

Chapter 6.1

Battery Safety

This could be you . . .

A sealed metal box containing a lead acid battery exploded and fatally injured a technician. Sparks from open electrical contacts in the box ignited the hydrogen released by charging and discharging the battery.

A battery pack with four D cell lithium batteries accidentally shorted on a metal work table and the battery exploded. A nearby technician fell from a chair but escaped serious injury.

A worker was checking out an auto-starter motor by placing the terminals across a lead acid battery. The motor was suspended over a battery. The motor ignited the venting hydrogen and blew the lid off the battery. The worker escaped serious injury from flying debris and battery electrolyte.

1. Applicability of this chapter

You are required to follow this chapter if you:

- a. Purchase, store, test, handle, maintain, or use batteries.
- b. Purchase, design, develop, build, handle, or test devices or systems that use batteries.
- c. Approve the activities in sub-paragraphs a or b above as an employee of or support contractor to the Safety and Mission Assurance Directorate (mail code NA), the Energy Systems Division (mail code EP), or the Facilities Management and Operations Division (mail code JM).

2. Scope of this chapter

This chapter defines the specific provisions required for handling batteries to be used for common battery, facility, and spaceflight operations as follows:

- a. **Common battery operations**, with the exception of disposal, are excluded from this chapter. These applications include batteries used in calculators, watches, cell phones, pagers, car batteries, etc. A list of these exemptions is contained in paragraph 4 of this chapter.
- b. **Facility operations** include a wide range of ground support operations that indirectly support space operations. Examples of such are maintenance facilities, battery back-up power systems, batteries for vehicles, etc.
- c. **Spaceflight operations** include prototype, flight, and flight-type batteries to be used on the International Space Station (ISS), shuttle, or any spacecraft application.

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The hazards associated with facility and spaceflight operations are unique to each other and require a different approval process. The extent of the hazard controls and verification required depends on the battery chemistry, capacity, complexity, charging profile, and application. A battery is defined as two or more cells connected in a series or parallel configuration.

3. Battery application

Certain battery chemistries are toxic and potentially lethal in certain environments. For instance, some batteries that are safe for facility operations may not be safe inside a crewed vehicle (spaceflight operations). It is important to understand the battery's application and seek advice from the appropriate experts. The activities listed in paragraph 1 require coordination and approval from one of the following sections depending on the application:

- a. For Facility Operations: The Safety and Mission Assurance Directorate (NA) and the Utilities Branch of the Facilities Management and Operations Division (JM5). For battery facility operations, paragraph 4 lists the exceptions to the approval requirements.
- b. For Spaceflight Operations: The Safety and Mission Assurance Directorate (NA) and the Energy Systems Division (EP). For spaceflight battery uses, reference JSC 20793, "Manned Space Vehicle Battery Safety Requirements."

4. Exemptions from approval requirements

There are currently no exemptions from the approval process for spaceflight operations. Refer to paragraph 2 for the definition of facility and spaceflight operations. The following batteries in the following applications do not require the approvals listed in paragraph 3 above if used for no- spaceflight applications. These exemptions apply only if you use the batteries or devices as the manufacturer intended with no modifications:

- a. In general, the battery uses an electrochemical couple (chemistry) that is well known, well understood, and nontoxic, and that has a long application history. Also, the battery is used in a device that:
 1. Is a commonly used commercial design and available commercially.
 2. Usually includes a user's manual that describes the use or maintenance of the battery.
 3. Uses a battery with well-known hazards that are controlled with the battery's or device's design.
- b. Lead-acid, nickel-cadmium (Ni-Cd), or nickel-iron secondary batteries to start or power:
 1. Vehicles such as cars, trucks, buses, mobile cranes, mobile manlifts, electric drive wheelchairs, earth-moving equipment, forklifts, and other materials-handling equipment.
 2. Standard boats and aircraft.

3. Facility emergency lighting systems, emergency communications systems, or other commercially available emergency power systems.
- c. Alkaline-manganese; lead-acid; lead-acid batteries with immobilized electrolyte(gel-type); leclanche; lithium ion and lithium ion polymer secondary; lithium primary coin or button cells of 300 milliamperes or less; mercuric oxide-zinc; Ni-Cd; nickel-metal hydride; silver-zinc button cells; silver-zinc primary; and silver-zinc secondary batteries with no modifications may be used in the following commercial off-the-shelf (COTS) equipment for personal use and non-flight applications according to manufacturer's instructions:
 1. Calculators, personal digital assistants, laptop computers, and small computer uninterruptible power supplies.
 2. Watches and clocks.
 3. Radios, walkie-talkies, and cellular telephones.
 4. Flashlights and lanterns.
 5. Cameras and flashes.
 6. Portable sound and video recorders and players including battery-operated microphones, television sets, and compact disc players.
 7. Hearing aids.
 8. Radiation detectors (Radiacs).
 9. Metal detectors.
 10. Test equipment such as multimeters, ohm-meters, or pyrometers.
 11. State-of-the-art medical equipment in wide use in hospitals and clinics.

If a battery use is not listed above but meets the criteria in paragraph 4.a of this chapter, contact the Safety and Mission Assurance Directorate (NA) and the Utilities Branch of the Facilities Management and Operations Division (JM5). You may request a deviation from this chapter.

5. Battery hazards

An MSDS shall always be available for anyone using a nonexempt battery regardless of the application (see paragraph 4 for a list of exceptions). Always refer to the MSDS to learn about specific hazards for the planned application. The Energy Systems Test Area (ESTA) covers planned abusive testing under its General Operating Procedure Manual (GOPM), EP-WI-004. General battery hazards may be any of the following:

- a. **Crushing Forces:** Certain batteries may require a lifting plan due to their mass to avoid crushing forces due to drop, which can then lead to other hazards. Chapter 8.5, "Lifting Operations and Equipment Safety," provides the details.

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- b. **Electrical Potential:** All batteries possess the potential for electrical shock if mishandled or abused. Depending on the battery and chemistry, this can range from minor personal discomfort to a lethal shock.
- c. **Electrolyte Leakage:** A battery can leak electrolyte from a number of conditions such as charging or discharging incorrectly, dropping, penetration, short circuit, vacuum, etc.
 - If electrolyte gets on your skin or clothing, flush the affected area with copious amounts of water and get medical attention immediately. Do not put any neutralizing solution on your skin.
 - If electrolyte gets in your eyes, flush thoroughly and continuously with only water for a minimum of 15 minutes while rolling your eyes and lifting your eyelids. Do not put any neutralizing solution in the eyes. Get medical attention immediately; you may need help effectively flushing your eyes.
- d. **Environmental Pollution:** All batteries contain materials that are considered to be an environmental pollutant if venting or leakage occurs. Planned venting and release of polluting compounds shall be inside a controlled environment designed to handle such an event. Proper disposal of all batteries is required (see paragraph 12).
- e. **Fire:** Many batteries contain flammable electrolyte. Planned fires shall be inside a controlled environment designed to handle such an event. Be careful: Do not unintentionally abuse a battery, mechanically or electrically.
- f. **High Sound Levels:** High sound levels include noise from the battery bursting or venting. Planned venting shall be inside a controlled environment designed to handle such an event.
- g. **Oxygen-deficient Atmosphere:** This is typically not a hazard since the toxic atmosphere will come into effect before asphyxiation occurs. However, inert gases used during battery testing may cause an oxygen-deficient atmosphere and should be examined on a case-by-case basis.
- h. **Shrapnel or Blast Wave Over-Pressurization:** High-temperature venting, rupture, or explosion may occur when a battery gets too hot from external heat sources or heat generated by the battery itself (runaway reaction). Planned venting or bursting shall be inside a controlled environment designed to handle such an event. Observe the following precautions:
 - 1. Hydrogen or mixtures of hydrogen and oxygen generated during open circuit storage, discharging, over discharging, charging, and overcharging can be explosive
 - 2. Brazing or soldering operations may be necessary for attaching pressure fitting and sealing vent on the battery for pressure testing. Test articles need to be prepared properly; that is, fully discharged, vented with a separate hole and have liquid electrolyte removed before attaching the pressure fitting.
- i. **Temperature:** During abusive conditions such as overcharge or over-discharge, battery case temperature may exceed the upper touch temperature limits of 113°F. Planned

abusive testing shall be done in the appropriate thermal chamber and the temperature verified before handling.

- j. **Toxic Atmosphere:** Batteries contain materials that may be considered toxic. This can be in the form of a liquid or a gas. In addition, batteries contain strong corrosives, either acid or alkali depending on battery chemistry.

6. General battery precautions

You shall follow these precautions in both facility and spaceflight operations. See paragraph 2 for the definition of facility and spaceflight operations:

- a. Have all nonexempt batteries or related assembly and test procedures approved by Energy Systems Division personnel before performing any work. Assembly procedures shall include, where appropriate, mandatory inspection points and step-by-step assembly instructions or drawings
- b. Keep metallic objects, which could cause short circuits or arcing, away from battery terminals.
- c. While storing or operating batteries, store or operate such that accidental shorting cannot occur. Use a nonconductive rack or a rack with a nonconductive coating, or use the original manufacturer's storage container or plastic bags individually wrapped.
- d. Don't wear rings, metal watchbands, chains, or other jewelry while handling or working with batteries. If you can't remove your ring, cover it with insulation, tape, or a glove.
- e. Erect barriers or shields to protect nearby personnel from exploding or rupturing batteries in battery charging areas.
- f. Provide adequate ventilation systems.
- g. Never attempt to charge a non-rechargeable (primary) battery.
- h. Never charge or discharge batteries by any device or method other than that supplied by the equipment manufacturer. If a commercial battery test stand is to be used, a Test Readiness Review (TRR) shall approve the test before operations can proceed.
- i. Consider all leakage from batteries as toxic and corrosive. Take precautions to avoid touching, ingesting, or inhaling battery electrolyte liquid or gases.
- j. Never store batteries or battery electrolyte with food or drink items.
- k. Construction or Test Operations: Provide facilities for quick drenching or flushing within 25 feet of battery handling areas.
- l. Maintain eyewashes and safety showers per sub-paragraph 10.1.3.e of this handbook.
- m. All aqueous battery systems shall be vented, not hermetically sealed.
- n. Use spot welding, not soldering, to attach leads directly to a battery. Soldering generates excessive heat and can lead to the battery venting. Never do any hot work unless you are qualified and understand the hazards of hot work on batteries. (Hot work permit needed,

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see chapter 5.8, “Hazardous Operations, safety practices and certification,” of this handbook.)

- o. If a battery vents or catches on fire, take precautions to avoid inhalation of the fumes. In the event of an unplanned fire, call x33333.
 - p. Provide equipment and supplies for emergency flushing and neutralizing spilled electrolyte in areas where electrolyte is used outside of the battery or the possibility exists for venting or leaking such as in a test area. Wastes or wastewaters generated during flushing or neutralizing spilled electrolyte may not be discharged to the storm sewer, ground, or ditch unless they are generated during emergency response. Before discharging wastes or wastewaters to the sanitary or process sewer, you shall get approval from the Environmental Office. In general, call uncontrolled spills or releases of electrolyte into the Emergency Operations Center (x33333) and unplanned spills or releases into Facility Work Control (281-483-2038). Always reference the MSDS for neutralizing agents, but in general use:
 - 1. Sodium bicarbonate (baking soda) for spills involving an acid electrolyte.
 - 2. Citric acid for spills involving an alkali (base) electrolyte.
- Note:** This subparagraph applies to unplanned releases and does not apply to routine discharges to the sanitary sewer that have been approved by the Environmental Office via JF1109, “Sanitary Sewer Discharge Approval Request.”
- q. Review the MSDS for each battery and battery chemistry and have this MSDS locally available for operators of the battery.
 - r. If a battery has toxic electrolyte and a rupture occurs, evacuate the area and notify the fire department by calling JSC’s emergency number (x33333). Response personnel shall use air breathing equipment—such as air packs or air face masks and separate K-bottles of breathing air—rubber gloves, and a chemical apron.
 - s. The ESTA routinely handles abusive tests on batteries such as the ones listed below. Unless planning an abusive test with a TRR, never perform any of the following actions:
 - 1. Attempting to charge primary (non-rechargeable) batteries. They could vent toxic materials or explode.
 - 2. Short-circuiting or high-current discharging batteries.
 - 3. Overheating or exposing batteries to temperatures higher than the manufacturer’s recommendations.
 - 4. Over-discharging a battery. This includes discharging at high currents or below the manufacturer’s recommended voltage cutoff.
 - 5. Opening, crushing, puncturing, or otherwise mutilating a battery.

7. Facility operation requirements

You shall follow these precautions:

- a. Provide emergency eyewashes and showers for quick drenching or flushing in accessible locations that require no more than 10 seconds to reach for the following activities:
 - 1. Doing maintenance work on or with electrolyte- or corrosive-based batteries (examples: removing battery cap to fill or refill or adding electrolyte or water).
 - 2. Moving or handling batteries where they could be dropped.
- b. Maintain batteries only in designated battery maintenance areas.
- c. Battery banks designed to supply power shall have disconnect devices. This will prevent sparks during the connection process.
- d. Follow these requirements when lifting or moving batteries:
 - 1. See Chapter 8.5, “Lifting Operations and Equipment Safety,” of this handbook.
 - 2. Use a conveyor, an overhead hoist, or other material handling equipment to handle heavy batteries, such as those used in forklifts or other materials handling equipment.
 - 3. Use a suitable spreader when lifting batteries with an overhead lifting device. This prevents the lifting cables or chains from squeezing and possibly cracking the battery case.
 - 4. Protect battery terminals and exposed conductive surfaces with nonconductive materials when using cables or chains for lifting.
 - 5. Use proper terminal straps to lift a battery, unless the battery case has lifting pad eyes or similar attachment points.
- e. Ground all switch, control, light, and indicator cases as described in National Fire Protection Association Standard 70, “National Electric Code,” Article 250, “Methods of Grounding Conductor Connection to Electrodes.”
- f. If possible, route alternating and direct current circuits separately.
- g. Provide fire protection in charging areas.

8. Facility operation requirements for lead-acid batteries

You shall observe the following precautions to protect yourself from the following hazards:

- a. General lead-acid battery precautions:
 - 1. Wear a face shield and goggles when handling or servicing a battery.
 - 2. Locate servicing and charging installations in areas designated for that purpose.
 - 3. Guard charging equipment for industrial trucks to prevent damage by the trucks.
 - 4. Use replacement batteries of the same amp-hour or higher rating for industrial trucks as the original batteries.
 - 5. Position industrial trucks or vehicles properly and apply the brakes before changing or charging the batteries in place.
- b. Protection from explosion and fire hazards:

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1. Provide appropriate ventilation to prevent an explosive hydrogen-air mixture from accumulating.
 2. Never smoke where batteries are being charged, serviced, or worked on; in battery rooms; and near battery cabinets. Post NO SMOKING signs.
 3. Prevent open flames, sparks, or electrical arcs in battery storage and servicing areas.
 4. Provide fire protection in battery rooms and charging areas.
 5. Open battery compartments or covers when charging batteries to aid ventilation and heat dissipation, if applicable.
 6. Don't do any work involving heat sources or arcing on batteries until venting all of the hydrogen or oxygen gases by purging with an inert gas or positively ventilating all spaces that could trap explosive gas mixtures. Use a combustible gas meter to confirm ventilation is complete.
 7. Equip each battery with a flash arrestor vent cap for stationary installations and wherever else it is feasible.
 8. Inspect electrolyte levels in emergency light batteries to make sure they don't fall below the level of the plate tops.
- c. Protection from chemical hazards:
1. Wear a face shield or goggles, protective aprons, gloves, and boots while mixing electrolyte, activating dry charge batteries, or doing any work that could result in an electrolyte spill.
 2. Coat charging benches or tables with a nonconductive material that can withstand an electrolyte spill.
 3. Provide enough ventilation to prevent acid fumes from entering areas where alkaline batteries are serviced or used.
 4. Service alkaline-electrolyte batteries in an area isolated from lead-acid batteries.
 5. Label acid and alkaline electrolyte battery servicing equipment carefully and keep each kind of equipment separate.
 6. Don't use acid electrolyte equipment with alkaline batteries or alkaline equipment with acid batteries, otherwise you may generate large amounts of hydrogen and create an explosive mixture.
 7. Keep vent caps in place and make sure the vent caps work to avoid electrolyte spray when charging batteries. If the vents are clogged, the battery case may rupture from internal overpressure causing electrolyte to spray over a large area.
 8. Use a carboy tilter or siphon to handle electrolyte.
 9. Pour acid into water when mixing electrolyte. **Note:** Never pour water into an acid. The intense heat of the solution can cause violent boiling on the surface of the acid and can splatter onto your skin, eyes or clothing.

9. Facility operation requirements for Ni-Cd batteries

Aircraft Ni-Cd batteries are usually made of series-connected, prismatic, pressure-relieved cells. COTS equipment with Ni-Cd batteries installed typically use cylindrical cells with spring-loaded valves. These batteries operate as sealed cells except under abusive conditions. When using or handling Ni-Cd batteries, you shall follow the precautions listed below:

- a. Wear safety goggles, protective gloves, and a protective apron to work with vented Ni-Cd batteries or caustic electrolyte. Potassium hydroxide is a caustic electrolyte that can cause severe burns. **Note:** COTS alkaline cylindrical cells use essentially the same electrolyte.
- b. Assemble the battery in a container separate from the rest of the electrical control system.
- c. Make portable battery containers for vented cells as follows:
 1. Keep the free volume in the battery container to an absolute minimum. The free volume is the space in which hazardous gases may accumulate. There is no restriction on volume filled with other materials.
 2. Coat the battery terminals, interconnects, and wiring with a suitable alkali-resistant potting material. Coat all current-carrying battery components, if possible.
 3. Make sure the potting material doesn't seal vented cells.
 4. Provide an easily removable cover for the battery container.
 5. Consider using a splash-proof pressure vent to relieve pressure in the container.
 6. Make sure that all individual cells are vented.
 7. Don't seal vented cells in a container that will trap gases.
- d. To control explosion and fire hazards:
 1. Use a voltage-limited current taper and temperature-monitoring charging method to reduce gassing and electrolyte spray. Charge in a well-ventilated area under the manufacturer's recommendations with the battery box cover removed. An approved test program that has undergone a TRR may deviate from the manufacturer's charging recommendations.
 2. Make sure the individual cells are able to dissipate heat to prevent overheating during charge. Equip individual vented cells with flash arrestor vent caps where applicable.
 3. Never replace a battery box cover until the battery has been cleaned and at least 4 hours have elapsed since charging the battery where applicable.
 4. For each sealed battery, select cells that are matched for charge voltage capacity and charge retention.
- e. To address chemical hazards, use absorbent wicking materials to control electrolyte leakage within the battery box or case.

Requirements for lithium batteries

10. Requirements for safely using and handling lithium primary and secondary batteries

To safely use and handle lithium batteries, you shall follow these precautions:

- a. Hazards of handling lithium primary and secondary batteries:
 1. Under abusive conditions, lithium batteries can vent, explode, and burn, releasing highly toxic and corrosive materials. For more information on the toxic and explosive behavior of these batteries, reference ESTA-OP-0-49, "Lithium Battery Handler Certification," and JSC 20793, "Manned Space Vehicle Battery Safety Requirements."
 2. Some of the toxic, flammable, or corrosive ingredients that can be released are carbon disulfide, carbon monoxide, hydrobromic acid, hydrochloric acid, hydrocyanic acid, hydrogen, methane, methyl cyanide, sulfur dioxide, thionyl chloride, and secondary battery electrolyte solvents.
- b. Keep lithium primary batteries safe at all times. Never put them on conductive surfaces, on metal shelves, in desks, in electronics assembly areas, in receiving inspection areas, in machine shops, etc.
- c. Assemble, process, and handle lithium cells and battery packs with caution:
 1. Protect batteries under assembly from shorting against foreign objects by storing them in plastic bags or in the original carton.
 2. Use spot welding, not soldering, to attach leads directly to a battery. Only qualified personnel in the Energy Systems Test Branch may do spot welding on lithium batteries.
 3. Return lithium batteries to a controlled storage area in plastic or the original containers when the assembly or fabrication process is interrupted or stopped for any reason other than normal shift changes.
- d. Store lithium batteries at room temperature or lower in a dedicated, dry, well-ventilated location indoors.
- e. Handle lithium batteries only if trained and certified to use them safely as described in Chapter 5.8, "Hazardous Operations: Safe Practices and Certification," of this handbook.
- f. ESTA requires personnel operating and handling lithium primary batteries to be certified using ESTA-OP-0-49, "Lithium Battery Handler Certification."

11. What to do if a primary lithium battery emergency occurs

If a primary lithium battery emergency occurs, take the following actions as appropriate for the emergency:

- a. If the primary lithium battery has toxic electrolyte and abnormal use, or you have observed leaking, venting, or increasing battery temperature:
 1. Clear the area of personnel and have qualified and properly equipped personnel remove the batteries to a safe area.
 2. If possible, disconnect the batteries electrically from associated equipment after they have stabilized.
 3. Dispose of them using instructions in paragraph 12 below.
- b. If the primary lithium battery has toxic electrolyte and a rupture occurs, evacuate the area and notify the fire department by calling JSC's emergency number (x333333). Response personnel shall use air breathing equipment—such as air packs or air face masks and separate K-bottles of breathing air—rubber gloves, and a chemical apron.
- c. If a small fire occurs:
 1. Use a graphite powder or a Lith-X (Class D) extinguisher to extinguish burning lithium.
 2. **Don't use** water, sand, carbon tetrachloride, carbon dioxide, or soda acid extinguishers in lithium battery fires.
 3. Use these extinguishers only on nearby materials to prevent the fire from spreading.

12. Disposing of batteries

Dispose of discrepant or depleted cells as quickly as possible. The method of disposal depends on the chemistry of the battery as follows:

- a. In small quantities, you may dispose of alkaline batteries in site trash or garbage disposals. You shall dispose of large quantities of leaked or vented batteries through the Environmental Services Office (JE) support contractor using a JSC Form 1161. You can contact the facilities work control center at 281-483-2038.
- b. You shall dispose of all other battery chemistries through the Environmental Office (JE) support contractor using a JSC Form 1161. You can contact the facilities work control center at 281-483-2038.

Note: Refer to JPR 8550.1, "JSC Environmental Compliance Procedural Requirements," Chapter 3 for complete information on proper disposition of batteries.

- c. If disposing of large quantities of batteries, contact the Environmental Office (JE) support contractor in advance to plan for the proper accumulation, packaging, funding, and disposal to prevent a delay. You can contact the facilities work control center at 281-483-2038.

Note: This does not apply to routine generation of large quantities of batteries from test activities where a JSC Form 1104, "Waste Notification," has been submitted.

- d. Before contacting the Environmental Office (JE) support contractor (facilities work

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control center at 281-483-2038), perform the following actions:

1. Tape each battery with fiberglass or Kapton tape across the positive terminal to prevent inadvertent shorting. Place batteries dispositioned as “scrap” in an individual Ziplock plastic bag or a plastic container for each battery.
2. Separate the different chemistry batteries into different storage containers. For example, do not mix nickel metal hydrides with lithium ion batteries.

13. Reference documents

The following documents may help in the understanding or clarification of this chapter:

- a. EP-WI-004, “Energy Systems Test Branch’s General Operating Procedure Manual (GOPM)”
- b. ESTA-OP-0-49, “Lithium Battery Handler Certification”
- c. JPR 1700.1, Chapter 5.8, “Hazardous Operations: Safe Practices And Certifications”
- d. JPR 1700.1, Chapter 8.5, “Lifting Operations And Equipment Safety”
- e. JPR 8550.1, “JSC Environmental Compliance Procedural Requirements”
- f. JSC 25159, “Toxicological Hazard Assessments on Batteries used in Space Shuttle Missions”
- g. JSC 20793, “Manned Space Vehicle Battery Safety Requirements”
- h. NASA Reference Publication 1099, “Lithium/Sulfur Cell and Battery Safety”
- i. National Fire Protection Association Standard 70, “National Electrical Code,” Article 250, “Methods of Grounding Conductor Connection to Electrodes”
- j. MSDS for the battery chemistry of the planned application