northstarbattery.com

NSB BLUE+ Battery®

Thin Plate Lead Carbon

NSB Blue+ Battery®
Application Manual

PSoC CYCLING

FASTER RECHARGE

Table of Contents

Thin Plate Lead Carbon Technology

1 Introduction

1.1 Blue+ Lead Carbon Technology

The Blue+ battery has been designed for applications where there are frequent power interruptions. Several features of the Blue+ battery have been enhanced to meet the demands: cyclic endurance for moderate to shallow cycles, charge acceptance and the ability to remain at partial state of charge. The battery uses more lead per capacity than normal AGM batteries and it uses specially selected carbon additives to enhance charge acceptance and endurance in partial state of charge. It also uses a higher compression in order to keep the active mass in place for harsh servicing conditions.

1.2 Definitions

The definition for each of the following terms or abbreviations describes the context employed throughout this document.

Monobloc: Set of cells in one housing connected, physical unit in our case the 12 V battery with 6 cells.

Battery: Functional unit for storage of electrical power in either one monobloc or several connected in series.

DOD: Depth of Discharge, fraction of total capacity used in discharge, 0-100 %

SOC: State of charge fraction of total capacity that is charged in most cases 100%-SOC = DOD

EODV: End of Discharge Voltage
VPC: Volts per cell

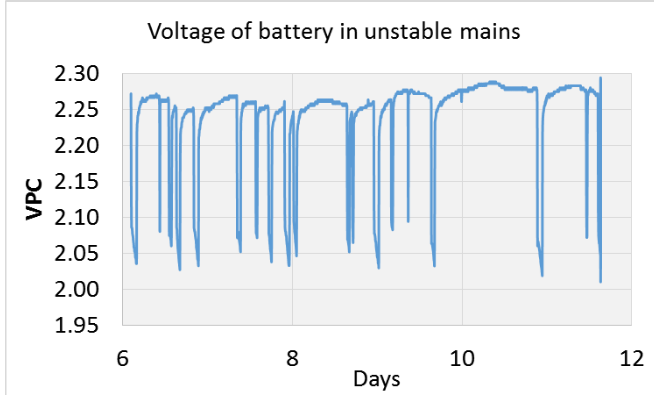
Electrolyte: In lead acid batteries a solution of sulfuric acid in water

String: Set of cells or monoblocs connected in series.

Note some terms may be used interchangeably given the circumstance.

1.3 Unstable mains service

Where the main electrical supply is of poor quality the batteries are used to provide service when the mains is off. Common to the poor grid operation are frequent interruptions. Often the time between the interruptions is so short that the battery cannot be fully recharged. So the battery may be fully recharged only rarely. This type of service is sometimes referred to as u-PSOC: uncontrolled-partial state of charge. Below an example of a battery in such an unstable mains environment.



As may be seen from the above chart. The monoboc operates at low voltage (VPC stated here) frequently in the first days of this graph. Rarely staying long enough at the float voltage level to reach full charge.

It has been shown that this type of service is stressful for normally designed AGM batteries. The Lead Carbon technology used in the Blue+ however enables greatly improved endurance in this type of service. Batteries which are not designed for this purpose only lasted 1/3 to 1/4 of the time of Blue+ when tested in laboratory cycles using the above field profile.

2 Charge

It is presumed that the batteries will be recharged following an outage (power interruption). Below you will find an outline of how this shall be performed, with descriptions of the terminology used and as well the basics of the use of the batteries. In real application it is presumed that the batteries will be used in a DC power system where the system functionality will control charge and discharge.

2.1 Charge & Discharge Rate

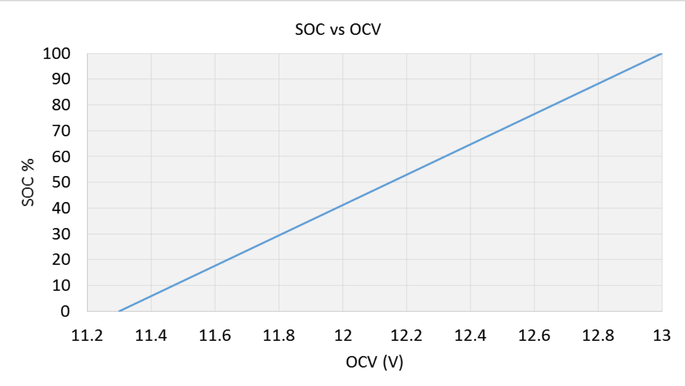
In this document, the charge and discharge rates (amps) are expressed as multiples of I10, where I10 is the current for a 10-hour discharge to 100% depth-of-discharge (DOD). These values serve to normalize data across a range of monobloc sizes. Consider the following example:

10-h discharge capacity NSB 100FT = 100 Ah (EODV =1.80 VPC @ 25°C).

1 x I10 = 1 x (10-h discharge current)
1 x I10 (NSB 100FT) = 1 x 10A = 10 A
2 x I10 (NSB 100FT) = 2 x 10A = 20 A

2.2 Determining State of Charge (SOC)

The SOC of a monobloc can be estimated by measuring the open-circuit-voltage (OCV) of the monobloc. If the monobloc has been recently recharged, a rest period of at least 12 hours after completion of recharge is required before taking measurements. If measured earlier the voltage is slightly higher and will indicate a too high SOC. The relationship between OCV and SOC for the Blue+ batteries is displayed in the following graph:

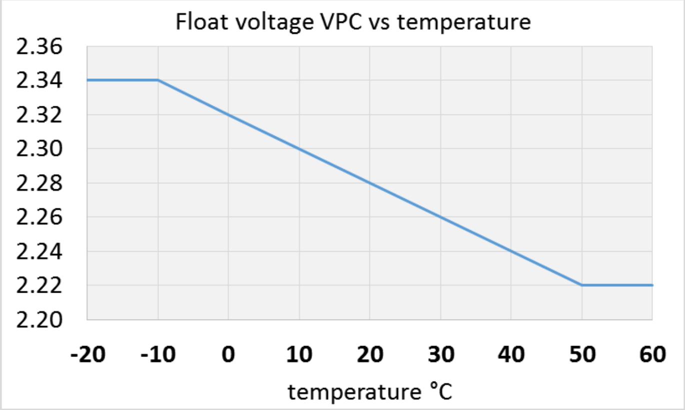


2.3 Float charge and thermal compensation

Thermal Compensation is the control of charging voltage depending on temperature. This serves to decrease the amount of overcharge that the batteries absorb at higher temperatures. Higher temperatures lead to quicker aging of the batteries. Temperature compensation cannot off-set all the detrimental effects that higher temperatures have.

The optimum level for float charging the Blue+ is 2.27 VPC ±0.02VPC at +25°C (+77°F). If the monobloc temperature increases above this level, a thermal compensation of -2 mV/cell/°C is recommended for safe operation and achieving optimal life. Conversely, if the temperature decreases below 25°C, the voltage should be increased by 2 mV/cell/°C. Most modern charge rectifiers have integrated temperature monitoring and voltage regulation which should be used in any environment where temperature is not precisely controlled.

The graph below shows values for an individual cell. The tolerance is ±0.02 V per cell.



2.4 Recharging

If the charging system is properly sized, a fast charging regime will serve to minimize the time needed to recharge Blue+ batteries.

There are two factors governing the recharge time: energy balance and charge acceptance. Batteries have charge acceptance – When applying the charging voltage to the batteries a current will flow into the battery. The more current the battery can accept the higher the charge acceptance. The charging current is dependent on factors like the SOC, the temperature and the charging voltage and actual design of the battery. To some extent the charge acceptance is also dependent on the nature of the preceding discharge. If the battery is freshly discharged the battery has a higher charge acceptance than when it has been stored a long time.

The energy in the battery must be restored when recharging a battery. This is done by restoring the charge into the battery with at least as much charge as has been taken out. The ratio between charge input and the preceding discharge is called charge return.

In the case that a battery has very high charge acceptance, it is the energy balance/charge balance that determines the charging time. When making rough estimates of size of charger and charging times this is the first consideration to look at. Charging times will always be longer than what is stated from the charge/energy balance.

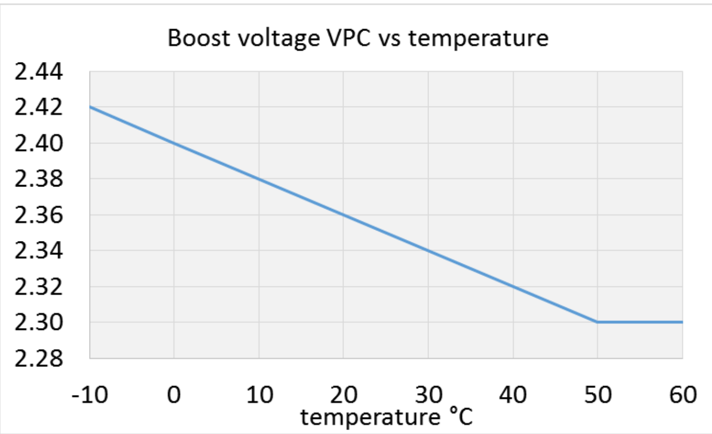
Batteries will need a charge return of a little more than a 100% in order to compensate for the coulometric-charge inefficiencies. Depending of the temperature and DOD this may vary from 0.5-6%, i.e. charge return of 100.5-106%. The higher the DOD and the higher the temperature is the higher this overcharge need to be to fully charge the battery.

2.4.1 Boost voltage

A charging voltage higher than the float voltage is recommended in situations where there are frequent power interruptions. This increases the charge acceptance and is especially helpful to shorten the time to full charge return and will speed up the achievement of a proper over charge. This is the boost voltage.

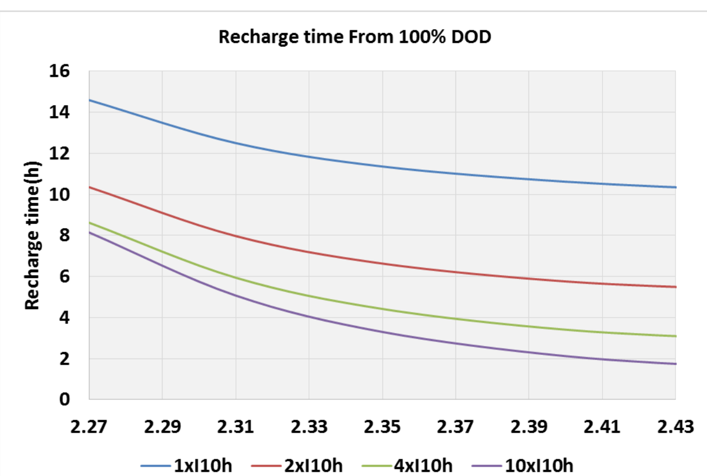
NorthStar recommends 2.35 VPC as boost voltage. This voltage is normally acceptable in 48 V power system used in telecomm application.

NorthStar recommends that the boost charge voltage shall be temperature controlled (temperature compensated) according to the graph below.



NorthStar also strongly recommend that the boost charge voltage shall be limited to 5 h of duration. This is counted from the time the battery voltage reaches the boost voltage and the charging current starts to decrease.

The following chart shows the time required to fully recharge a NSB Blue+ battery from a complete 100% DOD discharge, as a function of applied average voltage and available current.



2.4.2 Equalizing charge

Equalizing charge has the purpose of equalizing all the batteries or cells in a string by applying a higher voltage for a limited time. The individual objects in a string. Batteries, can become unbalanced i.e. the cells have slightly deviating voltages due to various reasons: cell differences, exposed to different temperatures for instance. The equalizing charge shall commence first when the batteries have been charged by normal means. The voltage should be the same as for the boost and same temperature controls shall be applied. Batteries shall be charged for 12-24 hours.

It shall be limited to the boost voltage level and shall not be longer than 16 hours.

3 Heat and Temperatures

Batteries will evolve heat especially during cycling, the charging and discharging. As a rule of thumb 15% of the turned over energy shall be assumed to be heat in a charge discharge cycle. This number will apply when the total cycle for a full turn-over is at least 24 h. So the climate system has to provide this cooling. A high operating temperature will be more stressful to the battery and active cooling is recommended.

The batteries need to be spaced and arranged so that the cooling of the monoblocs will be as uniform as possible. When batteries are placed on different shelves it is important that the air flow to the different shelves shall be arranged so that the batteries on different shelves have as uniform temperatures as possible.

3.1 Battery high temperature cut-off

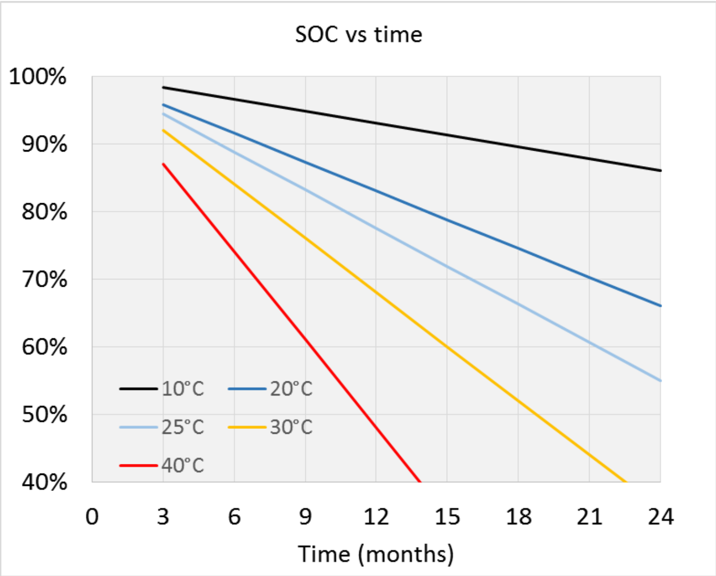
It is highly recommended to have a system which disconnects the battery at a pre-set high temperature. The pre-set temperature shall be in the interval 60-75 °C. This is in order to avoid thermal damage to the battery and as well in order to avoid thermal runaway.

4 Discharge

4.1 Storage and Self Discharge

During storage, lead-acid batteries will gradually self-discharge. It is recommended that monobloc SOC be maintained above 12.20 V at all times, while the battery is in storage, in order to avoid irreversible capacity loss. The rate of self-discharge increases with increasing temperature.

For example: a monobloc at 25°C will drop from 90% to 60% in 15 months, whereas the same monobloc at 40 °C will take just 6 months. As a result, maintenance charging needs to be performed more frequently at higher temperatures



The 50% SOC limit corresponds to 12.2 V for a monobloc recharge before this limit is passed.

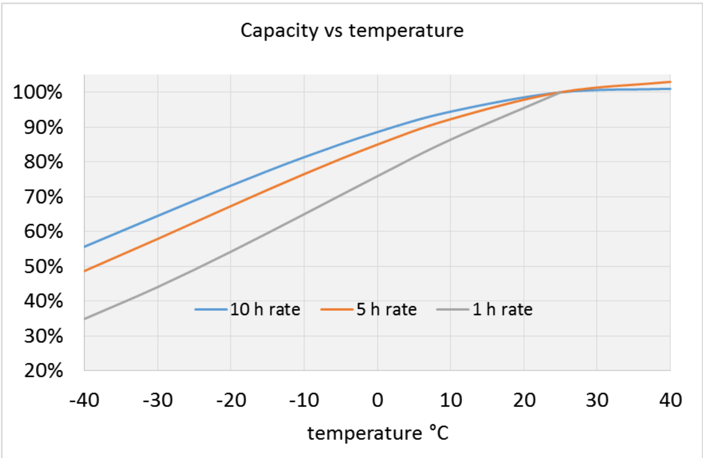
4.2 End of Discharge Voltage (EODV)

In the event of a deep discharge, a recommended minimum end-of-discharge voltage (EODV) should be used to avoid over discharge. The EODV should be adjusted based on the discharge rate, the following table provides a guide for EODVs at various discharge rates.

Discharge time (h)	EODV (VPC)
20	1.85
10	1.80
5	1.75
1	1.70

4.3 Low Temperature Performance

At low temperatures the capacity decreases. The capacity can be estimated using the graph below.



5 Useful Life

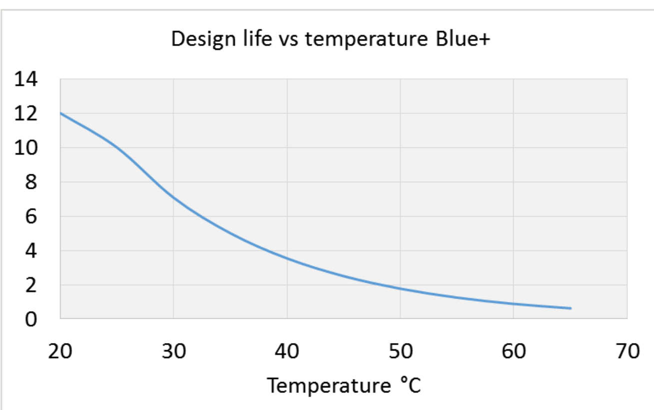
5.1 Shelf Life

NSB Blue+ batteries may be stored for up to 2 years, provided that the SOC is maintained above 50%. Failure to provide the required maintenance charging (see Section 4.1 Storage and Self Discharge) may lead to irreversible capacity loss.

5.2 Float Life vs. Temperature

Due to constant float charging, the lead grids within the positive plates undergo slow corrosion, which is a normal aging mechanism. The rate of this process increases with increasing temperature and, as a result, the temperature of monoblocs has a large effect on their float life.

For example, if the temperature rises from the recommended operating temperature of +25°C, to +45°C, the expected life of the monobloc will decrease from 10 to 2 years (see chart below). This is the overall average operating temperature during the life of the monobloc.



Under float operation, a monobloc is considered to have reached its end of life (EOL) when it can no longer deliver 80% of its original rated capacity. For example, a 100 Ah monobloc has reached EOL when its discharge capacity has dropped below 80 Ah.

6 Hybrid Operation Cyclic Operation

Hybrid operation refers to the use of Blue+ batteries in parallel to a generator set in a defined scheme, where the generator is run intermittently charging the batteries. When generator is not running the batteries provides the power. By this scheme there are savings in fuel consumption and the generator run time is decreased.

Blue+ batteries are well suited to this type of service. The following operational strategies can be applied

6.1 PSOC

It is recommended that the battery is cycled between a low SOC in the region 50-65% and is charged to SOC 95%. The charge return shall be in the range 100.5-101%. Every second week the battery shall be equalized using a 16 h equalization charge at 2.41 VPC.

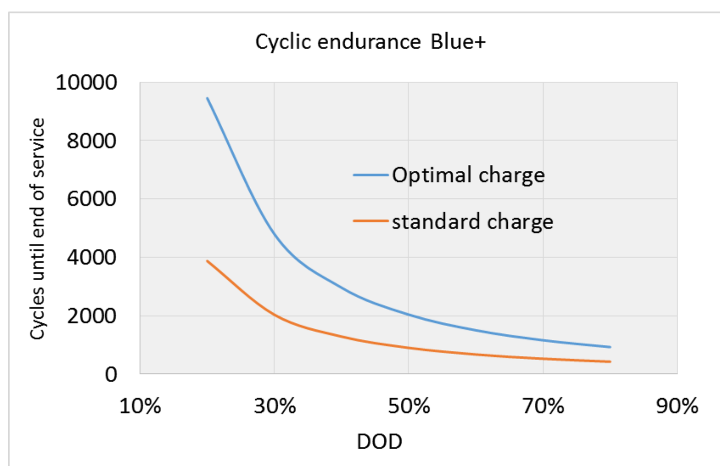
6.2 High Window PSoC (Q-charge)

It is recommended that the battery is cycled between a low SOC in the region 50-30% and is charged to 100%SOC using a charge return somewhat dependent on the DOD. Following table condenses the recommended charging times and recommended charge returns to use:

DOD window		30%	40%	50%
Charge return	min	101.00%	101.20%	101.40%
	max	101.20%	101.40%	101.60%
Charge time (h)	$2xI_{10h}$	2.25	3.00	3.75
	$3xI_{10h}$	1.50	2.00	2.50

6.3 Cycle Life vs. Depth of Discharge

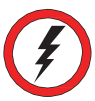
Blue+ batteries are designed to be able to operate in highly cyclic applications as well as PSOC applications. During optimal PSOC charging regime, NSB Blue+ batteries can be expected to achieve cycle life according to the chart below.



7.1 Battery Safety and Environmental Information

For full information please read the Material Safety Data Sheet (SDS). The SDS document may be downloaded from the NorthStar website www.northstarbattery.com

When dealing with Valve Regulated Lead Acid Batteries (VRLA) some additional safety information is required.

	Please read and observe the installation and operation instructions.
	When working on batteries wear appropriate Personal Protective Equipment (PPE). Refer to battery SDS for complete list.
	Do not expose the battery to an open flame or other ignition source. During operation an explosive mixture of hydrogen gas may accumulate.
	Battery terminals are always energized and, if short-circuited, cause electrical arcing. Always use insulated tools.
	Batteries are heavy objects. Use proper handling equipment safety gear during installation.
	Inappropriate lead acid battery disposal can result in environmental contamination. Please dispose of batteries according to regulations.
	Battery may be returned, shipping pre-paid, to the manufacturer or any distributor for recycling.
	Batteries contain concentrated sulfuric acid in water. Any fluid found outside the batteries should be regarded as acid.
	Clean all acid splash in eyes or on skin with plenty of clean water. Then seek medical help. Acid on clothing is to be washed with water
	Risk of explosion or fire. Avoid any short circuit. Metallic parts under voltage on the battery - do not place tools or items on top of the battery.

8 Receiving the Shipment

In addition to safety requirements (see section 7) special care should be taken when handling monoblocs. The following are some DOs and DON'Ts.

DO

Always use both handles on the monoblocs when lifting or carrying them.

Always have a straight back and lift using your legs when lifting or carrying monoblocs.

Always have appropriate safety gear (see section 7) available when handling monoblocs.

Always perform an Open Circuit Voltage (OCV) check on a monobloc PRIOR to installation, see section 10.2 Checking the Voltage Spread, and section 10.7 Charging.

Always perform a visual inspection of the monobloc prior to handling. If any damage or electrolyte leakage is detected during this inspection, do not install the monoblocs. Stop flow of material, contain/absorb small spills with dry sand, earth or vermiculite. Do not use combustible materials. If possible, carefully neutralize spilled electrolyte with soda ash, sodium bicarbonate, lime, etc. Wear acid- resistant clothing, boots, gloves and face shield. Do not allow discharge of un-neutralized acid to sewer.

Acid must be managed in accordance with approved local, state, and federal requirements. Consult state environmental agency and/or federal EPA.

Always use the packing from new monoblocs for transporting old monoblocs for proper disposal. If unavailable, place batteries on a pallet and strap them down securely for shipping.

Always dispose of monoblocs in accordance with local and national requirements.

Always follow the instructions provided with the monoblocs when installing them.

Always use insulated tools when handling monoblocs. Failure to do so can lead to electric shock, burns and/or damage to batteries and equipment

DON'T

Don't drag a monobloc along the floor. Doing so could cause damage to the monobloc case leading to a possible leakage of electrolyte.

Don't install a monobloc that has been dropped into any application. A dropped monobloc could have damage to either its internal or external casing leading to a possible leakage of electrolyte and damage to equipment.

Don't make the final connection to an application until all batteries in the string have had their interconnections finished and properly torqued. Battery terminals are always energized and, if short-circuited, can cause electrical arcing as well as damage to the batteries and equipment.

Don't dispose of batteries in unapproved sites. The batteries contain electrolyte and compounds of lead that are harmful to nature and can contaminate the environment if not disposed of properly.

Don't drill, or in any other way attempt to breach the monoblocs case. Doing so could lead to a possible leakage of electrolyte.

Don't force a monobloc into equipment. Forcing the monobloc into equipment can lead to a breach in the monoblocs internal or external casing causing a possible leakage or electrolyte or electrical short circuit.

Don't move the monoblocs using the terminals. The terminals are not designed to support the weight of the monobloc and damage to internal components could result.

9 Storage

9.1 Storage conditions

Below is a list of equipment that is recommended to be on hand in the area where monoblocs are stored.

1. DC volt meter
2. Battery chargers (with controlled voltage output setting +/- 0.05V)
3. Mechanical lifting device (such as a fork lift etc.)
4. Appropriate Personal Protective Equipment (PPE), as listed in the Battery Safety and environmental information section of this document.

It is strongly recommended to store the monoblocs in a cool dry environment. For more information see section 4.1 Storage and Self Discharge

The monoblocs should be stored in the original containers. The packaging serves to protect the monoblocs from harsh environmental conditions and accidental damage. If they must be removed, palletize them, and utilize as much of the original packaging as possible.

9.2 Storage time

For more information see section 4.1 Storage and Self Discharge

Shown above: different ways to correctly store monoblocs

10 Commissioning

Always use the installation instructions provided with the monoblocs and follow all outlines for safety and handling mentioned earlier in this document.

10.1 Unpacking the Batteries

When received, a visual check should be made on the monoblocs. If the monoblocs show transportation damage, physical damage to the case, leaking electrolyte etc. they should not be installed, and a claim should be initiated immediately.

Make sure all the accessories are present in the delivery. Please observe the cardboard sleeves around the monoblocs has no bottom! The cardboard should be removed prior to lifting the monoblocs. Please keep all packing material for future use if possible.

If the monoblocs cannot be put into place directly and need to be put on the floor/ground, put some of the cardboard material under them in order to protect the monobloc from hard surfaces. An alternative material is to use the top of the crate that the monoblocs were shipped in.

10.2 Checking the Voltage Spread

Before connecting the monoblocs in series, the voltage variation must be checked and the voltages shall recorded. If the voltage varies more than 0.15 V between the highest and the lowest monobloc voltage, the monoblocs should be charged individually before being connected in series.

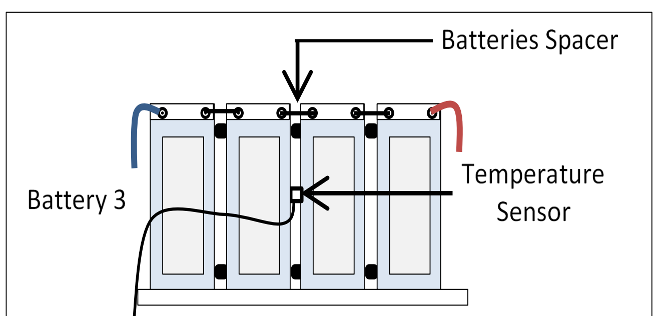
Alternatively the monoblocs may be matched in each string so that all the monoblocs have a voltage spread of less than 0.15V.

10.3 Putting the Batteries in Place

Make sure the monoblocs are all evenly spaced, aligned and rest on a flat surface. Resting the monoblocs on an acid resistant, electrically isolating surface is recommended to avoid possible ionic connection to ground and potential damage to equipment.

Monoblocs can be installed in any orientation, but inverted is not recommended.

Temperature sensors shall be installed in a proper way see figure for placement. The sensor shall be placed approximately at 2/3 of the height.



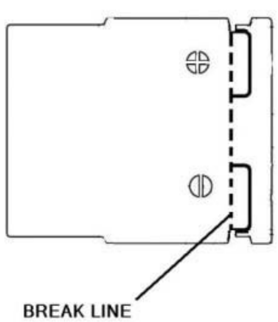
Drawing 3

10.4 Connecting the Batteries

The monoblocs shall be connected in series using the cable and connectors designed for the particular layout of your application. Refer to the particular layout of the system. Please observe the risk for arcing and high currents when connecting the monobloc string to the system. Preferably the last connection should be made at distance from the monobloc string.

If the system comprises a monobloc circuit breaker or any other means of disconnection, this shall be in an off condition when connecting the monobloc to the system. Before connecting cables, clean contact surface and apply a light coating of anti- oxidizing grease to contact surfaces. A torque wrench must be used for tightening the bolts on the battery. Recommended torque will vary depending on the size of the battery. Refer to the product label applied directly to the battery for recommended torque values.

The covers shall be put back after all connections have been completed. Please observe that when heavy cables are used, these need to be supported in order not to stress the monoblocs terminals. The isolation covers should be put back after all connections have been completed. See the figures below:



10.5 Application of Grease after Tightening Electrical Connections

Electrical grade conductive grease is applied directly to the battery terminals as a corrosion preventative measure during manufacturing. In typical indoor installations no additional grease is required to protect the terminals and other electrical connections after installation. The bus bars and other hardware provided with the batteries are plated to protect from corrosion.

10.6 Cleaning

Batteries shall only be cleaned using a dry soft cloth or alternatively cloth moistened with water – Any other substances should not be used or sprayed on the batteries. The plastic used for the batteries is sensitive to many solvents and other substances. Especially pesticides, insect repellants should be avoided entirely as these are known to have caused the plastic to experience severe cracking.

10.7 Charging

Please note! Never charge the batteries in their packaging! Batteries need to be unpacked and positioned with space between them before any charging is started.

10.8 First charge commissioning charge

Depending on the state of charge of the batteries it may take some time before they reach full state of charge. Below recommended charge based on the OCV values of the monoblocs.

OCV	Recharge Time
>12.80 V	3 day charge 2.27 VPC
12.6 - 12.8 V	3 day charge 2.27 VPC
12.3 - 12.6 V	1 day charge 2.41 VPC
12.1 - 12.3 V	1 day charge 2.41 VPC

10.9 Setting charging voltages in the system

Charging systems for batteries need you to set the float voltage, temperature compensation values and boost voltage settings. For convenience the settings for some of the most common configurations and temperatures have been added. The table below shows float voltage using temp compensation -2mV/cell/°C

T °C / °F	V (float) 24 V	48 V
20 / 68 13.68 ± 0.12V	27.36 ± 0.24V	54.72 ± 0.48V
25 / 77 13.62 ± 0.12V	27.24 ± 0.24V	54.48 ± 0.48V
30 / 86 13.56 ± 0.12V	27.12 ± 0.24V	54.24 ± 0.48V
35 / 95 13.50 ± 0.12V	27.00 ± 0.24V	54.00 ± 0.48V

For the boost voltage setting please consult section 2.4.1.

10.10 Over temperature safety feature setting

When the system has a high temperature disconnect it shall be set to disconnect the battery at a temperature preferably at 65°C but not higher than 75°C.

10.11 Battery block position labeling

Some customers may require marking/labeling of each battery block's position within a battery string, i.e. block number 1through 4 for a -48VDC battery string. Mark each battery in accordance with customer requirement (some customers may require the battery block connected to the 0V lead to be block #1 and the block connected to the -48VDC lead to be #4 or vice versa).

If marking is made with stickers or marker, put the mark on the existing battery label to avoid possible reaction between the glue of the sticker and the plastic jar or the marker's solvent and the plastic jar.

11 Maintenance

In absence of automatic monitoring systems the following maintenance is recommended:

Every 6 months check voltage of the power plant and individual voltages of the monoblocs. If the battery is judged to be fully charged no unit shall deviate more than 0.15 V from other units.

Check the batteries for integrity and cleanliness. If necessary, clean the dirty units.

12 Technical Specifications

For detailed technical specification, please refer to the product datasheet at www.northstarbattery.com

13 Contacts

EnerSys World Headquarters
2366 Bernville Road,
Reading, PA 19605, USA
Tel: +1-610-208-1991 / +1-800-538-3627

NorthStar®
an EnerSys company