Lead-Acid Battery Choices

Type	Maintenance	Vented Area Required	High Temperature Tolerance	Low Temperature Tolerance	Price	Orientation
Flooded	Watering	Yes	Yes	No	$	Upright
AGM	Minimal	Minimal	No	Yes	$$	Any
Gel	Minimal	Minimal	No	Yes	$$	Any

Note: Exceptions exist, especially with higher-end manufacturers.
Also: Some sealed batteries need to remain upright, like their flooded lead-acid counterparts.

Gel batteries require lower charging current, and both AGM and gel batteries require lower charge voltage than flooded ones. Most RE system chargers can be programmed to meet these requirements, but other charging sources, such as DC generators or car battery chargers, can permanently damage the battery.

Industrial Batteries

Many battery manufacturers offer industrial models that have higher capacities than commercial batteries. Most industrial batteries are individual 2 V cells which are connected together, often custom-configured into large battery banks and can be specified with their own cases and/or racks. Because of their higher Ah capacity, it's possible to build a large battery bank with fewer parallel connections (see "Equality in Design" sidebar).

Industrial batteries can be flooded or sealed, with the sealed versions often used for uninterruptible power supply (UPS) and other battery backup situations. Industrial batteries also come with a more substantial warranty than their commercial counterparts, are more expensive, and often require mechanical lifts to move.

Courtesy Surrette Battery Company

Rolls (aka Surrette) is known for its high-capacity batteries, including an 820 Ah, 6 V model and a 2,430 Ah, 2 V model.

Deciphering Capacity Specifications

Deep-cycle battery capacity is rated in amp-hours (Ah). The power equation dictates the relationship between amps, volts, and watts: A × V = W. When you add in the time factor for figuring energy capacity, the same holds true for the relationship between Ah and Wh: Ah × V = Wh.

To compare the energy capacity of batteries of different voltages, it's easiest to convert to Wh. For example, a 250 Ah, 6 V battery has half the capacity of a 250 Ah, 12 V battery.

6 V × 250 Ah = 1,500 Wh
12 V × 250 Ah = 3,000 Wh

Battery capacity specifications also depend on how quickly the battery is charging or discharging. The faster the charge/discharge rate, the less overall capacity a battery will have. For example, a battery may have a 100 Ah capacity when powering 2 A of LED lighting, but only 75 Ah with 8 A of compact fluorescents. To make matters worse, not all battery manufacturers clearly show what the charge/discharge rates are for the Ah ratings on their spec sheets. It's common to see C/100 rates (quite slow) to make a battery look like it has more capacity. Most folks in the RE world like to use a C/20 rate, which is close to the typical daily (24-hour) cycling found in RE systems.

OutBack EnergyCell Front Terminal Battery

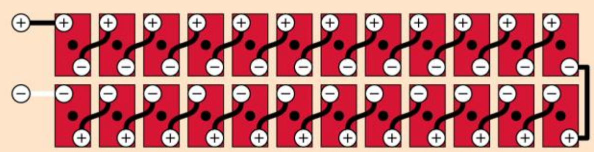
Courtesy U.S. Battery Manufacturing Company

This U.S. Battery L16 includes helpful battery labeling with amp-hour capacities at various C-rates, as well as stepped charge and temperature compensation specifications.

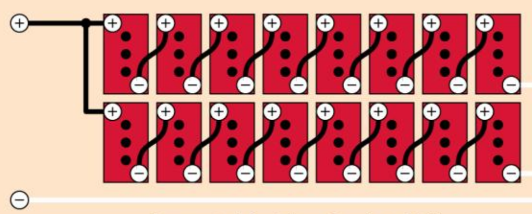
Equality in Design

To promote equal charging and discharging within a battery bank, it's important to limit the number of parallel connections. One series string is best for equal charging/discharging, but some designers prefer two strings for redundancy—in case one battery or cell fails, there will still be one functional series string at the correct voltage to rely on until the failed battery can be replaced. Three parallel strings are considered marginally acceptable, but more parallel connections introduce too many paths for the electrons to choose from when entering or leaving the battery strings. Some cells can be chronically undercharged due to minute variations in cell and interconnection resistance, decreasing the life of the bank. The best design uses batteries with higher amp-hour capacities and limits the number of parallel connections.

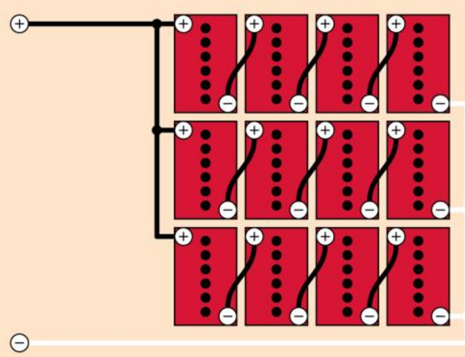
It can be tempting to design a battery bank with plans to add capacity in the future, but this is not good practice. Because of batteries' sensitivity to unequal charging/discharging within the bank, they should all be of the same make and model, and ideally manufactured in the same batch. Adding new batteries—even the same make and model—to a battery bank more than a year old is inviting problems, as the old batteries will already have higher internal resistance. Always size for the future from the beginning!



Most Desirable: Single Series String
e.g., 24 2 V cells at 1,000 Ah each
for 1,000 Ah at 48 V total



Acceptable: Two Series Strings
e.g., Two strings of eight 6 V cells at 500 Ah each
for 1,000 Ah at 48 V total

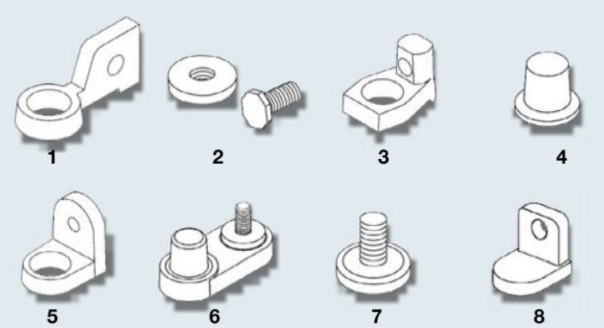


Less Acceptable: Three Series Strings
e.g., three strings of four 12 V cells at 333 Ah each
for 1,000 Ah at 48 V total

Undesirable: More than Three Series Strings
Multiple parallel connections create unequal string resistances, resulting in premature cell failure

Battery Terminals

Connections for battery cables come in various shapes and sizes, and often can be custom-ordered. Some are more compatible with the heavy-duty battery cable and lugs needed for larger inverters in residential PV systems. L-terminals are perhaps the most common, and are easily bolted to cable lug ends. Finding UL-approved connectors for batteries with automotive-type vertical posts can be difficult. The important part is to be sure your battery cables and terminals are compatible and appropriate for their application.



1. **Flag terminal with 3/8 in. hole**
2. **Insert with 5/16 in. threaded bolt**
3. **Offset post with horizontal hole**
4. **SAE "automotive post"**
5. **Heavy-duty L-terminal with 3/8 in. hole**
6. **Molded-in offset SAE post, with vertical 5/16 in. threaded stud**
7. **3/8 in. stud post**
8. **L-terminal with 1/4 in. hole**

Chilly Temps

Most battery capacity specifications are based on the ideal battery temperature of 77°F. That's an attainable temperature for conditioned spaces, but if your batteries are out in the cold, you'll need to make some adjustments. Flooded and sealed batteries behave a little differently under various temperature regimes, so be sure to check manufacturer's specs (see "Correction" table).

Sizing Correction Factors

Temp. (°F)	Flooded	AGM	Gel
77	1.00	1.00	1.00
50	1.19	1.08	1.11
32	1.39	1.20	1.25
14	1.70	1.35	1.42

Source: Trojan Battery

For a system requiring 1,000 Ah of capacity using flooded batteries in Arcata, CA, with common 40°F winter temperatures, you would have to extrapolate in the "Correction" table to get a correction factor of 1.29.

1,000 Ah × 1.29 = 1,290 Ah battery bank size for winter temperatures

Beware of below-freezing temperatures and flooded batteries. Since the electrolyte becomes very weak (closer in composition to water) in discharged flooded batteries, the electrolyte can freeze solid, which will ruin a battery! Cases can crack from the expanded ice, and internal connections may be damaged. For those conditions, sealed batteries are a better choice because their electrolyte solution has a much lower freezing point.

Courtesy Lena Wilensky

It's a cold snowmobile ride to maintain this remote data-monitoring system powered by a PV system with an AGM battery.

Courtesy Honey Electric

Proper temperature, ventilation, and spill containment are important for a safe, long-lasting battery bank.

Other Considerations

Location. Make sure to have adequate and appropriate space. Batteries need to be near the inverter for a short (usually less than 10 ft.) cable run, protected from unauthorized access, and properly enclosed and vented to keep corrosive, flammable gasses outside of occupied spaces. High temperatures will shorten a battery's life, especially sealed batteries, so keep them out of direct sun and provide air circulation if needed. Good access is critical for inspection, cleaning, watering (if flooded), and eventual replacement. If they're hard to get to, they'll be hard to maintain.

For remote systems, consider the ease of transporting and installing the batteries. Bumping up a rutted road and hand-carrying more than 4,000 pounds of preracked industrial batteries may not be an option, whereas more loads of 120-pound L16 batteries is much more feasible and may be able to provide the same overall energy storage.

Budget. Folks who are new to off-grid living may want to start with relatively inexpensive batteries. It's a little easier to replace a $5,000 five-year battery bank after two years of mistakes and learning, than a $15,000 set that should have lasted 20 years! And sometimes, even though sealed batteries might be a better match in terms of functionality (RV use, for instance), price difference will be the deciding factor. A flooded battery bank can be replaced twice as often as a sealed one for the same price.