GAMMATRON PTY. LTD.

# BATTERY CHARGER APPLICATION NOTES

## MAXIMUM BATTERY CHARGING RATE

The maximum battery charging rate is often specified by manufacturers as C/5 where C refers to the ampere-hour (Ah) rating of the battery. Using this terminology, a 10Ah battery being charged at a C/5 rate corresponds to a 2.0A current. Exceeding this maximum rate should be done only with the manufacturer's permission. Some particularly robust batteries may be charged at a 1C rate (or even higher). However, this usually requires a charger that is custom designed for the battery. The size of an off-the-shelf charger should generally be chosen so that the C/5 rate is not exceeded.

The plot thickens, however, if the charger is a 2-mode type that will be used to power an external circuit while charging the battery. In this case, the circuit will draw whatever current it requires leaving the rest for the battery. If the circuit draw is fairly constant, then the size of the charger may be increased to make up for the shortfall. If however, the current draw by the circuit varies a great deal, the current that is left over when the circuit load is at a minimum should not exceed the C/5 rate.

In this situation, even though the current draw may occasionally exceed the capabilities of the charger, the battery will make up the difference. As long as the average circuit load-current is less than the current rating of the charger, the charger will be able to recharge the battery.

The previous paragraphs discuss the largest charger that may be used. In many applications there is no need to recharge a battery quickly, and a smaller charger may be used to reduce size and heat and to save money. If a 2-mode charger is used, the unit need only be large enough to supply the leakage current of the battery (plus any draw from an external circuit). A 0.5A charger will eventually recharge and maintain a 50Ah battery.

If a 3-mode charger is used, it needs to be large enough to charge the battery at a C/10 rate or faster. If too large a battery is charged by any manufacturer's 3-mode charger, the extra leakage current of the too-large battery may cause the charger to lock-up in the absorption mode. This will overcharge the battery and shorten its life or destroy it.

## 2-Mode Charger:

First determine the charge rate in terms of C (the battery's Ah number). The charge rate is the battery Ah number divided by the current limit rating of the charger (minus the amount of current "stolen" by any external circuits that are connected during the charge cycle). For instance, if you have a 7.5Ah battery and a 2A charger and an external circuit that draws a constant 0.5A, then the charge rate is C/5. (7.5Ah / 1.5A).

When a 2-mode charger switches from constant-current (bulk) mode to constant-voltage (float) mode the battery is charged to a level from 85% to 100% depending on the charge rate. Because the charger is now in float mode, the remaining up-to 15% recharging can take quite a long time. The recommended mindset is to ignore the remaining charge and to assume that the battery is smaller than it really is. In other words, if you have a 10Ah battery that is charged to 85%, then in reality you are working with an 8.5Ah battery and should plan accordingly.

Using the charge rate you've selected, find the %recharged number from the following table and plug the number into the formula.

C/5 charge rate = 85% charged

C/10 rate = 90%

C/20 rate = 95%

C/100 rate = 100%

Recharge Time = (Ah / Bulk Charging Current) x (%charged at switchover point)

## 3-Mode Charger:

When the charger switches from constant-current (bulk) mode to absorption mode, the battery will be partially recharged according to the table and formula above. The remaining up-to 15% recharging occurs during the absorption mode. This will take an additional 2 to 4 hours.

The total time to recharge the battery to 100% can be approximated with the following formula:

Recharge Time = 1.25(Ah / Bulk Charging Current)

Float-charging a lead-acid battery with a temperature compensated, regulated DC voltage is almost foolproof. A fully discharged battery will draw a large charging current that will asymptotically decrease as the battery becomes charged. One problem, however, is that fully charging the battery can take a long time.

## Automotive Battery Taper Chargers:

There are several types of chargers in this catagory. They provide a high charging current per dollar of cost at the expense of battery life. They produce a pulsing DC current that is basically a steady DC current with a superimposed AC component. This AC component damages the battery.

Additionally, some of these chargers continue to trickle-charge the battery for as long as the battery is connected. This trickle-charging current is always too high for proper battery maintenance and causes battery electrolyte to evaporate. To counter this it is possible to automatically turn off the charger when the battery reaches a specific voltage or a arbitary period of time has passed. The charger is then automatically restarted when the battery discharges to a specific voltage. Unfortunately, the battery is still damaged by repeated overcharge and discharge cycles.

## Dual Level Chargers:

These units are available in several variations and are generally very gentle to batteries whilst the chargers are used as the designer intended. They do however, cost more than the automotive-style taper chargers. A review of what happens during the charging cycle can explain why improper use of one of these chargers can still cause battery damage.

When initially charging a discharged battery, this type of charger starts off in constant-current (bulk) mode. The battery is charged at the maximum current that the charger can supply. The charger remains in this mode until the battery voltage reaches the mode-switching voltage (approximately 15V at room temperature for a 12V system). At this point, the battery is between 85% and 95% fully charged. Some types of chargers (2-mode types) then immediately switch to a constant-voltage (float) mode, set to the battery's float voltage (close to 13.8V at room temperature).

Other designs (3-mode types) switch to a constant-voltage (absorption) mode, set to the 15V mode-switching voltage, until the battery charging current drops to a low level (typically 10% of the maximum charging current). At this point, the charger assumes that the battery is fully charged and switches its output voltage to the battery's float voltage. This extra time spent at an elevated voltage adds the final 5% to 15% of charge to the battery.

As expected, there are pros and cons with both of these dual-level designs. Spending extra time at an elevated voltage to add an additional 5% to 15% of charge to the battery, gets the battery to 100% charge more quickly. However, most 3-mode chargers gauge the required extra charging time by measuring the battery charging current. When the measured current has dropped to approximately 10% of the charger's rated current, the charger assumes that the battery has reached 100% charge. This will work if the battery is within a certain range of sizes matched to the charger's current-rating, and nothing, other than the charger, is connected to the battery.

If an external circuit diverts appreciable current from the battery while it is being charged, the 3-mode charger has no way of knowing that the battery is not the object drawing the current. If the circuit current-draw is above the 10% point that the charger is relying on, the charger assumes that the battery still is not 100% charged. The charger keeps its output voltage high (15V), waiting for the charging current to drop to 10%, which it never does. This over-charging eventually destroys the battery.

One safe way for an external circuit to occasionally draw current from this type (3-mode) of charger while it's powered is to draw more current than the charger can supply - with the battery making up for the shortfall. Obviously, while the battery is being temporarily discharged, the charger cannot simultaneously overcharge it.

A dual-level charger design (2-mode) that switches abruptly from constant-current (bulk) mode to constant-voltage (float) mode cannot be "faked-out" by an external circuit that is drawing current. The charger switches from bulk mode to float mode based only on the battery terminal voltage. The charger doesn't care how much current is being diverted by an external circuit. Also, the size of the battery that can be charged by this type of charger is essentially irrelevant. As long as the charger can make up for the battery's internal leakage current, it will charge the battery without ever overcharging it.