Guideline for Lithium Battery Safety in Research Applications

1. PURPOSE

Lithium batteries have become the industry standard for rechargeable storage devices. They are common to university operations and used in many research applications. This guideline is intended to provide UBC staff and researchers studying or using lithium-metal, lithium-ion (Li-ion), lithium polymer (LiPo) cells and battery packs information on how to safely handle them under normal and emergency conditions.

The guideline is directed to batteries industrially manufactured. The use of batteries and/or charging devices manufactured or modified in UBC research labs require site-specific risk assessments in order to identify the hazards and controls necessary. Please contact Safety & Risk Services to request an assessment.

Lithium battery fires and accidents are on the rise and present risks that can be mitigated if the technology is well understood. Most incidents are caused by batteries left on chargers for extended times, unattended charging, incompatible chargers, low quality batteries, shorts from improperly wired or isolated connections and damaged batteries. Accidents can happen during the entire life cycle of a battery: storage, use, and/or disposal. This guideline provides information to help prevent fire, injury and loss of intellectual and other property.

2. Battery Types

Batteries transform chemical energy to electrical energy. Lithium batteries have higher energy densities (up to 100 times higher) than legacy batteries (e.g. alkaline batteries). Lithium batteries are grouped into two general categories: primary and secondary batteries.

- **Primary (non-rechargeable) lithium batteries** (also known as lithium metal batteries) are comprised of single-use cells containing metallic lithium anodes. Non-rechargeable batteries are referred to throughout the industry as "Lithium" batteries. Primary lithium batteries contain hazardous materials such as lithium metal (an air sensitive and water reactive material), organic solvents, and potentially explosive components (e.g. lithium perchlorate electrolyte), which can lead to exothermic activity and runaway reactions above a defined temperature. The handling recommendations, in an emergency situation, for these batteries are different from Li-ion/LiPo.

Primary Li batteries (non-rechargeable)

- **Secondary (rechargeable) lithium batteries** are comprised of rechargeable cells containing an intercalated lithium compound for the anode and cathode. Rechargeable lithium batteries are commonly referred to as lithium-ion (Li-ion) batteries and lithium polymer (LiPo) cells. Li-ion batteries are used in battery packs for portable laptops, power tools and many other devices requiring electrical power. LiPo are commonly seen in applications like RC vehicles where their relatively light weight and high current draw, are an advantage. Li-ion/LiPo batteries have emerged in recent years as the most popular secondary batteries due to advantages that include light weight, higher energy density, low memory effect and longer life span. Since both battery types have similar chemistries they require similar care in charging and handling to avoid unsafe situations.

Secondary lithium batteries (rechargeable)

3. HAZARDS

3.1 Fire

Lithium metal – non-rechargeable lithium batteries contain lithium metal which is a water and air sensitive chemical. The reaction of lithium with water generates hydrogen gas which then ignites because of the heat of reaction. Exposed to air, lithium will catch on fire. The most likely cause of water or air exposure of lithium metal in the primary batteries is the loss of battery integrity (punctures, crushing, etc.).

Short-circuit of the cell – leads to fires and happens if lithium metal batteries (non-rechargeable) are operated as rechargeable batteries.

Thermal effects/exothermic activity – high energy primary lithium batteries based on thionyl chloride can experience self-heating starting what is known as a thermal runaway. Thermal runaway begins when the heat generated within a battery exceeds the amount of heat that is dissipated to its surroundings. This process can lead to the battery reigniting a long time after the fire is initially put out.

For secondary batteries there are several factors that can lead to thermal runaway:

- Internal or external short circuit (deformed battery that loses internal integrity)
- Overcharging the battery
- Excessive currents when charging or discharging the battery, e.g. when rapid charging

3.2 Explosion

Lithium perchlorate containing batteries (primary batteries) can cause fire and explosion if the perchlorate reacts with the with organic solvents also present in the batteries. The reaction is more likely to happen if the battery is exposed to high temperatures or the battery is subjected to higher than designed current loads.

3.3 Fumes or leaks of toxic substances

Fumes from burning secondary batteries could contain CO_2, CO, NO, NO_2, HCl, HCN, hydrocarbons and HF. These fumes can cause a series of health symptoms potentially even death. Skin contact with leaked electrolytes can cause irritation and/or burns.

3.4 Electrical current

Damaged high-voltage electrical systems can energize other components of an electric vehicle, posing a risk of electric shock, or even electrocution, and electrical burns.

Li-ion batteries assembled to offer higher voltages (over 60 V) may present electrical shock and arc hazards. Therefore, adherence to applicable electrical protection standards (terminal protection, shielding, PPE etc.) is required to avoid exposure to electrical hazards.

4. CONTROLS

4.1 Elimination or substitution

The most effective way to manage the risk associated with compromised lithium batteries is to eliminate the source of exposure. Does the hazardous item have to be stored onsite?

4.2 Engineering controls

Making physical modifications to facilities, equipment, and processes can reduce exposure.

Since fire is one of the main hazards associated with lithium batteries, installing physical barriers that can stop the spread of the fire is an engineering control that can be considered. Work with electrical vehicles and/or batteries in areas separated by wire walls and doors and away from combustible materials.

Install fire detection and prevention equipment in areas where work is lithium batteries is done and/or batteries are stored.

Local exhaust ventilation is recommended in order to reduce the impact of exposure to fumes or leaks of toxic substances.

4.3 Administrative controls

These involve changing work practices and work policies, providing awareness tools and training.

Training – students and staff working with lithium batteries must receive general chemical safety training. In addition, they must be familiar with this guideline and all documentation applicable to the project they are working on (see below for examples of documentation). Additional training might be necessary depending on the risk of the various projects (e.g. fire extinguisher training, battery manufacturer specific training).

Shippers, importers as well as individual transporting them over public roads must meet the requirements set out in the Transport of Dangerous Goods (TDG) regulations for the handling, offering for transport, transporting and importing of lithium batteries in Canada. TDG training is required.

Documentation – obtain and review the battery manufacturer's Safety Data Sheet (SDS), Technical Specification sheet(s), recalls/safety alerts and/or other documents available.

- Perform hazard analysis to understand the various failure modes and hazards associated with the proposed configuration and type(s) and number of batteries used
- Develop safe work procedures (SWP) for specific devices using lithium batteries and associated tasks with them. Include methods to safely mitigate possible battery failures that can occur

during: assembly, deployment, data acquisition, transportation, storage, and disassembly/disposal.

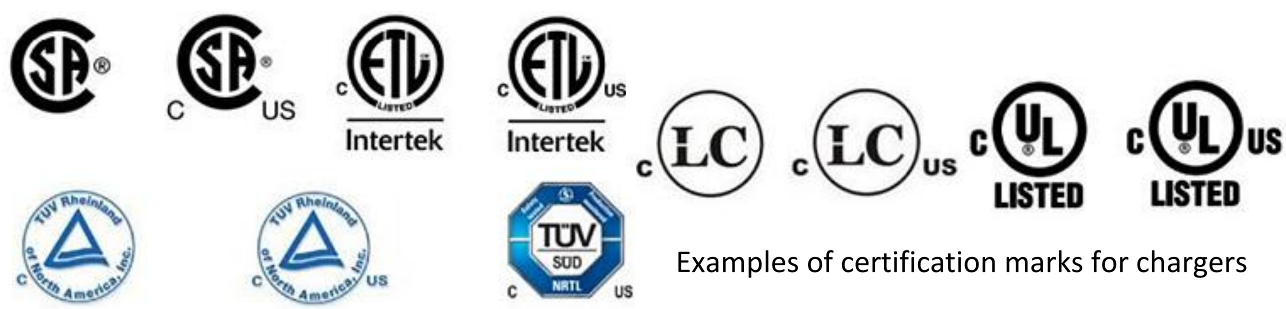
- TDG documentation and specialized packaging could be necessary for the shipping and receiving of lithium batteries. The requirements vary by mode of transport. TDG regulations for lithium containing batteries are based on their watt-hour (Wh) rating or amount of energy.

Certification

Batteries: in Canada, lithium batteries must meet specific certification requirements, primarily related to safety and transport, to ensure they can be shipped and imported legally.

- **UN 38.3** certification (for transport) is a standard outlined in the UN Manual of Tests and Criteria and ensures lithium-ion batteries are safe for transport by addressing potential hazards like fires.
- **UL 1642** standard (for safety and performance) is developed by Underwriters Laboratories and provides a framework for evaluating the safety and performance of lithium-ion batteries.

Chargers: must have Canadian certification marks such as: CSA, cUL, cETL. Chargers without these marks do not meet electrical safety standards and may cause electric shock and fires.



Examples of certification marks for chargers

Warning signs – apply signage in areas where multiple lithium batteries and or equipment containing lithium batteries are stored.

4.4 Personal protective equipment (PPE)

This is the least effective control. When used, there must always be at least one other control in place as well.

Full face respirators fitted with appropriate cartridges (depending on the battery type) should be available for emergency situations. Respirators must be fit tested for each individual potential user and testing is valid for one year. See the SRS webpage for more information on respiratory safety.

Eye protection and protective clothing are additional PPE items to be considered when working with lithium batteries. Based on the risk analysis the appropriate protective clothing could be a lab coat, overalls or even fire-retardant clothing.

5. BEST PRACTICES

5.1 Procurement

- Always purchase batteries from a reputable manufacturer or supplier. Cheap or counterfeit batteries do not undergo the same quality control processes and have a higher likelihood of failing.

The purchased batteries must have the UN 38.3 certification and ideally the UL 1642 certification as well (see "certification" section above).

- When purchasing, make sure batteries are shipped in protective packaging (i.e., hard plastic or equivalent).
- Inspect batteries upon receipt; **do not use** any batteries that show signs of damage from transport. Safely dispose of or return damaged batteries. Depending on damage, this could require specialized packaging (see 5.3 below).
- When purchasing charging cables or charging stations avoid buying "compatible with" products. Buy accessories directly from the battery supplier or products recommended by the battery supplier. Chargers must have Canadian certification marks (see "certification" section above).

5.2 Transporting, Shipping and Importing Batteries

- Take precautions to avoid dropping or crushing batteries during transport. When you need to transport a battery, protect the battery terminals and uninsulated connections from contact with other objects, use the original packaging or a suitable plastic container.
- Transport Canada regulates the safe handling, offering for transport, transporting and importing of primary and secondary lithium batteries by specifying classification, documentation, labelling, packaging and training requirements. All designs and types of lithium batteries must meet the requirements of the UN Manual of Tests and Criteria to be shipped or imported safely. Shippers and importers must meet the requirements set out in the Transport of Dangerous Goods (TDG) regulations for the handling, offering for transport, transporting and importing of lithium batteries in Canada. The requirements vary by mode of transport. TDG regulations for Lithium containing batteries are based on their watt-hour (Wh) rating or amount of energy.

WARNING: Failure to comply with regulations for shipping hazardous materials can result in significant civil penalties for the shipper.

5.3 Damaged batteries

- Damaged, defective or recalled batteries (DDR) are batteries that may be swollen, corroded, leaking, or showing burn marks and need to be shipped in special containers. Temporally store DDR batteries in non-flammable material such as sand and contact customerservice@call2recycle.ca to request a DDR container.

Containers for DDR batteries

5.4 Battery use

- Inspect batteries for signs of damage before use. Never use and promptly dispose of damaged or puffy/bulged batteries. Damaged lithium containing batteries are considered hazardous waste.
- Handle batteries and or battery-powered devices cautiously to not damage the battery casing or connections. Keep the work area free from any sharp objects that may puncture the insulating sleeve on cells.

- Keep batteries away from contacting conductive materials, water, seawater, strong oxidizers and strong acids. Make sure the working surface is made of a material that is not conductive and/or combustible. If you are working on a conductive material cover the surface with an insulating material.
- Avoid excessively hot and humid conditions, especially when batteries are fully charged. Ambient temperature should not exceed 60°C. Best working temperatures are between 15°C and 35°C. Do not place batteries in direct sunlight, on hot surfaces or in hot locations.
- Keep all flammable materials away from operating area**.**

5.5 Charging/Discharging

- Batteries must only be charged with a charger or charging method designed to safely charge cells or battery packs at the specified parameters. Be absolutely sure that the charger settings are correct for the battery pack being charged – both voltage and current settings.
- Plug chargers directly into the wall outlet – do not use extension cords.
- Never charge a primary (disposable lithium or alkaline) battery; store one-time use batteries separately. Do not mix different battery types or mix new and old together in a power pack.
- While charging, the charger and the battery should be put on a heat-resistant, nonflammable and nonconductive surface. Never leave a battery pack unobserved during charging. Always stay in or around the charging location so that you can periodically check for any signs of battery or charger distress. Occasionally check on output levels and balancing effectiveness.
- Allow time for cooling before charging a battery that is still warm from usage and using a battery that is still warm from charging.
- Disconnect batteries immediately if, during operation or charging, they emit an unusual smell, develop heat, change shape/geometry, or behave abnormally. Dispose of them as hazardous waste.

5.6 Storage of cells/battery/packs

- Every time a battery is not used actively (e.g. for more than 3 days), it should be placed in the storage area to avoid being damaged and becoming unsafe. Cell terminals must be protected by electrical insulating material.
- When not using your LiPo/Li-ion battery pack, store it at 50-70% of the pack's rated capacity. Li-ion/LiPo cells should never be stored fully charged. Many chargers have a "storage mode" that will either charge or discharge the cell to the proper storage voltage. Also, putting the cells in storage mode after every run, will help the battery to lengthen the usable life span.
- A Lithium battery fireproof safety bag or other fireproof container is recommended when storing batteries. Always follow manufacturer recommendations on fireproof bags for details on how to correctly use them. Whenever possible buy fire proof bags sold by or recommended by the battery supplier.

5.7 Storage area

- It is best to have a reserved area ONLY for Li-ion and Li-metal battery storage. Store batteries in a cool, dry and well-ventilated place at room temperature or lower. While batteries can be used safely between -20 and 60 °C (-4 to 140 °F), it is strongly suggested to avoid storing them at a temperature that is close to the upper or lower range.
- Avoid storing batteries in a refrigerator as this may create internal condensation when the battery is brought to room temperature, and they may become dangerous when operated.
- The storage area should be maintained free from any materials which can catch fire such as wood tables, carpet, or flammables (e.g. gasoline containers, propane tanks). The ideal surface for storing Li-ion batteries is concrete, metal, or ceramic or any non-flammable material.
- Batteries can be stored in a metal cabinet such as a chemical-storage cabinet but make sure that batteries are not touching each other.
- The storage area should have the engineering controls mentioned in section 4.2.
- ABC, CO_2, class D and/or lithium-specific fire extinguishers must be present in the area (depending on the type of batteries stored).
- Emergency supplies (see section below) must be present in the storage area.

5.8 Waste management

- Intact, undamaged batteries should be recycled. Do not put batteries in the trash. Do not store or reuse old, damaged, swelled or unwanted batteries. If they have not been used or charged within the past year they should be taken for recycling. BEFORE recycling prepare the battery:
    - **Tape the terminals**: Use electrical tape to cover the positive and negative terminals to prevent short circuits.
    - **Package securely**: Keep the battery in its original packaging or use a separate plastic bag to further isolate it secure it from movement.
    - **Do not mix with other batteries**: Separate lithium-ion batteries from other types to prevent potential hazards.
- Damaged Li-ion/LiPo batteries are considered to be hazardous waste and must be immediately disposed of.
    - **Package the battery in a non-flammable material, such as sand, as soon as possible**: This helps to absorb any potential electrolyte leakage and reduce the risk of fire.
    - **Do not place these batteries in the trash or in a regular recycling container**: They may present a safety hazard, such as a spark or fire, during transport or processing.
    - **Contact Call2Recycle or your local municipality for specific instructions on how to handle damaged batteries**: They can provide guidance on proper packaging and disposal methods.

6 EMERGENCY PROCEDURES

Each area where lithium batteries are used must have an emergency isolation container and a pail of sand. Emergency isolation containers safely hold depleted or damaged batteries that pose a potential fire risk and the sand is used as a smothering agent. Examples of emergency isolation containers include, ammunition boxes, ceramic pots or a cinderblock placed with the cavities facing up. An infrared thermometer should be kept on hand and used to monitor battery temperatures.

In an emergency situation if no PPE and/or emergency equipment is available, evacuate the area and call 911 and UBC Campus Security at 604-822-2222.

6.1 Swollen, Damaged, Overheating, Venting and Leaking Batteries

- If batteries show evidence of thermal runaway failure, be very cautious because the gases may be flammable and toxic and failure modes can be hazardous.
- While wearing gloves, goggles/safety glasses and lab coat (if available) disconnect the battery (if possible). Wear a respirator if there is evidence of gases evolving from the battery.
- Place the battery in an isolation container away from combustibles. Do not approach the cell until it reaches room temperature. The cell temperature can be checked using a remote device (i.e. infrared thermometer). If a remote device is not available, do not handle the cell for a period of at least 24 hours. Do not submerse actively overheating lithium batteries in water, since hazardous gases/vapors can be created.
- If leaking material is present, do not touch it. Evacuate all personnel from the area. The area should be secured to ensure that no unnecessary personnel enter. Call 911 immediately.

6.2 First Aid Procedures in Case of Contact with Electrolyte

- EYES – Use an emergency eye wash station to flush eyes with a for at least 15 minutes while forcibly holding eyelids apart to ensure complete irrigation of all eye and lid tissue. Call UBC First Aid (604-822-2222).
- SKIN – Remove contaminated clothing. Flush skin with cool water (using a shower if necessary). Continue to flush for at least 15 minutes. Call UBC First Aid (604-822-2222).
- INHALATION – Move to fresh air. Monitor airway breathing: if breathing is difficult call 911.

6.3 Exploded Cell, Lithium-metal or Lithium-ion Battery Fires

- If a cell has exploded, evacuate all personnel from the area. Secure the area to ensure that no unauthorized personnel enter. Activate the nearest fire alarm pull station and call 911 immediately. If a ventilation system is in place and it is safe, initiate ventilation and continue until the cell is removed from the area and the pungent odor is no longer detectable.
- Only personnel trained in fire extinguisher use should attempt to extinguish early stage (incipient) fires and only if it is possible to do so safely.
    - For fires involving primary cells (Lithium-metal batteries) only use a Class D fire extinguisher, as lithium-metal batteries contain large amounts of lithium which will react violently with water.
    - For secondary cells (rechargeable LiPo/Li-ion) batteries if battery begins to vent, the vapors are hazardous and flammable and may quite easily catch fire. If the gas release and fire is aggressive, do not attempt to put the fire out. Evacuate all personnel from the area, activate the nearest fire alarm pull station and call 911 immediately. Only personnel trained in fire

extinguisher use may attempt to extinguish early stage (incipient) fires using a Class ABC fire extinguisher and only if it is possible to do so safely. If the use of a portable fire extinguisher has little effect on extinguishing the fire, exit immediately. Do not initiate a second attempt. Li-ion/LiPo batteries do not have actual lithium metal so do not use a Class D fire extinguisher.

7 ADDITIONAL INFORMATION/RESOURCES

- Li-ion/LiPo SDS: Batteries_LithiumIon_SDS_for.gov.bc.ca
- Battery Safety Canada: www.canada.ca/en/health-canada/battery-safety
- Transport Canada: tc.canada.ca/en/lithium-batteries
- TDG Canada: shipping-importing-devices-containing-lithium-batteries
- Recalls and safety alerts (Government of Canada) recalls-rappels.canada.ca/en
- IOSH-The safety and challenges of Lithium-ion batteries: youtube.com/Li-Ion
- Li-Ion in research: MIT/lab-research-program/lithium-ion-battery-safety/
  - MIT/Lithium_Battery_Checklist.pdf
  - MIT/Lithium_Ion_Battery_Dos_and_Donts.pdf