CHARGETEK

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Equalization and desulphation of lead acid based batteries

Introduction

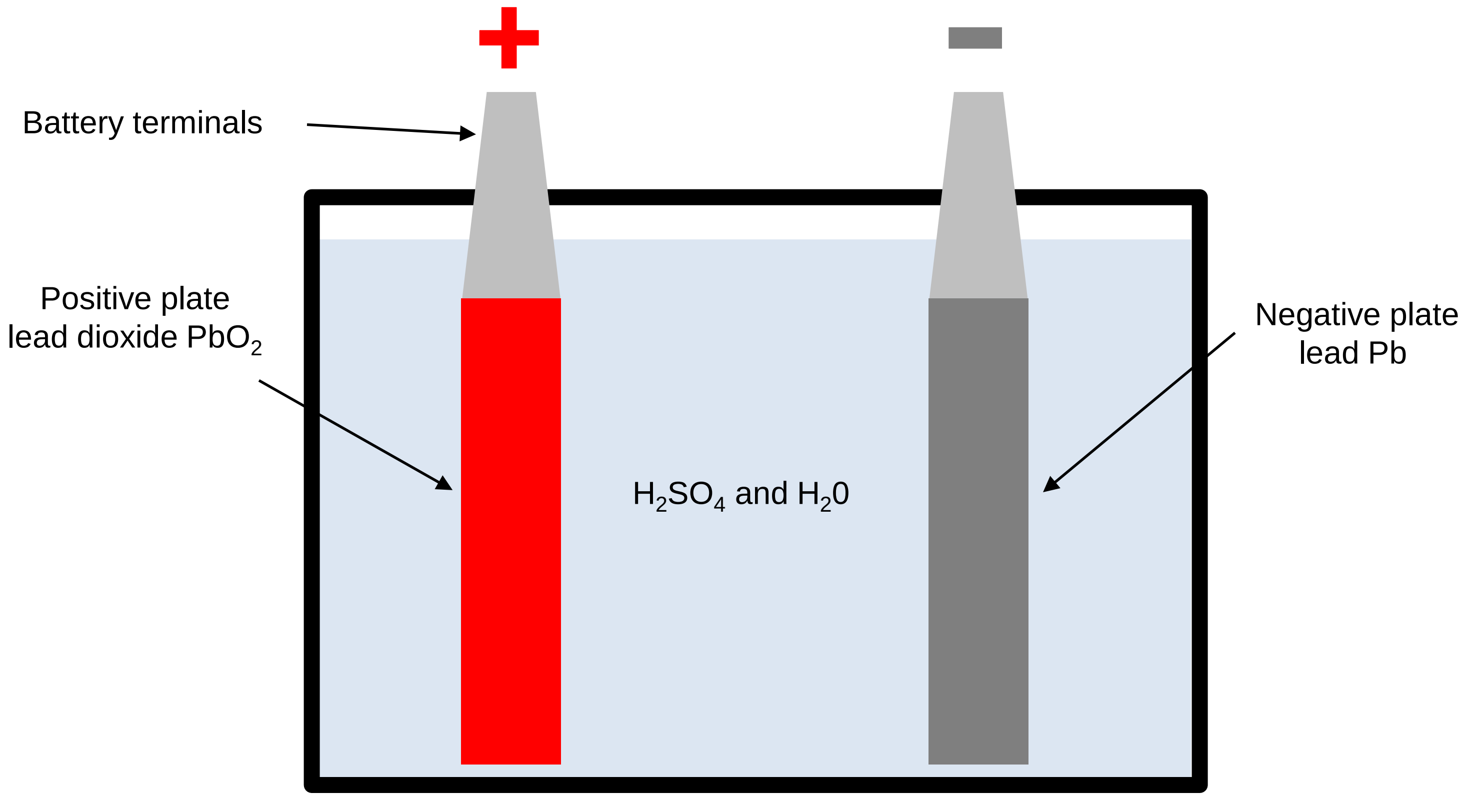
Battery life and restoration have become increasingly important. The freight cost of shipping dead and permanently damaged batteries back for maintenance and replenishing customers with replacements is prohibitive. Many misconceptions and misinformation have been disseminated about battery life and the mechanisms of degradation. In most cases, the primary culprit is plate sulphation. The sulphation, desulphation and restoration of lead acid based batteries is widely misunderstood.

This presentation describes and explains:

- The normal lead based battery charging and discharging cycle
- How and why batteries experience sulphation
- Normal and harmful sulphation
- Why damaging sulphation occurs
- What equalization is, what it does is and how it is accomplished
- What desulphation is, what is does and how it is accomplished

Fully charged battery

The chemical state of a fully charged battery is depicted below. The primary components are: a positive plate comprised of lead dioxide (PbO_2), a negative plate comprised of lead (Pb), and an aqueous solution comprised of sulphuric acid (H_2SO_4) and water (H_2O).



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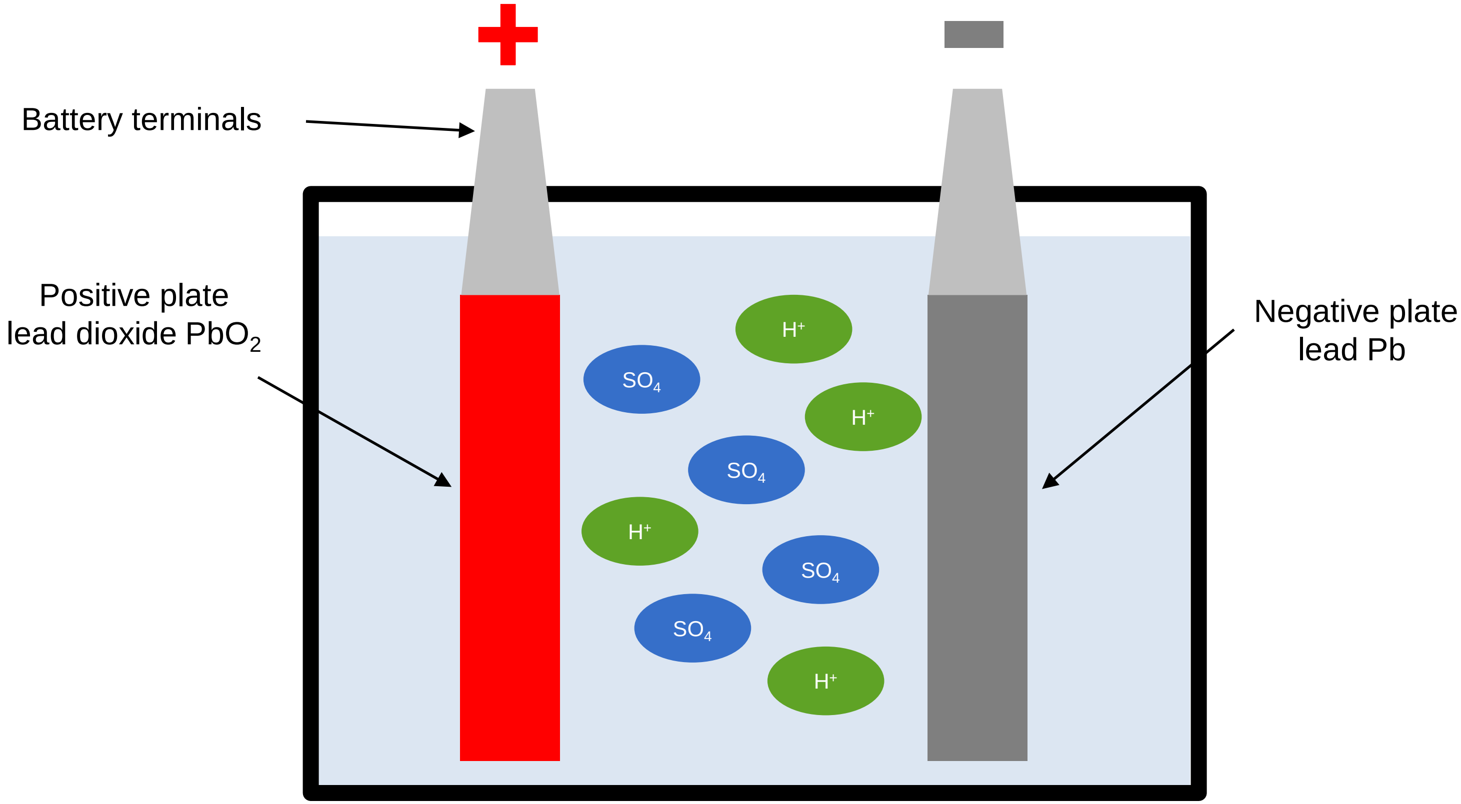
The chemistry of discharge

- The positive plate is comprised of lead dioxide PbO_2 and is slowly transformed into lead sulphate $PbSO_4$ during discharge
- The negative plate is comprised of lead Pb and is also slowly transformed into lead sulphate $PbSO_4$ during discharge
- At the end of a normal discharge, the resulting sulphation of the positive and negative plates is comprised of very fine lead sulphate $PbSO_4$ crystals
- sulphation on a small scale is a normal part of the discharge process
- The sulphation is removed by a three stage charge algorithm
- It is important to note that permanent and damaging sulphation is not normal and occurs when the lead sulphate is in a form that is not retroactive and is not removed from the plates during recharging. This occurs when the battery is left in a discharged state for extended periods of time

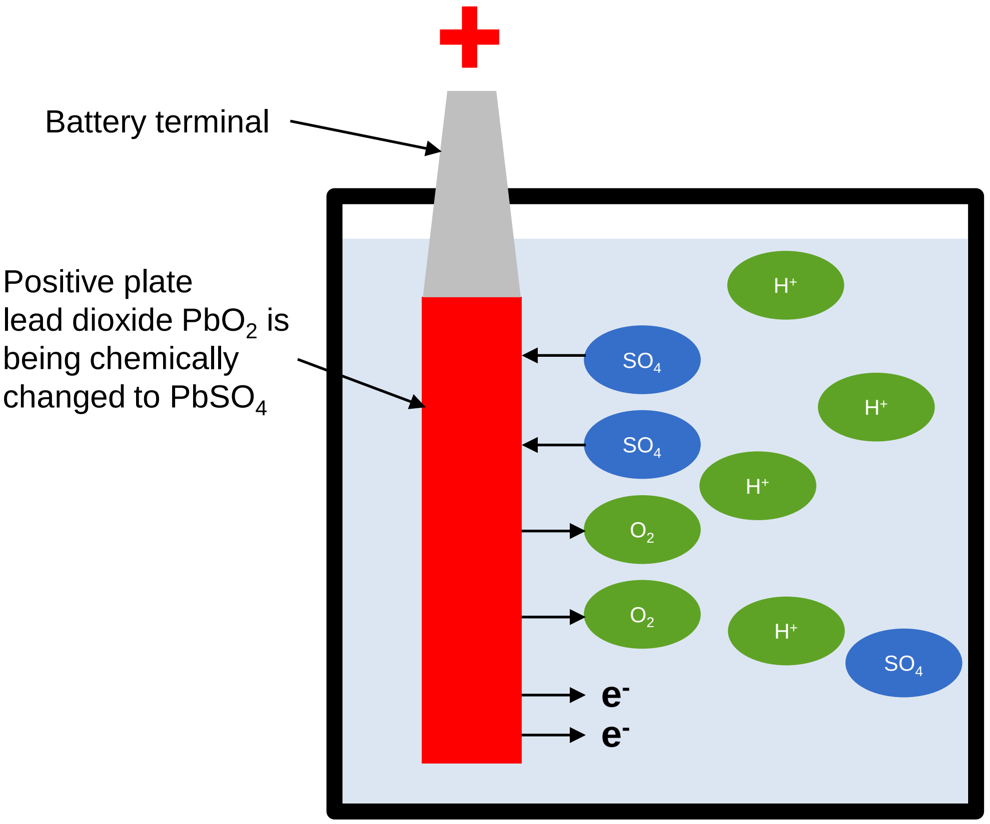
Battery chemistry during discharge

During discharge, the sulphuric acid disassociates into SO_4 and H^+ ions. The SO_4 molecule combines with both the positive plate and the negative plate to form lead sulphate $PbSO_4$ during discharge. Electrons freed from the hydrogen molecule in the sulphuric acid create the charge needed for electrical current.



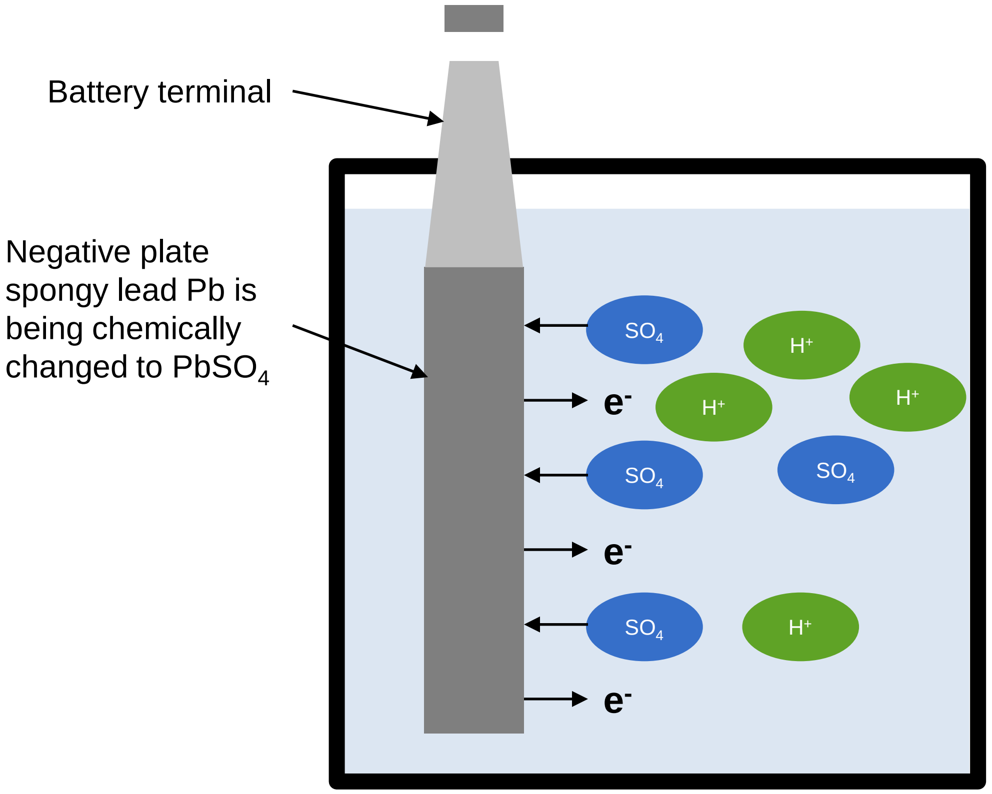
Positive plate chemical reaction during discharge

- During discharge, the positive plate is slowly being transformed to PbSO4 while the acid is being broken down and combining with the positive plate
- The hydrogen molecule is releasing electrons to provide current. The resulting Pb molecule combines with the free SO_4 molecule to produce lead sulphate ($PbSO_4$)
- The free O_2 molecule combines with the free hydrogen ions (H^+) to produce water
- In the process, two free elections are produced, which originate from the hydrogen atoms
- The solution is now being converted to water as the sulphuric acid is being dissociated



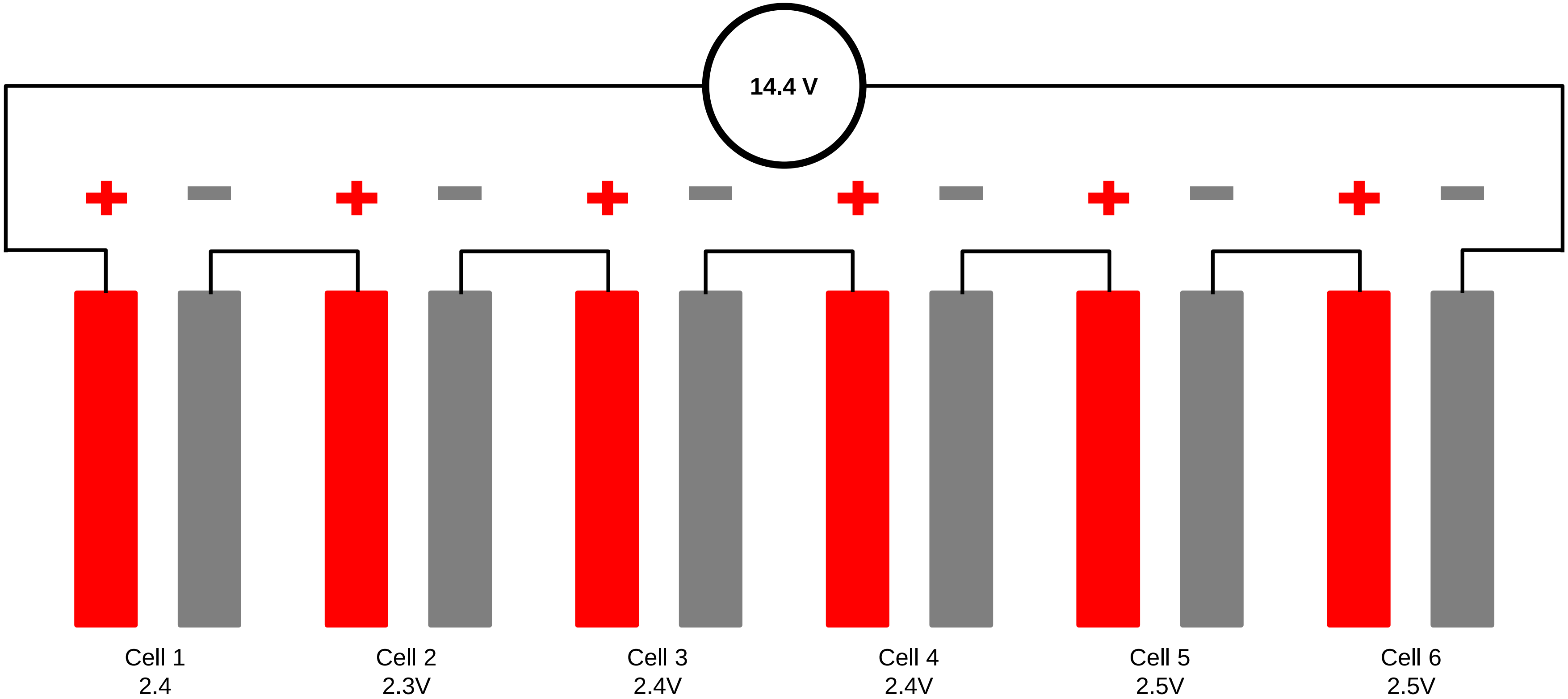
Negative plate chemical reaction during discharge

- During discharge, the Pb molecule combines with the SO_4 molecule to form $PbSO_4$, two positive hydrogen ions (H^+) and two free electrons
- The solution is now being converted to water as the sulphuric acid is being dissociated



Normal charging – no lead sulphate on plates

In every 12V battery, there is not a precise balancing of the individual six 2 volt cells. This can result in some cells being slightly undervoltaged (2.3 volts) and slowly accumulating sulphation after several charge / discharge cycles.

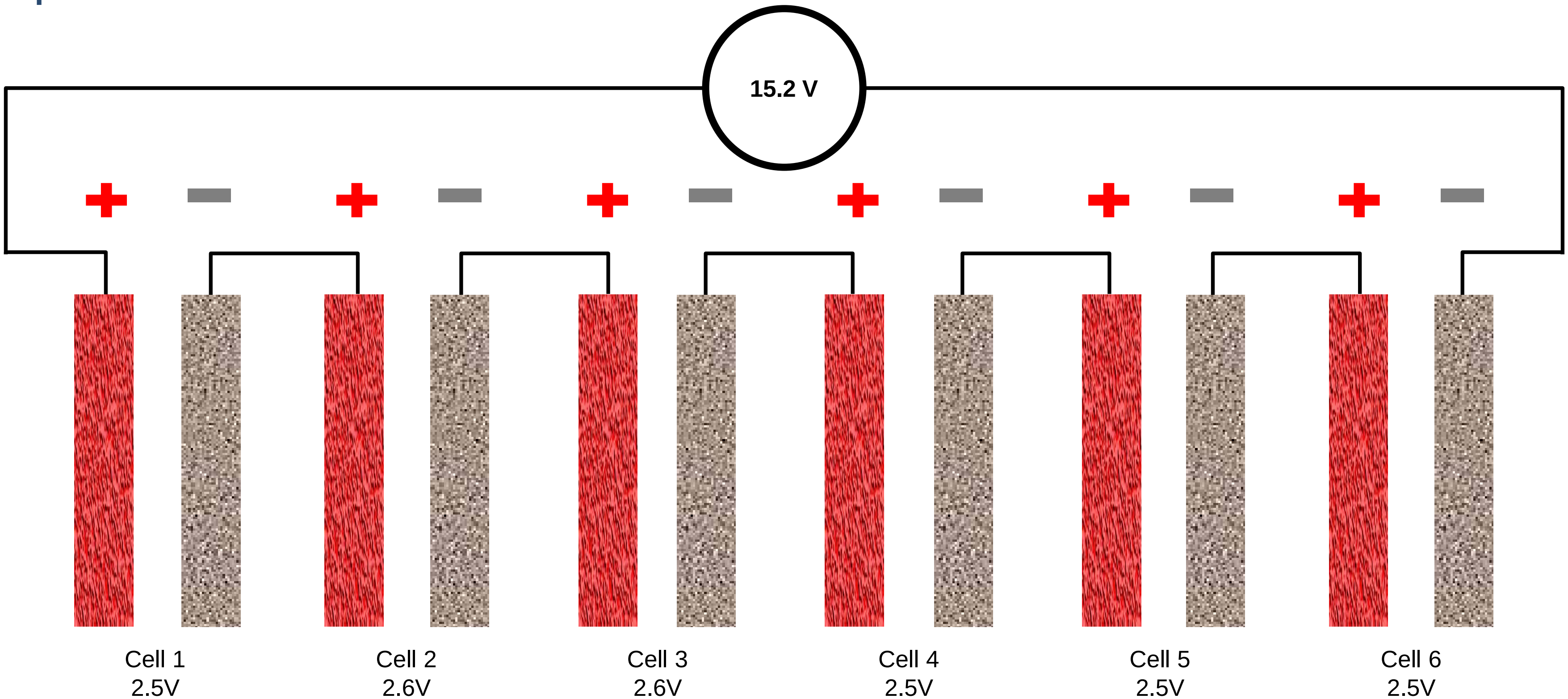


What is equalization?

- In a normal three stage charging algorithm, the max charging voltage is 14.4 - 14.6 volts
- A 12 volt lead-acid battery is comprised of six 2 volt cells connected in series
- There is always an inherent slight imbalance in voltage between the six cells
- It is possible one cell will not reach the targeted 2.4 volts / cell because of this imbalance
- Increasing the charging voltage to 15.2 volts assures that every cell will reach at least 2.5 volts to remove sulphation
- Equalization, when done properly at a low controlled current, generates slight heating of the electrolyte and forces current through plate areas that may be mildly sulphated
- The resulting effect removes any remaining sulphation and completely restores the plates
- Equalization must be time limited. Some cells can experience excessive overvoltage and cause permanent battery damage
- The equalization process only works on lightly sulphated plates. It will not work for heavily sulphated plates

Plates mildly sulphated over time can be restored by equalization

To eliminate the normal, mild sulphation resulting from discharge, an equalization routine is performed. A slight overcharge is applied to insure the lowest cell voltage is at least 2.5 volts. It is applied with a low current, typically limited to 0.5 amps. The equalization stage can extend up to 15 hours.

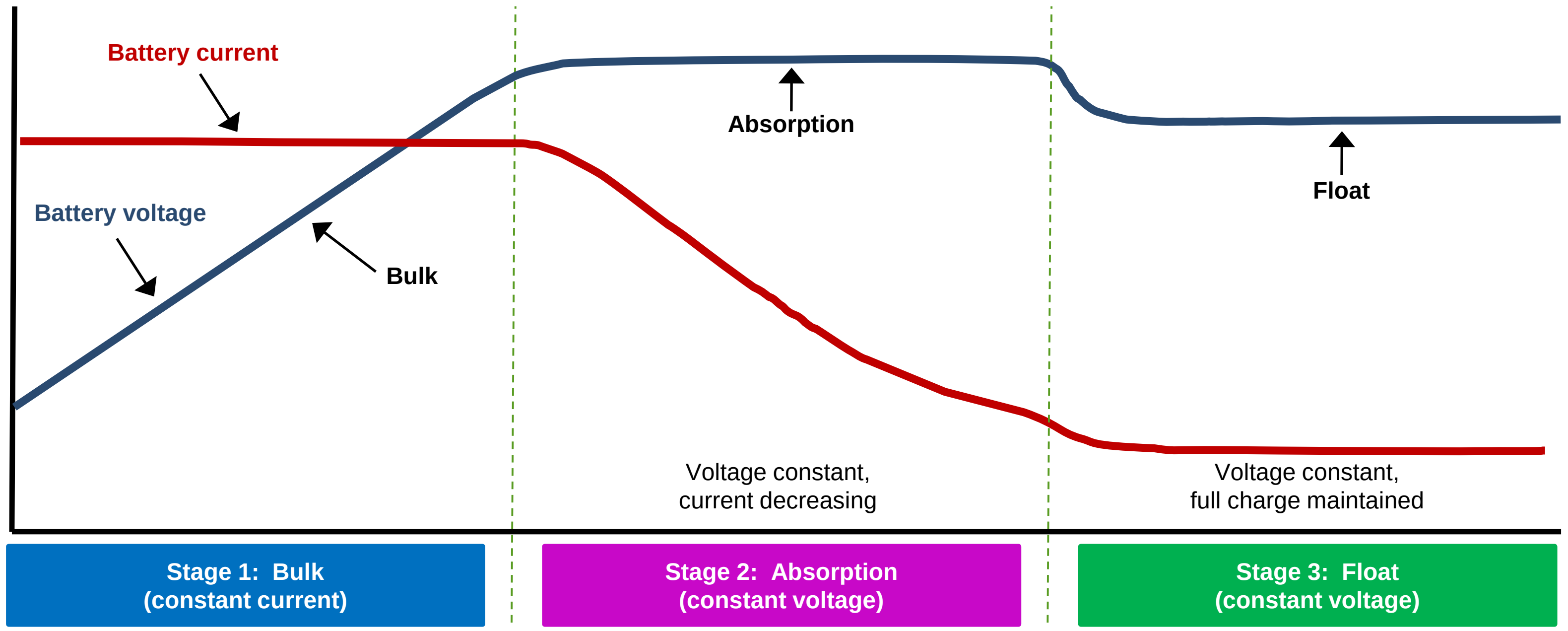


Three stage charging algorithm

Stage 1: **Constant current mode**
Battery is charged at constant current until the battery voltage reaches 14.4V

Stage 2: **Absorption mode**
Battery voltage is maintained at 14.6V until the charging current has decreased to C/20 (C is the battery's amp-hour rating)

Stage 3: **Float mode**
Battery voltage is reduced and regulated to 13.5V to maintain a full charge



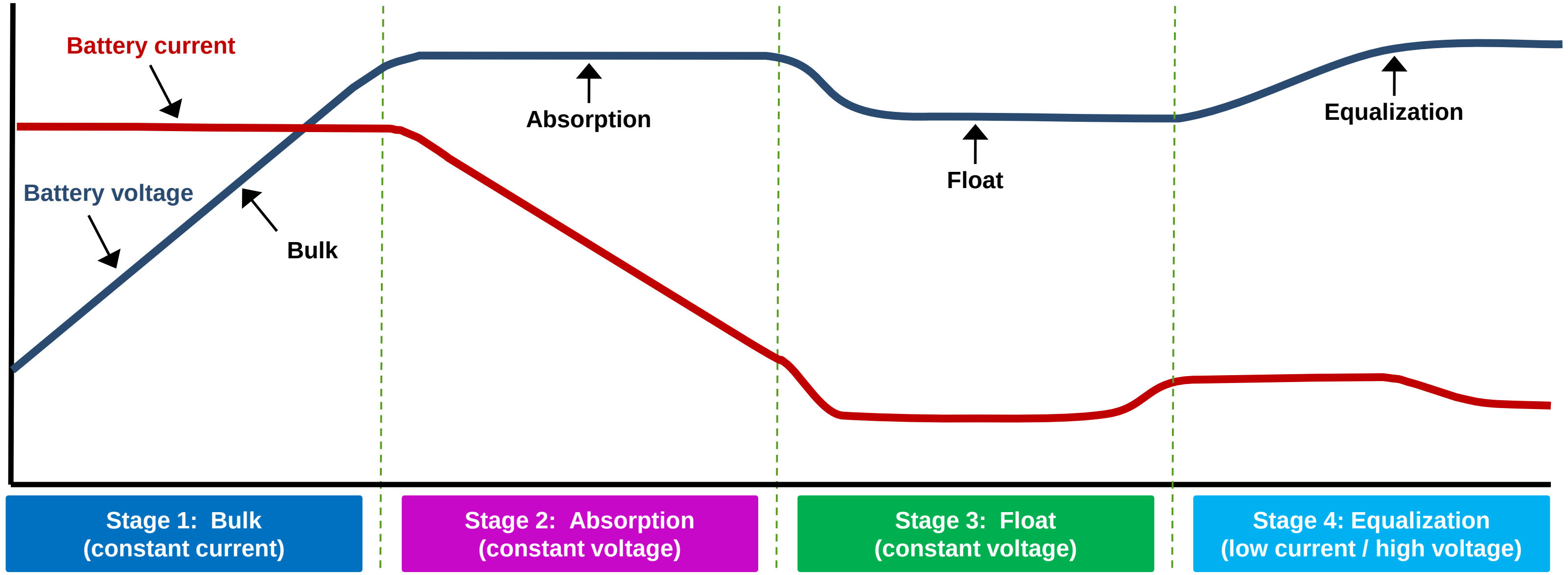
Example of four stage equalization algorithm

Stage 1: **Constant current mode**
Battery is charged at constant current until the battery voltage reaches 14.4V

Stage 2: **Absorption mode**
Battery voltage is maintained at 14.6V until the charging current has decreased to C/20 (C is the battery's amp-hour rating)

Stage 3: **Float mode**
Battery voltage is reduced and regulated to 13.5V to maintain a full charge

Stage 4: **Equalization mode**
Battery voltage is increased to 15.6V and the charging current is limited to ½ amp



When sulphation is not normal

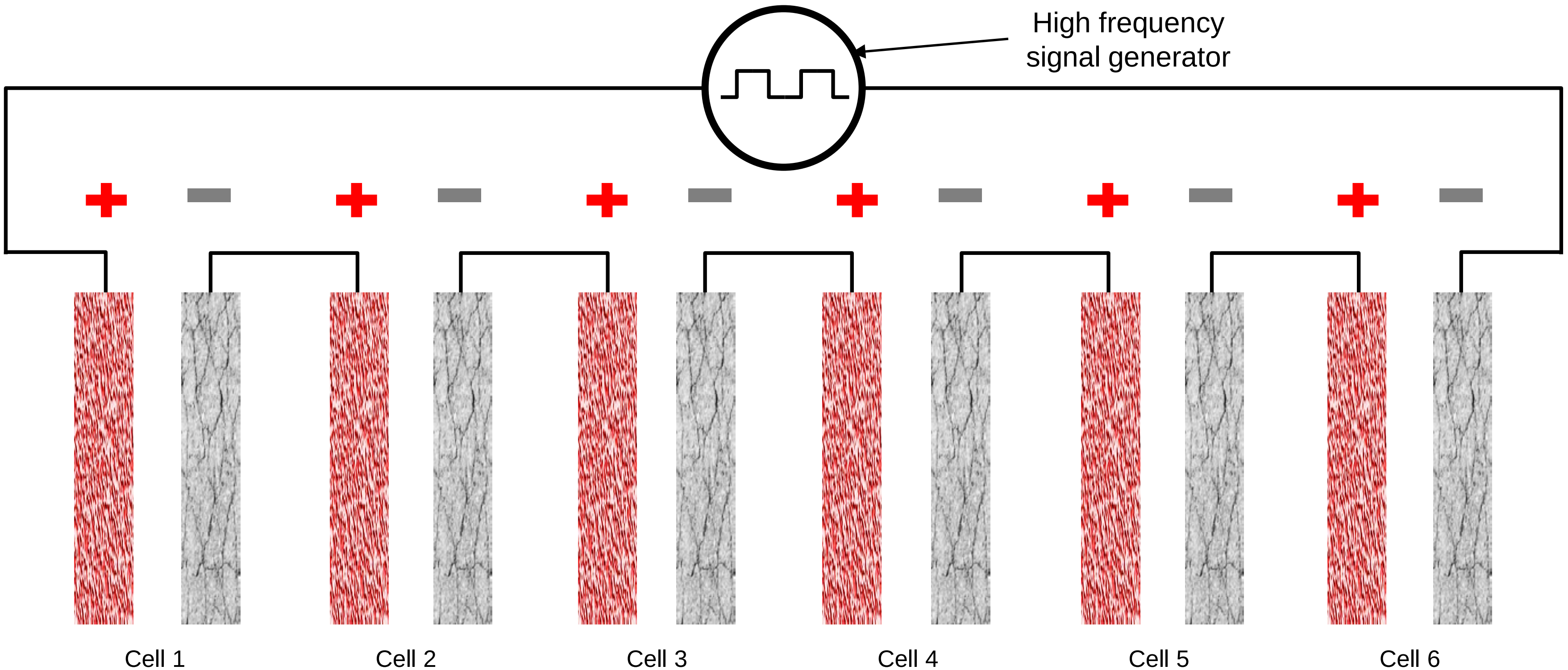
- If a battery is left discharged for an extended period of time, the sulphation resulting from a normal discharge continues to progress
- Instead of the sulphation forming fine particles, it begins to form hard crystals on the positive and negative plates
- Heavy plate sulphation is not easily removable by recharging, and over time is completely irreversible by recharging
- Sulphated plates are a poor electrical conductor and prevent normal recharging and equalization
- If high charging currents are forced through a sulphated battery, overheating and damage to the battery will occur
- A desulphating device is required to restore the battery to a normal condition

When is a desulphation device required?

- As noted before, sulphation is a normal effect of the discharge process. At the end of the discharge, both plates have been transformed to lead sulphate ($PbSO_4$)
- During a normal recharge, the chemical process is reversed, and the two plates are reverted back to lead and lead dioxide
- If the battery has been left discharged over an extended period of time, the sulphation will progress from fine crystals to very thick and hard crystals
- When thick crystals have begun forming on the plates, the equalization process will not work because not enough current can be forced through the battery to reverse the sulphation
- In order to remove the $PbSO_4$ crystals that have grown excessively, a desulphation device is required since a normal equalization process will not be effective

Heavy sulphation requires a desulphation device

If the lead sulphate has formed hard crystals on the plates, normal recharging or equalization is not feasible. The crystals are a very poor electrical conductor and, as a result, the battery can conduct only a minute amount of current. A desulphation device is required. The desulphation mechanism is an induced mechanical resonance of the crystals.



What is a desulphator?

- The natural or resonance frequency of the crystalline growth on the plates is 2-10Mhz
- A desulphation device generates high frequency signals in this range to break down the sulphur crystals that have formed on the plates by inducing a mechanical resonance
- For batteries with remaining sulphation that is not reversed by normal three stage charging, desulphation can be done overnight or with an equalization process
- For heavy abnormal sulphation, desulphation may take three to ten weeks
- The length of desulphation time required depends upon:
  - Size of battery and construction type, AGM, SLA, etc.
  - Degree of sulphation: how long the battery has been left in the discharged state
  - Temperature at which the desulphation is being performed
  - Type of desulphation device being employed
- The length of time a battery stays in its discharged state will have a proportional effect on the time needed to remove the sulphation

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Summary

- Sulphation of the positive and negative plates is a normal occurrence during the discharging of a battery
- Equalization can be used to desulphate a mildly sulphated battery if the recharging process failed to complete the reversal
- Equalization is not required after every recharge cycle
- Battery recharging should be performed in a timely manner to convert the lead sulphate PBO_4 in the plates back to lead Pb and lead dioxide PBO_2 quickly
- The battery should be recharged as quickly as possible after discharge to prevent excessive and permanent sulphation
- The degree of sulphation is determined by the length of time the battery remains in a discharged state
- A desulphation device is required when the sulphation has become excessive, preventing the battery from conducting electric current and accepting charge