OSHA® FactSheet

Lithium-ion Battery Safety

Lithium-ion batteries are one type of rechargeable battery technology (other examples include sodium ion and solid state) that supplies power to many devices we use daily. In recent years, there has been a significant increase in the manufacturing and industrial use of these batteries due to their superior energy storage characteristics. This increased use of lithium-ion batteries in workplaces requires an increased understanding of the health and safety hazards associated with these devices.

The hazards and controls described below are important in facilities that manufacture lithium-ion batteries, items that include installation of lithium-ion batteries, energy storage facilities, and facilities that recycle lithium-ion batteries.

Lithium-ion Batteries

A lithium-ion battery contains one or more lithium cells that are electrically connected. Like all batteries, lithium battery cells contain a positive electrode, a negative electrode, a separator, and an electrolyte solution. Atoms or molecules with a net electric charge (i.e., ions) are transferred from a positive electrode to a negative electrode through an electrolyte solution. Lithium cells store and release power by converting chemical potential energy into electrical energy using lithium ions or lithium metal. Electrolyte solutions allow ions to flow freely between the electrodes. There are several types of lithium cells, including cylindrical cells, prismatic pouch cells, and prismatic metal can cells.

Lithium-ion batteries use lithium in ionic form instead of in solid metallic form and are usually rechargeable, often without needing to remove the battery from the device. They power devices such as mobile telephones, laptop computers, tablets, cameras, power tools, electric vehicles, and machinery, and are also used in large Energy Storage Systems (ESS).

Potential Hazards

Lithium-ion batteries may present several health and safety hazards during manufacturing, use, emergency response, disposal, and recycling. These hazards can be associated with the chemicals used in the manufacture of battery cells, stored electrical energy, and hazards created during thermal runaway, (see below) which can include fire, explosions, and chemical byproducts.

Chemical Hazards

Lithium-ion batteries contain various components that present different chemical hazards to workers, such as flammability, toxicity, corrosivity, and reactivity hazards. These chemicals may enter the workplace as raw materials or recycled materials. As processes change, any new chemicals must be thoroughly assessed for potential safety and health impacts to the workplace and workers.

A lithium-ion battery cathode is made of a lithium metal oxide material. The choice of cathode material depends on the desired characteristic of the battery. These materials can include lithium cobalt oxide ($LiCoO_2$), lithium manganese oxide ($LiMn_2O_4$), lithium nickel manganese cobalt oxide ($LiNiMnCoO_2$), lithium nickel cobalt aluminum oxide ($LiNiCoAlO_2$), or lithium iron phosphate ($LiFePO_4$).

Common materials for a lithium-ion battery anode include carbon-based materials such as graphene, nanofibers, carbon nanotubes, graphite, and titanium-based materials such as lithium titanate and titanium dioxide.

Lithium-ion batteries contain electrolytes that are a combination of solvents with an electrolytic salt. Lithium hexafluorophosphate, the most common salt used in lithium-ion cells, can react with water to form hydrogen fluoride (HF). The most common solvents used in lithium-ion batteries include ethylene carbonate (EC), propylene carbonate (PC), dimethyl carbonate (DMC), ethyl methyl carbonate (EMC), and diethyl carbonate (DEC). Some of these electrolytes are flammable liquids and requirements within OSHA's Process Safety Management standard may apply to quantities exceeding 10,000 lb.

Many of the chemicals used in lithium-ion battery manufacturing have been introduced relatively recently. Consequently, there may be limited toxicological information and few established OSHA permissible exposure limits (PELs). Additionally, because some of OSHA's PELs may be outdated and inadequate for protecting worker health, employers should consider alternative occupational exposure limits (OELs) developed by technical, professional, industrial and/or government organizations to ensure worker protection. For chemicals without occupational exposure limits, Occupational Exposure Banding and Control Banding can be used with the Hierarchy of Controls to manage risks and prevent exposure to hazardous chemicals. See the NIOSH Control Banding webpage and the OSHA Permissible Exposure Limits – Annotated Tables for additional information and explanation.

Additionally, when a lithium-ion battery or cell does not meet exemptions under OSHA's Hazard Communication Standard (HCS) as an "article," the manufacturer or importer is required to classify the chemical hazards and provide the hazard information to downstream users. For additional information, see OSHA's Letters of Interpretation regarding the Coverage of lithium-ion batteries under the Hazard Communications Standard (6/23/2021) and Applicability of the HCS to Lithium-ion Batteries (12/1/2022).

Safety Hazards

In addition to electrical hazards, lithium-ion batteries can also present hazards resulting from thermal runaway. Because lithium-ion batteries combine a flammable electrolyte with a significant amount of stored energy, thermal runaway reactions are possible. Thermal runaway is a chain reaction where the heat released from the failure of one cell damages nearby cells. This can be initiated by internal short circuiting due to defects during manufacturing, mechanical damage to the battery, exposure to excessive heat or cold, and improper charging.

Thermal runaway can be identified by several indicators including a rise in battery temperature, venting of gas, vapor, or smoke from the battery, or the presence of fire. Fires caused by thermal runaway can produce additional chemical hazards that may include hydrogen fluoride (HF), hydrogen chloride (HCl), hydrogen cyanide (HCN), phosphoryl fluoride (POF3), carbon monoxide (CO), carbon dioxide (CO2), black carbon, and other potentially hazardous chemicals and particulates.

For additional information see OSHA's Safety and Health Information Bulletin on Preventing Fire and/or Explosion Injury from Small and Wearable Lithium Battery Powered Devices.

Safety by Design

Whether manufacturing or using lithium-ion batteries, anticipating and designing out workplace hazards early in a process adoption or a process change is one of the best ways to prevent injuries and illnesses. Hazard controls must be addressed in the initial design and construction phases, as well as implemented through changes to management and manufacturing processes as production methods and energy storage technologies evolve. Safety by design includes the proactive substitution and adoption of less hazardous technologies. See the NIOSH webpage, Prevention through Design, for additional information.

Safety and Health Management System

Establishing a safety and health management system (SHMS) (i.e., safety program) is an effective way of protecting workers from potential hazards associated with lithium-ion

batteries. A mature and effective SHMS can prevent workplace injuries and illnesses by using proactive approaches to find and fix workplace hazards before they cause injury and illness to workers. To be effective, the SHMS must have meaningful worker engagement and participation. In many workplaces, worker participation may include a safety committee that can bring workers and management together to identify and find solutions, and to promote safety and health. See the OSHA webpage Recommended Practices for Safety and Health Programs for additional information on implementing a successful SHMS or program.

Hazard Controls

Lithium-ion battery hazard controls should be implemented according to the Hierarchy of Controls. Controlling hazards at the source is the most effective method to eliminate or reduce hazards. . OSHA's Transitioning to Safer Chemicals Toolkit is a step-by-step resource with information, methods, tools, and guidance for employers and workers to proactively reduce or eliminate chemical hazards at the source through informed substitution.

Additionally, hazard controls that can be implemented in workplaces that manufacture or use lithium-ion batteries include:

- Ventilation, including local exhaust ventilation (LEV) and enclosures
- Process automation and isolation of hazardous materials
- Storage of lithium-ion batteries and devices in dry, cool locations
- Following National Fire Protection Association (NFPA) guidance for the installation of Energy Storage Systems
- Following manufacturer's instructions for storage, use, charging, and maintenance of lithium-ion batteries
- Limiting the quantity of stored lithium-ion batteries
- Following the manufacturer's guidance on how to extinguish small battery fires
- Continuous monitoring for flammable and toxic gases in large storage locations
- Using shipping guidance provided by the US Department of Transportation and International Air Transport Association (IATA) and following proper shipping and packaging requirements provided in 49 CFR 173.185
- Disposing of lithium-ion batteries and devices containing these batteries, at designated recycling facilities and not placing them in municipal trash or recycling bins
- Not mixing battery types (e.g. lithium-ion, alkaline, lead acid) in recycling facilities
- Providing safety showers and eyewash stations in locations where exposure to electrolytes may occur
- Developing and implementing an emergency response plan, including emergency procedures, and creating training for response personnel that addresses possible physical and chemical hazards, including hazardous decomposition products (e.g., hydrogen fluoride)
- Conducting a hazard assessment and using proper personal protective equipment (PPE), when appropriate

Training

Education and training are important tools for informing workers and managers about workplace hazards and controls. Workers must be trained in a language and at a literacy level they understand. Appropriate training may include, but is not limited to, Hazard Communication (29 CFR 1910.1200) training, Hazardous Waste Operations and Emergency Response (HAZWOPER) (29 CFR 1910.120) training, and Process Safety Management (29 CFR 1910.119) training . OSHA's publication Training Requirements in OSHA Standards provides a general overview of the training requirements in specific OSHA standards.

In workplaces with lithium-ion batteries, it is important that employers ensure that an emergency action plan (EAP) includes lithium-related incident response procedures based on the manufacturer's instructions and NFPA guidance for responding to battery failures, including fires and/or explosions caused by thermal runaway, and that workers are trained on these procedures.

For workplaces involved in the manufacturing, repair, use, and recycling of lithium-ion batteries, it is important for employers to ensure that exposed workers receive appropriate information about the hazards associated with lithium-ion batteries and that workers receive training on the physical and health hazards associated them.

OSHA Standards

While there is not a specific OSHA standard for lithium-ion batteries, many of the OSHA general industry standards may apply, as well as the General Duty Clause (Section 5(a)(1) of the Occupational Safety and Health Act of 1970). These include, but are not limited to the following standards:

- 1910 Subpart L - Fire Protection
- 1910 Subpart S - Electrical
- 1910.39 Fire Prevention Plans
- 1910.119 Process Safety Management of Highly Hazardous Chemicals
- 1910.120 Hazardous Waste Operation and Emergency Response
- 1910.132 Personal Protective Equipment
- 1910.134 Respiratory Protection
- 1910.147 The Control of Hazardous Energy (Lockout/Tagout)
- 1910.151 Medical Services and First Aid
- 1910.178 Powered Industrial Trucks
- 1910.1000 Air Contaminants
- 1910.1020 Access to employee exposure and medical records
- 1910.1200 Hazard Communication

These standards are also representative of the types of protections that apply to the manufacture and use of other energy storage technology, whether in use now or under development.

Consensus/Industry Standards and Programs

- National Fire Protection Association, NFPA 855 Standard for the Installation of Stationary Energy Storage Systems
- International Electrotechnical Commission, IEC 62281 Safety of Primary and Secondary Lithium Cells and Batteries During Transport
- Underwriters Laboratories, UL 2054 Standard for Household and Commercial Batteries
- Underwriters Laboratories, UL 9540 Standard for Energy Storage Systems and Equipment
- The American Society of Safety Professionals, ANSI/ASSP Z10.0 Occupational Health and Safety Management Systems
- International Organization for Standardization, ISO 45001 Occupational Health and Safety Management Systems

How to Contact OSHA

OSHA's mission is to assure America's workers have safe and healthful working conditions free from unlawful retaliation. For more information, visit www.osha.gov or call OSHA at 1-800-321-OSHA (6742), TTY 1-877-889-5627.

This is one in a series of informational fact sheets highlighting OSHA programs, policies or standards. It does not impose any new compliance requirements. For a comprehensive list of compliance requirements of OSHA standards or regulations, refer to Title 29 of the Code of Federal Regulations. This information will be made available to sensory-impaired individuals upon request. The voice phone is (202) 693-1999; teletypewriter (TTY) number: (877) 889-5627.

Occupational Safety and Health Administration

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