Forklift Battery Basics

This material is a compendium of information from Power Designers USA LLC, Battery Council International, and Battery University

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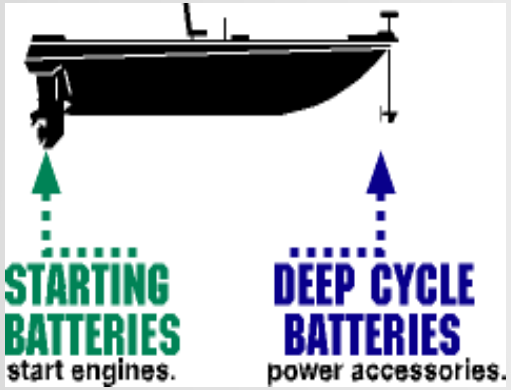
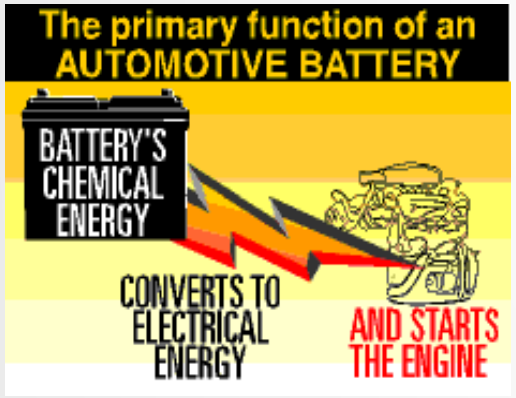
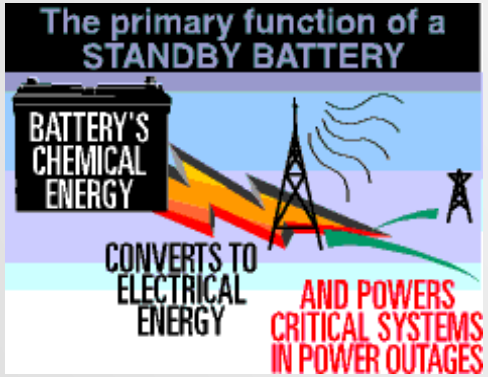
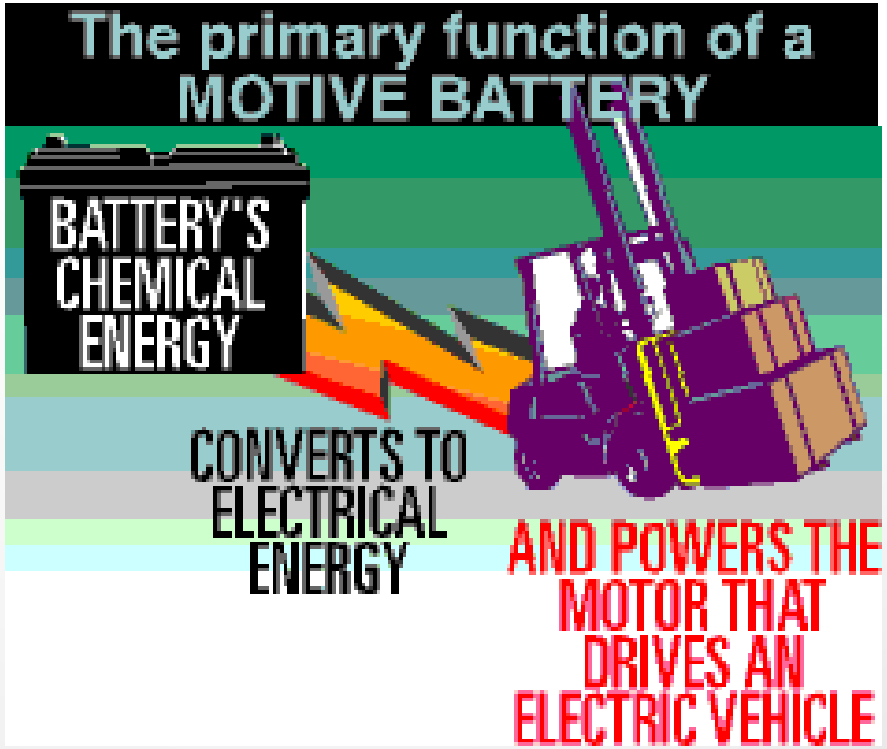
Battery Functions in Different Applications







Why we are here



Battery Capacity

Nameplates and Decoding

Battery Nameplates provide information on the number of cells, the plate design capacity, and the number of plates.

These are separated by a dash and examples are 12-85-13, or 18-125-15, or 24-125-15

The first number tells us how many cells in series

The second number is the plate design capacity

The third number represents the number of plates in each cell, and is always odd

To decode the battery voltage and rated capacity is simple

Take the number of cells times 2 to get voltage

12 cells = 24 volts

18 cells = 36 volts

24 cells = 48 volts

36 cells = 72 volts

40 cells = 80 volts

Take the number of plates, subtract 1 and then divide by 2

13 plates becomes a multiplier of 6 (13-1)/2

15 plates becomes a multiplier of 7 (15-1)/2

Take the plate capacity times the multiplier to get rated ampere hour capacity

85*6 = 510 Ahr

125*7 = 875 Ahr

Battery Capacity

Nameplates

A Short Quiz

What is the voltage and nameplate capacity of an 18-125-15 battery?

36 volt 875 Ahr

Here are the steps for review

18*2=36

15-1=14

14/2=7

7*125=875

Let's try one more, what is the voltage and nameplate capacity of an 12-85-13 battery?

24 volt 510 Ahr

Here are the steps for review

12*2=24

13-1=12

12/2=6

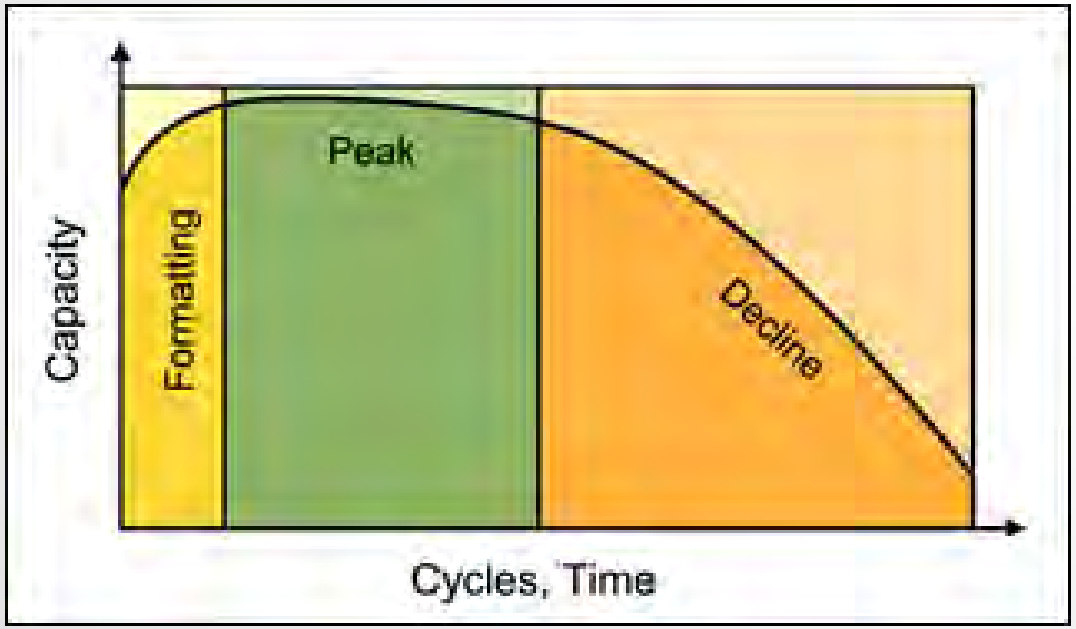
6*85=510

Battery Capacity

Usable Capacity

Usable Capacity for lead acid batteries is defined as the batteries ability to produce the rated number of ampere hours when discharged at a constant current equal to 16 percent of the nameplate rating for a 6 hour period. Full capacity for a lead acid battery is achieved by applying a charge, followed by a discharge and recharge. The factory begins the process, which is completed in the field as part of regular use. Lead acid typically reaches the full capacity potential after 50 to 100 cycles.

The Battery manufacturer typically delivers a battery needing only a few cycles to achieve full capacity



NOTE: <u>A New Truck and Battery</u> may initially not have the performance and run time expected due to the battery not being fully formed

Battery Capacity

Life Cycle

Conventionally Charged Batteries have a life cycle of approximately 5 years based on single shift use of the battery. That is 1 discharge of 80% of the battery nameplate capacity; and 1 charge cycle using a charging current equal to 15% to 17% of battery nameplate capacity, returning slightly over 100% of the nameplate capacity; in a 24 hour period, or approximately 1825 cycles. This is dependent on proper battery care.
With some degraded capacity a lifetime of 8 to 10 years is possible.

Opportunity and Fast charged batteries have a life cycle of approximately 3 to 5 years. In this instance a single battery replaces 2 or 3 batteries that are conventionally charged and used. To obtain this 3 to 5 year life care must be taken to provide the battery with a finish and equalize charge cycle on a once a week basis. More to follow on this topic when we talk charging.

Battery Capacity

Degradation Over the Life Cycle

All batteries degrade with time the key to prolonged life is proper care!

We'll say that again the key to prolonged life is proper care!

To keep lead acid in good condition, apply a fully saturated charge lasting 14 to 16 hours including finish and equalize once a week.

If the weekly charge cycle does not allow this, give the battery a fully saturated charge once every few weeks, or risk degraded performance.

- If at all possible, operate at moderate temperature
- Avoid deep discharges
- Store only in a charged condition

Battery Capacity

Self Discharge

Batteries self discharge, as the conversion from Sulfuric Acid to Water continues even when no load is applied to the battery. Lead is converted on a plate to Lead Sulfate as part of this process.
Self-discharge is not a manufacturing defect but a battery characteristic; although poor fabrication practices and improper handling can increase the problem.

Self discharge can be thought of as energy leaking from your battery. Lead Acid batteries leak about 5% of capacity per month.
The self-discharge of all battery chemistries increases at higher temperatures, and the rate typically doubles with every 10°C (18°F). Store batteries cool when possible!
High cycle count and aging also increase self-discharge of all batteries.
Older batteries leak more energy in the form of self discharge.

A short quiz to review

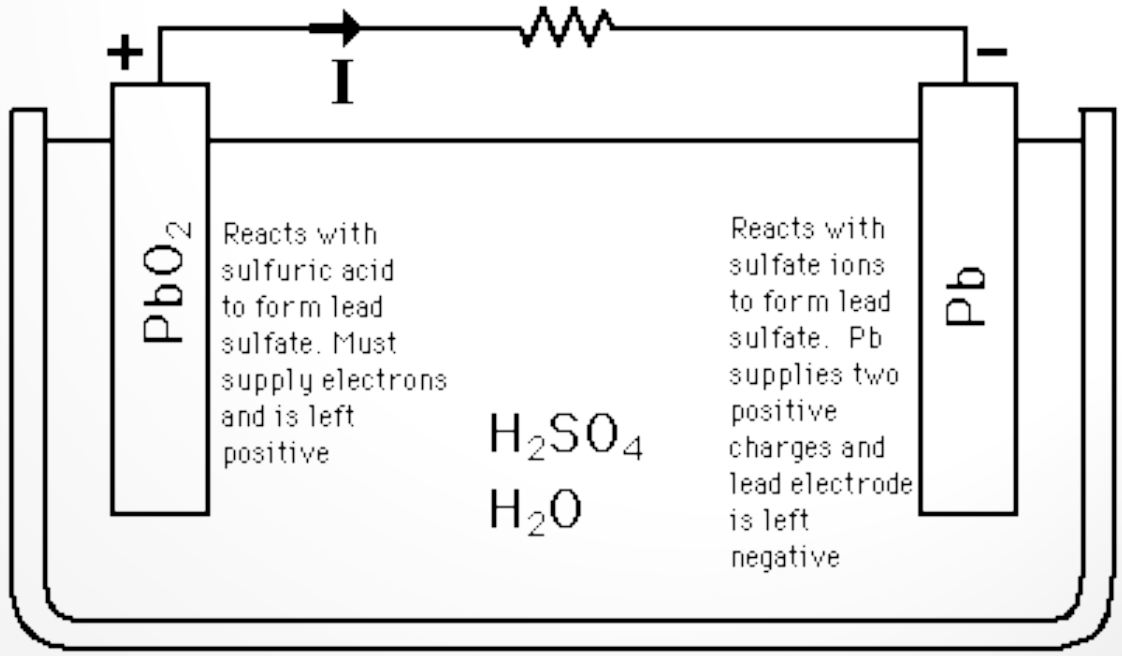
Why is it important to store your batteries charged?
They self discharge!

Why is it important to store your batteries cool?
Self discharge increases with temperature.

Battery Care

Chemistry a Brief View

Batteries use a chemical reaction to produce a voltage between their output terminals. The reaction of lead and lead oxide with the sulfuric acid electrolyte produces a voltage. Supplying energy to an external load discharges the battery. Charging the battery reverses the reaction.



Battery Care

Specific Gravity

Specific Gravity in batteries is a measurement of the relative density or weight of the electrolyte compared to water.

The Hydrometer is a tool that measures specific gravity. Here is how it works: When a lead acid battery accepts a charge, the ratio of sulfuric acid to water increases, and the electrolyte gets heavier, and specific gravity increases.

The table values represent a rested cool battery

Approximate state-of-charge	*Average specific gravity*	*Open circuit voltage*
100%	*1.265*	*2.10*
75%	*1.225*	*2.08*
50%	*1.190*	*2.04*
25%	*1.155*	*2.01*
0%	*1.120*	*1.98*

Battery Care

Watering

Outside of charging, **Watering** is the single most important step in maintaining a flooded lead acid battery; a requirement that is all too often neglected. The frequency of watering depends on usage, charge method and operating temperature. Over-charging also leads to water consumption.

- All batteries should be checked every week after the equalization charge and cool down; then water added. This assures that the top of the plates are never exposed. A naked plate will sustain **irreversible** damage through oxidation, allowing lead sulfate to harden and leading to reduced capacity and lower performance.
- A battery should only be watered when fully charged to prevent diluting the electrolyte.
- Water should only be added to a depth of approximately ¼ inch above the moss plate. In practice a lot of battery technicians, approximate this to one-half the distance between the moss plate and the bottom of the fill neck.
- Automatic watering systems will best insure proper electrolyte level.

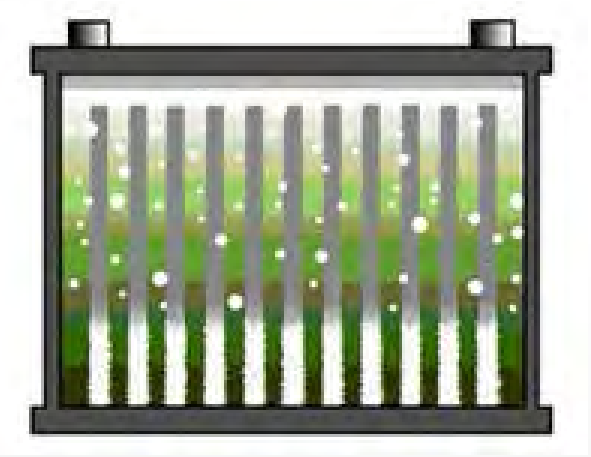
Battery Care

Stratification and Acid Addition

In normal use the electrolyte is evenly distributed. After prolonged storage the sulfuric acid will settle to the bottom of the plates. Charging at a low current will cause the electrolyte to mix and evenly distribute.

Normal Electrolyte Distribution
Water and acid is evenly mixed

Stratified Electrolyte Distribution
Acid has settled, concentrating at the bottom



The electrolyte of a stratified battery concentrates at the bottom, starving the upper half of the cell. Acid stratification occurs if the battery dwells at low charge below 80 percent.

Battery Care

Simple Guide to Battery Care and Life

- When conventionally charging, allow a fully saturated charge of 14–16 hours, including an equalize charge once a week.
- For opportunity or fast charging, finish and equalize charge once a week to restore capacity and specific gravity when, adding 6 to 12 hours to the cycle
- Charge in a well-ventilated area.
- Always keep a lead acid battery charged.
- Avoid storage below 2.07V/cell or at a specific gravity level below 1.190.
- Avoid deep discharges.
  - The deeper the discharge, the shorter the battery life will be.
  - A brief charge on a 1–2 hour break during heavy use prolongs battery life when conventionally charging
  - A brief charge on every 10 minute or more break, is essential when opportunity or fast charging

Battery Care

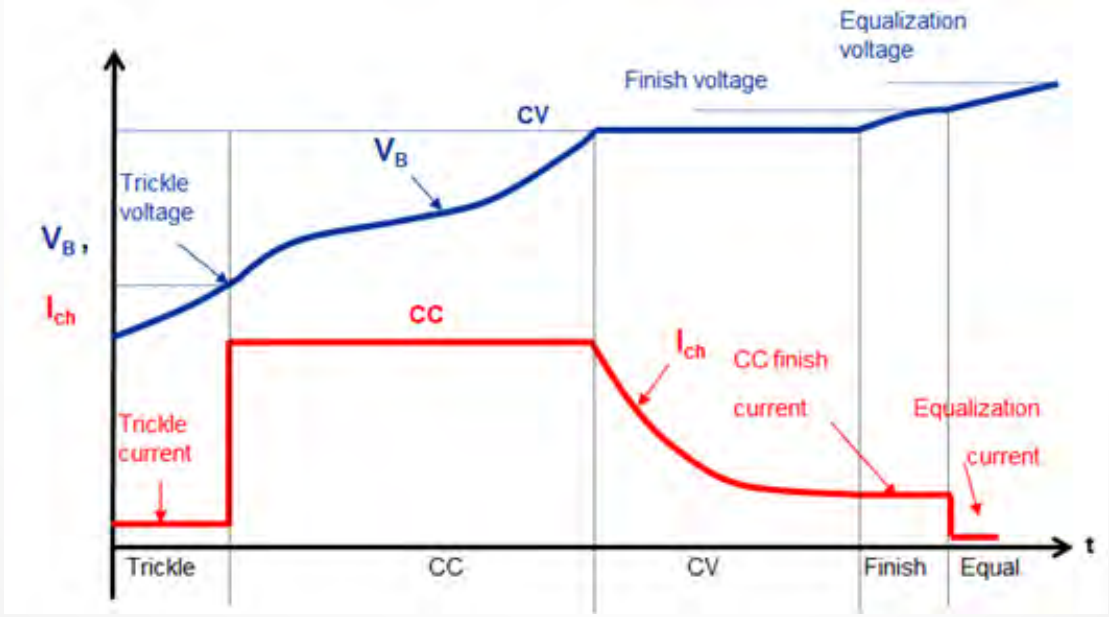
Simple Guide to Battery Care and Life Continued

- Never allow the electrolyte to drop below the tops of the plates.
  - Exposed plates sulfate and become inactive.
  - When low, add only enough water to cover the exposed plates before charging.
- **Always fill to the correct level after charge,** approximately ¼" above the moss plate, check with the battery manufacturer for specific depths.
- Never add acid, unless attempting to repair or recover a bad cell
  - This would raise the specific gravity too high causing excessive corrosion and sulfation.
- When watering use distilled or deionized water.
  - Tap water may be usable in some regions.

Battery Charging

Charge Curve

Charging a battery consists of several modes.
Trickle is used when a battery is overly discharged, the output current is 3% of rated capacity, this restores the battery to the level where it can accept charge at a higher rate.
Constant Current is used to charge the battery from 20% of capacity to 80% of capacity. The output current is 16% to 17% of rated capacity for conventional charging, 25% for opportunity charging, and 40% for fast charging.



Constant Voltage is used to fill the battery from 80% of capacity to >95% of capacity. The desired voltage is set and current is allowed to decrease as the battery nears the full capacity state.
Finish has an output current of 3% to 5% of rated capacity to bring the battery to 100% of capacity.
Equalize has an output current of 3% of rated capacity and is used to force additional conversion of lead sulfate and lead oxide to sulfuric acid, raising gravity and insuring full capacity is available

Battery Charging

Recovery Charging Cycle

A unique feature of all Power Designers chargers is the **Battery Recovery / Desulfation Cycle.** While trickle charging allows an over discharged battery, in most cases, to charge to a state where faster charging is possible, a more tailored approach is needed for soft sulfated batteries and batteries that are unable to reach full specific gravity when charged.

- **Battery Recovery / Desulfation Cycle** is an extended period of a constant low output current over a period of 6 to 18 hours
- The **Battery Recovery / Desulfation Cycle** is programmed from the front panel and can be run on demand as needed
- In general use of the **Battery Recovery / Desulfation Cycle** will increase specific gravity by 0.010 to 0.012, this is an increase of 5% to 10% in capacity over an unrecovered battery

Battery Charging

Conventional Charging

Conventional charging

- more than one battery is available per truck, typically one battery for each shift of operation
- constant current rate of 16% to 17% of rated battery capacity
- always brings the battery to full capacity by providing a finish charge
- requires weekly equalization
- lowest temperature of the charging types
- centralized charging, all chargers in a single location
- requires the greatest labor of the charging types, it requires changing the battery in and out of the charging station; and in and out of the truck, taking up to 15 minutes per change
- is the least environmentally friendly of the charging types, requiring the greatest number of batteries to be present. Each battery adds lead and acid to the facility both of which are considered to be environmental and health concerns

Battery Charging

Opportunity and Fast Charging

Opportunity and Fast charging

- are a variation on the same theme, higher constant current rate than conventional
  - Opportunity charging typically uses a constant current rate of 25% of battery nameplate capacity
  - Fast charging typically uses a constant current rate of 40% of battery nameplate capacity
- is used only when only one battery is available per truck.
- maintains the battery between 20% ad 80% state of charge by charging on every scheduled break
- is point of use charging, chargers are distributed throughout the facility
- requires analysis ahead of installation to determine
  - how much capacity is used per day relative to battery capacity
  - how much charging time is available, essentially can I replace what was removed
  - is time available during the week or weekend to finish and equalize
- results in higher battery temperature, as the increased current contributes to resistive heating
  - temperature feedback, for monitoring, is required for fast charging

Battery Charging

Opportunity and Fast Charging

Opportunity and Fast charging

- means fewer batteries, less lead and less acid, and is more environmentally friendly
- eliminates the labor to change batteries
- requires disciplined truck operators to make sure charging happens on every break
- requires down time once a week to finish and equalize charge, more on this in the next slide
- **Fast** charging requires a battery designed with thicker connectors between the cells to reduce resistance and heating

Battery Charging

Opportunity and Fast Charging Finish and Equalize

Opportunity and Fast charging require a finish charge once a week

Finish has an output current of 3% to 5% of rated capacity to bring the battery to 100% of capacity.

- Finish charging more than once a week can increase gas production and loss of electrolyte
- Chargers can be programmed to finish charge at the end of the last shift of the day, the battery is fully charged and cool by morning

Opportunity and Fast charging require an equalize cycle once a week

Equalize has an output current of 3% of rated capacity and is used to force additional conversion of lead sulfate and lead oxide to sulfuric acid, raising gravity and insuring full capacity is available

- Equalize cycling more than once a week increase gas production and loss of electrolyte
- **Equalize cycling is needed to restore capacity and gravity**
- Water levels should always be checked after an equalize cycle and water added if low

Battery Sulfation

Causes and Cures

Soft Sulfation occurs each time a battery is discharged and is a normal part of battery operation

Negative plate reaction

$Pb(s) + HSO_4(aq) \rightarrow \mathbf{PbSO_4(s)} + H^+(aq) + 2e^-$

Positive plate reaction

$PbO_2(s) + HSO_4(aq) + 3H^+(aq) + 2e^- \rightarrow \mathbf{PbSO_4(s)} + 2H_2O(l)$

This soft sulfation reaction is reversible when the battery is charged

Hard Sulfation occurs when the soft sulfation hardens due to

- Excessive discharge
- Storage in a discharged state
- Acid addition drives sulfation that cannot be recovered during charge
- Plates are exposed due to low water allowing the crystal to solidify

A unique feature of **ALL Power Designers** chargers is the **Battery Recovery / Desulfation Cycle**

Power Designers also offers a **Battery Cycler** that allows

- Battery capacity testing
- Automated battery cycling to break sulfation; recover capacity and gravity

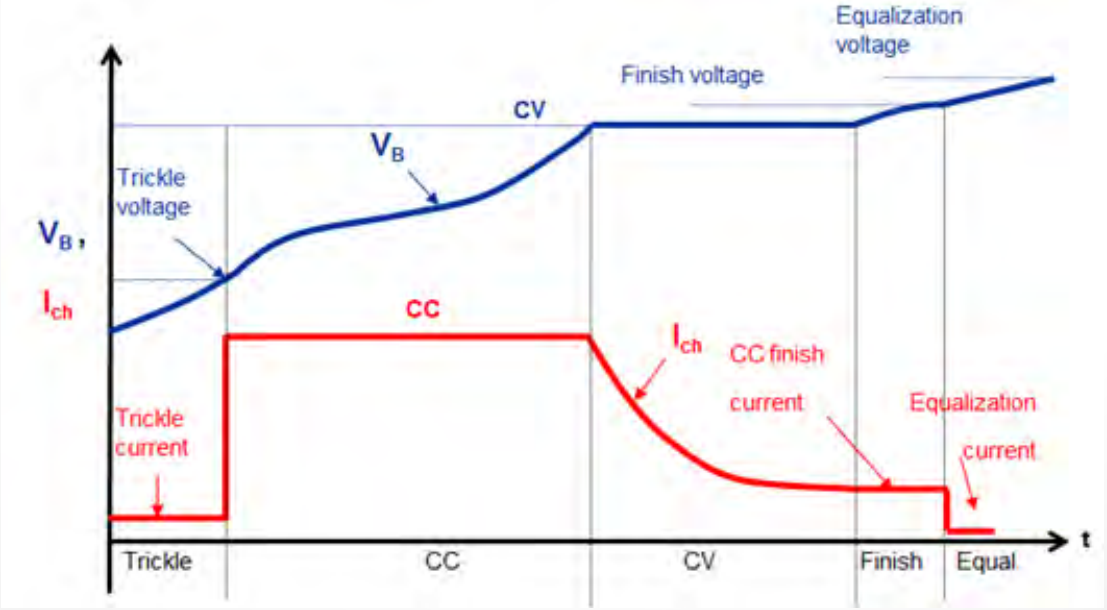
Battery Quiz with Answers

What are the three most important thing to insure battery life?

1. Keep the Battery charged
2. Keep the battery watered
3. Keep the battery cool

What is are the 5 parts of a charge cycle?

HINT Here is the curve



1. Trickle
2. Constant Current
3. Constant Voltage
4. Finish
5. Equalize

Conventionally charged batteries typically last?

5 years

Sulfation naturally occurs when the battery is charged or discharged?

Discharged

What charging feature is common to all Power Designers chargers

The Recovery / Desulfation cycle

Thank You
On Behalf of
Power Designers
For Your
Participation

Additional Slides with Detail on Chemistry in Case of Questions

Battery Care

Chemistry a Brief View

Batteries use a chemical reaction to produce a voltage between their output terminals. The reaction of lead and lead oxide with the sulfuric acid electrolyte produces a voltage. Supplying of energy to an external load discharges the battery. Charging the battery reverses the reaction.

Discharge

Negative plate reaction

$Pb(s) + HSO4(aq) \rightarrow PbSO4(s) + H+(aq) + 2e-$

Positive plate reaction

$PbO2(s) + HSO4(aq) + 3H+(aq) + 2e- \rightarrow PbSO4(s) + 2H2O(l)$

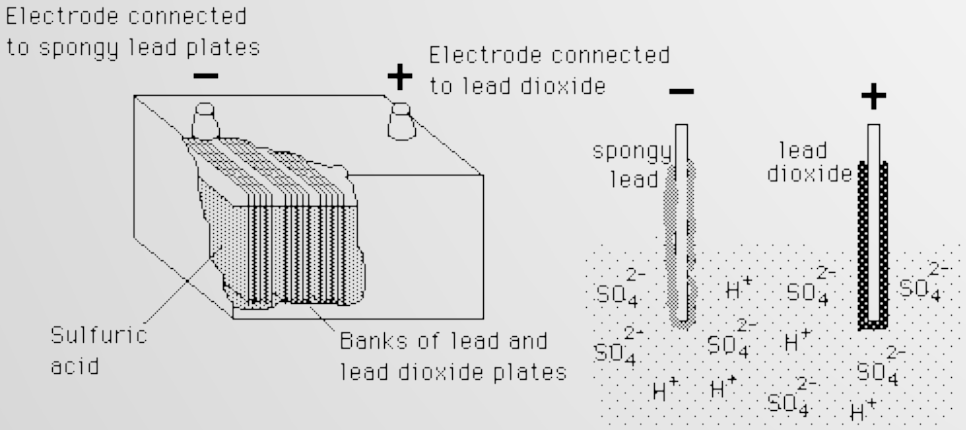
Charge

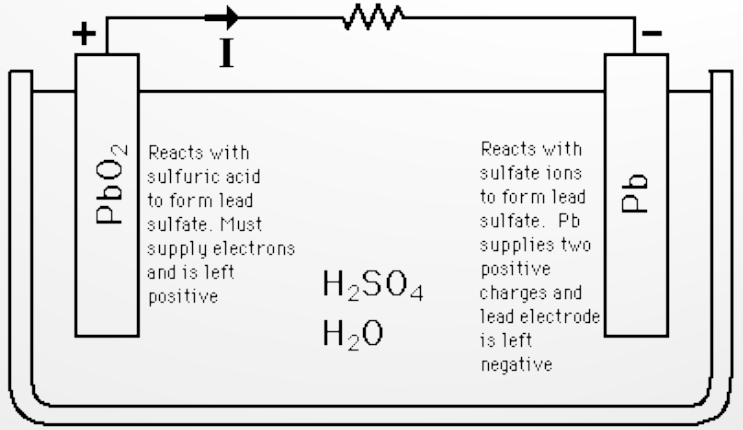
Negative plate reaction

$PbSO4(s) + H+(aq) + 2e- \rightarrow Pb(s) + HSO4(aq)$

Positive plate reaction

$PbSO4(s) + 2H2O(l) \rightarrow PbO2(s) + HSO4(aq) + 3H+(aq) + 2e-$





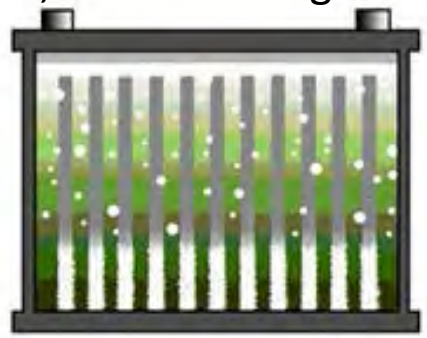
Battery Care

Stratification and Acid Addition

In normal use the electrolyte is evenly distributed, after prolonged storage the sulfuric acid will settle to the bottom of the plates. Charging at a low current will cause the electrolyte to mix and evenly distribute

Normal Electrolyte Distribution
Water and acid is evenly mixed

Stratified Electrolyte Distribution
Acid has settled, concentrating at the bottom



Stratification can produce false low specific gravity readings. The electrolyte of a stratified battery concentrates at the bottom, starving the upper half of the cell. Acid stratification occurs if the battery dwells at low charge (below 80 percent), never receives a full charge and has shallow discharges. Adding acid to a battery especially if performed on a discharged or stratified battery reduces battery life.

Excessive acid concentration, forces more lead sulfate to form on the plates reducing capacity and promoting hard sulfation. Excess acid promotes corrosion of the plates and the connections inside the battery.

Battery Care

Specific Gravity

Specific Gravity in batteries is a measurement of the relative density or weight of the electrolyte compared to water. When a battery is charged lead sulfate on the negative plate is converted to lead and sulfuric acid, lead sulfate on the positive plate is converted to lead oxide and sulfuric acid. Both these reactions convert the water in the electrolyte that was part of the original mixture and that created during discharge.
The Hydrometer is a tool that measures specific gravity. Here is how it works: When the lead acid battery accepts charge, the sulfuric acid gets heavier, causing the specific gravity to increase. As the SoC decreases through discharge, the sulfuric acid is removed from the electrolyte, binds to the plate, forming lead sulfate, water is produced. The density of the electrolyte becomes lighter and more water-like, and the specific gravity gets lower.
The table values represent a rested cool battery

Approximate state-of-charge	*Average specific gravity*	*Open circuit voltage*
100%	*1.265*	*2.10*
75%	*1.225*	*2.08*
50%	*1.190*	*2.04*
25%	*1.155*	*2.01*
0%	*1.120*	*1.98*