FREQUENTLY ASKED QUESTIONS

Introductory Note: *In calendar year 1999, Deltran introduced the Battery Tender® Plus into the marketplace. The main reason was that many more AGM style lead acid batteries were being used in a variety of power sports engine start applications. Many of the answers to the following questions directed at the Battery Tender® Plus battery charger also apply to the original Battery Tender® battery charger.*

THE QUESTIONS:

THE ANSWERS:

1. How can I tell if my battery is charged or not?

Lead acid batteries are made up of cells. Each cell is approximately 2 volts, so a 12-volt battery has 6 individual cells. It turns out that a fully charged 2-volt cell has a voltage of approximately 2.15 volts. Oddly enough, a fully discharged 2-volt cell has a voltage of 1.9 volts. That's only a difference of 0.25 volts on each cell from fully charged to fully discharged. So a 12-volt battery will measure at about 12.9 volts when it's fully charged and about 11.4 volts when it is fully discharged. That's a total of 1.5 volts that represents the full range of charge on a 12-volt battery. To make a good guess at how much charge your battery has left, you can assign a percentage of charge remaining that is directly proportional to the battery voltage. Let's see how we can do that.

If the battery voltage is 12.15 volts, how much charge is left? Beginning with 11.4 volts representing no charge or 0% charge available, subtract 11.4 volts from the voltage that you read. So 12.15 – 11.4 = 0.75 volts. Since there are only 1.5 volts above 11.4 volts that represents the full range of charge, we can divide the difference that we just calculated by 1.5 volts to get the percentage of charge remaining. 0.75 volts / 1.5 volts = 0.5 or when expressed as a percentage, multiply by 100 and get 50%.

Here's the procedure written as a formula that is applicable to 12 Volt Batteries:

OPEN CIRCUIT BATTERY STATE OF CHARGE CALCULATION
% Charge = SOC

% Charge = ((Measured Battery Voltage – 11.4 volts) / 1.5 volts) x 100

Equation 1 Open Circuit Battery State of Charge Calculation

That seems easy enough. So what's the catch? In order for this formula to work, the battery must be in a rest state. In other words, the battery should not be supplying power to any type of load. The experts say that the battery should remain at rest for at least 24 hours to get an accurate measurement, but in a pinch a couple of hours is good enough to make a reasonable guess. Even if the battery is connected to a load, as long as the load current is less than 1% of the battery capacity in amp-hours, then this method is probably good enough in most cases. It's all a matter of how accurate you want to be. If you're a scientist or engineer trying to develop a battery powered product, then you probably want a more accurate measurement than if you're going fishing for the weekend and you just want to know if you need to take the time to charge your battery before you use it.

There is one more thing to keep in mind. The only way to be absolutely sure that your battery is fully charged is to do a load test. It is best to have the battery dealer do this for you. We only mention it here because it is possible for a battery to indicate a good voltage, but then immediately when you try to use it, it acts like it's dead. This doesn't happen very often, but it's good to know that it is a possibility.

2. How long will it take to charge a battery?

We can make a pretty good guess by just dividing two numbers:

Approximate Recharge Time Calculations

(Battery Capacity) / (Charger Current) = Hours

(Amp-Hours) / (Amps) = Hours

Equation 2 Approximate Recharge Time Calculations

Suppose I have a 50 Amp-Hour battery. That's a fairly typical size for an automotive engine start type battery. Now let's say I have a 10 Amp charger.

(50 Amp-Hours) divided by (10 Amps) = 5 Hours.

So we would estimate that it will take a good 10 Amp charger about 5 Hours to recharge a 50 Amp-Hour battery. **Actually this rough estimate usually tells us how long it takes to recharge the battery to about 80% of its capacity.**

To complete the recharge of a battery to 100% with a 3-step charger, it turns out that it will probably take an equal amount of time, or another 5 hours to recharge the last 20% of the battery capacity.

To complete the recharge of a battery to 100% with a 4 step charger, in most cases it will take less time than with a 3 Step Charger to recharge the last 20% of the battery capacity. These times are different for all of the software versions.

3. How can I tell if my battery needs to be replaced?

Referring back to the discussion of how you can calculate the charge level of your battery, we know that about 1.5 volts represent the full range of charge on a 12-volt battery. Now it is possible to over discharge a battery, well beyond its intended design. It is possible to take the battery voltage on a 12-volt battery down to 3 or 4 volts under load. That would constitute a severe over-discharge. Many lead acid batteries will not respond kindly to such abuse. Although if this only happens a few times, the battery voltage may recover to 8 or 9 volts without recharging. There is also a good chance that the battery can be restored to full health provided that it is recharged with a few hours of experiencing the severe over-discharge.

Now we said that 11.4 volts represents 0% state of charge. So the battery is sitting at a negative state of charge relative to its normal use. We usually don't talk about negative state of charge, but rather that the battery was discharged 120% to 150% of rated capacity. Without knowledge of very recent severe over-discharge conditions, we could make a judgment about the condition of the battery by a voltage measurement. If the battery voltage on a 12-volt battery is only 8 or 9 volts, when measured in a rest state, then there is a very good chance, in fact a very, very good chance that battery is defective. At the very least it is safe to say that the battery has been severely over-discharged.

4. How is the Battery Tender® Plus battery charger different from a trickle charger?

The Battery Tender® Plus battery charger delivers 1.25 amperes during bulk charge mode, holds the battery charge voltage constant at 14.4 VDC during absorption charge mode until the battery charge current drops to 0.1 amperes at which time it then automatically switches to a float charge mode. During float charge mode, the output voltage of the Battery Tender® Plus battery charger is 13.2 VDC, which is well below the gassing voltage of a lead acid battery. This keeps the battery topped off, while minimizing any detrimental effects to do gassing. The Battery Tender® Plus battery charger is able to perform these complex switching functions because its electronic circuitry is controlled by an on board microprocessor.

Although they often appear to be a better economic choice for the typical consumer, trickle chargers do not have the advantage of sophisticated electronic control. Therefore, as they allow the value of charge current to trickle down to what appears to be safe levels, the output voltage of the charger rises well above 15 VDC, sometimes even going higher that 16 VDC depending on the charger type and the battery that is connected to it. Either voltage is well above the gassing voltage of a lead acid battery. If the battery remains connected to this high level of voltage for an extended period of time, even less than 1 day, extreme damage can be done to the battery. What appears to be a cost savings for the charger may actually cost several times the charger price in replacement batteries.

5. How is the Battery Tender® Jr. battery charger different from a trickle charger?

In a fashion similar to the Battery Tender® Plus, the Battery Tender® Jr. employs a higher level of sophistication in its use of electronic control to maintain a battery in a full state of charge over extended periods of time. Although its power output is less than the Battery Tender® Plus, the Battery Tender® Jr. employs a similar charge control method to keep the battery at full charge while minimizing the long-term risk of overcharge and premature capacity loss. Trickle chargers are simply not capable of regulating the output voltage applied to a battery as the battery ages, or if a different battery with different characteristics is connected to the trickle charger's output terminals. The Battery Tender® Jr. is capable of charge maintenance on all lead acid battery types, including both AGM and GEL cells.

6. What makes the Battery Tender® Plus battery charger different from other automatic battery chargers?

Many automatic battery chargers turn off when the battery voltage rises or the charge current falls to a preset level. Then after a period of time, when the battery self discharge characteristics have reduced its terminal voltage significantly, sometimes to the point where the battery has given up almost 90% of its stored charge, the charger will turn on and recharge the battery. This type of cycling will dramatically reduce battery life. The Battery Tender® Plus battery charger does not turn off. It automatically switches to a safe float voltage level that keeps the battery charged and yet does not do any harm to the battery or cause any reduction in its useful life.

7. Is the Battery Tender® Plus battery charger more expensive than a trickle charger?

In simple terms, comparing only the "off-the-shelf", retail price dollars, probably yes. However, in terms of the total cost of ownership, including the likely dramatic reduction in battery life resulting from using a trickle charger, then the answer is ABSOLUTELY NO. The Battery Tender® Plus will more than make up the difference in price by extending the useful life of only one engine start battery. Multiply this savings over the 5 year Deltran warranty period and you will save enough in battery cost to more than pay for the Battery Tender® Plus battery charger.

8. Is the Battery Tender® Jr. battery charger more expensive than a trickle charger?

The Battery Tender® Jr. will do a much better job in maintaining the charge on a battery than a typical trickle charger. Just like the Battery Tender® Plus, the Battery Tender® Jr. will provide more long-term value and hence a significant improvement in the total cost of ownership. The initial price may be higher than trickle chargers with comparable output power capability, but like the ad says, "The Battery Tender® Jr. is like a trickle charger with a brain." That added measure of on-board intelligence provides the means for the Battery Tender® Jr. to more safely and effectively maintain the charge on a battery much larger than its competitor's in the same power range. A trickle charger simply cannot regulate its output voltage to consistently safe levels over extended periods of time as the battery characteristics change.

9. How long can I leave the Battery Tender® Plus battery charger connected to a battery?

In theory, you can leave the Battery Tender® Plus battery charger connected to a battery forever. Like they say, "Just plug it in and forget about it!" Practically speaking, it is a good idea to check on the battery at least once a week. Strange things can happen. Sometimes a battery can have a weak cell that won't show up until the worst possible time. Of course, that time is usually when the battery is connected to a charger. If something goes wrong, then you have to deal with the question of the chicken and the egg. Which came first? Did the battery fail because it was connected to the charger or did the charger fail because it was connected to the battery?

No matter how good a product is, anything can break. With a battery and a charger connected together, it's a much better idea to be proactive and anticipate problems, however unlikely they may be. In more than 99.9% of cases, nothing will go wrong. That still leaves about 0.1% where something might. Learn to respect electricity. A little common sense can go a long way.

10. How can the Battery Tender® Plus battery charger that is rated at 1.25 amperes recharge a battery as fast as another charger that is rated at 3 amperes?

To recharge a battery, it is necessary to replace the charge that the battery delivered during the last time that it was used. The dimensions or units describing electrical charge are the Coulomb or, more conveniently in the context of battery charging, the Amp-Hour. The abbreviation for amp hour is Ah.

A battery charger delivers charge (amp-hours) to the battery by using an electrical current (Amps) at its output over a period of time (Hours). The numerical product of the electrical current and time period is the amount of charge delivered. This is true in a general sense for any charger.

What is not obvious is that for the calculation of charge returned to be valid is that the electrical current at the output of the battery charger must be constant during the period of the calculation. This, and the amplitude of the charge current are the critical features of a battery charger that determine how fast it will recharge a battery.

Because of the many different ways that a battery charger can be constructed and electronically controlled, there are many cases where one charger can have a higher numerical charge current rating and yet not charge a battery as fast as some other charger with a lower current rating. This is unfortunate for the consumer because there is really no way to tell based on industry standards because the standards define construction and fault protection methods to ensure safety. Those standards do not define a framework that limits how a battery charger's numerical charge current rating is determined.

This is not unlike some of the confusion that exists when attempting to compare a battery's performance based on its ratings, although the Battery Council International (BCI) clearly defines the tests that must be performed on a battery for it to be rated at a specific number of cranking amps. No such governing body exists to define a similar testing process to control how manufacturers rate the charge current output of a battery charger.

The confusion with batteries is application specific. For example, 'How long will a 950 Amp battery run the trolling motor in my bass boat?' The 950-amp rating tells the consumer how many amps the battery will deliver for 30 seconds, when starting an engine, at a specific temperature before the battery terminal voltage drops to 7.2 volts. The 950-amp rating says absolutely nothing about the capacity of the battery, which is what you really need to know to estimate the answer to the trolling motor question. However, the BCI does define a different rating that is more appropriate for that application. That rating is the "Reserve Capacity". The reserve capacity is the number of minutes that the battery will deliver 25 amps while the battery terminal voltage remains above 7.2 volts.

With battery chargers the electrical current rating alone cannot ensure an accurate estimate of recharge time. Only by looking at the charge current time profiles of two chargers connected to the same size battery, in the same state of charge, can one accurately compare recharge time.

Deltran's claim that the 1.25 amp Battery Tender® Plus battery charger will charge a battery in the same amount of time as a typical 3 amp charger is based on the fact that the Battery Tender® Plus charge current is very nearly constant during the bulk charge period, while a typical 3 amp charger, configured like so many chargers on the market, is not.

11. Can I leave the Battery Tender® Plus battery charger connected to a battery while I'm using the battery to power another appliance like a radio?

Yes, you can leave the Battery Tender® Plus battery charger connected to a battery even when the battery is being used. As far as the Battery Tender® Plus battery charger is concerned, the appliance just makes the battery look like it's not fully charged. The Battery Tender® Plus battery charger can supply up to its full 1.25 amp current output even while its output voltage is at the lower, float level of 13.2 volts. It is only when the battery voltage drops below somewhere between 12.0 and 12.5 volts that the Battery

Tender® Plus battery charger will reset and begin the full charger cycle. All that means is that when the appliance is no longer being used by the battery, the battery voltage will rise normally and there will be an absorption period of a few hours where the Battery Tender® Plus battery charger holds the battery voltage at 14.4 volts until the charger current drops to below 0.1 amp, or until 8 hours has elapsed during the absorption charge period. Then the Battery Tender® Plus battery charger goes back into float mode where its output voltage is constant at only 13.2 volts.

12. Is there any danger that the Battery Tender® Plus battery charger can cause any damage to other automotive electronic systems while it is connected to the battery in my automobile?

No. As long as the automotive electronics system is functioning properly, there should be no problem. Typical automotive electronic systems run between 14 and 15 volts with the alternator running. The maximum voltage output of the Battery Tender® Plus battery charger is 14.4 to 14.5 volts.

13. How is the Battery Tender® Plus battery charger different from the original Battery Tender® battery charger?

OVERVIEW and COMPARISON: The original Battery Tender® and Battery Tender® Plus battery chargers are both designed to provide a quick, economical means to recharge motorcycle and engine start batteries used in other power sports equipment. Typically, power sports engine start batteries are in the 12 Ah to 20 Ah capacity ranges. Both chargers are constant voltage type with precisely regulated output current limits. Both chargers have a regulated, nearly constant 1.25-ampere output charge current during the bulk charge phase. Physically, there is virtually no difference between these 2 chargers. Both the Battery Tender and the Battery Tender Plus® operate in 3 charge modes, bulk charge, absorption charge, and float charge.

RECHARGING AGM BATTERIES: The primary difference between these 2 chargers is that the Battery Tender® Plus was specifically designed to accommodate the charging requirements of the new, Absorbed Glass Matte (AGM) style batteries. To achieve that goal, it was necessary to modify the absorption charge mode in the following way. The Battery Tender® switches to float mode when the charge current drops to 0.5 amps. The Battery Tender® Plus switches to float mode when the charge current drops to 0.1 amps. The result is that for an extended period of time, not to exceed 6 hours, the Battery Tender Plus® output voltage will be held at a constant voltage that is significantly higher than the float voltage.

With the Battery Tender®, the switchover at 0.5 amp results in an absorption charge mode length of approximately 1 hour. During this 1-hour period, the battery charge voltage is held constant at a value of approximately 14.3 volts. Because of the slightly higher voltage recharge requirements of AGM batteries, and because AGM batteries require a longer period of constant voltage absorption, the Battery Tender® Plus controls the output voltage at 14.4 volts while it waits for either the charge current to decrease to 0.1 amp or for the absorption charge mode control timer to expire. The end result is that the Battery Tender® Plus absorption period is longer and at a slightly higher voltage than that for the Battery Tender®.

USING THE BATTERY TENDER® AND THE BATTERY TENDER® PLUS TO RECHARGE LARGER BATTERIES: Both chargers are designed to recharge and maintain batteries commonly used in motorcycles and power sports equipment. The typical size of those batteries is 16 to 20 amp-hours. The cold crank rating of that size battery is typically 250 to 350 CCA (Cold Cranking Amps). If either charger is used on a much larger battery, like a typical car battery rated at 650 to 900 CCA with a capacity rating of 40 to 70 amp-hours, then the time to fully recharge may be very long. Particularly on AGM batteries, the last 5% of recharge is the most difficult to deliver to the battery. That is why it is important to extend the absorption charge period longer than is possible with either charger. Even with the 6 hour safety timer used on the Battery Tender® Plus, a larger battery may have the higher, constant absorption voltage removed while the battery is still drawing much more than 0.1 amp. Once either charger switches over to the lower float voltage of 13.2 VDC, the voltage potential available to force the charge current into the battery is very low. By this time, the rest state battery voltage is probably at 12.7 to 12.8 VDC. That leaves only 0.5 to 0.6 VDC to push the current. Near the end of the absorption mode, with the rest state battery voltage at the same levels, the charger voltage is at 14.4 VDC, leaving a voltage potential of 1.7 to 1.8 VDC to push the current into the battery. That's almost 4 times the push available, compared to what's available in the float mode. That's why it takes so much longer to recharge a battery, once the charger switches over to float.

CAUTION: SOME THOUGHTS ON CONTINUOUS USE OF THE BATTERY TENDER and BATTERY TENDER PLUS® AUTOMATIC BATTERY CHARGERS: Even though both chargers are designed for continuous use, with features that automatically drop the recharge voltage to safe "float" or "maintenance" levels, common sense dictates that ANY ELECTRICAL APPLIANCE CAN MALFUNCTION. Even with a field failure rate at only a small fraction of a percent, the likelihood that either charger will fail is still not zero. It is a good idea to check the battery and charger at least once a week, just to be safe.

14. Can the Battery Tender® Plus battery charger be used to charge more than 1 battery simultaneously if the batteries are connected in parallel?

Yes, the Battery Tender® Plus battery charger can be used to charge more than 1 battery simultaneously when those batteries are connected in parallel. Theoretically, there is no reason that you cannot recharge your batteries in parallel, or that you can't use a larger battery. HOWEVER, you must recognize that the amount of time required to recharge may be much longer than you would normally expect. Effectively, by charging more than 1 battery in parallel, the charger behaves as if one larger battery is connected to its output terminals.

The Battery Tender® Plus only puts out 1.25 Amperes. That means it will take over 24 hours to recharge a 32 Ah battery to 80%, assuming that is fully discharged. It will take another 12 to 24 hours on top of that to recharge the last 20%. If you put an even larger battery in parallel with it, then the total times may double or triple. That is not a reason for concern.

The real concern is that the Battery Tender® Plus will only switch over from 14.4 VDC absorption voltage when the current draw from the battery drops below 0.1 amps or after an 8-hour period in absorption mode. Under normal circumstances, with battery capacities up to 32 Ah, this is a good thing and the Battery Tender® Plus will switch over to the long-term storage voltage of 13.2 VDC with no problem. In fact, it usually turns out that the amount of time spent at the constant voltage of 14.4 VDC, typically a few hours, is good for the battery, especially the newer AGM style batteries. There is a maximum time limit of 8 hours at 14.4 VDC. As long as the charger switches over to 13.2 VDC before the 8-hour timeout, then the battery will be 100% recharged.

However, the larger the battery that you try to recharge, the higher likelihood that the charger current will never drop below 0.1 amps with 14.4 VDC applied, no matter how long the charger is connected. That means that the charger output will remain at 14.4 VDC for the maximum time period of 8 hours. This is also not a problem for the battery in terms of "dry-out", but again with the larger batteries if the charge current has not been reduced to a maximum of a few tenths of amps, then there is a good possibility that the battery will not be 100% recharged before the switchover to 13.2 VDC. This will result in even more time required before 100% recharge is achieved.

Our recommendation is that you not charge batteries in parallel, again assuming that the batteries are 100% discharged. If the batteries are only partially discharged, then it is probably OK to charge them in parallel.

15. Can I charge more than one battery at a time with a single charger?

This is a very general question and its answer will cover many aspects of both battery and battery charger characteristics. And the answer is both YES and NO, depending on several circumstances. Here are 8 items to consider:

A. Are the batteries connected in series or parallel?
B. Are the batteries the same type, that is, are they flooded, sealed, GEL, AGM, etc.?
C. Are the batteries the same size, that is, do they have the same amp hour capacity?
D. And are the batteries used for deep cycle applications, like large marine batteries that are used to run trolling motors, or are they engine start batteries used for automobiles, motorcycles, sports watercraft, or all terrain vehicles? (This latter type of battery is referred to as SLI, which stands for Starting, Lighting, & Ignition.)
E. Are the batteries discharged to the same level before recharging?
F. What is the nominal output voltage rating of the charger?
G. What is the nominal output current rating of the charger?
H. What type of battery is the charger designed to recharge? What this means is what type of charging algorithm is used? In other words, what voltage levels, current levels, and timing does the charger employ as it recharges the battery?

This seems like an awful lot of questions to ask before we can say “YES” or “NO” to charging more than one battery with a single charger. The short answers are given first, and then a more detailed discussion follows.

SERIES CONNECTIONS: If the answer to question 15.A) is that the batteries are connected in series, where the battery voltages add to make a larger voltage, then for optimum recharging, the answers to questions 15.B), C), D), and E) must be yes. The batteries must be the same type, the same size, used in the same application, and they must be discharged to the same level before they are connected to a battery charger. The answer to question 15.F) is that the nominal output voltage of the charger must equal the total nominal voltage of all of the series connected batteries added together. The answer to question 15.G) is that the nominal output current rating of the charger must match the battery manufacturer’s recommendation

PARALLEL CONNECTIONS: If the answer to question 15.A) is that the batteries are connected in parallel, where the battery voltages must be the same and the battery capacities add, so that the charger behaves as if it is charging a larger battery, then for optimum recharging, the answers to questions 15.B) and D) must be yes. The batteries must be the same type and used in the same application. For question 15.C), although desirable, it is not essential that the batteries be the same size if they are connected in parallel when recharging. Similarly for question 15.E), it is not absolutely necessary that they must be discharged to the same level before they are connected to a battery charger.

The answer to question 15.F) is that the nominal output voltage of the charger must equal the nominal voltage of the batteries connected in parallel. Remember, that all of the battery voltages must be the same or they can't be connected in parallel. The answer to question 15.G) is that the nominal output current rating of the charger must match the battery manufacturer's recommendation. This gets a little complicated because it affects the maximum size difference, the amp hour capacity difference between the largest and smallest battery connected in parallel. It also affects the limit on the total amp hour capacity of all the batteries connected in parallel.

BATTERY CHARGER DESIGN: SERIES and PARALLEL CONNECTIONS:
Whether the batteries are connected in series or parallel, the answer to question 15.H) is that the charger must be designed to provide the output electrical power and timing control for the type of battery being recharged. This includes the output voltage and current discussed in questions 15.F) and G).

DETAILED DISCUSSION to support SERIES and PARALLEL Battery Charging:
Let's start by saying that for the purpose of this discussion, most batteries fall into three categories based on their use or application. These groups are: deep cycle (marine), SLI, or standby power. Within these three application groups we can now consider the type of battery. Flooded and sealed lead acid batteries have different charging requirements. There are also several different types of flooded and sealed batteries. But again, let's limit the discussion to 3 categories: flooded, sealed GEL, and sealed AGM.

COMPARISION of GENERAL BATTERY CHARGING REQUIREMENTS by TYPE:
The maximum recharge voltage is the highest for sealed AGM, and the lowest for sealed GEL, with flooded batteries falling somewhere in between. The exception to this rule is flooded SLI batteries that have antimony added to their lead grids. The highest voltage is delivered during the equalization charge period. Equalization charging will be discussed later. The maximum recharge current is the highest for sealed AGM and sealed GEL, and the lowest for flooded batteries. Most battery manufacturers will specify the maximum recharge current to be a percentage of the amp hour capacity.

For example, many flooded SLI batteries are limited to 10% to 20% of the amp hour capacity. For more specific example, consider a 20 Ah, flooded SLI battery, as you would find in a motorcycle, sports watercraft, or ATV. In this case, the charger should only deliver a maximum charge current of 2 to 4 amps to the battery. On the other hand, sealed AGM batteries are becoming very popular in these SLI applications. Sealed AGM batteries do not usually have the same maximum charge current limitations as flooded batteries. However, some AGM battery manufacturers continue to prefer to make a more conservative recommendation for the maximum charge current.

In this regard, with one more known fact about the majority of commercially available battery chargers, the conservative approach to recommending a maximum charge current is usually not necessary. That fact is that most commercially available battery chargers are not true constant current chargers. What most battery chargers do is one of two things. They either allow the charger output current to immediately taper (reduce in amplitude) in response to an increase in battery voltage, however slight that voltage increase may be, or they maintain a regulated current limit until such time that the battery charger develops sufficient voltage for the charger to switch to a true, constant voltage mode of operation.

The initial period, prior to the constant voltage mode of operation is called the bulk charge period. The constant voltage period is called the absorption charge period. It is during the absorption charge period that the charging requirements for AGM batteries differ most significantly from those for flooded batteries and GEL cells. AGM batteries require a longer period of constant voltage, so long in fact, that the current drawn by AGM batteries is virtually nil for up to several hours at the end of the absorption period. Typically it takes 1 to 2 hours for the battery charge current to drop to a few tenths of an amp at the beginning of the absorption period. After the battery charge current drops to this very low level the AGM battery still requires several more hours with the constant absorption voltage being applied.

The precise electro-chemical requirements for this extended, essentially “zero” current high constant voltage period are debatable. Suffice it to say that a significant body of empirical evidence supports this claim. Without an extended, “zero” current, constant voltage absorption period, the cycle life of AGM batteries is dramatically reduced. The reduction may be by as much as a factor of 2 or 3 to 1. In other words, an AGM battery designed to deliver 400 deep cycles may only deliver 200 or as few as 125 deep cycles if the length of the absorption period is not sufficient. One deep cycle is defined as a battery discharge where the battery capacity is depleted to between zero and 20% of its fully charged value. We could say that the State Of Charge (SOC) of the battery is 0% to 20% after a deep cycle discharge. This is described as a Depth Of Discharge (DOD) between 100% and 80%.

No such lengthy, “zero” current, constant voltage absorption period requirement exits for either flooded SLI or GEL cells. However, both of these battery types do benefit from extended float maintenance charge periods. This is usually referred to a “topping off” the batteries. There is some debate amongst battery and battery charger professionals about the benefits and risks of extended float maintenance charging. The major difference between float maintenance charging and absorption charging is that the float voltage is only a few tenths of a volt above the fully charged, rest state voltage of the battery. This is typically 13.2 to 13.6 volts. This voltage range is below the gassing voltage of the battery. The absorption voltage is about 1 volt higher, 14.2 to 15.0 volts. The absorption voltage range is above the gassing voltage of the battery.

THINGS TO CONSIDER when CHARGING BATTERIES CONNECTED IN SERIES: The highest charge voltage is delivered during the equalization period. For

AGM batteries in particular, this higher voltage, between 15.5 and 17 volts for an AGM battery string has an interesting added benefit. For as few as 4 identically sized batteries, discharged to the same DOD, after recharge without an equalization period, the individual battery voltage may vary by as much as 1 volt across the string.

EQUALIZATION VOLTAGE IMPACT on SERIES CHARGING: Let's consider 4 AGM batteries connected in series. The individual battery voltages would optimally be in the 14.5 to 15.0 volt range, while the charger delivers its absorption voltage. Let's say 14.7 volts per 12-volt battery for this discussion, or a total of 58.8 volts. Without high voltage equalization, it is possible, in fact even likely after a few discharge / charge cycles, that the lowest battery voltage in the string may be 14.2 volts and the highest battery voltage in the string may be 15.2 volts, with the other 2 battery voltages being 14.9 and 14.5 volts. Within a matter of minutes after the charger applies an equalization voltage of 15.5 volts per 12-volt battery, or 62 volts total, each of the 4 batteries will "snap" in line, varying by no more than 0.2 volts per 12-volt battery.

The optimal timing of this equalization voltage application, much like the extended absorption period, is a subject of debate among industry professionals. Again, the empirical evidence is clear pertaining to the result. If the individual battery voltages in the string are not equally matched, with only a few tenths of a volt per 12 volt battery, then the long term ability of the battery string to deliver a significant percentage of its design deep cycle life is dramatically reduced. An analogy can be drawn to the 6 individual cells comprising a single 12-volt battery. If a single 2-volt cell is weaker than the other 5, then the 12-volt battery will not consistently deliver its design deep cycle capacity over time. This observed result is called "Premature Capacity Loss" or PCL. There are other reasons for a battery to exhibit PCL, but sub-optimal series string charging is certainly one of them.

CHARGING BATTERIES in SERIES that HAVE NOT BEEN DISCHARGED TO THE SAME DOD or BATTERIES that ARE A DIFFERENT SIZE (AH Capacity): Just as a single, weak 2 volt cell will degrade the performance of a 12 volt battery, recharging batteries connected in series that have different beginning SOCs or have been discharged to different DODs will have a similar result. The lowest SOC battery in the string will most likely never recover fully, remaining undercharged, while the highest SOC battery in the string will become overcharged. Either case situation result in premature capacity loss.

Similarly, although at first glance the effect seems to be the opposite, the smallest Ah capacity battery in the string will become overcharged, while the largest Ah capacity battery will likely never be fully recharged. This assumes that that both or all of the batteries have been discharged to the same DOD prior to recharge. Different size, Ah capacity batteries is a more complicated case than same size batteries discharged to different DODs.

An argument could be made that different size batteries could function and be fully recharged, by exerting careful control over both the discharge and the recharge. However, the smaller battery will experience a deeper discharge on each cycle, thereby approaching the end of its cycle life sooner. Over time, the smaller battery will not be able to be fully recovered and it will become the weak "cell" in the single battery analogy.

16. Can I charge batteries with different voltages on a single charger, either a 12-volt or a 6-volt charger?

One of the answers to this question is a special case of the general question asked earlier about charging more than one battery at a time. That specific answer is that if the total nominal battery voltages of all of the batteries connected in series equals the nominal voltage output of the battery charger then you can use a single charger. For example, two 6-volt batteries connected in series can be recharged with a single 12-volt charger. Of course, all of the previous restrictions about charging batteries connected in series apply to this case.

To this question answer more directly for single batteries, NEVER use a charger on a single battery unless the nominal output voltage of the charger matches the nominal battery voltage. For example, only use a 12-volt charger with a 12-volt battery. Do not use a 12-volt charger on a 6-volt battery or a 6-volt charger on a 12-volt battery.

> ***If the nominal charger voltage is larger than the nominal battery voltage, then the situation can become dangerous.***

The reason that this situation is dangerous is because the battery cannot develop a voltage high enough to allow the charger to complete the different phases of its charge cycle. That means that the charger will be "stuck" in the bulk charge mode, continually delivering electrical current to the battery for as long as AC power is applied to the charger, or until the charger safety mechanisms engage. In this case, the only type of safety mechanism that would work properly would be one designed to sense a battery voltage increase over a specific period of time. Even then, depending on the specific design parameters, that type of charger safety mechanism may not be sufficient to prevent serious damage to the battery or even a potential fire hazard, or even worse, a risk of explosion.

> ***If the nominal charger voltage is smaller than the nominal battery voltage, then one of two things will happen: nothing, or the battery will be discharged.***

The reason that nothing may happen is that many chargers are protected from reverse current. Usually a semiconductor-switching device called a diode provides this protection. A diode only allows electrical current (charge) to flow in one direction. For a battery charger that direction is out of the charger and into the battery. If a 6-volt charger is connected to a 12-volt battery, the 12 volt battery will try to deliver current to the 6 volt charger because electrical charge always moves in the direction from the higher voltage to the lower one. If the charger is protected from reverse current, then no current will flow, and nothing will happen. Of course, the battery will not be recharged, and if it is deeply discharged, then remaining in that condition may result in permanent damage to the battery. If the charger is not protected from reverse current, then the battery will be discharged. Likewise in this case, the battery may be damaged severely from being over discharged.

17. What happens if the AC power is removed from the Battery Tender® Plus battery charger while it is connected to a fully charged battery?

If the battery is fully charged, then the Battery Tender® Plus battery charger's green light will be on. Once the AC power is removed from the Battery Tender® Plus battery charger, the green light will go out and the charger not have any effect on the battery. The Battery Tender® Plus battery charger is protected from reverse current, so it will not discharge the battery. Of course, like we said earlier when discussing nominal voltage mismatches between a battery and a charger, the battery will not be recharged either.

When AC power is restored to the Battery Tender® Plus battery charger, it will restart its charge cycle. The sequence of events should go something like this. The red light will come on for a few minutes. Then the green light will start flashing while the red light stays on. The next thing that happens is what may confuse some people who use the Battery Tender® Plus battery charger. Remember, the battery was fully charged, so you may ask, "Why doesn't the green light just come right back on?"

The reason that the green light doesn't come on immediately is that when the charger first comes on, the battery is sitting there, fully charged, at a voltage of about 12.9 volts. The charger immediately tries to bring the battery voltage up to about 14.5 volts. This takes a finite amount of time, although it should only be a few minutes if the battery is fully charged. Then, when the battery reaches 14.5 volts, the charger will hold it there until one of two things happen. Either the battery charge current will drop to less than 0.1 amp (from an initial value of 1.25 amps) or, if the current does not drop below 0.1 amp, then the charger will hold the battery voltage at 14.5 volts for 6 to 8 hours.

There are a couple of reasons why the battery current may not drop below 0.1 amp. First, on a larger battery, like an automotive SLI battery, the internal losses of the battery may consume more than 0.1 amp. Second, if the vehicle or the system that the battery is connected to has appliances that consume electricity, then that consumption of electricity, coupled with the battery internal losses may very likely exceed the 0.1 amp limit. This second cause is very common and its result is that the Battery Tender® Plus battery charger's timer circuits will be fully engaged. So it will take 6 to 8 hours for the green light to come on. Fortunately, the Battery Tender® Plus has the ability to continue to supply its full current even after it has switched over to the lower, float, maintenance charge voltage of 13.2 volts. When the charger turns the green light back on, it also drops its output voltage to this float, maintenance charge level of 13.2 volts.

Note: It only takes a momentary AC power outage to cause the Battery Tender® Plus battery charger to reset.

18. What is Temperature Compensation and how important is it?

While a battery is being charged, it is important that the charger absorption and float, maintenance voltages closely match the recommendations of the battery manufacturer. The absorption voltage match is important for quick charging. The float, maintenance voltage match is important for long term, storage charging.

Batteries are sensitive to temperature. Recall the number of TV ads showing how tough a battery is when it can start a vehicle in sub-zero temperatures. Cold temperatures tend to reduce a battery's ability to deliver current to a load. High temperatures not only increase a battery's ability to deliver current to a load, but also increase a battery's internal losses.

Temperature compensation is a way to change a charger's output voltage to maintain optimum compatibility with the battery's charging requirements. The way it works is that the charger senses the ambient temperature. Then it increases the charge voltage when it is cold and decreases the charge voltage when it is hot. Typical values for temperature compensation for a lead acid battery are minus 0.0025 to minus 0.004 volts per degree Centigrade per 2-volt cell. For a 12-volt battery, that would be minus 0.015 volts to minus 0.024 volts per °C. The reference temperature requiring zero charge voltage compensation is 25 °C or 77 °F.

How important is temperature compensation? Like with most everything else about batteries, it depends on the application. For industrial, critical load, standby power applications, where the batteries may be connected to a live charger for a number of years, then temperature compensation can have a significant influence on battery life. In many consumer applications like SLI, deep cycle marine, etc., temperature compensation will increase long-term battery performance, but it is probably not essential in all applications. Where it is most beneficial is in helping to minimize the negative impact of a battery's self-discharge characteristics in high temperature environments.

Deltran Battery Tender® Plus Battery Chargers Overcome the Negative Impact of High Temperature on Battery Performance.

The self-discharge rate of a battery is directly dependent upon the ambient temperature of the battery environment. At higher temperatures, the chemical reaction rates that determine self-discharge will also increase.

When a battery sits idle, its self-discharge characteristics will reduce its ability to deliver power on its next use. If the battery either sits long enough, or if the ambient temperature rises high enough, then the battery may become fully discharged. In fact, it is possible for the battery to be over-discharged to the point where it cannot be recovered.

The Deltran Battery Tender® Plus battery chargers overcome the negative impact of higher ambient temperature and battery self-discharge in two ways. First, the Deltran Battery Tender® Plus battery charger applies a safe, float, maintenance voltage level to the battery to overcome its internal losses and counteract the self-discharge phenomena. Second, the Battery Tender® Plus battery charger automatically compensates the amplitude of its charge voltages for changes in ambient temperature. It reduces the amplitude of the float, maintenance voltage as the ambient temperature increases and it increases the amplitude of the charge voltages in colder temperatures. In mathematical terms, this type of compensation scheme is called a "Negative Temperature Coefficient".

The temperature compensation ratio employed by the Deltran Battery Tender® Plus battery chargers is approximately minus 3.67 millivolts per battery cell per degree Centigrade of temperature rise above 25 °C. Stated another way, the output voltage of the Deltran Battery Tender® Plus battery charger will drop 0.022 volts, or 22 millivolts, for every degree Centigrade temperature rise, when it is connected to a 12-volt battery.

In the event that the temperature would rise enough so that the Deltran Battery Tender® Plus battery charger voltage output drops below the what would be considered a normal operating voltage for a 12 volt battery, then the Deltran Battery Tender® Plus battery charger automatically disconnects itself from the battery via an internal solid state mechanism, affording an extra measure of safety in a very high temperature environment.

19. What is Float / Maintenance Charging? Is it really necessary?

Historical Background: Charging batteries in a float / maintenance mode has been standard practice for decades when batteries have been used for standby power applications, such as telecommunications, UPS (Uninterruptible Power Supply), and emergency lighting. Also, the U.S. military has invested literally billions of dollars in developing standby battery charger systems for uses in countless weapon systems: ships, aircraft, ground vehicles, etc. The simple definition of float / maintenance charging is that voltage is continuously applied to the battery terminals. The amplitude of that voltage varies between 0.2 volts and 0.6 volts above the rest state voltage of the battery when it is fully charged. The purpose of continuous float / maintenance mode charging is to maintain the battery in a fully charged condition so that when it is called into service, it will be able to deliver its full charge capacity. Until recently, the most commonly used battery chemistry in sophisticated military weapons systems has been NiCd, rather than lead acid. Nevertheless, the concept of continuous float / maintenance charging has been around for a long time.

In the early 1990's, engineers and product managers at Deltran corporation successfully applied this same battery charging concept to engine start batteries. The original Battery Tender® battery charger was marketed for use in the motorcycle industry. After many years of continued success, the Deltran charger product offering was expanded to include many higher-powered chargers, in different physical packages, both portable and permanently mounted, and with different output charge voltage and output charge current configurations. The Battery Tender® Plus battery charger is an improved version of the original product. Its design is optimized for use with sealed, gas-recombinant, absorbed glass matte, lead acid batteries. It has been on the market since 1999.

Technical Discussion Categories: There are basically 2 categories of technical issues that need to be discussed when debating the merits of float / maintenance charging. 1) What observable characteristics of the battery support and detract from using continuous, float / maintenance charging? 2) What observable characteristics of battery chargers support and detract from using continuous, float / maintenance charging?

1) A. Battery Voltage vs. SOC: In the first category, batteries develop a voltage that indicates how much charge is available for use. The relationship between battery terminal voltage and State Of Charge (SOC) is reasonably linear. For a 12-volt, lead acid battery, that relationship is defined by a 1.5-volt change in terminal voltage that represents the entire SOC range from 0% to 100%. Also, that voltage must be measured when the battery is in a state of rest (the battery terminals are open-circuited), neither being charged nor discharged. A fully charged 12-volt battery will have a terminal voltage of approximately 12.9 volts and a fully discharged (0% SOC) battery will measure 11.4 volts at its terminals. Therefore, a change of 0.15 volts represents a 10% SOC difference.

1) B. Internal Battery Losses: All lead-acid batteries develop and store charge as a result of an internal chemical reaction. There are 2 primary internal loss mechanisms. The first is a result of the chemical interaction between the internal battery elements. That interaction is continuous and it is affected by temperature. It is also affected by whether the battery is being charged, discharged, or in a state of rest. In all 3 situations, the battery terminal voltage will change. In one sense, the battery is never truly in a state of rest, rather, its terminals are connected either to a charger (being charged), or to a load (being discharged) or the battery terminals not connected to anything (the terminals are open-circuited, or in a "state of rest").

The second primary internal loss mechanism is due to the physical interconnections between the chemically interacting elements and the electrically conductive paths to the battery terminals. This second loss mechanism is usually called the internal resistance of the battery. When the battery terminals are open-circuited, that is, not connected to either a battery charger or a load, only the internal chemical losses influence the battery terminal voltage. When the battery is being either charged or discharged, both the chemical losses and the internal battery resistance influence the battery terminal voltage.

The simplest battery model for electrical circuit analysis is an ideal battery in series with a resistor. The voltage of the ideal battery is the open circuit voltage that represents SOC. The value of the series resistance is the battery internal resistance, typically measured on a fully charged battery at a frequency of 1000 Hertz. That resistance value is usually in the 5 to 10 milliohm range. More sophisticated battery models account for the fact that the internal resistance is not constant over the range of SOC. Even more sophisticated models include a complex impedance (some combination of resistance, inductance, and capacitance) in parallel with the ideal battery. For example, because of the construction of lead acid batteries, the equivalent electrical capacitance is in the range of several tens of thousands of Farads. For this reason, specifying a ripple component of output voltage on a battery charger when it is connected to a battery is somewhat futile because of the tremendous voltage-filtering characteristic of the battery's equivalent electrical capacitance.

Since the internal resistance of the battery is very small, its impact on the value of voltage measured at the battery terminals is only significant during high rate (lots of current) discharges and charges. When the battery is being discharged, the battery terminal voltage is less than its open circuit value. Conversely, when the battery is being charged, its terminal voltage is more than its open circuit value. The difference between the voltages is calculated by the product of the charge or discharge current and the internal resistance. In float / maintenance charging situations, the charge current is usually very small, so that the difference between the open circuit voltage and the actual battery terminal voltage is also small.

2) A. Battery Charger Output Voltage vs. AC Line Voltage (Output Voltage Regulation): This one aspect of Power Supply (battery charger) Line Regulation is very important because the output voltage of the battery charger must be in a certain range, and it must not deviate significantly from that range, otherwise a battery can be overcharged, or it can be undercharged. Fortunately, in the United States, the national AC power grid, the AC power distribution system, is very stable. Therefore, battery charger line regulation characteristics have less impact than they would when the AC power, particularly the AC line voltage varies significantly. In general, one could say that the simpler the construction of a battery charger, the more likely it is to have larger percentage line regulation characteristics. The larger the percentage, the more the output voltage will vary with the AC line voltage.

2) B. Battery Charger Output Voltage vs. Temperature (Temperature Compensation): This battery charger characteristic probably has more influence on the battery than line regulation. Even if a battery is kept at its ideal float voltage, and it that ideal voltage is compensated properly for temperature, an increase of only 7 °C to10 °C can cut the battery life in half, assuming that the higher temperature remained for the entire observation period. Short-term fluctuations in temperature have little impact on battery life, unless the temperatures are extreme. In general, cold is good, hot is bad, very cold is better (but too cold can be worse), and very hot is worse. At the extreme cold end, bad things can happen as well, but those bad things are just dramatic reductions in the battery performance. At the extreme hot end, while the battery is charging, it can emit dangerous gasses. The ideal temperature compensation range for lead acid batteries is typically in the range of 2.5 to 4.0 millivolts per 2-volt cell, per degree Centigrade. The temperature compensation coefficient is also negative, meaning that the change in charging voltage is in the opposite sense as the change in temperature. If the temperature goes up, the charging voltage comes down and vice-versa.

Arguments For and Against Continuous Float / Maintenance Charging: From the preliminary background on batteries and chargers, positions can be taken for or against continuous float charging. The main argument against continuous float charging is that the battery will: a) be undercharged, or b) be overcharged, and / or c) be permanently damaged as a result of a) or b). The main argument for continuous float charging one of convenience in that it is better to have the battery fully charged when you need to use it. An automatic, well-regulated, temperature-compensated charger can keep the battery fully charged and at the same time minimize the risks of long-term damage to the battery due to either under-charging or over-charging. The alternative is to let the battery internal losses run their course, which for most batteries means that they are fully discharged within a few months. If you forget to recharge them periodically, and they become severely over-discharged, even due to only internal losses, the plates will become severely sulfated. For many batteries, that means that they are permanently damaged.

Recommendations for Using the Battery Tender® Plus in Continuous Float Mode Charging: The line regulation characteristics of the Battery Tender® Plus are excellent; less than 1% for line voltage between 115 VAC and 125 VAC. This charger is temperature compensated and it has a special charging algorithm optimized for sealed, gas-recombinant, AGM, lead acid batteries. Numerous motorcycle owners have reported to Deltran over the years that their batteries have lasted 3 years or more. Before using the Battery Tender® charger, they would have to replace their batteries as often as every 6 months.

20. Can the Battery Tender Plus successfully perform the initial charge on a new, flooded, motorcycle battery?

Background: The motorcycle dealers receive batteries from the manufacturer in a dry state. The plates are dried out, and there is no acid in the cell compartments. (Do not confuse this with a dry-cell battery.) The dealer must fill the individual battery cells with acid and then put them on a shop charger to pre-charge prior to selling them to a customer. As the batteries arrive from the manufacturer, the plates are approximately 80% "formed". The initial pre-charge, post-formation charge, or more correctly, formation-finishing charge, must be conducted at a specific power level and for a specific time period. Each manufacturer has its own recommendations, for example one manufacturer recommends that the charger deliver a constant current equal to 10% to 15% of the battery amp-hour capacity and that the charge current be applied to the battery for a period of 5 to 10 hours.

Answer 1) Certainly if the dealer has properly pre-charged the battery after filling it with acid, then the answer is **ABSOLUTELY YES.**

Answer 2) If the dealer has not properly pre-charged the newly filled battery prior to the sale, then the answer is **YES, WITH SOME QUALIFICATIONS:**

Qualification A) The Battery Tender® Plus should be left on the new battery for a minimum of 24 hours on float, in addition to whatever amount of time it takes for the charger to get to the float stage. It is not clear how to correlate the 80% formed plates with a given state of charge once the cells are filled with acid. To be safe, assume that the batteries require a full 100% charge after the cells are filled.

For example, a 16 Ah battery will take about 13 hours to get to the absorption voltage (constant 14.4 Volts). It may take another 6 to 8 hours to reach the float voltage (constant 13.2 Volts). This may sound awkward; because what happens is that the battery charge current drops while the absorption voltage is held constant. When the battery current drops to 0.1 amp, or if 6 to hours have elapsed at the absorption voltage, the charger automatically switches its output from 14.4 V to 13.2 V. So it may take the better part of 20 hours to reach the float stage. Add another 24 hours to that and you are at 44 hours. Throw in another 4 hours for good measure and you get a nice round, even 48 hours, or 2 days.

Qualification B) Although there are probably several charging methods that will be equally effective, regardless of who manufactures the battery, in the interests of technical consistency, they will not officially sanction any initial charging method other than those published in their technical applications literature.