Battery Requirements and Guidelines

Introduction

This supplemental document identifies and discusses codes, regulations, and best practices for battery use and installation as they relate to the Solar Decathlon. A battery system can be hazardous because it is a continuously "energized" source of electricity and contains corrosive electrolytes. Also, batteries can be heavy, can cause fires, and can produce explosive or corrosive gases. Solar Decathlon team members need to be aware of these inherent hazards to minimize the risk to themselves and the public when transporting, installing, maintaining, using, or replacing a battery. Although this document focuses on lead-acid batteries, most of the information and discussion applies to all battery chemistries.

Because this competition has a strong public outreach component, the Organizers are providing these guidelines to reinforce the importance of safety at the Event. The public viewing the Solar Decathlon homes may choose to incorporate some of the features and technologies in their own homes. Because solar-powered homes will be new to many people, the homes need to demonstrate safe photovoltaic (PV) and battery systems. Although most people are familiar with automotive batteries, the batteries in the Solar Decathlon homes will be larger, and they are subject to additional regulations and considerations.

General Applicability and Interpretation

This document lists and discusses most of the codes, standards, and recommendations that apply to batteries typically used in solar-powered homes. Although the list may look exhaustive, some codes, standards, or recommendations have been left out intentionally or may have been left out inadvertently. Also, state and local jurisdictions and the sponsoring school may have additional requirements beyond the international or national codes listed here.

Interpreting the codes, regulations, and recommendations is ultimately the responsibility of the individual Solar Decathlon teams and their institutions. In this document, the Organizers have established a minimum level of battery safety consistent with published codes, regulations, and recommendations. Individual teams or their sponsoring institution may add their own additional requirements.

Battery codes, regulations, and recommendations have only a minor impact on the home's energy usage. Batteries are emphasized here primarily because they represent an important safety issue. Teams must make safety a priority throughout the competition.

In addition to safety, proper interpretation of codes, regulations, and recommendations can improve a battery's performance and extend its lifetime. Although the Solar Decathlon competition on the National Mall takes place over a brief period of time, a battery system should be designed, installed, and operated as if the house were to be occupied full time and the battery system lifetime needed to be maximized through proper operation and maintenance. The public will scrutinize the Solar Decathlon homes and the schools they represent, so all battery systems must be properly installed and operated.

Battery Terminology

Commonly accepted terms will be defined to interpret the codes and to discuss the issues within the context of the Solar Decathlon Rules and Regulations and with other battery industry experts. The **cell** is the smallest electrical unit capable of producing voltage. In the lead-acid battery chemistry, the cell produces 2 V nominally. The **battery** consists of ALL the cells that are series or parallel connected.

Confusion begins when referring to the home's battery. Many of the codes and standards refer to "batteries" as the collection of individual batteries that comprise a battery. This publication, when discussing the Solar Decathlon competition, regulations, and suggested best practices, will refer to the house battery as the **battery bank** or **battery system**.

State-of-charge (SOC) is the percent of electrical energy stored in a battery compared to the manufacturer's rated capacity of the battery. A full battery has a 100% SOC and a discharged lead-acid battery has a 20% SOC. Most batteries are not fully discharged to 0% SOC, even though the manufacturer's rated capacity is based on a full discharge. **Depth-of-discharge** (DOD) is the inverse of SOC. A fully charged battery has a 0% DOD whereas a discharged lead-acid battery has an 80% DOD.

Battery Chemistries

There are several electrochemical battery types available for solar-powered homes. The most common battery type is lead-acid because of availability and cost. Other battery types that have been used are nickel-cadmium (NiCd), nickel-iron (NiFe), nickel metal hydride (NiMH) and lithium-ion. Each battery type has its own specific operating, transportation, cleanup, and disposal requirements. The battery manufacturer should supply this information along with a Material Safety Data Sheet (MSDS). Whereas some of the discussion in this document focuses on lead-acid batteries, most of the discussion is applicable to all types of batteries.

Most of the battery chemistries can be incorporated into vented or sealed battery configurations. Figure 1 shows the different types of lead-acid batteries. The vented (or flooded) configuration contains liquid electrolyte (either acid or base). During normal operation, electrolyte or electrolyte film may be present on top of the battery case because of the venting of hydrogen gas, overcharging, or overfilling vented configuration batteries. Standard maintenance requirements for a vented battery include visually checking the electrolyte level and adding distilled water, if needed. In the vented configuration, electrolyte can spill out if the battery is tipped, or if the case becomes damaged. A vented battery should come with spark arrestor vent caps for each cell. After-market hydrogen recombinant and spark arrestor vent caps may also be available to help reduce water loss. Check with the battery manufacturer before replacing any vent caps.

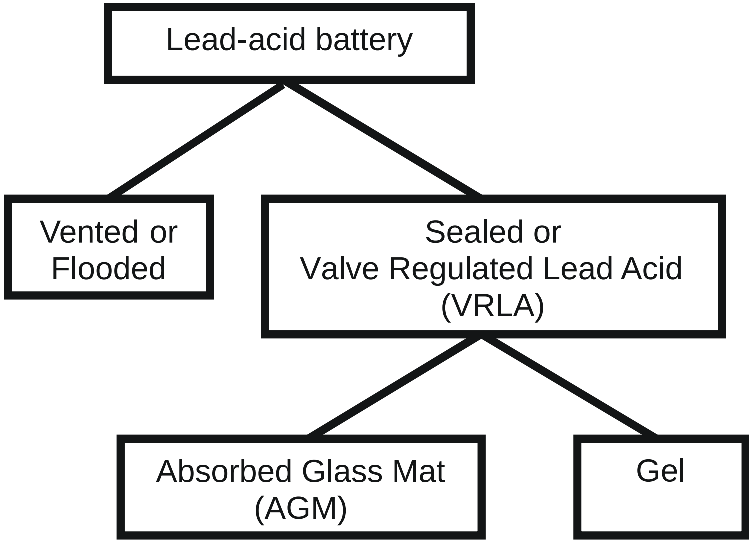

Figure 1. Different types of lead-acid batteries

The sealed (or valve-regulated lead-acid [VRLA]) battery configuration avoids many of the vented battery configuration's disadvantages by immobilizing or minimizing the electrolyte. Absorbed glass mat (AGM) batteries are different than gel batteries, even though both are sealed lead-acid batteries. An AGM battery immobilizes the electrolyte by absorbing the electrolyte into a fiberglass mat. A gel battery immobilizes the electrolyte by adding silica gel creating a semi-solid mass.

Under normal operating conditions in a sealed battery, the hydrogen gas that is generated during charging and discharging is recombined with oxygen inside the cell. Depending on the manufacturer, sealed batteries can usually be placed in any orientation (with the battery terminals on top or on the side). Some manufacturers claim that certain orientations of their sealed battery improve battery-recharging efficiency. Check with the manufacturer before placing a battery in an orientation different than as received. Sealed batteries are generally more convenient to install and operate, even though the initial and operating costs may be higher.

Battery Hazards and Risks

A battery presents many hazards and risks—all of which can be minimized through proper design, installation, operation, maintenance, and disposal. A battery is always "energized"—there is no on/off switch. Even a battery that is "discharged" still contains a lot of energy.

The corrosive electrolyte inside the battery can cause physical injuries to the user or additional damage to the battery if the electrolyte leaks out of the case, spills from the battery in an accident, or vents to the atmosphere. A battery can be heavy and awkward. Poorly designed battery rooms with limited space can hinder safe lifting and installation (or removal) of a battery. If improperly manufactured or maintained, a battery can cause a fire. Also, a fire near the battery can be started if the wiring and connections are improper or maintained poorly.

A vented or flooded battery will produce hydrogen gas during normal operation. A vented lead-acid battery with antimony-containing lead plates will produce more hydrogen than a battery with calcium-containing lead plates. A sealed or VRLA battery should contain all gases during normal operations. However, during abnormal circumstances, excess pressure inside the sealed battery will cause the battery to vent hydrogen gas. A sealed battery contains a one-way pressure relief vent that can release excess pressure from inside the battery case if the battery is overcharged or overheated, or if there is a battery failure. The total amount of hydrogen gas that can be generated from a vented or sealed battery can be similar but depends on the total amount of electrolyte inside the battery. The rate of hydrogen evolution is a function of the SOC, battery age, and current.

In summary, the risks to be considered when installing, utilizing, and maintaining a battery bank are:

- Explosion/flammability of hydrogen gas
- Electric shock and electric current hazards
- Acidic or caustic electrolyte spills, exposure, or both
- Gravity related issues (such as battery lifting and batteries falling off racks due to seismic events).

Codes and Regulations

There are several national level code organizations that regulate the use of battery systems in building applications. The codes and regulations cited here come from the National Fire Protection Association (NFPA), International Code Council (ICC), Occupational Safety & Health Administration (OSHA), and Department of Transportation (DOT).

Battery System Codes

Code Name	Relevant Section(s)	Location	Comments
2002 National Electric Code (NEC)	Article 480 and Part VIII of Article 690	2002 NEC Handbook CD	Requirements for storage batteries and batteries used in PV installations
2003 International Fire Code (IFC)	Sections 608 and 609	2003 ICC Codes CD	Specific requirements for stationary lead-acid battery systems and VLRA battery systems
2003 International Mechanical Code (IMC)	Sections 502.1, 502.3, 502.4, 502.5	2003 ICC Codes CD	Ventilation requirements
OSHA Regulations	29 CFR Part 1926.441	http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10742	Not as detailed as other codes

Battery Shipping Regulations

DOT classifies all electrochemical batteries as hazardous materials subject to regulation when transported in interstate commerce. Individual states generally adopt DOT regulations for intrastate commerce. All trucking companies and drivers should be familiar with the appropriate regulations for each state. Teams need to fully disclose to the driver and trucking company all potentially hazardous materials (batteries, ethylene-glycol, cleaning solvents, paints, etc.) that are being transported.

Most of the DOT regulations relevant to the Solar Decathlon are contained in Title 49 of the Federal Code of Regulations (49 CFR). The Hazardous Materials Table in 49 CFR Part 172.101 lists different types of batteries. All lead-acid batteries, both vented (flooded) and sealed (VRLA), are considered “wet batteries.” Section 49 CFR Part 173.159 describes wet batteries and their packaging requirements. Generally, loads with wet batteries need to be placarded (the diamond-shaped warning label on trucks), which requires a driver with a Commercial Drivers License (CDL) and a Hazardous Material endorsement. There are two possible placarding exceptions mentioned below.

49 CFR Part 173.159 (d) defines “nonspillable” batteries that do not require a placard if all requirements in that subsection are met. The battery manufacturer can state compliance with (d)(2) – labeling and (d)(3) – the vibration and pressure differential tests. Get a copy of the certification from the battery manufacturer. Subsection (d)(1) states, “The battery must be protected against short circuits and securely packaged.”

49 CFR Part 173.159 (e) could exempt flooded batteries from placarding if all four requirements are met. Subsection (e)(2) states, "The batteries must be loaded or braced so as to prevent damage and short circuits in transit." Subsection (e)(3) states, "Any other material loaded in the same vehicle must be blocked, braced, or otherwise secured to prevent contact with or damage to the batteries."

Compliance with the protecting, blocking, bracing, and preventing damage exceptions (d)(1), (e)(2), and (e)(3) in 49 CFR Part 173.159 is usually determined only after an accident. DOT inspectors will rarely give approval in advance. If there was an accident and the batteries shifted, broke, or caused a fire, the requirements probably weren't met. The problem can cascade further. Because the exception wasn't met, the truck should have been placarded and driven by a driver with a CDL and a Hazardous Material endorsement.

Because the Solar Decathlon homes will have a battery system and will be transported in interstate commerce, all DOT regulations are applicable. If a team hires a company to transport its home, the team must fully inform the company and driver about the weight and type of batteries and provide an MSDS. The transportation company assumes responsibility for compliance with all shipping regulations. If the team transports the home containing a battery system using its own driver, the driver (and possibly the school) assumes responsibility for meeting all DOT regulations.

Because of dynamic loading, a battery rack suitable for a stationary application will not be suitable for transportation. Teams should take special care in packing batteries for transportation. The battery system could be transported separately (from the house) and installed on site before the competition. After the competition, the battery system should be removed from the house for return transportation.

Recommended or Best Practice Standards

The Institute of Electrical and Electronics Engineers (IEEE) publishes consensus standards on a wide variety of topics. An IEEE standard is useful because it presents best practice recommendations and reflects a consensus within the industry.

IEEE Standard	Title
450-1995	Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications
484-1996	Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications
485-1997	Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications
928-1986	Recommended Criteria for Terrestrial PV Power Systems
929-2000	Recommended Practice for Utility Interface of PV Systems
937-2000	Recommended Practice for Installation and Maintenance of Lead-Acid Batteries for PV Systems
1013-2000	Recommended Practice for Sizing Lead-Acid Batteries for PV Systems
1106-1995	Recommended Practice for Maintenance, Testing and Replacement of Vented NiCd Batteries for Stationary Applications
1115-2000	Recommended Practice for Sizing NiCd Batteries for Stationary Applications
1145-1999	Recommended Practice for Installation and Maintenance of NiCd Batteries for PV Systems
1187-1996	Recommended Practice for Installation Design and Installation of VRLA Batteries for Stationary Applications
1188-1996	Recommended Practice for Maintenance, Testing, and Replacement of VRLA Batteries for Stationary Applications
1189-1996	Guide for Selection of VRLA Batteries for Stationary Applications
1374-1998	Guide for Terrestrial Photovoltaic Power System Safety
1375-1998	Guide for Protection of Stationary Battery Systems

IEEE standards written specifically for PV systems with a battery system are 928, 937, 1013, 1145, and 1374. The other standards may contain additional information that is useful for design and installation of any battery. IEEE Standard 929 is appropriate for grid-connected, utility-interactive PV systems.

Solar Decathlon Competition

National Park Service Requirements

National Park Service (NPS) is asking decathlon teams to adhere to OSHA standards.

Inspections

As with all codes, ultimately the code inspectors will determine if the code is met physically or by intent. Appropriate calculations for seismic design of racks and ventilation requirements for battery systems should be submitted for approval in advance. On-site inspections before the competition will be performed to ensure that health and safety requirements are met.

Performance Monitoring Requirements

Organizers expect teams to have a single physical location where the battery bank may be monitored with a watt transducer, shunt, or similar device. All electrical layouts that have separate PV arrays serving separate battery banks are discouraged and must be approved by the Rules and Regulations Committee.

Discussion, Best Practices, and Suggestions

Although not directly related to a Solar Decathlon Contest, battery system operation and maintenance, battery system locations, ventilation, enclosures, secondary containment, racks, and proper protective apparel can affect overall safety and can impact the cost of your renewable energy system over its lifetime. To help teams meet code requirements, the following provides suggestions and outlines best practices when designing, installing, maintaining, and utilizing a battery system.

Battery Operation and Maintenance Considerations

Something as mundane and easy to forget as battery maintenance can make or break the economics of your system. Pay careful attention to battery manufacturer recommendations, in terms of maintenance, to get the most out of your battery system.

The battery is the most significant element in your renewable energy power system that has variable efficiency. Depending on how well you take care of your batteries, you can realize round trip and life efficiencies that vary from as low as 20%–30% to as high as 85%–90%. Choosing the right charge/discharge strategy; selecting the correct battery system charger/charge controller; and utilizing a sound dispatch strategy for charging devices, meeting loads and auxiliary loads are all important.

Operation

The renewable energy system designer/operator can control battery system operation to a large degree. How the designer/operator manages the battery system will have a strong affect on how well the battery system performs and how long it lasts. Proper management can also minimize safety risks.

Sometimes, it is difficult to find literature (from manufacturers, testing agencies, and academia alike) that describes exactly how to get the most out of a bank of batteries. Required parameters such as load profile, type of charging sources, resource profiles, dispatch strategy, dump load dispatch, etc., can vary from system to system. Therefore, this variability makes it difficult to understand each system well enough to optimize its battery operation strategy. There are, however, a few guidelines to keep in mind when developing your own operation strategy for your specific renewable energy system. They include:

1. Batteries reach peak round trip efficiencies when operated in the 50%–85% SOC range.
2. Batteries cannot stay too long in the 75%–90% SOC range without damage from sulfation (i.e. batteries need to be periodically fully charged, on a monthly or a quarterly basis).
3. Batteries kept at a high SOC (such as float or standby) can last a very long time. However, they will not realize much throughput in their lifetime.
4. Batteries repeatedly deeply discharged (to as low as 20% SOC) will realize a higher throughput but a shorter life (some manufacturers recommend discharging to 50% SOC to extend the battery life).
5. Manufacturers can or will often provide a curve that describes the depth of discharge/cycle life relationship. However, these curves are produced under fairly strict conditions that can be difficult to duplicate in the field. Treat these curves as a reference, not a warranty.
6. When there is a large amount of sunlight, it's probably better to run as many productive loads (pump water, chill milk, make ice) as you can to reduce the amount of energy that needs to be cycled through your battery system.
7. Avoid leaving batteries at a low SOC because batteries left at a low SOC can begin to sulfate within days.

Maintenance

A well maintained and operated battery system can last many years. A poorly maintained and operated battery system can last a matter of weeks. Clearly, it's easier to damage a battery system than it is to maintain it well. However, here is a list of checks that can be performed (most battery maintenance guides will include at least some of these checks):

Monthly:

1. Visually inspect the batteries (look for corrosion, damaged or missing caps, wet/damp spots around caps, cracks or leaks, signs of heaving posts, damaged cable leads, damaged terminals or connectors).
2. Physically check for loose connections (loose connections can lead to overheating and seriously affect battery efficiency).
3. Check the temperature at the battery terminal and look for batteries that deviate (thermally) from the norm.
4. Take voltages of each battery (or cell if using 2 V cells) with and without current flowing and look for variation from the average. The cell voltage for a battery at open circuit that shows variation of as little as .15 V from the average can indicate a problem with that battery.
5. If using vented (flooded) batteries, take specific gravity measurements with the batteries at open circuit and look for any variations from the mean (a variation of as little as 0.02 can indicate a problem with that battery.
6. Also, if using vented (flooded) batteries, check fluid levels and fill as required (never allow the plates to become exposed to the air, use only distilled water, note which batteries are using more water and see if a pattern is developing, don’t overfill with water, and never remove excess electrolyte solution).
7. Clean the tops of the batteries with a solution of 1/8 lb. baking soda per quart of warm water. Check with the battery manufacturer for approved detergents.

Quarterly: (in addition to the monthly checks)

1. Check connection resistance of inter-cell or inter-battery connectors (one step more than looking for loose connections) of 10% of the battery system.
2. Measure the temperature of a random sample of 20% of the battery system.

Annually: (in addition to monthly and quarterly checks)

1. Tighten all bolts to recommended torque.
2. Record all connection resistances.
3. Perform a capacity test.

Optional: Thermographic scans (if this technology is available—even a camcorder with infrared imaging can do the trick) can provide an excellent insight into connection problems between batteries or cells.

If your system is equipped with a battery monitor (E-meter, Tri-Metric, Data Acquisition System (DAS), etc.), periodically check your round trip efficiencies. A drop in efficiency doesn't necessarily mean that your whole battery bank is dead. It is more likely that a few batteries or cells within the battery bank need to be replaced or charged separately. The sooner you replace or charge a battery or cell that is pulling an entire string down, the better. Battery banks tend to experience cascade type failures. A single bad battery or cell may accept less current causing the entire battery bank to accept less current.

These guidelines are only an example, and not an exemplary, maintenance guide. For a more comprehensive and thorough manual, contact the battery manufacturer; most battery manufacturers will provide a manual. Proper operation and maintenance does not guarantee that you will not experience some sort of failure in at least one of your batteries before the battery bank reaches its maximum expected life cycle. Yet, failure to maintain your battery bank all but guarantees a shortened and inefficient life for your batteries.

Good Battery System Locations

Sometimes the placement of a battery bank is an afterthought. This is not a good idea. As mentioned previously, proper operation and maintenance of your battery bank can make the difference in the economic viability of your renewable energy system. If a battery is not in an accessible location, proper maintenance probably will not happen, or if it does, it will be a nuisance every time it is done. Also, the environment surrounding the batteries (such as ambient temperature) can have a serious impact on the expected life of the batteries (overheating of batteries is one of the principal failure modes). Finally, the distance between the batteries and the principal load (typically the inverter) is directly related to system efficiency (the closer the two are, the better).

Accessibility to the battery system increases the likelihood of its proper maintenance in a safe manner. Storing batteries in a mechanical crawl space or in an attic exposes batteries to elevated temperatures. This is probably one of the fastest methods to ruin a battery bank. A battery bank should be placed in an enclosure with a locked cover, or in a separate room with a door that can be locked.

Keep in mind the following when planning where to place batteries:

- For vented (flooded) batteries, a minimum of 18 in. is required between the top of the battery or battery post (whichever is higher) and the structure above it, to allow safe inspection and routine maintenance. For sealed or VRLA batteries, a reasonable working distance is required.
- Minimize the distance between batteries and the primary load (not only does cable become expensive if batteries are placed far from the inverter, but the induction of cables becomes a factor)
- Protect batteries from overheating and from cell-to-cell temperature variations (Don't place them in an attic or mechanical space that experiences high temperatures. Don't place them in a dark box on the south side of the house. Don't put them above or too near a heat source.)

- Protect batteries from cold and freezing. Whereas a charged battery has a low freezing point, a cold battery has less available capacity.
- Make the battery system accessible for routine inspections and maintenance.
- Don't place batteries directly below electronics. Batteries can (and vented batteries do) emit corrosive gases that are damaging to many things, especially electronics.
- Don't locate batteries where things will be inadvertently dropped on them.

Ventilation

Code references for this section:

- IMC2003: Sections 502.3, 502.4, and 502.5
- IFC2003: Sections 608.5, 609.6, and 609.7

Hydrogen gas presents a fire hazard in any battery system installation regardless of battery type. Abnormal conditions, such as failure of the charge controller, may cause the PV charging current to flow unregulated into a fully charged battery system. In some cases, an individual cell on the battery fails and will act as a sink for the full battery system current. If any type of battery is overcharged, it can emit significant amounts of hydrogen. The total volume could be less in some battery types because there is less electrolyte, but the maximum rate of gas evolution can be similar. For scenarios like these, Solar Decathlon regulations require a well-designed ventilation system.

Hydrogen gas is very light and has a strong propensity to disperse. It is also highly combustible and can ignite under a relatively wide range of conditions (batteries have been known to explode even in open air). Because vented or flooded batteries emit hydrogen gas, special care should be taken to avoid its accumulation. Sealed batteries certainly can, have, and do emit hydrogen gas when something goes wrong. Therefore, all systems must ventilate, either passively or actively, directly to the outside air.

Energy consumption from a mechanical ventilation fan is a small portion of a building's total energy consumption. One measure to reduce the amount of energy used by ventilation fans is to only turn the fans on during charging and discharging of the battery bank.

With either mechanical ventilation or natural ventilation systems, the ventilation system should be designed to prevent pressure differentials on or around the building from causing hydrogen gas to accumulate in the ventilation pipe, duct, or devices.

In choosing whether to use active or passive ventilation systems, consider the following:

Passive Ventilation:

This type of ventilation is acceptable if the battery system room or enclosure has an exterior wall or opens to the exterior of the building. For this type of ventilation to work, vents must be placed near the ceiling and near the floor.

Active Ventilation:

This type of ventilation is required if the battery system room or enclosure does not have an exterior wall or exterior access. Unless a DC brushless motor is used, the fan motor must be located in outside air and must push fresh air into the battery system room or enclosure. The ventilation fan should be activated when charging or discharging the battery system but must also be fail-safe. (A DC fan that runs directly from the batteries via a normally closed relay is an acceptable form of fail-safe. An AC fan that runs off the inverter is not).

Enclosures

Code references for this section: IFC2003 Sections 608.3, 608.7, 609.4, and 609.9

Battery systems must be fully contained in enclosures or rooms that remain within the 800-ft^2 footprint. A battery system room will be permitted in lieu of a separate battery system enclosure if designed in accordance with IFC2003 Section 608.3 or 609.4.

A battery system enclosure is an appropriate means of separating the batteries from the rest of the electrical equipment, without building a separate room. This protects electrical equipment from battery gas emissions, minimizes the volume required to be ventilated (especially important if the electrical/battery system room does not have an exterior wall or exterior access), and prevents accidental contact with the batteries. Battery system enclosures must be constructed of acid-resistant materials (most plastics). A plastic bag draped over the tops of the batteries is not an enclosure. Whether or not an enclosure is used, all batteries should have some means of preventing accidental contact across the terminals (Plexiglas or rigid plastic covers are acceptable). The cover must be locked so access to batteries inside the enclosure is limited to the team's decathletes.

For inspection and maintenance purposes, the top of an enclosure should be at least 18 in. above the top of a battery or battery post (whichever is higher) unless the lid of the enclosure is hinged. A hinged lid on the enclosure will allow adequate access for maintenance and inspection and therefore can be in closer proximity to the top of a battery or battery post. It is recommended that the lid not touch the post or an electrical conductor under any circumstance.

Secondary Containment

Code references for this section: IFC2003 Sections 608.4 and 609.5

The purpose of secondary containment is both to capture any spills from watering vented or flooded cells as well as to capture any leaks from cracked or damaged batteries. Secondary containment systems should be sized according to IFC2003 Section 608.4 so as to capture the entire contents of at least one battery. Secondary containment systems only work when constructed of sealed, acid-resistant material. A plastic bag is not considered secondary containment.

If racks are used, secondary containment should be used on each rack level. Whereas a single pan at the lowest level may protect the environment, it does not protect the lower batteries from what goes on above.

Battery System Racks and Stacking

Code references for this section:

- NEC2002 Section 480.8
- IFC2003 Sections 608.7 and 609.9

If possible, battery system racks should be designed such that batteries are easily inspected, cleaned, and maintained. Most racks will have two levels and under certain circumstances may have three levels. As stated before, accessibility increases likelihood of proper maintenance. Keeping rack height minimized offers better accessibility. It also diminishes the likelihood of injury due to lifting batteries. For example, lifting a battery above a person’s head to place it on the rack could be a dangerous situation.

Battery racks can provide an appropriate means of assembling many batteries within a smaller footprint; but care needs to be taken in the selection and design of the battery system rack. The rack levels must be spaced so as to allow easy and safe access to each battery level during routine inspection and maintenance. For vented batteries, a minimum of 18 in. is required between the top of a battery or battery post (whichever is higher) and the rack structure or ceiling above. This amount of space is required for safe inspection and maintenance. All racks containing sealed batteries must provide adequate space for access with tools to verify tightness of terminal connections.

Placement of Disconnects

Code references for this section: NEC2002 Article 230 Part VI and Article 690 Part III

Battery system disconnects should be located as close to the exit as possible, should be as close to shoulder height as possible, and should be clearly labeled. Battery system disconnects, like fire extinguishers, should be readily accessible in case of an emergency. I should not be necessary to enter deep into a room where batteries are experiencing catastrophic failure to actuate the battery system disconnects. In addition, battery system disconnects should be readily accessible for emergency response personnel.

Other Considerations

Proper spill clean-up kits should be on hand in the event of electrolyte spills. Proper personal protective equipment (PPE) should be available for dealing with leaking cells and cleanup of electrolyte.

Smoke alarms should be placed in the electrical space where batteries are contained. The smoke alarm should be loud enough or should have a remote location indicator so the alarm can be heard outside of the electrical space. Fire extinguishers rated for electrical and chemical fires should be on hand in the event of battery failure.

In addition to any NEC requirements regarding the electrical system of the entire house, all battery enclosures shall be marked with the National Fire Protection Association's (NFPA) Hazard Warning Diamond appropriate to the battery technology contained within the enclosure.