



## **How POWERPLUS WORKS**



Power Plus is our battery chemistry enhancing additive. PowerPlus has a triple function in our battery service protocol with all types of lead acid batteries. In new batteries, it can simply be added to prevent hardening of soft lead sulfate ( $\text{PbSO}_4$ ). In batteries that are on service duty now with a state of charge or cycle life at/or above 50% it can regain the lost capacity and protects the battery against hard sulfation buildup. If the batteries are removed from service, PowerPlus is accompanied with our special chargers to recover the original service capacity of the battery again. In all three instances PowerPlus also is a contributor to control excess growth of amorphous corrosion layer of the type  $\text{PbO}$  that inhibits movement of electricity in or out of the battery.

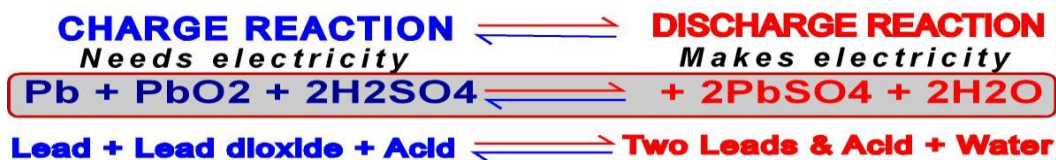
Because of the participation of PowerPlus in the chemical reaction in lead acid batteries the State of Health (SOH) and State of Charge (SOC) is stable and long lasting promoting increase life span in the battery. Here are main benefits in all lead acid batteries:

- Doubles batter service life span
- Inhibits hardening of lead sulfates
- Aids in reducing excess growth of corrosion layer
- Aids to sustain low resistance to accept charge
- Reduces water drying out
- Reduces autoself discharge
- Eliminates downtime events due to fail capacity
- Ensures OEM specified runtime and capacity

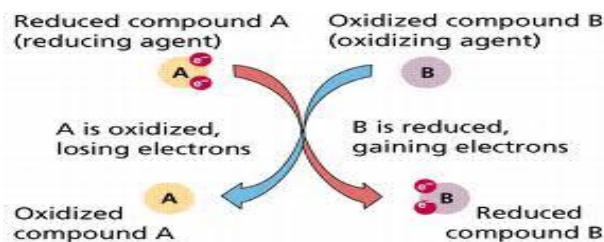
**How PowerPlus Works**

PowerPlus is an agent design to sustain continuous production of healthy soft moist and porous lead sulfate (PbSO<sub>4</sub>) species in both negative and positive plates. In addition, PowerPlus also aids in the formation of healthy corrosion layer of the type PbO<sub>2</sub> and in controlling evolution of amorphous corrosion layer of the type PbO that passivates the positive electrode. Substantial scientific research in lead acid battery as well as our field experience has confirmed to us that the two most pervasive failures in lead acid battery is due to hardening of the lead sulfate and uncontrolled growth of amorphous corrosion layer of the type PbO. They both (sulfation and PbO corrosion) are contributors to other dysfunctional symptoms that facilitate complete failure of capacity and performance of lead acid batteries. Both, hardening of the lead sulfate and formation of amorphous corrosion layer, are electrochemically interrelated and needs to be explained in order to understand the morphology and thermo-kinetics at play here and the reach of our solution.

First thing is to clearly conceptualize that a lead acid battery will not be so without the formation of lead sulfate (PbSO<sub>4</sub>) and the formation of healthy corrosion layer of the type PbO<sub>2</sub>. The lead sulfate formation and healthy corrosion layer both are part of the natural electrochemical thermo-dynamics of the battery. Both are byproduct of the chemical reaction between sulfuric acid and the two leads paste active materials. The formation of PbSO<sub>4</sub> takes place during the discharging phase of the battery and it is reversed during the charging phase. Below it is a summarize view of the electro-chemical reaction in a lead acid battery:



It is important to understand that the lead acid battery depends on this double chemical reaction commonly known as *reduction* and *oxidation*. This reaction is typically called a *redox reaction*. During the redox reaction one element is oxidized and another is reduced. If an element is oxidized then it loses electrons and if it is reduced then it gains electrons. Here is a view of the redox reaction:



**Corrosion Layer Formation**

The corrosion layer is a byproduct of the spontaneous electrochemical reaction in the battery. It is assumed that the corrosion layer is prevalent at the positive grid plate. The chemical reaction at the positive plate causes for a duplex production of corrosion species. The species are the dioxide lead PbO<sub>2</sub> and the monoxide lead PbO. Some specimens of the lead (Pb) that makes the positive grid plate joins with two molecules of oxygen forming PbO<sub>2</sub> or with one oxygen molecule to produce PbO. The joining process takes place through electrolysis means causing dissolution of the lead metal material that makes the positive grid plate. This joining is

a deterioration of the conductive structure (grid plate) that moves current *in* or *out* of the battery.

The  $\text{PbSO}_4$  (lead sulfate) formation occurs at the lead paste mass while the corrosion layer ( $\text{PbO}_2$ ) occurs at the surface of the positive plate or at what many call the *interface area*. This interface area is located between the paste and the surface area of the grid plate. This interface is considered also as the *area of contact* between the paste and the surface of the grid plate. If the interface of the positive plate is populated with amorphous corrosion layer ( $\text{PbO}$  = monoxide lead) then electron transportation through the lead grid plate to *in-or-out* of the battery is inhibited. Here is a view of the elements that makes a positive grid plate:

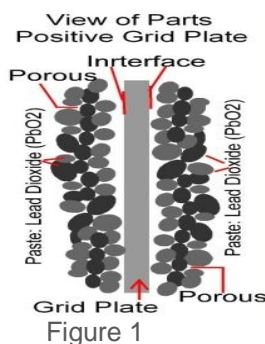
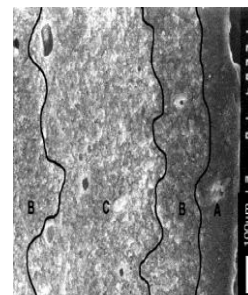
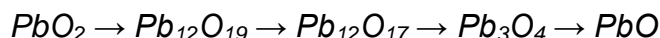


Figure 1 is a graphical view by us to show the different parts of the positive grid plate. Figure 2 is a cross-section view of the grid plate surface after 4 hours of soaking in electrolyte solution. The outer sub-layer (A); (B) is the intermediate sub-layer; and (C) is the central (inner) sub-layer. This image was taken from the scientific paper by Pavlov et al published in the Journal of Power Sources, Volume 140, Issue 1, 10 January 2005, Pages 168–180.



The basic principle of corrosion layer formation is simple. A lead metal dissolution is reduced through the application of a cathodic current in acidic electrolyte. This mechanics causes for lead metal to lose mass (electrons) that becomes  $\text{PbO}_2$  or  $\text{PbO}$ . At the same time the lead dioxide can decompose to  $\text{PbO}$  upon exposure to high voltage and/or temperature. The reaction can be appreciated as follows:



The stoichiometry of the end product  $\text{PbO}$  (monoxide lead) can be controlled by increasing the temperature and the voltage during charging. Therefore, thermal decomposition of healthy lead dioxide ( $\text{PbO}_2$ ) into amorphous lead monoxide ( $\text{PbO}$ ) in lead acid battery electrochemical reaction is possible if temperatures or charging voltage are above normal. Research suggests that the formation of healthy corrosion layer of the type  $\text{PbO}_2$  of which nucleation of  $\text{PbSO}_4$  depends should be most expected at the interface with temperatures between  $68^\circ\text{F}$  to  $110^\circ\text{F}$  ( $20^\circ\text{C} \rightarrow 43^\circ\text{C}$ ). Thus, this precipitation is controlled by the temperature and the potential employed for polarizing the battery (the charger). The fact that if a voltage potential of +1.1VDC or more is aggregated to the absorption charging phase of the battery then it is found that  $\text{PbO}$  is the chief product. J.J. Lander in his extensive research suggest that if voltage potential is increased during charging then either the reaction can proceed by direct oxidation of  $\text{Pb}$  to  $\text{PbO}$  or by oxidation of  $\text{Pb}$  to  $\text{PbO}_2$  to be followed by a solid-phase reaction that changes  $\text{PbO}_2$  into  $\text{PbO}$ . We understand that J.J. Lander is saying that there are two pathways for amorphous corrosion layer growth of the type  $\text{PbO}$ . One pathway is created directly due to invariant high voltage during charging and the second pathway is also accompanied by invariant high voltage charging and abnormal high temperature that can cause a change of existing  $\text{PbO}_2$  specimens into  $\text{PbO}$ . This is an event that should be avoided during charging in order to have a healthy lead acid battery.

Precipitation of the hydrated porous soft lead sulfate ( $\text{PbSO}_4$ ) is expected during cycling of lead acid battery as well as formation of healthy  $\text{PbO}_2$  that comprises the corrosion layer. The PowerPlus contribution is at one hand to inhibit tendency of moist and porous lead sulfate to decay as a hard crystal and also ensuring that propagation of amorphous corrosion layer of the type  $\text{PbO}$  does not take place. In addition, generation of excess  $\text{PbO}_2$  at the corrosion layer zone must be controlled to avoid continuous erosion of the lead grid plate material and uncontrolled growth of overall electrode paste mass. This is excess growth is regulated through contribution of PowerPlus that supply to the electrochemical reaction in the battery sufficient oxygen and hydrogen molecules to protect the porosity of the lead paste mass and to prevent rapid and continuous growth of amorphous corrosion layer of the type  $\text{PbO}$ .

### Elimination of Hardening of Lead Sulfate

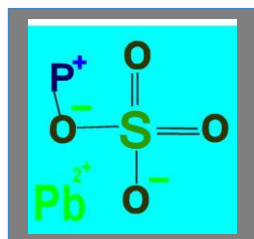
Our theory of the electrochemistry associated with premature battery failure suggests that inhibiting evolution of non-porous hard lead sulfate can ensure reduce formation of healthy  $\text{PbO}_2$  and minimal precipitation of monoxide lead ( $\text{PbO}$ ) at the interface (see Lam et al, Culpin, Pavlov, & Ruetschi). This theory contains that there is a structural electrochemical relation between hydrated porous lead sulfate ( $\text{PbSO}_4$ ) and reduce production of healthy  $\text{PbO}_2$  layer on the interface. In addition, it holds that if lead sulfate mass hardens PowerPlus aids to reconvert the crystallized lead sulfates to original conditions. This means that during the lead acid battery chemical reaction yielding  $\text{PbSO}_4$  the PowerPlus easily reacts with electrical input in acid environment to actively shield soft hydrated lead sulfates from hardening. In addition, PowerPlus ensures that sulfuric acid continually returns back to the battery electrolyte strengthening the specific gravity of the battery to its OEM specifications. OEM specifications generally are at the 1,265 specific gravity (SG). If a battery is sulfated or is discharged the SG can drop all the way to water state (1,000 SG) which means that all the sulfuric acid is now trapped in  $\text{PbSO}_4$  hard crystals state. Hence, PowerPlus will recover the SG given that the battery's lead paste mass is reactive to electrical input.

The gaining of healthy soft hydrated and porous lead sulfate also ensures that corrosion layer is under control because exothermic temperatures are regulated with the efficiencies of the battery to accept charge and to give discharging loads. It is well known that increase in resistance to accept a charge in a battery augments temperature as the battery is exposed to longer time under electric force to be charged. Resistance to accept charge can increase charging voltage potential by +1.1V or more causing evolution of amorphous corrosion layer of the type  $\text{PbO}$ , known as lead monoxide (i.e. book *Lead Acid Batteries Science & Technology* by D. Pavlov; and J.J. Lander). It is also known that conversion of soft lead sulfate into hard lead sulfate happens before production of corrosion layer at the plate interface area. P. Ruetschi described in his study of corrosion layer that  $\text{PbSO}_4$  takes place at 300mV below formation of any duplex production of corrosion layer of the type  $\text{PbO}_2$  or  $\text{PbO}$ . This means that lead sulfate formation and hardening it is a prior occurrence to corrosion layer precipitation. In addition, Ruetschi also provides evidence that  $\text{PbSO}_4$  precipitates first because it is the first making contact with the ionized acidic electrolyte in the battery.

As pressure for hardening of lead sulfate is available through various conditions (inconstant temperature, invariant charging, low water table in electrolyte, poor routine maintenance, etc.) it is PowerPlus the one protecting the soft lead sulfate from hardening with the sulfuric acid. The reason this happens is that PowerPlus becomes part of the chemistry of the battery as covalent compound that links itself to other participants in the chemistry of the battery. As you

know, a covalent compound what it does is to link itself to other non metal atoms in which electrons (ions) are shared between them. Since sulfuric acid ( $H_2SO_4$ ) and lead (Pb) and sulfuric acid and lead dioxide ( $PbO_2$ ) are continuously interchanging atomic values as ionic species then PowerPlus enters to participate in the exchange of electrons with sulfuric acid. The contribution of PowerPlus in this exchange of electrons is to provide the electron that prevents the hardening of  $PbSO_4$  (lead sulfate) or if it becomes hard then lose it with aid of electrical input (XCharger or Genesis equipments).

From a theoretical electro-chemical point of view, the combination of various atoms sharing electrons (ions) can form various molecular orbitals. The orbitals that formed with the combination of  $Pb + SO_4 + PowerPlus$  are: one orbital is a bonding catalyst, another is a non-bonding catalyst, and still another is anti-bonding agent. The anti-bonding participant in this exchange of orbitals is PowerPlus. The bonding electron is the sulfuric acid ( $H_2SO_4$ ) that tends to harden (crystallize), despite any ambience conditions when it is part of  $PbSO_4$ . The non-bonding contributor is the two types of lead (Pb &  $PbO_2$ ). Essentially, this notion of various molecular orbitals exchanging energies, with two electrons delocalized (not found in one specific region) over other atoms, it is considered in chemical terms as *resonance hybrid*. This *resonance hybrid* refers to the use of Lewis dot structures modeling technique when dealing with molecules. Below is a view of a lead sulfate molecule ( $PbSO_4$ ) and PowerPlus using Lewis electron dot structure diagram to illustrate the participation of PowerPlus in it:



<b>Name(s):</b>	$PbSO_4$ (Lead Sulphate) Sulfuric acid, lead(2+) salt (1:1)
<b>Formula:</b>	$O_4PbSP^+$
<b>Element System:</b>	O-Pb-S- $P^+$ (PowerPlus is $P^+$ )
<b>Element Names:</b>	Oxygen, Sulfur, Lead, PowerPlus
<b>Molecular Weight:</b>	303.253 <sup>g</sup> / <sub>mol</sub> 526.462

Every structure associated with the chemical reaction in a battery has a certain quantity of energy which determines the stability of the  $PbSO_4$  molecule. The problem with lead acid battery chemical reaction is that the stability of  $PbSO_4$  (lead + sulfate) is reactive to environmental conditions that propel hardening or as some preferred: *passivation*. In order to improve the stability of moist soft porous  $PbSO_4$  a contributor with lower energy structure such as PowerPlus is necessary to facilitate a bonding without hardening effect. This is what we referred to when we affirmed that “*PowerPlus shields the fresh  $PbSO_4$  from hardening*”.

Furthermore, a molecule with PowerPlus as delocalized electron is a contributing force making possible resonance structures evolution. So that you know, electron delocalization can be used to explain conductivity, malleability, and ductility of metals. In the case of PowerPlus, the actual resonance structure is an intermediate agent with overall energy lower than each of the other contributors. This intermediate agent forms between different contributing structures differs only in the position of electrons, but not in the position of nuclei. Hence, PowerPlus is an electron delocalization agent that lowers the potential energy of a fresh  $PbSO_4$  molecule making it more stable than any of the other contributing structures ( $H_2SO_4 + Pb + PbO_2$ ). The new gained stability is significant because it is the factor provided by PowerPlus that disallows hardening by reactive response to internal or external ambience factors affecting the battery. In other words, PowerPlus keeps the soft moist and porous lead sulfate intact even when charging has taken place inappropriately or ambience is not desirable for the battery.

Generally, Power Plus and the XCharger (or Genesis) will restore the specific gravity of a discarded battery to its OEM specifications (1.265) and will in turn produce a battery that is producing similar cranking amps or amp-hours for what the battery was rated originally. Power Plus when added to a new battery will maintain its specific gravity, supports continuity of soft moist porous lead sulfate, preserve the capacity rating of the battery, protects against excess formation of amorphous corrosion layer of the type PbO, aids to regulate growth of healthy corrosion layer of the type PbO<sub>2</sub> and extend its service life span beyond manufacturer specification. Our field experience in the last decade alone have proven that when Power Plus is added to new batteries their service life is doubled despite cold and hot climates ambience. This is true even in batteries that are removed from service and are reconditioned to service with our electro-chemical enhancing process.

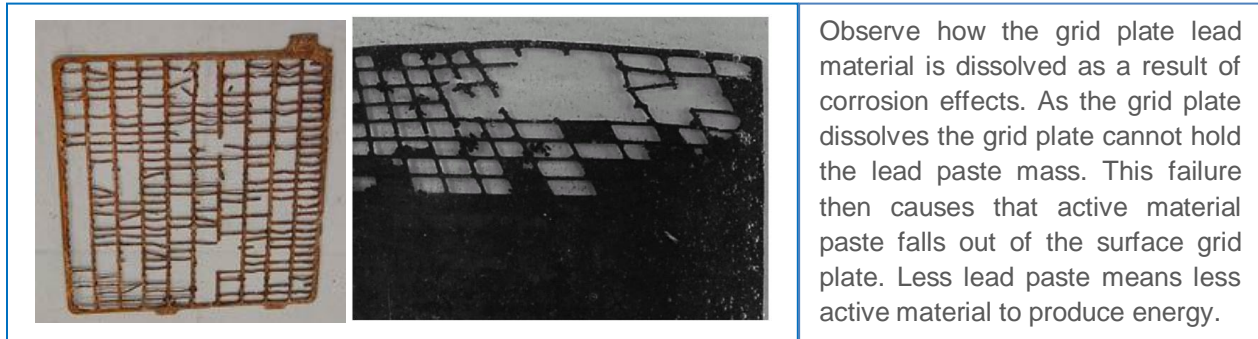
### Eliminating Corrosion Layer

Substantial research has been published on the growth process, behavior mechanism, and development of a passivating layer of monoxide lead (PbO) beneath the PbSO<sub>4</sub> mass. For example, Pavlov and Iordanov have described the growth process of a passivating corrosion layer of the type PbO on the surface of positive electrode. Ruetschi followed up with an explanation of the growth process of the corrosion layer (PbO) suggested by Pavlov and Iordanov. More recently, Culpin et al have presented a detail description of the mechanism for PbO formation. All these researchers, just to name few, agreed that the PbSO<sub>4</sub> layer (lead sulfate active material) when it has hardened on both the positive or negative plates is considered to act as a film membrane that blocks the movement of HSO<sub>4</sub><sup>-</sup> and SO<sub>4</sub><sup>2-</sup> ions. This causes a decrease in acidity at the surface of the lead plates that when accompanied with a high charging voltage promotes a chemical reaction between Pb<sup>+</sup> and OH<sup>-</sup> ions to form monoxide lead or PbO. Hence, the acidity depression is associated with a retardation of the diffusion of H<sub>2</sub>SO<sub>4</sub> through the outer PbSO<sub>4</sub> layer. Researchers also convene that a corrosion layer dominated with species of the type PbO yields increase resistance to accept charge and higher exothermic temperature that hinders plate structures and battery performance.

Under the participation of PowerPlus species the net flow of H<sup>+</sup> ions is promoted to slow down the acidity environment at the corrosion layer zone. Therefore, the shift towards reduction in acidity within the interior of the corrosion layer facilitates generation of healthy PbO<sub>2</sub> species during charging. As a result, the PbO layer developed under PowerPlus contribution will be thinner than that produced under invariant-current charging without PowerPlus. Furthermore, PowerPlus also propels that the growth of the thin film of PbO layer becomes discontinuous and dispersed through the grid plate surface. This type of behavior will serve to reduce the resistance to accept charge and to improve the capacity performance of the battery.

Some of the literature on anti-corrosion layer formation also suggests that the use of ingredients such as tin, silver, antimony, black carbon, selenium, arsenic, bismuth, and other can serve as protective elements against corrosion of lead grid plate material in acidic substance such as sulfuric acid. In fact, most batteries nowadays use a mixture of tin and calcium and/or antimony mixed with lead to make the electrodes somewhat resistance to corrosion. These aggregates serve to control decay of the positive plate mass due to corrosive force of the H<sub>2</sub>SO<sub>4</sub> acid. However, the interest in alloys to control corrosion layer mainly aims at insulating the electrode plates to regulate production of the corrosion layer, but not to eliminate and limit the duplex generation of corrosion layer as PbO<sub>2</sub> and PbO.

Therefore, despite the use of anti-corrosion alloys employed on the making of positive grid plates still new lead acid batteries today will produce a passivating corrosion layer of the type PbO. Below is a sample view of the effect of corrosion on the positive grid lead plate:



Our claim with PowerPlus is that it has the benefit of controlling healthy corrosion layer formation of the type PbO<sub>2</sub> to minimum. This agency aids in preventing depletion of lead grid plate material during oxidation phase by securing low acidity environment for the reaction. In addition, PowerPlus continually ensures replenishment of hydrogen and oxygen ions to both the positive and negative plate. Thus, because of the agency of PowerPlus corrosion layer formation of the type of PbO<sub>2</sub> occurs to minimum during the battery chemical reaction due mainly to low acidity and healthy deposition of PbSO<sub>4</sub> during the so call oxygen evolution in the battery during charging.

Often the interaction of positive plate interface and sulfuric acid is sourced with abnormal ambience temperature and increase in exothermic temperature. The increase in exothermic temperature it is also associated with conversion of the soft lead sulfate to hard crystals mass and excess growth of non-conductive corrosion layer of the type PbO. Thus, higher resistance opposing charge can be generated by sole agency or share collaboration of the hard sulfated lead paste mass and the insulating corrosion layer of the type PbO. Therefore, if the lead sulfate is kept soft and moist the resistance of the battery is within normalcy allowing normal charging and at the same time disallowing decay of healthy corrosion layer into amorphous corrosion layer of the type PbO. PowerPlus also aids in preventing that the anti-corrosion ingredients (i.e. tin, antimony, silver, selenium, arsenic, bismuth, etc) in the plate's mixture are expose to temperatures where no longer their protective agency fails propelling formation and growth of bad corrosion layer.

Furthermore, as mentioned above, batteries nowadays come with ingredients in their electrode plates that are resistant to corrosion of lead in acid. The main purpose of these aggregates is to prevent rapid dissolution of positive lead grid plate mass due to the oxidation reaction. The problem is that as lead acid battery efficiencies begin to decline the resistance of the battery to accept charge is increased. This decay in the chemical reaction propels increase in exothermic temperatures causing fatigue of the protective corrosive ingredients. Hence, corrosion layer evolves due mainly to a change in the morphology of the battery due to hardening of lead sulfate mainly. Therefore, if the soft lead sulfates formation is kept to normalcy this will allow a high efficiency of interaction with the electrode plate and its surface interface contact. In summary: the benefit of PowerPlus Battery Chemical Enhancer consists in disallowing hardening of the lead sulfate and inhibiting growth of corrosion layer of the type PbO.



As a battery service specialist we urge you to take advantage businesswise with PowerPlus. Understand that PowerPlus is a product that you use in your daily battery service shop and that you can also commercialize it if you desire. This can be another stream of revenue that you can create in your town. You can sell it as a protector and preserver of battery capacity and to double battery life span. If you want to sell PowerPlus in your area please let us know so that we help you with media samples for you to use in your campaign and packaging.



Finally, know this clearly: PowerPlus is environmentally friendly compound, biodegradable, non-hazardous, and non-regulated, non-toxic, safe for transport, and non-harmful to health. It allows you to have a *go green* business marketing

PowerPlus is inactive until added into a lead acid battery electrolyte. Storage of PowerPlus in liquid state is at room temperature to avoid crystallization if expose to below 45 °F (7 °C). If crystallization takes place all you do is warm the water to room temperature again to restore its solvent condition. Shelf life is five years.

**PowerPlus Dosage**

We developed our battery additive PowerPlus as a lead acid battery chemical enhancer process that can be use in various battery service applications. Once PowerPlus is injected into the battery electrolyte it will become active as part of the electrochemistry of the battery aiding in the continuous formation of hydrated soft lead sulfate. This contribution of PowerPlus is twofold. At one hand aids in a healthy assembly of soft porous lead sulfate preventing hardening or strong bonding of the PbSO4 molecule. A second function is to aid in controlling evolution of the amorphous corrosion layer with only one oxygen molecule (PbO).

A battery serviced with PowerPlus will not require more dosages through the life span of the battery. It is a onetime event. PowerPlus Battery Enhancer then can be used in new batteries as a preventive and protective feature to preserve the health of batteries. In batteries currently in use with state of charge or a state of health at least at 50% it will restore its full capacity as the battery is on service now. On batteries that are out of service because of depletion of their capacity PowerPlus will aid rescuing the lost potential of a battery if used with our special battery charge XCharger. Keep in mind that the electrolyte configuration and application of the battery is not an issue. Electrolyte can be liquid or gel type and the ventilation system can be vented or regulated. Batteries can be deployed in any application imaginable nowadays. This will not matter either. For sealed batteries you will have to drill holes to the top lid to inject the PowerPlus to each cell. Hole must be covered with a rubber or plastic plug. Here is our recommendation for how much PowerPlus substance you can use in different types of batteries.

CHART OF POWERPLUS DOSAGE FOR ALL LEAD ACID BATTERIES					
Battery type	Capacity	PowerPlus		Electrolyte	Application
Cranking	100-700 CCA	1/2 oz	15 cc	Electrolyte can be of liquid acid or gelatinous formulation.	Any application of the battery will not harm PowerPlus desulfation effect.
Cranking	750-1200 CCA	1.5 oz	44 cc		
Cranking	1200 CCA & up	2 oz	60 cc		
Deep cycle	100-250 Ah	2 oz	60 cc		
Deep cycle	260-400 Ah	3 oz	90 cc		
Telecom/UPS	100-250 Ah	2 oz	60 cc		
Telecom/UPS	260-400 Ah	3 oz	90 cc		
Telecom/UPS	450-900 Ah	5 oz	150 cc		
Telecom/UPS	1000 Ah & up	7 oz	210 cc		

*The quantity of PowerPlus recommended here is for each battery cell of 2 volts.*

## REFERENCES

There is extensive scientific literature studying morphology and evolutive thermodynamics of the corrosion layer and hardening of lead sulfate. Here is a sample of the literature that we referenced this instructive document.

B. Culpin, A.F. Hollenkamp, D.A.J. Rand; *The effect of tin on the performance of positive plates in lead/acid batteries*; Journal of Power Sources, Volume 38, Issues 1–2, March–April 1992, Pages 63-74.

De Marco, R. and Jones, J. (1997). *Extension of the life and enhancement of the energy density of maintenance-free lead/acid batteries*. AEDB Qly Report, November: 1-34.

J. J. Lander; *Further Studies on The Anodization of Lead in Sulfuric Acid Solution*; Electrochemistry Branch, Naval Research Laboratory, Report 4475, January 31, 1955.

R.H. Newnham; *Remote Area Power Supply (RAPS) system and Valve Regulated Lead Acid Batteries*; Chapter 14 of the book Valve-Regulated Lead Acid Batteries by Rand et al; Elsevier, 2004.

D. Pavlov; *Formation of Lead Acid Batteries and Structure of Positive and Negative Masses* in Chapter 3 of the book Valve-Regulated Lead Acid Batteries by Rand et al; Elsevier, 2004.

D. Pavlov; *Lead Acid Battery Science and Technology*; Elsevier, 2011.

D. Pavlov, N. Iordanov; *Growth Processes of the Anodic Crystalline Layer on Potentiostatic Oxidation of Lead in Sulfuric Acid*; J. Electrochem. Soc. 1970 117(9): 1103-1109.

P. Ruetschi; *Ion Selectivity and Diffusion Potentials in Corrosion Layers: PbSO<sub>4</sub> Films on Pb in H<sub>2</sub>SO<sub>4</sub>*. Electrochem Soc. 1973 120(3): 331-336.

M. Taguchi; T. Hirasawa; *Influence of Sn Content on the Corrosion Behavior of Pb-Ca-Sn Alloys in High Temperature Sulfuric Acid*; Japan Institute of Metals and Materials (JIM), Vol. 41. No. 10 (2000) pp.1307 to 1311.

M. G. Verde et al; *Achieving high efficiency and cyclability in inexpensive soluble lead flow batteries*; Energy Environ. Sci., 2013, 6,1573.

