Deka®

SOLAR

PHOTOVOLTAIC BATTERIES

Monoblock VRLA System

Installation & Operating Manual

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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 or AC loads 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 PV system can provide energy to load without energy from PV array

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.

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 (25°C) 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.

Excessive heat will increase the natural corrosion factors of a lead-acid battery. This increase corrosion of the positive plates contributes greatly to reducing the overall life of the battery.

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

Example:

Consulting the chart in Appendix C; it indicates that at a 50% DoD, a battery is susceptible to freezing at -40°F (-40°C). To ensure the electrolyte will not freeze, the battery should be designed to limit the DoD to < 45%

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

Bulk *continued*

that is provided by the battery charger is replenishing its 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 following 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:

Example:

<u>Maximum Charge Current</u>

Battery Rating: 1186 (C20)

2374A – 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 (8A & 8G)

C20 x 0.39 / charge current available

<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 (8A & 8G) as part of a daily charge setup. Based on PV applications, unpredictable recharge availability, periodic equalize may be required.

Charge Controller/Inverter charge setting recommendations are detailed in System Operation section of this manual. 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 charge controller/inverter 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 1188 IEEE 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.

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.

Disadvantages:

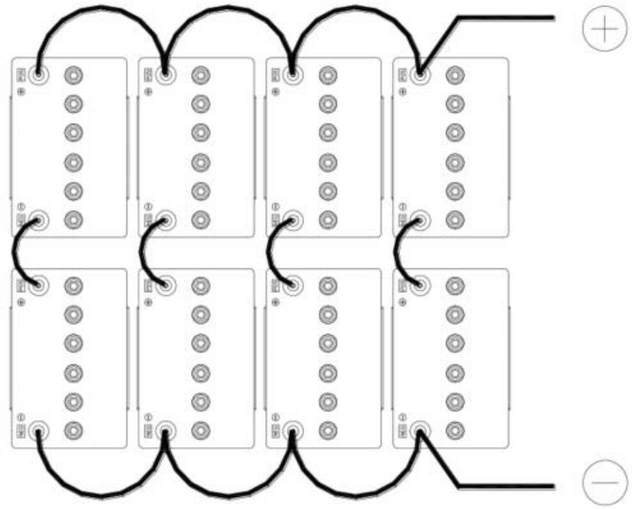
- The interunit cables are required to increase in gauge size to accommodate the increase in current of each connected string.
- Maintenance and battery diagnostics require the entire battery system to be disconnected from the renewable energy system, leaving no back up energy source.
- Wiring connection 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.

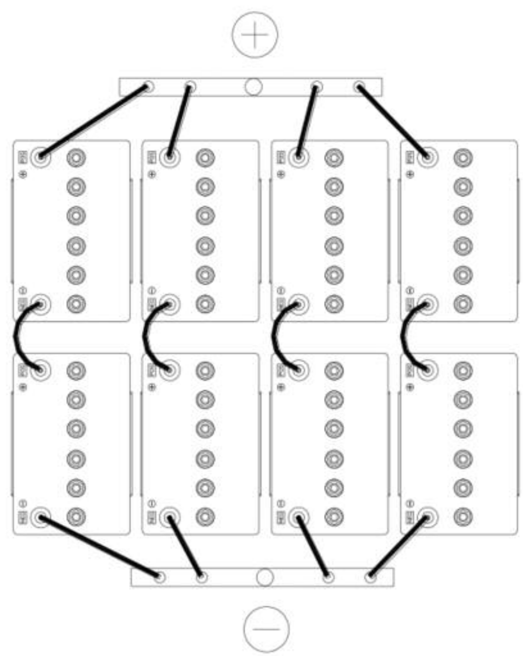
Advantages:

- 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

Daisy Chain Wiring



Common Bus Wiring



ONLY TRAINED AND AUTHORIZED PERSONNEL SHOULD INSTALL, REPAIR OR CHARGE BATTERIES.

When used properly, a lead-acid renewable energy battery is a safe, dependable source of electrical power. However, if proper care and safety precautions aren't exercised when handling a battery, it can be an extremely dangerous piece of equipment.

There are four hazardous elements in a lead-acid battery: sulfuric acid, explosive gases, electricity, and weight.

SAFETY PRECAUTIONS

Although all valve-regulated batteries have the electrolyte immobilized within the battery, the electrical hazard associated with batteries still exists. **Work performed on these batteries should be done with the tools and the protective equipment listed below.** Valve-Regulated battery installations should be supervised by personnel familiar with batteries and battery safety precautions.

WARNING: Risk of fire, explosion or burns. Do not disassemble, heat above 104ºF (40°C), or incinerate.

Protective Equipment

Although VRLA batteries can vent or leak small amounts of electrolyte, electrical safety is the principle but not the only concern for safe handling. Per IEEE 1188 recommendations, the following minimum set of equipment for safe handling of the batteries and protection of personnel shall be available:

1. **Safety glasses with side shields, or goggles, or face shields as appropriate. (Consult application specific requirements)**
2. Electrically insulated gloves, appropriate for the installation.
3. Protective aprons and safety shoes.
4. Portable or stationary water facilities in the battery vicinity for rinsing eyes and skin in case of contact with acid electrolyte.
5. Class C fire extinguisher.
6. Acid neutralizing agent.
7. Adequately insulated tools (as defined by ASTM F1505 "Standard Specification for Insulated and Insulating Hand Tools).
8. Lifting devices of adequate capacity, when required.

Procedures

The following safety procedures should be followed during installation:

(Always wear safety glasses or face shield when working on or near batteries.)

1. These batteries are sealed and contain no free electrolyte. Under normal operating conditions, they do not present any acid danger. However, if the cell jar or cover is damaged, acid could be present. **Sulfuric acid is harmful to the skin and eyes.**

Flush affected area with water immediately and consult a physician if splashed in the eyes.

Consult SDS for additional precautions and first aid measures.

SDS sheets can be obtained at www.eastpennmanufacturing.com

2. Prohibit smoking and open flames, and avoid arcing in the immediate vicinity of the battery.
3. Do not wear metallic objects, such as jewelry, while working on cells. Do not store un-insulated tools in pockets or tool belt while working in vicinity of battery. Keep the top of the battery string dry and clear of tools and other foreign objects.
4. Provide adequate ventilation **(per IEEE standard 1187 and/or local codes)** and follow recommended charging voltages.
5. **Never** remove or tamper with the pressure relief valves, except for cell replacement. Warranty void if vent valve is removed.
6. Inspect flooring and lifting equipment for functional adequacy.
7. Adequately secure cell modules, racks, or cabinets to the floor.
8. Connect support structures to ground system in accordance with applicable codes.

RECEIVING & STORAGE

Receiving Inspection

Upon receipt, and at the time of actual unloading, each package should be visually inspected for any possible damage or electrolyte leakage. If either is evident, a more detailed inspection of the entire shipment should be conducted and noted on the bill of lading. Record receipt date, inspection data and notify carrier of any damage.

Unpacking

1. **Always wear eye protection.**
2. Check all batteries for visible defects such as cracked containers, loose terminal posts, or other unrepairable problems. Cells with these defects must be replaced.
3. Check the contents of the packages against the packaging list. Report any missing parts or shipping damage to your East Penn agent or East Penn Mfg. Co. immediately.
4. Never lift batteries by the terminal posts.

Storage

1. 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).
2. Stored lead-acid batteries self discharge and must be given a boost charge to prevent permanent performance degradation.

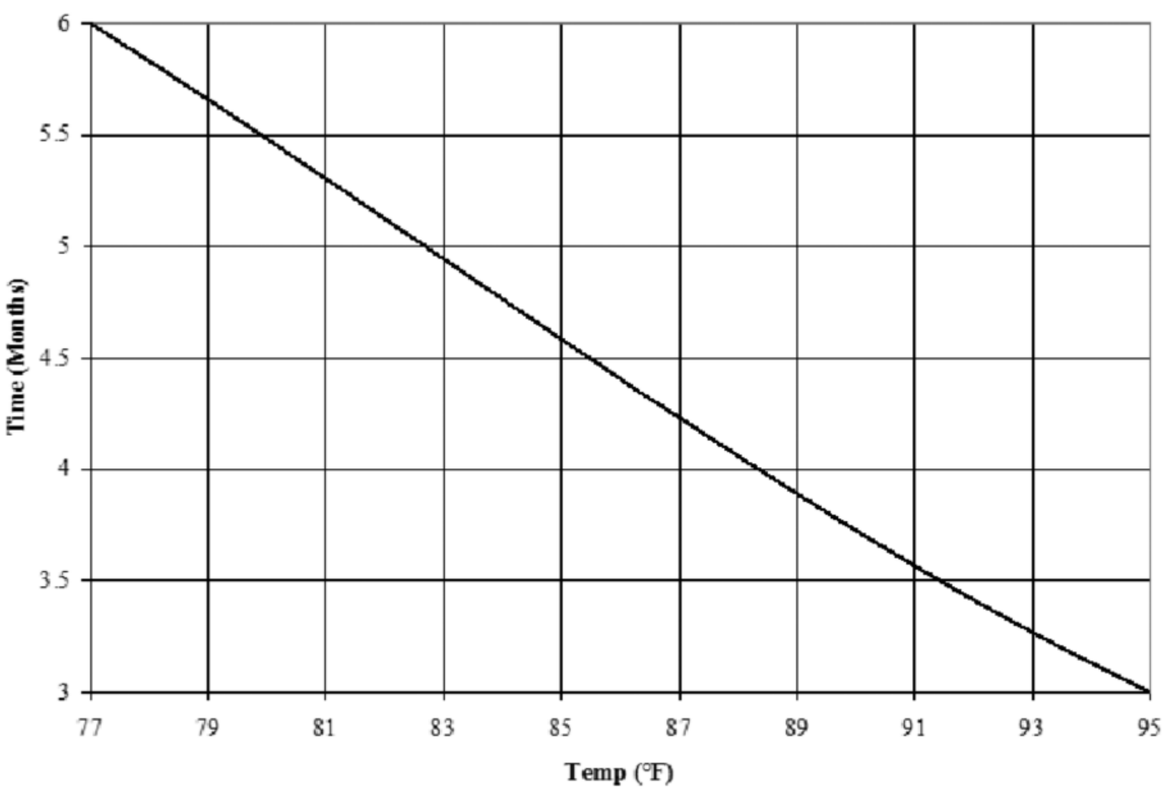
   0°F to 77°F (-18°C to 25°C) storage:

   Batteries should be recharged six months from date of manufacture.

   >77°F (25°C) storage:

   Use the chart below for recharge intervals. Voltage readings should be taken on a monthly basis. Batteries that reach 12.60V per 12V battery (6.30 per 6V battery) or less should be recharged regardless of scheduled interval. Record dates and conditions for all charges during storage.
3. If a boost charge is required; the recommended charge is 24 hours at a constant voltage equal to 14.40V per 12V battery (7.20V per 6V battery).
4. Do not store beyond 12 months.

Battery Storage Chart



INSTALLATION

General

Caution should be taken when installing batteries to ensure no damage occurs. Batteries shall not be dropped, slid, or placed on rough or uneven surfaces such as tray lips or grated flooring. Mishandling of batteries could result in equipment damage or human injury. East Penn will not be liable for damage or injury as a result of mishandling or misuse of the product.

Grounding

When grounding the battery system, proper techniques should be applied per electrical standards, such as NEC and/or local codes, as well as User Manual of specific application.

BATTERY ASSEMBLY

(Always wear eye protection.)

1. Set up the batteries so that the positive post (+) of one battery is connected to the negative post (–) of the next battery for all series connections.
2. All battery electrical contact surfaces shall be cleaned by rubbing gently with a non-metallic brush or pad before installing connectors. No-Ox-ID grease can be used but is not required.
3. Install all electrical connectors / cables and bolting hard¬ware loosely to allow for final alignment of batteries. Torque to manufacturer recommendations.
4. After torquing, read the voltage of the battery string to ensure the individual batteries are connected correctly. The total voltage should be approximately equal to the number of batteries times the measured voltage of one battery (when connected in series). If the measurement is less, recheck the connections for proper voltage and polarity.
5. Read and record connection resistance and note the method of measurement. This helps determine a satisfactory initial installation and can be used as a reference for future maintenance requirements. See Appendix B, recording forms, in the back of the manual. Clean, remake and re-measure any connection having a resistance measurement greater than 10% of the average of all the same type of connections.
6. Battery performance is based on the output at the battery terminals. Therefore, the shortest electrical connections between the battery system and the operating equipment results in maximum total system performance.
7. Cable size selection should be determined by current carrying requirements as well as providing a minimum voltage drop between battery system and operation equipment. Proper techniques should be applied per electrical standards, such as NEC and/or local codes. Note: Excess voltage drop will reduce the support time of the battery system.

SYSTEM OPERATION

There are several factors that affect the operation of the battery system concerning its ability to deliver capacity and life expectancy. Many chemical reactions are affected by temperature, and this is true of the reaction that occurs in a storage battery. The chemical reac¬tion of a lead-acid battery is slowed down by a lowering of the electrolyte temperature that result in less capacity. A battery that will deliver 100% of rated capacity at 77° F (25°C) will only deliver 65% of rated capacity at 32°F (0°C).

Charging

Consult Charger User Manual of specific application for Safety and Operating requirements.

For cyclic applications it is important that the battery system be charged fully after each discharge. It is recommended that 108% to 115% of the Ah (Amp Hour) capacity removed from the battery system be replaced after each discharge. This additional Ah is to compensate for any efficiency losses between the battery charger and the battery system.

Charging Parameters

Charge Voltage

Bulk Charge:

Current limited to 30% of C20 or 6 times I20.

Absorption Charge:

12.10V to 14.40V per 12V battery

Float Charge:

13.44V to 13.56V per 12V battery

Equalize:

14.40V to 14.60V per 12V battery

Note: Divide values in half for 6-volt battery.

Temperature Compensation

Battery voltage should be adjusted for ambient temperature variations.

3mV per °C (1.8°F) per cell

18mV per 12V battery

9mV per 6V battery

For temperatures above 77°F (25°C) subtract and for temperatures below 77°F (25°C) add.

Consult **Voltage Compensation Chart in Appendix D** for temperature compensation voltage maximum and minimum limits.

The average battery operating temperature should not exceed 95°F (35°C) and should never exceed 105°F (40.5°C) for more than an eight-hour period. Operating at temperatures greater than 77°F (25°C) will reduce the operating life of the battery. **If operating temperatures are expected to be in excess of 95°F (35°C), contact East Penn for recommendations.**

Discharging at temperatures less than 77°F (25°C) will reduce the capacity of the battery.

SYSTEM OPERATION *continued*

Charge Current

To properly determine the amount of charge current required the following variables are to be considered:

- DoD (Depth of Discharge)
- Temperature
- Size & efficiency of the charger
- Age and condition of battery(ies)

Maximum charge current should be limited to 30% of the C20 Ah rate for the battery(ies) being used in the system.

Example: 8G24 C20 rate – 73.6Ah

Max. recharge rate: 73.6Ah x 0.3 = 22.1A

Consult **Charging Current vs Charging Time chart in Appendix E** as a guide line to determine recharge time from 0% to 90% state of charge at an initial charge current.

Discharge Voltage Curve

To estimate battery voltage during a constant current discharge at various DoD (Depth of Discharge) consult chart **Discharge Voltage Curve in Appendix E.**

NOTE: Battery voltage can vary depending on temperature, age, and condition of battery.

State of Charge

Battery state of charge can be determined by measuring the open circuit voltage. Consult the below table.

State of Charge vs. Open Circuit Voltage*

% Charge	Gel	AGM
100	12.85 or higher	12.80 or higher
75	12.65	12.60
50	12.35	12.30
25	12.00	12.00
0	11.80	11.80

NOTE: Divide values in half for 6-volt battery(ies)

*The “true” O.C.V. of a battery can only be determined after the battery has been removed from the load (charge / discharge) for 24 hours.

RECORD KEEPING

Voltages, Temperatures & Ohmic Readings

Consult User Manual of specific application for additional Safety & Operating requirements.

Record keeping is an important part of battery maintenance and warranty coverage. This information will help in establishing a life history of the battery and inform the user if and when corrective action needs to be taken. (Refer to Appendix B, Battery Maintenance Report).

After installation and the batteries are at a fully charged condition, the following data should be recorded:

Depending on application, some of the following recommendations may not apply.

- Battery and/or string terminal voltage
- Charger voltage
- Individual battery float / charge voltages
- Individual battery ohmic readings**
- Ambient temperatures
- Terminal connections should be checked to verify all connections are properly torques. Micro-ohm readings should be taken across every connection. Refer to meter manufacturer’s instructions for proper placement of probes. If any reading differs by more than 20% from its initial installation value, re-torque the connections. If the reading still remains high, clean contact surfaces according to installation portion of this manual.

**** Note: To provide accurate consistent values, battery systems must be fully charged, at same temperature and probes placed at same location each time readings are taken.**

MAINTENANCE

Always wear eye protection when working on or near batteries. Keep sparks and open flames away from batteries at all times.

Consult User Manual of specific application for additional Safety & Operating requirements.

Annual Inspection

Depending on the application, some of the following recommendations may not apply.

1. Conduct a visual inspection of the battery(ies).
2. Record battery and /or string voltage. The accuracy of the DMM (Digital Multimeter) must be 0.05% (on dc scale) or better. The DMM must be calibrated to NIST traceable standards. Because voltage readings are affected by discharge and recharges, for cyclic applica¬tions, the battery(ies) must be in a fully charged condition prior to taking readings. Batteries should be within ± 0.30 volts (+ 0.15 volts for 6V) of the average battery float voltage.
3. Record charger voltage.
4. Record the ambient temperature.
5. Record individual battery ohmic readings.***
6. Record all interunit and terminal connection resistances. Micro-ohm readings should be taken during this inspec¬tion. If any reading is greater than 20% from initial readings, retorque the connection. Recheck the micro-ohm reading. If the reading remains high, clean contact surface according to installation portion of this manual.

***** Note: To provide accurate / consistent values, battery(ies) must be fully charged, at same temperature and probes placed at same location each time readings are taken.**

Rectifier Ripple Voltage

FREQUENCY

Ripple that has a frequency greater than 667Hz (duration less than 1.5ms) is acceptable, unless it is causing additional battery heating.

Ripple that has a frequency less than 667Hz (duration greater than1.5ms), must meet the following voltage specification to be acceptable.

VOLTAGE

Ripple voltage shall be less than .5% peak to peak of the manufacturer's recommended string voltage.

Battery Cleaning

Batteries, cabinets, racks, and modules should be cleaned with clean water. If neutralizing is required, use a mixture of baking soda and water. Use clean water to remove baking soda residue. Never use solvents to clean the battery(ies).

Capacity Testing

Capacity tests should not be run unless the battery's operation is questionable. Do not discharge the battery(ies) beyond the specified final voltage. When discharging at higher rates, extra connectors may be required to prevent excessive voltage drop. When performing capacity testing and recording data use applicable standard and/or User Manual.

Should it be determined any individual battery(ies) or cell(s) need to be replaced, contact your nearest East Penn agent or East Penn Mfg. Co.

To determine if a battery can deliver its rated capacity, a test discharge, or capacity test, can be performed. This test helps determine the "health" of a battery and whether or not it should be replaced.

Only experienced battery technicians should be allowed to prepare a battery for discharge testing and to conduct the actual discharge test.

The test is conducted by discharging a fully charged battery at a specific rate until the battery voltage drops to a predeter¬mined volts per battery, times the number of batteries in the battery system. By noting the time elapsed between when the battery was put on discharge and when the final voltage was reached, you can determine whether the battery is delivering its rated capacity:

1. Give the battery an equalizing charge until the current has stabilized. Start the test and record the starting time.
2. Record individual battery voltages and overall battery system voltages during the first hour at 10 minutes, 30 minutes and then 60 minutes. After the first hour, take hourly readings until the first battery voltage reaches 10.80 volts per battery. From this point on, record the voltage of the batteries every 5 minutes. monitor the voltage of the low batteries and as the voltage of each battery drops below the predetermined final voltage, record the time.
3. When the majority of the batteries reach termination value, stop the test. Don't let any battery go into reversal.

For example, if the test was run at the 360 minute rate was terminated after 336 minutes; the capacity percentage would be 93%

4. If the battery system delivers 50% or more of its rated capacity, it can be returned to service. If the test indicates less than 50% of the battery's rated capacity is being delivered, the battery system should be either repaired or replaced, depending upon its age and overall condition.

For more detailed information on capacity testing, contact East Penn Manufacturing Company or your local authorized East Penn Representative.

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.

C_{20} – 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.

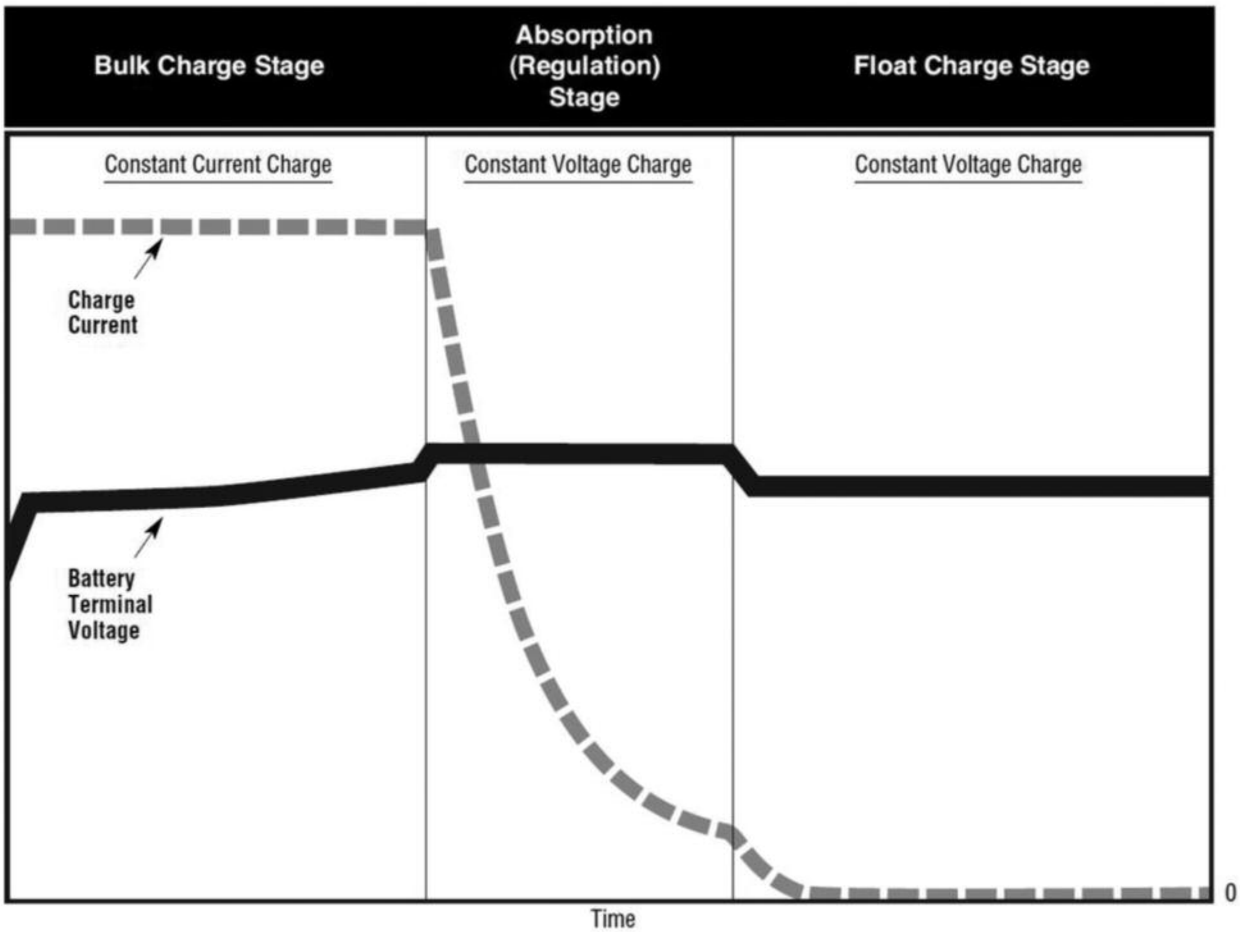
Worksheet to be submitted to sales representative for battery recommendation.

RENEWABLE ENERGY WORKSHEET

Date:	
1 Company Name:	
Address:	
City, State, Zip Code:	
2 Project Name & Description:	
3 Nominal System Voltage (DC)	
4 Days of Battery Reserve	
5 Load Data	
a. Total Load (Design Load):	
b. Type of Load (AC or DC):	
c. Number of Occurences:	
d. Duration of Each Occurrence:	
e. Low Voltage Disconnect:	
f. Inverter Efficiency:	
g. Power Factor:	
6 Array Size / Output (watts):	
7 Recharge time in	
Summer:	
Winter:	
8 Average Ambient Temperature	
Summer:	
Winter:	
9 Battery Space Constaints:	

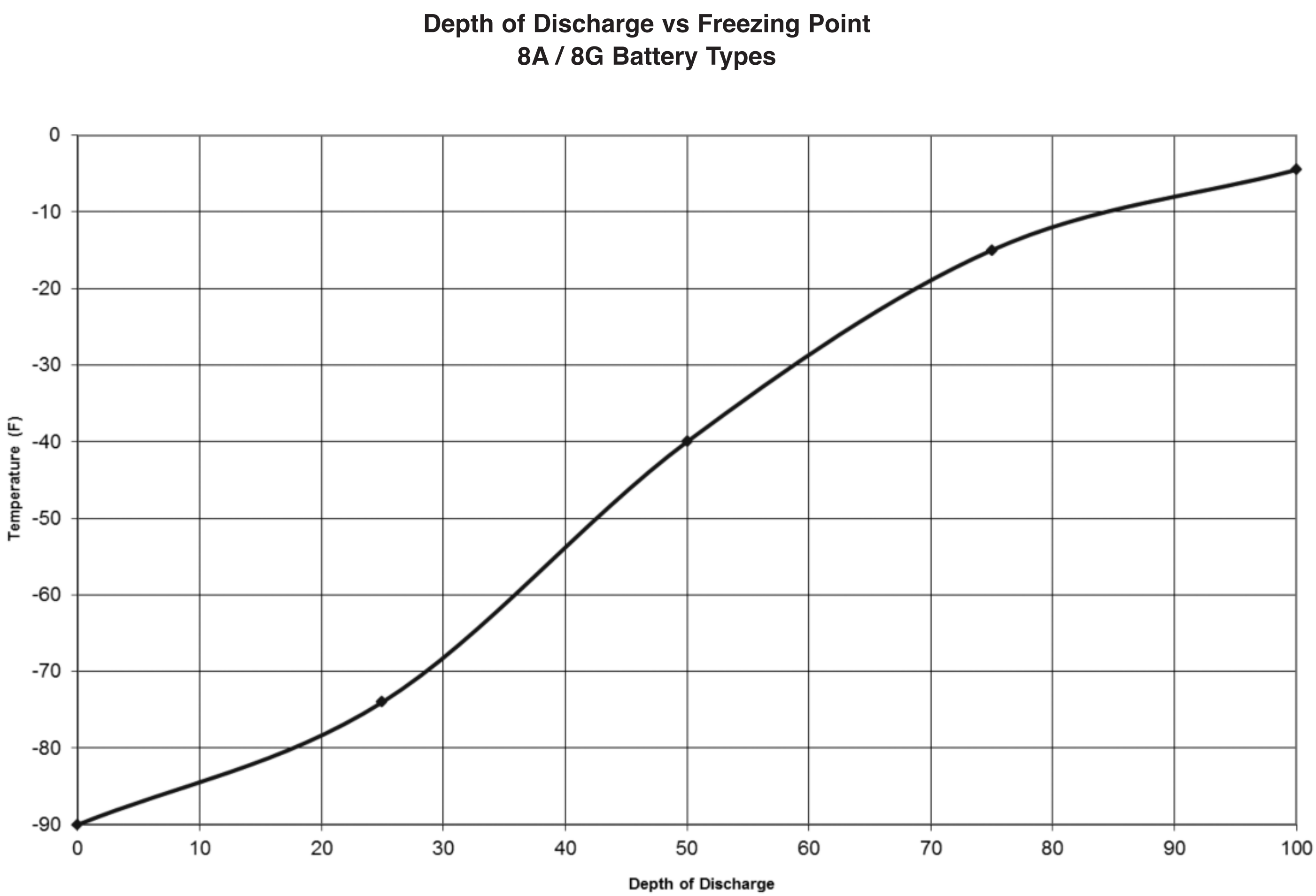
APPENDIX B

Example of typical 3 stage charger



APPENDIX C

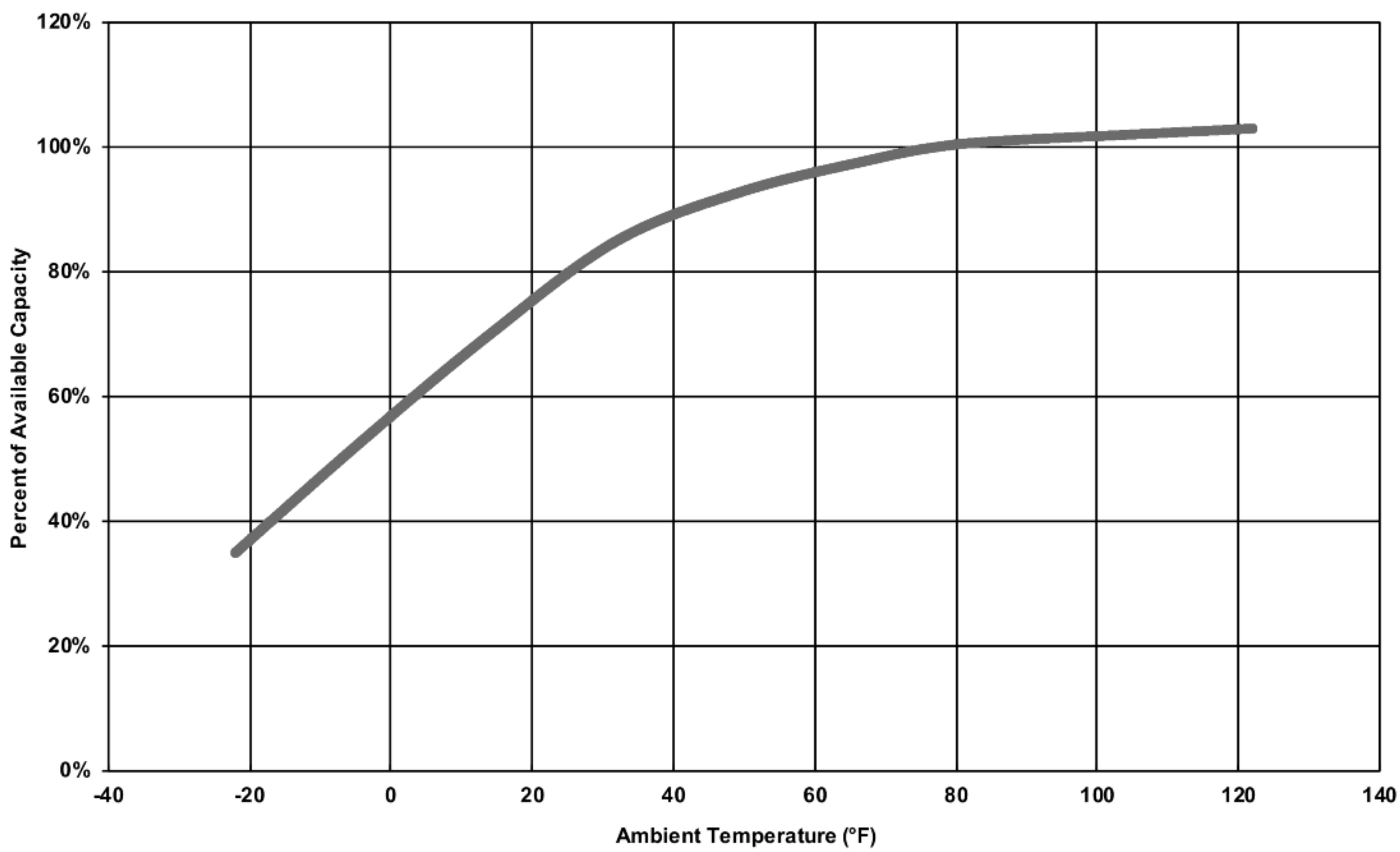
Depth of Discharge vs. Freezing Point



APPENDIX D

Capacity vs. Operating Temperature

Capacity vs Operating Temperature



APPENDIX E

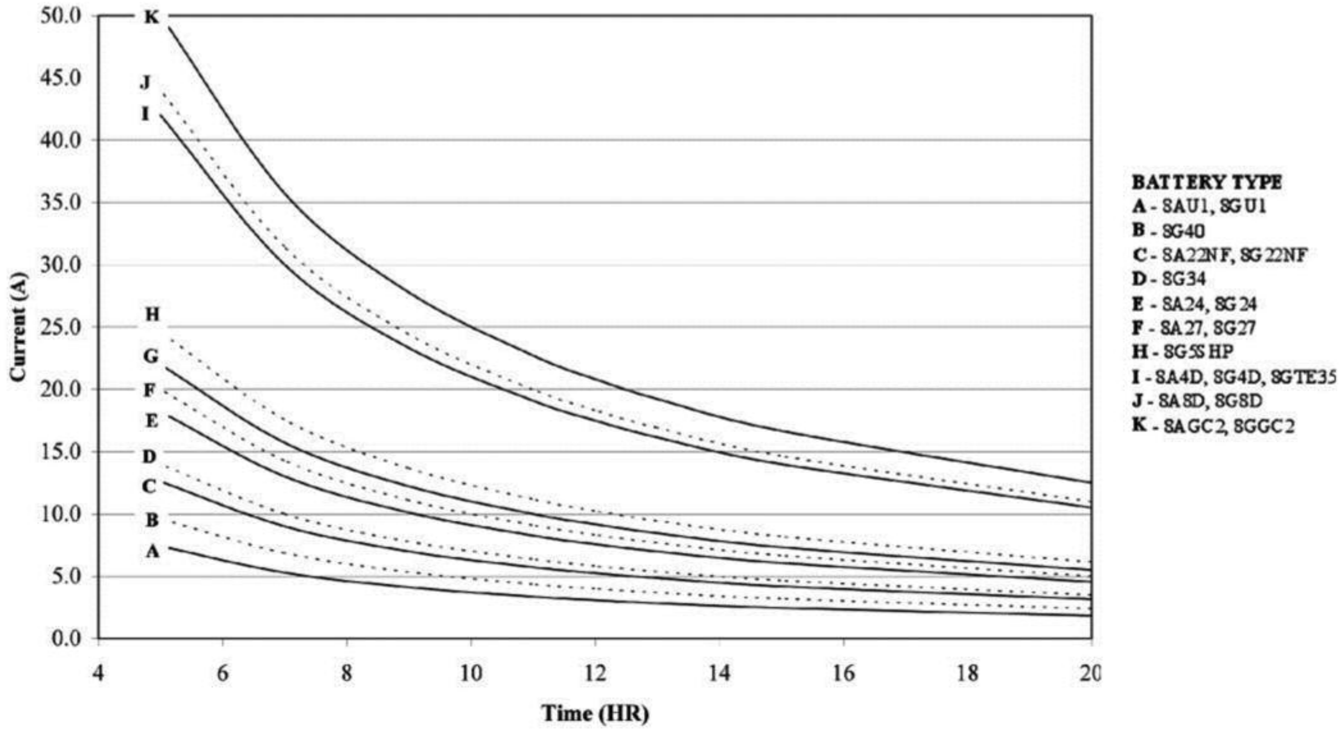
Voltage Compensation Chart

ºC	Float	Charge/Absorption		ºF
		Min.	Max.	
≥35	13.32	13.62	14.40	≥95
34	13.34	13.64	14.42	93.2
33	13.36	13.66	14.44	91.4
32	13.37	13.67	14.45	89.6
31	13.39	13.69	14.47	87.8
30	13.41	13.71	14.49	86.0
29	13.43	13.73	14.51	84.2
28	13.45	13.75	14.53	82.4
27	13.46	13.76	14.54	80.6
26	13.48	13.78	14.56	78.8
25	13.50	13.80	14.58	77.0
24	13.52	13.82	14.60	75.2
23	13.54	13.84	14.62	73.4
22	13.55	13.85	14.63	71.6
21	13.57	13.87	14.65	69.8
20	13.59	13.89	14.67	68.0
19	13.61	13.91	14.69	66.2
18	13.63	13.93	14.71	64.4
17	13.64	13.94	14.72	62.6
16	13.66	13.96	14.74	60.8
≤15	13.68	13.98	14.76	≤59

Note: 1. Above values based on 12-volt battery
2. Divide above values in half for 6-volt battery.

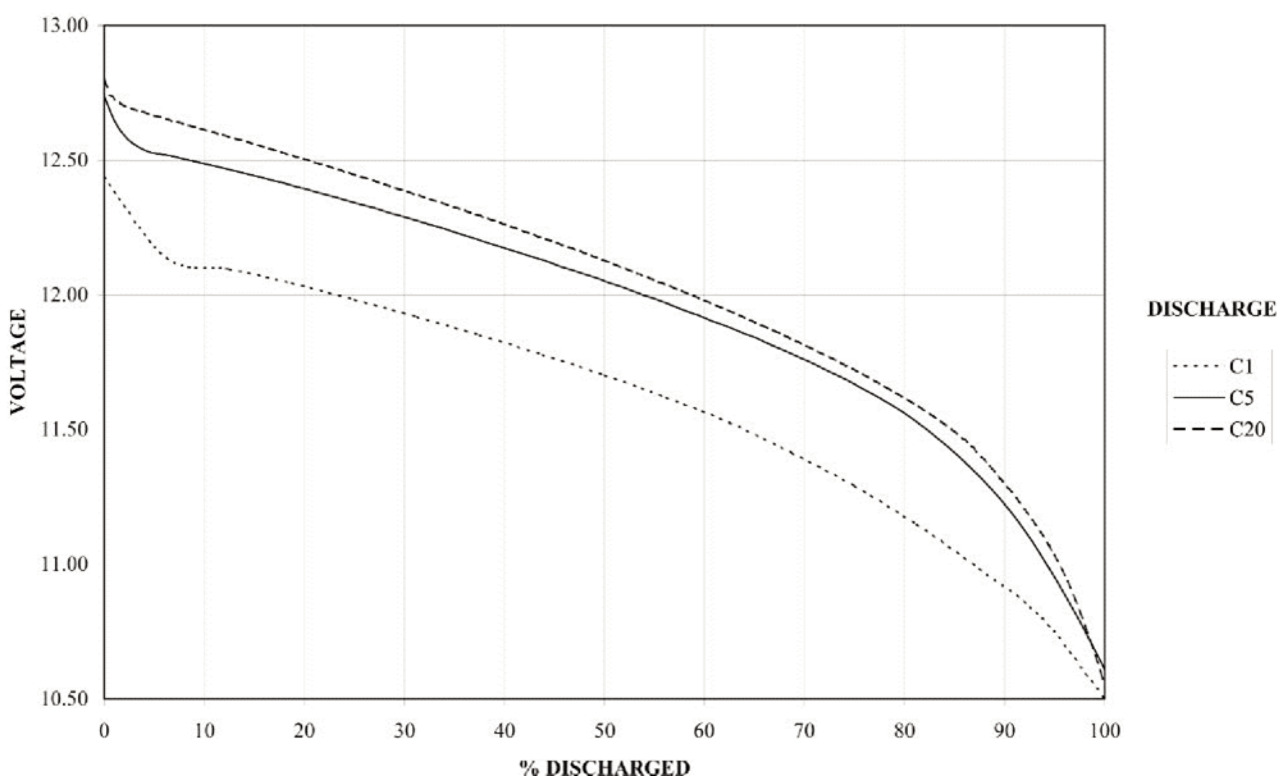
APPENDIX F

Charging Current vs Charging Time chart



*** Above values are to 90% SOC (State of Charge) based on C100 Ah capacity**

Discharge Voltage Curve



EASTPENN BATTERY MAINTENANCE REPORT

Company: ______________________ Service Date: ____________

Address: ______________________

Battery Location & I.D. Number: ______________________ Battery I.D. #: ____________

Total No. of Units: ____________ Charger Output Voltage: ______ Float Current: ______ Ambient Air Temperature: ______ °F

Battery Type : ____________ Total Battery Voltage: ______ *(To be read @ battery terminals)* Installer: ____________

Date of Mfg. : ____________ Panel Meter Voltage: ______ *(Display Voltage)* Date Installed: ____________

Site Load Current: ______ *Amps* Conductance / Impedance Meter: ____________ **(Mfg. & Model)**

Rectfier Mfg. & Model: ____________ AC Ripple Voltage: ____________ *(Note if voltage is expressed in RMS, Peak or Peak to Peak)*

Environment (i.e. Hut, Central Offic, etc…): ______________________

Unit No.	Serial Number	Unit Temp.	Unit Volts (Float)	Unit Ohmic Value	Unit No.	Serial Number	Unit Temp.	Unit Volts (Float)	Unit Ohmic Value

Remarks and Recommendations: ______________________

Readings Taken By: ______________________

(Form available as an Excel Spreadsheet. Consult your EPM Representative.)

***Notation*: This form must be completed and submitted with any product warranty claim.**

Readings should be taken at Installation and at least annually thereafter.

Notes:

www.dekabatteries.com

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e-mail: sales@mkbattery.com

E.P.M. Form No. 2478. 12/19