Backwoods Solar

ATTENTION: BATTERY CARE IS CRITICAL!

1) Batteries must be placed into service immediately. They cannot be put into storage for future use without risk of permanent damage.

2) Your charging equipment: charge controller, inverter/charger must be programmed properly AND should use a temperature sensor. Default settings are typically incorrect! Please consult specific product manuals online or call us if you have any questions, (208) 263-4290.

Backwoods has had the most success with the following set point recommendations. Please read this whole document for a thorough understanding of how they can be adjusted for your specific system. The set points below are nominal and should not be construed as absolute for final system design. Backwoods Solar makes no warranties-expressed or implied-based on the data in this document.

Set Points for Flooded Lead Acid Batteries				
System Voltage	Bulk/Absorb Voltage	Float Voltage	Equalization Voltage	Absorb Time
12 Volt	14.8	13.5	15.5	1 -2 Hours
24 Volt1	29.6	27	31	1 -2 Hours
48 Volt	59.2	54	62	1 -2 Hours

Set Points for Sealed Batteries				
System Voltage	Bulk/Absorb Voltage	Float Voltage	Equalization Voltage*	Absorb Time
12 Volt	14.2	13.5	---	1 -2 Hours
24 Volt	28.4	27	---	1 -2 Hours
48 Volt	56.8	54	---	1 -2 Hours

*Sealed batteries should never be equalized.

Rev: 7/5/18

232-1230 Transport

BATTERY CARE AND MAINTENANCE

Many factors affect the life of your battery bank and three actions on your part are critical:

1) Programming your equipment with proper voltage set points.
2) Frequently recharging your battery bank to a full state of charge.
3) Confirming the batteries have reached a full state of charge.

Programming

Once a solar system installation is finished the charging equipment must be configured. The factory default settings will likely *not* be appropriate for your specific system. These settings can include Bulk/Absorb Voltage, Float Voltage, Equalization Voltage, Absorb Time, Equalization Time, and Battery Bank Capacity.

Charge Controllers and Inverters with built-in battery chargers often include remote temperature sensors to automatically counteract the effect of temperature fluctuations on the proper recharging of any battery bank. As indicated below, the care and health of batteries can be greatly impacted by failing to adjust voltage set-points for temperature swings. Using the temperature sensor designed for those components is the easiest way to ensure your voltage set-points are appropriately adjusted. Without one, you would need to manually adjust recharging set-points as temperature fluctuates or risk permanently degrading battery performance and health.

Every system is different; not just in the equipment, but also in the application. Backwoods has found that no one set of "perfect" values exists. Determining which values work best is a matter of starting with best recommendations, evaluating systems performance, and using that feedback to fine tune the settings.

Our best recommendation is to consider a two-pronged approach. First, get a copy of the battery spec sheet for your battery set. Backwoods includes links to spec sheets for the batteries we sell on our website. A quick internet search for *"brandname modelnumber spec sheet"* can yield the same results. Manufacturer's spec sheets will have their recommendations for their products, often showing a range of values for a given setting.

The second step is to consider *your* system and *your* application. Historically, a lot of battery data was collected under conditions different than seen in off-grid applications. Some based on automobile engine charging of batteries, some on fixed test-bed lab conditions, some using a constant steady power source such as utility power. An off-grid home will have varying conditions though; hours of sunlight seasonally, partially cloudy days, low-usage and high-usage days, etc. This leads to many systems using a set point at or beyond the manufacturer's recommended set points.

A system operating in a season or location with a shorter window of sunlight hours may use a slightly higher bulk/absorb voltage set point due to the lack of sunlight hours for an ideal absorb time. A system operating with a longer solar window may be suited fine with standard voltage set points, and a slightly longer absorb time. Systems heavy on solar panels relative to the size of the battery bank may use standard set points, while systems heavy on the battery bank size may need higher set points.

Other factors that can affect the choice of set points can include the size of the daily loads the system supports; heavier daily loads may be suited with higher set points, while systems with smaller, light-duty loads may be satisfied with lower set points. The set points for backup charging through a generator can be affected by the size of the generator; potentially using higher set points for smaller generators. A battery bank backed-up by utility power, being present 24/7, will probably be served fine with standard set points.

Determining the "correct" set points for your system is a matter of process and observation. Observing state of charge at the end of a sunny day, or at the end of a generator cycle will let the operator know if the set points are adequate. Not being fully charged may call for an increase in voltage and/or absorb time. Battery banks that do achieve full charge but got unusually hot or burned off excessive amounts of water may need set points reduced.

Given the ranges and all the variables, what is a good *starting* voltage set point? In most cases Backwoods has found values at the higher ends of the ranges to work the best for "typical" off-grid systems; where sunlight is seasonally limited, and systems are used modestly on most days. In some cases, we have found numbers outside of the manufacturer's recommendations work best. Again, **always use feedback** from your system performance to fine tune your settings.

Verifying State of Charge

Hydrometer, Voltage and Battery State of Charge

A guideline of battery bank operation is to not discharge a battery set too deeply, and to return it to a full state of charge as soon as possible. Heavy, deep discharging and letting a battery bank operate in a partial state of charge will dramatically shorten the lifespan of the set. In well balanced systems where the array and battery bank were sized to match the expected daily loads, the solar array can be expected to charge the bank to full on the sunny, summer days of the year. Using a generator during the shorter, cloudier days of winter to return the battery bank to a full state of charge on a regular basis is considered a necessity for the health of the battery bank.

The best tool a system owner will use with flooded lead acid batteries to verify state of charge will be a hydrometer. A hydrometer draws in a sample of the battery electrolyte and provides a numerical reading called the Specific Gravity that reflects state of charge. Learning to properly use and read a hydrometer, recording readings in a log book, and checking hydrometer readings as part of a routine maintenance cycle will provide a bounty of useful information to evaluate system performance.

Manufacturers will publish Specific Gravity tables for their products. Always go to their website for documentation for the most accurate information for your system. Below is a good, basic Specific Gravity table from Home Power Magazine:

1.275 100% Crown Batteries

Back down to 61 lower

Specific Gravity	% Full
1.255 – 1.275	100%
1.215 – 1.235	75%
1.180 – 1.200	50%
1.155 – 1.165	25%
1.110 – 1.130	0%

BE AWARE! The table above is for reference only. Some brands will expect a specific gravity number of 1.280 or higher for a 100% state of charge.

Also be aware the Specific Gravity readings are affected by the temperature of the electrolyte. Many hydrometers have built-in temperature compensation to account for this effect. Simple tables like the one below can be used if needed:

Electrolyte Temperature		Points to Subtract From or Add to Specific Gravity Readings
°C	°F	12 volt
+60	+140	+0.024
+55	+130	+0.020
+49	+120	+0.016
+43	+110	+0.012
+38	+100	+0.008
+33	+90	+0.004
+27	+80	0
+23	+70	−0.004
+15	+60	−0.008
+10	+50	−0.012
+05	+40	−0.016
−02	+30	−0.020
−07	+20	−0.024
−13	+10	−0.028
−18	0	−0.032
−23	−10	−0.036
−28	−20	−0.040
−35	−30	−0.044

Figure 9-37. *Sulfuric acid temperature correction.*

Sealed batteries such as Gel and AGM batteries do not allow access to the electrolyte, meaning that hydrometers cannot be used to measure state of charge. Voltage readings from a handheld voltmeter, checking individual batteries is one technique for checking sealed batteries. Amperage flow at the end of an absorption cycle can also be used to verify a full 100% state of charge is being achieved.

Volt meters show VOLTAGE, not state of charge. You have to interpret voltage correctly to know the battery state of charge. This can be confusing at first when the voltage varies more than you would expect it to.

The catch: while the battery is charging, voltage rises “artificially” because of the process of charging. It settles back down when charging ceases. While the battery is being discharged, voltage falls “artificially”. The voltage change, in each case, is in proportion to the amount of current flowing. When the battery is at rest, no current going in or out for an hour or more, voltage will settle to an indication of its state of charge. Again, recommendations vary between manufacturers with some saying to wait up to 24 hours with no system activity for the most accurate reading. Not using your system for 24 hours is unrealistic for most homes, so good judgment and consistently waiting the same amount of time will produce a reliable sampling.

The range of battery voltage at rest is small compared to the fluctuation caused by charging and discharging. Rest voltage will be between 12.0 (low) and 12.6 (full). While charging they can be pushed immediately up to 13.2, and as high as 15 when near full charge. Spinning a washing machine, when no solar is coming in, voltage may drop to 11.5 or less. So, it is best to read battery voltage in the morning before sunrise, or at night with only very small loads running to get a better indication of state of charge.

Below is a generic table correlating voltage to state of charge.

State of Charge	**12 Volt battery**	**Volts per Cell**	48 Volt Battery
100%	12.7	2.12	50.88
90%	12.5	2.08	49.92
80%	12.42	2.07	49.68
70%	12.32	2.05	49.2
60%	12.20	2.03	
50%	12.06	2.01	
40%	11.9	1.98	
30%	11.75	1.96	
20%	11.58	1.93	

Voltage readings must also be compensated for temperature as well. Voltage reads falsely high when colder than 77F and falsely low when warmer. The following table from Morningstar shows the magnitude of effect that temperature will have on voltage readings. For example, at a temperature of 50F, on a 48-volt system, the voltage is reading 1.80 volts falsely higher than it actually is.

Temperature	12 Volt	24 Volt	48 Volt
40°C / 104°F	– 0.45 V	– 0.90 V	– 1.80 V
35°C / 95°F	– 0.30 V	– 0.60 V	– 1.20 V
30°C / 86°F	– 0.15 V	– 0.30 V	– 0.60 V
25°C / 77°F	0 V	0 V	0 V
20°C / 68°F	+ 0.15 V	+ 0.30 V	+ 0.60 V
15°C / 59°F	+ 0.30 V	+ 0.60 V	+ 1.20 V
10°C / 50°F	+ 0.45 V	+ 0.90 V	+ 1.80 V
5°C / 41°F	+ 0.60 V	+ 1.20 V	+ 2.40 V
0°C / 32°F	+ 0.75 V	+ 1.50 V	+ 3.00 V
– 5°C / 23°F	+ 0.90 V	+ 1.80 V	+ 3.60 V
– 10°C / 14°F	+ 1.05 V	+ 2.10 V	+ 4.20 V
– 15°C / 5°F	+ 1.20 V	+ 2.40 V	+ 4.80 V

One other technique that can be used to determine if a battery is reaching a full state of charge is to observe the amperage going into the battery at the end of the absorb charging stage. If the value of the amps is 2% or lower than the rated amp-hour capacity of the battery bank, then it can be assumed the battery is at 100% state of charge. Example: a battery bank of 740 amp-hours with 14.8 amps or less flowing into it at the end of the absorption cycle will be considered at, or very near fully charged. While this technique works well on larger systems with larger arrays, be aware that smaller arrays that don't deliver much amperage, perhaps only 2% to begin with, won't be well-served with this technique as a smaller starting value can quickly be diminished to less than 2%, simply because there isn't as much power available to work with.

All of the above information in this section can be used to develop feedback for fine tuning your equipment. Verify if equipment settings are delivering a full state of charge to the battery bank, and make adjustments as necessary. It is a process that can and should be repeated in the initial commissioning of the system as well as over the lifetime of the battery set.

Routine Operation, Battery Bank Maintenance

Battery lifespan is greatly affected by the depth of discharge they are treated to, and how often they are returned to a full state of charge. Operating a battery bank at a partial state of charge for extended periods will significantly reduce its lifespan. Well balanced systems will have enough array capacity to get the battery bank to a full state of charge on a daily/regular basis in the summer months. A back-up generator for battery charging can be essential for the winter months, or the monsoon season in the southwest.

Backwoods typically recommends system sizing such that the expected daily loads will take 3 days of no solar or generator charging to discharge the battery bank from 100% to 50%. **50% is CRITICALLY LOW** though. We do not recommend taking a battery bank that low on a regular basis. Its fine for emergency occasions, perhaps once or twice a year, but discharging to 50% on a regular basis will significantly shorten the lifespan of the set. The "3 days to 50%" is just a guideline for sizing, it provides a single day discharge of 15-17% which is much healthier for the batteries. In the winter months, most operators will allow the bank to discharge to a 70% state of charge over a couple days, and then run their generator to recharge the set before letting them go any lower. In the summer months, with good array sizing and more hours of sunlight, the system should be hitting 100% state of charge on an almost daily basis.

Flooded lead acid batteries do burn off water during the charging cycle. The key consideration is that the lead plates should never be exposed to air. Portions of plates exposed to air for extended periods will lose the functional capacity of that material. Use distilled water only to keep the levels in a safe operating range, above the plates and below the fill port. Be cautious adding water when batteries are discharged (or just wait until they are fully charged). Electrolyte expands when charged. If you top your batteries off at a lower state of charge there is a good chance they will overflow the caps during the next charging cycle.

For flooded lead acid batteries, the next part of proper battery care is to equalize them every 30-60 days. Equalization is a controlled overcharge of the batteries for an hour or two depending on battery bank size. **SEALED BATTERIES ARE NOT MEANT TO BE EQUALIZED.** The frequency of equalization is determined by your hydrometer readings. Checking all cells of the battery bank, and recording them in a log book will show discrepancies developing between the strongest and weakest cells of the bank. When the difference in readings is more than 0.020, the battery bank is due for an equalization. Equalization takes the battery bank to a higher voltage level than normal, and will produce more heat than normal. For this reason, do NOT equalize for long drawn out periods of several hours. Instead, equalize for an hour or two at most, let the batteries rest for an hour and then check hydrometer readings again to see how much the gap in readings has shrunk. If it has decreased significantly, then you are done. If there is still a modest gap, a second round of equalization can be done.

After an equalizing charge is finished refill the batteries with distilled water if needed. The level of the electrolyte will vary somewhat depending on the state of charge so it's best to check the level when the battery is fully charged. Use distilled water only...no spring water no matter how clean and pure it appears! Be aware that water added to batteries will "float" on the top of the electrolyte. If an operator were to take a hydrometer reading shortly after adding water, the values will seem dramatically undercharged as it's mostly water that is being sampled. Another daily charging cycle will serve to physically mix the water and electrolyte, which will then provide an accurate state of charge reading.

To recap...**Voltage set points** correct? **Full charge** daily/weekly? **Equalize** 30-60 days? **Add Distilled** water? This reminder note is only an overview and is not meant to be a substitute for the literature supplied with the system. Feel free to call with any questions (*208-263-4290*).

BATTERY CONNECTIONS

Batteries connected in **SERIES**: positive (+) of one to negative (-) of the next to make 12 or 24 or 48 out of lower voltage batteries. **ADD VOLTAGE** of each battery so connected to get the total: four 6-volt batteries series make 24 volts. **AMP-HOUR** rating of the whole string is the same as amp hour rating of one component battery.

Two or more batteries or series strings of batteries connected in **PARALLEL**:

Positive (+) end to positive (+) end, and negative (-) end to negative (-) end

Voltage must be the same in each cell or string of cells to be connected parallel. Series strings that are then connected parallel to other strings are called **SERIES-PARALLEL. ADD BATTERY CAPACITY** amp hours for each string that is parallel connected to get total. **VOLTAGE** of parallel connected battery sets is not increased.

It is easy to remember the difference. Notice that **SERIES** batteries are actually arranged in a series if you follow from the negative (-) end to the positive (+) end, just like the batteries in a flashlight, head to tail. Like a series of locomotives pulling a train, voltage (pressure) is increased by cascading cells in series.

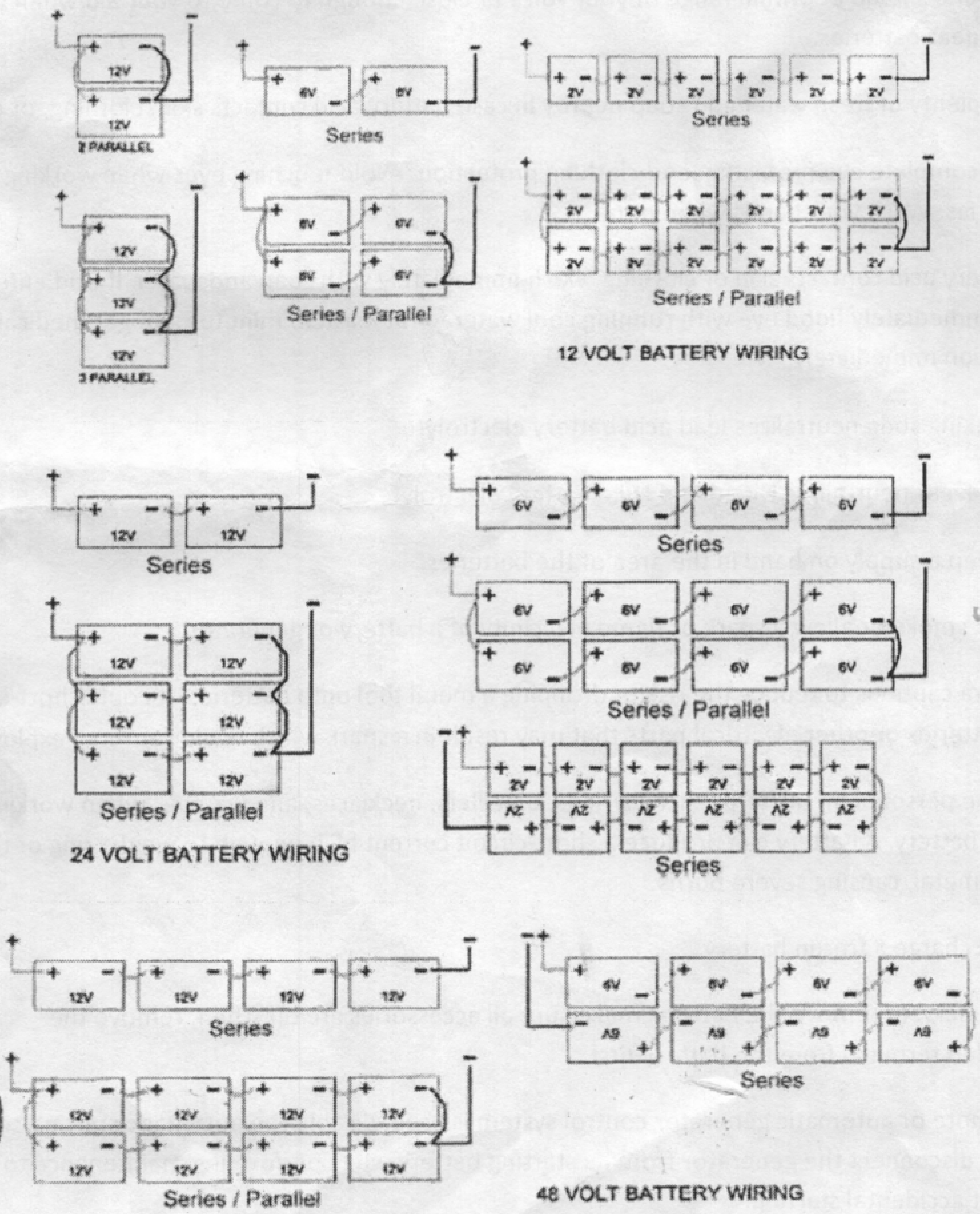
But **PARALLEL** battery strings are actually parallel arrangement of the batteries, next to each other, increasing the bulk of the battery set making it larger. <u>Batteries can be arranged in any way they fit on the floor, as long as the actual wire connections are done exactly as shown</u>.

54 @ 200 AMS.

CAUTION This can be confusing if you don't understand the reason for each connection. **INCORRECT CONNECTIONS ARE DANGEROUS.** Follow the safety precautions of gloves, goggles, insulated tools, or get experienced help. There must be NO sparks as batteries are connected or the connection is **VERY WRONG!**

680 Amp

12, 24 & 48 Volt Battery Wiring Diagrams

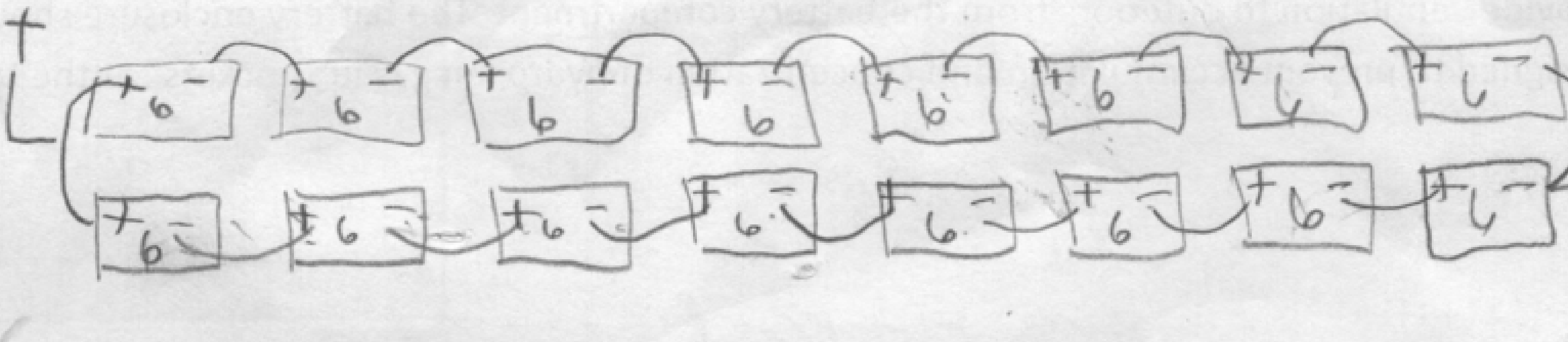


2,0 cable's
Allow 9000 Watts
or less
should be okay

When discharged
Over 5 hrs

340 Amp hrs
340 Amp hrs

680 Ah 42.5



When discharged
Over 20hrs

430 Amp Str1
430 Amp Str2

860 Amps hrs

IMPORTANT SAFETY INSTRUCTIONS

CAUTION

GROUNDING INSTRUCTIONS- For most installations, the negative battery conductor should be bonded to the grounding system at one (and only one point) in the system. Systems using ground fault protection in the DC circuitry will not need this bond. All installations should comply with national and local codes and ordinances.

PERSONAL PRECAUTIONS

1. Someone should be within range of your voice or close enough to come to your aid when your work near batteries.

2. Have plenty of fresh water and soap nearby in case battery acid contacts skin, clothing, or eyes.

3. Wear complete eye protection and clothing protection. Avoid touching eyes while working near batteries. Wash your hands when done.

4. If battery acid contacts skin or clothing, wash immediately with soap and water. If acid enters eye, immediately flood eye with running cool water for at least 15 minutes and get medical attention immediately.

    - Baking soda neutralizes lead acid battery electrolyte.
    - Vinegar neutralizes NiCad and NiFe battery electrolyte.
    - Keep a supply on hand in the area of the batteries.

5. **NEVER** smoke or allow a spark or flame in vicinity of a battery or generator.

6. Be extra cautious to reduce the risk of dropping a metal tool onto batteries. It could short-circuit the batteries or other electrical parts that may result in a spark which could cause an explosion.

7. Remove personal metal items such as rings, bracelets, necklaces, and watches when working with a battery. A battery can produce a short-circuit current high enough to weld a ring or the like to metal, causing severe burns.

8. **NEVER** charge a frozen battery.

9. If necessary, to remove the battery, make sure all accessories are off. Then, remove the grounded terminal from the battery first.

10. 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.

11. Provide ventilation to outdoors from the battery compartment. The battery enclosure should be designed to prevent 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.

12. Clean battery terminals. Be careful to keep corrosion from coming in contact with eyes.

13. Study all the battery manufacturer's specific precautions, such as removing or not removing cell caps while charging and recommended rates of charge.

14. For flooded lead acid batteries, add distilled water in each cell until the battery acid reaches the level specified by the battery manufacturer. This helps purge excessive gas fumes from the cells. Do not overfill. For a battery without cell caps, carefully follow the manufacturer's recharging instructions.

Safety When Working Around Lead Acid Batteries & Ensuring Longest Life

**adapted from Windy Dankoff in P V Network News May 1985, updated 2014*

Batteries are corrosive and explosive too. Wear eye protection, and wrap your wrench handles in electrical tape to prevent shorting between terminals.

Batteries should be placed in a cool, dry location, away from radiant heat sources. Some ventilation should be provided (a low air inlet and a high air outlet to let explosive hydrogen rise out is recommended). Be sure you allow at least a foot of space above the batteries so you can get your hydrometer and fill water in there.

Apply *Battery Coat* to the terminal and bolts thoroughly AFTER you assemble the interconnects. If you have not done this, do it now before they turn green and cruddy and fall apart. Bad battery connections cause sparks which can touch off an explosion. They also cause extremely high and low voltage surges in your system that can cause all sorts of damage.

Keep your battery tops clean and dry by wiping them occasionally with a rag and baking soda solution. Wet acidy tops provide a conductive path between terminals resulting in energy loss and more corrosion.

Take hydrometer readings frequently at first, and compare them to your volt meter indication. Soon, you will learn how to interpret the volt and ammeters so that you can easily estimate how full your battery is. Different types of batteries have different voltage characteristics. You must learn to interpret your voltmeter reading (and adjust your regulator if needed) with the **HYDROMETER** as your guide. **Don't let your batteries get over-discharged,** building up barriers of sulfate crystals and **DETERIORATING RAPIDLY**. As your battery charge gets low, you **MUST** depend on your hydrometer to accurately gauge your charge level. As you recharge a low battery, the voltage will gradually rise, **BUT** hydrometer readings lag behind, rising alarmingly slowly, only to shoot up suddenly as full charge approaches. This is because you are reading the solution above the plates. The solution between the plates **IS** getting charged, getting heavier, in proportion to the actual charge level, but **IT DOES NOT RISE AND MIX WELL UNTIL THE END OF THE CHARGE CYCLE**, when bubbles produced mix it around.

Keep a glass, or a good plastic hydrometer hanging with the bulb between two nails and the tip in a glass jar. It is your "*gas gauge*". A monthly check of every cell will indicate weak cells. Don't consider the bank "*topped off*" until the weakest cell is full. Watching for weak cells will help you predict battery failure many months in advance.