Michigan Technological University
Environmental Health and Safety
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Lithium Battery
Workplace Safety Guidelines

Revision Log

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Michigan Technological University
Environmental Health and Safety

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Purpose

Michigan Technological University (Michigan Tech) is committed to the health and safety of the entire campus community. These guidelines apply to all **Lithium Battery** users on the Michigan Tech campus and other university owned properties, for the safe use and handling of these types of batteries under normal and emergency conditions.

This document is intended to summarize Michigan Technological University's safety policies for **Lithium-ion (Li-ion)** and **Lithium-ion polymer,** usually referred to as **Lithium polymer, (LiPo) cells** and **battery packs** for the administration, faculty, staff, students, visitors, and external contractors that work or live on campus and satellite properties. **Lithium metal** batteries are not covered by this document.

In alignment with the University's mission, Michigan Tech supports the safe use of **Lithium batteries** for educational and research activities. **Lithium-ion** batteries must be used, stored, and disposed of with caution, due to the potential for fire, explosion, personal injury and property damage. Over the past few years, there have been serious incidents on campus involving **Lithium-ion batteries**, including batteries left on chargers for extended periods, unattended and incompatible chargers, modified charging stations, shorts due to improper wiring or isolated connections, punctures or damage to cells, and batteries manufactured to specifications that do not meet UL or equivalent Nationally Recognized Testing Laboratory (NRTL) certification.

When designed, manufactured, and used properly, **Lithium-ion batteries** are a safe, high energy density power source. The batteries may generate heat, catch fire, or even explode if they contain design defects, are made of low-quality materials, are assembled incorrectly, are used or recharged improperly, or are damaged during transport or handling.

Users should contact their departmental safety officer or Environmental Health and Safety if they have questions **BEFORE** using Li-Ion batteries.

Scope

This program applies to all campus and university owned properties and associated events where **Lithium-ion batteries** are used, handled, charged, maintained, stored, or collected for disposal.

While these guidelines apply to all uses of **Lithium-ion batteries** they focus on Li-Ion batteries, and equipment using Li-ion batteries for research and education purposes. Also see the section "Work Practices for Using Lithium Ion Batteries" when using large numbers of Li-ion batteries or when using batteries supplying large amounts of current.

Research projects developing, modifying or intentionally damaging cells, batteries, Battery Management Systems, or equipment using Li-Ion batteries must have written Hazard Assessments and Standard Operating Procedures related to the specific activities that are planning on conducting.

Responsibilities

Principal Investigator (PI), Faculty, Staff, or students using Li-Ion batteries will:

- Implement all applicable provisions of these guidelines.
- Read and follow the battery's and equipment's manufacture instructions for proper charging, storage, use, and disposal.
- Obtain and review the battery manufacturer's Safety Data Sheet (SDS), Technical Specification sheet(s) and/or other documents available.
- Ensure that any associated Safety Data Sheets (SDSs) are in the University electronic SDS Database,
- Perform job hazard analysis (JHA) or similar Hazard Assessment to understand the various failure modes and hazards associated with the proposed configuration and type(s) and number of batteries used.
- Ensure that written standard operating procedures (SOPs) for **Li-ion** and **LiPo** powered devices are developed and include methods to safely mitigate possible battery failures that can occur during assembly, charging, deployment, data acquisition, transportation, storage, and disassembly/disposal.
- Not charge research devices or standalone **Lithium-ion** batteries or battery packs if it is unattended in a vacant room. Exceptions can be granted after discussion and agreement with the VPR's Research Integrity or Environmental Health and Safety.
- Ensure that at the conclusion of operations the battery assemblies are disposed of properly or left in a safe condition for storage.
- Contact Environmental Health and Safety prior to shipping **Lithium-ion batteries** or **equipment containing Lithium-ion batteries.**.

Environment, Health, & Safety (EHS) will:

- Maintain this Guidance.
- Assist in training and communicating safety requirements to university personnel.
- Assist in development and review of JHAs and other Hazard Assessments.
- Identify and oversee maintenance of appropriate portable fire extinguishers.
- Provide guidance on hazardous waste management of damaged or leaking batteries. Batteries that have reached the "end of life" or are no longer in service can be disposed of through the Facilities Battery Recycling program.
- Review and approve shipments of **Lithium-ion batteries**.
- Assist in the investigation of incidents involving **Li-ion/LiPo batteries**.

Background - Introduction to Li-ion and LiPo batteries

Definitions of terms used here can be found in **Appendix A** at the end of this document.

Primary vs. secondary batteries

Batteries transform chemical energy into electrical energy. Primary batteries, such as alkaline batteries are not generally rechargeable after exhausting their chemical energy.

Primary **Lithium batteries** contain lithium metal, a water reactive material; the emergency handling recommendations for Lithium metal batteries are different than for Li-ion/LiPo secondary batteries.

Secondary batteries can be recharged, with chemical reactions that are reversible by supplying electrical energy to the cell (i.e. “charging” the battery). Secondary batteries age during each cycle so they are not indefinitely rechargeable.

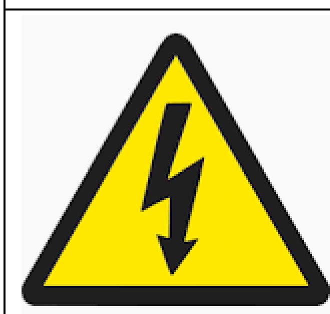
Advantages of Lithium-Ion (Li-Ion) and Lithium Polymer (LiPo) batteries

Before the introduction of Li-ion batteries, lead acid, nickel-cadmium and nickel-metal-hydride were the most common types of secondary batteries. 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 a longer life span. They provide a compact and powerful energy source for research projects and Remote Controlled (RC) vehicles requiring electrical energy.

With this technology, lithium-ions are stored in the anode (negative electrode composed of metal oxides), and transported during the discharge to the cathode (positive electrode, composed of graphite) in a flammable organic electrolyte. There are two distinct styles of rechargeable lithium batteries in use. Li-ion batteries are used in battery packs for portable laptops, power tools and many other devices requiring electrical power. LiPo batteries are commonly seen in applications such as remote and autonomous controlled vehicles where their relatively light weight and high current draw are an advantage.

Both battery types have similar chemistries, as well as similar charging, handling, and safety considerations.

Hazards of Li-ion and LiPo batteries

	**Lithium** (atomic element number 3) is an alkaline metal that reacts with water. To prevent reaction with moisture in ambient air, it must be encased in a compatible substance such as oil. Lithium is flammable and can spontaneously ignite, however, Lithium compounds contained in Li-Ion batteries are different from pure lithium metal and tend to be more stable.
	Most incidents with **lithium batteries** happen when the battery's shell is damaged and the lithium is exposed to air/moisture. Lithium compounds contained in Li-Ion batteries tend to be more stable, though they can still be corrosive, irritating or toxic, depending on the exact chemistry of the battery.
	Short circuits and electrical shock can cause injury, blindness, and death, and permanently damage equipment. They can cause excess heat, fire, and arcing – where energy 'jumps' through the air to a nearby conductive material. This is especially dangerous with batteries that supply continuous strong current.

Hazards - continued

Physical Damage

Damage to **lithium-ion batteries** can occur immediately or over a period of time, from physical impact, exposure to extreme temperatures, and/or improper charging:

- **Physical impacts**:
  Physical damage due to dropping, knocking, crushing, excessive vibration, or puncturing the battery.
- **Temperature:**

  Exposure to temperature outside their charging or operational limits. See the manufacturer's specifications, but in general:

  Exposure to temperature above 100°F/38°C can accelerate failure in cells with defects or damage from other causes.

  Exposure to temperatures., below (32 °F /0°C during charging can lead to permanent metallic lithium buildup on the anode, increasing the risk for failure.
- **Improper Charging:**

  Charging a device or battery without following the manufacturer's instructions may cause damage to rechargeable Li-ion batteries

  Most Battery Management Systems embedded in manufacturer-authorized chargers will cycle the power to the battery on and off during, and especially at the end of the cycle, to avoid overcharging.

  Ultra-fast chargers may not cycle power – thus causing overcharging. Do not use them unless the manufacturer has specified that these types of chargers are compatible with your battery.

  Never charge or use a battery that is bulging, hissing, leaking, or feels hot to the touch.

Short Circuits

Electrical current takes the path of least resistance, When that path is through a short-circuit instead of the load, the battery can inadvertently and unexpectedly deliver a high, unrestricted current flow in a short period of time.

Short circuits can cause serious burns and other injuries, blindness, and death to the user, as well as permanently damaging equipment. Short circuits can cause excess heat, fire, and arcing. This is especially dangerous with batteries that supply large amounts of continuous current.

Never touch both battery terminals with your bare hands at the same time. Don't wear rings, watches, or jewelry made of conductive materials (e.g., silver, gold, copper, or steel). Only use non-conductive tools to remove terminal or cell caps.

Thermal Runaway

Thermal Runaway is when the heat and pressure inside of a battery cell rise faster than can be dissipated and can cause fires and the release of toxic fumes. The increased heat in the battery may destabilize the active materials, starting a self-sustaining exothermic reaction, i.e., the release of additional heat.

External heat sources, internal shorts, or other malfunctions can disintegrate cells and destroy a battery pack over several hours or within seconds. Some packs are fitted with dividers to protect against this chain reaction.

Increasing pressure or heat can cause uncontrolled chemical and combustion reactions between the electrolyte solution and electrodes, which can lead cell walls to expand and byproducts to leak out. Chemical byproducts frequently include combustible or flammable substances, which is why it is important to understand the chemistry of your battery.

Soldering

DO NOT solder directly to batteries.

DO NOT solder near batteries.

Heat generated from the soldering iron can destabilize and damage the battery, causing it to bulge, hiss, leak, catch fire, and even explode.

Any soldering must be done to a separate terminal connector, not to the battery itself. Be sure to store the battery safely away from the soldering area.

Work Practices for Using Lithium Ion Batteries

The following sections outline best work practices when using large numbers of Li-ion batteries or when using batteries supplying large amounts of current.

Before Starting Work

- Be familiar with general University emergency procedures.
- Review manufacturer's Safety Data Sheet.
- Ensure that a written SOP is available for the experiment that includes all safety information;
- Make sure your Li-ion batteries, chargers, and associated equipment have been tested in accordance with an appropriate test standard (e.g., UL 2054), certified by a Nationally Recognized Testing Laboratory (NRTL), and rated for their intended uses.
- Inspect your battery for signs of damage prior to each use: bulging, hissing, leaking, or smoking. Do not use your battery if it displays any of these characteristics.
- If applicable, understand one-handed working techniques.
- Remove watches, metal rings, and other metal jewelry when working with or near large batteries or power supplies. If the metal from your jewelry comes into contact with a terminal, you become part of the circuit. Effects can vary from a small electric shock to burns or even electrocution, depending on the power of the battery.
- If you are designing wearables using **Lithium-ion batteries**, make sure they are easily removable if they start to react while being worn.
- Identify the location of the nearest eyewash and shower and verify that they are accessible.
- Locate and verify that appropriate fire response and spill cleanup materials are available,
- When determined by the written hazard assessment, ensure a second person who knows emergency procedures is in the area.

Best Practices for Lithium-ion Cell/Battery Use

- Always purchase batteries from a reputable manufacturer or supplier. Cheap/counterfeit batteries may not have the same quality control processes, increasing the failure potential.
- Be sure to read all documentation supplied with your battery.
- Never burn, overheat, disassemble, short-circuit, solder, puncture, crush or otherwise mutilate battery packs or cells*
- Do not put batteries in contact with conductive materials, water, seawater, strong oxidizers and strong acids.
- Avoid excessively hot and humid conditions, especially when batteries are fully charged. Do not place batteries in direct sunlight, on hot surfaces or in hot locations.

- Always inspect batteries for any signs of damage before use. Promptly dispose of damaged or puffy batteries.

- **Lithium-ion batteries** assembled to offer higher voltages (over 60V) may present electrical shock and arc-flash hazards. Any activities using battery voltages exceeding 60V must follow the University's Electrical Safety rules and regulations.*

- Do not reverse the polarity.

- Do not mix different types of batteries or mix new and old ones together (e.g. in a power pack).

- Do not open the battery system or modules*

- Do not use the unit without, or otherwise modify, its Battery Management System*.

- Immediately disconnect the batteries if, during operation or charging, they emit an unusual smell, develop heat, change shape/geometry, or behave abnormally.

- Exercise caution with new products where all safety considerations may not be recognized or that may encourage cheap knock-offs built without adherence to safety standards.

*Research projects developing, modifying or intentionally damaging cells, batteries, Battery Management Systems, or equipment using Li-Ion batteries must have approved written Hazard Assessments and Standard Operating Procedures related to the specific activities that are being conducted.

Battery Charging/Discharging

The Li-ion battery packs found in portable laptops, cell phones, wearables and similar devices usually, if from a reputable manufacturer, require no user input for charging other than connecting it to a manufactures approved charging cable/device. They contain a Battery Management System (BMS) in the battery pack that controls the charging process. Those charging these batteries still need to follow all manufacturer recommendations and be alert for anomalies like unusually hot batteries.

The majority of rechargeable **Li-ion/LiPo** batteries used for research and instructional activities require supervision during charging and discharging activities. Over-charging can lead to runaway thermal reactions due to the high energy densities and flammable organic electrolytes contained within a given Li-ion/LiPo battery. Li-ion/LiPo battery users should incorporate the following recommendations when charging/discharging these types of batteries:

- Use chargers or charging methods approved by the manufacture of the battery or device.

- 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.

- Disconnect batteries immediately if, during operation or charging, they emit an unusual smell, develop heat, change shape/geometry, or behave abnormally.

- For series packs (2S and above), always balance charge with a charger capable of monitoring the condition of individual cells to prevent individual cells being overcharged.
- The charger and the battery should be located on a heat-resistant, non-flammable, and nonconductive surface.
- It is best practice to charge and store **Lithium Polymer** batteries in a fire-retardant container like a high quality LiPo Sack.
- Keep all flammable materials away from the charging area.
- Do not overcharge (greater than 4.2V for most cells) or over-discharge (below 3V).
- Make sure that batteries do not exceed manufacturers recommended operating temperatures during charging or discharging. Use caution if charging a battery that is still warm from usage, or using a battery that is still warm from charging.
- Never parallel charge since chargers cannot monitor the current of individual cells.
- Do not leave batteries connected to chargers after charging is complete.

Note that some larger batteries have on-board BMS that will automatically partially discharge a battery after a specified amount of time.

Working Area (General Requirements)

A safe working environment for **Lithium batteries** should be well-ventilated, dry, and free from extreme temperatures, direct sunlight, and flammable materials. In addition:

- Make sure the working surface is made of a material that is not conductive and noncombustible. If you are working on a conductive material, cover the surface with an insulating material.
- The area should be clear of any flammable or combustible materials such as wood tables, carpet and gasoline or other solvent.
- Keep the area free from any sharp objects that may puncture the insulating sleeve on cells.
- Ambient temperature should not exceed 60°C. Best working temperatures are between 15°C and 35°C (59-95F).

Shipping or Transporting

Transporting **Lithium-Ion Batteries** or equipment containing **Lithium-Ion Batteries** is considered "**Dangerous Goods**" because they can pose significant safety risks during transportation. **Do not** ship **Lithium-Ion Batteries** or equipment containing **Lithium-Ion Batteries** without approval from Environmental Health and Safety.

Shippers shall ensure batteries are properly packed, prepared, and communicated to the air carrier to ensure shipments arrive safely. When shipping a Li-ion battery, specific regulations must be followed.

Domestic transportation is regulated by the U.S. Department of Transportation (DOT). Internationally, air transportation is regulated by the International Air Transport Association (IATA). Maritime transport is controlled by the International Maritime Organization (IMO) whose regulations are contained in the International Maritime Dangerous Goods (IMDG) Code.

All packages containing Li-ion batteries MUST be packed under the supervision of someone with documented training for the transportation authority listed above.

WARNING: Failure to comply with regulations for shipping hazardous materials can result in significant civil penalties for the shipper of up to $100,000 per violation.

A major risk of shipping **lithium batteries** is short-circuiting of a battery or inadvertent activation while in transport. All batteries should be packed to eliminate the possibility of a short-circuit or activation.

To help prepare shipments (NOTE do NOT seal boxes until they've been inspected by someone with documented shipping training):

- Ensure batteries cannot come into contact with other batteries, conductive surfaces or metal objects while in transport.
- Pack cells and batteries in fully enclosed inner packaging made of nonconductive material (e.g., plastic bags)
- Ensure exposed terminals or connectors are protected with non-conductive caps or tape or by other similar means.
- Secure batteries by packing them to prevent shifting during transport or loosening of terminal caps.
- Do not use envelopes or other soft-sided packs.

Transporting **Lithium-ion batteries** for teaching or research projects between buildings or on campus property are not subject to official shipping regulations. However, the following safety guidance should be followed for transporting:

- Do not transport batteries in a metal box.
- Do not carry batteries in your pocket. Coins, keys or other metallic objects can cause batteries to short circuit.
- Keep away from heat, transport in a container or padded bag to prevent shock if dropped or impacted.
- Do not transport a fully charged battery. The recommended State of Charge (SoC) is 30% or less. Note: this does not refer to your smart devices, computers or **lithium ion batteries** contained in equipment with an approved battery management system.

- Cover terminals to prevent contact being exposed to short circuiting.
- If contained in equipment, make sure the power is isolated from electronic devices, or disconnect the battery.

Storage

Proper **Lithium-ion battery** storage is critical for maintaining an optimum battery performance and reducing the risk of fire and/or explosion. Many incidents causing **Lithium-ion battery** fires have been connected to inappropriate storage areas or conditions. While Lithium-ion spontaneous fires are rare, they need just an internal short circuit to start a series of reactions that may lead to a fire. Other factors that pose a higher risk of fire in a storage area are: the type of cell design, chemistry, temperature, state-of-charge, and length of storage period.

The following guidelines will reduce the risk of fire and/or explosion of stored batteries.
Management of Cells, Batteries, and Battery Packs:

- Remove the **Lithium-ion battery** from a device before storing it.
- 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.
- When not using your LiPo/Li-ion battery pack, store it at 60-70% of the pack's rated capacity. **Lithium-ion cells** should never be stored fully charged, it is suggested to store them with a voltage around 3.8V. Most of the chargers have a "storage mode" that will either charge or discharge the cell to the proper storage voltage. Experts recommend to put the cells in storage mode after every run, this will help the battery to lengthen the usable life span.
- It is a good practice to use a **Lithium-ion battery** fireproof safety bag or other fireproof container when storing batteries. Always follow manufacturer recommendations on fireproof bags for details on how to correctly use them. Only use fireproof bags that have been certified by UL, FM or other approved National Recognized Testing Laboratory.
- Cell terminals must be protected by an appropriate electrical insulating material.

Management of the Storage Area:

- Store batteries in a dry and well-ventilated place at room temperature; avoid storing in refrigerators, in garages, or other spaces where temperatures are above or below "room temperature".
- It is best to have a reserved area ONLY for **lithium-ion battery** storage. It has to be a cool and dry place, away from heat sources.
- The area should be maintained free from any materials which can catch fire such as wood tables, carpet, or gasoline containers. The ideal surface for storing **lithium-ion batteries** is concrete, metal, or ceramic or any non-flammable material.
- Batteries can be stored in a metal cabinet. Battery terminals MUST be covered. Ensure stored

batteries are not touching each other.

- It is recommended that the storage area have fire detection sensors and be protected by sprinklers.
- Never leave batteries unsecured where they can be damaged by someone.
- An appropriate fire extinguisher for **Li-Ion** fires must be located near the storage area.

Disposal of cells and batteries

It is illegal and unsafe to place Li-Ion batteries in the University's general waste stream, including building trash receptacles or trash dumpsters.

Do not mix **Lithium-ion batteries** with other types of batteries, such as alkaline, cadmium or other rechargeable spent batteries.

Submit a Facilities Management Work Order for intact, non-leaking, non-bulging Li-Ion batteries.

Contact Environmental Health and Safety for disposal of damaged batteries that are leaking, bulging, or have previously caught fire.

Emergency Procedures and Equipment

Portable Fire Extinguishers

An appropriate fire extinguisher for **Lithium-Ion Battery** fires must be located near the storage area. Selecting the "appropriate" extinguisher depends on the number, size and current capacity of the batteries.

At a minimum, an ABC fire extinguisher needs to be immediately available. However, since thermal runaway events can be difficult to control for areas with multiple batteries or for larger batteries an extinguisher with encapsulating technology may be more appropriate.

The National Fire Protection Association standard NFPA 18A recommends fire extinguishers that employ encapsulation technology. Encapsulation reduces the risk of re-ignition, provides burn-back resistance, and can be effective in extinguishing fires that are difficult for plain water to extinguish, such as Class D and lithium-ion battery fires.

Note that Environmental Health and Safety oversees the purchasing and management of all fire extinguishers on campus.

Emergency Scenarios

All batteries should be handled with caution, but **Li-ion/LiPo** batteries pose additional safety risks due to their high energy density and flammable electrolyte. When these batteries are poorly manufactured, overcharged or over discharged, incorrectly handled and/or connected, or exposed to excessive mechanical and physical stress, conditions may arise and lead to thermal runaway that in turn may lead to the venting, leaking, explosion and/or fire of the battery cell or pack.The following hazards should be addressed in written hazard assessments and Standard Operating Procedures.

If the situation is an emergency, it involves a fire, injury, or possible potential for property damage, immediately call 911 for assistance.

If not an emergency contact Environmental Health and Safety for technical advice and assistance.

Damaged Batteries

Battery damage may not always be visible. Events that may damage a Li-ion battery include a fall of 12 inch or greater; crash with a speed of 20mph; puncture by a sharp object; expansion due to overheating. Use of a damaged battery may lead to thermal runaway and subsequent fire.

Procedure:

Prior to following the steps below, contact your supervisor, lab manager, or departmental safety officer. If these individuals are not available, contact Environmental Health and Safety.

1. After the impact/accident, if the battery is not hot and/or leaking or smoking, disconnect

the battery.

2. Remove the battery from the equipment wearing gloves, goggles/safety glasses and lab coat.

3. To discharge the battery, ensure it is in a well-ventilated area and place the battery in a metal or hard plastic bucket.

    a. Fill the bucket with a 3% salt water solution.

    b. After 2 days in the salt water bath, call EHS for disposal.

    c. Check the voltage across the terminals to ensure it has reached 0 V.

4. Alternatively, to discharge the battery use a resistor with resistance greater than 10 times the rated internal resistance of the battery.

5. Keep in mind that there may be no visible damage, a delayed fire can occur hours or days after the impact/accident. It is safest to discharge the battery immediately.

Overheating, Venting and Leaking Cells

When a cell's internal temperature and pressure rise faster than the rate at which they can be dissipated, cell overheating will occur. This may be caused by electrical shorting, rapid discharge, overcharging, manufacturer defects, poor design, or mechanical damage, among many other causes. In series or parallel connected strings of batteries, high connection resistance from a poor electrical connection can lead to overheating. The overheating of a given cell may produce enough heat to cause adjacent cells to overheat in response. If the cell does not return to room temperature it may vent and catch fire, or explode. Sounds like "clicks" and "puffs" may indicate a preliminary vent release. Depending on the cell type and manufacturer, the critical temperature ranges around 120-300 °C (250-570 °F) (see manufacturer manual for details on the battery you are using).

Follow this emergency procedure if you have overheating, venting or leaking cells:

1. If the battery is showing indications of thermal runaway **call 911** for assistance.

2. If you notice hot cells, **and it is safe to do so**, disconnect the charger and remove any external short circuit if present.

3. If a cell is venting or smoking, evacuate all personnel from the area. The area should be secured to ensure that no unnecessary persons enter.

4. If leaking material is present, do not touch it.

5. Do not approach the cell until it reaches room temperature. The cell temperature can be checked using a remote device (i.e. infrared thermometer).

6. If a remote device is not available, do not handle the cell for a period of at least 24 hours.

7. Contact EHS for assistance in removal of the damaged battery cell as hazardous waste.

Exploded Cell

Similar to a vented cell, an exploded cell is the result of an overheated or mechanically damaged cell. After the explosion of a **Lithium-ion battery**, the room could fill quickly with dense white smoke that could cause severe irritation to the respiratory tract, eyes and skin. All precautions must be taken to limit exposure to these fumes.

Procedure:

1. If the battery has exploded **call 911** for assistance

2. Evacuate all personnel from the area. The area should be secured to ensure that no unnecessary personnel enter.

3. If a ventilation system is in place and it is safe to, turn it on, initiate ventilation and continue until the cell is removed from the area and the pungent odor is no longer detectable.

4. Contact Environmental Health and Safety for assistance in removal of the damaged battery cell as hazardous waste.

Lithium-ion Battery Fires

Li-ion fires may occur as a result of thermal runaway, shorting and other conditions that result in increased temperatures. Once the battery begins to vent flammable vapors, it may quite easily catch fire. Michigan Tech personnel are not required to fight fires. Trained fire extinguisher users should attempt to extinguish early stage (incipient) fires only if it is possible to do so safely. Portable fire extinguishers that can be used include Encapsulating Agent, ABC (dry powder) and carbon dioxide (CO2). Smothering the fire with sand or sodium bicarbonate may also be effective. After extinguishing the fire, water should be used to prevent the affected battery from reigniting and adjacent batteries from overheating.

Procedure for a Small-Scale Fire:

A typical example is a small wastebasket fire.

1. Evacuate all personnel from the area.

2. Activate the nearest fire alarm pull station or **call 911**.

3. If you are trained in fire extinguishers and knowledgeable of the type of battery in use, take the closest Encapsulating, CO2 or ABC extinguisher.

4. Make sure you are positioned between the fire and the nearest exit before attempting to extinguish the fire.

5. If the use of a portable fire extinguisher has little effect on extinguishing the fire, exit

immediately. Do not initiate a second attempt.

6. If you are able to put out the flames, pour water over the battery to cool it down if this will not create an electrical hazard. You might need 1 to 5 or more liters of water depending on the size of the battery in use.

7. By-products of combustion may be toxic when inhaled. In the event of heavy smoke, exit the area immediately. Ensure others have left the area and close doors behind you as you leave.

8. Environmental Health and Safety will need to assess the situation for cleanup and waste management after the situation is under control.

Procedure for a Large-Scale Fire:

For "larger" fires that have been active for a time, and/or those involving furnishings, interior finishes, and structural building components.

1. Evacuate the area immediately.

2. Activate the nearest fire alarm pull station or **call 911**.

3. **Do Not** attempt to extinguish the fire by using a portable fire extinguisher.

4. Plan to be available for emergency personnel to provide information. This may include the size, location, and nature of the fire, as well as identifying any hazardous materials, especially in the event of a laboratory fire.

5. Detailed information on fighting a **lithium-ion battery** fire can be found in Guide 147 (Lithium-ion Batteries) of the US DOT Emergency Response Guide.

6. Environmental Health and Safety and Facilities Management will assess the situation for cleanup and waste management after the scene is cleared by Emergency personnel.

Personal Exposure Guidelines

Follow these steps for people exposed to Li-Ion batteries that have leaked, exploded, or caught on fire:

Skin Contact

1. Wash with plenty of tepid water for at least 15 minutes using the closest available sink, safety shower, or drench hose. Remove any exposed clothing as well as any jewelry.
2. Seek medical attention by **Dialing 911**.

Eye Contact

1. Using eyewash, flush eyes while holding eyelids open.
   Seek medical attention immediately by **Dialing 911**.

Inhalation

1. If safe to do so and the person is able to walk, move them to fresh air
2. Seek medical attention immediately by **Dialing 911**.

Ingestion

1. Never give anything by mouth to an unconscious person.
2. Seek medical attention immediately by **Dialing 911**.

Incident reporting

Report all incidents and near-misses involving **Lithium-ion batteries**.

A "Near-Miss" is an unplanned event, condition, or behavior that did not result in injury but had the potential to do so. Near Misses can be reported through the EHS Page.

All work-related illnesses and injuries must be reported to EHS immediately (within 24 hours).

If in doubt about whether or not to report an incident or near-miss, it is better to err on the side of caution and report the event.

Training Requirements

Safety Skills: Haz Com, Li Battery, Portable Fire Exting.
UL Training for Research?

emergency response?

For this lets consider a tiered training approach…

1. Level 1 (Awareness)
2. Level 2 (Handling/Assembly)
3. Level 3 (Testing/Abuse/Synthesis/Recycling)

Hand on Competency assessment for critical tasks (glove box use, electrolyte handing, cell assembly/modification)

Authorization by the Lab Manager/PI before working….

References and Additional Resources

Regulatory references and additional reading

Add all listed

Appendix A Definitions

Anode: the negative electrode typically made with a graphite active material coated onto a metal (usually copper) foil current collector.

Cathode: the positive electrode typically made with a metal oxide (LiMO2, where M= Ni, Mn, or Al) or a phosphor-olivine (i.e., LiFePO4) coated onto a metal (usually aluminum) foil current collector.

Electrolyte: lithium salt (i.e., typically $LiPF_6$) in a mixture of flammable organic carbonate solvents.

Battery Management System (BMS): Battery management systems are critical to the safe operation of lithium-ion battery packs. The system protects against: over-charge, over discharge, and excessive currents and temperatures. The BMS protects the pack from exceeding upper and lower voltage and temperature limits. It will also limit current as a function of temperature. BMS systems can have multiple configurations depending on the application.

Battery Pack: An assembly of cells that are connected in series and/or parallel. Each battery pack contains only one type of cell. Connecting cells in parallel increase the pack capacity (ampere hour, Ah) and in series the pack voltage.

Cell: A single battery (Understanding Battery Specifications).

Lithium-Ion: A lithium-ion battery is a type of rechargeable battery in which lithium-ions move from the negative electrode to the positive electrode during discharge and back when charging.

Lithium-ion Polymer cells: Same chemistry as lithium-ion cells but the electrolyte is made as a gel with a polymer host which reduces flammability and prevents leakage of liquid electrolyte from a damaged cell.

Pouch cell: The case of the battery is a polymer-aluminum laminate, similar to the material used for potato-chip bags, allowing for light and slender designs.

Primary (non-rechargeable) lithium metal cells: These cells have lithium metal anodes paired with a variety of cathode materials and corresponding nominal voltages. Depending on the chemistry and application cells may be available in button and cylindrical form factors. These cells are not rechargeable.

Secondary (rechargeable) lithium (lithium-ion) cells: These cells are rechargeable. Depending on the quality, design, and operating window these cells typically can be cycled from hundreds to thousands of cycles. The long cycle life is made possible because the lithium is not present in metallic form. Lithium is intercalated into the electrode active materials and moves from the anode to the cathode during discharge and from the cathode to the anode when charging in ionic form. Lithium-ion cells are generally available in cylindrical, prismatic, and pouch form factors.