BATTERY & CABLING PRIMER

This booklet is intended to introduce you into low voltage DC systems and the shortcomings you will encounter.

LEISURE COOL

Putting pleasure into the outdoors

BATTERY TYPES

The two most common categories of car and deep cycle batteries are wet and Valve Regulated Lead-Acid (VRLA). Within the wet category, the three most common battery types are Standard (Sb/Sb), Low Maintenance (Sb/Ca) and "Maintenance Free" (Ca/Ca). In the VRLA category, there are AGM or Absorbed Glass Mat (Ca/Ca), spiral wound AGM, and Gel Cell (Ca/Ca) lead-acid batteries. The one additional category for smaller (typically below 50 AH) deep cycle batteries is SLA (Sealed Lead-Acid) using AGM (Ca/Ca) or Gel Cell (Ca/Ca) VRLA construction. All VRLA batteries are sealed with a safety pressure relief valve or plug in case of excessive gas pressure build up due to overcharging or overheating.

Normal motor vehicle (SLI) lead acid batteries are shallow cycle batteries. This means that if the battery is repeatedly discharged by as little as 20%, its life is shortened. They are designed to give a burst of high power for a very short time, for example when starting a vehicle engine.

Deep cycle batteries are specially designed to give a steady current over a long period of time. They are specifically designed to withstand deep cycling - that is deep discharge, and must be fully recharged each time they have been discharged. Deep cycle batteries are capable of being repeatedly discharged by as much as 80%.

Deep cycle batteries are rated in amp-hours as opposed to starting batteries (SLI) which are rated in CCA (cold cranking amps). The amp-hour rating of a battery is usually at the C20 rating. That means a 100Ah battery is designed for you to draw 5 amps and the battery will work for 20 hours. If you draw 20 amps from the same battery, it will work for about 4 hours instead of the expected 5 hours. In each of these cases the battery would be completely drained which is disastrous for the battery. We recommend you do not discharge below 50% before recharging as soon as possible.

Car starting batteries are specially designed with thin (1.02 mm) and more porous plates for a greater surface area in order to produce the high current required to start an engine. They are engineered for up to 5,000 shallow (to 3% Depth-of-Discharge) discharges. Starting batteries should NOT be discharged below 10% Depth-of-Discharge (DoD). They use sponge lead and expanded metal grid paste plates rather than solid lead plates. Leisure "dual purpose" batteries are a compromise between a car and a deep cycle battery and are designed for starting and prolonged discharges at lower amperage that typically consumes between 20% and 50% of the battery's capacity. The plates are thicker than in starting batteries, but thinner than in deep cycle batteries. Deep cycle batteries have much thicker (up to 6.35mm) plates, thicker grids, more lead, and weigh more than car batteries of the same size. They also have a slightly higher Specific Gravity and are normally discharged between 20% and 80% DoD at a lower amperage. Deep cycle batteries will typically outlast two to ten car batteries in a deep cycle application. Reducing the average DoD and the number of discharge/charge cycles of a deep cycle battery will significantly increase its service life. For example, an average of 50% DoD will last twice as long or more as if it is has an 80% average DoD. A 20% DoD average can last up to five times longer than with a 50% DoD average.

A common application is using a DC to AC inverter, which is used to convert 12vDC to 240vAC. It takes 24 to 28 amps of 12vDC power to make one amp of 240vAC power, so deep cycle batteries or vehicle charging systems should be used to power inverters and NOT starting batteries.

The amount of storage time, that you can leave your vehicle parked and still start your engine is dependent on such things as the battery's initial State-of-Charge (SoC), the Reserve Capacity (or amp hour capacity), the amount of natural self-discharge and parasitic (ignition key off) load, temperature and battery type. Car manufacturers normally design for at least 14 days, based on a fully charged battery in good condition, moderate weather, and no additions to the original car's parasitic load. When a battery drops below 100% SoC, sulfation starts, and this will reduce the capacity of the battery and if left, will kill the battery.

BATTERY CAPACITY

In 1897 a German scientist Dr Peukert found that a battery will provide less amp-hours when it is discharged at a faster rate. This gives an indication how old battery technology is and how little wet batteries have changed in over 100 years. The typical capacity of a wet deep cycle battery at various discharge rates is as follows:

Hours to discharge	Capacity achieved
20	100%
10	89%
5	78%
3	66%
1	45%

CHARGING BATTERIES

Battery Type Ca=Calcium Sb=Antimony	Absorption Charge Voltage	Float Charge Voltage	Equalizing Charge Voltage
Wet Standard (Sb/Sb)	14.5	13.2	15.5
Wet Low Maintenance (Sb/Ca)	14.4	13.2	15.8
Wet Maintenance Free (Ca/Ca)	14.8	13.2	15.8
AGM (Flat Plate) VRLA	14.3	13.6	15.6*
AGM (Spiral Wound) VRLA	14.6	13.6	N/A
Gel Cell (Ca/Ca) VRLA	14.1/14.4*	13.8/13.2*	N/A
*Safety factor for **Under Charging** and protecting against **Over Discharge**			

People kill more deep cycle and starting batteries with bad charging practices than batteries will die of old age. In order to charge a battery the charging voltage needs to be approximately two volts higher than the battery voltage to overcome the internal resistance.

The chemistry of a flat battery is such that the sulphuric acid it contains is consumed in producing lead sulphate on both the negative and positive plates. The strength of the remaining acid can be so low that it presents a high resistance to the current flow within the battery. Under these conditions it is worth leaving A charger connected doing apparently very little and sometimes, after days of this treatment, the current will start to flow and a charge may be restored. The older the sulphate, the harder it is to recharge and this is the reason why lead acid batteries need to be kept in a charged condition. A battery may never fully recover from a state of deep discharge.

Lead-acid batteries do not have any "memory effect". However, continuous undercharging will lower the capacity of the battery due to the accumulation of permanent lead-sulfate (sulfation). Deep discharges below 20% SoC (approximately 12.0 volts) can damage batteries and shorten their lives.

battery voltage	percentage charge	specific gravity	Comment
12.70	100	1.265	
12.64	95	1.257	
12.58	90	1.249	
12.52	85	1.241	
12.46	80	1.233	Lower level for SLI Batteries
12.40	75	1.225	Recharge if being stored and battery reaches this voltage
12.36	70	1.218	
12.32	65	1.211	
12.28	60	1.204	
12.24	55	1.197	
12.20	50	1.190	Lower level for deep cycle batteries
12.12	40	1.176	
12.04	30	1.162	
11.98	20	1.148	Risk of cell reversal / permanent sulfation if below this level
11.94	10	1.134	
10.50	00	1.120	Fully Discharged

If a battery is fully discharged and continues to have a load, i.e leaving the headlights on, it is possible for one or more cells to reverse polarity. To correct polarity, fully discharge the battery and recharge it again at a high voltage with 1 amp for a number of days.

Standard vehicle alternators are for various reasons designed to recharge batteries between 70 to 80%. This works very well, until it comes to charging storage batteries where you need as much capacity as possible. Also batteries can take 8-12 hours of continuous engine running to achieve this charge. They are primarily designed to rapidly top up the surprisingly small amount of energy that is removed from the battery by the starter motor on engine start up, and then to keep up with all the accessories, radios, head lights etc. They were never designed to recharge deeply discharged batteries unless modified or replaced with a specialised charging alternator, and a smart multi stage regulator. Many standard battery chargers suffer from the same less than perfect regulation as car alternators, and achieve similar results, but taking much longer to do it.

As an example if you have a 100 A/H battery, and your main charging source is your vehicles alternator or a standard battery charger. As we have seen both of these will only charge a battery to about 75% (75 A/H), and if you want them to last, you should not discharge your batteries below 50% (50 A/H) of their capacity, so all you can really safely use of this 100 A/H battery is 25 A/H.

Most 240 volt generators are very slow and inefficient when it come to charging batteries via their 12 volt circuits, if using a generator it is much better to use a smart charger connected to the 240 volt outlet.

CHOOSING A BATTERY CHARGER

The safe rule to charger size and battery capacity (C) is a current not exceeding 1/10th of the battery size measured in amp hours; C/10. For example, a 50amp-hour battery should be charged at no more than 5 amps. A lower charge rate will do the battery no harm but a higher rate, particularly at the completion of the charge, will lead to excessive gassing and progressive damage of the battery's internal plates. Fortunately most of the standard or unregulated chargers that are on offer will show a decline in current as full charge is approached. This is a desirable feature.

If the time available for charging is short, the battery is expected to bear the brunt of this impatience. A recently discharged automotive battery can safely accept very high initial currents (C/4 or more) but by 60% of recharge this should be reduced to C/10.

The new generation of sealed lead acid batteries need careful charging and this involves electronic control of the charge. Most of these batteries need to be fully charged to perform satisfactorily and this is a compelling reason to buy the correct charger for the job. Serious damage to these batteries will occur if a simple charger is left to run with the battery beyond its voltage limit. Automatic or "smart" chargers will also treat a standard automotive battery to an ideal charge cycle.

A non-adjustable (trickle) charger **CANNOT** be left on a battery permanently without danger. It will continue to deliver (trickle) current into a battery if the battery voltage will allow it to do so. Over time, this trickle is quite capable of taking the battery into the gassing stage where it will lose water and may suffer permanent damage.

All battery chargers except the automatic models, have to be regularly checked to prevent overcharging. If your battery is not used very often, leave an automatic charger on it. It will maintain the optimum voltage for years if need be, so that the battery is ready at a moment's notice.

CHARGING STAGES

Three stages - bulk, absorption and float are normally used for wet car and motive deep cycle batteries with an optional equalizing stage. Three stages--bulk, absorption and float are normally used for AGM (Ca/Ca) and Gel Cell (Ca/Ca) VRLA car and deep cycle batteries. Three stages - bulk, float and equalization are normally used for wet stationary deep cycle batteries and two stages - bulk and float are normally used for VRLA stationary deep cycle batteries with an optional equalization stage in some cases.

Bulk Stage

The BULK stage is where the charger current is constant and the battery voltage increases, which is normally during the first 80% of the recharge. Give the battery whatever current it will accept as long as it does not exceed 25% of the 20 hour (expressed "C/20") ampere hour (AH) capacity rating, 10% of the Reserve Capacity (RC) rating, wet batteries do not exceed 51.5° C, and VRLA batteries do not exceed 37.8° C.

Absorption Stage

The Absorption stage is where the charger voltage is constant between 14.1 VDC and 14.8 VDC at 26.7°C and the current decreases until the battery is fully charged, which is typically the last 20% of the recharge. For wet batteries, gassing (making a bubbling sound) usually starts at 80% to 90% of a full charge and is normal. A full charge typically occurs when the charging current drops off to 2% (C/50) or less of the AH capacity of the battery and each cell of a wet battery is moderately gassing equally. For example, end current for a 50 AH (C/20) battery is approximately 1.0 amp or less. If the battery will not "hold" a charge, the current does not drop after the estimated recharge time, and a wet battery is hot (above 51.5°C), then the battery may have some permanent sulfation. Manual two-stage chargers that have a bulk and absorption stage must be turned off when the battery is fully charged to prevent overcharging.

Float Stage

The optional FLOAT stage is where the charge voltage, depending on the battery type, is reduced to between 13.0 VDC and 13.8 VDC at 26.7°C, held constant. It can be used indefinitely to maintain a fully charged battery to overcome the natural self-discharge of the battery. The current is reduced to approximately 1% (C/100) or less. Three-stage "smart" chargers usually have the bulk, absorption and float stages.

Equalizing Stage

The optional EQUALIZING stage is a controlled 5% to 10% absorption overcharge to equalize and balance the voltage and specific gravity in each cell. Equalizing reverses the build-up of the chemical effects like electrolyte stratification where acid concentration is greater at the bottom of the battery. It also helps remove sulfate crystals that might have built up on the surface or in the pores of the plates. The recommended frequency varies by battery manufacturers from once a month to once a year. For stationary deep cycle batteries, some short daily (30 minutes or less) equalizations have proven to be beneficial and not require the longer equalization cycles. They are not as hard on a wet battery because they do not produce as much gas or heat the battery. To equalize, check that the electrolyte is covering the plates in each cell and fully recharge the battery. Then increase the charging voltage to the battery manufacturer's recommendation, or if not available, add 5% to 10% to the absorption charging voltage. Heavy gassing should start occurring in each cell. Do not allow the wet battery to get above 51.5°C or a VRLA battery above 37.8°C.

CABLING

Properly sized wire can make the difference between inadequate and full charging of a battery; dim and bright lights; feeble and full performance of appliances. Designers of low voltage power circuits are often unaware of the implications of voltage drop and wire size.

There are 3 methods around the world to grade cable. The Americans use AWG, Europeans use ISO and the third is the Society of Automotive Engineers (SAE). The AWG and ISO methods use the cross-sectional area of the copper conductor. The SAE system uses the overall diameter including insulation, and depending on the thickness of the insulation (plastic is cheaper than copper) it could have a copper conductor with a cross-sectional area of as little as 1.25mm² even thought the cabling states it is 4mm². What really matters, is how much copper core the cable has in square mm², not how thick the overall cable is. SAE cable is often marketed as 10-amp, 30-amp, 50-amp and so on. This rating is simply the current it can carry before the plastic cover and the copper core starts to melt. It has no other significance.

Wire sizing is a major problem, if you load test the standard cigarette lighter type outlet fitted to the rear of many 4x4's. Most of these outlets state "120 watts Max", but if you put a 100 watt (8 Amps) load on them the voltage will drop by about 2 volts, i.e. battery shows 12.6 volts but the outlet is only receiving 10.6 volts. The wiring is simply not heavy enough to supply a reasonable current at the required voltage. When the vehicle is running the alternator lifts the battery voltage up to 13.9 - 14.5 volts, so at the plug you have around 12 volts, but as soon as you turn the motor off the voltage drops. It is better to install a new outlet with a heavier cable. A cigarette lighter plug easily looses contact in the outlet with a small bump capable of loosening the plug. When running a new cable ensure it is correctly fused, cannot rub or chafe through and is protected from sharp edges etc.

To determine cable size you must know:

The total conductor length,
The current that the cable will carry,
The permissible voltage drop (0.36 volts for most 12v purposes).

From that it is possible to work out conductor size in sq mm as follows.

Voltage drop = Length of conductor (metres) x current (amps) x 0.017 divided by conductor cross section (sq mm).

In other words there is really no such thing as '5 amp' or '10 amp' cable. There is only cable that can carry 5 or 10 amps over a certain distance without exceeding 'n' volts drop. If that distance is one metre, 1 sq mm cable is fine. But if that distance is 100 metres, even starter cable is too thin!
Size the wire for approximately 2 or 3% drop at a typical load.
Voltage loss is also power loss. Thus if you lose 0.8 volts along a cable carrying 15 amps - the loss is 15 x 0.8 watts = 12 watts. If the fridge cycles on 10 hours every 24 hours - that's 120 watt/hours/day lost. Globe brightness of incandescent and halogen globes is proportional to the fourth power of the voltage so the effect of voltage drop is profound: e.g. 5% voltage drop causes 20% loss of brilliance.

Universal plug **HELLA type socket** **50 Amp ANDERSON Plug**

The universal plug can be used in a standard cigarette lighter socket, and will also fit the HELLA type socket. If you are going to run a compressor type fridge the best fitting for this job is the HELLA type socket, these sockets are well made and provide good electrical contact and a positive click. If however you are using an adsorption type fridge, these fridges draw a constant 10.5 to 18.5 amps and need a heavier connection, here the "Anderson" type plug, rated at 50 Amps it's a sure, safe and easy way to transfer heavy currents.

Dual Battery Systems

A dual battery system consists of a second battery added to a motor vehicle. This auxiliary battery is used so you don't run the risk of discharging your vehicles main starting battery. You need an efficient way of charging this battery using the cars alternator, and more importantly a way of isolating it.

Auxiliary Batteries.

You should think about how big a battery you can afford to fit, and not how small and cheap a battery you can get away with. The larger the battery the less percentage wise you will be draining it, and the longer it will last both in power usage and battery life, with the extra advantage of more capacity when needed.

The Battery Isolator.

The battery isolator is a device that allows the cars alternator to recharge the auxiliary battery while protecting the cars starting battery from discharging, if these batteries are simply linked together you run the risk of draining them both to a level that you can not start the engine. There are many ways to operate these battery isolators, some much better than others. The cheapest and most dangerous way is that you manually turn them on and off. Other methods used to isolate the batteries use some form of relay or a solenoid.

The solenoid is an electronic switch that can handle large (charging) currents, much more than standard switches can, and they are operated by applying a small amount of power to them, this is turn actuates a solenoid that links the batteries together so that large currents and be passed between the batteries.

The easiest way to use a solenoid is to turn the solenoid on as soon as you start the engine, and turn it off when you shut down the engine, this has been the cheap way of doing it for many years, but it's far from ideal. The best way for most situations is to use a VSR (voltage sensitive relay) activated solenoid. When you start your engine it first lets your starter battery recover its charge. Once it achieves 13.6 volts, it closes the contacts on the solenoid. This links both batteries together for charging purposes. When it senses 12.7 volts, it will open the solenoid contacts and isolate the batteries, leaving your starting battery for starting and your auxiliary battery for auxiliary functions

Diode Isolator

A voltage drop, inherent in diodes, reduces the charge voltage to the battery causing the charge current to be significantly reduced. When full charge is approached, a diode isolator still drops from 0.55 to 0.7 Volts. This voltage drop reduces the voltage available to the battery which inhibits full and complete charging within typical operating times. As a result full charge will not be achieved unless you operate the vehicle for very long periods. Often, the vehicle is not operated long enough and then, the battery sits for a while with less than full charge. This condition causes the battery plates to sulfate, which will gradually degrade its performance and lead to early failure. To overcome this problem, a second diode is placed in series with the auxiliary battery and the alternator output is modified to output a higher voltage. This has detrimental effects on the starting battery's performance and life expectancy

Either system has its own sacrifices. So the debate continues and some have chosen diode isolators, while others have chosen relay systems, and still others have chosen heavy duty switches along with diode isolators.

Be informed, most salespeople don't have a clue, make sure that you do!

It is in everyone's best interest to be well informed, there is so much misinformation and so many myths out there that it's all but impossible for people to make an informed decision. Be it fridges, solar panels, batteries etc, they are a great investment in making peoples leisure and lifestyle activities more rewarding, but they do cost money, and not small money either.