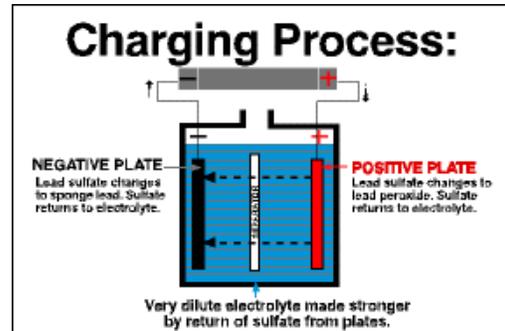


Recharging Batteries

Battery charging takes place in the following 4-basic stages:

- *Bulk*
- *Absorption*
- *Equalizing*
- *Float*



1 Bulk Charge (1st Stage)

Current is sent to batteries at the maximum safe rate which is accepted until voltage rises to near (80-90%) full charge level.

Voltages at this stage typically range from 10.5 volts to 15 volts.

There is no "correct" voltage for bulk charging, but there may be limits on the maximum current that the battery and/or wiring can take.

2 Absorption Charge (2nd Stage)

Voltage remains constant and current gradually tapers off as internal resistance increases during charging.

It is during this stage that the charger puts out maximum voltage. Voltages at this stage are typically around 14.2 to 15.5 volts.

3 Equalizing Charge (3rd Stage)

This optional equalizing phase is a controlled 5% overcharge, which equalizes and balances the voltage and specific gravity in each cell, the effect of increasing the charge voltage.

Equalizing reverses the build-up of chemical effects like stratification, where acid concentration is greater at the bottom of the battery. It also helps to remove sulfate crystals that might have built up on the plates.

The frequency recommendation varies by manufacturer from once a month to once a year, from 10 to 100 deep cycles, or when a specific gravity difference between cells reaches .03 (or 30 points).

To equalize a battery, fully recharge it; next, increase the charging voltage to the manufacturer's recommendations (if you cannot find one, add 5%). Heavy gassing should start occurring at this stage (be very careful about safety precautions).

Take specific gravity readings in each cell once every hour. Equalization has occurred once the specific gravity values no longer rise during the gassing stage.

4 Float Charge (4th Stage)

After batteries reach full charge, charging voltage is reduced to a lower level (typically 12.8 to 13.2) to reduce gassing and prolong battery life. This is often referred to as a maintenance or trickle charge, since its main purpose is to keep an already charged battery from discharging.

Charger with PWM, or "pulse width modulation" accomplishes the same thing. In PWM, the controller or charger senses tiny voltage drops in the battery and sends very short charging cycles (pulses) to the battery.

This may occur several hundred times per minute. It is called "pulse width" because the width of the pulses may vary from a few microseconds to several seconds.

NOTE: For long term float charging, such as backup power systems that are seldom discharged, the float voltage should be set around 13.02 to 13.20 volts.

5 Charging Voltage and Current

Most garage and consumer (automotive) type battery chargers are bulk charge only, and have little (if any) voltage regulation. They are fine for a quick boost to low batteries, but do not to leave them on charging for long periods.

Use an external Constant Current charger, which is set not to deliver more than 12% of the Reserve Capacity (RC) rating of the battery and monitor the State-Of-Charge (SOC). Timers that will cut-off the charger when charging hours are completed will help prevent overcharging of the battery.

NOTE:

Reserve Capacity (RC) is the number of minutes a fully charged battery at 80° F (26.7° C) is discharged at 25 amps before the voltage falls below 10.5 volts. To convert Reserve Capacity (RC) to Ampere-Hours (AH) at the 25 amps rate, multiple RC by .4167.

For discharged batteries, the following table lists the recommended battery charging rates and times:

Reserve Capacity (RC) Rating	Slow Charge (RECOMMENDED)	Fast Charge
80 Minutes or less [32 Ampere-Hours or less]	15 Hours @ 3 Amps	5 Hours @ 10 Amps
80 to 125 Minutes [32 to 50 Ampere-Hours]	21 Hours @ 4 Amps	7.5 Hours @ 10 Amps
125 to 170 Minutes [50 to 68 Ampere-Hours]	22 Hours @ 5 Amps	10 Hours @ 10 Amps
170 to 250 Minutes [68 to 100 Ampere-Hours]	23 Hours @ 6 Amps	7.5 Hours @ 20 Amps
Above 250 Minutes [over 100 Ampere-Hours]	24 Hours @ 10 Amps	6 Hours @ 40 Amps

The best method is to slowly recharge the battery at 70° F (21.1° C) over a 10 to 20 hour period ($C/10$ to $C/20$) * using an external constant voltage (or tapered current charger) because the acid has more time to penetrate the plates and there is less mechanical stress on the plates.

***NOTE:**

C-rate is a measurement of the charge or discharge of battery overtime. It is expressed as the Capacity of the battery divided by the number of hours to recharge or discharge the battery.

For example, assume that the Amperes-Hour capacity of the battery is 220 AH, then it would take 11 hours (220 divided by 20) to recharge or discharge the battery using a C/20 rate.

For a Constant Voltage charger, apply regulated voltage at approximately 13.8 to 16 volts and should be based on the manufacturer's recommendations and temperature.

A 10 Amps Constant Voltage charger is suitable for most simple recharging or charging applications.

More expensive three-stage microprocessor controlled chargers are also available that will automatically provide bulk, absorption and float charging. A four-stage charger will provide an equalizing charge in addition to the bulk, absorption and float charging.

An excellent automatic Constant Voltage battery charger is a 15-volt regulated power supply adjusted to the manufacturer's recommendations or, if not available, refers to voltage ranges below which were based on the electrolyte temperature at 70° F (21.1° C).

Battery Type	Charging Voltage	Float Voltage	Equalizing Voltage
Wet Low Maintenance	14.4	13.2	15.1
Wet Maintenance Free	14.8	13.4	15.5
Sealed & VRLA	14.4	13.2	15.1
AGM	14.4	13.6	15.5
Gel Cell	14.1	13.2	N/A
Wet Deep Cycle	14.5	13.2	15.8

NOTE:

To compensate for electrolyte temperature, which has a negative temperature compensation coefficient, adjust the charging voltage .0028 (2.8 millivolts) to .0033 (3.3 millivolts) volts per cell per degree F.

*For example, if the temperature is 30° F (-1.1° C), then **increase** the charging voltage to 15.19 volts for a wet low maintenance battery.*

*If 100° F (43.3° C), then **decrease** the charging voltage to 13.81 volts.*

If left unattended, cheap, unregulated trickle or manual battery chargers can overcharge your battery because they can decompose the water out of the electrolyte.

Avoid using fast, high rate, or boost chargers on any battery that is sulfated or deeply discharged. The electrolyte should **NEVER** bubble violently while recharging because high currents only create heat and excess explosive gasses.

Most flooded (Wet Cell) batteries should be charged at no more than the "C/8" rate for any sustained period.

Note: "C/8" is the battery capacity at the 20-hour rate divided by 8.
For a 220 AH battery, this would equal 26 Amps.

GEL Cells batteries should be charged at no more than the C/20 rate, or 5% of their AH capacity.

Charging at 15.5 volts will give you a 100% charge on Lead-Acid batteries. Once the charging voltage reaches 2.583 volts per cell, charging should stop or be reduced to a trickle charge.

Note: *Flooded or Wet Cell batteries **MUST** bubble (gas) somewhat to insure a full charge, and to mix the electrolyte.*

Float voltage for Lead-Acid batteries should be about 2.15 to 2.23 volts per cell, or about 12.9 to 13.4 volts for a 12 volt battery. At higher temperatures (over 85 degrees F) this should be reduced to about 2.10 volts per cell.

NEVER ADD ACID to a battery except to replace spilled liquid. Distilled or de-ionized water should be used to top off non-sealed batteries.

Float and charging voltages for GEL Cell batteries are usually about 2/10th volt less than for flooded to reduce water loss.

Flooded or Wet Cell battery life can be extended if an equalizing charge is applied every 10 to 40 days. This is a charge that is about 10% higher than normal full charge voltage, and is applied for about 2 to 16 hours.

This makes sure that all the cells are equally charged, and the gas bubbles mix the electrolyte. If the liquid in standard wet cells is not mixed, the electrolyte becomes "stratified". You can have very strong solution at the top and very weak at the bottom of the cell.

With stratification, you can test a battery with a hydrometer and get readings that are quite a ways off. If you cannot equalize for some reason, you should let the battery sit for at least 24 hours and then use the hydrometer.

AGM and GEL Cell should be equalized 2-4 times a year at most. Please check the manufacturer's recommendations, especially on GEL Cell ones.