

# Battery Banks for Inverter Systems

## Application Note

Xantrex Inverter/  
Chargers

976-0114-01-01 Rev A

## Purpose

This Application Note supplies general information about batteries and battery banks. It includes information such as:

- safety precautions when working with batteries, (page 1)
- battery bank location, enclosures, and accessibility requirements, (page 2)
- battery types best suited for inverter systems, (page 3)
- battery bank sizing and amp-hour requirements, (page 5)
- battery bank configurations, (page 10) and
- battery care and maintenance (page 14).

This information is provided for reference only. For detailed information, see your battery manufacturer or your system designer.

## Safety Precautions When Working With Batteries



### **WARNING: Explosion, Electrocution, or Fire Hazard**

Failure to comply with the safety instructions regarding working with batteries can result in explosions, electrocution, or fire hazards. Be sure to study all warning/caution labels or notes related to working with batteries. These labels could be on the batteries or on the supporting equipment connected to the batteries as well as in the documentation provided with the batteries.

1. Follow all instructions published by the battery manufacturer and the manufacturer of the equipment in which the battery is installed.
2. Make sure the area around the battery is well ventilated. Battery enclosures should be designed to prevent the accumulation and concentration of hydrogen gas in “pockets” at the top of the compartment. Vent the battery compartment from the highest point. A sloped lid can also be used to direct the flow to the vent opening location.
3. Never smoke or allow a spark or flame near the engine or batteries.
4. Use caution to reduce the risk of dropping a metal tool on the battery. It could spark or short circuit the battery or other electrical parts and could cause an explosion.

5. Remove all metal items, like rings, bracelets, and watches when working with lead-acid batteries. Batteries produce a short circuit current high enough to weld metal to skin, causing a severe burn.
6. Have someone within range of your voice or close enough to come to your aid when you work near batteries.
7. Have plenty of fresh water and soap nearby in case battery acid contacts skin, clothing, or eyes.
8. Wear complete eye protection and clothing protection. Avoid touching your eyes while working near batteries.
9. If battery acid contacts skin or clothing, wash immediately with soap and water. If acid enters your eye, immediately flood it with running cold water for at least twenty minutes and get medical attention immediately.

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**Important:** Baking Soda neutralizes lead acid battery electrolyte. Vinegar neutralizes spilled NiCad and NiFe battery electrolyte. Keeping a supply on hand when working with batteries is a good idea.

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10. If you need to remove a battery, always remove the ground terminal from the battery first. Make sure all accessories are off so you don't cause a spark.
11. Never charge a frozen battery.
12. If a remote or automatic generator control system is used, disable the automatic starting circuit and/or disconnect the generator from its starting battery while performing maintenance to prevent accidental starting.

## Battery Bank Location, Enclosures, and Accessibility

**Location**                      Locate the inverter as close to the batteries as possible in order to keep the battery cable length short. However, note the following warnings and important notes about inverter location.



### **WARNING: Explosion and Corrosion Hazard**

Do not locate the inverter directly above the batteries or in the same compartment as vented batteries. See the recommendations for vented enclosures and enclosure requirements below.

Vented batteries generate hydrogen and oxygen, which if accumulated, can be ignited by an arc caused by connecting the battery cables or switching a relay. Vented batteries also generate hydrogen-sulfide gas, which is corrosive to electronic equipment.

Batteries can sometimes release explosive gas, please see the battery manufacturer's recommendations for ventilation requirements.

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**Accessibility**                      Locate the batteries in an accessible location if maintenance is required. Two feet clearance above the batteries is recommended for access to the battery caps. They should be located as close to the inverter as possible without limiting access to the inverter's disconnects.

**Vented enclosures** For safety and to limit access to the batteries, the batteries should be housed in an enclosure or dedicated room that can be locked or screened, and ventilated. It should be vented to the outside by a 1-inch minimum vent pipe located at the top of the enclosure. An intake vent should be installed at the bottom of the enclosure to promote air circulation.

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**Important:** These vents exhaust corrosive and explosive hydrogen sulfide gases and must not be overlooked when designing an enclosure.

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**Enclosure requirements** The enclosure should be made of an acid resistant material or have a finish that resists acid to prevent corrosion and must be capable of containing the electrolyte from at least one battery should a leak occur.

Enclosures located outside must be rainproof and screened to prevent access by rodents or insects and insulated from extreme temperatures.

Batteries will give their best performance and service life when operating in a 20 to 25 °C (68 to 77° F) environment.

## Battery Basics

**Batteries** Batteries are available in different sizes, amp-hour ratings, voltage, liquid or gel, vented or non-vented, chemistries, etc. They are also available for starting applications (such as an automobile starting battery) and deep discharge applications.

**Recommendations** Consider the following recommendations for battery use.

- Use only the deep discharge types for inverter applications.
- Use the same battery type for all batteries in the bank.
- Use only batteries from the same lot and date in your battery bank. This information is usually printed on a label located on the battery.

## Battery Types

There are two principal types of batteries: starting and deep-discharge (with several different types of chemistries). Batteries can be either sealed or non-sealed (vented).

**Deep discharge** The battery types recommended for use in an inverter system are: Flooded Lead Acid (FLA), Sealed Gel Cells (GEL), Sealed Absorbed Glass Mat (AGM); and alkaline types such as Nickel-iron (NiFe) and Nickel-Cadmium (NiCad).

**Starting** Automotive (starting) batteries are designed to provide high starting current for short periods of time and are not appropriate for inverter applications.

### Deep-cycle Flooded Lead Acid (FLA)

**Description** A flooded lead acid battery is designed to be deep-discharged before being recharged, making it suitable for inverter applications. Flooded batteries require periodic maintenance consisting mainly of adding distilled water to the cells.

Attributes                      Attributes of sealed batteries are:

Types of FLA Batteries	Attributes
Golf Cart	<ul style="list-style-type: none"> <li>• Popular for smaller off-grid home systems</li> <li>• Many medium sized inverter systems use “L16” batteries</li> <li>• Rugged, long lasting</li> <li>• Typically rated at 6 volts (220 to 350 amp hours)</li> </ul>
Industrial (electric forklift)	<ul style="list-style-type: none"> <li>• Popular in large inverter systems</li> <li>• Extremely rugged - lasts up to 10 years or more in an inverter system</li> <li>• Typically 2 volt cells (1,000 amp hours or more)</li> </ul>

## Sealed Batteries (Gel and AGM)

Description                      Gel Cell and Absorbed Glass Mat (AGM) batteries are sealed and do not require the addition of distilled water. Since these batteries are valve regulated, over-charging can cause irreversible damage.

Attributes                      Attributes of sealed batteries are:

Types of Sealed Batteries	Attributes
Gel Cell	<ul style="list-style-type: none"> <li>• Gelled electrolyte instead of liquid</li> <li>• Long life (up to 1500 cycles, typical)</li> <li>• Low self-discharge</li> </ul>
Absorbed Glass Mat	<ul style="list-style-type: none"> <li>• Electrolyte is contained in glass-fibre mats between battery plates</li> <li>• Similar to gel cells in characteristics</li> <li>• Good low temperature performance</li> </ul>

## NiCad and NiFe Batteries

Disadvantages                      These types of batteries can be used but may not be optimized for your inverter for the following reasons:

- Alkaline batteries, such as NiCad and NiFe types, have a nominal cell voltage of 1.2 volts per cell.  
 Most Xantrex inverters and battery chargers are optimized for use with lead acid batteries having a nominal 2.0 volts per cell (that is, 12 cells for a 24-volt system and 24 cells for a 48-volt system).  
 The number of cells required in a battery bank for alkaline batteries must, therefore, be adjusted for a 24- and 48-volt system (i.e, 20 cells for a 24-volt system and 40 cells for a 48-volt system).
- Alkaline batteries require a higher charge voltage to fully recharge, and drop to a lower voltage during discharge compared to a similarly sized lead-acid type battery.

Other options                      Another option for 24-volt (only) alkaline battery banks is to use only 19 cells instead of 20. Fewer cells allow the battery charger to operate more closely to the settings used for lead-acid batteries. However, the battery voltage will drop to as low as 18 volts when discharging the batteries.

Consult the battery manufacturer or supplier regarding system requirements and battery charger settings for alkaline type batteries.

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## Understanding Battery Capacity Ratings

Amp-hour capacity	Every deep cycle battery has a capacity which is measured in amp hours. Amp hours are a measure of current flow over time. An amp-hour figure is derived simply by multiplying current (amperes) by the amount of time the current flows (hours). This applies equally to the amount you take out of a battery (discharging) or the amount you put into it (charging). amp hours are frequently referred to by the abbreviations A-h or Ahr.
Discharge rate	Deep cycle batteries have their amp-hour rating expressed as "at the x-hour rate". This is an average rate of current flow that would take x number of hours to discharge the batteries. Common amp-hour figures are at the 6-hour rate, the 20-hour rate and the 100-hour rate. A battery is classified as having fewer amp-hours if is being discharged at a faster rate, such as the 6-hour rate. There is an inevitable amount of heat associated with the flow of current through a battery. The higher the amount of current, the greater the amount of heat generated. The heat is energy which is no longer available to the battery to power loads. Hence, at a higher discharge rate, the batteries effectively have fewer amp hours available. Generally the 20-hour rate is the most common one. If you are trying to gauge the battery size on a battery that is says it has different amp hours at different hour rates, use the 20-hour rate.
CCA rating	Starting batteries are rated in CCA (Cold Cranking Amps), or other types of "cranking amps". This expresses battery capacity in terms of its ability to provide large amounts of current instantaneously to start an engine. It has no time factor, such as hours, taken into account. This is one reason that starting batteries are not appropriate for inverter systems. There is no reliable way to calculate run time for an inverter, using cranking amps as a figure. Some batteries, such as marine starting batteries, are rated in both CCA and amp hours. This type is appropriate.

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**Important:** Batteries must have a known amp-hour rating (Ahr or A-h) of some size in order to be appropriate for an inverter system.

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## Battery Bank Sizing

Running time and size	The battery bank's size determines the length of time the inverter can supply AC output power. The larger the bank, the longer the inverter can run and the longer the recharge time.
Depth of discharge	In general, the battery bank should be designed so the batteries do not discharge more than 50% of their capacity on a regular basis. Discharging up to 80% is acceptable on a limited basis, such as a prolonged utility outage. Totally discharging a battery can reduce its effective life or permanently damage it.
Days of autonomy	For off-grid, stand-alone applications, design a battery bank that can power the loads for three to five days without requiring recharging. This design calculation assumes a worst case scenario where there is no recharging taking place during these days of autonomy.  Days of autonomy may vary depending upon the availability of other charging sources, the critical nature of the load and other factors. If the system is to be powered by renewable energy sources such as solar, wind, and micro-hydro, determine the appropriate number of days of autonomy by allowing for cloudy or calm weather as well as other seasonal variations in available energy.

If an engine generator is part of the system design, the days of autonomy can be determined by simply deciding how often you are prepared to run the generator. Significant battery cost reductions can be achieved by shortening the days of autonomy and allowing a generator to run for a scheduled time period daily.

Back up power systems which use utility power for recharging should use the estimated number of days of maximum power outage for determining days of autonomy.

In general, determine how long you want to use the battery bank between recharges and size it accordingly.

## Grid-tie with Battery Backup

If renewable energy sources (solar, wind, hydro etc.) are going to be used for battery charging, then the amp-hours of the battery bank needs to be 5 times the size of the charging source. For example, if you have a wind turbine that can produce 100-amps DC, then size the battery bank to 500 amp-hours. This is because the batteries aren't just used for storage, they are also a buffer for all the charging energy which is brought into them.

Renewable energy sources require using charge controllers. Some charge controllers cannot respond quick enough to prevent over-voltage conditions in rapidly changing input levels (i.e., wind gusts or grid power interruptions). Small battery banks cannot absorb large spikes in input power that can occur under those conditions. Larger sized battery banks can provide a buffer to prevent equipment damage until the charge controllers take over.

## Understanding Amp-hour Requirements

### Amp hours

To estimate the battery bank requirements, you must first calculate the amount of power you will draw from the batteries during your period of autonomy. This power draw is then translated into amp hours (Ah)—the unit of measure to express deep-cycle battery capacity.

Amp hours are calculated multiplying the current drawn by the load by the length of time it will operate.

### Watts-to-amps

To calculate amps when the power consumption is expressed in watts, use the following equation:

$$A = W/V \text{ (where } W = \text{watts and } V = \text{volts DC)}$$

*For example:*

*A 100 watt light bulb will draw approximately 8.33 amps DC  
(8.33 Adc = 100 watts/12 Vdc)*

*If the light runs for three hours it will consume (8.33 Adc x 3) or 25 Ah of power.*

*For these calculations, do not use the AC amp rating of a device. AC amps are measured on a different scale and will not give correct results.*

### Time and power

The length of time a load is operated will affect the power draw. In some cases, an appliance which draws a large wattage may not consume as many amp hours as a load drawing fewer watts but running for a longer period of time.

*For Example:*

*A circular saw draws 1500 watts or 125 amps DC. It takes 5 seconds to complete a cross cut. Twelve such cuts would take a minute and you would consume  
 $125 \text{ Adc} \times 0.016^* \text{ hour} = 2 \text{ Ah}$  (\*1/60 = 0.016)*

**Observation** The circular saw, while it draws more power, consumed fewer amp hours of electricity because it ran for a short period of time.

## Calculating Amp Hours

Table 1 provides an example of typical wattage for selected appliances. However, you should try to find the exact wattage on the appliance label.

Use the specifications noted on the label of each AC appliance that is to be connected to the inverter and fill in the values specific for those appliances on the worksheet provided in Table 3.

**Table 1 Typical Appliance Wattage**

Appliance	Watts	Appliance	Watts
Fluorescent Type Light	10	Blender	400
Computer	200-300	Toaster	1000
Microwave (compact)	600-800	Hot Plate	1800
Microwave (full-size)	1500	Washer/Dryer	375-1000
Stereo or VCR	50	3/8" Drill	500
Color Television (19")	150	Hair Dryer or Iron	1000
Refrigerator (3 cu ft)	180	Vacuum Cleaner	1200
Refrigerator (12 cu ft)	480	Coffee Maker	1200

To determine the amp hours you will consume, you need to list your anticipated loads and the length of time you will operate each one. Determine the number of hours per day and the number of days during the week you will use the appliance. For example, you use the microwave every day, but a bread maker only once a week. If you use an appliance for less than an hour, express the time as a decimal portion of an hour. See Table 2 on page 8 for an example of how to make these calculations. Use Table 3 on page 8 to fill in your respective values.

**Amps to watts**

All electrical appliances have labels which state their energy consumption. Look for an amps rating on motors and a watts rating on other appliances.

If the label plate has expressed power consumption in AC amps, multiply by volts for the watts required. (watts = volts x amps)

**Considerations**

When calculating battery bank size, consider the following:

- Motors typically require 3 to 6 times their running current when starting. Check the manufacturer's data sheets for their starting current requirements. If you will be starting large motors from the inverter, increase the battery bank size to allow for the higher start-up current.
- Refrigerators and ice-makers typically run only about 1/3 of the time, therefore, the running wattage is 1/3 of the total wattage of the appliance. Divide the total wattage of the appliance by 3 when determining the battery requirements.

**Calculations**

Complete the following steps to calculate the amp-hour requirements per day for your system. Use Table 2 as examples to help you complete your own worksheet. Table 3 is provided for you to fill in your actual values.

**To calculate amp-hour requirements:**

1. Determine the loads the inverter will power and enter their wattage in the watts column.
2. Determine the number of hours (or decimal portion of hours) the appliance is used each day. Enter this figure in the Hours column.

3. Determine the number of days the appliance will be used during the week. Enter this figure in the Days column.
4. Multiply Hours x Days for each load identified to determine the watt/hours per week.
5. Add the total watt/hours per week for all loads then divide by 7 to obtain the average total watt/hours per day.
6. Divide the total average per day by the DC nominal voltage.

This figure represents the average amp-hours per day that you will use.

**Table 2** Example Worksheet for Determining Average Daily Load in Amp-hours

Load	Watts	Hours per Day	Days per week used	Weekly watt-hours
5 lights: 15 W CFL	75 W	5	7	2625
Bread maker	1200	0.75	2	1800
Energy-efficient refrigerator	200 x 0.3	24	7	10080
Laptop computer	50	6	5	1500
Total weekly watt-hours of AC load				16005 Wh
Divided by days per week				7
Average total watt-hours per day				2286
Divided by DC nominal voltage				24
Average amp-hours per day (Ah/d)				95

### Worksheet for Calculating Amp Hour Requirements

Use Table 3 below to calculate the amp hour requirements for your specific installation.

**Table 3** Worksheet for Determining Average Daily Load in Amp-hours

Load	Watts	Hours per Day	Days per week used	Weekly watt-hours
Total weekly watt-hours of AC load				
Divided by days per week				7
Average total watt-hours per day				
Divided by DC nominal voltage				(12, 24 or 48)
Average amp-hours per day (Ah/d)				

## Calculating the Battery Bank Size

### Calculation

Use the information provided by Table 3 and follow the formula below to determine the size of the battery bank required to support the amp-hour requirement identified in Table 3. Table 4 provides an example of this formula. Use Table 5 to fill in the values specific to your system.

**To calculate the battery bank size required to support your loads:**

1. Determine the average amp hours needed per day to support the loads connected to the system. (Use the value calculated in Table 3).
2. Divide the average amp hours needed per day by the efficiency of the inverter.
3. Divide the value derived in step 2 above by the efficiency of the battery.
4. The value derived from step 3 is your “adjusted amp hours per day”.
5. Divide the value derived in step 4 above by the “Depth of Discharge” specific to the battery being used (usually 50%).
6. Multiply the value derived in Step 5 by the desired “Days of Autonomy”.
7. The result is the number of amp hours the battery bank must support. Select the number of batteries that meets or exceeds the battery bank size required value in the last line of Table 5.

**Table 4** Example Worksheet for Determining Battery Bank Size

1. Average amp hours per day (example is from Table 2)	95
2. Divided by inverter efficiency <sup>a</sup>	$95 \div 0.9 = 106$
3. Divided by battery efficiency (usually 0.75)	$106 \div 0.75 = 141$
4. Adjusted amp hours per day	141
5. Divided by Depth of Discharge (usually 50% remaining)	$141 \div 0.5 = 282$
6. Multiplied by days of autonomy	$282 \times 5 = 1410 \text{ Ah}$
7. Battery bank size required	1410 Ah

<sup>a</sup>.90% is used in this example for illustrative purposes only. Substitute the actual value of the inverter efficiency being used to get your correct value.

### Worksheet for Calculating Battery Bank Size

Use Table 5 below to calculate the battery bank size for your specific installation.

**Table 5** Worksheet for Determining Battery Bank Size

1. Average amp hours per day (from Table 3)	
2. Divided by inverter efficiency	
3. Divided by battery efficiency (usually 0.75)	
4. Adjusted amp hours per day	
5. Divided by Depth of Discharge (usually 60%)	
6. Multiplied by days of autonomy	
7. Battery bank size required	

## Battery Configurations

The battery bank must be wired to match the inverter's DC input voltage specifications. In addition, the batteries can be wired to provide additional run time. The various wiring configurations are:

- Series                      Wiring batteries in series increases the total bank output voltage. This voltage **MUST** match the DC requirements of the inverter or inverter and/or battery damage may occur.
  - Parallel                    Wiring the batteries in parallel increases the total run time the batteries can operate the AC loads. The more batteries connected in parallel the longer the loads can be powered from the inverter.
  - Series-Parallel           Series-parallel configurations increase both the battery voltage (to match the inverter's DC requirements) and run-time for operating the AC loads. This voltage must match the DC requirements of the inverter.
- Batteries with more than two or three series strings in parallel often exhibit poor performance characteristics and shortened life.

### Wiring Batteries in Series

- Effect                      Wiring the batteries in a series configuration increases the voltage of the battery string. Six-volt batteries can be combined to form 12-volt, 24-volt or 48-volt battery banks. In the same way, 12-volt batteries connected in series form 24-volt and 48-volt battery banks. The total current capacity of the bank does not increase and remains the same amp-hour rating as it does for a single battery.
- Important                 The voltage must match the DC requirements of the inverter.

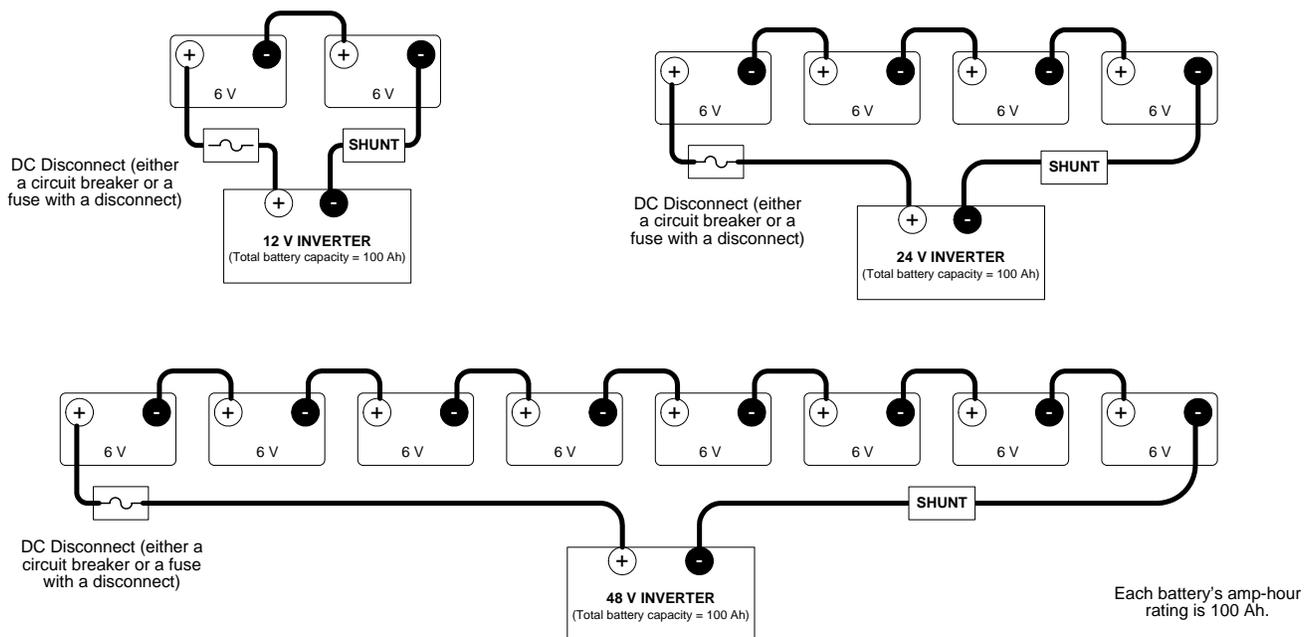


Figure 1 6-volt Battery Wiring - "Series" Configuration

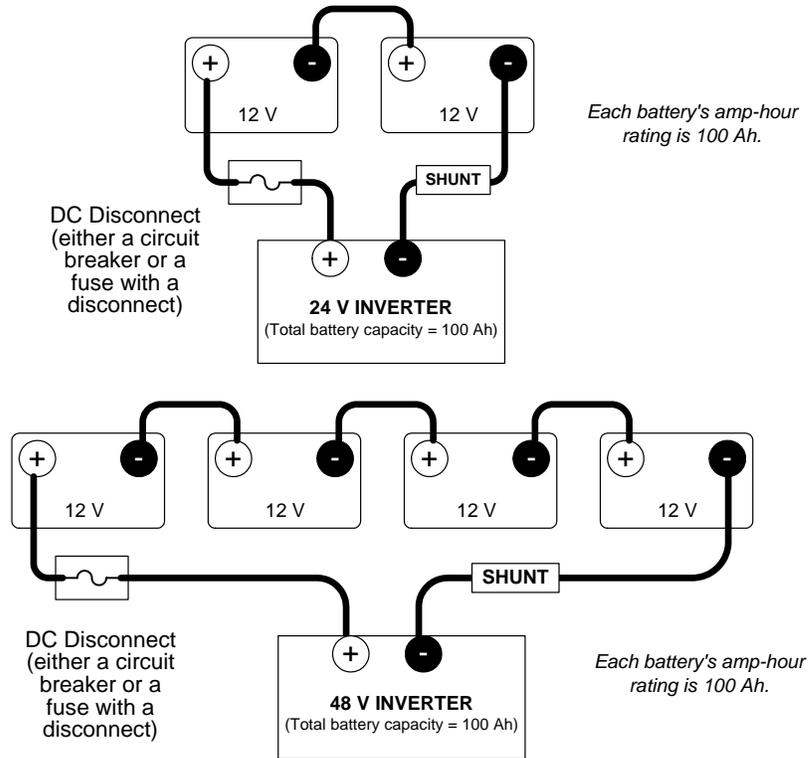


Figure 2 12-volt Battery Wiring - "Series" Configuration

## Wiring Batteries in Parallel

### Effect

Wiring the batteries in a parallel configuration increases the current of the battery string. The voltage of the battery bank remains the same as an individual battery. "Parallel" configurations extend the run times of the AC loads by providing increased current for the inverter to draw from. In a parallel configuration, all the negative battery terminals are connected together and all the positive battery terminals are connected together.

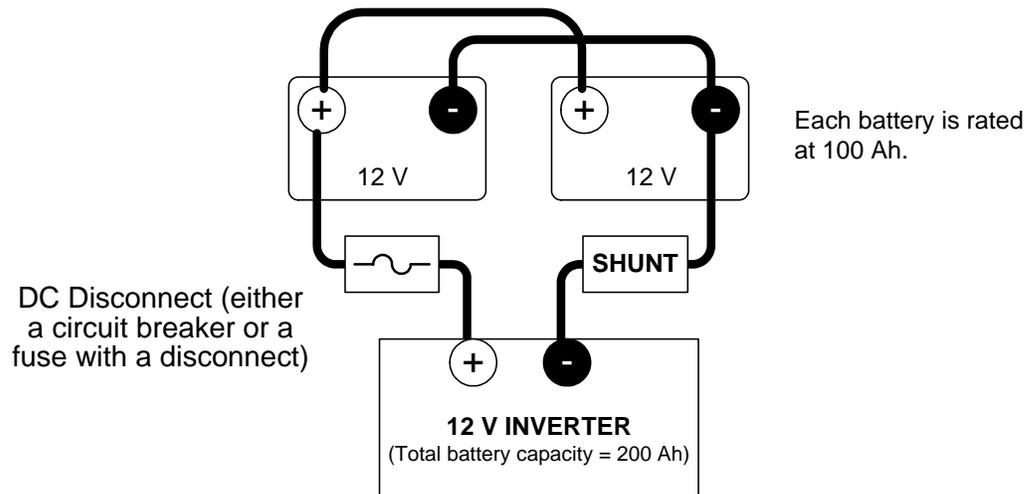


Figure 3 Battery Wiring in Parallel (Example Only)

## Wiring Batteries in Series-Parallel

**Effect** Wiring the batteries in a series-parallel configuration increases the current and voltage of the battery bank. “Series-parallel” wiring is more complicated and care should be taken when wiring these banks.

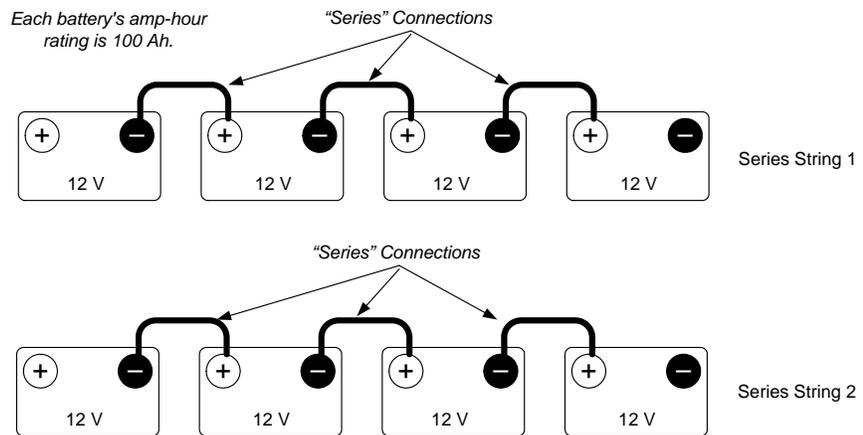
**Steps** It is done in three steps; wiring the batteries in series, wiring them in parallel, then wiring the string to the inverter.

**Series wiring**

**To wire in series:**

1. First wire the batteries in “series” (voltage adds) with the positive terminal of one battery connected to the negative terminal of the next battery to meet the inverter’s DC input requirements (48 volts shown in Figure 4 and Figure 5.)
2. Repeat this step for the next battery string.

Two identical strings of batteries are now wired in series.

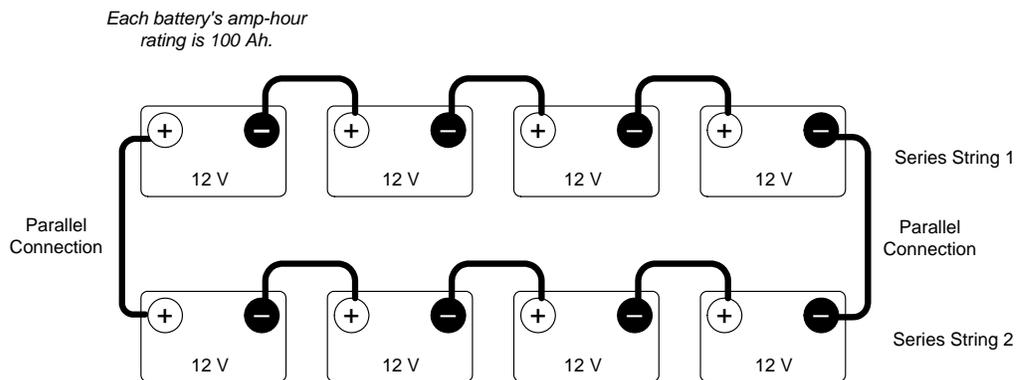


**Figure 4 Step 1 - Wiring Batteries in “Series”**

**Parallel wiring**

**To wire the batteries in parallel:**

1. Connect the positive terminal of the first battery string to the positive terminal of the second battery string.
2. Connect the negative terminal of the first battery string to the negative terminal of the second battery string.



**Figure 5 Step 2 - Two series strings wiring in “Parallel”**

Connect to inverter

**To connect to the inverter:**

1. Connect a cable from the positive terminal of the first battery string to the inverter's positive DC terminal (via a fused device).
2. Connect the negative terminal of the last battery string to the negative terminal of inverter's DC terminal.

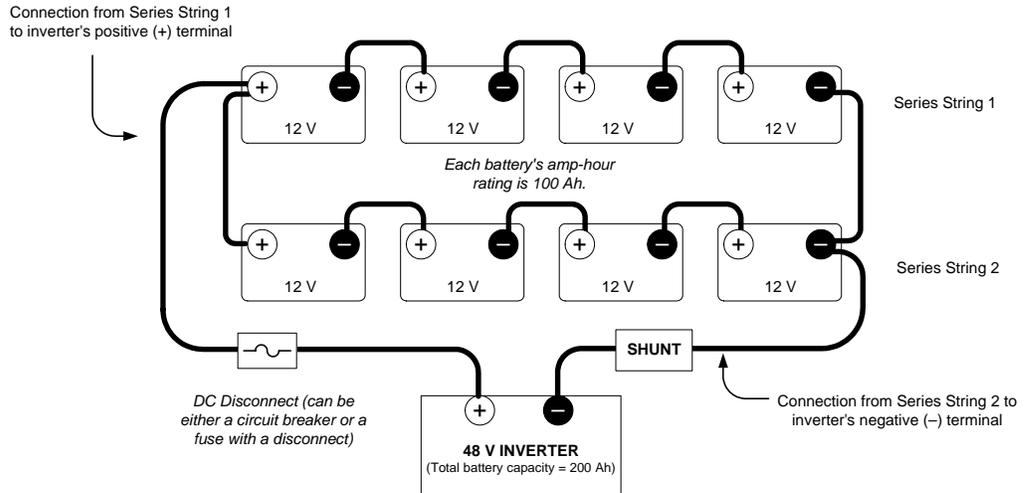


Figure 6 Step 3 - "Series-Parallel" Configuration Wired to the Inverter

## Battery Connections for Stacked Inverters

When using inverters in a stacked configuration, the same battery bank must be used for both inverters. To ensure even charging of the batteries, each inverter must be connected to both strings as shown in Figure 7. In other words, for Inverter 1, connect the positive cable to String 1 and the negative cable to String 2. For Inverter 2, connect the positive cable to String 2 and the negative cable to String 1.).

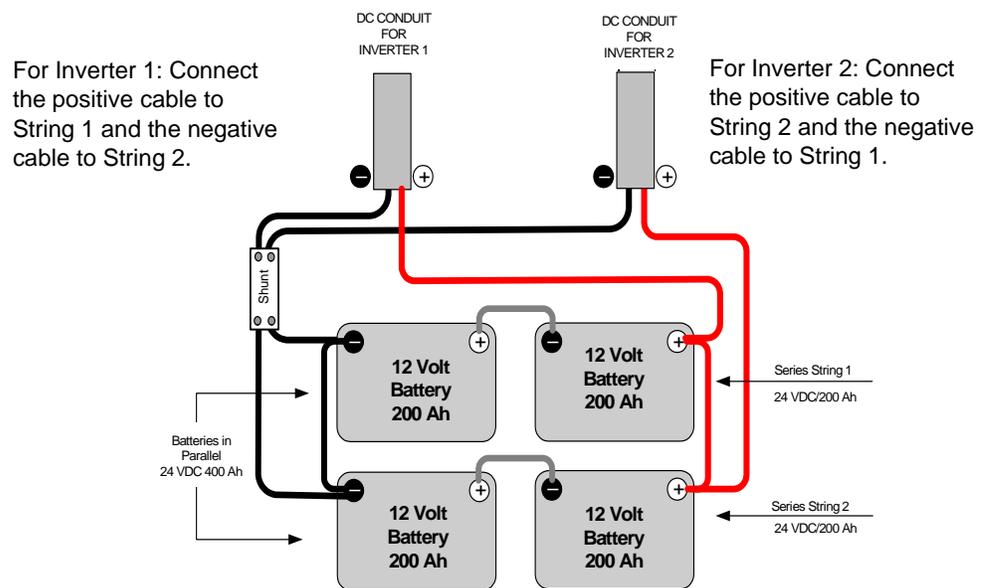


Figure 7 Battery Connections for Stacked Inverters (24 Vdc configuration shown)

## Battery Maintenance

### Maintenance strategy

To get the best performance from an inverter system, the batteries must be properly setup and maintained. This includes setting the proper voltages for Bulk and Float charging. See the “CAUTIONS” in the section on Equalization Charging that follows. In addition, the battery terminals should be inspected, cleaned, and re-torqued if necessary.

Neglecting any of these items may result in poor inverter performance and greatly reduce battery life.

## Battery Charging

### Charge Rate

The maximum safe charge rate is related to the size and type of the batteries. Flooded lead acid batteries (with removable caps) can be charged at a high rate. Small batteries may require a lower charge rate. Check with your battery vendor for the proper battery charging rate for the batteries used in the system.

### Bulk Voltage

This is the maximum voltage the batteries will be charged to during a normal charge cycle. Gel cell batteries are set to a lower value and non-sealed batteries are set to a higher voltage setting.

### Float Voltage

The Float voltage is set lower than the Bulk voltage and provides a maintenance charge on the batteries to keep them in a ready state.

### Temperature Compensation

For optimal battery charging, the Bulk and Float charge rates can be adjusted according to the temperature of the battery. This can be accomplished automatically by some inverter/chargers by using a battery temperature sensor (BTS). The sensor attaches directly to one of the batteries in the bank and relays temperature information to the inverter/charger through the BTS communications cable. Not all inverters/chargers have this capability.

When battery charging voltages are compensated based on temperature, the charge voltage will vary depending on the temperature around the batteries. The following table describes approximately how much the voltage may vary depending on the temperature of the batteries.

If you have liquid lead acid batteries (non-sealed), you may need to periodically equalize your batteries. Check the water level monthly to maintain it at the appropriate level.

**Table 6** Typical Bulk and Float Setpoints for Common Battery Types (Guidelines only)

Battery Type	12-Volt Systems		24-Volt Systems		48-Volt System		Equalizing Charge Process
	Bulk Volts	Float Volts	Bulk Volts	Float Volts	Bulk Volts	Float Volts	
Sealed Gell Lead Acid battery	14.1 Vdc	13.6 Vdc	28.2 Vdc	27.3 Vdc	56.4 Vdc	52.0 Vdc	Not recommended - Consult manufacturer
AGM Lead Acid battery	14.4 Vdc	13.4 Vdc	28.8 Vdc	26.8 Vdc	57.6 Vdc	53.6 Vdc	Charge to 15.5 Vdc (31 Vdc or 62 Vdc) or per manufacturer
Maintenance-Free RV/Marine Lead Calcium Battery	14.4 Vdc	13.4 Vdc	28.8 Vdc	26.8 Vdc	57.6 Vdc	53.6 Vdc	Not recommended - Consult manufacturer
Deep-Cycle, Liquid Electrolyte Lead Antimony Battery	14.4 Vdc	13.4 Vdc	28.8 Vdc	26.8 Vdc	57.6 Vdc	53.6 Vdc	Charge to 15.8 Vdc (31.6 or 63.2) or per manufacturer
NiCad or NiFe Alkaline Battery* (using 10 cells in series)	16.0 Vdc	14.5 Vdc	32.0 Vdc	29.0 Vdc	64.0 Vdc	58.0 Vdc	Not recommended - Consult manufacturer

**Table 7** Variances in Charging Voltage based on Battery Temperature

Temperature (around the BTS)		12-volt units		24-volt units		48-volt units	
Celsius	Fahrenheit	Lead Acid (6 cells)	NiCad (10 cells)	Lead Acid (6 cells)	NiCad (10 cells)	Lead Acid (6 cells)	NiCad (10 cells)
60	140	-1.05	-0.70	-2.10	-1.40	-4.20	-2.80
55	131	-0.90	-0.60	-1.80	-1.20	-3.60	-2.40
50	122	-0.75	-0.50	-1.50	-1.00	-3.00	-2.00
45	113	-0.60	-0.40	-1.20	-0.80	-2.40	-1.60
40	104	-0.45	-0.30	-0.90	-0.60	-1.80	-1.20
35	95	-0.30	-0.20	-0.60	-0.40	-1.20	-0.80
30	86	-0.15	-0.10	-0.30	-0.20	-0.60	-0.40
25	77	0.00	0.00	0.00	0.00	0.00	0.00
20	68	0.15	0.10	0.30	0.20	0.60	0.40
15	59	0.30	0.20	0.60	0.40	1.20	0.80
10	50	0.45	0.30	0.90	0.60	1.80	1.20
5	41	0.60	0.40	1.20	0.80	2.40	1.60
0	32	0.75	0.50	1.50	1.00	3.00	2.00
-5	23	0.90	0.60	1.80	1.20	3.60	2.40
-10	14	1.05	1.20	2.10	1.40	4.20	2.80
-15	5	1.20	0.80	2.40	1.60	4.80	3.20
-20	-4	1.35	1.40	2.70	1.80	5.40	3.60
-25	-13	1.50	1.00	3.00	2.00	6.00	4.00
-30	-22	1.65	1.10	3.30	2.20	6.60	4.40
-35	-31	1.80	1.20	3.60	2.40	7.20	4.80
-40	-40	1.95	1.30	3.90	2.60	7.80	5.20

Temperature compensation is based on battery type—5 mv/cell for lead acid type batteries and 2 mv/cell for alkaline type batteries (NiCad or NiFe). The temperature compensation calculations are derived from Table 8.

**Table 8** Temperature Compensation Calculation

Battery Type	12-volt Systems	24-volt Systems	48-volt Systems
Lead Acid	0.030 volts (30 mV) per degree Celsius	0.060 volts (60 mV) per degree Celsius	0.120 Volts (120 mV) per degree Celsius
NiCad	0.020 volts (20 mV) per degree Celsius	0.040 volts (40 mV) per degree Celsius	0.080 volts (80 mV) per degree Celsius

**Important:** If the battery temperature is allowed to fall to extremely cold temperatures, the inverter with a BTS may not be able to properly recharge cold batteries due to maximum voltage limits of the inverter. Ensure the batteries are protected from extreme temperatures.

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## Equalization Charging

Purpose	An equalize charge helps to remove sulfate buildup on the battery plates and balances the charge of individual cells.
Effect	Equalize charging also produces gassing which stirs up the electrolyte mixture and helps distribute the acid more evenly.
Non-equalized batteries	Batteries that are not equalize charged can be damaged by sulfate accumulation, thus sealing off a percentage of the plates and reducing battery capacity. They may also have sulfuric acid accumulate at the bottom of the battery, potentially damaging the plates. At the same time, the electrolyte at the top of the battery gets watery. This effect is called stratification.
Frequency	Standard electrolyte vented batteries can be equalize charged every 9 to 12 months or sooner if you find that your battery capacity has decreased below normal.



### CAUTION: Damage to DC Loads

The high voltages reached during an equalize charge may damage DC loads that are connected to the inverter. Disconnect any DC loads from the inverter before running an equalize charge.



### CAUTION: Damage to Batteries

Equalization should be done for standard electrolyte vented batteries only. Sealed or GEL cell batteries should not be equalize charged. Consult your battery supplier for details on equalize charging for the battery type in your system.

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## Exercising the Battery Bank

Field experience has proven that batteries that sit and don't go through a discharge/recharge cycle very often have a reduced life cycle.

It is, therefore, recommended to exercise the battery bank by putting it through a charge/discharge cycle once a month. This can be accomplished by disconnecting any AC input sources and running the batteries down to approximately 50% state-of-charge.

## General Maintenance

The following general maintenance may be required depending on the type of batteries being used and/or the condition of the batteries.



### WARNING: Risk of Acid Burns

Wear appropriate eye protection and rubber gloves when carrying out battery maintenance activities.



### WARNING: Risk of Fire, Explosion and Burns

Use caution when wearing jewelry or working with metal tools around batteries. Do not allow any metal object to contact both battery terminals at the same time. The metal may become welded to the battery terminals causing extreme heating or fire.

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## Water Levels

- Electrolyte** At a minimum, check the level of the electrolyte in each battery cell once a month (for flooded batteries). It should be above the top of the plates, but not completely full. Most batteries have a plastic cup that just touches the electrolyte when the cell is full. Don't overfill the batteries, or the electrolyte will spill out when the batteries are being charged. Refill the batteries with distilled water only—"spring" water and regular tap water may have high mineral levels. These can poison the battery chemistry and reduce battery life and should not be used.
- When filling the battery, clean the surface first to prevent dirt from entering the cell. Fill the cell to just above the plates or to the bottom of the internal collar inside the battery. Never fill the cells to the top or acid will leak out during charging.
- Check the water level in the batteries frequently when performing an equalize charge and add water if necessary. Always follow the safety steps covered in the front of the manual.

## Checking the Cable and Cable Connections

- Cable Condition** Check the cables for the following possible problems:
- Inspect all battery cables for missing or damaged insulation or loose connections.
  - Inspect any openings that the cables pass through. All such openings must be equipped with a rubber grommet or conduit to prevent chafing on the cable.
  - If necessary, replace worn grommets.
  - If the cable insulation is worn, replace the cable.
- Battery Connections** Periodically check the battery connections for tightness and corrosion. If the connections are loose, then tighten them to the manufacturer's specifications.
- Check for Corrosion** Loose battery terminals and lugs exposed to open air corrode rapidly. The corrosion appears as a white powder or granular foam on the terminals and any nearby exposed metal parts. This powder is actually a crystallized form of sulfuric acid. If it contacts your skin, it will cause burns unless you rinse it off immediately. Most textiles that are exposed to this corrosive eventually dissolve.
- The most common cause of battery system failure is loose or corroded battery terminals and cable lugs. If any white powdery residue forms between the battery cable lug and the battery terminal, remove the cable for cleaning.
- Battery Terminals** Battery posts must be clean to reduce the resistance between the battery post and cable connection. A buildup of dirt or oxidation may eventually lead to the cable terminal overheating during periods of high current draw.
- Dirty batteries can leak current and tend to run warmer, which reduces the efficiency of the battery. Keeping the batteries and the battery enclosure clean will keep batteries operating efficiently.
- To reduce the amount of corrosion on the battery terminals, coat them with anti-corrosion grease or liquid neoprene (liquid electrical tape) after re-assembly. This will cure to form an airtight protective layer. This is available from automotive parts stores or battery suppliers. Do not apply anything between the terminal and the cable lugs. The connection should be metal to metal. Apply the protective material only after the bolts have been tightened.
- When batteries and/or the battery enclosure become dirty or corroded, following the instructions provided in "Cleaning the Batteries" on page 20.

## Checking the State-of-Charge

### State of Charge

The battery’s state-of-charge should be checked often and only when the battery is at a state of rest (when the battery is not powering loads or actively being charged). First thing in the morning is usually the best time to check the state of charge. If the batteries are readily accessible, a good estimate of a battery’s state-of-charge can be made by measuring the voltage across the individual battery terminals.

To determine the individual cell voltage, divide the voltage by the number of cells in the battery (25.2 volts divided by 12 cells = 2.1 volts per cell). There should be less than a 0.2 volt difference between each battery. If a greater difference is measured, the batteries may need to be equalized (liquid lead-acid types only) or replaced.

All batteries in the bank should measure the same voltage (this is not an accurate measurement for cross-tied batteries’ as each battery is in parallel with another battery making individual battery measurements impossible).

The voltage should match the following table for the entire battery bank output. These values give a good indication of the overall battery’s state of charge for the entire bank. Individual cell voltages (if available) are also shown as a percentage of charge.

The values given are for a FLA-type battery and at temperature of 77 °F (25 °C). Cooler temperatures produce lower voltage measurements.

**Table 9** Battery State-of-Charge

Percent of Full Charge	System Voltage			Individual Cell Voltage
	12 Volt	24 Volt	48 Volt	
100%	12.7	25.4	50.8	2.12
90%	12.6	25.2	50.4	2.10
80%	12.5	25.0	50.0	2.08
70%	12.3	24.6	49.2	2.05
60%	12.2	24.4	48.8	2.03
50%	12.1	24.2	48.4	2.02
40%	12.0	24.0	48.0	2.00
30%	11.8	23.6	47.2	1.97
20%	11.7	23.4	46.8	1.95
10%	11.6	23.2	46.4	1.93
0%	≤ 11.6	≤ 23.2	≤ 46.4	≤ 1.93

**Important:** Table 9 only applies for batteries that have been at rest for a minimum of 3 hours (i.e., no inverting, no charging).

## Preparation for Cleaning Batteries

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### WARNING: Personal Safety

Review the “Safety Precautions When Working With Batteries” on page 1 before you begin.

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Gather what you need before beginning.

#### Clothing

Appropriate clothing could include old clothes, rubber boots, or old shoes. Battery acid is highly corrosive, so wear something you can live without just in case you splash some on yourself. Be sure to wear rubber gloves and eye protection.

#### Tools

- Adjustable insulated wrench or appropriately sized sockets and ratchet for battery terminals
- Torque wrench
- A dedicated brush of sufficient stiffness to remove the corrosion. ***Be sure not to use this brush on anything after using it to remove corrosion.***
- 6 inch scrub brush
- Inexpensive ½ inch chip brush or soldering brush

#### Equipment

- Eye protection
- Rubber gloves
- Water hose with spray nozzle or five gallon watering bucket
- Empty spray bottle

#### Supplies

- Baking soda and/or vinegar. (Always keep on hand in the event of a spill.)
- Hand cleaner or soap and towels
- After reattaching cables: anti-corrosion grease or liquid neoprene (liquid electrical tape) (available at auto, RV, and marine stores)

## Disconnecting Batteries

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### WARNING: Shock Hazard/Personal Injury

Inverter systems may have more than one input source. Before removing any cables from the battery, ***disconnect all loads and charging sources.***

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#### To disconnect the batteries safely:

1. Disconnect all loads and charging sources.
2. Disconnect the Negative (-) battery cable first.
3. Disconnect the Positive (+) battery cable last.
4. Clean the terminals as described in “Cleaning the Terminals & Lugs” on page 20.

## Reconnecting Batteries

### To reconnect the batteries safely:

1. Reconnect the Positive (+) battery cable first.
2. Reconnect the Negative (-) battery cable last. Torque to manufacturer's specifications. Do not over-tighten.
3. Coat both terminals with anti-corrosion grease or liquid neoprene (liquid electrical tape) after re-assembly to prevent further corrosion. Do not apply anything between the terminal and the cable lugs. The connection should be metal to metal. Apply the protective material only after the bolts have been tightened.
4. Reconnect the loads and charging sources.

## Cleaning the Batteries

If corrosion or dirt has been found, follow the instructions below to remove it and clean the terminal connections.

## Cleaning the Battery Enclosure and Batteries

Remove any debris or obstructions that may be blocking any ventilation holes in the enclosure. Ensure that there is adequate space around the enclosure to allow for sufficient airflow.

### To clean the battery enclosure and exterior of the batteries:

1. Mix four ounces of baking soda with a gallon of fresh water and fill a spray bottle. Ensure that all caps are on tight on the battery so solution doesn't enter the battery.
2. Spray the solution on all exposed surfaces of the battery compartment, and wash down the exposed surfaces of the batteries and their enclosure.
3. Scrub stubborn areas with the scrub brush. Baking soda will neutralize any acid that may have collected on these surfaces.
4. Finish by rinsing with water.



### **CAUTION: Damage to Batteries**

Never let a baking soda solution get into the battery as it will neutralize the acid resulting in permanent damage.

## Cleaning the Terminals & Lugs

### To clean the battery terminals and terminal lugs:

1. Follow the instructions in "Disconnecting Batteries" on page 19 to safely disconnect the battery cables.
2. Use a brush with sufficient stiffness to remove dirt and corrosion. To remove any stubborn residue, sprinkle baking soda directly on the area and then rinse. *Do not use this brush on any other surface after using it to remove corrosion.*
3. Follow the instructions in "Reconnecting Batteries" on page 20 to safely reconnect the battery cables. Do not over-tighten.

To reduce the amount of corrosion on the battery terminals, coat them with anti-corrosion grease or liquid neoprene (liquid electrical tape) after re-assembly. This will cure to form an airtight protective layer. This is available from automotive parts stores or battery suppliers. Do not apply anything between the terminal and the cable lugs. The connection should be metal to metal. Apply the protective material only after the bolts have been tightened.

## Battery Bank Information Form

The following questionnaire is provided as a convenience to provide a summarized location for the information required to safely and efficiently charge and maintain a battery bank. Consult the battery manufacturer to collect or confirm the settings.

### Battery Bank Configuration

- Type/Chemistry
- Brand/Manufacturer: \_\_\_\_\_
  - Model: \_\_\_\_\_
  - Type/Chemistry (Flooded LA, Gel, AGM, NiCad, other): \_\_\_\_\_
  - Number of cells per battery: \_\_\_\_\_
- Configuration
- Single Battery (one unit)
    - This battery is a \_\_\_\_\_ Volt, \_\_\_\_\_ Amp-hour battery
  - Multiple Battery Bank
- Voltage/Amp Hour Rating
- Each individual battery in this bank is a \_\_\_\_\_ Volt \_\_\_\_\_ amp-hour battery. The amp-hour rate is rated at the \_\_\_\_\_ hour rate
  - This battery bank is configured as a \_\_\_\_\_ Volt, \_\_\_\_\_ amp-hour battery bank
  - This battery bank is configured with \_\_\_\_\_ batteries in series as one "series string" to create \_\_\_\_\_ Volts
  - \_\_\_\_\_ of these series "strings" of batteries are in parallel to create \_\_\_\_\_ amp hours.

### Charging Requirements

- Voltage
- Bulk voltage \_\_\_\_ volts per cell at 25°C (77°F)
  - Max charge rate \_\_\_\_ amps DC
  - Absorption Time \_\_\_\_ (charging held at the bulk voltage) (a.k.a. Acceptance charge) (note: some chargers do not have this feature)
  - Charging finish current (determines when to end charging or reduce to the float voltage) \_\_\_\_ Amps dc (note: some chargers do not have this feature)
  - Float voltage \_\_\_\_\_
  - Equalize voltage \_\_\_\_\_
  - Equalize time \_\_\_\_\_

- Equalize frequency (how often or when) \_\_\_\_\_
- OPTIONAL: Minimum normal charge rate \_\_\_\_ Amp dc (during a normal charging cycle the charger should be able to produce this many amps)
- Temperature compensation \_\_\_\_ V per degree C
- Charging values based on a battery temperature of \_\_\_\_\_ °C/°F

## Usage

- Normal recommended depth of discharge \_\_\_\_\_%  
(percent removed from the battery)
- Maximum recommended depth of discharge \_\_\_\_\_%  
(limit before turning off loads and recharging)
- For backup power systems - Frequency of system discharge test \_\_\_\_\_ months  
(discharge and recharge test)

## Notes

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Part number: 976-0114-01-01 Rev A

Contact information:

Phone: 1-800-670-0707 (toll-free in North America)

Phone: 1-360-925-5097 (outside North America)

Fax: 1-360-925-5143

Email: [customerservice@xantrex.com](mailto:customerservice@xantrex.com)

Web: [www.xantrex.com](http://www.xantrex.com)