within steel tanks that is used to help prevent corrosion of the tank itself.

ARRAY

Any number of photovoltaic modules connected together electrically to provide a single electrical output.

AWG

American Wire Gauge, a set of standards in the U.S. specifying the diameter of wire. A higher number indicates smaller wire.

AZIMUTH

The angle between true south and a point on the horizon, measured in degrees east or west of true south.

BALANCE OF SYSTEMS (BOS)

Parts or components of a photovoltaic system other than the photovoltaic array or other generating equipment.

BALLAST

A circuit used to condition and stabilize an electric current, for example, in a fluorescent light.

BATCH SOLAR HOT WATER HEATER

The simplest of solar hot water systems. A tank of water within a glass-covered insulated enclosure aimed at the sun. Water is heated in the tank and then flows to the load or an auxiliary water heater.

BATTERY

Two or more electrochemical cells electrically interconnected in an appropriate series/parallel arrangement to provide the required operating voltage and capacity levels. Under common usage, the term battery also applies to a single cell if it constitutes the entire electrochemical storage system.

BATTERY CAPACITY

The total maximum charge, expressed in ampere-hours, that can be withdrawn from a cell or battery under a specific set of operating conditions including discharge rate, temperature, state of charge, age, and cutoff voltage.

BATTERY CELL

The simplest operating unit in a storage battery. It consists of one or more positive electrodes or plates, electrolyte that permits ionic conduction, one or more negative electrodes or plates, separators between plates of opposite polarity, a container for all the above, and posts or other terminals for electrical connection.

BATTERY CYCLE LIFE

The number of cycles, to a specified depth of discharge, that a cell or battery can undergo before failing to meet its specified capacity or efficiency performance criteria.

BATTERY LIFE

The period during which a cell or battery is capable of operating above a specified capacity or efficiency performance level. With lead-acid batteries, end-of-life is generally considered when a fully charged cell can deliver only 80 percent of its rated capacity. Beyond this state of aging, deterioration and loss of capacity begins to accelerate rapidly. Life may be measured in cycles or years, depending on the type of service for which the cell or battery is intended.

BETZ LIMIT

The theoretical maximum energy that a wind generator can extract from the wind—59.6 percent.

BIOMASS

Any organic matter available on a renewable basis, including agricultural crops, wastes, and residues; wood, wood wastes, and residues; animal wastes and municipal wastes; and aquatic plants.

BIOFUELS (BIOMASS FUELS)

Biomass converted directly to energy or converted to liquid or gaseous fuels, such as ethanol methane and hydrogen.

BLADE

The energy-capturing, aerodynamically designed part of a wind turbine, which interacts directly with the wind.

BLOCKING DIODE

A semiconductor connected in series with a solar-electric cell or cells and a storage battery to keep the battery from discharging through the cell when there is no output, or low output, from the solar cell. It can be thought of as a one-way valve that allows electrons to flow forwards, but not backwards.

BRAKE

Device for stopping a wind turbine. This can be an electric brake that shorts the output of the turbine (dynamic braking), or a mechanical brake that physically stops the rotation, as with a brake drum and shoe.

BREAKER

A manually operable switching device that also automatically opens a circuit in the event of over current.

BRITISH THERMAL UNIT (BTU)

The amount of heat required to raise the temperature of one pound (one pint) of water, one degree Fahrenheit. 1 watt-hour = 3.413 BTU.

BULK CHARGE

The initial phase of battery charging when the largest amount of energy is put into the battery.

BUSS

An electrical connection component that can accept multiple cables or wires.

BYPASS DIODE

A semiconductor device connected in parallel with a series block of parallel PV strings to prevent current from flowing back through any shaded or failed modules in the same block.

CAPACITANCE

An electrical effect in AC circuits that results in amperage peaking before voltage.

CATHODE

The electrode within a battery cell that undergoes the chemical process of reduction. Electrically, the cathode is the negative terminal of the cell.

CATHODIC PROTECTION

Systems that protect metal from corrosion by running small electrical currents along the metal. Most often used to protect well heads, and oil, gas, and water pipelines.

CELL (battery)

A single unit of an electro-chemical device capable of producing an electrical current by converting chemical energy into electrical energy. The cell is the basic unit used to store energy in the battery. The cell contains an anode, a cathode, and the electrolyte. A battery usually consists of several cells electrically connected together to produce higher voltages (sometimes the terms cell and battery are used interchangeably).

CELL (solar)

The smallest, basic photovoltaic device that generates electricity when exposed to light.

CHARGE CONTROLLER

A component of photovoltaic systems that controls the charging of the battery to protect the batteries from overcharge and over discharge. The charge controller may also indicate the system operational status. Standard charge controllers vary the current (A) based on preset voltage set points.

CHARGE RATE

The current applied to a cell or battery to restore its available capacity, specified in relation to total battery size. A C/20 rate is a charge rate that is 1/20th of the total battery capacity. Also called a "20-hour rate."

CIRCUIT

A group of electrical components that make a complete electrical path, providing some function.

CIRCUIT BREAKER

See BREAKER.

CLOSED LOOP SYSTEM

A solar hot water system of which no part is vented to the atmosphere or fed with fresh liquid. The system liquid, usually some form of antifreeze solution, is re-circulated. Closed loop solar systems are also known as glycol systems and indirect systems.

COB CONSTRUCTION

A traditional building technique using hand formed lumps of earth mixed with sand and straw.

COLLECTOR LOOP

The plumbing loop in a solar hot water system that includes the solar collectors. The collectors heat the fluid in the collector, and the heated fluid can be used directly (if water) or the heat can be exchanged to a potable water loop.

COMBINER BOX

A box where wires from individual PV modules or strings are combined into larger wires to run to the battery bank. Can also contain over current protection devices.

COMPACT FLUORESCENT LIGHT (CFL)

A smaller version of standard fluorescent lamps that can directly replace incandescent lights. CFLs use 65 to 80 percent less energy, while producing the same lumens.

CONCENTRATOR

A photovoltaic module that includes optical components, such as lenses, to direct and concentrate sunlight onto a solar cell of smaller area. Most concentrator arrays must directly face or track the sun.

CONDUCTION

Heat transfer from a hot object to a colder object through direct contact.

CONDUCTOR

A material with relatively low resistance through which electricity will readily flow—wires, cables, bus bars. The most common conductors are copper and aluminum.

CONDUIT

Metal or plastic tubing designed to protect electrical conductors.

CONTINUOUS OUTPUT RATING

The maximum amount of power an inverter may deliver to a load (or loads) for a sustained period of time.

CONVECTION
Heat transfers by the movement of fluid (usually air or water). Heat transfers through either the natural or forced movement of air.

CONVERTER
An electronic device for DC power that steps up voltage and steps down current proportionally (or vice-versa).

CRYSTALLINE SILICON

A type of PV cell made from a single crystal or polycrystalline slice of silicon.

CURRENT

Flow rate of electrons. See AMPERE.

CUTOFF VOLTAGE

Electrical equipment setting for the voltage level at which a battery is considered to be empty and the discharge process is terminated. Most commonly found in inverters and charge controllers that include a feature for low voltage disconnection.

CYCLE
One complete charge/discharge cycle of a battery. An AC sine wave's movement from zero to maximum positive, through zero to maximum negative, and back to zero.

CYCLE LIFE

Cycle life is the number of cycles a cell or battery will undergo before being considered "worn out." This point is usually defined as when the battery's capacity has decreased to 80 percent of its initial rated capacity.

DAYLIGHTING

The placement of windows and skylights to provide natural interior lighting and to reduce daytime electrical demand.

DAYS OF AUTONOMY

The number of consecutive days that a stand-alone renewable energy system will meet a defined load without additional energy input.

DC

Direct current. A one-way flow of electrons. Typical sources of direct current are solar-electric cells, rectifiers, and direct current generators. To be used for typical 120 volt or 220 volt household appliances, DC must be converted to AC (alternating current).

DC MOTOR, BRUSHLESS

High-technology motor used in centrifugal-type DC submersible pumps and other applications. The motor is filled with oil to keep water out. An electronic system is used to precisely alternate the current, causing the motor to spin.

DC MOTOR, BRUSH-TYPE

The traditional DC motor, in which small carbon blocks called "brushes" conduct current into the spinning portion of the motor. They are used in many applications, including DC surface pumps and also in DC submersible diaphragm pumps. Brushes naturally wear down after years of use and may be replaced.

DC MOTOR, PERMANENT MAGNET

A variable speed motor that uses permanent magnets instead of wound coils. Reduced voltage (in low sun) produces proportionally reduced speed and causes no harm to the motor.

DEEP-CYCLE BATTERY

A battery designed to regularly discharge 50 to 80 percent of its capacity before recharging.

DEGREE DAY

A quantitative index reflecting demand for energy to heat or cool buildings. Heating and cooling degree days show the difference between the mean daily temperature and a 65°F base. The higher the heating degree days at any location, the colder the winter. The higher the cooling degree days at any location, the hotter the summer.

DELTA T

Difference in temperature.

DEPTH OF DISCHARGE (DOD)

The ampere-hours removed from a fully charged cell or battery, expressed as a percentage of rated capacity. For example, the removal of 25 ampere-hours from a fully charged 100 ampere-hour rated cell results in a 25 percent depth of discharge. Depth of discharge is the opposite of state of charge (SOC).

DHW

Domestic hot water: refers to any system that provides hot water for household use.

DIFFERENTIAL CONTROLLER

An electronic switch that turns off or on based on the difference between two temperatures. In a solar hot water system, the controller measures the temperature at the collector and compares it to the water temperature in a storage tank to turn the pump on or off.

DIGITAL MULTIMETER (DMM)

A device with multiple electrical measurement capabilities, such as voltage, amperage, resistance, etc., commonly usable for both AC and DC circuits. It has a digital display.

DIODE

A semiconductor device that allows electrical current in only one direction.

DIRECT CURRENT (DC)

An electrical current that moves in one direction only.

DIRECT GAIN

In passive solar heating, a direct gain system relies on the sunshine to directly hit the substance or mass being heated. Direct gain systems used today usually rely on a layer(s) of glass to assist in holding the heat within a space where the heat is desirable.

DISCHARGE RATE

The rate at which energy is being drained from a battery.

DISCONNECT

Switch gear used to connect or disconnect components in a system.

DOWNWIND

In relation to a wind turbine, the direction away from the source of wind. A downwind turbine has its blades on the downwind side of the tower.

DRAFT TUBE

A tube added to the outfall of a hydro turbine to increase energy production by taking advantage of the drop in the tailrace.

DRAINBACK SYSTEM

A solar hot water system that only fills the collector when the temperature differential is appropriate. The water that is circulated through the collectors is stored in a reservoir. Draining the collectors provides freeze protection.

DRAINDOWN SYSTEM

A solar hot water system that uses a special drain down valve that redirects the collector fluid and drains it down when the collector system pump is not operating. These systems have been prone to failure and are not recommended.

DUTY CYCLE

The fraction of time a device or load actually uses energy in a unit of time. For example, a load that uses energy for 5 seconds out of every 10 seconds has a 50 percent duty cycle.

EARTH

Synonymous with “ground.”

EFFICIENCY (PV modules)

The ratio of power output of a photovoltaic cell to the incident power from the sun or simulated sun sources under specified standard insulation conditions. A solar cell that converts 1/10 of the sun's energy that strikes its surface to electricity has an efficiency of 10 percent.

EFFICIENCY

The effectiveness of a device to convert energy from one form to another or to transfer energy from one body to another. An electric pump that is 60 percent efficient converts 60 percent of the input energy into work—pumping water. The remaining 40 percent becomes waste heat.

ELECTRICAL POTENTIAL

Same as VOLTAGE.

ELECTRIC CURRENT

The rate at which electrons flow through an electrical conductor, usually measured in amperes (amps).

ELECTRICITY

Energy flow resulting from the flow of charged particles, such as electrons or ions.

ELECTROLYSIS

The breaking down of a chemical compound into simpler compounds or elements by the passage of electricity through the chemical compound. Commonly used to describe the extraction of hydrogen (and oxygen) from water.

ELECTROLYTE

The fluid in a battery, which is the medium of ion transport within an electrochemical cell. It provides a path for electron transfer between the anode and cathode of a battery cell.

ELECTROMAGNETIC RADIATION (EMR)

Magnetic radiation produced by a changing electrical current, such as alternating current (AC).

ELECTRON

A negatively charged particle. The movement of electrons in an electrical conductor constitutes an electric current.

EMBODIED ENERGY

The energy consumed by all of the processes associated with the production of a material. This includes the energy required in mining, transport, manufacturing, administration, use, disposal, etc.

ENERGY

The amount of work that a system or entity can do (potential energy) or is doing (kinetic energy), measured in joules. The product of power and time, measured in watt-hours. 1,000 watt-hours = 1 kilowatt-hour (KWH).

ENERGY DENSITY

A ratio of a battery or cell's capacity to either its volume or weight. Volumetric energy density is expressed in watt-hours per cubic inch. Weight energy density is expressed in watt-hours per pound.

ENGINE

A machine that converts energy into mechanical force or motion. Sources of energy include heat, chemical reaction, potential energy of elevated water, etc.

EQUALIZATION

The process of restoring all cells in a battery to an equal state-of-charge. For lead-acid batteries, this is a charging process designed to bring all cells to 100 percent state-of-charge.

EQUALIZING CHARGE

A continuation of normal battery charging, at a voltage level slightly higher than the normal end-of-charge voltage, in order to provide cell equalization within a battery.

EQUINOX (SPRING & FALL)

The time when the sun crosses the plane of the earth's equator, making night and day of equal length all over the earth, occurring around March 21st and September 21st.

EVAPORATION

The process of a liquid changing its state into a gas when heat is added. In the most common occurrence on earth, water evaporation requires 970 BTUs per pound (pint).

FEATHERING

In wind generators, this refers to an adjustment of the blades so that they catch less wind. This can prevent damage to the machine in high winds.

FINISH CHARGE

The final stage of battery charging, when the battery is charged at a slow rate over a long period of time.

FLAGGING

Noticeable deformation of trees from prevailing winds. Flagging is an indication of an effective wind site. Lack of flagging is not necessarily an indication of a poor wind site.

FLAT PLATE COLLECTOR

A solar thermal collector that converts the sun’s radiation into heat on a flat surface. Does not use reflecting surfaces or lens arrangements to concentrate the sun’s energy.

FLOAT CHARGE

A trickle charge to keep a battery fully charged at a safe voltage level with minimal gassing.

FLOAT SERVICE

A battery operation in which the battery is normally connected to an external current source; for instance, a battery charger that supplies the battery load under normal conditions, while also providing enough energy input to the battery to make up for its internal losses, thus keeping the battery always at full charge and ready for service.

FLOW

In hydro-electric terms, flow refers to the quantity of water supplied to a water source or exiting a nozzle per unit of time. Commonly measured in gallons per minute.

FLUORESCENT LIGHT

An electric lamp coated on its inner surface with phosphor and containing mercury vapor. When bombarded with electrons, the vapor emits ultraviolet light that causes the phosphor to emit visible light.

FRANCIS TURBINE

A type of reaction hydro-turbine used in low to medium heads. It consists of fixed vanes on a shaft. Water flows down through the vanes and out sideways.

FREESTANDING TOWER

A wind generator tower with no guy wires. This can be either a lattice tower or a monopole. Freestanding towers are the most expensive type of tower, requiring large excavations and large amounts of concrete.

FRICTION LOSS

Lost energy due to friction. In hydro systems, pipes sized too small can lead to serious friction losses. In any belt drive system, there will be some losses due to friction.

FULL SUN

The full sun condition is the amount of power density received at the surface of the earth at noon on a clear day—about 1 KW per m^2, or 1 sun. Lower levels of sunlight are often expressed as 0.5 sun or 0.1 sun.

FURLING

Reducing a wind generator’s swept area to protect it from high winds. Common furling methods are to tilt the rotor (blades) up or sideways out of the wind, or to feather (twist) the blades to degrade the airfoil.

FUSE

An electrical device that is designed to break a circuit by melting an internal conductor when the current in the circuit exceeds the maximum considered safe for the conductors or devices in the circuit.

GASSING

The production of hydrogen and oxygen gas from one or more of the electrodes in the cells of a battery. Gassing commonly results from the electrolysis of water in the electrolyte during charging.

GENERATOR

A device that converts mechanical energy into electrical energy.

GEOTHERMAL HEAT PUMP

A type of heat pump that uses the ground, ground water, or ponds as a heat source and heat sink, rather than outside air. Compare to HEAT PUMP.

GIN POLE

Either of two different types of devices used with wind generator towers. With a tilt-up tower, it describes the lever that helps tilt the tower up. With a fixed tower, it describes a temporary crane used to raise tower sections or the wind generator.

GLYCOL (Propylene Glycol)

An antifreeze, heat transfer fluid that is circulated through closed loop solar hot water collectors.

GOVERNOR

A device that limits the output of another device, such as a wind generator.

GOVERNING

Limiting the output of a device. In respect to small wind generators, governing normally happens through furling.

GRID

Transmission line network used to distribute electrical energy, generally by a commercial power utility.

GRID LINES

Metallic contacts fused to the surface of a solar cell to provide a low resistance path for electrons to flow out to the cell interconnect wires.

GRID-TIE SYSTEM

A renewable energy system that is connected to the utility grid, selling excess energy back to the utility. Also called a utility-interactive system.

GROUND

The connection of electrical components to the earth and/or each other for the purposes of dissipating static charge or protecting against a short circuit or lightning.

GROUND FAULT

Unwanted current path to ground.

GROUND MOUNT

A photovoltaic (PV) rack designed to be installed on the ground or other flat surface.

GROUND ROD (ELECTRODE)

A metal rod (typically 5/8 inch diameter) that is driven into the earth (typically 8 feet deep) and is electrically connected to the negative conductor and/or any metal parts, wiring enclosures, or conduit of an electrical circuit.

GUY WIRES

Steel cables that support a tower.

HEAD

The difference in elevation between two parts of a liquid-based system. In hydro power, the difference between a source of water and the location at which the water from that source may be used (synonym: vertical drop). With pumps, the vertical distance the pump must move the water.

HEADRACE

A flume or channel that feeds water into a hydro turbine.

HEAT EXCHANGER

A device that is used to transfer heat between fluids or gases through an intervening surface.

HEAT PUMP

A device typically used for heating and cooling of buildings by drawing from or dissipating into the ambient temperature of air or water. When cooling, a heat pump works like a refrigerator. When heating, it also works like a fridge, except the heat produced is used to heat a space.

HEAT SINK

A medium or container to which heat flows. Thermal mass walls and floors in a passive solar home act as a heat sink during the day.

HEAT TRANSFER

Heat is transferred from one substance or location to another by three methods—radiation, convection and conduction. The sun's rays are a good example of radiation; warm air rising is heat movement by convection; and touching a hot iron or frying pan with your hand is heat transfer by conduction.

HERTZ (Hz)

Cycles per second. Generally refers to the number of complete cycles of the AC sine wave per second, or the frequency at which a radio or computer processor works.

HYDRO-ELECTRICITY

Any electricity that is generated by the flow of water.

HYDROGEN FUEL CELL

A device that converts hydrogen to DC electricity.

HYDROMETER

A hydrometer is an instrument for measuring the density of liquids in relation to the density of water. The hydrometer is used to indicate the state of charge in lead-acid cells by measuring the specific gravity of the electrolyte.

HYDRONIC HEATING SYSTEM

A type of heating system where water is heated in a solar collector or boiler, and is pumped to heat exchangers or radiators in rooms. Radiant floor systems have a grid of tubing laid out in the floor for distributing the heat. Temperature of the space is controlled by regulating the flow and/or temperature of the circulating water.

HORSEPOWER

A measure of the capacity to generate energy or do work. 1 horsepower = 746 watts.

HYBRID SYSTEM

An energy system consisting of two or more generating subsystems, such as the combination of a wind turbine or diesel generator and a photovoltaic system.

INCANDESCENT LIGHT

An electric lamp that is evacuated or filled with an inert gas and contains a filament (commonly tungsten). The filament emits visible light when heated to extreme temperatures by electric current through it. Incandescent light bulbs are one of the most inefficient ways to light a home.

They produce a great deal of heat along with the light, and use three to four times as much energy for the same light output as compact fluorescent light bulbs.

INDUCTION MOTOR (AC)

A type of electric motor that requires a high surge to start, and a stable voltage supply, making it a challenge to run using a solar-electric system.

INSOLATION

The amount of sunlight reaching an area. Usually expressed in watts per square meter.

INTAKE

In a hydro system, the structure that receives the water and feeds it into the penstock (pipeline). Usually incorporates screening or filtering to keep debris and aquatic life out of the system.

INVERTER

A device that converts DC electricity (anywhere from 12 to 600 VDC) to AC electricity (typically 120/240 VAC).

ION

An electrically charged particle or molecule.

ISC

See SHORT CIRCUIT CURRENT.

IV CURVE

The graphical representation of the current versus the voltage of a photovoltaic cell, module, or array as the load is increased from zero voltage to maximum voltage, under standard test conditions.

JACK PUMP

A submerged pump mechanically activated by a rod extending above the well head to a reciprocating engine, motor or any other rotating device.

JOULE

The standard unit of energy (SI). One joule equals one watt-second, and 3600 joules = one watt-hour.

KILOWATT (KW)

One thousand watts.

KILOWATT-HOUR

One thousand watt-hours. Unit of energy used to perform work (energy and work are equivalent in units, energy being the potential value and work the achieved value).

Fuel equivalents: One barrel of crude oil contains roughly 1,700 KWH.

One ton of coal contains roughly 7,500 KWH.

One gallon of gasoline contains roughly 37 KWH.

One cubic foot of natural gas contains 0.3 KWH.

One ton of uranium ore contains 164 million KWH.

1.34 horsepower-hours.

1 KWH = 3,400 BTU. Can be compared to 860 calories (food energy value).

LATITUDE

A location's distance north or south of the equator measured in degrees.

LIGHT EMITTING DIODE (LED)

A semiconductor device composed of a PN junction designed such that electrons cause visible light during their migration across the junction.

LIGHTNING ARRESTOR

Devices that protect electronics from lightning-induced surges by carrying the charge to ground.

LINE/WIRE LOSS

The voltage drop or energy loss due to the resistance of wire in an electrical circuit. See VOLTAGE DROP.

LINEAR CURRENT BOOSTER (LCB)

An electronic circuit that matches PV output directly to a motor by converting unneeded voltage to higher usable current. Used in array-direct water pumping.

LOAD

Refers to equipment that is powered by electricity. Usually expressed in terms of amperes or watts. Any device or appliance that uses energy (such as a light or pump).

LOW-E GLASS

Glass coated with layers of metal or metal oxide. The coating emits very little radiation in the long-wave (infrared) spectrum, which diminishes heat loss from the building interior, and reduces heat gain in hot weather.

LUMEN

A unit of measurement quantifying the amount of light emitted from a light source.

MAGNETIC DECLINATION

The number of degrees east or west of true south from magnetic south.

MAXIMUM POWER POINT

The point on a PV module’s voltage/amperage curve where the product of current and voltage is a maximum (measured in watts).

MAXIMUM POWER POINT TRACKING (MPPT)

Electronically tracking the maximum power point of a PV module to achieve the highest possible output, by (in simplest terms) using surplus voltage to boost amperage.

MICROHYDRO

Hydro-electric plants producing more than 100 watts and less than 2,000 watts.

MODULE

The smallest no divisible, self-contained, and environmentally protected physical structure housing interconnected photovoltaic cells and providing a single DC electrical output. Commonly called a “panel.”

MOTOR

A device that converts electrical energy into mechanical energy.

MULTICRYSTALLINE CELL

See POLYCRYSTALLINE CELL

NANOHYDRO

Any hydro plant that produces less than 100 watts.

NATIONAL ELECTRICAL CODE (NEC)

A document that describes the legal standards for residential and commercial wiring practices with safety as the prime objective. Many U.S. jurisdictions base their wiring inspections on the *NEC*.

NET METERING

State by state legislation that requires utilities to purchase renewably produced electricity at the same price that they sell it, until a building's monthly or annual energy use is offset.

NOMINAL VOLTAGE

A reference voltage used to describe batteries, modules, or systems (for example, a 12 volt or 24 volt battery, module, or system).

NOSECONE

The pointed piece farthest toward the wind on a wind generator, designed primarily for cosmetic purposes, but also protects the blade attachment points and generator from the weather.

OFF-PEAK

The period of low energy demand, as opposed to maximum or peak demand.

ON-PEAK

Energy supplied during periods of relatively high system demands as specified by the utility.

OHM (Ω)

The unit that quantifies a material's resistance to electron flow.

OHM'S LAW

Basic formula defining the relationship between voltage, amperage, and resistance. Commonly stated as E = I x R, or Voltage = Amperage x Resistance.

OPEN CIRCUIT

When an electrical circuit is interrupted by breaking the path at one or more points, which stops the electrons from flowing. A light switch opens an electrical circuit when it turns off the light.

OPEN CIRCUIT VOLTAGE (VOC)

The maximum possible voltage across a PV array, module, or cell. The voltage across the terminals of a photovoltaic cell, module, or array with no load applied when the cell is exposed to standard insulation conditions, measured with a voltmeter.

OPEN LOOP SYSTEM

A fresh water or "direct" solar hot water system, generally for use in freeze-free climates.

ORIENTATION

Placement according to the directions N, S, E, or W.

OUTGASSING

The emission of gasses by a material. See also GASSING.

OVERCURRENT

Current that exceeds the rated current of the equipment or the ampacity of a conductor, resulting from overload, short circuit, or ground fault.

OVERCURRENT DEVICE

A safety fuse or breaker designed to open a circuit when an over current occurs.

PARALLEL CONNECTION

An electrical circuit with more than one possible path for electron flow. When wiring PV modules, this wiring configuration increases amperage (current), while voltage remains the same. Parallel wiring is positive to positive (+ to +) and negative to negative (- to -). Opposite of a series connection.

PASSIVE SOLAR

Any use of the sun's energy in a manner that is found in nature without the use of mechanical aid like pumps or fans. For example, heating a thermal mass (a concrete wall or slab, for instance) during the day with direct sunlight, and using the stored heat in that mass to warm a greenhouse or home at night.

PAYBACK

The period of time it takes for an energy generating device or system to pay for itself in fuel savings.

PEAK LOAD

The maximum load or electrical power draw occurring in a given period of time.

PEAK POWER POINT

Operating point of the IV (current-voltage) curve for a photovoltaic cell or module where the product of the current value times the voltage value is a maximum. Also called the “maximum power point.”

PEAK SUN HOURS

The equivalent number of hours per day when solar irradiance averages 1,000 watts per meter squared.

PELTON WHEEL

A common impulse turbine runner—the wheel that receives the water, changing the pressure and flow of the water to circular motion to drive an alternator, generator, or machine. Pelton wheels (named after inventor Lester Pelton) are made with a series of cups or “buckets” cast onto a hub.

PENSTOCK

The pipe in a hydro system that carries the water from the intake to the turbine.

PHANTOM LOAD

A device that consumes energy even when its switch is off, such as the digital clock on a VCR.

PHOTON

The actual (physical) particle unit of light, as the electron is a particle of electric charge. Solar-electric modules use photons to generate electricity. Photons not captured by the cell are either reflected, pass through the panel, or are converted to heat in the solar array.

PHOTOVOLTAIC ARRAY

A collection of solar modules connected in series, parallel, or series-parallel combination to provide greater voltage, current, or power than can be furnished by a single solar module. Solar-electric arrays can be designed to furnish any desired voltage, current, or power.

PHOTOVOLTAIC CELL

A device composed of specially prepared semiconductor material or material combinations exhibiting the ability to convert incident solar energy directly into electrical energy.

PHOTOVOLTAIC EFFECT

The phenomenon that occurs when photons, the particles in a beam of light, knock electrons loose from the atoms they strike. When this property of light is combined with the properties of semiconductors, electrons flow in one direction across a junction, setting up a voltage. With the addition of circuitry, electrons will flow and electrical energy will be available.

PHOTOVOLTAIC MODULE

A PV module consists of series and/or parallel wired cells typically made from layered silicon crystals that convert light energy to DC electricity. The number of modules in a given system varies depending on the combined load being powered.

PIPE LOSS (Frictional head loss)

The amount of energy or pressure lost due to friction between a flowing liquid and the inside surface of a pipe.

P-N JUNCTION

The semiconductor junction in a photovoltaic cell that shunts electrons into a circuit. Electrons are bumped across this junction by photons (light particles).

POLE MOUNT

A PV mount that is installed on the top or side of a pole usually set in concrete. Can be fixed or seasonally tilted.

POLYCRYSTALLINE CELL

A wafer of silicon with a multi-grained structure. All grains have the same atomic crystal lattice, however, each grain has a unique orientation in space, producing a unique reflection of light, resulting in a "patchy" mottled appearance. AKA multi crystalline cell.

POST AND BEAM CONSTRUCTION

A traditional building technique in which post and beam framing units are the basic load-bearing members. Post and beams may be of wood, structural steel, or concrete. In this system, there are fewer framing members, leaving more open space for in-fill. Often used in straw bale construction.

POWER

The rate of energy use or generation per unit time, measured in watts. 1 watt = 1 joule per second.

POWER FACTOR

The ratio of real power (watts) to apparent power (volt-amps) in an AC circuit. Power factor describes the offset between voltage and amperage peaks in AC. 1 is called “unity” power factor, and is when voltage and amperage peak at the same time—they are then said to be “in phase.” Power factor is calculated by dividing W by VA.

PRESSURE

The “push” behind liquid or gas in a tank, reservoir, or pipe. Water pressure is directly related to “head”—the height of the top of the water over the bottom. Every 2.31 feet of vertical head gives 1 psi (pound per square inch) of water pressure.

PRIMARY CELL

A primary cell is an electrochemical cell (battery) that cannot be recharged. The chemical process within the primary cell is only one way—discharge. When a primary cell is discharged it is discarded. Common flashlight batteries are primary cells; they are disposable batteries that should be avoided.

PSI

See PRESSURE.

PULSE WIDTH MODULATION (PWM)

Varying the amount of DC energy sent to a load or other device by changing the length of time a pulse is left on compared to when it is off. The wider the pulse, the greater the energy transfer.

PURPA

The Public Utility Regulatory Policies Act, passed in 1978. Requires utilities to purchase excess generation from small-scale generators. However, without net metering, this can amount to a fraction of retail prices.

PV

See PHOTOVOLTAIC

PV ARRAY

Two or more photovoltaic modules wired in series or parallel.

PV ARRAY-DIRECT

The use of electricity directly from a photovoltaic array, without batteries or other electrical storage. Many solar water pumps work this way, using a tank to store water.

RADIATION
The sun's energy that comes to earth in the form of direct, diffuse, and reflected rays. The transfer of heat through electromagnetic waves, without heating the air between objects.

RADIOTELEPHONE

A two-way radio system that enables use of a regular telephone but with radio instead of wires.

RATED CAPACITY

The manufacturer's specification for the amount of charge that may be stored in a battery, commonly expressed in amp-hours at a specific rate of discharge.

RATED WATT

The manufacturer's specification for power output of a generating device. In most cases, this is not the most accurate measure to look at, since it predicts output only for ideal circumstances.

RATE OF CHARGE

The amount of energy per unit time that is being added to the battery. Rate of charge is commonly expressed as a ratio of the battery or cell's rated capacity to charge duration in hours. Example: A C/20 rate on a 100 AH battery would be 5 amps, the capacity of the battery divided by 20.

REGULATOR

A device that prevents overcharging of batteries by controlling the charge cycle, and are usually adjustable to conform to specific battery needs. Regulators do not step the voltage down, but control the rate of charge so the battery stays at a specified voltage. Also called CHARGE CONTROLLER.

RENEWABLE ENERGY

Flows of energy that are regenerative or virtually inexhaustible from natural ecological cycles. Most commonly includes solar (electric and thermal), biomass, geothermal, wind, tidal, wave, and hydro power sources.

RESISTANCE

Refers to how well a material conducts a flow of electrons, measured in ohms (Ω). Resistance is the property of materials to impede a flow of electrons through the material. All materials have some resistance. Those of low resistance are known as conductors, while those of high resistance are known as insulators. The unit used to measure resistance is the Ohm (Ω).

RESISTOR

A device with a known amount of resistance used in electrical circuits.

REST VOLTAGE

The voltage of a fully charged cell or battery that is neither being charged or discharged.

RF (radio frequency)

Any radiation of a frequency that may be received or radiated by radios. Common usage: RF interference (RFI); refers to the interference of radio frequency radiation with the operation of devices or appliances such as radios, televisions, computers, etc.

RMS

Root mean square; defines a time averaged value of a varying sinusoidal parameter, such as AC voltage, amperage, or wattage. The square root of the average of the squares of a set of numbers.

ROOF MOUNT

A PV or solar collector rack intended to be installed on a roof. For PVs, its elevation angle can be fixed or seasonally adjustable.

ROTOR

The blades of a wind generator, shaped to spin when exposed to wind, harnessing the wind's energy.

RUNNER

The part of a hydro turbine that accepts the water and turns its energy into rotating motion.

R-VALUE

The measure of a material's resistance to heat flow. The higher the R-value, the greater its insulating capabilities.

QUARTZ-HALOGEN LIGHT

An incandescent lamp filled with halogen gas. Somewhat more efficient than standard incandescents.

SECONDARY CELL

Secondary cells are batteries (electrochemical cells) that are rechargeable. The chemical reaction within the secondary cell is reversible, allowing the cell to be recharged many times.

SELF-DISCHARGE

The tendency of all batteries to lose energy. Self-discharge represents energy lost to internal chemical reactions within the cell. This energy is not and cannot be used from the battery or cell's output terminals.

SENSOR (Temperature)

Sensing device that changes its electrical resistance according to temperature. Used in the control system of a solar thermal system to measure collector and storage tank temperatures.

SERIES CONNECTION

A wiring configuration used to increase voltage from more than one supply. Series wiring is positive to negative (+ to -) or negative to positive (- to +). Opposite of parallel connection. Series circuits have only one possible path for electron flow.

SERIES REGULATOR

A device that prevents overcharging of a battery by disconnecting the charging source as the battery voltage approaches some upper limit.

SERIES STRING

A group of PV modules or batteries wired in series.

SHORT CIRCUIT

A circuit in which two source leads of opposite polarity or dissimilar potential are connected directly to each other with no regulation or load in between, allowing the full energy potential of the source to flow through the circuit. A short circuit will trip the breaker or fuse, and may damage components, or even cause a fire.

SHORT CIRCUIT CURRENT (ISC)

The current between two points in a circuit when the points are electrically connected with a conductor with essentially zero resistance. Normally applied to PV modules, which can be short circuited safely because they are limited current devices.

SHUNT (noun)

1. A resistive load through which electron flow is diverted, typically used to heat air or water.

2. A component with a precise, known resistance used to determine amperage by measuring the voltage across it and using Ohm's law (I = V/R).

SHUNT (verb)

To divert electrical current to a separate circuit or load.

SHUNT REGULATOR

A device that prevents overcharging of a battery by diverting some (or all) of the charging current to a resistive load when the battery voltage reaches a preset upper limit.

SIDE-OF-POLE MOUNT

A PV mount installed on the side of a pole. May be fixed or seasonally adjustable.

SILICON

A nonmetallic element, which when specially treated, is sensitive to light and capable of transforming light into electricity. Silicon is the basic material of most beach sand and is the raw material used to manufacture most photovoltaic cells.

SINGLE CRYSTAL CELL

A wafer of silicon that has a perfect, continuous, crystal lattice (on the atomic level).

SITE EVALUATION

An estimation of a location for its potential for solar, hydro, or wind power.

SOLAR THERMAL COLLECTORS

A solar collector is a device designed to absorb incident solar radiation and to transfer the energy to the fluid or air passing through it.

SOLAR COOKER

A device that converts the sun's energy into heat energy, which is then used to cook food.

SOLAR-ELECTRIC CELL

See PHOTOVOLTAIC CELL

SOLAR-ELECTRIC MODULE

See PHOTOVOLTAIC MODULE

SOLAR ENERGY

Energy coming directly from the Sun.

SOLSTICE (SUMMER & WINTER)

The longest and shortest days of the year. The longest day (Summer Solstice) is around June 21st in the Northern Hemisphere. The shortest day (Winter Solstice) is around December 21st in the Northern Hemisphere.

STAND-ALONE SYSTEM

A system that operates independently of the utility lines. It may draw supplemental electricity from the utility, but is not capable of providing electricity to the utility.

STANDARD TEST CONDITIONS (STC)

The standardized conditions of 1,000 watts per meter squared of solar insulation at 25°C (77°F) for testing PV module ratings.

STATE OF CHARGE (SOC)

A ratio, expressed in percent, of the energy remaining in a battery in relation to its capacity when fully charged.

STORAGE BATTERY

See BATTERY and SECONDARY CELL.

STRATIFICATION

The movement of heat by convection in gasses and liquids causes heat to stratify in layers, the warmest being on top. Stratification is caused by gravity, since the warmer gases and liquids are less dense than the cooler layers.

STRAW BALE CONSTRUCTION

A building technique using straw bales for the walls. See POST AND BEAM CONSTRUCTION.

STRUCTURAL INSULATED PANELS (SIPs)

A no-cavity solid building system of wall and roof panels "sandwiching" polystyrene insulation between an outer and inner sheathing panel (typically oriented strand board (OSB) or metal).

SUSTAINABLE

A material or energy source, which if managed carefully, will provide at current levels indefinitely.

SULFATION

The formation of lead-sulfate crystals on the plates of a lead-acid battery, which decreases battery capacity by impeding the opportunity for chemical reaction within a cell. Sulfation can be caused by leaving the battery in a discharged state for long periods of time.

SURGE CAPACITY

The maximum amount of AC power an inverter may deliver to a load (or loads) for a short period of time, such as when starting a motor.

SWEPT AREA

The area (in square feet or meters^2) that a wind generator's rotor (blades) sweep. This is the collector area for a wind generator. The larger the collector, the more energy it will capture.

SWITCH

A device that breaks an electrical circuit, halting the flow of electrons through the circuit.

TAIL

The part of a wind generator that makes the rotor face into the wind. Often the tail is also involved in governing the machine, by folding down or sideways to swing the rotor out of the wind.

TAILRACE

The pipe, flume, or channel in a hydroelectric system that carries the water from the turbine runner back to the stream or river.

THERMAL BREAK

A material of low thermal conductivity placed in such a way as to reduce the flow of heat between two materials of high thermal conductivity.

THERMAL MASS

A material that has the ability to absorb, store, and release heat energy. The more heat energy that is required to change the temperature of high-density materials (concrete, bricks, tiles), the more thermal mass the materials have.

THERMOSYPHON

Passive solar hot water systems that rely on the natural convection of liquids to collect energy. Designed with the tank above the collection surface.

THIN FILM

A PV manufacturing technique where silicon is vapor deposited, a few molecules thick, onto another material.

TILT ANGLE

A fixed angle measured from the horizontal to which a solar array is tilted. The tilt angle is chosen to maximize the array output. Depending upon latitude, season, and time of day, the optimum angle will vary.

TILT-UP TOWER

A non-climbable wind generator tower that tilts up and down to allow installation and servicing of the turbine on the ground. Normally these employ a gin pole—a horizontal lever arm that helps raise and lower the tower.

TOP-OF-POLE MOUNT

See POLE MOUNT.

TRACKER

A mounting rack for a PV array that automatically tilts to follow the daily path of the sun through the sky. A "tracking array" will produce more energy through the course of the day than a "fixed array" (non-tracking), particularly during the long days of summer. Some trackers are single-axis while others are dual-axis.

TRANSFORMER

An electrical device that steps up voltage and steps down current proportionally (or vice-versa). Transformers work with AC only.

TRASH RACK

A large strainer at the input to a hydro system. Used to remove debris from the water before it enters the pipe.

TURBINE

An engine that produces rotary motion through reaction or impulse, or both, with moving fluid or gas. The resultant rotary motion is usually used to drive an alternator generator.

TURGO

In hydroelectric systems, a type of impact hydro runner optimized for lower heads and higher volumes than a Pelton runner.

UNINTERRUPTIBLE POWER SUPPLY (UPS)

A power supply providing continuous, uninterruptible service—commonly used in telecommunications and computer networks.

UPWIND

In relation to a wind turbine, toward the wind. An upwind turbine has its blades on the upwind side of the tower.

UTILITY GRID

Commercial electrical energy distribution system. Synonyms: Mains, Grid.

UTILITY-INTERTIE (UI) SYSTEM

See GRID-TIE SYSTEM.

VOLT (V)

The volt is the unit used in the measurement of electromotive force (electrical “pressure”). A standard electrical definition of the volt is: an electromotive force of 1 volt is necessary to move a current of 1 ampere through a 1 Ω resistor. It is often also referred to as electrical potential difference or potential difference.

VOLTAGE

A measure of the force or "push" given the electrons in an electrical circuit; a measure of electrical potential. Analogy: pressure in a water pipe. AKA Potential.

VOLTAGE DROP

Loss of voltage (electrical pressure) caused by the resistance in wire and electrical devices. Proper wire sizing will minimize voltage drop, particularly over long distances. Voltage drop is determined by four factors: wire size, current (amps), voltage, and length of wire. Water analogy: friction loss in pipe.

VOLTAGE, NOMINAL

A way of naming a range of voltage to a standard. Example: A “12 volt nominal” system may operate in the range of 10 to 20 volts. We call it “12 volts” for simplicity.

VOLTAGE, OPEN CIRCUIT

See OPEN CIRCUIT VOLTAGE

VOLTAGE, PEAK POWER POINT (Vpp)

The voltage at which a photovoltaic module or array generates at the highest power (watts). A “12 volt nominal” PV module will typically have a peak power voltage of around 17 volts. A PV array-direct solar pump should reach this voltage in full sun conditions. In a higher voltage array, it will be a multiple of this voltage.

VOLTMETER

A device for measuring the voltage difference between any two points in an electrical circuit.

WATT

Unit of power. Power is the rate of generating or using energy. One watt is the power developed or dissipated in a one volt circuit in which there is a current of one ampere (6.28 million electrons per second). Watts = amps X volts.

WATT-HOUR

A unit of measurement quantifying an amount of energy used or generated. A load that consumes 1 watt for 10 hours uses 10 watt-hours.