Five ways to extend the life of your lead acid battery. Part I

Although high-quality batteries are more expensive up front, they are also more reliable and their longer life-expectancy allows you to recoup your investment in the long run.

How long they last is directly related to how they are used …or abused. Simply knowing what you should and shouldn't do to a battery will save you thousands – if your battery bank is large. Let's take a closer look at batteries, and at five simple ways to extend their life…

In this article we're going to look at the main causes of premature battery failure – these are:

1. Running a battery 'flat …then failing to re-charge
2. Persistent Undercharging
3. Overcharging
4. Charging too quickly
5. Ignoring temperature considerations

This article is specifically about lead batteries. There are also many other kinds of battery chemistries such as lithium, but this information is specifically about lead.

In order to understand what is going on inside a battery, we need to know how it is constructed, and what happens when we discharge and re-charge it.

A lead acid battery cell is approximately 2V. Therefore there are six cells in a 12V battery – each one comprises two lead plates which are immersed in dilute Sulphuric Acid (the electrolyte) – which can be either liquid or a gel. The lead oxide and is not solid, but spongy and has to be supported by a grid. The porosity of the lead in this condition makes it fully accessible to the the electrolyte, enabling a chemical reaction to occur relatively easily throughout the thickness of the plate as the battery performs its task of storing and releasing energy.

That chemical reaction is fairly complicated – but we need only notice a couple of things about it: As power is drawn from a battery sulphuric acid is lost from the electrolyte and combines with the lead plates to form lead sulphate. Conversely – recharging the battery forces the sulphate to leave the lead plates and return, once more, to the electrolyte forming dilute Sulphuric Acid. The second thing we need to notice is that if the charging voltage is too high, or is maintained for too long another chemical reaction begins in earnest: the water in the electrolyte decomposes into oxygen and hydrogen.

The decomposition of the water in the electrolyte into oxygen and hydrogen gas (electrolysis) is normal during the final stages of battery-charging – but is usually quite limited. Wet-cell batteries require topping-up periodically with (de-ionised) water to replace the liquid which has been lost over time. Low maintenance batteries don't need topping-up – in fact they cannot be topped-up because they are sealed. Sealing the battery prevents the Hydrogen and Oxygen gases from escaping; instead they recombine under pressure, the gases are trapped and are re-absorbed during the discharge cycle. Such batteries are, however, provided with a pressure-release valve in case of over-gassing – caused by charging at too high a voltage. We'll be taking a look at charge-voltages later.

Driven by the movement of electrons, the cyclical passing back and forth of sulphate, between the lead plates and the electrolyte, sounds fairly simple – so what could possibly go wrong? Three things in the main:

The spongy lead plates can become coated in a hard layer of lead sulfate crystals which prevents access to the plates. This condition is called sulphation – eventually it denies all access to the battery's storage capacity. The cohesive structure of the lead breaks down allowing some lead to fall away – this deterioration of the plates is known as 'shedding'. Electrolyte – either as a liquid or a gel – decomposes and is lost as gas. The electrolyte is the agent for chemical reaction – when it is much reduced, or absent, the battery cannot function.

These are the principle maladies which cause either an unacceptable loss of capacity in a battery, or a failure to store or release energy at all. There are others.

To make matters worse, the functional limitations brought about by any one of these damaging events, will frequently trigger a second or third mode of failure.

There are several ways to destroy even a brand-new battery in a week or less – and it is those that we will be taking a look at first …but before we do let's establish a few general rules for using our battery without causing it any life-shortening damage.

When choosing a battery size (capacity) for our job, remember that it will last longest if it is never depleted by more than half its capacity …in other words, it is never discharged below 50% state of charge (SOC).

Partially discharged batteries should be re-charged as soon as possible. Damage is caused by leaving them in a partial state-of-charge …the lower the charge; and the longer a battery is left in a discharged condition – the greater the damage.

It is safe to cycle a battery between 50% SOC and 80% SOC – it is quite efficient to do so, too. But this kind of cycling cannot be continued for extended periods. Recharging a drained battery to about 80% state of charge can be achieved quickly – but returning a battery to 100% SOC takes much longer because the rate at which it can accept charge is very much reduced as it approaches full-charge. It is important to allow the necessary charge time to return a battery to 100% SOC at least once every 30 cycles – that's monthly for a battery which is in use every day. There are several reasons for this which we will cover a bit later.

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Next week we will look at what happens when a battery is discharged too deeply …and then left in a discharged state.

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Discharging too deeply and leaving the battery 'flat'

The worst treatment a battery can experience (apart from receiving a dangerously high charge voltage) is to be drained of all charge, and then stored without re-charge.

What happens that when a battery is deeply discharged – particularly below 20% SOC – the plate is mechanically damaged by the extensive formation of sulphur crystals which undermines the material's cohesion. Some of the material loosens, and begins to fall away. This degrading process will happen anyway, as the battery ages, but deeply discharging a battery greatly accelerates that ageing process.

So much for discharging too deeply: If the battery is then left in a discharged condition the tiny crystals of sulphate which have formed begin to grow. The sulphate on the surface of the plates begins to harden – eventually forming themselves into an impenetrably hard white coating around the lead plate, which plugs the porosity of the material – and greatly impedes the diffusion of ions which drive the chemical process. By this stage the battery's capacity, and its ability to accept or release energy will be so slow that it will be unable to do the work for which it has been chosen.

This kind of battery damage occurs when, for example, a vehicle's headlights have been left on, and the vehicle remains unused for a period of days or weeks …or a battery has been left on a shelf in a workshop for a period of months, and it has self-discharged until it is flat. Almost undoubtedly, in both cases the battery will have to be recycled.

If any of the damage is reversible, it can be reversed by recharging the battery in the normal way (it may be slow if it will recharge), and then applying an equalisation charge until the battery voltage reaches 16V or 17V (for a 12V battery) for a period of, say, three hours. This will force the sulphated areas of the plate to release the sulphate back into the electrolyte. Success is not guaranteed, and in nearly all cases there will be some permanent capacity loss.

Be very careful to monitor the battery closely at these high charge voltages, as this will also be causing the electrolyte to separate into gas.

Charging a battery too quickly

A battery should be charged with a current no greater than 20% of it's capacity. For example, if the battery has a 100 amp/hour rating, its maximum charge current should be no greater than 20amps. A discharged battery is able to accept much higher rates of charge – for a short time – but this kind of charging should be avoided. High-output alternators, for example, seem to promise very efficient and fast battery recharging – but high charge currents damage the cohesion of the lead plates – leading to shedding of the plate material, and accelerating ageing.

At first this shedding 'only' reduces the battery's capacity – later, as lost material accumulates at the bottom of the battery, it will eventually touch both the positive and the negative plate creating a short and the cell will not function. The battery will lose the voltage from that cell (failure of the other cells will not be far behind).

An exacerbating factor, with charging a battery too quickly, is that fast charging increases the battery's temperature. The controlled charge cycle for a particular battery – the voltages at which it is charged during each of its three charge-phases – have been calculated with the assumption that the battery temperature is 20ºC (usually) at higher temperatures the charge voltages should be reduced. Failure to reduce the charge voltages result in more damage to the cohesion of the lead plate and gassing of the electrolyte (electrolysis) – which will rapidly reduce the quantity of the electrolyte in a wet cell battery. In sealed batteries the problem is, if anything, worse: The pressure valves will release gas in order to avoid rupturing the battery case and the lost electrolyte cannot be replaced.

It’s worth noting that not all batteries are the same and that some – for example Spiral cell batteries – can withstand the effect of fast charging better than others.

Repeated Failure to fully re-charge a battery

Most of us monitor the state-of-charge of a battery by the rough and ready method of ‘observing battery voltage’. In the fast-charge installation imagined above, for example, voltages climb so quickly that it gives us the illusion that our battery is fully charged, and that we can therefore terminate the charge cycle believing that the job to be nearly done. Although batteries charged and discharged in this way are actually more ‘efficient’ (in that most of the energy offered to the battery is absorbed by the battery) – short sharp charge cycles result in persistent undercharging. Repeated undercharging causes three problems:

An undercharged battery plate has not returned all of its sulphates to the electrolyte. As noticed earlier, sulphate crystals left for a period of time begin to form themselves into a hard coating – sulphation. We have already mentioned that this coating reduces a battery’s capacity – but it also result in a higher resistance to charging, requiring much longer charge times …which in turn increases the likelyhood of undercharging – thereby resulting in further sulphation. That’s a circle of deterioration we need to break.

Stratification of the electrolyte is the condition we haven’t yet mentioned – it occurs where the electrolyte remains static and ‘unmixed’ for an extended period. Acid – being denser than water – falls to the bottom of the electrolyte, and will stay there unless the electrolyte is agitated in some way. This agitation could be when the vehicle, or boat, in which the battery is installed begins to move or roll. In a static installation the electrolyte is only mixed when, during recharging, the gassing voltage is reached, and the gas bubbles rising through the electrolyte, mix it thoroughly. Stratified electrolyte is weaker at the top and stronger at the bottom with the result that more of the chemical reaction takes place lower down on the lead plates. In that circumstance the bottom of the plates do all the work whilst the top of the plates take a holiday so that the plate will age more quickly than if the work was shared more evenly.

Finally – we mentioned there are six cells in a 12V battery. These cells are never exactly identical – some will have a lower capacity, some will be slower to charge. It is important to make sure that all cells periodically achieve a full-recharge so that they are in harmony with each other – if they don’t, the cells which were slightly inferior in performance gradually become worse: their capacity declines, the rate at which they can be recharged becomes slower, and they begin to lag further and further behind in performance, compared to the other cells. This process of bringing the cells into harmony is called Equalization.

Overcharging:

Overcharging frequently occurs when a battery is ‘stored’ whilst still connected to a battery charger. Unable to accept any more power the water in the electrolyte decomposes into Hydrogen and Oxygen. The level of the electrolyte will fall below the level of the plates causing irreparable damage to that part of the plate – and eventually the battery will dry out completely.

Rather than leaving a battery on a continuous float charge during storage, it is better to leave it open-circuited, and recharge it every week or two in order to replace energy lost through self-discharge.

Temperature

Every battery type – deep cycle/starter/wet-cell/gel/spiral cell/AGM/Valve regulated – has a slightly different charging requirement, or 'charge algorithm'. These charge algorithms dictate the voltage which must be reached before entering a new charge phase. Variation from those preset limits – by even a few percent – has a dramatic effect on whether the battery will finish its charge cycle over- or under-charged. And as we discussed above, both under- and over-charging accelerated the ageing process – or shorten the battery's life.

In order to establish a charge algorithm for a battery it must be assumed that the battery will be at standard ambient temperature – and the standard is usually 20°C. But of course that temperature is frequently inappropriate – batteries used in the tropics, or in Polar regions will be stored at very different temperatures from the assumed standard; batteries installed in hot engine rooms often experience 50°C; and the temperature of batteries which are being fast-charged will also climb dramatically from the ambient temperature.

It is important that the battery charging device has a battery-temperature sensing ability, and applies a temperature-compensation to its charge voltage. For example a battery whose temperature is 30°C at the start of a charging cycle may well rise by a further 10°C during charging. The charge voltage for this battery should be reduced by 0.5V to avoid damaging the battery, especially batteries which are particularly vulnerable to high charge-voltages – such as a gel, or Absorbed Glass Mat.

One other thing – at higher temperatures batteries experience an accelerated chemical decomposition – every 10°C rise in temperature above the assumed operating temperature will halve the expected life of the battery.

In summary:

When selecting a battery, make sure it is the correct type for the work it has to do …engine starting, or deep cycle; standby-power, or power surge. Make sure the battery bank has the capacity to serve its purpose easily. In practice, for long life, this means specifying a capacity around four times the requirement. Ensure that the battery duty cycles includes a period when the batteries can be brought slowly up to 100% state of charge and allowed time beyond that so the the cells can equalize. This should be at least once every 30 cycles. Installing an automatic load shut-down device in order to prevent draining a battery below, say 20% SOC, may be the best investment you can make.
Sulphation: Lead and lead-dioxide react with sulphuric acid to form lead sulphate – small crystals which easily reforms back to lead, lead-dioxide and sulphuric acid. After time, some lead sulphate does not revert, but forms a stable crystalline coating which no longer dissolves on recharging. Sulphation can be reduced if a battery is fully re-charged after a discharge cycle. Sulphated batteries have less lead, less sulphuric acid, block the absorption of electrons, leading to lower battery capacity, and can only deliver only a fraction of their normal discharge current. The best method of prevention is to ensure the battery is periodically fully-recharged.

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