Risk navigator

Batteries, battery chargers, and rechargers

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Products liability

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About Markel's Risk Solution Services team

Risk Solution Services provides technical insight related to existing and potential insured risks at Markel. The team partners with our customers, claims, and underwriters to educate on both current and future risk trends and supports our clients with a broad offering of risk management solutions.

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Batteries

A battery is a power source (electrochemical apparatus or device) which stores chemical energy and converts it into electrical energy. Batteries are present in a variety of products and most contain hazardous materials. Release of hazardous materials into the environment is dangerous and regulated, and failure to comply with regulations may result in costly remediation.

The use of batteries in consumer products continues to grow exponentially. With the production of batteries and the miniaturization of portable products, manufacturers have sought to increase battery-operating times while reducing the size and weight of the battery and the battery-powered product. This has led to battery chemistries that pack higher energy in smaller packages. High-energy chemistry batteries include lithium ion, lithium-ion polymer, and lithium-metal batteries that are thinner, smaller, and lighter weight and contain more energy than traditional rechargeable and non-rechargeable batteries. Although conventional battery chemistries such as lead acid pose fire and explosion hazards, the combination of high-energy volatile chemistry packed into a small volume requires special safeguards to minimize potential hazards. High-energy density batteries need enhanced safety systems and additional care when using and handling—both in and when removed from the product; and batteries must be properly tested with the product in its intended use and with the charger as a system.

Batteries, including high-energy chemistry batteries such as zinc-based technologies, have inherent limitations such as round-trip efficiency (RTE)—a ratio of the amount of usable energy that can be discharged from a storage system relative to what was put in originally and other parameters by which they are often categorized.

Many batteries also have inherent risks associated with their application and storage. However, several alternate high-energy chemistry batteries, including those that are zinc-based, are usually ascribed as being safer with respect to fire, explosion, and overheating conditions than earlier batteries like alkaline and lithium ion.

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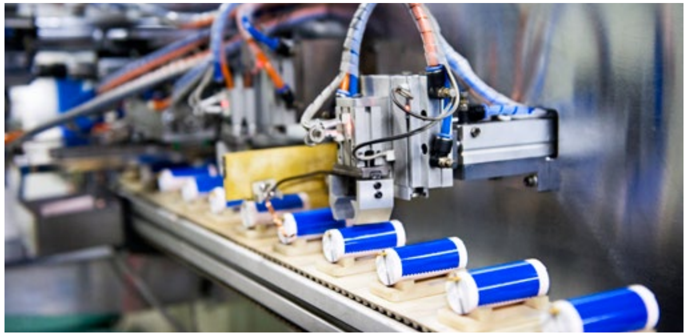
Manufacturing

Battery manufacturing is often a highly automated process with workers involved in handling bulk chemicals and operating various types of machinery. Risks are a function of battery chemistry, size, and technology employed in manufacturing as well as the type of battery being manufactured and include environmental risk from the release of metals in the air and water; health risks associated with chemical exposure; and transportation and storage risks, including fire and explosion, property damage, and personal injury risks during battery use and misuse.



Components

The basic components of a standard dry battery cell include a zinc anode and a carbon cathode within a central rod. Cadmium, carbon, lead, nickel, and other materials are used in various designs. The basic components of a standard wet battery cell also include an anode, a cathode, a liner or separator (to separate the anode and cathode), a current collector, and an electrolyte. Terminology shifts slightly when discussing other types of batteries, including lithium and zinc-based technologies, osmosis technologies, and other futuristic types.

Types of batteries

Batteries are broadly categorized as primary, which cannot be recharged after one use, or secondary, which can be electrically recharged. One classification system of batteries commonly used includes:

- **Dry batteries** (excluding lithium) are normally used in flashlights or small appliances and toys and include alkaline, nickel metal hydride, nickel cadmium, and carbon zinc batteries. These are the most common batteries consumers will come in contact with and include A, AA, C, and D batteries
- **Wet batteries** (lead-acid or lead-alkali batteries) are used in automobiles, forklifts, wheelchairs, uninterruptible power supply (UPS) systems, and other applications. They contain electrolyte acid or alkaline corrosive battery fluid. Many of these batteries, especially in the automobile industry, are fully enclosed. Lead-acid batteries have effective specific energy (ESE) (i.e., how much energy [watt-hours] is stored in a given unit of volume [liters] or weight [kilograms]) around 40 which is too low for power electric cars and other end products of that type to use
- **Lithium batteries** (also known as lithium metal or lithium-ion batteries [LIBs]) provide more energy and a longer operating life than other battery chemistries. They are used in long-term applications such as pacemakers and are popular in portable electronic devices such as laptop computers. They also have a higher potential to catch fire if damaged when compared to other batteries and may be susceptible to thermal runaway—which leads to a violent release of energy. LIBs must retain approximately 30 percent of

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their charge during storage. LIBs have had significant drawbacks in large-scale energy storage applications and are presently in competition with manufacturers of zinc batteries. Lithium batteries are also subject to dendrite deposits that can eventually short the battery or cause a fire. This is a common phenomenon when lithium batteries are charged fast, resulting in microscopic fibers of lithium building up on the surface of the lithium electrode. Lithium-ion batteries have effective specific energy (ESE) around 160 (Nissan) to 260-280 (Tesla) for some automobiles depending on the type. The ESE will go down once additional loads are considered and applied. Lithium-ion batteries are not primarily made of lithium. Cobalt may account for up to one-third of the battery weight. Manganese, aluminum, and other materials may also be integral to a lithium-ion battery

- **Saltwater batteries** (sodium-ion [Na-ion] or sodium-ion batteries [SIBs]) are generally designed for multi-hour applications and are rechargeable metal-ion batteries which use a saline solution as its electrolyte. In their present form, they are a newly marketed product and are still under investigation and study. They are being studied and tested as an alternative source for renewable energy storage applications for wind and solar power. SIBs can be completely drained to zero without damaging the active materials which makes them safer to handle than LIBs. They are nonflammable, recyclable, and overall relatively safer to handle than other batteries. SIBs are generally still in the experimental state. Due to battery costs for LIBs decreasing dramatically, SIBs still make up an insignificant percentage of the battery market
- **Magnesium, cadmium, manganese or cobalt oxide** may often utilize flammable electrolytes, raising risks higher than those for the basic lead-acid and other batteries
- **Zinc and nickel batteries** are becoming more common in industrial applications for energy storage. Though they may also suffer from dendrite deposits, zinc and nickel batteries are currently accepted as being less prone to fire and explosion than lithium-ion batteries. Currently some zinc-sponge batteries have shown an ESE rating around 120, increasing their competitiveness with lithium-ion batteries
- Other batteries utilizing various technologies are currently also under study, including osmosis and reverse osmosis technologies and the use of nanostructured bilayered vanadium oxide electrodes for rechargeable sodium-ion batteries

Battery packs and chargers

Batteries may or may not come in packs. A battery pack is a set of any number of batteries or individual battery cells. Battery packs may be configured in a series, parallel, or a mixture of both to deliver the desired voltage, capacity, or power density. They will include the batteries or cells themselves, interconnections between individual batteries or cells, connection points which are meant to be utilized to connect the battery pack itself with the item to be powered, and possibly charge control and indicator devices and apparatus depending on the sophistication of the battery pack and the item(s) being powered end use. Battery packs are generally used either internally or externally.

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Remote battery packs are mostly experimental in nature and are not generally available on the current consumer and industrial market.

Hazards, recalls, and legal cases

Risks involved with battery packs and chargers include:

- Utilizing the wrong battery pack or charger with the wrong end device
- Incompatible amperage or voltage
- Users switching battery packs to try to increase power to end device (e.g., on children's toys such as powered vehicles or hobby devices such as miniature powered airplanes)
- Improper user repairs
- Improper user alterations (especially to connectors)
- Utilization of cheaper, illegally imported, or smuggled units (usually through Canada)
- Utilization of falsely identified and certified battery packs and chargers (usually the American National Standards Institute [ANSI], UL, CS, or the Deutsches Institut für Normung)

The Consumer Product Safety Commission (CPSC) has received numerous consumer complaints and manufacturer and retailer reports involving hazards associated with batteries and battery chargers. Potential hazards noted by the CPSC include:

- Overheating
- Fire
- Electrical shock from battery chargers
- Thermal burns
- Exposure to alkaline battery electrolytes
- Hazards involving high-velocity ejected internal components of batteries

Reports to CPSC indicate incidents have occurred while the product is generally in one of the following situations or operational modes:

- In use
- In storage
- During battery charging

There have been a number of recalls involving various batteries and battery technologies. The most notable recall is lithium-ion batteries, including battery packs, battery chargers used in cell phones, portable computing products, personal electronic products, and electric scooters and hoverboards.

There have also been a number of recalls involving other types of batteries used in products such as:

- Battery-powered ride-on toys
- Portable battery-powered tools (CPSC)

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An additional Markel legal search and report on batteries from June 2021 resulted in over 12,500 individual battery-related cases and reported:

- Second-degree and third-degree burns
- Battery explosions
- Bad smells
- Thermal runaway
- Ignition
- Battery depletion
- Short circuiting
- Various overheating scenarios

Such incidents resulted in the following personal injuries from batteries:

- Thermal burns
- Chemical burns
- Permanent disfigurement
- Shocks
- Death

Battery packs and associated systems and assemblies resulted in additional cases involving:

- Property damage from overheating and resultant fire
- Lack and/or loss of full charge potential
- Decrease in round-trip efficiency (RTE)
- Parasitic battery drain
- Unexpected power offs (UPOs)
- Slow or other degraded performance of device being powered
- Lack of moisture protection and resistance
- Explosion
- Aching and resultant fire

Battery chemistry

Spill of hazardous materials, exposure to hazardous and/or non-hazardous waste that can lead to chronic health issues and/or death, battery explosions, fire caused by a battery, and face and eye injury due to leakage of a battery are all common in the battery industry. Also common are ingestion and inhalation hazards by both third parties visiting battery manufacturing and sales facilities and users of batteries and associated products. Some of the more notorious chemicals involved include:

Mercury

Battery chemistries have shifted over time. Mercury was phased out of certain types of batteries due to the Mercury-Containing and Rechargeable Battery Management Act passed in 1996. Directive 2006/66/EC of the European Parliament addresses acceptable metal content within batteries and upholds earlier prohibition of marketing all batteries with more than 0.0005 percent mercury by weight—with some exceptions.

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Cadmium

Cadmium battery use has declined due to health concerns and concerns regarding environmental contamination. Cadmium is considered a hazardous waste. Directive 2006/66/EC of the European Parliament addresses acceptable metal content within batteries and upholds earlier prohibition of marketing all batteries with more than 0.002 percent cadmium by weight—with some exceptions.

Battery storage

Appropriate battery storage is a major issue, especially with lithium batteries, as their proliferation increases the need for large quantity battery storage.

Before the widespread use of lithium batteries, the majority of storage issues surrounding lead acid batteries usually pertained to assuring the charge of stored batteries was not impeded, the batteries were as close to 100 percent charged during storage as possible, or involved the utilization of rechargers while batteries were in storage. The rechargers oftentimes repaired or altered, causing fires.

However, lithium storage has sensitized the battery industry to the proper storage of batteries as the storage for most lithium batteries is approximately 59°F. Lithium and nickel batteries need to be stored at approximately 40 percent charged.

Lithium batteries not stored at proper temperatures can become unstable, causing excessive heat to damage them internally and a potential fire.

All batteries, especially lithium, must be stored and charged at all times according to the manufacturer's recommendations. Batteries should not be taken into storage facilities until it has been determined that the facilities are at the required temperature for battery storage.

Buildings utilized to store batteries, whether inside or outside lithium or otherwise, should always be equipped with fire suppression systems, be climate controlled, utilize mechanical ventilation, have fiberglass-grated flooring, and meet the applicable entrance and egress requirements of National Fire Protection Association (NFPA) 101, *Life Safety Code*.

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Standards applicable to batteries (partial list)

Standard specifications relating to batteries are numerous and may include the American Society for Testing Materials (ASTM), UL, ANSI, the National Electrical Manufacturers Association (NEMA), and the International Electrotechnical Commission (IEC) standard specifications, among many others. These standard specifications include but are not limited to:

- NFPA 70 – *National Electric Code*
- IEC 60086-4:2000 – *Primary batteries. Safety standard for lithium batteries*
- IEC 62281. Ed.1. – *Safety of primary and secondary lithium cells and batteries during transport*
- ASTM D7148-13 – *Standard Test Method for Determining the Ionic Resistivity (ER) of Alkaline Battery Separator Using a Carbon Electrode in an Electrolyte Bath Measuring System*
- ASTM D7131-09 – *Standard Test Method for Determination of Ion Exchange Capacity (IEC) in Grafted Battery Separator*
- NFPA 111-2013 – *Standard on Stored Electrical Energy Emergency and Standby Systems*
- IEEE 484-2008 – *Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications*
- IEEE 1145-2007 – *Recommended Practice for Installation and Maintenance of Nickel Cadmium Batteries for Photovoltaic (PV) Systems*
- IEEE 1578-2007 – *Recommended Practice for Stationary Battery Electrolyte Spill Containment and Management*
- IEEE 1635/ASHRAE 21-2012 – *Guide for the Ventilation and Thermal Management of Batteries for Stationary Applications*
- UL 1989 – *Standard for Standby Batteries*
- UL Subject 2436 – *Spill Containment for Stationary Lead Acid Battery Systems*
- UL Subject 9540 – *Safety of Energy Storage Systems and Equipment*
- ANSI/CAN/UL 2272 – *Electrical Systems for Personal e-Mobility Devices*
- ANSI/NEMA C18 – *Safety Standards for Primary, Secondary and Lithium Batteries*
- IEEE 1625 – *Standard for Rechargeable Batteries for Multi-Cell Computing Devices*
- IEEE 1725 – *Standard for Rechargeable Batteries for Mobile Telephones*
- UL 1642 – *Standard for Safety for Lithium Batteries*
- UL 2054 – *Standard for Household and Commercial Batteries*
- UL 2595 – *Standard for Safety for General Requirements for Battery-Powered Appliance*

Issues for risk managers to consider

- Battery manufacturers are typically concerned about environmental hazards from spills of the chemicals used during production. Batteries generally contain heavy metals, toxic chemicals, or other hazardous elements (e.g., cadmium, zinc, mercury, manganese, iron, silver, and lithium) that may pose certain environment hazards
- Many landfills have gradually become contaminated with these types of metals and now have either strict controls in place or have been closed. Some battery manufacturers have started to reduce the levels of mercury they are putting into their batteries

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- There are currently very few major dry-cell manufacturers in the US. However, there are still several smaller manufacturers usually owned and operated by parent corporations, including foreign entities
- Two battery designs dominate the field: lead-acid batteries commonly used to start gas cars and lithium-ion batteries used in smartphones and electric cars
- The global lithium-ion-battery market is expected to grow to more than $75 billion by 2024
- Some key international vendors dominating the global large and advanced battery technology market are GS Yuasa Corp., Johnson Controls, LG Chemical, Panasonic, Samsung SDI, and SANYO Electric Co. Ltd.
- Motor vehicles will post the largest increases in dollar terms as motor vehicle production rises after more than a decade of decline. It will also be the fastest-growing market in percentage terms with overall battery demand bolstered by expanding production and sales of hybrid/electric vehicles (HEVs)
- Batteries have chemical hazards associated with corrosive or flammable electrolytes as well as electrical hazards

Hazards associated with batteries include chemical burn, fire, and electrical shock. Handling and transporting risks are of concern. Mishandled, improperly packaged or stored, overcharged, or defective batteries can short circuit, overheat, and cause a fire.

Fire damage includes not only physical damage but may also include the release of toxins into the air.

Following proper quality assurance or quality control (QA/QC) activities reduce the risk of faulty products and products liability claims. Quality control should occur at various points in the manufacturing process.

Health hazards associated with batteries include:

- Potential exposure to chemicals during the manufacturing process and during use or abuse, if the packaging fails
- Skin tissue damage from chemical burns is possible, and exposure to metals may result in health hazards
- Choking or ingestion of button cell batteries can lead to internal burns
- Lead is a known toxin. Children in particular are susceptible to developmental and nervous system damage related to lead

Batteries short-circuiting may result in a fire or an explosion. Battery manufacturers need to understand the risks associated with manufacturing, storage, shipment, and use. They must comply with standards, regulations, and guidance to manage risk.

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The US Department of Health and Human Services and the National Institutes of Health classify cadmium and cadmium compounds as known human carcinogens. It is possible that additional health effects may not arise until many years after exposure. The potential health hazards vary by battery type and chemistry but range from central nervous system toxicity to cancer. Both frequency and severity can be expected with battery manufacturing and use.

Human and ecological health is impacted by the release of battery chemicals into the environment. Numerous metals are toxic to aquatic organisms and may accumulate in the food chain, resulting in addition exposure to humans.

- In battery manufacturing and use, ventilation should be appropriate with air filters and scrubbers present to limit air emissions
- Process water should be treated and tested prior to discharge to meet permit and clean water standards. Facility washing, capturing, and treating rainwater limits emissions. Workers in high lead exposure areas must leave work clothes and shoes at the facility and shower and wash their hair before going home
- Packaging wet batteries for air transport must incorporate an acid or alkali-proof liner or packaging of sufficient strength and be adequately sealed to prevent a leaking batter from leaking electrolyte fluid from the packaging

The Mercury-Containing and Rechargeable Battery Act makes it easier to collect and recycle Ni-CD batteries and certain small sealed lead-acid batteries. The Act requires the following:

- Batteries must be easily removable from consumer products
- Battery labels must include the battery chemistry, the recycling symbol, and a phrase indicating that the user must recycle or dispose of the battery properly
- National uniformity in collection, storage, and transportation of certain batteries
- Phase out the use of certain mercury-containing batteries

Spills

- Spills can be both accidental and premeditated, and can be critical in nature
- Lead-acid battery general land disposal is now prohibited
- Personnel may not place a used lead-acid battery in mixed municipal solid waste, landfills, or municipal solid waste incinerators
- Personnel may not dispose of a used lead-acid battery except by delivery to a retailer, wholesaler, or secondary lead smelter, or to a collection or recycling facility authorized under state law or by the Environmental Protection Agency (EPA)
- No retailer shall dispose of a used lead-acid battery except by delivery to the agent of a wholesaler or a secondary lead smelter, or to a battery manufacturer for delivery to a secondary lead smelter, or to a collection or recycling facility authorized under state law or by the EPA

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- Despite being accompanied by appropriate warning labels and instructions, batteries are still mishandled and spills are common
- Improper jumpstarting and/or recharging of batteries can and do result in severe injuries to parties involved
- Hazardous wastes are generated by battery manufacturing operations
- Hazardous chemicals can oftentimes be found in wastewater associated with battery operations manufacturing or otherwise, especially common in collection sites
- There is possible soil contamination at battery sites due to airborne lead dust or runoff
- There is potential for non-compliance with applicable state and federal (e.g., EPA) regulations at battery sites

Recycling

- In the US and in Europe more than 98 percent of lead-based batteries are currently recycled to produce new batteries, placing them among the most recycled products in the world
- The lead-acid battery gains its environmental edge from its closed-loop life cycle
- The typical new lead-acid battery contains 60 to 80 percent recycled lead and plastic
- Lithium-ion batteries can be reprocessed to recover some of the cobalt inside but not at purity levels needed for new batteries
- Batteries are being studied to be taken out of cars when their performance drops after about seven to ten years and repurposed for grid storage at lower efficiency for another seven to ten years

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Questions for risk management to consider

- What types of batteries are being manufactured, transported, utilized, or recycled?
- What types of metals and other materials are being utilized and incorporated? Different types of batteries (e.g., dry, wet) are comprised of different metals with different levels of risk. For example, lithium metal and lithium-ion batteries provide more energy and have the potential to generate a significant amount of heat and catch fire if damaged, improperly packaged, or not carefully designed. Wet batteries (e.g., lead-acid or lead-alkali batteries) contain electrolyte acid or alkaline corrosive battery fluid, which can burn. Alkaline, nickel metal hydride, nickel cadmium, and carbon zinc batteries have different chemistries and varying hazardous components, including mercury

- How are raw materials being stored? Storage and use of bulk metal ores carries risk of metal explosions and fires that could damage a facility and affect neighboring communities. Fires and explosions may also release toxic metal fumes into the air which could require evacuating people near the facility
- Are products manufactured to standard specifications? Products that are not manufactured to specifications may be defective, increasing the possibility of third-party claims
- If batteries and subassemblies are being imported, is there documentation that they have properly gone through US customs?
- Many imported products are not manufactured in strict adherence with known national standards and/or could be defective. Foreign manufacturers of batteries, chargers, and battery packs are extremely difficult to serve notice to
- What QA/QC activities are performed for product manufacturing? Is it performed in house or by a third party? If foreign, what is the name of the QA/QC entity, and have they provided their professional coverage?
- Is there adherence to the Hazardous Materials Regulations (HMR; 49 CFR parts 100-185) requirements for packaging, hazard communication (e.g., package marking, labeling, shipping papers), and handling?
- For international shipping, is there adherence to International Civil Aviation Organization (ICAO) shipping requirements?

  Shipping batteries requires precautions and adherence to regulations to avoid fires, injuries, or other incidents during transport

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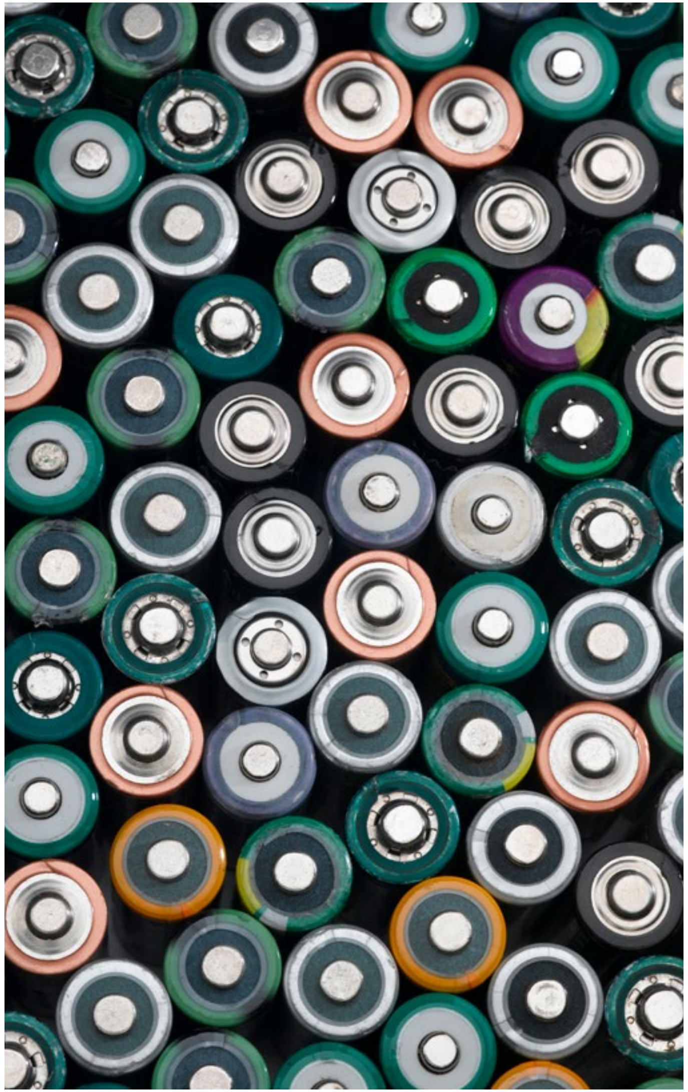
- During transport, are batteries individually packaged or separated to prevent damage and short-circuiting?
- For air transport, is there confirmation that medium and large lithium batteries meant for international air transport meet the following:
  - The batteries/cells have passed the tests found in the United Nations (UN) Manual of Tests and Criteria prior to offering medium and large lithium batteries for air transportation
  - Batteries are marked and labeled in accordance with the Hazardous Materials Regulations (HMR) as Class 9 hazmat
  - The batteries are accompanied by hazardous materials shipping documents and labeling prepared in accordance with the HMR describing the batteries
- If air transportation is necessary especially in international cases, is the appropriate documentation and requirements for lithium battery transportation testing, as detailed in the UN Manual of Tests and Criteria, Sub-section 38.3 (UN 38.3, UN International Air Transport Association [IATA]), US Department of Transportation (DOT) being followed?
- Are rechargeable batteries being sold?
- Are used batteries being sold?
- Are any repaired or altered batteries being sold?
- Is there an applicable UL standard involved with the battery or battery charger under consideration? Is the product UL listed and/or UL certified?
- Is there compliance with the Mercury-Containing and Rechargeable Battery Act, making it easier to collect and recycle Ni-CD batteries and certain small sealed lead-acid batteries?



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- Are batteries being recycled, or are damaged or defective batteries being accepted? How are returns and transport safely managed?
- Damaged or defective lithium batteries, including those being returned to the manufacturer as part of a safety recall, are forbidden for transportation by aircraft as they have the potential of producing heat, fire, or short circuit. How is the transport handled?
- Is there compliance with environmental regulations? Are permit discharge limits being met?
- Are batteries being sold to manufacturers of end products? Product liability risk increases if product labels do not adequately warn consumers. Many batteries are purchased for use in consumer products, and contracts with the makers of devices should document battery specifications to reduce incompatibility errors
- Is the worker health and safety program current and in compliance with applicable guidance and regulations? The risk of worker action over claims increases if an employer does not provide proper workplace controls and personal protective equipment (PPE)
- The Occupational Safety and Health Administration (OSHA) developed occupational exposure limits or guidelines for lead, cadmium, nickel, and other components of batteries. Are these limits being enforced and how?
- Are safety data sheets (SDS) being supplied with products? If so, are they also available in Spanish, the language of the market being serviced, and/or in any primary language of any worker?

The CPSC further recommends the following:

- Components and battery-powered products comply with applicable voluntary standards
- New components and products that are not yet subject to voluntary standards be designed considering the best practices from similar voluntary standards
- Battery-powered products be designed with a system approach addressing thermal protection, charge and discharge protection, and use in product, including:
  - Having cells tested and found suitable for intended loads and conditions and manufactured with good quality control
  - Having battery packs with proper battery management systems, including charge control, short-circuit protection, and cell balancing incorporated
  - Having chargers that comply with applicable voluntary standards and are suitable for the product
  - Having end-product systems (including cells, batteries, chargers, and product) tested together for safe function and appropriate conditions

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