Deka

SOLAR

PHOTOVOLTAIC BATTERIES

Renewable Energy Technical Manual

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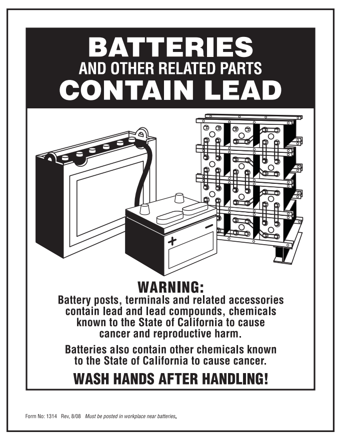
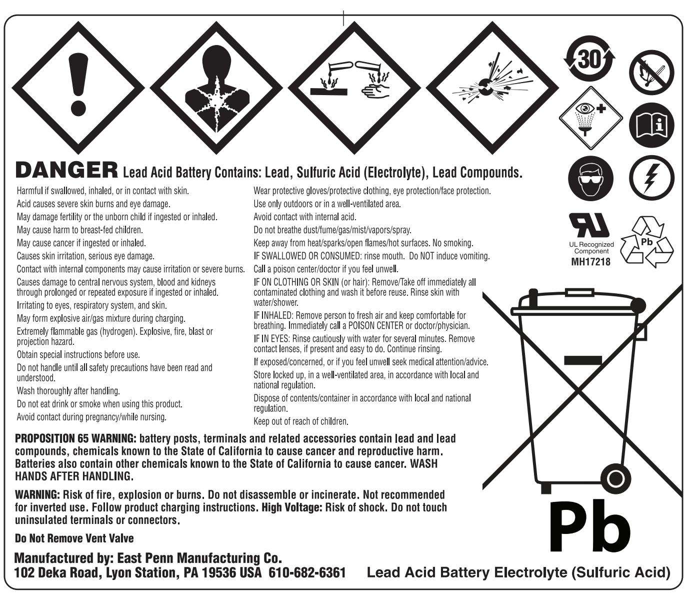
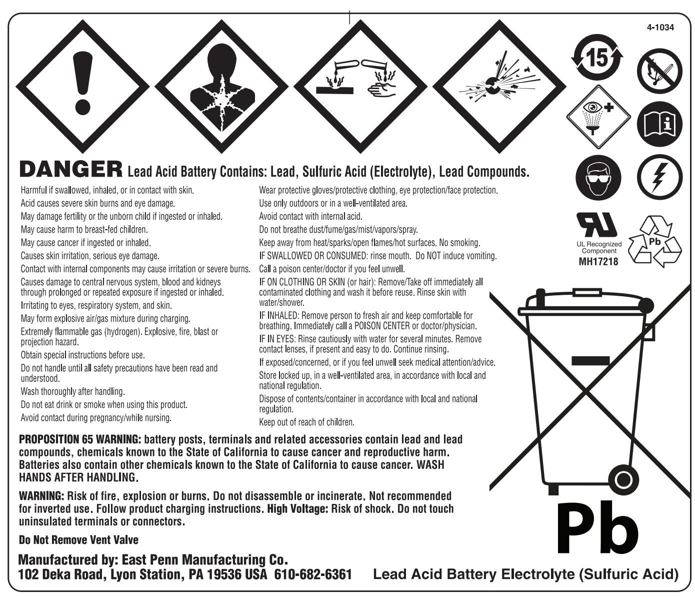


PROPOSITION 65 WARNING: Battery posts, terminals and related accessories contain lead and lead compounds, chemicals known to the State of California to cause cancer and reproductive harm. Batteries also contain other chemicals known to the State of California to cause cancer. **WASH HANDS AFTER HANDLING.**





Renewable Energy applications that depend on battery power as part of the system operation must be at maximum performance at all times. To ensure this high rate of performance is achieved, the battery charging system must be set properly. A battery/battery bank that is undercharged or overcharged will affect the battery system performance & life, as well as the performance of the entire system.

Key factors that affect a batteries ability to provide the capacity and long life that is expected are: System Design, Storage, Temperature, Depth of Discharge (DoD), Charging and Maintenance.

SYSTEM DESIGN

Systems Design is the process of defining the architecture, components, modules, interfaces, and load data for a system to satisfy specified requirements. For a solar system these components are the PV modules, inverter/charge controller & batteries, as well as the different interfaces of those components.

To properly size a battery/battery bank for a renewable energy system the following parameters are required:

Load – Amount of DC current (Amps, Ah) or power (Watts, Wh) a battery is required to supply to a DC load, AC load or both through an inverter.

Time – expressed in hours the battery will be required to provide the load.

System Voltage – DC system operating voltage

Ambient Temperature – Average temperature of battery room or enclosure.

Depth of Discharge (DoD) – The proportion of energy that has been removed from a battery; typically in a 24hr period

Example: 100% DoD is removing all of the energy from a battery.

Autonomy – Length of time, typically in days the PV battery bank can provide energy to load without energy from PV array, generator, grid, etc…

Design Margin - Factor (typically expressed as a percentage) to allow for future load additions.

A Renewable Energy Worksheet is provided in Appendix A listing the above requirements along with additional information requirements

BATTERY OPERATION

There are several factors that affect the operation of the battery concerning its ability to deliver capacity and life expectancy.

Storage

Cells should be stored indoors in a clean, level, dry, cool location. Recommended storage temperature is 0°F to 90°F (–18°C to 32°C).

Consult specific battery Installation & Operating manuals for time interval & boosting requirements.

Temperature

Many chemical reactions are effected by temperature, and this is true of the reaction that occurs in a storage battery. The chemical reaction of a lead-acid battery is slowed down by a lowering of the electrolyte temperature that results in less capacity. A battery that will deliver 100% of rated capacity at 77° F will only deliver approximately 65% of rated capacity at 32°F.

At temperatures below 32°F (0°C) a battery can freeze dependent on the DoD (Depth of Discharge). The higher the DoD, the closer to 32°F (0°C) before the battery will freeze. The graph in Appendix C should be consulted to verify the DoD of the battery / battery bank at the end of the discharge will not be susceptible to freezing in a particular application. If the electrolyte would freeze, the internal damage would be irreversible requiring the battery to be replaced.

Depth of Discharge (DoD)

Depth of discharge is a function of design. The deeper the discharge per cycle, the shorter the life of the battery. A cycle is a discharge and its subsequent recharge regardless of depth of discharge.

Systems should be designed for shallow discharges. The result of shallower discharges is typically a larger capacity battery at prolonged battery life.

A Cycle vs. DoD chart should be consulted to determine the number of cycles at a specific DoD and the projected life in years the battery / battery system will provide prior to needing replacement.

Charging

Majority of battery capacity/life issues can be traced to improper charging. Improper charging settings may lead to an overcharging or undercharging condition.

Typical Inverters/Charge Controllers charging lead-acid batteries use 3 stage charging: Bulk, Absorption and Float with an optional equalize stage. **See Appendix B for an example of a typical 3-stage charging curve.**

Inverter/Charge Controller Settings

Proper Inverter/Charge Controller settings are necessary to ensure peak battery performance and life. All bulk, absorption, float and equalize settings should be verified they are within the battery manufacturers settings. These settings are included but not limited to; voltage, current and time. Consult individual battery Installation & Operating manuals for inverter/charge controller setting recommendations. **Default settings should not be presumed to be correct.**

For battery systems located in an uncontrolled temperature environment, temperature compensation must be used.

Bulk

Current is applied to the batteries at the maximum safe rate they will accept until voltage rises to near (80-85%) full charge level. The battery voltage rises because the charging current that is provided by the battery charger is replenishing its

Bulk *continued*

internal charge capacity. The charger current is flat (constant) and the battery voltage is rising.

Maximum allowable charge voltage & current allowed by the battery manufacturer should be used to ensure the most energy is returned within the bulk stage.

Bulk Charge Stage Time Calculation:

Max Time (Hr) = (Ahr x 1.2)/Avg. Current (A)

Ahr = Amp hours removed during discharge.

1.2 = Recharge multiplier

Avg. Current = Average current available to battery from charger.

Note: Avg. current should be < maximum current limits for installed battery. Charge current limits available from your East Penn representative.

Max Time (Hr) – Maximum charge time for battery to reach 80% - 85% state of charge

Absorption

The charger will attempt to hold its output voltage constant while the battery continues to absorb charge (draw charging current) from the charger. The rate at which the battery continues to absorb charge in this mode gradually slows down. The amplitude of the charger current is gradually decreasing. The charge current is falling and the battery voltage is flat (constant).

Some Inverter/Charge Controllers can either use time or current to determine the length of the absorption stage.

Time regulated absorption is based on a predetermined time after the battery has completed the bulk stage (charge voltage has reached its maximum set point). A lead-acid battery is said to be at 80% to 85% SOC (State of Charge) when the voltage set point is met and the current starts to taper; considered the start of absorption. The remaining time required to reach 100% SOC is based on ever changing factors: solar isolation (summer vs. winter), ambient temperature, battery type (flooded, VRLA), and battery age.

Absorption stage time should be set to optimize the available sun hours during the winter and/or cloudy months. If improperly set, there is a risk of undercharging the battery system.

It is recommended to set the absorption time to the maximum time setting possible to take advantage of all available charging light regardless of time of year or weather issues. Using this method, the sun availability will determine the absorption time. Following this recommendation, there is no risk of overcharging if the battery charge voltage is set within the recommended settings.

The amount of available power (current) to the batteries is important for getting a battery charged. Available power (current) to the batteries is the remaining power (current) after connected loads are satisfied. Maximum charge voltage and current allowed by the battery manufacturer should be used to ensure the most energy is returned to the batteries.

The below calculation will assist in identifying the necessary maximum charge current for the system. If the calculation shows the absorption time is greater than the minimum average peak sun hours for the installation location, the amount of available current to the batteries should be increased, which could be accomplished by a larger array or a secondary power source such as a generator.

Charge Current Verification:

FLOODED

C20 x 0.44/charge current available

Example:

<u>Maximum Charge Current</u>

Battery Rating: 1186Ah (C20)

237A – Charge current (maximum)

1186Ah x 0.44 / 237 = 2.20 hrs

<u>Minimum Charge Current</u>

Battery Rating: 1186Ah (C20)

118A – Charge Current (minimum)

1186Ah x 0.44 / 118A = 4.42 hrs

VRLA (AGM & GEL)

C20 x 0.39/charge current available

Example:

<u>Maximum Charge Current</u>

Battery Rating: 183Ah (C20)

55A – Charge current (maximum)

183Ah x 0.39 / 55A = 1.30 hrs

<u>Minimum Charge Current</u>

Battery Rating: 183Ah (C20)

18.3A – Charge Current (minimum)

183Ah x 0.39 / 18.3A = 3.90 hrs

Current regulated absorption is using the charge current to determine battery state of charge, which eliminates a majority of the variables previously mentioned with time based absorption (solar isolation, ambient temperature, battery type). Charging in constant voltage, when a battery/battery system reaches the absorption voltage setting the current will start to taper. The point at which the current stops tapering or declining is referred to as the stabilizing current. This is an indication that the battery is fully charged and the current the battery/battery system is drawing is only needed to keep the battery at the set voltage. This minimum or stabilizing current will change based on the charge voltage setting. Battery manufacturer should be consulted for current settings.

An additional option for determining the SOC of a battery is monitoring the Ah (amp hour) removed from a battery during a discharge and the amount of Ah returned during charge; similar to a gas gauge in a car. The Ah in and out should be monitored on a continuous basis to keep track of the overall SOC not just from day to day.

Float

The voltage at which the battery is maintained after being charged to 100% SOC (State of Charge) to maintain capacity by compensating for self-discharge of the battery.

Equalize

A charge, at a level higher than the normal float voltage, applied for a limited period of time, to correct inequalities of voltage, specific gravity, or state of charge that may have developed between the cells during service.

Note: Equalize charging not required on VRLA (AGM/Gel) as part of a daily charge setup. Based on PV applications, unpredictable recharge availability, periodic equalize may be required.

Equalize *continued*

Consult individual Installation & Operating Manuals for details on Inverter/Charger Controller settings to properly charge East Penn lead-acid batteries. A voltage range is provided because of equipment setting availability/limitations, however for optimal charge performance all setting should be at the highest setting of the battery range that the inverter/charge controller can handle.

Maintenance

IEEE (Institute of Electrical and Electronics Engineers) suggests batteries be checked on a monthly, quarterly and yearly basis. Each time period requires different checks. A maintenance log should be initiated at the time of installation.

Typical checks consist of voltage, specific gravity (not required for VRLA) and visual inspections. Periodic verification of voltages will ensure battery is being fully charged and operating properly. If any conditions are found that are out of specifications, corrections should be made.

A good battery maintenance program is necessary to protect life expectancy and capacity of the battery. **Reference IEEE 450 for Flooded batteries and IEEE 1188 for VRLA (Valve Regulated Lead-Acid) batteries.**

BATTERY LOCATION

When planning a battery system the following requirements should be considered:

- **Space**
- **Floor Preparation**
- **Battery Racking System**
- **Ventilation**
- **Environment**
- **Operating Equipment**

Space

It is recommended that aisle space be provided in front of all battery racks be a minimum of 36.0” (915mm). The design should meet all applicable local, state and federal codes and regulations.

Floor Preparation

It is recommended to consult with a structural engineer to determine if the existing floor will withstand the weight of the battery and the battery racking system. The floors in which the battery will be located should have an acid-resistant coating. Any battery spills should be neutralized with non-corrosive, water based neutralizing chemical (ex: baking soda/water solution) that is user safe and environmentally compliant.

The area should always be washed with clean water to remove any acid neutralizing chemical residue.

Battery Racking System

The battery should not be installed directly on a floor. There should be some type of barrier/racking between the floor and the batteries. This barrier/racking should be sufficient to handle the weight of the battery. The battery racking system must be suitably insulated to prevent sparking and eliminate any grounding paths.

Adequate space and accessibility for taking individual battery or cell voltage, hydrometer readings and adding water should be considered. If installed in an earthquake seismic zone, battery racking system must be of sufficient strength and adequately anchored to the floor. Battery rack design and anchoring should be reviewed by a structural engineer.

Ventilation

It is the responsibility of the installer to provide detailed methods or engineering design required by Federal, State and local regulations to maintain safe levels of hydrogen in battery rooms/enclosures.

The rate of hydrogen evolution is highest when the battery is on charge. Explosive mixtures of hydrogen in air are present when the hydrogen concentration is greater than or equal to 4% by volume. To provide a margin of safety, battery room/enclosure must be ventilated to limit the accumulation of hydrogen gas under all anticipated conditions. This margin of safety is regulated by Federal, State and Local codes and is typically limited to 1% to 2% by volume of the battery room/enclosure.

Consult all applicable codes to determine specific margin of safety. Hydrogen gas calculations can be determined by using proper formulas.

Hydrogen gas is lighter than air and will accumulate, creating pockets of gas in the ceiling. The ventilation system should be designed to account for and eliminate this situation. Ventilation system must be designed to vent to the outside atmosphere by either natural or mechanical means in order to eliminate the hydrogen from the battery room/enclosure.

Environment

Batteries should be located in a clean, cool and dry place and isolated from outside elements. The selected area should be free of any water, oil and dirt from accumulating on the batteries.

Operating Equipment

Battery systems are sized based on a specific load (Amps or Watts) for a specific run time to a specific end voltage. Battery performance is based on these values, as measured at the battery terminals.

For proper operation of the battery system the following should be considered:

- Distance between battery system and operating systems should be kept at the shortest distant possible.
- Cables are to be of proper gauge to handle system loads and minimize voltage drops.
- All cable lengths from battery system to operating system should be of the same wire gauge and length.

The above is to ensure the battery cable used will be able to carry the charge/discharge current & minimize the voltage drop between equipment.

Electrical equipment should not be installed above the batteries, because of the possibility of corrosive fumes being released from the battery(s).

Series/Parallel Wiring

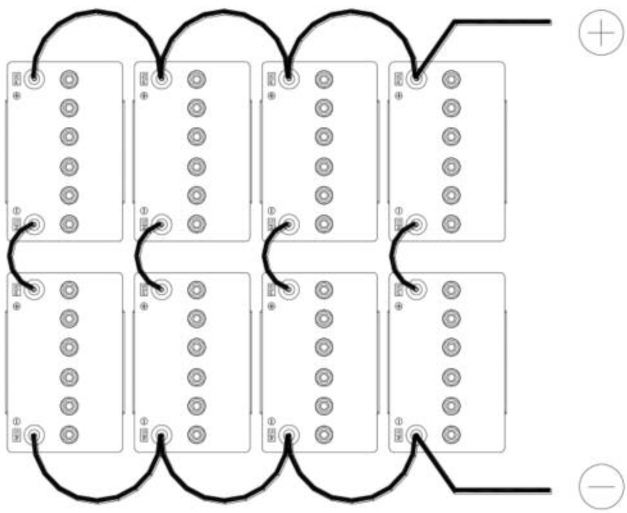
Series and parallel wiring of batteries as well as battery to inverter/charge controller wiring should be designed to minimize voltage drop. Wire gauge, wire length as well as interbattery connection layout are all variables in reducing voltage drop as well as providing battery balance between parallel battery strings.

Proceeding are examples of common wiring layouts with narrative of the advantages and / or disadvantages of each.

Series/Parallel Wiring *continued*

Daisy chain wiring

A wiring scheme in which multiple devices are wired together in sequence. All interconnecting wiring should be of same length to minimize voltage drop.

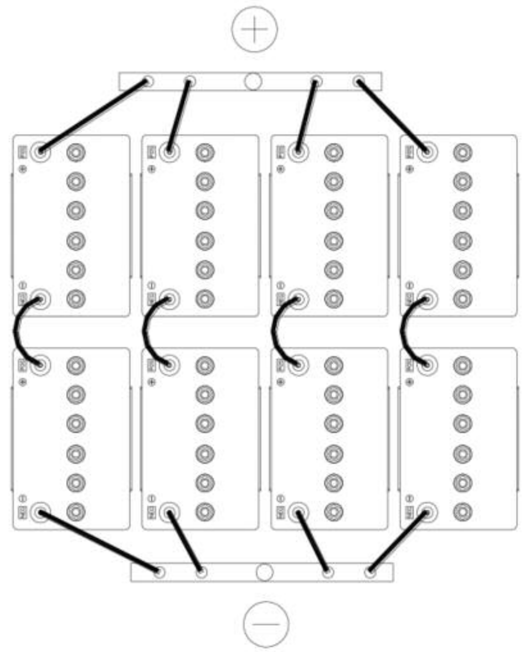


Disavantages:

- The interunit cables are required to increase in gauge size to accommodate the increase in current of each connected string.
- Maintenance and battery diagnostics require the entire battery system to be disconnected from the renewable energy system, leaving no back up energy source.
- Wiring connection assessment difficult to follow with multiple wirings connected to same battery terminal, increasing chance of re-connection wiring errors.

Common bus wiring

A wiring scheme in which same polarity terminals are connected to a single termination point. All interconnecting wiring should be of same length to minimize voltage drop.



Advantages:

- Cables can be of same gauge.
- Maintenance and battery diagnostics can be performed on a single string while maintaining a level of back up energy source from the other strings staying connected to the renewable energy system.
- Wiring connection assessment simplified by single point cabling reducing re-connection wiring errors.

GLOSSARY:

AGM – Absorbed Glass Mat – A class of VRLA (Valve Regulated Lead-Acid) battery in which the electrolyte is absorbed into a glass mat.

Ambient Temperature – The average temperature of the battery room. Temperatures below 77°F (25°C) will reduce battery capacity. Temperatures above 77°F (25°C) will reduce battery service life.

Amp Hour (Ah) – Amps times Hours

Battery Efficiency – The amount of Ah return required to achieve full SOC vs. the amount of Ah removed during discharge. Require 110% to 115% Ah return.

Capacity – The capacity of a battery is specified as the number of Amp-Hrs that the battery will deliver at a specific discharge rate and temperature. The capacity of a battery is not a constant value and is seen to decrease with increasing discharge rate.

C20 – Battery capacity measured in Ah (amp hour) at the 20hr rate.

End Voltage – The minimum voltage at which a DC system will operate.

Flooded – A battery in which the products of electrolysis and evaporation are allowed to escape to the atmosphere as they are generated. Electrolyte is free flowing throughout the battery.

Gel – A class of VRLA (Valve Regulated Leda-Acid) battery in which the electrolyte is immobilized in a gel form (sulfuric acid mixed with silica).

Parallel – A circuit that provides more than one path for the flow of current. A parallel arrangement of batteries (usually of like voltages and capacities) has all positive terminals connected to a conductor and all negative terminals connected to another conductor. If two 12-volt batteries of 50 ampere-hour capacity each are connected in parallel, the circuit voltage is 12 volts, and the ampere-hour capacity of the combination is 100 ampere-hours.

Series – A circuit that has only one path for the flow of current. Batteries arranged in series are connected with negative of the first to positive of the second, negative of the second to positive of the third, etc. If two 12-volt batteries of 50 ampere hours capacity each are connected in series, the circuit voltage is equal to the sum of the two battery voltages, or 24 volts, and the ampere-hour capacity of the combination is 50 ampere-hours.

SOC (State of Charge) – The amount of deliverable low-rate electrical energy stored in a battery at a given time expressed as a percentage of the energy when fully charged and measured under the same discharge conditions. If the battery is fully charged the "SOC" is said to be 100%.

Temperature Correction – A factor used to compensate for battery capacity and/or adjust battery voltage at ambient temperatures greater than or less than 77°F (25°C).

Undercharge (Deficit charge) – Charging a battery with less ampere-hours (Ah) than is required to return the battery to its initial state-of-charge. This results in a reduction in the battery state-of-charge.

VPC – Volts per Cell

VRLA – Valve Regulated Lead Acid – a lead-acid cell/battery that is sealed with exception of a valve that opens to the atmosphere when the internal gas pressure exceeds atmospheric pressure by a pre-selected amount. VRLA batteries provide a means for recombination of internally generated oxygen and the suppression of hydrogen gas evolution to limit water consumption.

APPENDIX A

Completing all parameters ensures accurate battery sizing.

Worksheet to be submitted to sales representative for battery recommendation.

RENEWABLE ENERGY WORKSHEET

Deka SOLAR

Date:

1 Company Name:
Address:
City, State, Zip Code:

2 Project Name & Description:

3 Nominal System Voltage (DC)

4 Days of Autonomy

5 Load Data
a. Total Load (Design Load):
b. Type of Load (AC or DC):
c. Number of Occurrences:
d. Duration of Each Occurrence:
e. Low Voltage Disconnect:
f. Inverter Efficiency:
g. Power Factor:

6 Array Size / Output (watts):

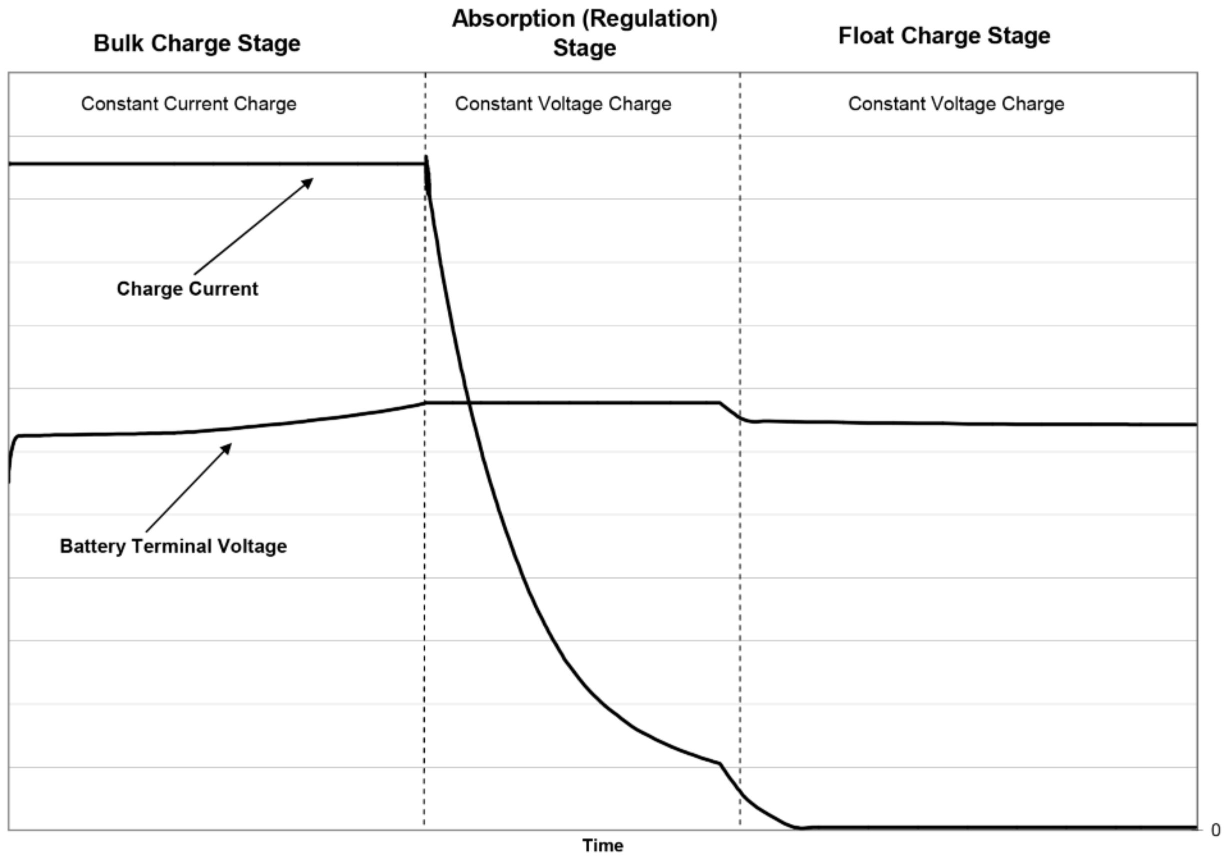
7 Recharge time in sun hours
Summer:
Winter:

8 Average Ambient Temperature
Summer:
Winter:

9 Battery Space Constraints:

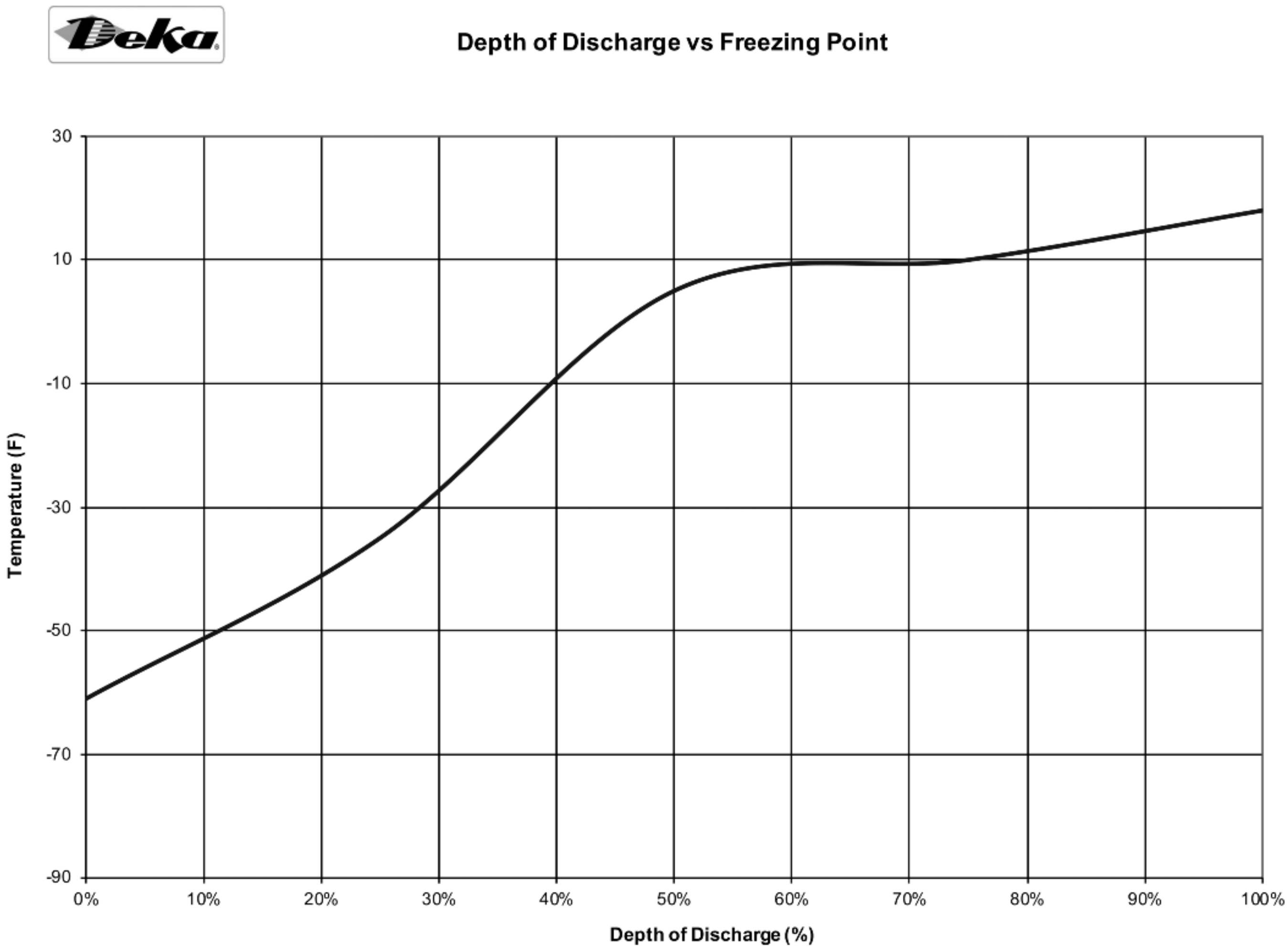
APPENDIX B

Example of typical 3 stage charger



APPENDIX C

Below graph is for general reference only. Consult specific battery Installation & Operating Manual for applicable graph.



QUALITY SYSTEM CERTIFIED ISO 9001 ISO/TS 16949
ENVIRONMENTAL SYSTEM CERTIFIED ISO 14001

UL Recognized Component

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