C&D TECHNOLOGIES

Constant Voltage Charger Selection for VRLA Batteries

Please Note: The information in this technical bulletin was developed for C&D Dynasty 12 Volt VRLA products. While much of the information herein is general, larger 2 Volt VRLA products are not within the intended scope.

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INTRODUCTION

For optimum system cost and performance the battery and charger should be specified as a system. Not only does the charger capability determine the recharge time required but it also has a significant impact on the service life of the battery.

Typically, other than cost, the time required to recharge a battery is the major concern of the battery system user. The recharge time required will be a direct function of the output voltage and current capability of the charger, depth of discharge of the battery and the battery temperature. Utilizing a higher charging voltage or greater charging current capability can be correctly assumed to reduce the recharge time required to attain the desired state of charge. However, higher recharging voltage and current availability may also have a negative impact on battery service life. Other important considerations in the charger selection relate to the battery's tolerance for AC ripple voltage present on the charger DC output and the limitations of any critical load connected in parallel.

Therefore, the selection of the charger must consider the characteristics and limitations of the battery and any parallel connected load as well as the desired recharge time and charger cost.

Charging Current Acceptance

A profile of battery current acceptance and charger output voltage during a typical recharge is illustrated in Figure 1. This profile will vary depending on the depth of the preceding discharge and the charger output characteristics. In general however, that period known as the "bulk phase" takes the battery to approximately an 85% to 90% state of charge (SOC) while the so called "absorption phase", with declining current acceptance, takes the battery to a 95% SOC. The last 5% of capacity is restored during what is called the "float phase". Due to the very low current acceptance during this "float phase" an extensive period of time is required to attain the necessary ampere hours of recharge to reach a 100% SOC.

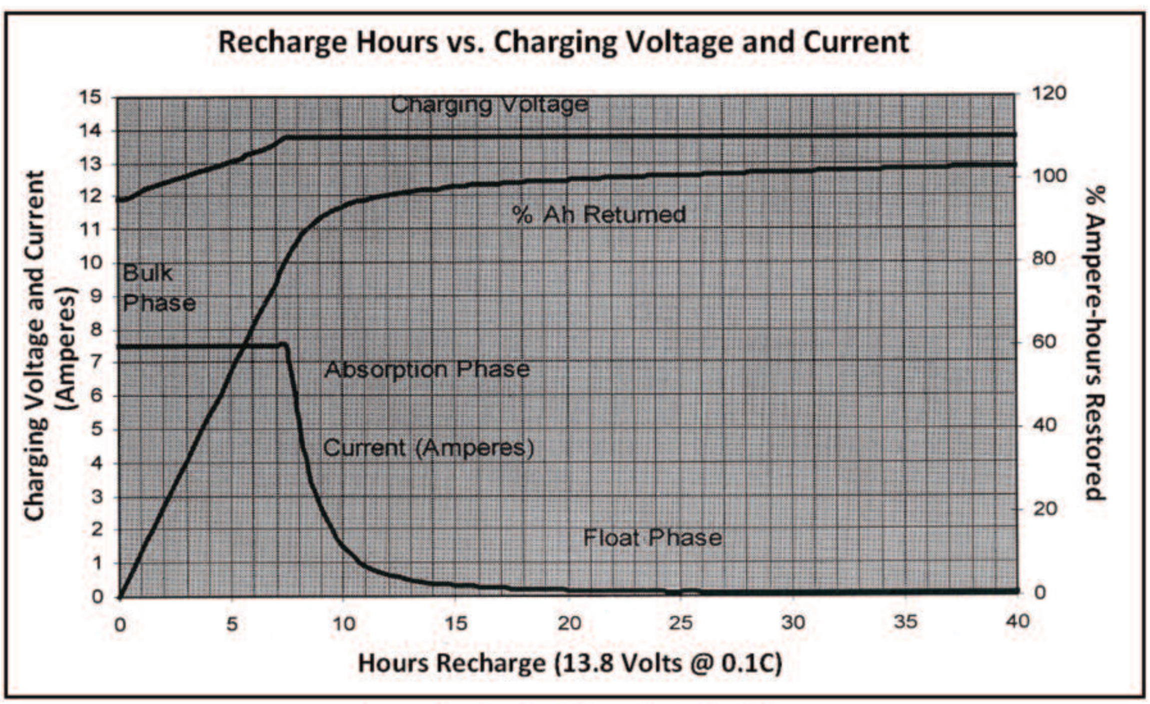

Figure 1 - Typical Charging Profiles

Recharge Time

The VRLA battery has internal resistance and other characteristics such that it is not 100% efficient during discharge or recharge. As a result, to attain a 100% state of charge (SOC) it requires that the battery be recharged with about 110 Ampere hours for every 100 Ampere hours removed during the discharge. Due to the relatively low charging current acceptance of the battery once it has attained approximately a 90% state of charge, the time to attain a 95% or 100% state of charge is greatly extended. Note in Figure 2 that it requires 4 times as long to reach 100% SOC as it does to reach 90% SOC.

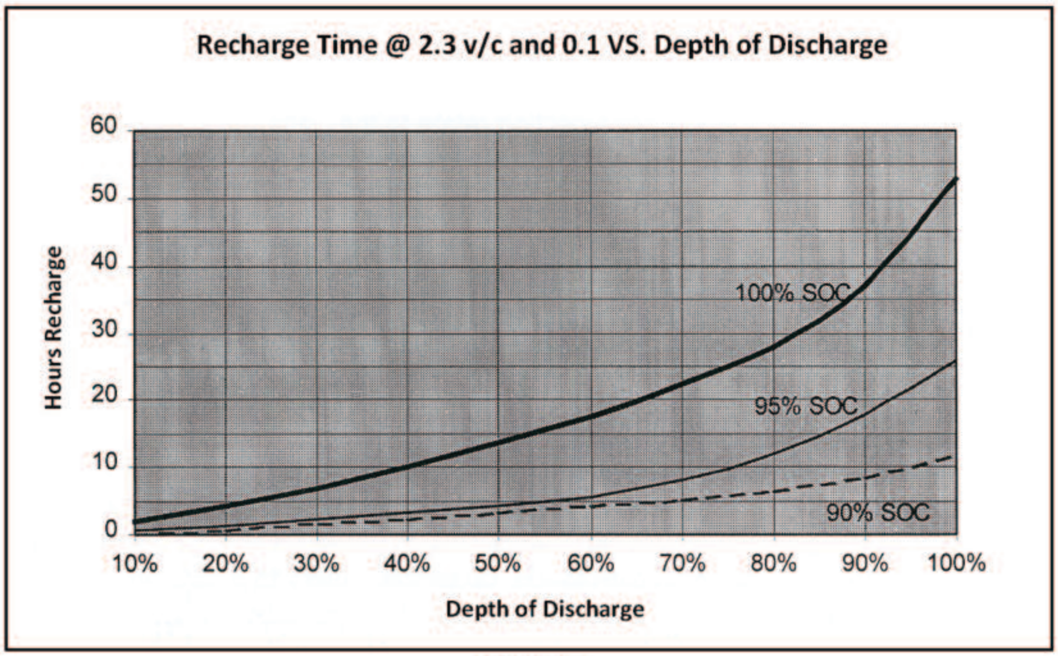

Figure 2

Attainment of 100% SOC requires an inordinate amount of time, as shown in Figure 2. It is usually most practical size the charger to provide for 90% to 95% SOC and then oversize the battery by 5% to 10% to assure it can deliver the required autonomy following a reasonable recharge period.

CHARGER RECOMMENDATIONS AND OUTPUT LIMITATIONS

Selection of the appropriate charging system for the battery will typically be a function of the cost and bulk of the charger and battery performance in terms of recharge time and service life. The charger selected for a cyclic application is typically lower capacity, less sophisticated and less costly than the charger/rectifier utilized in a float service application. In the case of float service applications such as for UPS and telecommunications systems, the requirements of the critical load will also be a major factor in the charger/rectifier selection because the critical load may have more stringent voltage regulation and purity requirements than the battery itself.

There are several characteristics that the VRLA battery charger should posses regardless of the application and these would include:

1. AC input circuit breaker
2. AC input voltage of nominal +/- 10% capability
3. DC output circuit breaker or fuse
4. Charger/charging status indicator(s)
5. Output short circuit protection
6. Over voltage alarm/disconnect feature
7. High temperature alarm/disconnect feature
8. Output voltage and current monitoring
9. Diode isolation of the charger output from the load

Charging Voltage Limitations

The voltage at which the battery is charged is critical to recharge time, performance and service life. The minimum charging voltage required to fully recharge a lead acid battery is a direct function of the electrolyte specific gravity (SG) which determines the fully charged open circuit voltage (OCV) of the cell. The VRLA batteries have an electrolyte specific gravity from 1.280 to 1.325 and the recommended charging voltages are as noted in Table 1.

VRLA Series	Electrolyte Specific Gravity	Recommended Float Voltage/Cell	Recommended Equalization Voltage/Cell	Recommended Cycle Service Voltage/Cell
TEL	1.300 (AGM)	2.26 to 2.30 v/c	2.40 to 2.47 v/c	Not Rec.
UPS	1.310 (AGM)	2.26 to 2.30 v/c	2.40 to 2.47 v/c	Not Rec.
VRS	1.300 (AGM)	2.26 to 2.30 v/c	2.40 to 2.47 v/c	2.40 to 2.47 v/c
DCS	1.300 (AGM)	2.26 to 2.30 v/c	2.40 to 2.47 v/c	2.40 to 2.47 v/c
SGC	1.300 (AGM)	2.26 to 2.30 v/c	2.40 to 2.47 v/c	Not Rec
BBG	1.325 (GEL)	2.26 to 2.30 v/c	2.35 to 2.40 v/c	Not Rec
BBA	1.300 (AGM)	2.26 to 2.30 v/c	2.35 to 2.40 v/c	Not Rec

Table 1 - Recommended Charging Voltage Per Cell

Exceeding the recommended charging voltages will result in excessive electrolysis of the water in the electrolyte, gassing, dryout and premature wear out of the battery plates.

Using less than the recommended float voltage will result in the inability to bring the battery to a full state of charge, following discharge, resulting in residual lead sulfate remaining in the plates and declining capacity with successive cycles. The impact of improper float charging voltage on service life is noted in Figure 3.

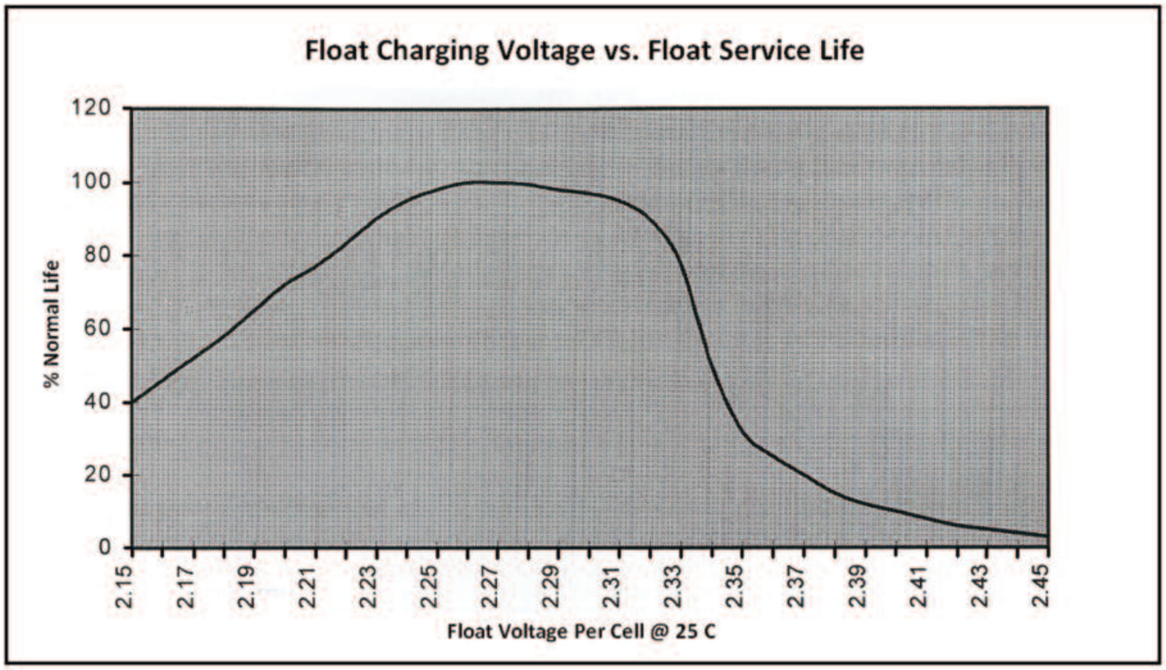

Figure 3

Battery Charging Current Limitations

The required output current capability of the charger is typically determined per the equation;

$$I_C = \frac{Ah_R \times K_x}{T_R}$$

Where:
- I_C = Required charger current available in amperes
- Ah_R = Ampere hours removed during the discharge
- T_R = Recharge time desired in hours
- K_x = A constant determined as a function of the charging voltage, battery depth of discharge (DOD) and attainable recharge times to specific states of charge (SOC).

The battery has an internal resistance (R_i) and as charging current (I) passes through the battery, heat will be generated as a function of the square of the current multiplied by the internal resistance of the battery (watts = I^2R_i). There is additional heat generated as a result of the exothermic oxygen recombination cycle, which occurs at the negative plate of the VRLA battery. With high current availability, deep depth of discharge (DOD) and higher charging voltages the duration of the high charging current may be such as to cause the battery to become excessively warm. To maintain battery heating below a 10°C (18°F) temperature rise during recharge, the charging current availability should be limited to the recommendations noted in Table 2. These recommendations reflect both the rate and depth of discharge of the battery being recharged.

Maximum Rate Discharge Period to End Point Voltage	Approximate % Depth of Discharge Relative to 20 Hour Rated Capacity	Recommended Charging Current Limit Relative to Battery 20 Hour Rated Capacity
15 Minute	45%	C_{20}/1 (100 amps per 100 AH)
30 Minute	55%	C_{20}/2 (50 amps per 100 AH)
1 Hour	60%	C_{20}/3 (33 amps per 100 AH)
3 Hour	75%	C_{20}/4 (25 amps per 100 AH)
8 Hour	90%	C_{20}/5 (20 amps per 100 AH)
20 Hour	100%	C_{20}/6 (17 amps per 100 AH)

Table 2 - Recommended Maximum Charging Current (I_c) vs. Depth of Discharge

Battery Charging AC Ripple Voltage and Current Limitations

When the DC charging voltage contains an AC ripple voltage (V_{rms}) component an AC ripple current (I_{rms}) will flow through the battery in addition to the normal DC charging current. Due to the low internal resistance (R_i)of the battery the resulting AC ripple current can be very large, up to 100 times as large as the DC float current, and result in significant heating ($I_{rms}{}^2R_i$) of the battery in float service applications. Since the battery service life is reduced by 50% for every 18°F (10°C) above it's rated operating temperature of 77°F (25°C) any long term increase in it's temperature should be avoided. The recommended charger output maximum allowable AC ripple voltage (V_{rms}) and current (I_{rms}) are noted in Table 3.

Application	Max. AC (RMS) Ripple Voltage	Max. AC (RMS) Ripple Current
Cycle Service Charger	1.5% of DC Charging Voltage	0.15C Amperes RMS (15 Amps RMS per 100 Ah capacity)
Float Service Charger	0.5% of DC Float Voltage	.05C Amperes RMS (5 Amperes RMS per 100 Ah of capacity)

Table 3 - Recommended Maximum AC Ripple Voltage and Current

CYCLE SERVICE CHARGER SELECTION

Typical battery cycle service applications are those where the battery supplies primary power for systems such as trolling motors, electric scooters, wheelchairs, robots and portable instrumentation, lighting or communications systems.

These chargers are typically of the SCR, ferro-resonate or magnetic amplifier type and have less regulation and minimal filtering of the output voltage. In these applications the battery is usually discharged to an 80% or greater depth of discharge at a relatively low average rate. It is Typically desired to recharge the battery as quickly as possible using a higher charging voltage. Following recharge of the battery the charger must be disconnected or the higher charging voltage switched to a lower float charging level to prevent permanent damage to the battery.

Table 4 presents recommendations related to the selection of a charger for cycle service application.

Charger Characteristic	Recommended Limitations				Comments
Fast Charge DC Voltage/Cell	2.45 v/c	2.4v/c	2.45 v/c	2.4 v/c	
DC Charging Amperes Available	0.2 C	0.2 C	0.1 C	0.1 C	.02C is the minimum recommended current availability
Recharge Hr. following the discharge cycle(s) totaling 90% DOD	7.2 to 95% 18 to 100%	10.2 to 95% 20.2 to 100%	10.3 to 95% 20.9 to 100%	10.6 to 95% 24.8 to 100%	
Switch to Float Voltage/Cell or Disconnect @ "X" D.C. Amperes Current Acceptance	10a. per Ah	5 ma. per Ah	10a. per Ah	5 ma. per Ah	0.005C at 2.4 v/c (5 ma. per Ah of rated capacity) 0.01C at 2.45 v/c (10 ma. per Ah of rated capacity)
Max. DC Charging Amperes Recommended	C/5 or 0.2 C				20 amperes per 100 Ah of rated capacity
Max. DC Float Voltage/Cell	2.3 v/c				2.25 to 2.30 v/c Range
% Charging Voltage Regulation	+/- 3% for "Fast" Charge Voltage +/- 1% for "Float" Charge Voltage				
Max. AC Ripple Voltage/ Cell	1.3% Vrms of "Fast" Charge Voltage 0.5% Vrms of "Float" Charge Voltage				Induces ripple current.
Max. AC Ripple Current/Cell	0.15 C During "Fast" Charge (15 A per 100 Ah) 0.05 C During "Float" Charge (5 A per 100 Ah)				Results in battery heating.
Max. Charging Temperature	-4°F to +122°F				
Float Voltage Temp. Compensation Factor	-0.0028 v/c per°f Min. = 2.17 v/c Max. = 2.50 v/c				Not normally required unless battery would remain on "float" for indefinite periods following recharge.

Table 4 - Cycle Service Charger Output Characteristics

When selecting a charger for a portable power (cycling) application it is necessary to determine:

1. Recharge time required
2. Ah removed from the battery
3. Ah rated capacity of the battery at the 20 hour rate
4. Depth of Discharge (DOD) (item 2 divided by item 3 x 100%)

With the above information, the output current required from the charger can be determined using Equation 1.

Equation 1 $$I_C = \frac{Ah_R \times K_x}{T_R}$$

Where:

I_C = Charger current available in amperes

AH_R = Ampere hours removed during the discharge

K_x = Empirically derived constant selected from Figures 8, 9 or 10 for attaining a 95% or 100% state of charge (SOC) at a specified recharge voltage per cell.

T_R = Recharge time desired in hours

For example, assume a 33 Ah battery will be 90% discharged and it is desired to recharge it at 2.4 v/c within 16 hours to 95% SOC. Keep in mind that the maximum recommended charging current in this case would be C/5 (0.2C) or 6.6 amperes in this case of a 33 Ah battery per Table 2.

Parameter	Value	Comment
Rated 20 hr. Capacity (C_{20})	33 Ah	VRS12-33IT
Ampere-hours Removed (Ahr)	29.7 Ah	90% x 33 Ah
Depth of Discharge (DOD)	90%	
Charging voltage	2.4 v/c	14.4 vdc for 12 volt battery
Recharge time in hours (Rt)	16 Hours	Desired
Recharge SOC	95%	Desired
K_{95}	2.25	Ref. Fig. 9 – 2.4v/c @ 0.2C

Refer to Figure 9 and note that K_{95} for 2.4 v/c would be 2.25 (@ 0.2C current limit). The charger required output current would then be calculated as:

Equation 1 $$I_C = \frac{Ah_R \times K_x}{T_R}$$

$$= \frac{(33 \text{ Ah} \times 90\%) \times 2.25}{16 \text{ Hr.}}$$

= 4.18 amperes minimum

An alternative I_c can be calculated utilizing the K_{95} from either Figure 8 or 10 for the 2.4 v/c at 0.1C current limit curve of 1.18.

$$= \frac{(33 \text{ Ah} \times 90\%) \times 1.18}{16 \text{ Hr.}}$$

= 2.19 amperes minimum

In this case, at 2.4 v/c, a charger with an output of between 4.2 and 2.2 amperes will be adequate to recharge the battery from 90% DOD to 95% SOC within 16 hours.

If the battery is to be frequently charged only to a 95% SOC it will be required that the battery be occasionally equalized or overcharged to assure 100% SOC and prevent the battery from "cycling down".

If the charger has the capability to recharge at 2.45 v/c, the above process should be repeated using this value in that it will be found that a charger with an even lower current output (and thus more economical) can be utilized.

Assume it is desired to recharge the battery to 100% SOC using 2.45 v/c in 16 hours without exceeding the maximum recommendation of I_c = 0.2C (6.6 amps in this case). The required charger output capability is calculated as follows:

Parameter	Value	Comment
Rated 20 hr. Capacity (C_{20})	33 Ah	VRS12-33IT
Ampere - hours Removed (Ahr)	29.7 Ah	90% x 33 Ah
% Depth of Discharge (DOD)	90%	
Charging voltage	2.45 v/c	14.4 vdc for 12 volt battery
Recharge time in hours (Rt)	16 Hours	Desired
Recharge SOC	100%	Desired
K_{100}	4.0	Ref. Fig.9 – 2.45v/c @ 0.2C

Using Figure 9 , the K_{100} is found to be 4.0 (at 0.2C current limit) and the charger current capability required is calculated as:

$$= \frac{(33\text{ Ah x }90\%)\text{ x }4.0}{16\text{ Hr.}}$$

= 7.43 amperes minimum

Note that 7.43 ampere requirement is greater than the 6.6 ampere (0.2C) maximum recommended. This indicates that the battery cannot be recharged to 100% SOC within 16 hours at the recommended rate. Therefore, if the maximum rate of 6.6 amperes is to be used, the recharge time to 100% SOC is determined as:

$$Rt = \frac{(33\text{ Ah x }90\%)\text{ x }4.0}{6.6\text{ Amperes}}$$

Rt = 18 Hours to 100% SOC

Once the battery is fully charged, the high rate charging voltage (greater than 2.3v/c) must be discontinued to prevent gassing and dryout of the battery. Rather than simply disconnecting the charger at the completion of recharge, the charger can be automatically switched to the lower float voltage. This voltage change should be initiated when the charging current acceptance has declined to .005 amperes per Ah of rated capacity at 2.40v/c or .01 amperes per Ah of rated capacity at 2.45v/c. In this case with a 33Ah battery, the switching point would be approximately 0.165 amperes at 2.4v/c and 0.333 amperes at 2.45v/c.

EMERGENCY LIGHTING CHARGER SELECTION

In emergency lighting systems the charger is used to maintain the battery in a state of readiness on float charge and to recharge the battery following a loss of utility power and operation of the emergency lights. The battery is not normally connected to the critical load (lights) so the charger output requirements are determined solely by the required recharge time and battery characteristics.

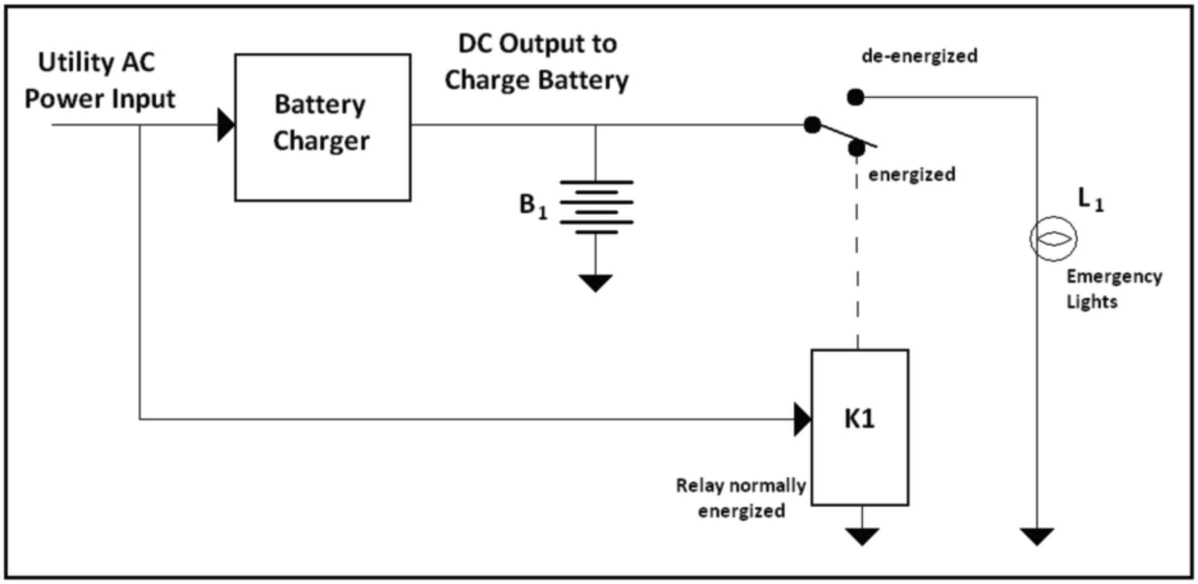

Figure 4 - Emergency Lighting System

Selection of a charger for emergency lighting purposes must consider not only the needs of the battery but also the requirements of the UL 924 (Emergency Lighting and Power Equipment) standard. While this standard does give minimum battery operating time (1.5 hours) for the emergency lights and maximum recharge time (168 hours) requirements for the battery it also specifies relevant safety, construction and performance criteria to assure personnel safety.

Table 5 provides recommendations for characteristics of the charger, which contribute to attaining the desired performance and service life from the battery.

Charger Characteristic	**Recommended Limitations**				**Comments**
Recharge Hr. to 95% SOC (assumes 65% DOD @ 90 min. rate)	4.9 Hr. 10 95% SOC	6.8 Hr. to 95% SOC	9.8 Hr. to 95% SOC	13 Hr. to 95% SOC	
DC Float Voltage Cell	2.3	2.3	2.25	2.28	2.25 to 2.3 v/c @ 77°F
DC Charging Amperes Available	0.2 C	0.1 C	0.2 C	0.1 C	C = Battery 20 Hr. Rated Ah Capacity
Max. DC Charging Amperes Recommended	0.3 C	0.3 C	0.3 C	0.3 C	(assumes 65% DOD@90 min, rate) C = Battery 20 Hr. Rated Ah Capacity
Min. DC Charging Amperes Recommended	0.02 C				2 amperes per 100 Ah of 20 Hr. rated capacity
DC Equalize Charge Voltage/Cell	2.4 volts/cell				Normally only used for 24 hours at time of installation
% Charging Voltage Regulation	+/ - 1% for "Float" Charge Voltage				
Max. AC Ripple Voltage/Cell	0.5% Vrms of Roe Charge Voltage				Induces ripple current.
Max. AC Ripple Current	0.05 C During Float Charge 5 Amps rms per 100 Ah				Results in battery healing.
Max. Charging Temperature	-4°F to -122°F				
Float Voltage Temp. Compensation Factor	-0.0028 v/c per˚F Min. = 2.17 vic Max. = 2.50 vic				Not normally required unless battery would remain on float for indefinite periods following recharge.

Table 5 - Emergency Lighting Charger Recommended Output Characteristics

Again, the minimum required charger output current could be calculated using Equation 1.

Assume that a 24 Ah battery will be discharged to a 65% DOD at the 90 min. rate and it is desired to recharge the battery to 95% SOC at 2.3 v/c within 24 hours.

Parameter	Value	Comment
Rated 20 hr. Capacity (C_{20})	24	UPS12-100MR
Ampere-hours Removed (Ahr)	16.9	24 Ah x 65%
% Depth of Discharge (DOD)	65% @ 90 min. rate	
Charging voltage	2.3 v/c	
Recharge time in hours (Rt)	24 Hr.	
Recharge SOC	100%	
K_{95}	1.05	From Fig.10 (0.1C @ 2.3 v/c)

The minimum required current would be calculated as:

Equation 1 $$I_C = \frac{Ah_R \times K_x}{T_R}$$

$$I_c = \frac{(26 \text{ Ah} \times 65\% \text{ DOD}) \times 1.05}{24 \text{ Hr.}}$$

I_c = 0.739 amperes

The value of 0.739 amperes is well below the recommended maximum of 7.2 amperes (0.3C) and above the recommended minimum of 0.02C of 0.48 amperes as noted in Table 5. There for a charger with an output that was current limited to between 0.7 and 7.2 amperes would be selected.

UPS CHARGER/RECTIFIER OUTPUT REQUIREMENTS

A UPS system may have a separate rectifier dedicated to recharging and maintaining the battery, similar to the arrangement shown in Figure 5 or the battery may be connected directly across the main rectifier in parallel with the inverter as shown in Figure 6. When selecting a rectifier/charger for use in a UPS system it should comply with the construction, performance and safety requirements as presented in standard UL 1778, titled Uninterruptible Power Supply Equipment.

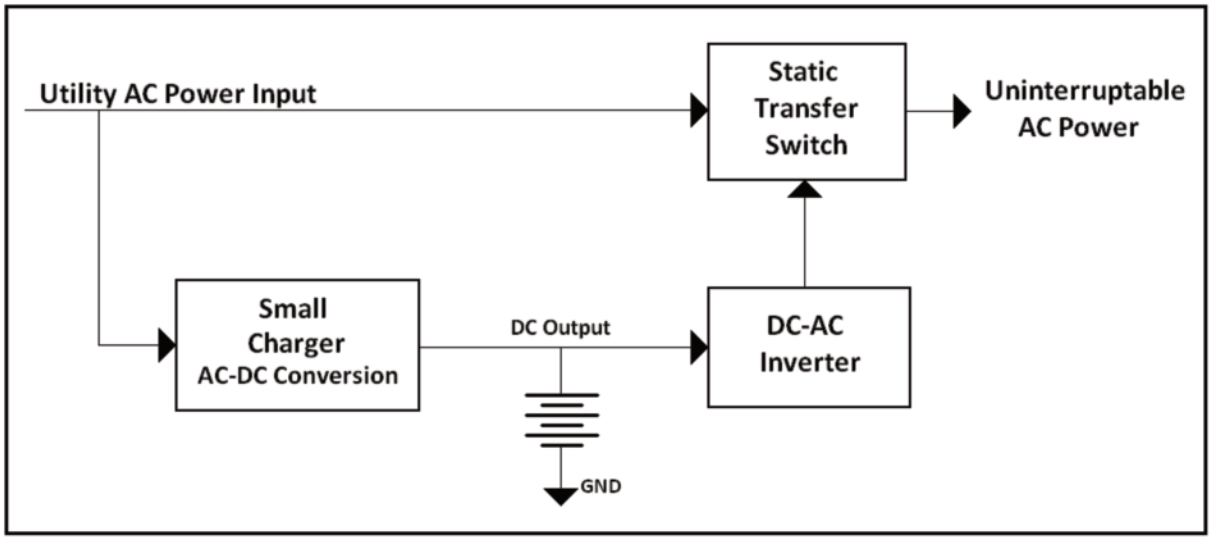

Figure 5

Naturally, when the battery utilizes the same output that is supplying the DC to AC inverter as shown in Figure 6, the rectifier must supply current adequate to power the inverter at full rated load in addition to recharging the battery. Consequently, when the UPS is not operating at full load , and the charging circuit does not have a separate regulator, more current is available to recharge the battery.

Excessive recharge current will result in reduced recharge time but will also result in potentially excessive heating of the battery. This should be considered when defining the charging system to be utilized as well as when sizing the battery.

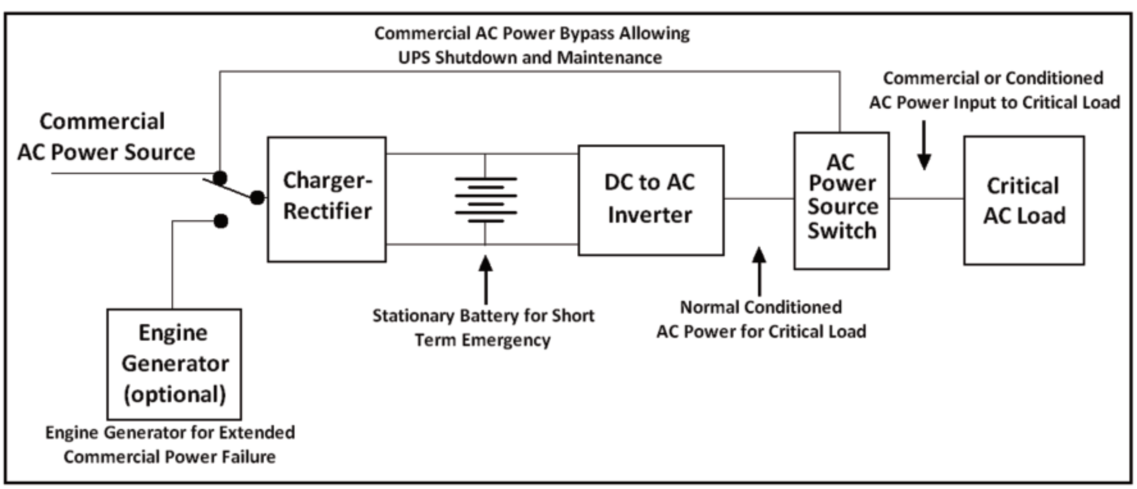

Figure 6 - On Line UPS System Block Diagram

Table 6 indicates the recommended characteristics for the charger output to attain 95% SOC.
To provide a second full length standby period (e.g. 15 minutes) at full load following a short recharge period (e.g. 90 minutes) it is recommended to oversize the battery by 5% or 10% rather than to increase the charging voltage and current availability. This will normally result in a less expensive charging system and less abuse of the battery.

Charger Characteristic	Recommended Limitations				Comments
DC Float Charge Voltage/Cell Recommended	2.3 v/c	2.3 v/c	2.3 v/c	2.3 v/c	Use of 2.4 v/c beyond the initial 1.5 hours is not recommended.
Charging Current Available	1.0 C	0.5 C	0.2C	0.1C	Max. 1.0C at 15 min rate discharge
Recharge Time to 95% State of Charge Following15 Min. Max. Rate Discharge to 45 % DOD	60 min	80 min	168 min	180 min	
Recharge Time to 95% State of Charge Following 30 Min. Max. Rate Discharge to 55% DOD	1.0 C not rec. for 55% DOD	130 min	228 min	312 min	Max. 0.5C at 30 min rate discharge
Max. DC Fast (Equalize) Charge Voltage/ Cell	2.4 v/c	2.4 v/c	2.4 v/c	2.4 v/c	Normally only used for 24 hr. at time of installation. Not recommended for more than 90 min. for fast recharge.
%Charging Voltage Regulation	+/- 1%				
Max. AC Ripple Voltage/ Cell	.5% Vrms of "Float" Charge Voltage				Induces AC ripple current
Max. AC Ripple Current	0.05 C During "Float" Charge 5 amperes per 100 Ah of capacity				Creates battery heating
Max. Charging Temperature	-4˚F to +122˚F				Recommended the charging source be disconnected from battery at 122˚F.
Float Voltage Temp. Compensation Factor	-0.0028 v/c per˚F Min. = 2.17 v/c Max. = 2.50 v/c				This is an important consideration when the battery is placed in an environment with wide temperature swings.

Table 6 - UPS Battery Charger Output Characteristics Recommendation

When sizing the rectifier/charger for a UPS system, keep in mind that it must be capable of supplying the requirements of the DC/AC inverter as well as the power to recharge the battery. For example, assume that a 60 KVA DC to AC inverter drew 53.3 kW at 240 VDC or approximately 222 amperes (53,300 watts/240VDC). The charger/rectifier would then have to provide 222 amperes plus that required to recharge the battery.

The battery sized to provide 15 minutes of autonomy for the inverter would be rated at approximately 130 Ah at the 20 hour rate and would be discharged to approximately a 40% DOD during the 15 minute discharge.

Parameter	Value	Comment
Rated 20 hr. Capacity (C_{20})	141 Ah	UPS12-490MR
Ampere - hours Removed (Ahr)	55.5 Ah	222 amps x 0.25 Hr.
% Depth of Discharge (DOD)	40%	
Charging voltage	2.3 v/c	
Recharge time in hours (Rt)	90 Minutes	
Recharge SOC	95%	
K_{95}	1.25	Fig.11 (0.5C to 95% SOC)

Assuming it was desired to recharge the battery to a 95% SOC within 90 minutes at 2.3 v/c, the charging current available would be calculated as:

$$I_c = \frac{AH_R \times K_x}{T_R}$$

I_c = 46.3 amperes charging current available or approximately 0.3C

Therefor the total charger/rectifier output capability should be approximately 222 amperes plus the 46 amperes required for charging for a total of 268 amperes. Notice that if the inverter were only operating at 75% of full load and drawing 167 amperes, there would be a total of 101 amperes (0.78 C) available for recharging the battery. As can be seen, as the load continues to be reduced, the recommended maximum charging current noted in Table 2 for the battery will be exceeded. For this reason, it is recommended that there be a separate current limiting capability for the battery charging function and that it be appropriately adjusted as a function of the UPS load and anticipated battery DOD.

Telecommunications Charger/Rectifier Output Requirements

Typically in telecommunications systems the battery is connected in parallel with the critical load at a power distribution point. The charger/rectifier then has to supply the power to not only the critical load but also to recharge the battery following a power outage. Naturally since the critical load and battery are sharing power, when the critical load is not demanding full load current, the excess current is available for battery charging. Again, while the additional available current may expedite the recharge process it may also abuse the battery resulting in reduced service life. A similar situation occurs when the charger/rectifier is sized for future growth or an additional rectifier is connected in parallel for improved reliability. This can result in excessive recharge current being available if the battery has been sized only with respect to providing the required standby time for the present critical load.

In these cases, a battery should be initially sized with respect to the battery load. An alternate battery should then be sized according to the charger output capability using 100 Ah of battery capacity per 20 amperes of charging current available (per Table 2). Then the larger of the two batteries should be utilized.

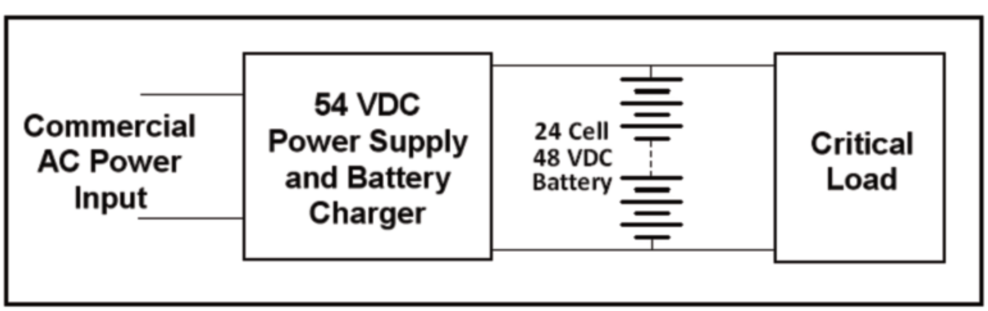

Figure 7 - Typical Telecommunication DC System Block Diagram

The following Table 7 summarizes the recommended characteristics for the charging output to the telecommunications battery system.

Charger Characteristic	Recommended Limitations				Comments
DC Float Charge Voltage/Cell	2.3 v/c	2.3 v/c	2.25 v/c	2.25 v/c	2.25 to 2.30 v/c Range@77°F
DC Charging Amperes Available	0.2 C	0.1 C	0.2 C		
Recharge Hr. Following an 8 hour discharge at the 8 hour rate to approximately an 88% DOD	12 Hr. to 95% SOC	17 Hr. to a 95% SOC	27 Hr. to 95% SOC	34 Hr. to a 95% SOC	
Max. DC Charging Amperes Allowable	C/4 (.25C) for 3 Hr. discharge rate C/5 (.2C) for 8 Hr. discharge rate				25 amperes per 100 Ah Rated Cap. 20 amperes per 100 Ah Rated Cap.
% Charging Voltage Regulation	+/- 1%				
Max. AC Ripple Voltage / Cell	.012 volts rms per cell				0.5% rms of float voltage-note that the telecom electronics may not allow this amount of ripple voltage.
Max. AC Ripple Current	C/20 or 0.05 C				5 amperes rms per 100 Ah of rated capacity
Max. Charging Temperature	-4°F to +122°F				Recommended the charging source be disconnected from battery at 122°F.
Float Voltage Temp. Compensation Factor	-0.0028 v/c per°F Min. = 2.16 v/c Max. = 2.5 v/c				This is an important consideration when the battery is placed in an environment with wide temperature swings.

Table 7 - Telecommunications Rectifier/Charger Recommended Output Characteristics

In the typical telecommunications system the rectifier/charger is required to have excellent filtering to eliminate any AC ripple voltage that would degrade the performance of the critical load . In addition, the battery is always in parallel with the load and supplies an additional degree of filtering of the rectifier output during normal operation. One "rule of thumb" specifies that the battery capacity in Ahs should be at least four times greater than the available charging current to assure adequate filtering of the rectifier output to the critical load. Since the load and battery are in parallel any rectifier output capability not being demanded by the load is then available to recharge the battery. The minimum current required to recharge the telecommunications battery is calculated in much the same manner as was used to size the required charging current for a battery in a UPS application.

For example, assume that a telecommunications load requires an average of 20 amperes and it is desired to provide 5 hours of autonomy. It is furthered desired to recharge the battery, following the 5 hour discharge, to 95% SOC within 24 hours at 2.25 v/c.

The battery required to provide the 5 hour 20 ampere capability would be rated at approximately 115 Ah at the 20 hour rate. The DOD would then be :

$$\frac{100\% \times (20 \text{ Amps} \times 5 \text{ hr})}{115 \text{ Ah}} = 87\% \text{ DOD}$$

Parameter	Value	Comments
Rated 20 hr. Capacity (C_{20})	115 Ah	
Ampere-hours Removed (Ahr)	100 Ah	20 Amperes x 5 Hr.
% Depth of Discharge (DOD)	87%	100 Ah/ 115 Ah= 0.87
Charging voltage	2.25 v/c	
Recharge time in hours (Rt)	24 Hr.	
Recharge SOC	95%	
K_{95}	6.5	Fig. 10 (0.2C @ 2.25 v/c)

The rectifier charging current capability required would be calculated as:

$$I_c = \frac{AH_R \times K_x}{T_R}$$

$$= \frac{(20 \text{ amperes} \times 5 \text{ hours}) \times 6.5}{24 \text{ Hours}} \qquad (K_{95} \text{ from 2.25 v/c 0.2C curve in Fig.10})$$

= 27.1 amperes available for battery recharging.

There for the rectifier output should be capable of a total of 27.1 amperes (recharging current) plus 20 amperes (critical load current) or 47.1 amperes. Normally one 50 ampere rectifier or two 25 ampere rectifiers in parallel would be used to supply these requirements. When an n+1 reliability philosophy is employed with respect to the rectifiers it is recommended that 2+1 of the 25 ampere rectifiers be utilized so as to minimize the total current available. In this case, with the n+1 philosophy, the current available to recharge the battery would be 55 amperes (75 - 20) and this exceeds the 0.2C limit recommended for these longer duration discharges. Therefor, it is advised in this case that the battery capacity (C) be increased from 115 Ah per Equation 2.

Equation 2: $I_c = 0.2\ C$

55 amperes = 0.2 C

55 amperes = 275 Ah minimum capacity

At this time it would be beneficial to repeat the sizing problem using a charging voltage of 2.3 v/c with a current limit of 0.1C. It will be found that a lower current less expensive charger can be used at the higher charging voltage and still meet the recharge time requirements.

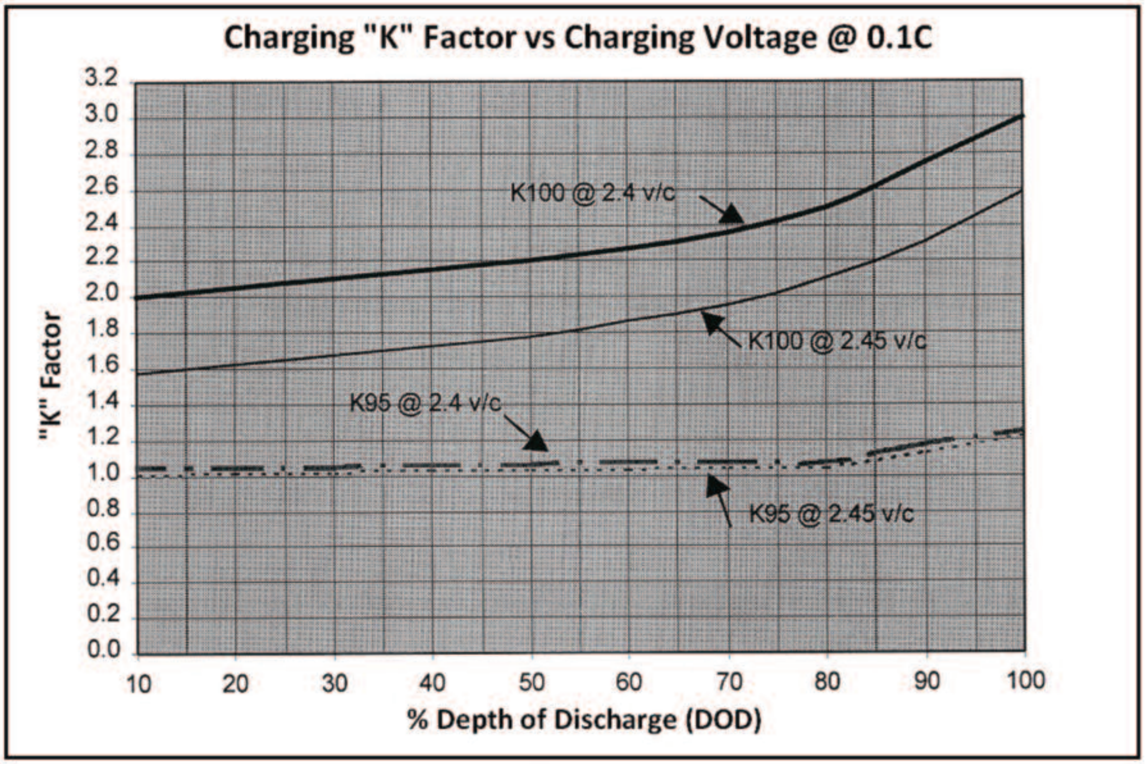

Figure 8

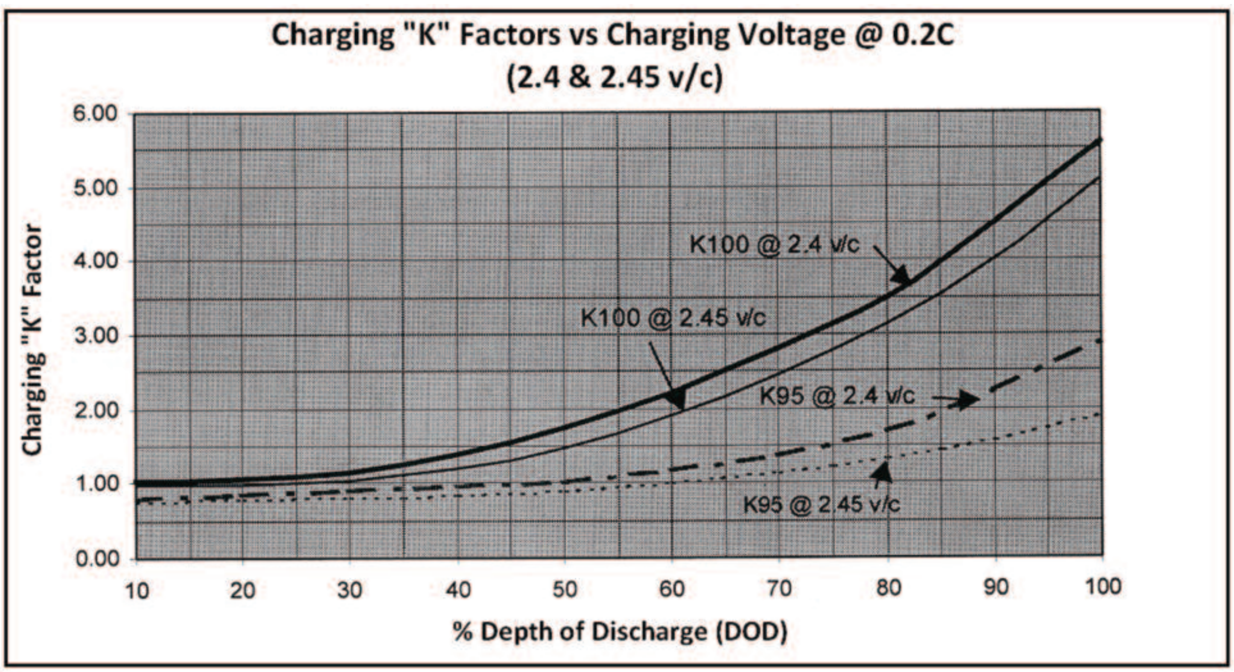

Figure 9

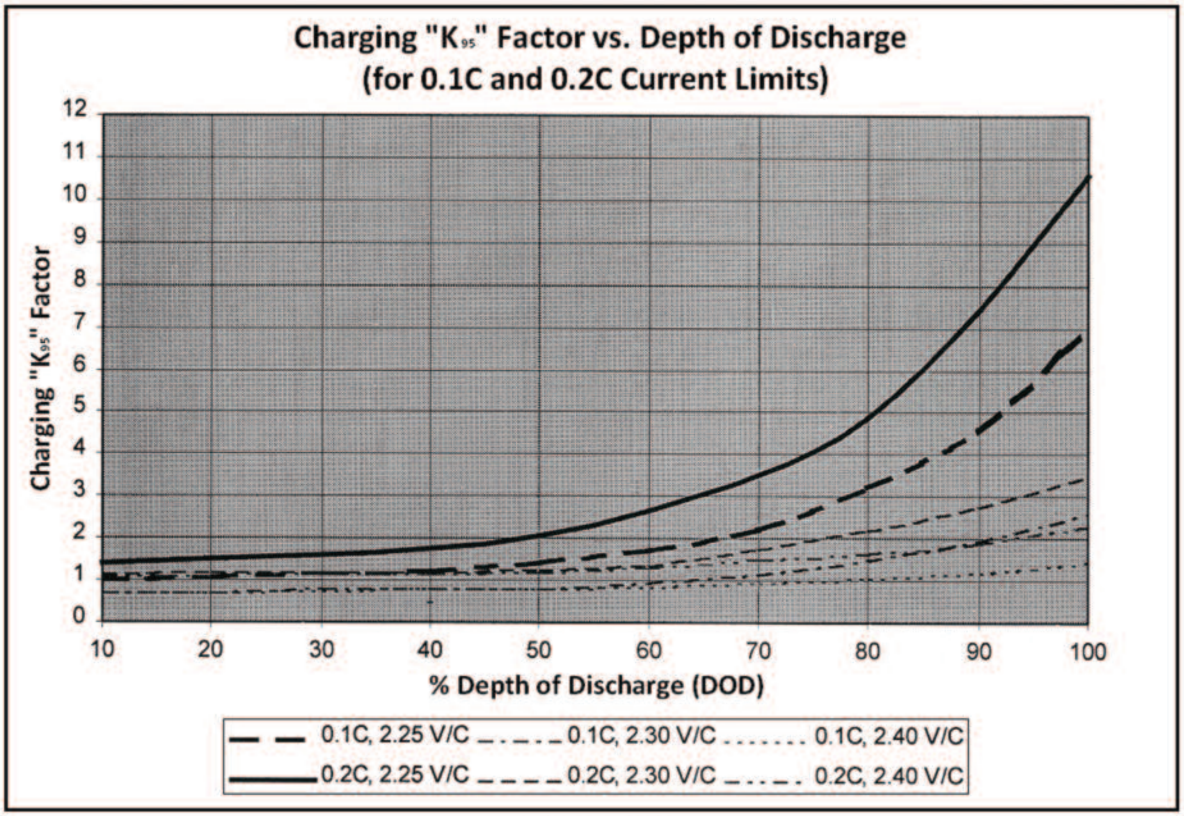

Figure 10

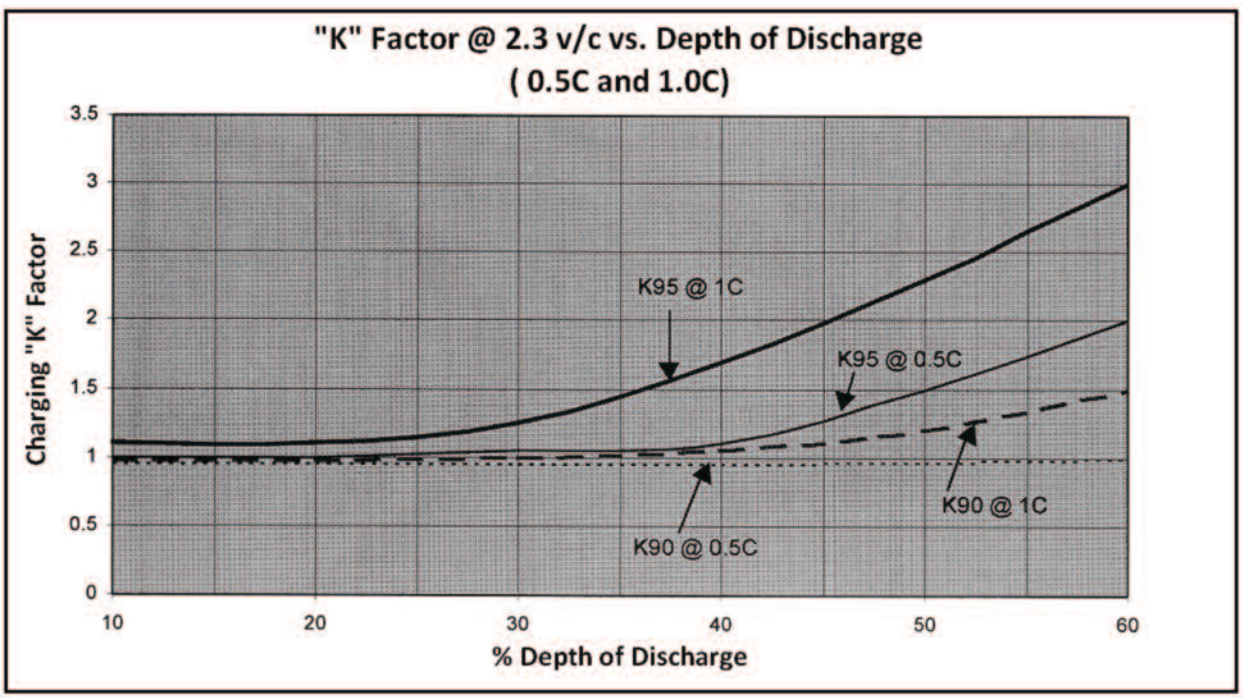

Figure 11

Summary

When selecting a charger, it should contain those characteristics, which assure the personal safety of the operator as well as the safety of the equipment in the application. Consideration should also be given to those features of the charging system that provide for automatic monitoring of the system performance and batteries.
When calculating the charger required current availability , Equation 1 should be used

Equation 1 $$I_C = \frac{Ah_R \times K_x}{T_R}$$

If the required current (I_C) is greater than that recommended for the battery application in Table 2, consider one or more of the following:

1. size the battery based on the charger output (e.g. 100 Ah battery per 20 amperes I_C)
2. oversize the battery such that a lower SOC (e.g. 90% or 95%) is required to provide the required autonomy
3. increase the allowable recharge time

This will result in extended run time during standby operation and cooler batteries during recharging.
To calculate ampere-hours removed during a constant current discharge it is simply the ampere load multiplied by the duration of the load in hours.
When the ampere-hours removed must be calculated for a constant power load it can be calculated as:

"X" Ahr = (watts per cell/average v/c) x hours discharge duration

C&D TECHNOLOGIES, INC.
1400 Union Meeting Road
P.O. Box 3053 • Blue Bell, PA 19422-0858
(215) 619-2700 • Fax (215) 619-7899 • (800) 543-8630
customersvc@cdtechno.com
www.cdtechno.com