Lithium-ion (Li-Ion) Battery Safety

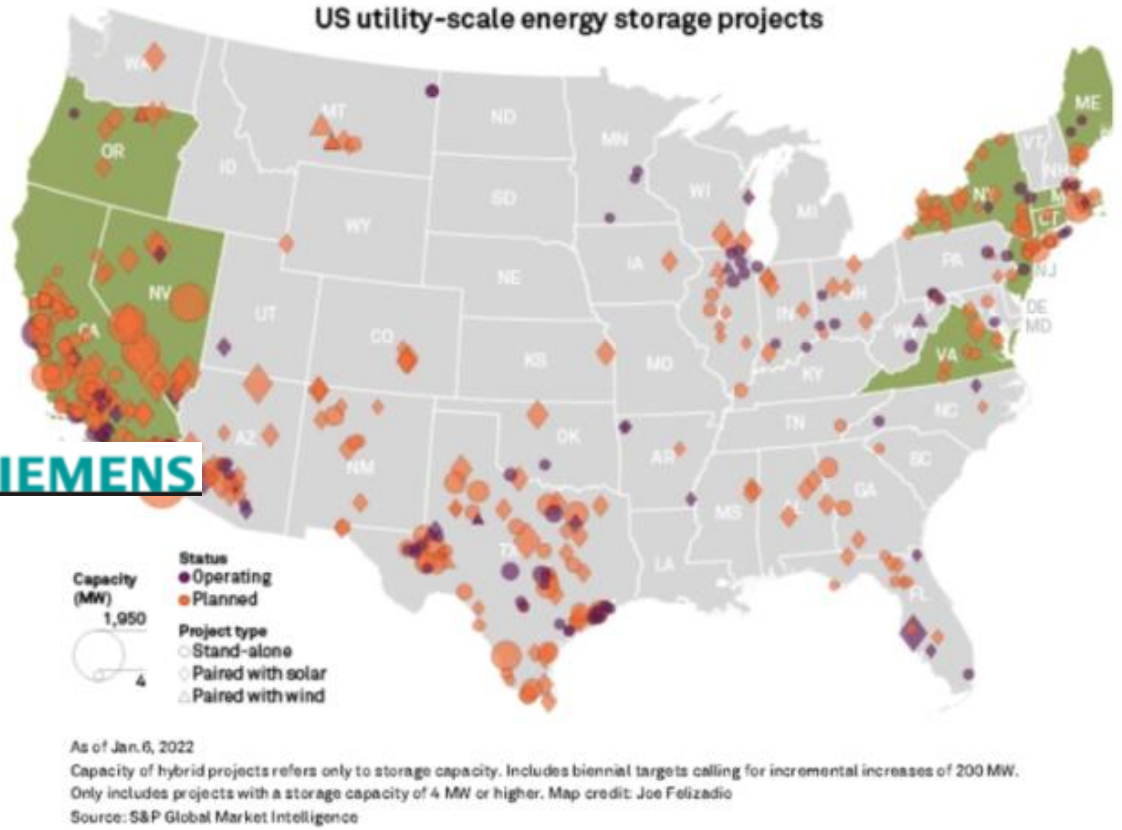
Agenda

- Overview/Scope
- Hazards
- Codes and Standards
- Storage
- Charging
- Emergency Procedures
- Training
- SARA 312 Reporting

Scope

Where Can We find Lithium-ion Batteries?

- Vaping devices
- Personal electronics
- Cell phones
- Tablets & laptops
- Tools
- E-bikes
- Scooters
- Solar power backup storage
- Electric Cars
- Electric buses
- Hoverboards



SIEMENS

SIEMENS

Scope

Global market for lithium-ion batteries

$44 Billion in 2021

$193 Billion by 2028

Fire risks from lithium-ion storage

25,000 over heats or fires in five-year period

40 known large-scale fires at lithium-ion battery energy storage systems

www.tuvsud.com/en-us/services/risk-management

ancouver fire officials say fires caused by lithium-ion batteries have increased 500 per cent in the city since 2016.
CTV)

Lithium-Ion Battery Safety- FDNY

Fires caused by lithium-ion batteries have increased dramatically in New York City with deadly consequences. These rechargeable batteries are found in electric bikes and scooters, cars, laptops, tablets, phones and common household devices. Lithium-ion battery fires have caused deaths, serious injuries and devastating damage to property around the city.

Hazards

Lithium-Ion Battery Safety

- Fires caused by lithium-ion batteries have increased dramatically in New York City with deadly consequences. These rechargeable batteries are found in electric bikes and scooters, cars, laptops, tablets, phones and common household devices. Lithium-ion battery fires have caused deaths, serious injuries and devastating damage to property around the city.

How Much Water?

Firefighters needed 40 times the amount of water normally used to contain a fire of a gas-powered vehicle when attempting to extinguish a blaze when a Tesla crashed.

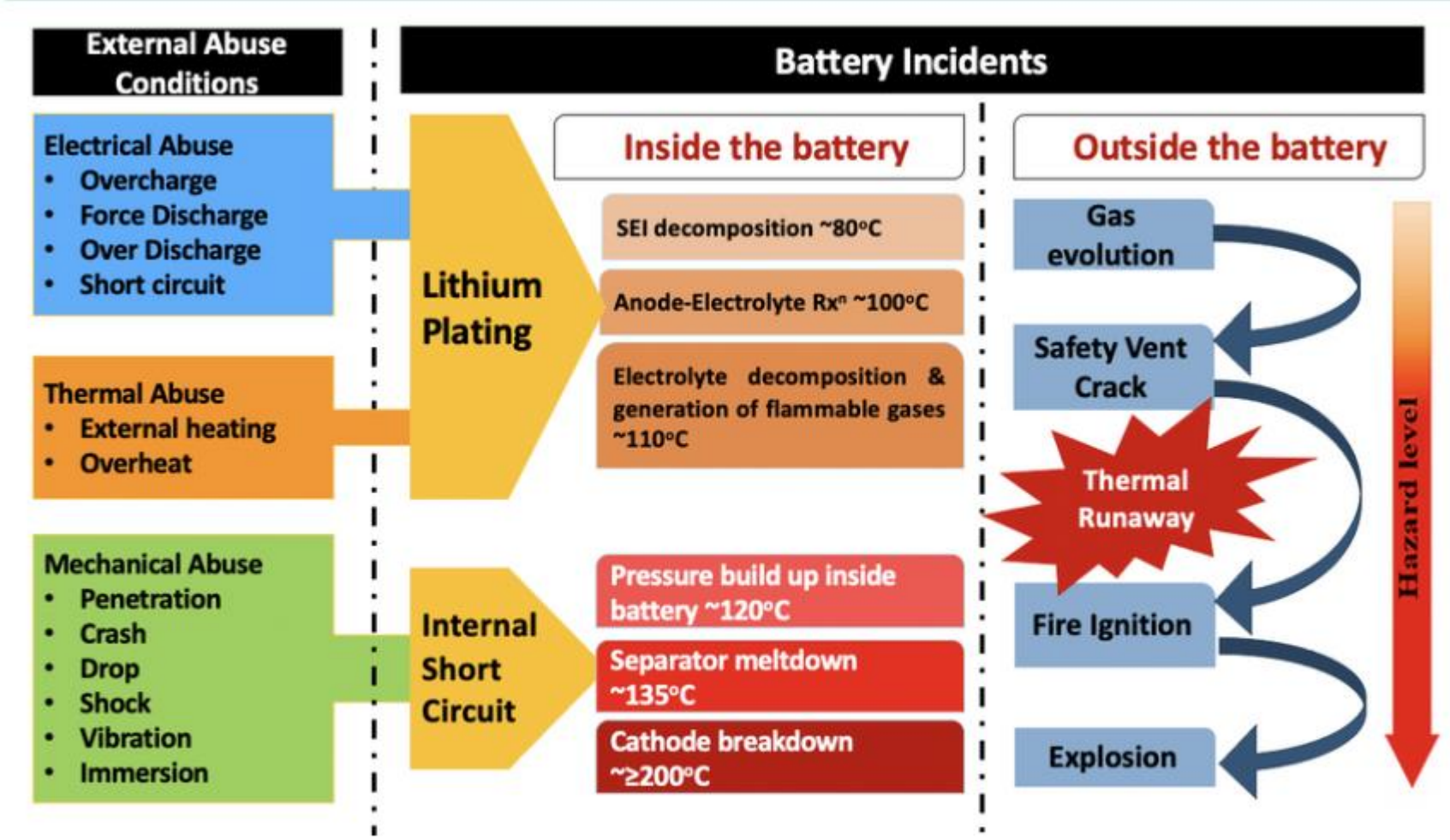
> “Normally a car fire you can put out with 500 to 1,000 gallons of water,” Austin Fire Department Division Chief Thayer Smith said, according The Independent.
>
> “But Teslas may take up to **30,000-40,000 gallons** of water, maybe even more, to extinguish the battery pack once it starts burning and that was the case here.”

Hazards

- Li-ion batteries are known to have issues with overheating and flammability when they become damaged.
- Once they catch fire, they are extremely difficult to put out due to a chemical process called Thermal Runaway.
- A Li-ion battery cell first begins to fail when it is subjected to an abuse factor like heat, improper charging, falling, etc. This can lead to off-gassing and hissing, smoke, and eventually fire.
- Smoke and fire often occur almost simultaneously, so by the time you see smoke, thermal runaway has typically already begun.

So what do these Batteries Look Like?

Damage to Li-Ion Batteries and Hazards



Understanding LIB performance in unsafe conditions is critical.

Photo Credit: Cyngi Energy

Toxic Gasses

Off-gassing usually occurs due to a breakdown of the Li-ion battery cell electrolyte, causing over-pressurization of the battery case. Later, temperature will increase dramatically, smoke is then emitted, and fire breaks out.

The off-gassing is the emissions of **toxic gasses** that are the larger threat. These batteries are known to off-gas Hydrogen Fluoride (HF) and other toxic gases. HF can be inhaled or absorbed through the skin.

When HF comes in contact with water it will create Hydrofluoric Acid. This exposure can lead to very serious illnesses such as damage to lung tissue and other internal organs, skin ulcers, pulmonary edema, irritation to eyes, nose and respiratory tract to name a few.

While the battery was submerged in water, it continued to off-gas, for this reason.

From Wikipedia - **Hydrofluoric acid** is colorless, acidic and highly corrosive. When hydrofluoric acid comes into contact with human skin, it causes deep burns

Applicable Codes / Standards

Applicable Codes / Standards (as of today)

UL 1973, 2596, 9540, 9540(A)

FM Global Standards

49 CFR 173.185

Fire Code Requirements (International Fire Code)

Table 608.1
BATTERY REQUIREMENTS

REQUIREMENT	NONRECOMBINANT BATTERIES		RECOMBINANT BATTERIES	
	Flooded Lead Acid Batteries	Flooded Nickel-Cadmium (Ni-Cd) Batteries	Valve Regulated Lead Acid (VRLA) Batteries	Lithium-Ion Batteries
Safety caps	Venting caps (608.2.1)	Venting caps (608.2.1)	Self-resealing flame-arresting caps (608.2.2)	No caps
Thermal runaway management	Not required	Not required	Required (608.3)	Not required
Spill control	Required (608.5)	Required (608.5)	Not required	Not required
Neutralization	Required (608.5.1)	Required (608.5.1)	Required (608.5.2)	Not required
Ventilation	Required (608.6.1;608.6.2)	Required (608.6.1;608.6.2)	Required (608.6.1;608.6.2)	Not required
Signage	Required (608.7)	Required (608.7)	Required (608.7)	Required (608.7)
Seismic protection	Required (608.8)	Required (608.8)	Required (608.8)	Required (608.8)
Smoke detection	Required (608.9)	Required (608.9)	Required (608.9)	Required (608.9)

www.mysafetysign.com

Storage Overview

Minimize Charge Level

- Less than 50% - no major loss history, 30% or less required for air

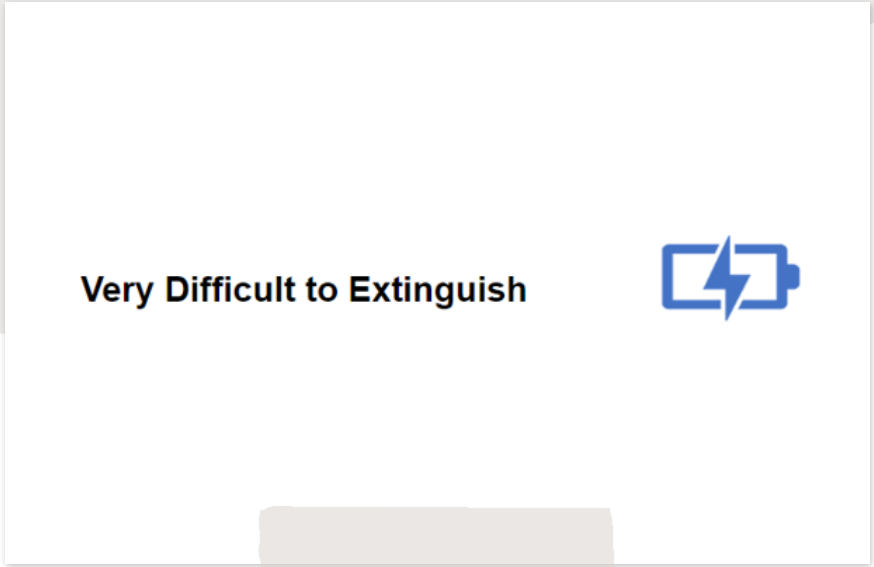
Separate from other Storage

- 2-hour separation for dedicated warehouses
- At least 10ft (3m) to other combustibles
- No storage above Li-ion Batteries

Limit Storage Height

- Max 15ft (4.5m) high storage in a building no more than 40ft (12m) high

Fire/Emergency Response Planning



- Worse with large batteries
- “Positive” feedback loop for breaching additional cells
- Water cannot reach interior battery cells to cool them
- Gas extinguishing can put the fire out initially, but does not cool fire – may reignite
- Foam is somewhat better than gas
- Encapsulation agents show promise (no large-scale tests yet)

Fire/Emergency Response Planning

May Need to Let the Fire "Burn Out"

- Do not shut off protection prematurely – extreme patience is required since the fire can re-ignite.
- Can provisions be made to move burning batteries to an outside safe burn area?

- **Fire is not "out" until all batteries involved in the fire or near the area have been removed from the building.**

Emergency Procedures – Emergency Action Steps

If there is evidence of a battery malfunction (e.g., swelling, heating, or irregular odors). Use personal protective equipment, such as gloves, goggles/safety glasses and lab coat/apron.

- If batteries are showing evidence of thermal runaway failure, be very cautious because the gases may be flammable and toxic and failure modes can be hazardous.
- Disconnect the battery (if possible).
- Remove the battery from the equipment/device (if possible).
- Place the battery in a metal or other container away from combustibles.
- A fire watch should be present until all potentially damaged equipment containing lithium-ion batteries is removed from the area following a fire event. Fires involving lithium-ion batteries are known to reignite. Lithium-ion batteries involved in fires should be adequately cooled in order to prevent reignition.
- Report all thermal runaway events and fires, including those that are small, and self-extinguished or are successfully extinguished.
- Contact the fire department and advise them that an emergency response is not needed and that you are just requesting follow-up.

Emergency Procedures - Medical Emergencies

- If there is an irritation of the respiratory tract, seek immediate medical attention.
- If electrolyte gets onto the skin, wash the area thoroughly with soap and water.
- If it gets into the eyes, rinse at an emergency eyewash station for 15-minutes and seek medical attention.
- In the event the battery leaks and the fluid gets onto your skin or into your eyes do not rub. Rinse well with water and immediately seek medical care.

Facts About Hydrogen Fluoride (Hydrofluoric Acid)

Hydrogen fluoride goes easily and quickly through the skin and into the tissues in the body. There it damages the cells and causes them to not work properly.

- The seriousness of poisoning caused by hydrogen fluoride depends on the amount, route, and length of time of exposure, as well as the age and preexisting medical condition of the person exposed.

Breathing hydrogen fluoride can

- damage lung tissue and cause swelling and fluid accumulation in the lungs (pulmonary edema).

Skin contact with hydrogen fluoride may cause

- severe burns that develop after several hours and form skin ulcers.

Eye exposure to hydrogen fluoride may cause

- prolonged or permanent visual defects, blindness, or a total destruction of the eye.

Swallowing hydrogen fluoride can

- damage the esophagus and stomach. The damage may progress for several weeks, resulting in gradual and lingering narrowing of the esophagus.

Emergency Procedures

Emergency Isolation Container

- Each area where lithium-ion batteries are used must have an emergency isolation container on hand to safely hold depleted or damaged batteries that pose a potential fire risk until they are picked up for disposal.
- You can keep a pail of sand in the area to use as a smothering agent. The container must be placed in an area with as much clearance from combustible materials as possible. The purpose of the container is to contain a battery fire and prevent spread to the building or contents.

Battery Temperature Monitoring

- An infrared thermometer should be kept on hand and used to monitor battery temperatures.
- The ability to monitor the battery temperature from a safe distance is useful for batteries that are suspected to be overheating.

Extinguishing Fires

- **Difficult to Extinguish**
  - Water cannot reach interior cells to cool them
- **Long Lasting Fire**
  - Heat release is spread out
  - Each cell wall failure releases more flammable electrolyte
  - Difficult for air to get to the seat of fire
  - “Puffs” throughout the life of the fire

Emergency Procedures - Fire Extinguishing

A small Li-ion fire can be handled like any other combustible fire.

- Use a foam extinguisher, CO_2, ABC dry chemical, powdered graphite, copper powder or soda (sodium carbonate).
- Water-based products are most readily available and are appropriate since Li-ion contains very little lithium metal that reacts with water. Water also cools the adjacent area and prevents the fire from spreading.
- In the event of a thermal runaway, which may result in a visible release of gas and/or intensive smoke build-up from the battery, evacuate the location immediately and contact the Fire Department.
- Firefighting operations must be performed by trained firefighters with full personal protective equipment and self-contained breathing apparatus.

Emergency Procedures - Fire Extinguishing

- If a Li-ion battery overheats, hisses or bulges, immediately move the device away from flammable materials and place it on a non-combustible surface. If at all possible, remove the battery and put it outdoors to burn out. Simply disconnecting the battery from charge may not stop its destructive path.
- Ensure that emergency responders are informed that the battery has Lithium-ion chemistry.
- Any indication of a thermal event (gas, heat) requires fire suppression methods to be applied (absence of flame is not sufficient to consider the thermal runaway event stopped or extinguished).
- Large amounts of spray water and/or complete immersion into water can be used effectively to cool the battery and contain a Lithium-ion battery thermal event.
- In the case of the battery outgassing or after suppression of the fire, store the battery in a safe place outside (access restriction, hazard indications) for a minimum of 24 hours.
- It is recommended to monitor the temperature frequently to detect any potential new heat generation. In the instance that a thermal event reoccurs follow the same firefighting methods.

Safe Disposal of Lithium-ion Batteries

- Lithium-ion batteries contain elements that may pose health risks to individuals if they are allowed to leach into the ground water supply.

  Lowes and Home Depot typically will take these batteries but there may be other outlets as well. In the United States and Canada, a large network of over 30,000 battery drop-off locations may be found at www.call2recycle.org. The supplier of the product may also take them back so check that route as well.

- To render the battery safe, apply tape over any exposed connectors to prevent the accidental shorting of the positive and negative terminals of the battery during transport. Place each battery into its own plastic bag, seal the bag, and deposit the battery into the recycling container.

  NEVER dispose of the battery in a fire or incinerator, as the battery may catch fire and explode.

Training

- All associates that use or handle Lithium-Ion batteries must be trained before using on:
  - storage,
  - handling/use,
  - charging,
  - damage,
  - PPE,
  - medical emergencies,
  - disposal and
  - emergency notification procedures.

Lithium-Ion Batteries and EPCRA 311 / 312 Reporting Requirements

- Some lithium-ion batteries may qualify under EPCRA Section 311(e)'s "consumer product exemption", which excludes from reporting *"any substance to the extent it is used for personal, family, or household purposes, or is present in the same form and concentration as a product packaged for distribution and use for the general public."*
- When determining whether any of the lithium-ion batteries you have at a facility are exempt from Tier II reporting, ask:

  Are lithium-ion batteries in the same packaging and concentrations as lithium-ion batteries sold for use by the general public If the answer is **yes**, regardless of whether it is intended to be distributed for use by the general public or used for the same purpose as a consumer product, then those batteries are exempt.

  If the answer is **no**, then all other lithium-ion batteries at your facility should be included in your Tier II report.

SARA 311/312 (Tier II) Reporting

- **YOU DON'T NEED TO REPORT:** Batteries that the maintenance department uses to power their cordless drills, because these are sold for use by the general public (i.e., the same batteries available for purchase at a hardware store).
- **YOU DON'T NEED TO REPORT:** Solar batteries of a size (e.g., ~3 kWh) that consumers would use in their homes.

- ***YOU MUST REPORT*:** Batteries used to power forklifts, because these are not sold for use by the general public.
- ***YOU MUST REPORT:*** Solar batteries of a size (e.g., ~100kWh) that typically have only industrial applications.

SARA 311/312

- Lithium-ion batteries do not contain any EHSs, so your threshold determination:
- **Calculate** the total quantity of lithium-ion batteries present throughout the facility at any one time.
- **Report** the batteries as a mixture (e.g., "Lithium-ion Batteries")
- *Note that if your facility has previously fulfilled your EPCRA Section 311 (SDS reporting) obligations by reporting the lithium-ion batteries as a mixture, then they must report in the same manner on their Tier II report. The opposite is also true - if you previously reported as components on your Section 311 reporting, then your facility must do the same on your Tier II report.*
- **Example Quantifying as a Mixture (not for use in California)**

Battery Type	Quantity at Facility	
Forklift (Small) - 375 lb. batteries	10 batteries	10 x 375 lb. = **3,750 lb.**
Forklift (Large) - 750 lb. batteries	6 batteries	6 x 750 lb. = **4,500 lb.**
Process Equipment - 2,500 lb. batteries	2 batteries	2 x 2,500 lb. = **5,000 lb.**
TOTAL		**13,250 lb.**
Hazardous Chemical Threshold		10,000 lb.
13,250 lb. ≥ 10,000 lb. threshold ***Lithium-ion batteries need to be reported at this facility.***		

- In performing the threshold determination, you will need the following items:
- The number of lithium-ion batteries at your facility,
- The weight (or estimated weight) of each battery at your facility, and
- The hazardous chemical reporting threshold for the area that your facility is in (CA may differ from other states so check your state and local requirements)
- As shown in the Example above, all you will need to do is add up the total weights of the lithium-ion batteries and compare it to the hazardous chemical reporting threshold.

How do I report?

Now that you have your quantity of reportable lithium-ion batteries and have confirmed you exceed applicable thresholds, the last step is adding it to your Tier II report. This section discusses the individual sections that need to be completed in order to add the batteries to your report. Note: Where examples are provided, the data and scenario above are used.

Chemical Details

Though the interface will vary depending on the state you are filing in, the following will be true when reporting your lithium-ion batteries:

1. **"Mixture"** should be checked
2. CAS Number should be **blank or "N/A"** (CAS Number is not required for mixtures)
3. "EHS" should be marked **"No"**
4. Physical State will be **"Solid"**
5. Because the mixture does not contain any EHSs, the "Mixture Components" section is not required to be filled in, though it is recommended to complete this section as a best practice.
    A. Components can be found in Section 3 of your SDS. When given a range for a component, such as "5-10%", we recommend reporting the higher end of the range (e.g., 10%).

How do I report?

Hazards

- Most lithium-ion batteries will have similar hazards, but it is **very important** to reference the SDS from the manufacturer specific to the batteries that are at your facility. That way, first responders and emergency planners will be working with the most accurate information.
- Typical hazards as they are reported in a Tier II report may be:

  Physical Hazards:
  - Explosive
  - Flammable
  - Self-heating

  Health Hazards:
  - Acute toxicity (any route of exposure)
  - Skin corrosion or irritation
  - Serious eye damage or eye irritation
  - Respiratory or skin sensitization
  - Carcinogenicity
  - Specific target organ toxicity (single or repeated exposure)
- Hazards can typically be found in Section 2 of Section 15 of your SDS for your battery.

How do I report?

Storage Locations

Lithium-ion battery storage locations will consistently be reported with the following properties:

- **Container Type:** Battery
- **Pressure:** Ambient Pressure
- **Temperature:** Ambient Temperature

How do I determine the weight of my lithium-ion batteries?

- First, determine the manufacturer and model number of your battery. Many manufacturers have charts on their websites that display the specifications (including weight) for their various battery models. If that is unavailable, contact the manufacturer directly.

When you have your information the enter it in your 312 report like you did with your Lead Acid batteries.

Fire and Inhalation Danger

Found Everywhere and More Coming

SUMMARY

Codes have not caught up!

SARA 312 aka Tier II Reporting

General Information on Li-ion Batteries

- https://batteryuniversity.com/article/bu-304a-safety-concerns-with-li-ion
- https://batteryuniversity.com/article/bu-205-types-of-lithium-ion
- https://batteryuniversity.com/article/bu-409-charging-lithium-ion
- https://batteryuniversity.com/article/bu-808-how-to-prolong-lithium-based-batteries
- https://batteryuniversity.com/article/bu-808a-how-to-awaken-a-sleeping-li-ion
- https://batteryuniversity.com/article/bu-808b-what-causes-li-ion-to-die
- https://batteryuniversity.com/article/bu-809-how-to-maximize-runtime
- https://batteryuniversity.com/article/bu-810-what-everyone-should-know-about-aftermarket-batteries