Maui Wildfires 2023
Lithium-Ion Battery Standard Operating Procedures
August 24, 2023

1. OBJECTIVE

The handling of damaged lithium-ion batteries presents significant hazards to fire response personnel. This standard operating procedure (SOP) is established as a set of general guidelines for Lithium-Ion batteries and proper handling to protect all fire response personnel. The purpose of this procedure is to outline the minimum requirements for safe handling and use of fire damaged lithium-ion batteries. This SOP, is geared towards the following categories of lithium-ion batteries: Battery Energy Storage Systems (BESS), electrical vehicles (EVs), micro mobility devices (e-bikes and scooters), and small batteries (vape pens, computers, cell phones, etc.)

2. HAZARDS

Burned, or partially damaged lithium-ion batteries are susceptible to thermal runaway. This is a chemical reaction that produces self-sustaining high temperatures that can result in explosion, fire, and the release of toxic and flammable vapors. The vapor cloud includes more than combustion products and can include the following toxic vapors:

- Hydrogen (30%-50%)
- Carbon Monoxide
- Hydrogen Fluoride
- Hydrogen Chloride
- Hydrogen Cyanide
- Phosphoryl Fluoride
- Organic Solvent Droplets
- Ethane, methane, and other hydrocarbons

Figure 1: diagram depicting a cascading thermal runaway event

Burned or damaged batteries are unpredictable and cannot be considered discharged or free of hazards. Reignition is common and can occur for 30-90 days from an initial thermal runaway event. Additionally, extreme temperatures and mechanical damage (such as puncturing or jostling during transport) can also trigger thermal runaway events.

*****NOTE: When a lithium-ion battery is about to undergo thermal runaway, the following may be observed: Bulging, cracking, hissing, popping sounds, leaking, rising temperature, and white smoke. This process occurs in 3-5 seconds.**

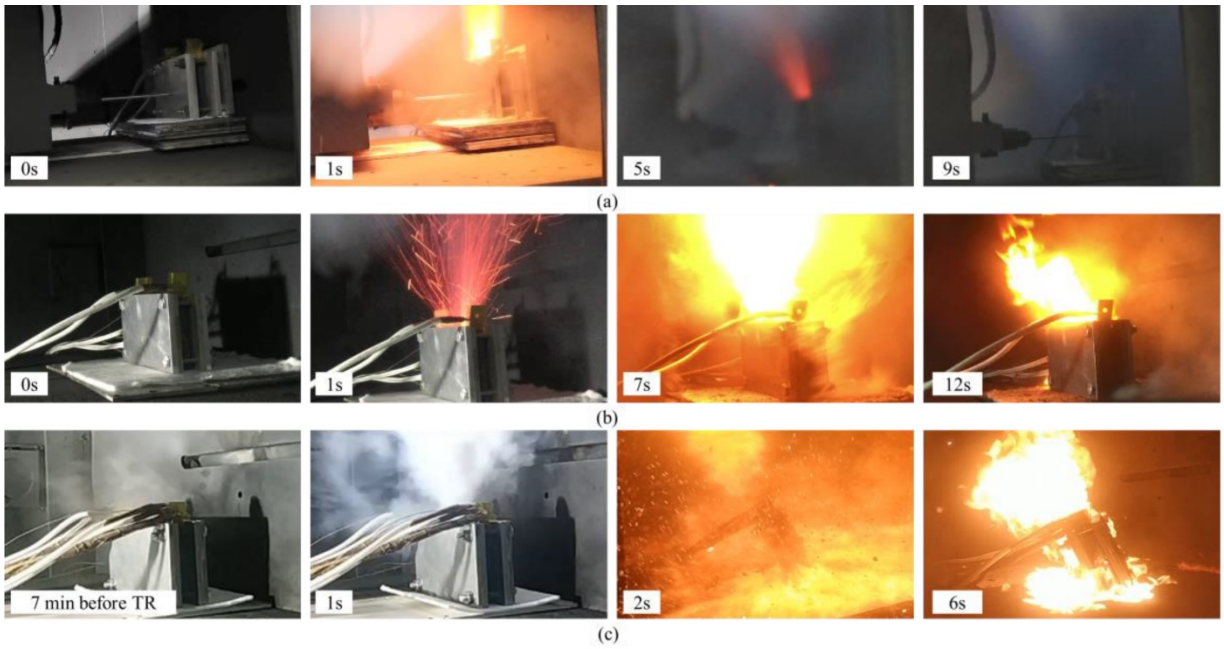

Figure 2: Thermal Runaway behavior under different mechanical/chemical damage

EMERGENCY PROCEDURES: If any of these observations occur or if there is a suspected lithium-ion fire event, stop work, and evacuate all personnel at least 330 feet in all directions (per NFPA ERG guidelines). Do not attempt to extinguish the fire. Water and other smothering agents will not stop the oxidizing chemical reaction. Once in a safe location, contact the local fire department and then incident command.

3. LITHIUM-ION BATTERY HANDLING AND TRANSPORT

If an HHW collection team encounters damaged lithium-ion batteries, by no means shall anyone touch or disturb the item. Lithium-Ion batteries should be marked with red paint and noted in Survey123 as a return visit required by the Battery Task Force.

3.1 LITHIUM-ION BATTERY IDENTIFICATION

Lithium metal batteries are primarily made up of a lithium metal strip, rolled up as an anode. Lithium-Ion Batteries that will be encountered include:

1. Cylindrical Cells (18650 or 2170): The most common battery in micro mobility devices (scooters, e-bikes, etc.). Electrical vehicles commonly use thousands (5,000 plus) of cylindrical cells in a series.
2. Prismatic cells: Rectangular in shape and larger than the cylindrical cell. These can be found in some hybrid vehicles and hold more charge than a cylindrical cell.
3. Pouch Cells: Common in computers and cell phones.

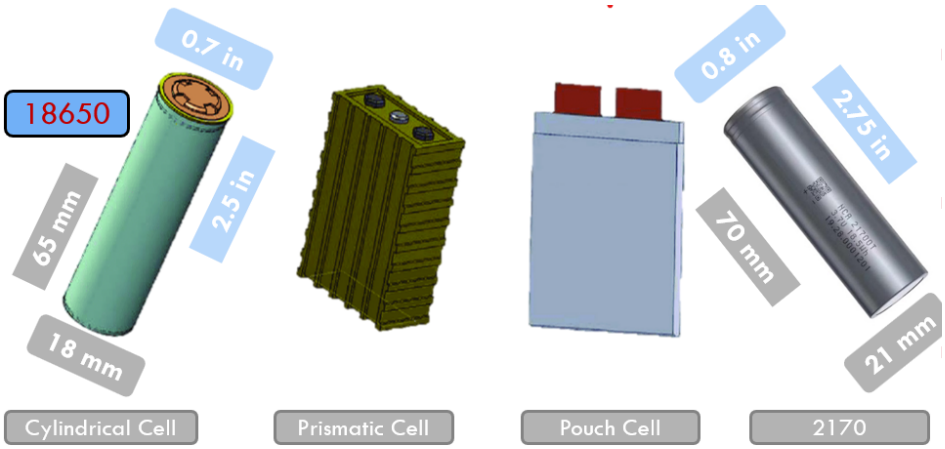

Figure 3: Depiction of lithium-Ion battery types

All these variations of batteries come with Pros and Cons from more or less stable, more or less compartmentalization, more or less resistant to physical damages. However, they all behave very similarly during an emergency.

Figure 4: (Left) Lithium-Ion battery cell depicting lithium metal strip rolled up; (Right top) Burned 18650 cells; (right bottom) Fire-damaged pouch-cell batteries

Figure 5: Wildfire damaged Tesla powerwalls

3.2 BATTERY TASK FORCE

A Battery Task Force will be stood up specifically to handle lithium-ion batteries. This task force will be trained on how to safely identify and handle lithium-ion batteries and will conduct all lithium-ion battery collection. The task force will consist of ERRS and START personnel as well as an electrician. Once field team identify lithium-ion batteries on a parcel, the Battery Task Force will deploy.

1. The electrician will ensure that batteries are disconnected from a power source before any work is conducted. A multimeter/voltohmmeter tool will be utilized to assess for charge in the field before handling or transporting batteries.
2. Once batteries are disconnected from power source, ERRS crew will load batteries into the flat bed or dump truck. **Do not puncture, break, tear, or force open any lithium-ion batteries or battery packs. Doing so can initiate a thermal runaway scenario.**
    - Batteries should be handled with the proper PPE according to the site HASP.
    - Batteries should only be handled when they are cool, use thermal imaging to determine batteries battery temperature before handling.

3.2.1 Loading and Transport to Staging Area

Batteries need to be packaged properly for transport to the staging area and handled with care to prevent mechanical damage (such as puncturing or jostling during transport) that would lead to thermal runaway. The following should be considered to help prevent a cascading thermal runaway event during transport to the staging area:

- Small lithium-ion batteries should be transported in a drum packed with cell block to prevent a cascading thermal runaway in transport to the staging area.
- Larger batteries, such as power walls, should be loaded directly into a dump truck and covered with a fire blanket to help contain a thermal runaway event during transport. **Larger batteries should not be stacked or torn apart during handling or loading. To**

the extent practicable, as few large batteries should be loaded into one truck for transport as possible and priority should be placed on transporting items to the battery staging area before picking up additional loads.

- The Battery Task Force will transport only lithium-ion batteries to the staging area and should not simultaneously transport any other HHW such as flammable compressed gas cylinders.

Figure 5: Small lithium-ion batteries can be transported according to DOT Special Permit-16532 in a regular drum with cell block.

4. LITHIUM-ION BATTERY STAGING AND TREATMENT

4.1 STAGING AREA REQUIREMENTS

Damaged lithium-ion batteries should be staged a safe distance (minimum 330 feet according to evacuation requirements) from other hazardous materials and/or the general public. Ideally, a separate lithium-ion battery staging area will be identified to allow sufficient operating distance to prevent propagation during a cascading thermal runaway and release of toxic vapors. It is suggested that the appropriate Fire Department tour the staging area and provide input on the storage locations of damaged lithium-ion batteries.

The following should be taken into consideration when choosing an appropriate staging area:

- Safe ingress/egress for workers and emergency services should be implemented so in the event an of an emergency workers can evacuate quickly, and firefighting resources will have the space they need to respond.
- Distances from residents, businesses, and vegetation.
- Work should be conducted in a well-ventilated area, preferably outside.
- A staging area should allow ample space to separate batteries from each other to prevent propagation during an emergency. Separate large lithium-ion batteries from each other and from other battery types.
- Security guard should be posted during off hours to prevent access to the site and raise the alarm in case of emergency.
- Monitor battery temperature. It is theorized that 60°C is the critical temperature, above which Li-ion batteries are prone to failure. UAS thermal imaging should be considered.

- Conduct perimeter air monitoring using particulate and 5 gas meters (X-Sites, MultiRaes, AreaReas, DustTrak).
- Conduct worker air monitoring using 5 gas (MultiRae, X-Site) and toxic vapor meters (SPM Flex with acid gas tape).

4.2 BATTERY DE-ENERGIZING OPERATIONS

Once batteries are brought to the staging area, they should be immediately de-energized or brined by submerging them in a saltwater solution of 0.5%. Brining can occur in small drums or in larger containers (pictured below). The process should last approximately three days. De-energized batteries that are cool to the touch should be tested at least 24 hours after treatment to ensure full discharge and should contain zero volts, or as close as possible before being shredded or packaged for transport and disposal/recycling.

Additionally, de-energizing batteries can release toxic vapors such as HF, CO, CL_2, and HCl. Appropriate health and safety procedures according to the site HASP should be implemented during these operations, including donning appropriate PPE. Brine solution should be analyzed for TCLP RCRA metals prior to disposal.

Figure 6: (Left) Small scale brining operations; (Center/Right) large scale brining operations

4.3 BATTERY SHREDDING

If end-point recycling facilities are not an option or batteries are unable to be transported even once they are de-energized, battery shredding should be considered. Batteries must be completely discharged, and the batteries must be shred to 0.5" or smaller pieces.

Battery shredding operations will greatly increase the risk of thermal runaway, explosion, and release of toxic vapors. As such, appropriate health and safety procedures according to the site HASP should be implemented during these operations, including donning appropriate PPE, conducting air and temperature monitoring, and having clear emergency procedures.

5. LITHIUM-ION BATTERY PACKAGING FOR T&D

Once batteries are de-energized, they can be packaged and transported to end point recycling facilities according to DOT Special Permits 16532 and 21329, and transporters specifications. These permits require a submittal for approval and can take 7-90 days to be approved. Permits can be issued to individual companies, or they can be issued to a specific site. Shredded batteries present non-hazardous waste and do not require these special permits for transportation.