BATTERY BOX *design*

Story & photos by Allan Sindelar

Batteries are a necessary, albeit expensive, component in off-grid RE systems—so you'll want to give them good care. Good 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. Battery enclosures serve four main functions:

- Provide physical protection to the batteries from tools, falls, dust, debris, etc.
- Isolate and safely vent hydrogen gas to the outdoors.
- Maintain a consistent temperature among the cells.
- Meet the requirements of the *National Electrical Code*, Articles 480 and 690 (Section 690.71), see sidebar.

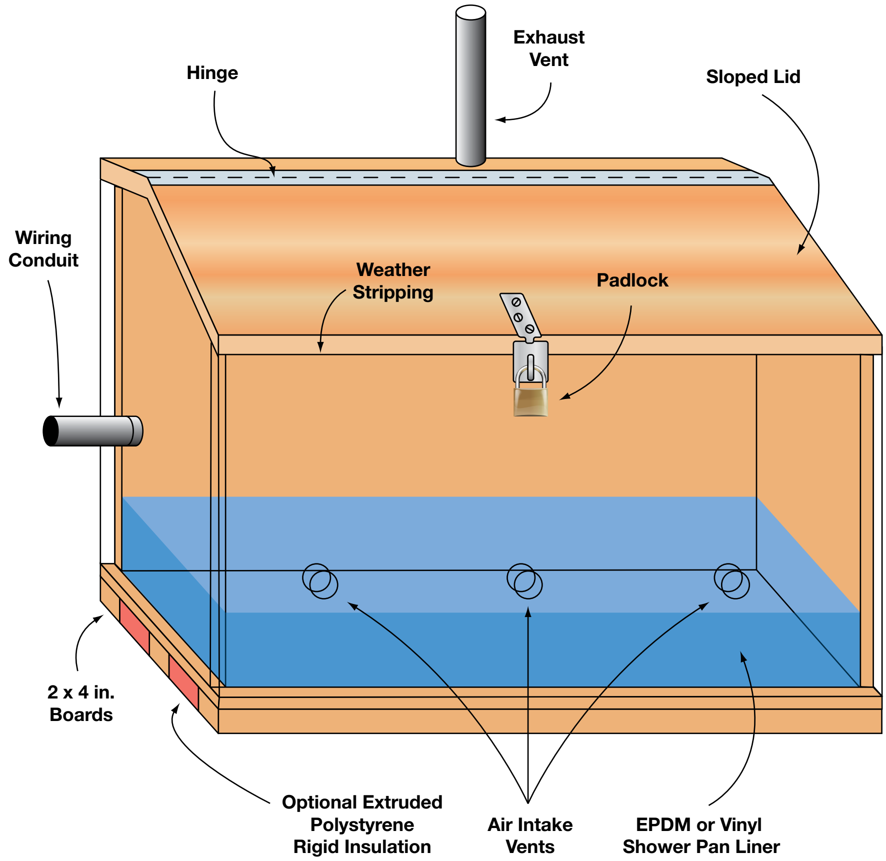
Physical Protection. Batteries store electrical energy using a chemical reaction, and can present acid burn, electrical burns, or explosion hazards if they are improperly handled or contained. When it comes to housing your batteries, your goal should be to provide a clean, dry, ventilated, semiconditioned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

Although we have seen a variety of materials used successfully—plastic storage totes and coolers, fiberglass-reinforced plastic, sheet PVC, and even old refrigerators—plywood works fairly well for residential boxes. It's familiar, attractive, versatile, dimensionally stable, and strong. Most owner-builders and building crews can make a good box, and it is adaptable to specific sites and needs. The wood will quickly decay, however, if it comes in contact with battery electrolyte. Plywood should be 1/2-inch thick at minimum; better is 3/4-inch, or a combination of 3/4- and 1/2-inch panels. The box may be called on to support a ton or more of batteries. "A-C" or "B-C" grade or better is recommended. ("A" is the highest grade. The first letter indicates the quality of the face veneer; the second letter, the back veneer.) The best plywood material we have used is called "Baltic Birch," available through wholesale lumber and hardwood suppliers. It is 1/2-inch thick with nine plies, and comes in various sheet sizes, including our preferred 60- by 60-inch. Besides being attractive, it is dimensionally stable and easy to work with.

A battery box should typically not be deeper front to back than about 24 inches or maintenance becomes difficult on the rear rows. This is about the depth of three rows of L16s or two rows of larger industrial-type cells. The length of the box often ends up between 48 and 60 inches. For example, a row of four L16s is about 50 inches. If space is factored in between each battery for ventilation, this translates into a box length of about 60 inches. Two or three sheets of 60-inch plywood is enough for most battery enclosures, with little of the waste if the panels had been cut from conventional 4-by-8-foot plywood.

There are many configurations for battery boxes. This large box is double-sided, with power vents and transparent lids for easy viewing.

Battery Box Construction Details



Battery Box Checklist

- ✓ Battery box should be in tempered space (but not in living spaces)
- ✓ Vent hydrogen gas to the outdoors
- ✓ Line battery box to contain battery acid spillage
- ✓ Place air intake vents low, but above liner
- ✓ Use duct seal around the battery cables where it enters the conduit to keep gas out of the conduit
- ✓ Caulk the battery box and seal cover with weather stripping
- ✓ Plywood: $^{1}/_{2}$- to $^{3}/_{4}$-inch thickness; A-C or B-C grade or better
- ✓ Insulate bottom of box if floors stay cold all winter
- ✓ Restrict access to batteries, such as with a latch and/or padlock
- ✓ Keep battery box depth at 24 inches or less to reach and maintain back batteries
- ✓ Leave room for battery posts, cables, interconnects, and handles, and maneuvering a water jug

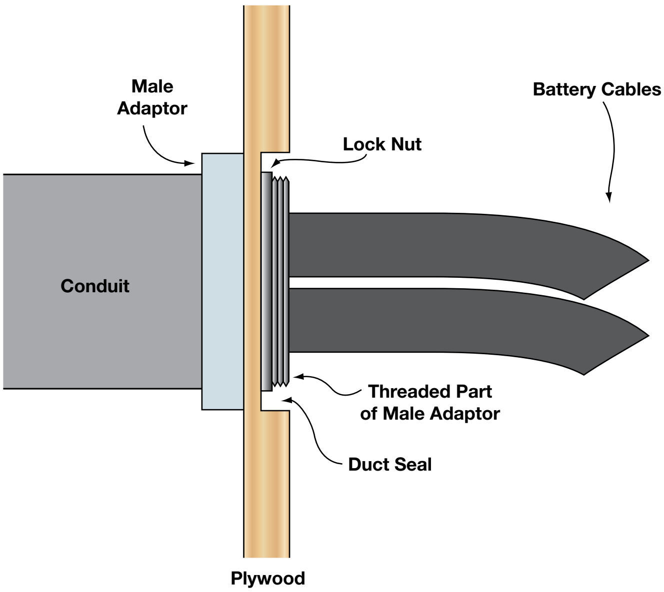
Even if a box can be less than 48 inches long, a larger enclosure may be justified. A small system that uses golf-cart batteries may some day be upgraded to L16s or industrial 2 V cells. A golf-cart battery is about 10 $^{1}/_{2}$ inches long; an L16 is about 12 $^{1}/_{4}$ inches. So upsizing the box initially to fit future battery possibilities may save money in the long run.

To plan a successful battery box layout, draw out the batteries on paper, or make cardboard templates. Leave room around battery cases for ventilation, to hide rope handles, to maneuver a distilled water jug, and to get fingers and tools into the box for service. Leave 3 to 6 inches above the battery tops for cables and interconnects. Plan the placement and lengths of your interconnects so that all fill caps are readily accessible and battery cables do not lay over the cell tops.

The inside of the box should be carefully caulked, and painted or treated with a penetrating sealer to resist minor spills or corrosive vapors. For best results, a liner of 40-mil EPDM rubber or pond liner (available at many nurseries or home improvement stores) is placed in the bottom and about 6-8 inches up the sides, folding instead of cutting for the corners. This liner protects the wood and forms a leakproof

Well-constructed battery enclosures are an important part of the balance of the system equipment, and should not be ignored.

Securing Battery-to-Inverter Conduit



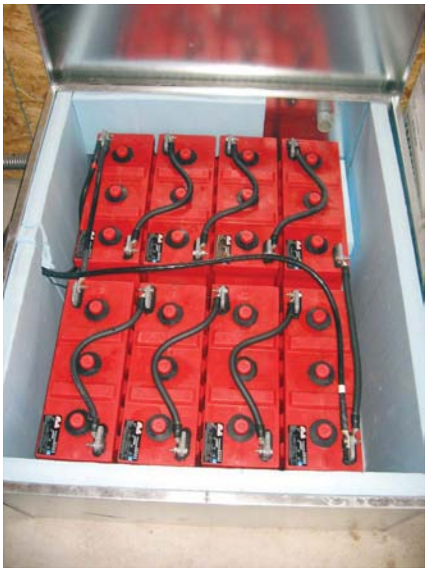
container to contain any accidental spills or leakage from the cases. Above this level, typically three 1- or 1 1/4-inch inlet ventilation holes are drilled across the front. The outside of the box should be finished with primer and paint if exposed to the weather, or varnish or penetrating oil, if inside. A removable box front can make replacing batteries easier, but this is generally only necessary with heavy industrial cells (which may tip the scales at more than 150 pounds each).

The cover should be hinged at the top to seal securely, yet allow access to the batteries for service. A piano hinge works well, as it prevents warping and is easy to seal. The lid should be sloped, partly to guide vapors up toward the vent, but mostly to discourage storing things on the box and resultant neglecting of normal maintenance. A flat-top panel about 4 inches wide behind the piano hinge will accommodate the vent pipe. The cover should be sealed with weather-stripping—soft neoprene works well; foam won't last. A kerf cut into an inside trim strip allows modern replaceable door weather-stripping to be used. Silicone rubber "flipper seals" are ideal because they are effective over a wide range of gaps and require little closing pressure (see Access). The cover should have latches. Even hooks and eyes, especially if adjustable, make a good basic latch. Use a lock, like a padlock and hasp, to prevent access to the battery by unqualified people.

A well-designed box will have a base similar to a kitchen cabinet to allow for a toe-kick space and to raise the batteries for ease of maintenance. If the bank sits on a cold slab, the box's floor can be built on 2-by-4 sleepers with rigid foam fit between or above them, keeping your battery bank warmer. Extruded polystyrene insulation panels will support battery weight.

For cable entry into the box, some installers place the conduit hole lower in the box, below the battery tops, since the hydrogen gas rises, and would be less likely to go into the conduit. Electrical conduit fittings are designed to attach to junction boxes made of thin sheet metal, not thicker plywood.

Battery boxes aren't always made from plywood. This example is fabricated from stainless steel.



A peek inside this battery enclosure shows a clean installation, with ample room for the battery cases and interconnects.

To secure battery conduit fittings to the battery box, we use two concentric hole saws from opposite sides, creating a 1/4-inch-thick flange to fit a lock ring around 1 1/2-inch (for 2/0 cables) or 2-inch (for 4/0 cables) battery conduit. This allows the threads of the conduit fitting to get into the box

This battery box, with a removable front, makes future battery replacement easier.

with enough room for the lock nut to be attached. Then we use "duct seal," available at electrical supply houses, to carefully seal this fitting around the cables to keep gases away from the electrical equipment.

Safe Venting. Hydrogen is explosive if allowed to collect to a concentration exceeding about 4%. The gas mixture given off during charging also contains minute amounts of sulfuric acid, which is corrosive to electronics and most metals. As such, a well-built battery box is both sealed and vented, so that the gas may be carried to the outdoors to dissipate. Fortunately, hydrogen is Earth's lightest element, so it easily rises in air. A vent pipe at the top of the box will work. A second low vent allows ventilation air to enter the box.

The vent is typically made of 2-inch PVC water pipe or the equivalent. Larger sizes of PVC pipe may be used, but excessive venting can let too much heat escape in winter. The exhaust vent should exit through the building wall or roof, with all laterals rising. An insect screen should cover the outside end, with protection from rain and snow entry.

Zephyr Industries' Power Vent can be installed in a vertical section of the PVC stack, and works well for smaller venting demands. When the battery voltage rises to a setpoint below the gassing voltage, the vent's DC fan is activated. A backdraft damper prevents reverse airflow into the room. Many modern charge controllers and some inverters can automatically control Power Vent operation by one of their auxiliary relays; some even have "vent fan" as a programmable option.

Keeping Temperatures Constant. Insulating a battery box seldom makes much difference if the insulated box is located

Before You Build, Check the *Code*

National Electrical Code (NEC) Article 480 and Section 690.71 address battery installation and containment, and should be referred to prior to designing or building your battery enclosure. In most instances, residential battery systems are limited to 50 VDC nominal. (Requirements for battery packs operating at greater than 50 VDC nominal are not addressed in this article.)

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. In the *NEC Handbook*, an explanation is given for Section 480.9 (A), stating 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 heat removal, normally is 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 Handbook* 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 batteries: "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).

This battery enclosure allows for stacking batteries, reducing the footprint required. This is one clear benefit of sealed batteries, as access to cell caps to add water is unnecessary.

in a cold environment. Insulation slows the rate of heat loss from a warm space or object to a cooler space. Batteries are not a significant heat source; the normal charge/discharge process produces a negligible amount of usable heat. No amount of insulation will prevent batteries from eventually reaching the temperature of the environment around the insulated box, so while insulation may be included, it's important to locate the box in a tempered space. 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 75°F.

Access

Allan Sindelar (allan@positiveenergysolar.com) installed his first off-grid PV system in 1988, founded Positive Energy in Santa Fe, New Mexico, in 1997, and has lived off-grid since 1999. He is a licensed commercial electrician and a NABCEP-certified PV installer.

Resources:

Conservation Technology • www.conservationtechnology.com/building_weatherseals.html • Silicone weather stripping

Zephyr Industries • www.zephyrvent.com • Power Vent