

## INTRODUCTION

The purpose of this paper is to describe and demonstrate the techniques stated in the various standards related to battery charger sizing. It is important to properly size the charger to the application and to perform said sizing using industry accepted techniques. This consideration will ensure that the charger when applied is properly sized and neither oversized nor undersized.

Drawing from the author's personal experience it seems that many applications may employ either a general rule of thumb or provide "margins of safety" not really required or advised by the standards. This sizing method usually results in battery chargers that are oversized. Properly using the industry standard techniques will aid in avoiding oversized battery chargers. This would result in applications where the chargers would be sized more appropriately to the need. It is safe to assume that proper sizing usually results in smaller capacity chargers and a more efficient lifetime operation with lower initial costs, but more importantly proper sizing determines a charger of proper capacity.

### CONSTANT POTENTIAL, CURRENT LIMITED CHARGING

#### Constant Potential (Constant Voltage) Charging Description

Constant-potential (CP) charging is considered to be one of the oldest methods of battery charging still in use and had its earliest beginnings in the aircraft industry for recharging lead acid batteries. This technique today is commonly used in all forms of stationary applications because batteries may be left on float charge for an extended period of time. For this paper we are dealing with the calculations related to Constant Potential charging.

It is common to see constant potential charging for utility, communications, stationary engine start, UPS and process control systems applications. All of these and others will require that a battery remain on float charge for extended periods of time. This charge method maintains the battery's state of charge until such time as the battery is required to support the load. It is common for these applications that the charger may serve as a power supply while the battery is standing by in float mode.

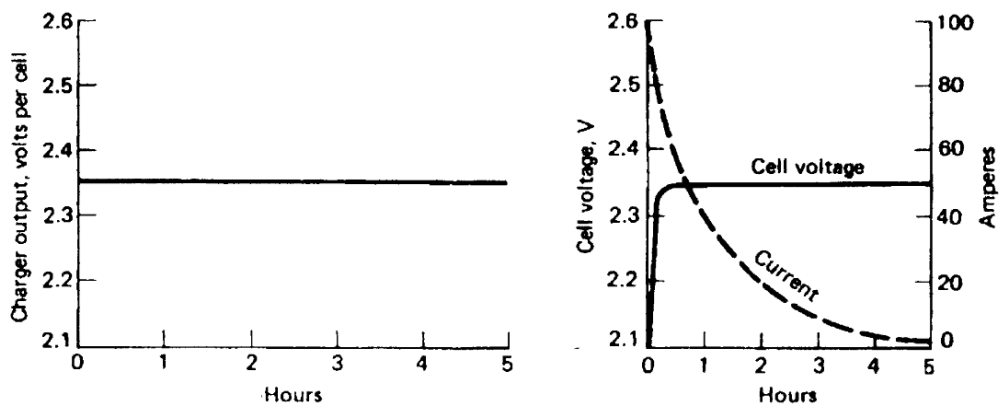


Fig 1 – Representation of Constant Potential Charging

## **Float Mode**

In very simple terms, constant potential charging is successful because the technique requires that the battery be maintained at a certain voltage, using a well regulated supply that provides current only to achieve and maintain the determined voltage. Once the determined voltage is achieved the back EMF of the battery will allow the charger to taper the current down to a minimal value so as to maintain a float or maintenance charge such that the battery will neither self discharge nor overcharge.

## **Equalize Mode**

It is typical that these chargers offer a dual rate charging system so as to allow the charger to provide an equalized or high rate charge. In this mode the output voltage of the charger is set higher than in the float mode. Again, the charger action is similar to the float mode in that the charger will act as a current source until the desired voltage is achieved. When the desired equalize voltage is achieved the back EMF of the battery will allow for the output current to taper down.

## **Constant Potential – Current Limited Operation**

The battery charger used in constant potential charging will be of the constant potential-current limited type. The charger will be specifically designed to accommodate the charge profile by employing a current limiting circuit that limits the output current of the charger when the battery potential is low. Typically, the charger will have a form of adjustment that allows the output current limit to achieve a maximum level that is somewhere between 105% and 125% of the charger's catalog rating. Many chargers will also allow for current limit adjustments that fall below the charger's catalog rating.

In application, the constant potential current limited charger will charge a depleted battery by first acting as a current source since it sees a battery whose voltage is below the value determined to maintain charge. During this period of the profile the charger will deliver current up to the charger's current limit set point until the desired battery voltage is achieved. When the desired battery voltage is achieved the charger tapers the output current and then becomes more of a voltage source.

When the charger is operating as a two rate charger and the battery employed must be equalized at a higher voltage than the float voltage value, this equalize process occurs until such time as the charger switches from the equalized to the float mode. When the charger returns to float mode the current will drop to zero or near zero until such time as the back EMF of the battery goes below the float voltage threshold.

## **Constant Loads vs. Transient Loads**

Stationary battery chargers are designed to accommodate constant loads while recharging batteries. Constant loads are those loads that remain steady and present as

part of a load profile. Typical of these loads are lamps, instruments, recording equipment etc. that is always on during normal operation.

Transient loads are those which are fleeting and usually represent a very high current demand in relation to the constant load. This current level will be sustained for a very short period of time. Typical examples of transient loads are switchgear action (either charging or releasing of switchgear), engine start, or motor starting. Each of these applications requires a high current demand for a very short period of time. In all cases it is recommended that these transient loads be accommodated by the battery and not the charger.

The charger is not used to accommodate transient loads for several reasons. First, if the charger is able to respond to these quick acting load demands there would be no way for the charger to know if it is responding to a switchgear load or a battery demand. Responding quickly to battery demands could result in battery damage.

Sizing a battery charger for transient loads would result in battery chargers that are much larger than needed. Batteries do not provide any form of self regulation so therefore the charger must be the regulating force in the battery/charger circuit to ensure that a successful float application is achieved. Chargers in float service are typically designed to keep their transient response rate between 200ms and 500ms so as to inhibit the charger's ability to cause any battery damage or load damage. These response rates would be too slow to accommodate most transient loads.

## BATTERY CHARGER SIZING

### THE CHARGER SIZING FORMULA

$$\frac{(\text{AH Removed}) \times 1.R}{T (\text{Desired Recharge Time})} + L (\text{Constant Loads}) = \text{Amperes Charger}$$

Several permutations of this same formula have been shown in different resources. I shall further dissect and represent this formula to cover the majority of applications and considerations. It is important that the calculation to determine charger size be followed with a certain amount of discipline since when properly applied it provides for the least amount of wasteful energy in application.

Power supplies and battery chargers in particular offer the best efficiencies the closer they operate to their full load rating. Therefore, the opposite is also true, if you employ a battery charger that is severely oversized in an application, it will be operating more inefficiently.

### THE CHARGER SIZING FORMULA DEFINED

**AH removed** – This number is the AH removed from the battery after either a complex load profile is calculated or tabular information is used. While it may be typical to use

the battery AH rating, it is actually required that you only recharge what you take from a battery. It is not necessary to recharge a battery from “empty to full” if you are only using a percentage of the battery’s capacity.

Other considerations that affect a battery size such as, design margin, age factor, temperature correction, etc. are not to be added in as part of the battery’s AH removed. These factors do not reflect the AH removed or discharge from the battery.

**1.R, R= Recharge Factor** – Recharge factor very simply is the additional energy required to recharge a given battery. AH Removed represents the energy removed from the battery. In order to return that same amount of energy we must put back what we take out plus a little more to accommodate the losses. This defines the recharge factor, it tells us how much more energy we must replace to get back to full charge.

Deriving the recharge factor is based on battery manufacturer’s recommendations. Typically the following values have been used in the industry. Note that you may use these values if a battery manufacturer does not state any specific values to use.

Wet Vented Lead Acid – 1.1, 1.15  
Valve Regulated Lead Acid – 1.15  
Wet Vented Nickel Cadmium – 1.3, 1.35, 1.4  
Valve Regulated Nickel Cadmium – 1.4

**T (desired recharge time)** – This value is provided in whole hours and will typically be a number between 8 hours and 24 hours. Typically, 8 to 12 hours and in certain cases as much as 24 hours are used as an acceptable recharge time. The basis for this is determined by the application, but the limits between 8 hours and 24 hours are a practical matter.

**T (desired recharge time)** – This value is provided in whole hours and will typically be a number between 8 hours and 24 hours. Typically, 8 to 12 hours and in certain cases as much as 24 hours are used as an acceptable recharge time. The basis for this is determined by the application, but the limits between 8 hours and 24 hours are a practical matter.

For the most part, batteries will not accept a charge, regardless of how much current is available in less than about 8 hours and will not recharge from a practical standpoint in more than 24 hours, using typical constant potential-current limited charging techniques. While this comment is a generalization it is also a safe bet. If you want to recharge a battery either faster or slower than the 8 hour to 24 hour window, I would suggest that you check with the specific battery manufacturer. Certain battery products may be able to recharge either faster or slower than the general rule allows.

**L (constant loads)** – This number will represent those loads that are constant. As mentioned previously, these are the loads as represented by the profile as always present. These are not the loads that are transient. It is important to note that if you

have a very high constant load it may be added in here. Load intensity is not a determining factor by itself. High load intensity coupled with very short time duration together defines transient loads. Previously stated, transient loads should be accommodated by the battery and not the battery charger.

**Amperes Charger** – Charger output current is defined as the result of the calculation. However, there are some additional considerations in finally selecting a battery charger.

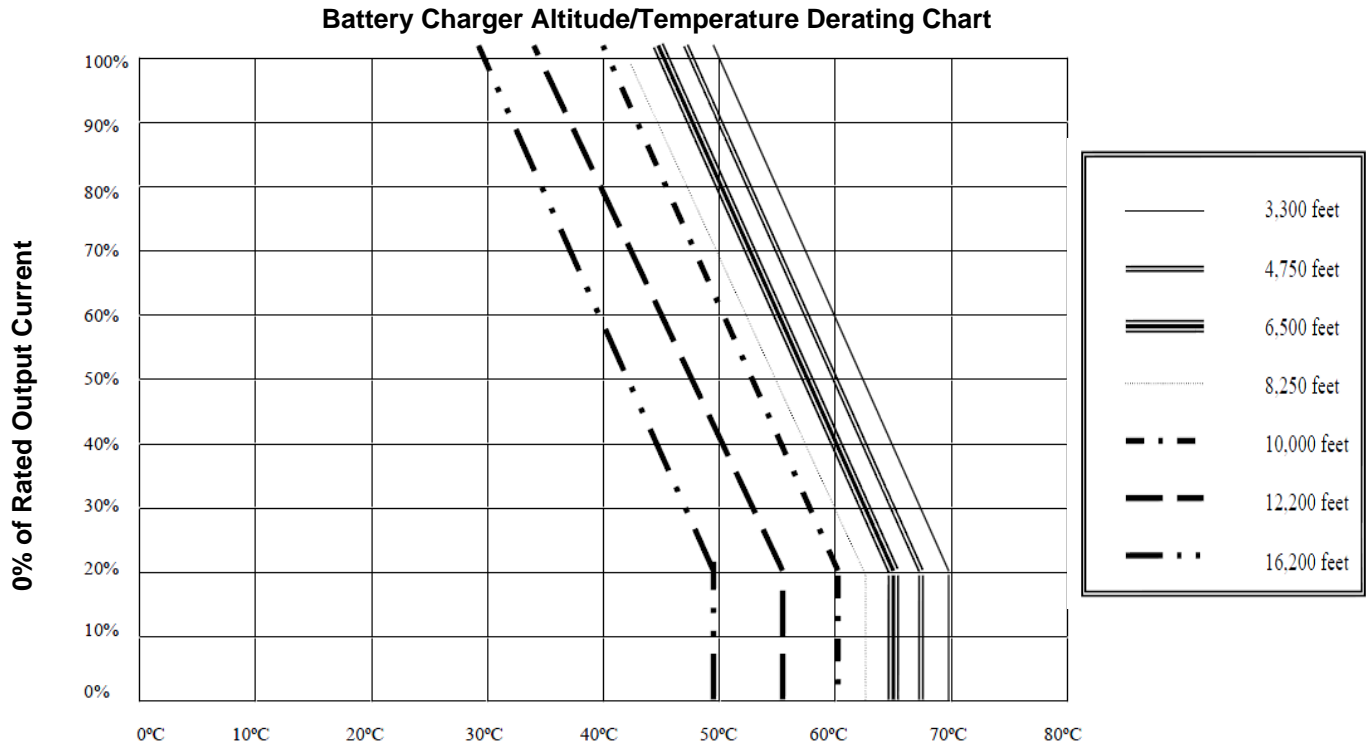
Unlike a typical battery size calculation, sometimes it makes sense to pick a charger whose output is slightly smaller than calculated. For example, if the calculation determines a 26.5A charger output, it is perfectly acceptable to use a 25A output charger rather than a 30A charger. This is because of several factors; the most important is that the charger's current limit range is probably at least 110% of rating without any degradation of output. Therefore, the 25A charger can output 27.5A continuously, without degradation so the requirement to accommodate a 26.5A charger output is within the acceptable range of the 25A charger being selected.

**Other Amperes Charger Considerations** – It is also important to include consideration of the following factors which may be introduced by the specifier:

- **Temperature Correction**
- **Altitude Correction**
- **Design Margin**
- **Anticipated Growth**

- **Temperature Correction & Altitude Correction**, the factors related to these items require more than basic consideration. In many cases the actual correlation is such that you can de-rate the charger by application rather than performance. For example, as you increase altitude the ambient temperature could be lower. Since that is interrelated you could have a charger in an application at 10,000 feet but the highest ambient might be only 40 deg C rather 50 deg C to still allow for 100% of rated output. (See Figure 2) In this case there would be no reason to select a larger charger to accommodate this environment, since the existing charger could meet the new environmental situation. It is imperative that you consult a charger manufacturers de-rating chart to determine actual charger performance.
- **Design Margin**, is based on the designer's knowledge of a possible condition of load. There is no standard for design margin in battery chargers since they do not age and lose capacity over time as batteries do. Therefore any consideration of design margin is in addition to any standard and the result of the designer's judgment.
- **Anticipated Growth**, is based on good planning. If you know that this application will eventually require a larger charger due to loads already anticipated it is a good engineering practice to add that capacity to the

charger at the outset. However, two considerations should be given when this occurs. First, be sure that the selected charger can tolerate the charger to battery ratio and still provide all the filtering and regulation desired. Typically charger to battery ratio is expressed as a 4:1 ratio where the charger output current is no larger than ¼ of the battery's overall AH capacity. In many cases a charger classified as a battery eliminator can solve this issue if the ratio is not met. Second, instead of starting out with a larger charger it may be prudent to add another charger of similar output at a later time in parallel to the existing charger to accommodate the needed added capacity.



**Fig 2 - Typical Temperature/Altitude De-rating Chart**

### Charger Sizing Sample Calculation

Assuming a 200AH wet vented lead acid battery where the AH removed is 150AH, the recharge time is 8 hours and the constant load is 25A.

The following formula would be populated as follows:

$$\frac{(\text{AH Removed}) \times 1.15}{T (\text{Desired Recharge Time})} + L (\text{Constant Loads}) = \text{Amperes Charger}$$

$$\frac{150\text{AH} \times 1.15}{8 \text{ Hrs.}} + 25\text{A} = 46.563 \text{ Amp Charger} \rightarrow \text{use } 50\text{Amp output charger}$$

---



## SUMMARY

Proper use of the battery charger formula to determine charger size will result in a proper sized charger and account for the many important considerations in designing a stationary battery charger application. Understanding all the details and required information to properly size a battery charger will result in more efficient installations and less waste in terms of costs at inception and energy use during the life of the installation.

## BIBLIOGRAPHY

1. David Linden, ed., Thomas B. Reddy, ed., "Handbook of Batteries" McGraw Hill Publishing, New York, New York 2002
2. IEEE Power Systems Committee, "IEEE Orange Book – IEEE Std 446-1987", IEEE, New York, New York 1992
3. IEEE Power Engineering Society, "IEEE Std 946-2004 – IEEE Recommended Practice for the Design of DC Auxiliary Power Systems for Generating Stations ", IEEE, New York, New York 2005
4. National Electrical Manufacturers Association, "NEMA Standards Publication PE5 - 1996", NEMA, Rosslyn, Virginia 1997