

BATTERY BOX

basics

by John Meyer & Joe Schwartz

If you're planning to install an off-grid renewable energy (RE) system, or a grid-tied system designed to provide backup power during utility outages, batteries will be a necessary component. Well-planned battery enclosure design and construction will protect you, your family, and your property from potential battery mishaps, and can enhance the effectiveness of the battery bank as well.

Batteries store electrical energy using a chemical reaction, and can present chemical burn, electrocution, or explosion hazards if they are improperly handled or contained. When it comes to housing your batteries, your goal should be to provide a clean, dry, ventilated, semiconditioned space that limits unqualified people from coming into contact with the battery bank.

Safe Containment

There are three common options for safely containing your battery bank—manufactured battery enclosures, site-built boxes, and modifying off-the shelf plastic tubs or toolboxes. In addition, some very large systems use a separate, lockable, and well-vented room or shed to contain the entire battery bank and limit access.

Several RE equipment manufacturers build and sell battery enclosures fabricated from sheet metal, which are typically shipped flat for on-site assembly. Many of these enclosures are intended primarily for use with sealed battery types, such as absorbed glass mat (AGM) batteries commonly used in grid-tied RE systems. These units may not include trays to capture leaked or spilled electrolyte, or have sufficient working clearances to access flooded batteries for regular watering. As such, some manufactured enclosures are inappropriate for use with the flooded lead-acid batteries often used in off-grid systems. The individual batteries and complete battery banks used in utility backup applications are typically smaller than those used in off-grid systems, where the batteries are cycled daily and more storage is usually required for cloudy or windless periods. As a result, many of the manufactured enclosures are not designed to contain the larger batteries used in off-grid systems. If the batteries you're using are compatible with a given manufactured enclosure, the total battery pack capacity may still require purchasing multiple units. Before

A well-constructed, site-built battery enclosure.



you buy, make sure to consider what type of batteries you'll be using, and if the manufactured enclosure is suitable for your application.

While manufactured enclosures are the norm when it comes to battery-based grid-tie systems, site-designed and built battery boxes are the common approach for battery containment in residential-scale off-grid systems. Most of these enclosures are constructed of wood, and the designs are tailored to both the size of the battery bank and its location. Plastic tubs or toolboxes are also commonly used in off-grid systems, either by themselves or in conjunction with a wooden outer enclosure for additional physical protection.

Construction Considerations

If you're planning to build your own battery box, consider several design details.

Size. How many batteries are there, what are their physical dimensions, and what is the layout of the battery bank? These factors will determine the size of the enclosure. Draw the layout of your battery bank to scale before you start building. Allow for approximately $1/2$ inch of space between each battery to facilitate air circulation around the battery bank, which will keep the individual batteries operating at similar temperatures, as well as leave some room for the slight expansion batteries may experience at elevated temperatures and as they age. Include an additional 2 to 4 inches of space around the perimeter of the battery bank, and at least 6 inches above the tops of the batteries, which will leave adequate room for interconnect cabling. If you think you may expand your battery bank in the future, size the enclosure with this in mind.

Materials. The majority of site-built battery boxes are constructed with standard framing lumber and plywood. Wood is a good material choice because it is non-conductive, and will prevent an electrical short from occurring between an exposed battery terminal or cable and the box. One shortcoming of using lumber is that over time, leaked or spilled battery electrolyte will undermine its structural integrity. A seamless (or sealed), acid-resistant liner should be placed along the bottom and sides of the box to contain battery acid



Courtesy William Miller

An accident waiting to happen—exposed battery terminals and lots of metal objects in the vicinity that present electrical shorting hazards. Don't try this at home!

spills or electrolyte overflow, and protect the wood against deterioration. Construction plastics, like polyethylene, are commonly used, and acid-resistant epoxy sealers are another good option. The height of this liner should be sufficient to hold at least 1.5 gallons (or one battery's worth) of electrolyte in case of catastrophic failure.

Structure. Battery enclosures should be structurally stout. If you don't have any framing experience, enlist the help of



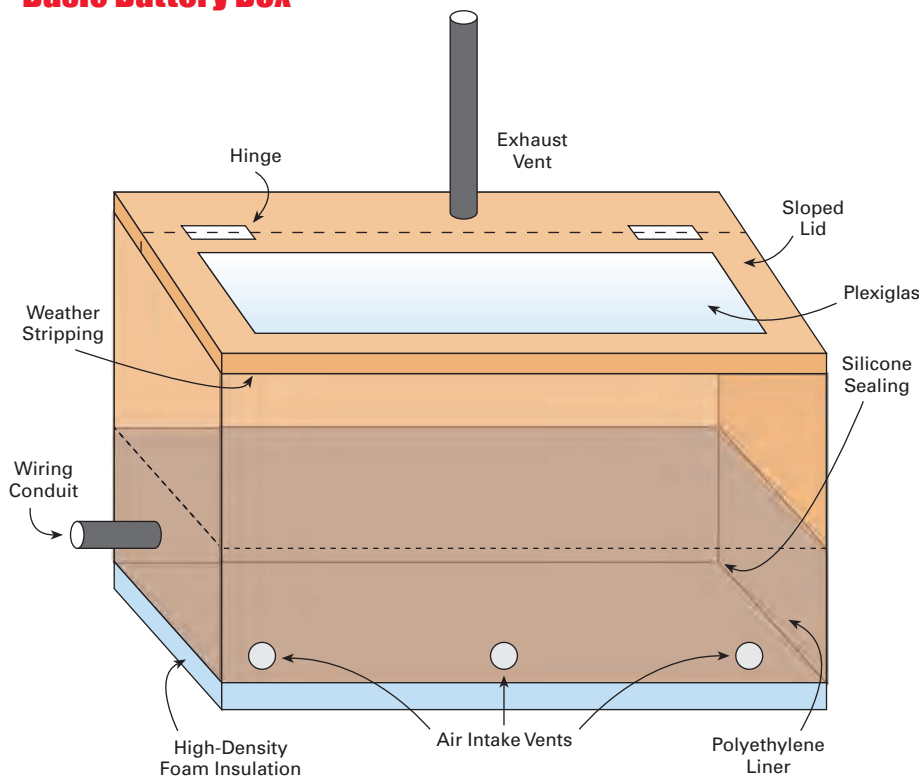
Courtesy www.outbackpower.com

Manufactured battery enclosures are commonly used in grid-tie systems with battery backup. (Batteries not included.)



Courtesy www.midnitesolar.com

Basic Battery Box



an experienced carpenter. Compared to a freestanding battery box, a built-in battery enclosure that uses two or more existing walls requires fewer materials, is easier to construct, and provides structural integrity to the box. If you do use an existing wall surface for part of the box construction, consider replacing or covering any drywall with 1/2-inch plywood or masonry/cement board.

Access. Access to the box for battery inspection and maintenance is typically from the top. Keeping this access design very basic will help ensure that critical battery service can be easily performed. A hinged lid, with a means to safely hold it open, is easier and safer than removing and replacing an unhinged, bulky box lid. Also consider making the top of your battery box sloped. This simple feature helps discourage items being placed atop the box, which can inhibit convenient access to the batteries.

Insulation. When it comes to battery enclosure design, one of the conundrums is figuring out how to keep the batteries warm in the winter and cool in the summer. At times, the

Battery Enclosures and the *National Electrical Code*

National Electrical Code (NEC) articles 480 and 690.71 address battery installation and containment, and should be referenced prior to specifying or building your battery enclosure. In most instances, residential battery systems are limited to 50 VDC nominal. (Requirements for battery packs operating at over 50 VDC nominal are not addressed here.)

Regardless of battery type (sealed or flooded), adequate ventilation is required to “prevent the accumulation of an explosive mixture.” While ventilation specifics are not clearly outlined in the *NEC*, some important considerations are identified. Article 480.9 (A) states that, “hydrogen disperses rapidly and requires little air movement to prevent accumulation. Unrestricted natural air movement in the vicinity of the battery, together with normal air changes for occupied spaces or for heat removal, will normally be sufficient. If the space is confined, mechanical ventilation may be required in the vicinity of the battery.”

Because hydrogen is “lighter than air and will tend to concentrate at ceiling level,” the *NEC* states that “some form of ventilation should be provided at the upper portion of the structure. Ventilation can be a fan, roof ridge vent, or louvered area.” A common approach used to meet these requirements, especially when flooded batteries are used, is the inclusion

of one or more air intake vents installed low on the battery enclosure, used in conjunction with a pipe-connected exhaust vent that routes gases to the outdoors.

All live parts of battery systems, including terminals and cable lugs, are required to be guarded, or covered, to protect against the possibility of an electrical short if a tool or other metal object is inadvertently dropped across the batteries. In addition, access to the battery bank should be limited, either by locking the battery room or enclosure, or restricting access with some other permanent means (Article 110.27).

The battery enclosure cover or doors should allow adequate and convenient access to the battery bank for qualified people, and adequate working clearances should be provided (Article 110.26).

Finally, the *NEC Handbook* includes the following reference to flooded versus sealed battery types: “Although valve-regulated batteries are often referred to as ‘sealed,’ they actually emit very small quantities of hydrogen gas under normal operation, and are capable of liberating large quantities of explosive gases if overcharged. These batteries therefore require the same amount of ventilation as their vented counterparts.” (Article 480.9)

goal will be to ventilate the enclosure while still keeping the batteries in the correct temperature range. While there's no silver bullet, it's always a good idea to insulate at least the bottom of the battery box if it rests on a concrete slab. High-density foam insulation is the material for the job. Covering this insulation with $\frac{5}{8}$ -inch or thicker plywood will help evenly distribute the weight of the batteries. If you live in a cold climate, insulating all surfaces of the box will help contain some of the heat generated during the battery-charging process.

Sealing. Hydrogen is the lightest element, and flooded batteries release it every time they're under charge. Trying to completely seal a battery box against hydrogen release will always be a lost cause, but proper sealing approaches will help direct the majority of the gases released during charging to the outdoors via the enclosure's exhaust vent or vents. Apply a gasket around the perimeter of the box lid to help create a good seal. Flexible, $\frac{1}{8}$ -inch-thick foam weather stripping, typically sold in rolls at hardware stores, works well. Corners of wooden boxes can be caulked, or sealed with an acid-proof sealant.

Venting. Most enclosures housing flooded lead-acid batteries will be directly vented to the outdoors. A 2-inch or larger pipe exiting from the highest point in the top of the box is usually sufficient. Intake venting should be placed near the bottom of the box, opposite the pipe vent, to allow incoming fresh air to replace air leaving through the upper vent. To keep out rodents and the like, the vents should be screened.

Conduit. Wiring conduit should be sealed with silicone caulk or plumber's putty, and always enter the battery enclosure below the tops of the batteries. Hydrogen gas is light, and will head skyward as soon as it leaves the batteries. Conduit runs exiting the top of the battery box can route battery gases right into your power center, which may result in component corrosion over time, and could present an explosion hazard if there was ever a spark or catastrophic failure in the power-conditioning equipment.

Siting Your Battery Bank

Besides the type of enclosure for your batteries, another decision related to your new battery bank is where to locate it. Flooded batteries release gas when they are charging, and the gas is corrosive, and potentially explosive if exposed to spark or flame. Sealed batteries can also off-gas if overcharged. As a result, never locate batteries in living spaces. Garages, shops, or dedicated rooms or outbuildings are the most common location for battery banks.

The temperature inside your battery enclosure is another important consideration. Battery capacity is temporarily diminished at low ambient temperatures, and deeply discharged batteries housed in unconditioned enclosures in cold climates are vulnerable to freezing, which can result in cracked cases, spilled electrolyte, and destroyed batteries.

On the other end of the temperature spectrum, operating batteries at temperatures above 110°F can result in the shedding of active materials from the battery plates. The resulting sediment buildup on the bottom of the case can lead to electrical short circuits. Batteries like to live at about the same temperatures humans enjoy. For optimal battery performance and longevity, select a location and enclosure design that will keep your batteries between 50°F and 80°F, and will rarely experience temperatures above 100°F or below 40°F.

Finally, locate the battery bank as close as possible to the power conditioning equipment (inverters, charge controllers, disconnects, etc.), while maintaining sufficient working clearance to access system disconnects and components for servicing. In most battery-based systems, high current is common between the batteries and the inverter. Keeping the associated cable length to a minimum will limit voltage drop and power loss, and help keep system costs down.

John Meyer's elevated, custom-built battery enclosure is located adjacent to the system power-conditioning hardware.



Additional Design Ideas

Beyond the basics of battery enclosure design and construction, these additional details can help you build the perfect battery box.

Raise it. A battery box raised off the floor will provide easier access to the batteries for maintenance, and create some convenient storage space below the enclosure for battery maintenance and safety items. Depending on the specifics of your battery box location and battery size, a platform height of 18 inches should be ideal. Raised battery box designs should not be considered unless you or a friend has some construction experience, and can determine the appropriate framing

Courtesy John Meyer



A vent fan can improve air exchange in the battery box.

specifications. At more than 100 pounds per battery, a typical battery bank is very heavy. A strong and sturdy platform, and excellent protection against acid damage to the enclosure's floor sheathing and framing must be provided for any raised battery box.

Removable front. Consider making the front of your battery box removable. The only time you should need to remove this panel is when you replace your batteries, but it is far easier and safer to slide the batteries in and out of the front of the box than to lift them over the sides.

See-through top. A see-through plastic panel (Plexiglas) in the top of the box will allow visual inspection of the batteries without lifting or removing the lid. It's also a great feature if you plan to show off your system to friends, neighbors, or anyone else interested in how RE systems work.

Power venting. The *National Electrical Code* does not require the use of active or mechanical venting unless the location of your battery bank is confined in a space that does not receive the regular air exchanges that occur when doors or windows are opened and closed. However, mechanical ventilation does offer a couple of distinct advantages over passive ventilation—increased air exchange and reduced heat loss.

In battery enclosure power-venting applications, a small DC fan is installed in the exhaust vent pipe. The fan is controlled by either an auxiliary relay (some inverters and charge controllers have this feature built in) or by a separate voltage-sensing switch. When the battery voltage reaches a user-determined

Courtesy John Meyer



Battery Dangers

- Heavy—can cause injury and damage if dropped or lifted improperly
- Contain acid that will cause burns as well as damage materials
- Flooded types regularly off-gas potentially explosive hydrogen
- Contain large amounts of stored energy, which if released inadvertently (such as with an electrical short circuit) can shock or result in fire

setpoint, the fan is turned on, drawing gases from the box. When the batteries are not charging, the fan remains off. One commonly used vent fan includes a simple back-draft damper, which closes off the exterior vent when the batteries are not charging. The big advantage is that in cold climates, outdoor air is kept out of the battery box unless the batteries are charging, which helps keep both battery temperature and capacity up during the cold months.

Another good application for active venting is if your battery bank is located in a garage or shop that you spend some time working in. The smell of the gases released by charging batteries is anything but pleasant, and power venting can significantly increase your quality of life in the shop. Keep in mind that activities that require an open flame or could lead to sparking should *never* be done in the vicinity of your battery bank.

Automatic, single-point battery watering systems make maintaining flooded lead-acid batteries a snap.

Automatic battery watering system. The main maintenance task associated with flooded batteries is checking and filling battery electrolyte level. This task can be greatly simplified by using an automatic, or single-point, watering system. In these systems, the factory battery caps are removed and replaced with valved caps that are connected to a water tubing system. Distilled water stored in a small, elevated or pressurized reservoir is sent to the individual batteries when filling.

Buy It or Build It

Batteries are an expensive RE system component, and they also have a limited operational life. The better you take care of them, the longer they'll last. Limiting the depth of battery discharge and regularly recharging the bank are the two most important things you can do to keep your batteries healthy and happy. A well-designed enclosure will help you manage battery temperature, and make watering and maintaining the bank more convenient, both of which are also critical to battery longevity.

But the most important feature of a battery enclosure is the safety it provides. Preventing people who are unacquainted with batteries from coming into contact with them is job number one. Proper venting to eliminate potential corrosion and fire hazards is a close second. So build or buy that ideal battery box, and you'll have the most trouble-prone component of your RE system wrapped up tight.

Access

John Meyer, 5426 California Ave. SW, Seattle, WA 98136 • 206-915-9771 • jrmeyer@comcast.net

Joe Schwartz, *Home Power*, PO Box 520, Ashland, OR 97520 • joe.schwartz@homepower.com • www.homepower.com

Battery Enclosure Suppliers:

DP&W Power-Fab • 800-260-3792 • www.power-fab.com

MidNite Solar • 425-374-9060 • www.midnitesolar.com

OutBack Power Systems • 360-435-6030 • www.outbackpower.com

Power Battery Co. • 973-523-8630 • www.powerbattery.com

Radiant Solar Technology • 707-485-8359 • www.radiantsolartech.com

Zomeworks • 505-242-5354 • www.zomeworks.com

Enclosure Accessories:

Zephyr Industries • 719-503-0718 • www.zephyrvent.com • Power vent

Solar Converters • 519-824-5272 • www.solarconverters.com • Voltage-controlled switch

Battery watering systems:

Battery Filling Systems • 877-522-5431 • www.batteryfillingsystems.com

JWP/Pro-Fill • 616-822-7587 • www.janwp.com

