Devices for the Prevention and Reversal of Battery Sulfation

Rick Astley 2017

Most classic car owners know the lead-acid battery can permanently fail if allowed to fully discharge, and to prevent that happening a trickle — sometimes called a float or maintenance — charge should constantly be applied during any prolonged storage.

The deterioration is usually caused by sulfation (also spelled sulphation). Sulfation, which is a coating of lead sulfate crystals around both the positive and negative plates, is a normal product of battery discharge. It occurs as sulfur from the sulfuric-acid and water solution combines with the lead in any lead-acid battery. Indeed, when a battery is fully discharged, all the sulfuric acid is theoretically combined with the lead and only slightly acidic water is left as an electrolyte. Even when your car is not using any current, the battery will self-discharge over time and so sulfation occurs. However, there are two types of sulfation: one, called soft sulfation, is normal and reverses when the battery is charged and the other, called hard sulfation, is not reversible and can occur when a battery has been allowed to remain in a low state of charge for weeks or months. Hard sulfation will prevent battery operation.

Many of us remove the battery from the car in winter and store it in a warmer environment like a basement. While this may seem like TLC, the higher the temperature of a battery, the faster it will self-discharge; in fact the self-discharge rate will double for every 18°F/10°C increase in temperature. Keeping the battery trickle charging is therefore even more important in this case. The reason some go to the hassle of removing the battery is that, should a battery crack open because of freezing, then not only is it ruined but a dangerous sulfuric acid solution, albeit much weakened, could seep elsewhere in the car and garage. Freezing of the sulfuric-acid/water mixture is, however, almost impossible in a charged battery in which the temperature would have to fall to below -90°F/-68°C before it would freeze; a natural temperature not found on this planet. On the other hand, because the electrolyte in a fully discharged battery is mostly water, it can freeze at temperatures that are consider normal during winter in many climates.

I am sure some of us have found that, even though we have gone to the trouble of trickle charging a battery over the winter months, it nevertheless has been found to have failed anyway. Research in the last decade or so has shown that the prolonged single direction of current into the battery during trickle charging, while helpful, does not altogether prevent hard sulfation occurring. However, short duration voltage pulses mixed with an overall steady charge, have been proven to considerably decrease the occurrence of hard sulfation and moreover, can remove it too.

Soon after this became known, electronic devices that condition the battery with charge, and discharge pulses, applied thousands of times a second became available. I first saw such devices and was given one for testing, some years ago, but they were expensive and unproven. Mine seemed to work okay but I wasn't able to do any true comparative testing, so I could never really judge the device's efficacy. Independent tests have now shown them to be both effective for the prevention and reversal of hard sulfation, and competition has lowered the price considerably.

As was stated previously, self discharge occurs more quickly in warm weather and if you own any vehicle that has a lead acid battery, not just a car but perhaps a mower, boat or golf cart, that is sometimes left unused for days or weeks in any season, then a desulfator can increase battery life considerably, perhaps even doubling it.

Two types of device are now generally available. The first fits permanently across the battery. When the vehicle is in use with the battery being charged by the much more powerful generator and its normal loads — such as lights and ignition — discharging it, the device is overwhelmed and does very little. When the vehicle stops the device comes into action, pulse discharging the battery, storing that energy and then pulsing it back as a charge. It does this thousands of time each second, keeping the battery working in an non-stressful manner and so preventing sulfate build-up.

The second type of desulfator is combined with a trickle charger and is ideal for those who want to provide a maintenance charge to the battery while it is in storage but do not want to have two separate devices hanging off it.

Desulfators use very little battery power but are not 100% efficient so that if a non-charging type is connected across an inactive battery for a long period, it will itself discharge it. To prevent this happening, some will stop working when the battery voltage falls to between 12.4V and 11.5V, depending on brand.

Desulfators work at high frequencies and to prevent signal attention, most manufacturers recommend that they be connected directly to the battery because the signals diminish if they have to travel down long wires. To simplify connection, they are usually provided with ring terminal connectors that make installation to the battery terminals very easy. One disadvantage of permanently connected desulfators is that, because they work at high frequencies, they can in rare cases interfere with entertainment systems or even disrupt sophisticated electronic systems found on all modern cars.

A desulfator, together with trickle charging, can rescue a battery that has seemingly reached its end-of-life because of hard sulfation. The process can take 3-weeks, so be patient. Most manufacturers provide instructions for doing this.

In summary:

- If the battery is used in a vehicle that is used every day then hard sulfation is unlikely to occur.
- If the vehicle is inactive for several days at a time, rather than months, then a desulfator connected across it will extend the battery’s life.

- If the vehicle is in storage or otherwise not used for months at a time then it will need recharging, using either a separate trickle charger and desulfator or a combined trickle charger/desulfator will provide the best protection.
- If you the battery is a gel type, as installed on small self-starting walk behind mowers for example, then while a desulfating device will also protect it, you will need to verify whether the battery is a 6V or 12V type before ordering.

Do you need a desulfator?

At 68°F/20°C, a new modern battery, left idle, will lose about 0.1% to 0.2% of its charge per day due to self-leakage. As it ages, that figure will rise to about 1% per day. Sulfation is considered a problem once the battery falls below 80% of capacity.

The table below provides some indication of the effect of those self-discharge rates over time. Figures in red indicate that there is risk of sulfation and it can be seem that a new battery with a discharge rate of only 0.1% per day is unlikely to sulfate even after being idle for 26 weeks. Nevertheless, a desulfator, together with an integrated or separate trickle charger will keep the battery active and should slow the rate at which the batteries ages and moves toward the 1% day discharge rate. Note that, once the battery ages and discharges at the 1% per day rate, sulfation becomes a problem in less than 2 weeks.

State of Charge of an Idle Lead Acid Battery at 68°F/20°C

New Battery ↘

	Discharge rate per day (%)					
Weeks	**0.1**	**0.2**	**0.4**	**0.6**	**0.8**	**1**
1	99.3%	98.6%	97.2%	95.9%	94.5%	93.2%
2	98.6%	97.2%	94.5%	91.9%	89.4%	86.9%
4	97.2%	94.5%	89.4%	84.5%	79.9%	75.5%
6	95.9%	91.9%	84.5%	77.7%	71.4%	65.6%
8	94.6%	89.4%	79.9%	71.4%	63.8%	57.0%
10	93.2%	86.9%	75.5%	65.6%	57.0%	49.5%
12	91.9%	84.5%	71.4%	60.3%	50.9%	43.0%
14	90.7%	82.2%	67.5%	55.4%	45.5%	37.3%
16	89.4%	79.9%	63.8%	51.0%	40.7%	32.4%
18	88.2%	77.7%	60.3%	46.8%	36.3%	28.2%
20	86.9%	75.6%	57.1%	43.1%	32.5%	24.5%
22	85.7%	73.5%	53.9%	39.6%	29.0%	21.3%
24	84.5%	71.4%	51.0%	36.4%	25.9%	18.5%
26	83.4%	69.5%	48.2%	33.4%	23.2%	16.1%

Remember that these numbers in the chart above are for 68°F/20°C. In a cold garage over winter the discharge rate is somewhat less, but in the same location in summer or if a battery is overwintered in a warmer environment, discharge rate can be significantly higher as shown in the table below.

Temperature Effect on Self-Discharge Rate

Discharge Rate (%)	Temperature (°F/°C) 14°/-10°	32°/0°	50°/10°	68°/20°	86°/30°
	0.01	0.03	0.05	0.10	0.20
	0.03	0.05	0.10	0.20	0.40
	0.05	0.10	0.20	0.40	0.80
	0.08	0.15	0.30	0.60	1.20
	0.10	0.20	0.40	0.80	1.60
	0.13	0.25	0.50	1.00	2.00

Bleed (mA)	Discharge Rate	Days to 80%
20	1%	20
30	1.5%	14
40	2.0%	11
50	2.5%	8

It’s not always practical to apply a charge to a battery every time it is left unused for an extended period. Some batteries are not easily accessible and not all storage places necessarily have available power. A stand-alone desulfator may in those cases seem a good idea, but there are other considerations. The desulfator itself is not 100% efficient, so it uses power and, should it have an LED indicator, that too will add to its bleed current. A typical figure for desulfator bleed current is about 40mA but may range between 20mA and 50mA. The table above shows:

1. How that range of bleed current equates to the discharge rate per day for a brand-new 48 Ampere Hour battery (a size typical found in small sports cars) that has a 0.1% per day self-discharge rate of its own.
2. The number of days that battery can remain idle before its capacity drops below the 80% level, generally considered to be that where sulfation is a risk.

Other vehicles like mowers and golf carts may well use smaller capacity batteries and older batteries will of course have higher self-discharge rates, both factors that will further shorten the time to 80% capacity.

If the possibility exists that a battery may remain idle for more than a week or so, then purchasing a desulfator that switches itself off when the battery voltage drops to a pre-determine level, would seem wise. Otherwise, the very device designed to prevent desulfation might well drain the battery below the 80% capacity level, and prematurely initiate it. Even better, if power is available and the battery is easily accessible, use a trickle charger too or a combined desulfator/trickle charger.

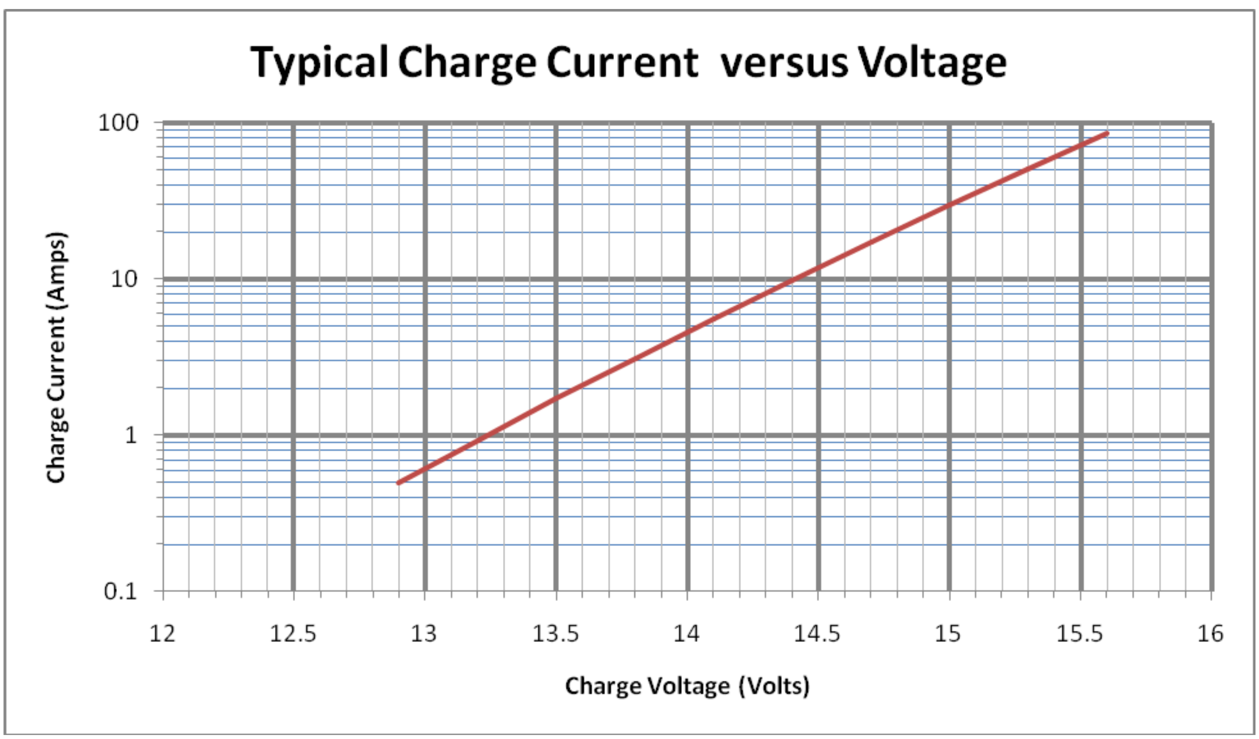
A fully charged standard 6-cell automotive battery should have a terminal voltage of 12.6V, at which it should remain for a long period when under little or no load. A desulfator that shuts itself off should do so at 12.6V or a little below.

How a Desulfator Works

When discussing desulfators, the terms positive and negative pulses are often used. A positive pulse momentarily increases the battery voltage and in so doing produces a short term charge current. Conversely, a negative voltage pulse results in a short term discharge current. These pulses are claimed to keep the battery awake and active and in so doing prevent the sulfation that might occur if the battery is idle or even accepting a sleepy steady dc charge. In the case of already sulfated batteries, there is evidence that the pulses will remove the hard sulfation preventing battery operation.

Some quite surprisingly high charge and discharge currents are claimed for desulfators, the magnitude of which may seem beyond the capability of such small devices applied to such a large power source such as an automotive battery. The secret is in the very short duration of the pulses. Energy (measured in Joules or Watt-seconds) is power (measured in Watts) multiplied by time (seconds). That means that it the time is very short indeed, perhaps in the order of millionths of a second, very little energy is required to produce quite powerful pulses.

Considering the case of charging, the chart below shows the case of a typical automotive battery under charged at different voltages.



With a normal trickle charge voltage of 13.2V applied, this battery accepts a charge at a little less than 1A. Note how an increase of as little as 1V in charge voltage to 14.2V increases the charge current to 7A while another 1V increase to 15.2V increases the charge current to a whopping 40A. If a desulfator can produce a positive voltage spike of several volts, even for a tiny amount of time, it will result a momentary very large charge current.

Similarly, during discharge the terminal voltage of a battery drops because of its internal resistance. While cranking the starter motor, using a fully charged battery, the voltage at the starter may drop to about 10V. Some of this voltage drop may be attributed to the resistance of the connections, solenoid contacts and supply cables, but the battery has some internal resistance too and that resistance may drop about 1.6V, so that its terminal voltage drops from 12.6V to 11V. If a 100A starter motor drops the terminal voltage of an automotive battery by 1.6V then if a desulfator can do the same, then is very plausible that it too is drawing 100A, albeit very briefly.

When applied to a battery without a trickle charger applied, the desulfator works by borrowing power from the battery in the form of a discharge pulse and then returning it in the form of a charge pulse. Even if a trickle charger is attached, its internal resistance is far too high to be able to supply much current during the discharge pulse, so the vast majority still has to come from the battery. During the charge pulse, internal diodes in the charger prevent back-flow into it, so all the charge pulse is directed to the battery.

How the pulses are applied in terms of duration and frequency varies quite a lot and there is no real knowledge as to whether any method is better at achieving its objective than any other. Of those tested, one produced an extremely short pulse of length one sixth of a millionth of a second and it so doing produced a significant voltage pulse 250 times per second. Another produced a longer pulse with a duration about 1 millionth of a second but of lower voltage, so that the total energy was approximately the same and it did this 10 thousand times per second. Another produced a burst of about 8 pulses, each some one millionth of a second in duration, and then paused for about 8 thousandths of a second before producing its next burst. More details of these tests can be found below.

It’s fair to question as to whether or not a large electro-chemical product such as a car battery can react fast enough to very high frequency pulses. To test that, the author put a very low resistance in between a desulfation device and a battery. If very high current pulses were flowing in and out of the battery then a proportional voltage would be dropped across the resistor and be readable using an oscilloscope. Such voltage pluses were detected and therefore show that the battery was absorbing and discharging the them. The actual magnitude of the current pulses is hard to measure because the series resistor itself, although of a very low value, is nevertheless significant with respect to the internal impedance of the battery, and so limits the current value. That’s why the charge versus voltage graph and the voltage change during cranking discussion above have been used to estimate the amperage effects of desulfators. More on this subject with graphs and one manufacturer's claims may be found below in the discussion concerning the Max desulfator below

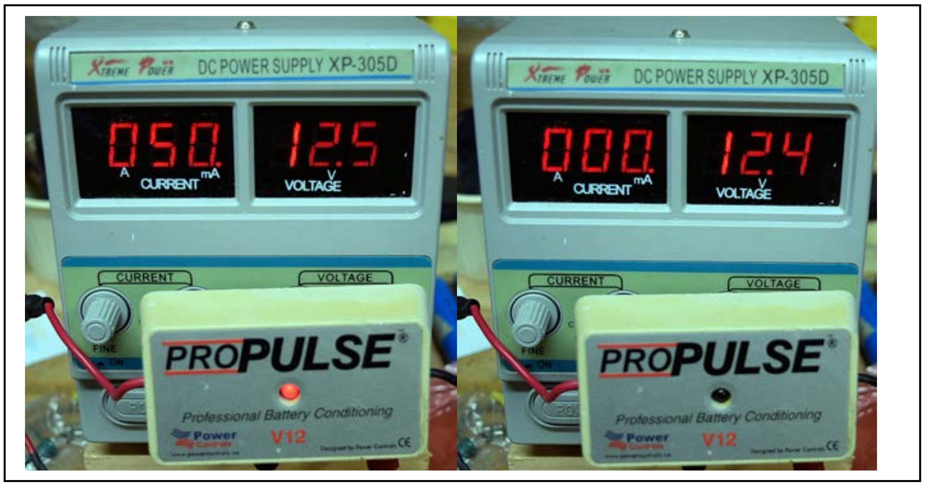
Some Desulfators Examined

Three different desulfators were examined in detail.

ProPulse

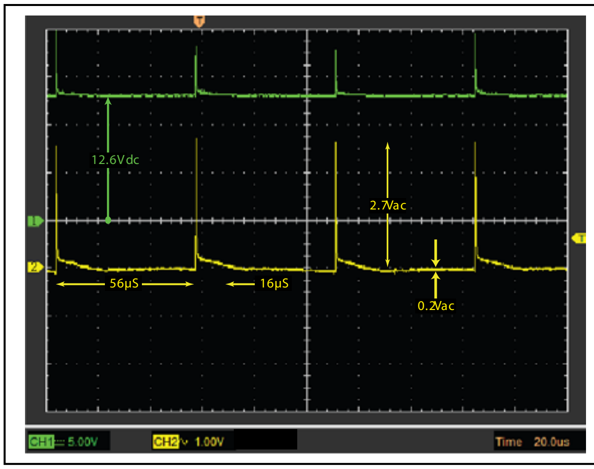
This device was given to me in about 2005 when I was working with its Norwegian maker and as such was an early commercially available desulfator. It is no longer available in the form I have, but is included here because some readers may own one and it has some features that are interesting in comparison with devices now on the market. The trade name ProPulse now appears to be owned by Sterling Power of Eliot, Maine, which sells desulfation devices that look rather different from mine but may well be quite similar internally.

This ProPulse desulfator is a flat box and is supplied with adhesive sponge tape intended to affix it to the side of the battery. The adhesive lasts about the same time as the battery itself, so the ProPulse has to be torn off, and its adhesive removed and replaced each time a battery is swapped.



In the illustration, it has been attached to an adjustable dc power supply to simulate a battery. As stated previously, a charged automotive battery should have a terminal voltage of 12.6V, and any drop below that indicates it has lost some capacity. This desulfator still draws a current of 50mA at 12.5V (left) and its own LED indicates that it is still drawing current. However, when the voltage drops to 12.4V (right), the current drawn drops to zero and the LED is no longer illuminated, indicating that the device has switched off. This action prevents the ProPulse from running down the battery with the attending consequences.

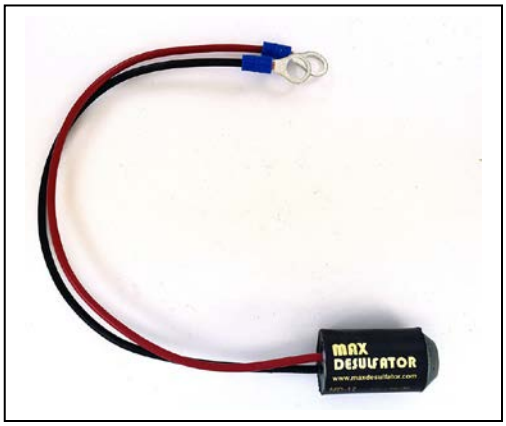
The ProPulse desulfator was found to emit a substantial charge pulse. The green dc line in the oscilloscope trace below shows those pulses superimposed on top of the 12.6V of the battery. To more accurately measure the magnitude of the pulse the yellow ac trace was simultaneously taken at 5x the scale of that for the dc, showing 2.7V peaks that when added to the standing 12.6V provide a total voltage pulse of 15.3V, which according to the graph on page 5, indicates a charge pulse of some 50A. That is significant, but it is also brief, lasting only 16μS (16 millionths of a second). It does this every 55µS, equating to a pulse rate of 18kHz (18,000 pulses per second). Note that this ProPulse device does not produce a significant negative pulse, instead it charges itself — and in so doing discharges the battery — slowly over the delay period. As will be seen later, this contrasts with other desulfators that charge themselves in a very short time, resulting in a briefer but much higher battery discharge.



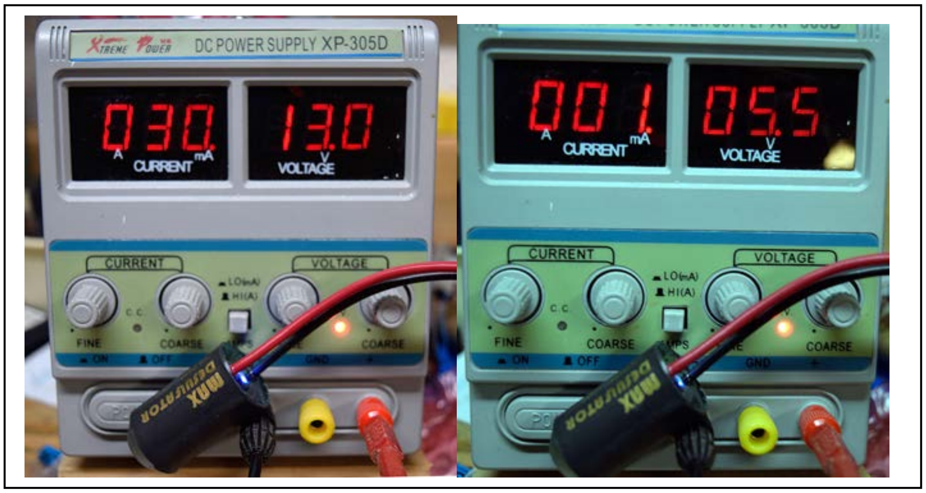
It may be that the small but long battery discharge pulse followed by the quick but large charge pulse of the ProPulse is equally effective at preventing and/or reversing desulfation as newer devices that exhibit both discharge and charge pulses of high magnitude and short duration. There is not enough data available to know for sure.

Max Desufator

The Max device is made in the USA and was purchased from eBay for use on my riding mower that often is unused for a couple of week at a time during the mowing season. During winter storage, a trickle charger is used in combination with the Max.

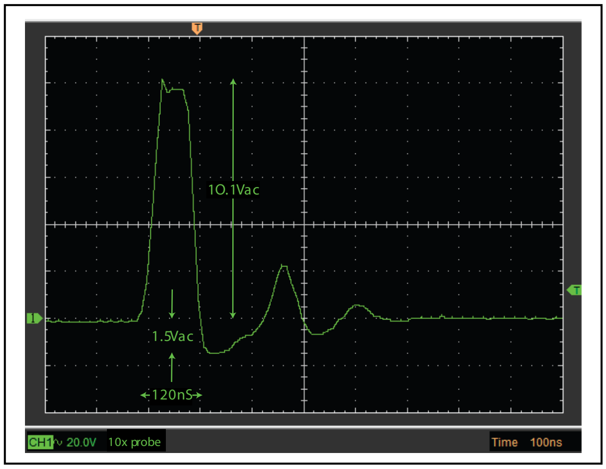


It is a cylindrical device and red and black connecting wires that terminate in ring terminals. In the case of my mower it was easy to use a zip tie to hold it firmly to the battery hold-down bar.

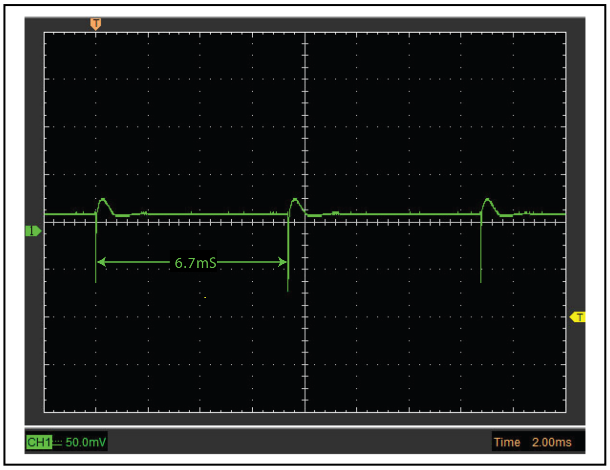


Like the ProPulse, the Max was attached to a variable voltage power supply to simulate a battery having different terminal voltages, depending on its state of charge. At 13V (left) the max consumed some 30mA. The table on Page 4 showed that on its own, ignoring any battery self-discharge, with 14-days a 30mA current draw can bring a battery's capacity to 80%, the value generally considered to be that where sulfation is a risk. Unlike the ProPulse, when the voltage was reduced, as that of a discharging battery would, it did not switch itself off. Indeed, as the illustration shows, even after the voltage was dropped to as low as 5.5V (right), the Max was still drawing a little current.

The main positive voltage charge pulse produced by the Max was extremely high. Here it shows it to be 10.1V above the 12.4V of the battery. A pulse of that magnitude is literally off the chart shown on Page 5 and theoretically equates to a charge of greater than 100A. The time period of the charge pulse is about 120nS, or 120 billionths of a second. The discharge pulse is also substantial, equating to a load on the battery of about 100A. It too is very short, being just about the same length as the charge pulse.



It was asked earlier if such short duration voltage pulses do in fact result in large current pulses in the battery. To test this, a 0.3Ω resistor was placed in series with the Max and the voltage across it recorded. Even this amount of resistance was very large compared to the internal resistance of the battery, so it itself impeded the flow of current in and out of it. The voltage values measured are thus meaningless. Nevertheless, the pulses recorded do show that the battery does react to the pulses. The Max manufacturer's claim of an 82A discharge pulse seems credible. Little charge current is exhibited in this trace because it doesn't take much current to cause the 0.3Ω resistor to drop any charge pulse voltage to below that of the battery's terminal voltage, at which point it cannot charge.



This oscilloscope trace also shows the rate at which the Max pulses are produced, one every 6.7mS, or at a frequency of 150 times per second.

BatteryMINDer Plus Model# 12117

The BatteryMINDer is a combined 1.3A charger, maintainer and conditioner, the supplier claiming, "High-frequency pulses safely remove sulfate from battery's plates that prevent the batteries from holding a full charge".

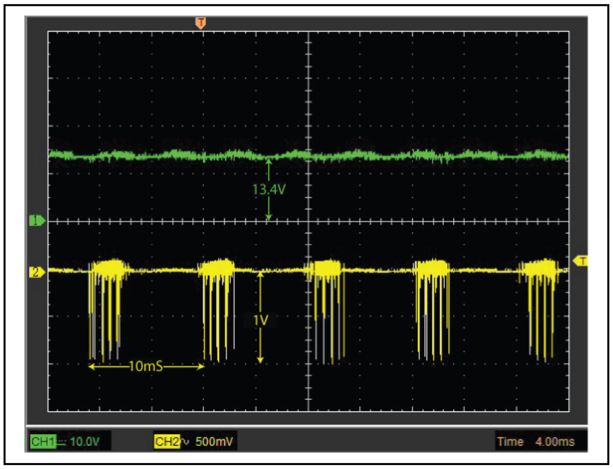
While other desulfator manufacturers supply very short connecting wires and warn against increasing that length, the BatteryMINDer comes with an approximately 12' long cable with large alligator clips for connecting it to the battery.

Manufacturer's picture

The stand-alone desulfators previously described were tested to determine if they switched off when the battery voltage drops. That test is irrelevant to the BatteryMINDer because it supplies a constant charge voltage of 13.4V to the battery in its maintenance mode.

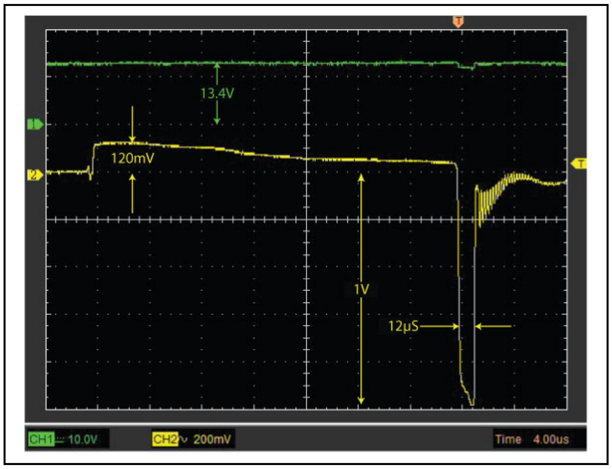
The BatteryMINDer has two LEDs. A red LED indicates that the unit is plugged in to ac power. The green LED indicates that the unit is connected to the battery. This LED is solid green when charging at full output but, when the battery reaches 14.2V, it trips to its 13.4V maintenance voltage whereupon the green LED flashes. A button allows the user to force the BatteryMINDer into maintenance mode if desired. The device also features short-circuit and reverse voltage protection.

When in maintenance mode the BatteryMINDer produces bursts of about 5 or 6 pulses every 10mS, or at a rate of 100 times per second. This pulses are superimposed on the constant dc charge voltage of 13.4V.



A closer look at one of these pulse shows it to be quite short in duration at some 12µS, but that's some 100 times longer than those produced by the Max described above.

The magnitude of the positive (charge) pulse is small at only 120mV, which the calculations used to produce on page 5 would indicate results in only a 0.38A charge pulse on top of the typical 1.4A standing charge that the 13.4Vdc maintenance charge voltage.



The 1V negative pulse, on the other hand, might be expected to result in a very short discharge pulse of some 80 or so amps.

Conclusions

Sulfation Prevention

There seems to be evidence that desulfators can extend battery life by preventing sulfation but whether any particular desulfator brand or waveform is better than another at this task has yet to be established. The cost of a desulfator compared to that of a new battery is so low, and there being little or no risk to using one, it seems worthwhile acquiring one anyway.

When storing any battery for a long period a maintainer with an integrated desulfator, like the BatteryMINDer, should keep it in good shape. Alternatively, a trickle charger with a separate stand-alone desulfator should do as good a job.

When a battery is to be left unused for just a week or so, a desulfator like the ProPulse, which switches itself out of circuit if the voltage becomes too low, should again prevent sulfation and not promote it by running the battery down as is possible with the Max.

Sulfation Reversal

Desulfators can be a part of the process of successfully reviving a sulfated battery.

Some desulfator manufacturers claim that, given time they will reverse sulfation. That implies that they will turn the hard sulfate back into the soft form that can recombine with the water and sulfuric acid electrolyte. Before and after pictures and videos can be seen where a view through the cell cap orifice shows that sulfate once covering the plates has disappeared, but where did it go? The best evidence available suggest that the pulses produced by the desulfator cause shedding of the hard sulfate, which then falls to the cell floor and does not return to becoming part of the battery chemistry. The battery may then be somewhat revived but it would be a good idea to check the specific gravity of the electrolyte and if necessary add acid as it will now have less sulfate than is ideal.