

ONTARIO FIRE DEPT., CA 2024

LITHIUM-ION BATTERY EMERGENCIES



Training Outline



- Battery Basics
- Firefighting Operations and Tactics
- Safety and PPE
- De-energizing, Air Monitoring, and Site Cleanup
- Transport and Disposal



BATTERY BASICS

Battery Types



Non-rechargeable Batteries (Alkaline)

Stable, no significant energetic releases.
Consistent energy, long-term power,
but loses strength over time.
Long shelf life.



Non-rechargeable Batteries (Lithium Metal)

Stable, large energy density. Can provide
strong energy surges even after a period
of low discharge. Lithium metal found
inside is **extremely water reactive**.

Battery Types



Parts of a battery

The answer to "what is inside a battery?" starts with a breakdown of what makes a battery a battery.

Container Steel can that houses the cell's ingredients to form the cathode, a part of the electrochemical reaction.

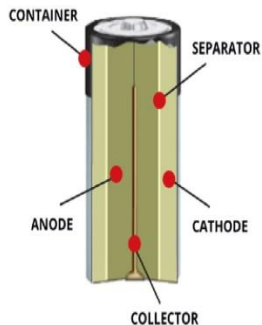
Cathode A combo of manganese dioxide and carbon, cathodes are the electrodes reduced by the electrochemical reaction.

Separator Non-woven, fibrous fabric that separates the electrodes.

Anode Made of powdered zinc metal, anodes are electrodes that are oxidized.

Electrolyte Potassium hydroxide solution in water, the electrolyte is the medium for the movement of ions within the cell. It carries the ionic current inside the battery.

Collector Brass pin in the middle of the cell that conducts electricity to the outside circuit.



Alkaline
Battery
(Inside)

Lithium
Metal
Battery
(Inside)



Inside a lithium metal cell

Battery Types



Lead Acid Batteries

Stable, low energy density.
Contains Lead and Sulfuric Acid.
Risk of explosion due to Oxygen and Hydrogen generation during charging



Nickel Cadmium (NiCad)/Nickel Metal Hydride (NiMH) Batteries

Rechargeable and stable
Suffers from "memory effect"
Can be smothered (METAL-X, Sand, etc.)
Water application can cause hydrogen gas release

Lithium-Ion Battery Types



18650
18x65mm



2170
21x70mm



Prismatic
Cell



Pouch
Cell

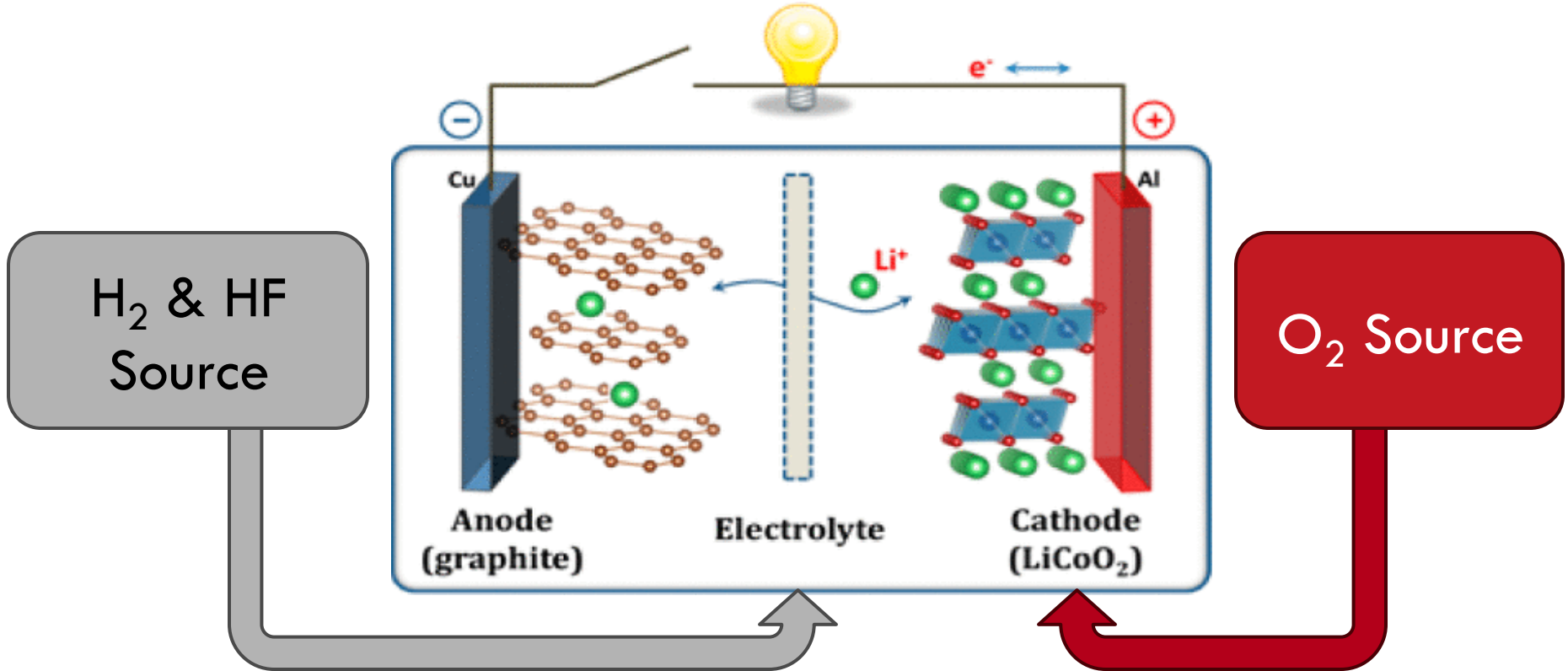
Cylindrical Cells (18650) are the most common cell in mobility (bikes, scooters, etc.) and are used by electric vehicles with 3000 to 7000 cells

Prismatic and Pouch Cells are found in industrial and consumer electronics, respectively; both are used in electric and hybrid vehicles



How do
Lithium-ion
batteries
work?

Li-Ion Battery Internal

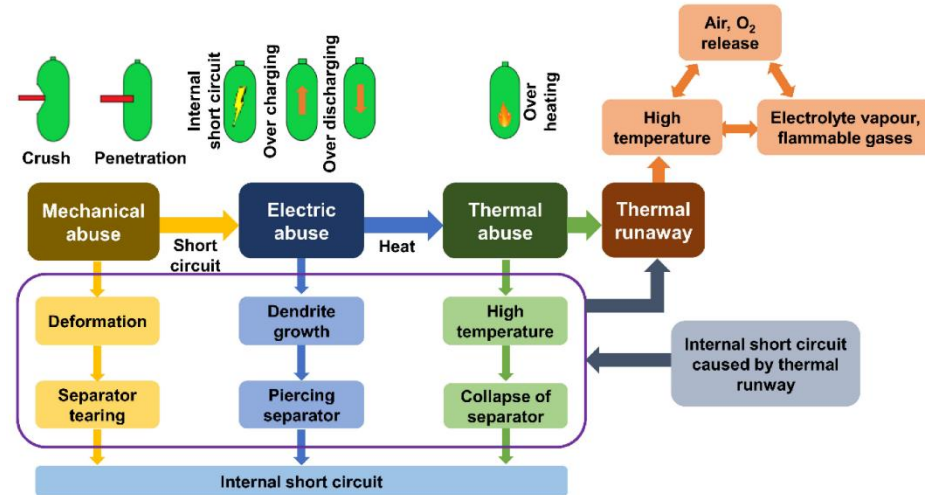


Li-Ion Battery Hazards and Failure

Thermal Runaway

- Thermal Runaway – heat generated by the Li-ion battery reaches a stage where it becomes self-sustaining. Exponential rise in battery temperatures. Results in explosion, fire, and release of toxic and flammable vapors.
- Vapor Cloud – if the gasses evolved during thermal runaway do not ignite immediately, they create a vapor cloud. NOT ONLY COMBUSTION PRODUCTS!

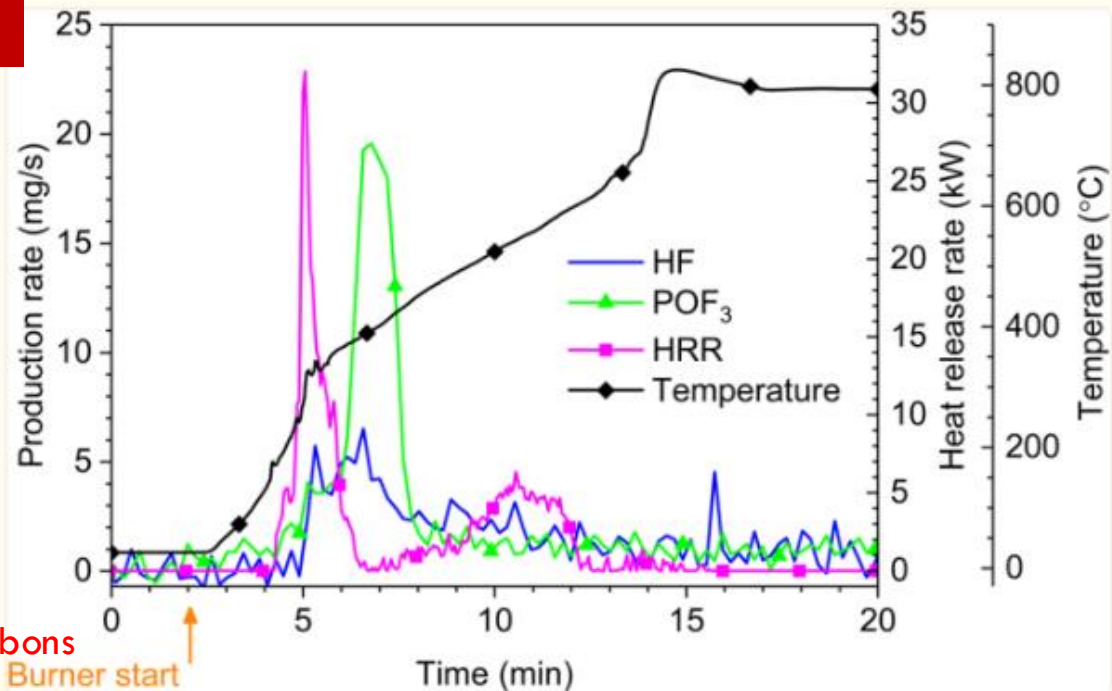
Additive Mechanism



Li-Ion Battery Toxic/Flammable Vapors

Toxic/Flam Vapors

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



Li-Ion Battery Toxic/Flammable Vapors



Vapor Production

6,000 L/kWh of vapors can be released during battery failure (Single 18650 10Wh = 60L; Single 21700 15-20Wh = 90-120L)

Electrolyte is flammable, usually contains lithium hexafluorophosphate (LiPF_6) or another Li-salt with fluorine

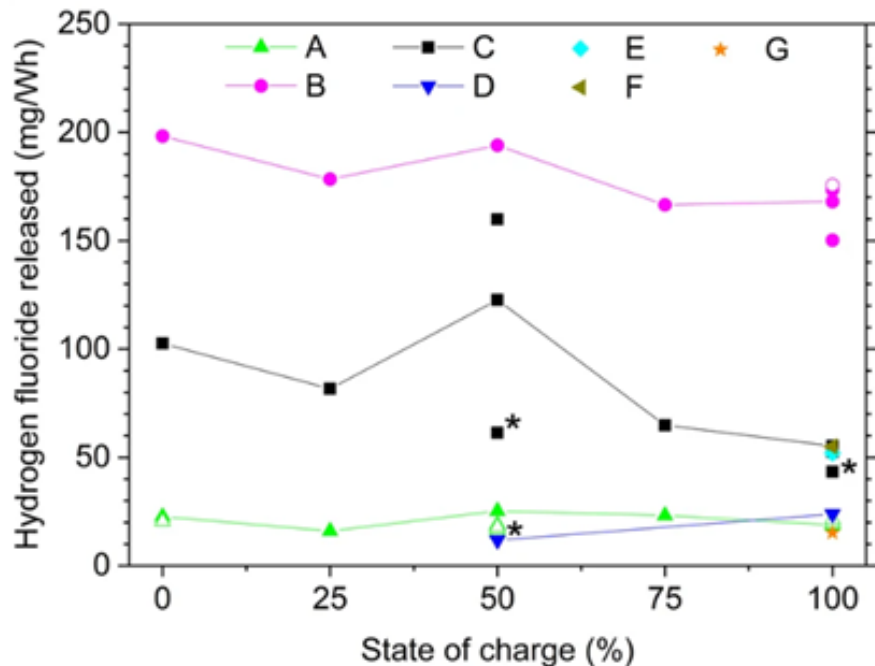
HF can be generated at 20-200 mg/Wh

- Electric Vehicle (100 kWh)

600k L of vapor with **2-20kg of HF**

- Energy Storage System (3 MWh)

16M L of vapor with **60-600kg of HF**





FIREFIGHTING OPERATIONS AND TACTICS

Voltage in Lithium-Ion Battery Tech



Cell Phones = 3.4 to 4.5V

E-Scooter = 28 to 48V

E-Bike = 48 to 52V

Prius = 200V

Tesla = 350 to 400V

F150 Lightning = 400V

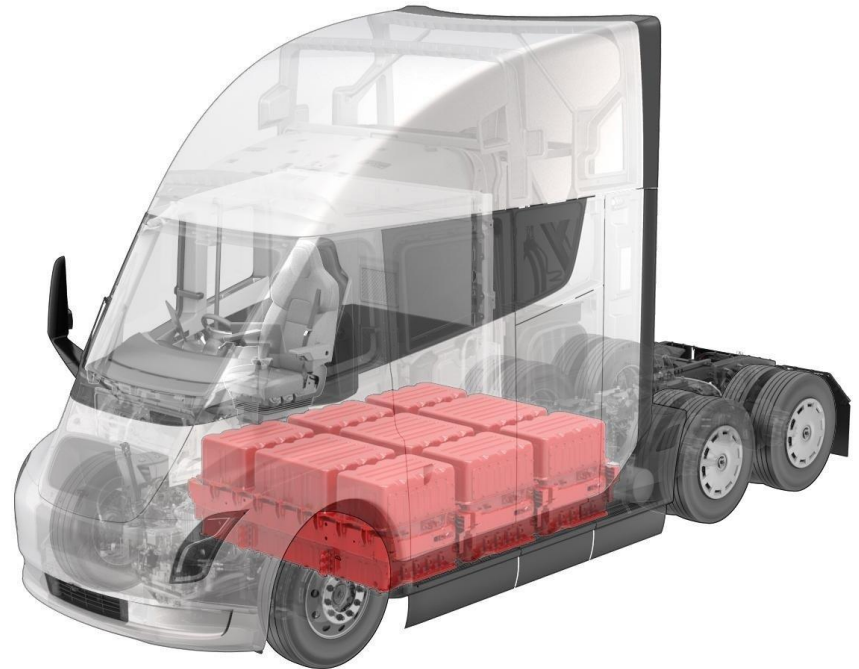
GMC Hummer = 400V

Ford Mach-e = 450V

Trolley = 600V

Tesla Truck = 800V (reported)

Tesla Semi = 1000V (reported)



Exponential Increase – Infrastructure



Federal Infrastructure Investment and Jobs Act (11/15/2021)

- \$6.3 Billion
 - Battery processing, manufacturing, and battery recycling and second life applications
- \$7.5 Billion
 - Rapid charging stations – 500,000 along highways and in communities
- \$5 Billion
 - School Buses





School Buses?

Rapid smoke and flame production

Exponential Increase – Infrastructure

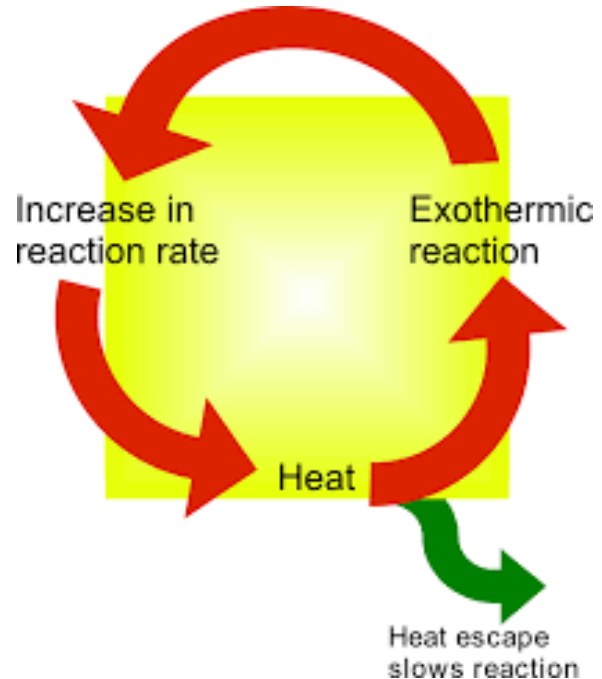


- 196 kWh
 - 1,176,000.00 Liters of Toxic and Explosive Gases



Differences in Lithium-Ion Battery Fires

- Very toxic atmospheres: Smoke-gases, metals, particulates
- Burn temperatures peak more rapidly
- Fires at cell level can burn without external oxygen - **can't smother!**
- Explosive potential: Deflagration Detonation from **hydrogen** and carbon monoxide gases
- Thermal Runaway reaction
 - Chemical reaction – rapid degradation
 - Exothermic
 - Does not require external oxygen
 - Nearly impossible to stop once it starts
 - Initiation may be a matter of time and unpredictable
- Thermal re-kindling is common – minutes, hours, days, weeks, months, years!



Propagation

- Propagation
 - Domino effect
 - Thermal Runaway heat from one battery-cell is likely to trigger neighboring cells
- Limiting propagation is primary goal
 - Cooling neighboring cells **may** prevent propagation
 - Removing exposed cells (i.e., removing other e-bikes, loose cells, etc.)



Four Primary Presentations of LIB

Energy Storage Systems

Electric Vehicles

Micro-mobility

Personal Electronics



48V13Ah 13S5P USA Ship 3-5days delivery

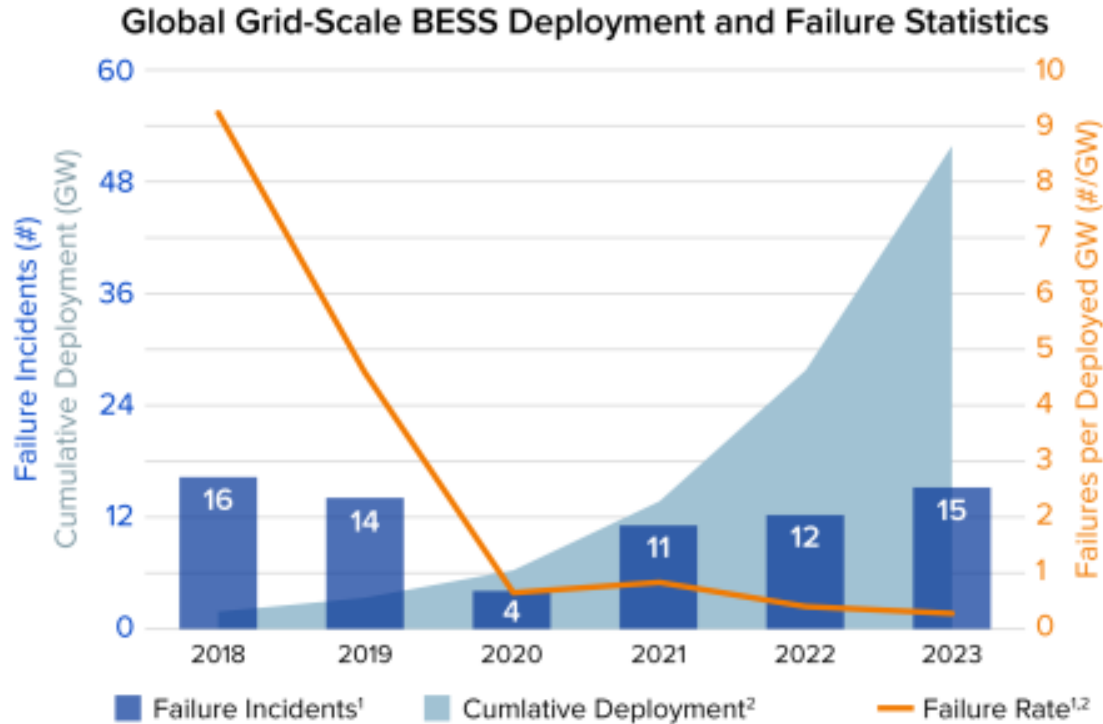


Frequency of Incidents

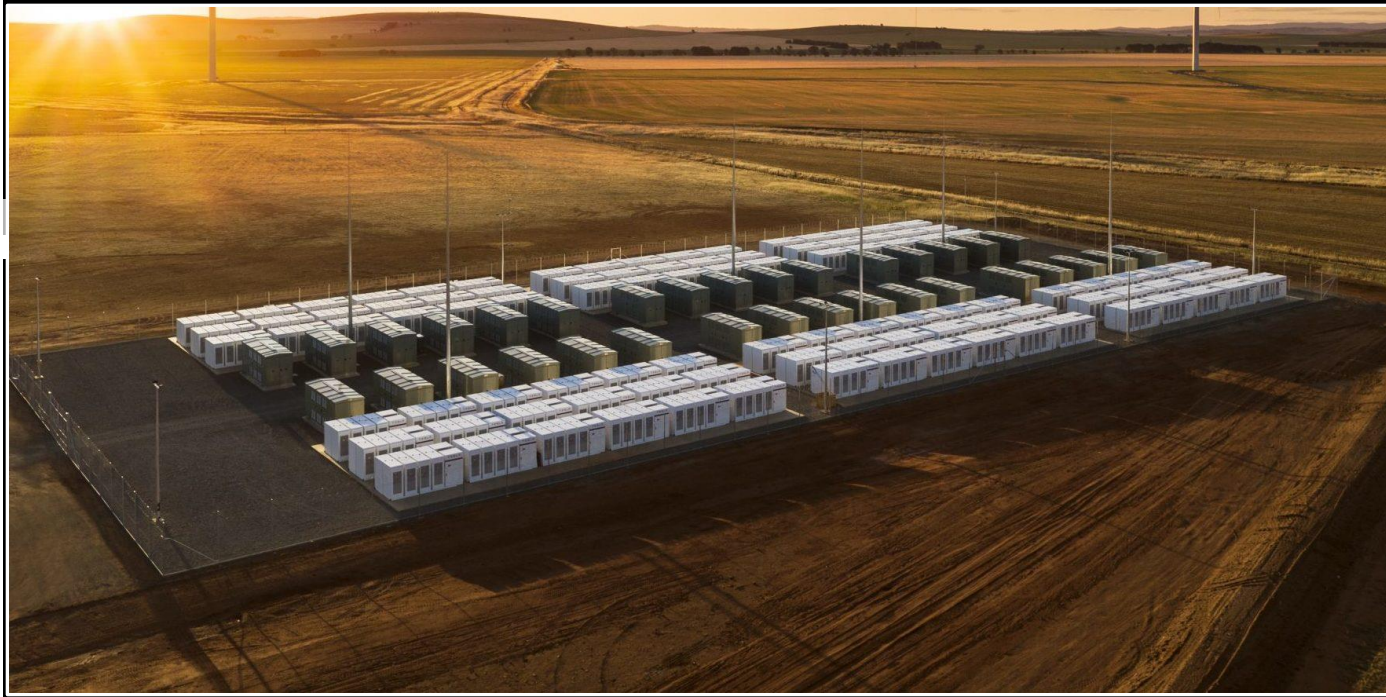


- FDNY LIB fires:
 - 44 in 2020
 - 220 in 2022
 - 268 in 2023 (18 killed, 150 injured)
 - Now leading cause of fires and fire deaths in NY City, 2024.
- San Diego LIB fires:
 - Approximately 50 in 2022
 - 104 in 2023
 - 67 as of 8/26/24 in 2024

Frequency of Incidents



Sources: (1) EPRI Failure Incident Database, (2) Wood Mackenzie. Data as of 12/31/23.



Battery Energy Storage System (BESS)



KEY TAKEAWAYS FROM APS EXPLOSION REPORT
SEVERAL VALLEY FIREFIGHTERS HURT IN 2019 BLAST

Battery Energy Storage System (ESS)

- Large Systems
- Multiple racks of batteries
- Surprise, AZ – 2019
- Regulations
 - NFPA 855
 - Safety measures
 - UL 9540 & 9540A
 - Testing of system

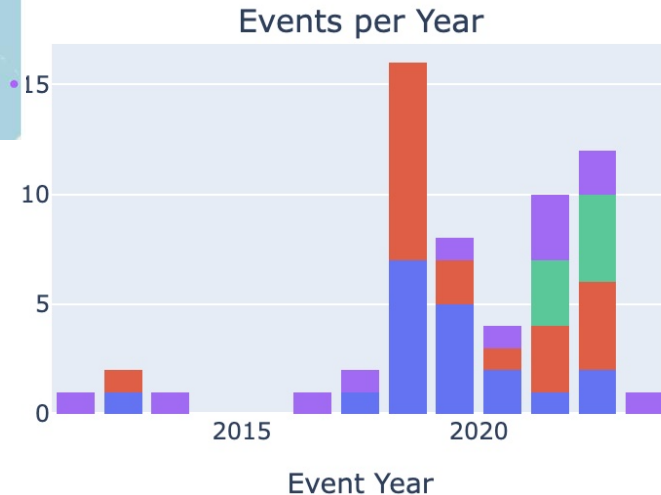


BESS – Failure Events

- China
 - 2 FF Dead
- Surprise, AZ
 - 8 FF injured
- Chandler, AZ
- Victoria, Australia
- Moss Landing, CA
- Valley Center, CA 2023
- Otay Mesa, San Diego, CA 2024
- Orange County, CA 2024



- [STORAGEWIKI.EPRI:](https://www.epri.com/Products/StorageWiki)
BESS FAILURE
INCIDENT DATABASE
(COMMERCIAL ONLY)





BESS Failure Tactical Considerations

- Signs of possible BESS Failure
 - Suspicious odor emanating from the BESS
 - Smoke
 - Battery thermal runaway fires are preceded by smoke
- If fire, smoke, or suspicious odor is observed, consider:
 - If possible, shut off the unit/system.
 - Evacuate the area of all non-emergency personnel.
 - Do not approach the unit and attempt to gain access.
 - Some BESS safety mechanisms are designed to maintain doors shut, and other have automatic ventilation doors.
 - Contact site emergency contact and/or manufacturer.

BESS Tactical Considerations

If Batteries Are Involved



- If a fire is confirmed:
 - Non-Intervention or Defensive Operations
 - Establish water supply.

- **#1-Life safety**
 - Stay out of smoke!
 - PPE
 - Structural Firefighting Gear and SCBA.
 - Rescue
 - Evacuate / Shelter-in-Place
 - Use as much "ground truth" as possible.

BESS Tactical Considerations

If Batteries Are Involved



■ **#2-Incident Stabilization**

- Let it burn!
 - Applying water to the burning unit will only delay the event.
 - May take multiple operational periods.
 - During periods of module propagation, there may be no sign of fire, but the event can still be active and flare up can still occur.
- Environmental Protection
 - Minimize/contain/redirect runoff if possible
 - Use lowest GPM needed

BESS Tactical Considerations

If Batteries Are Involved



■ **#3-Property Conservation**

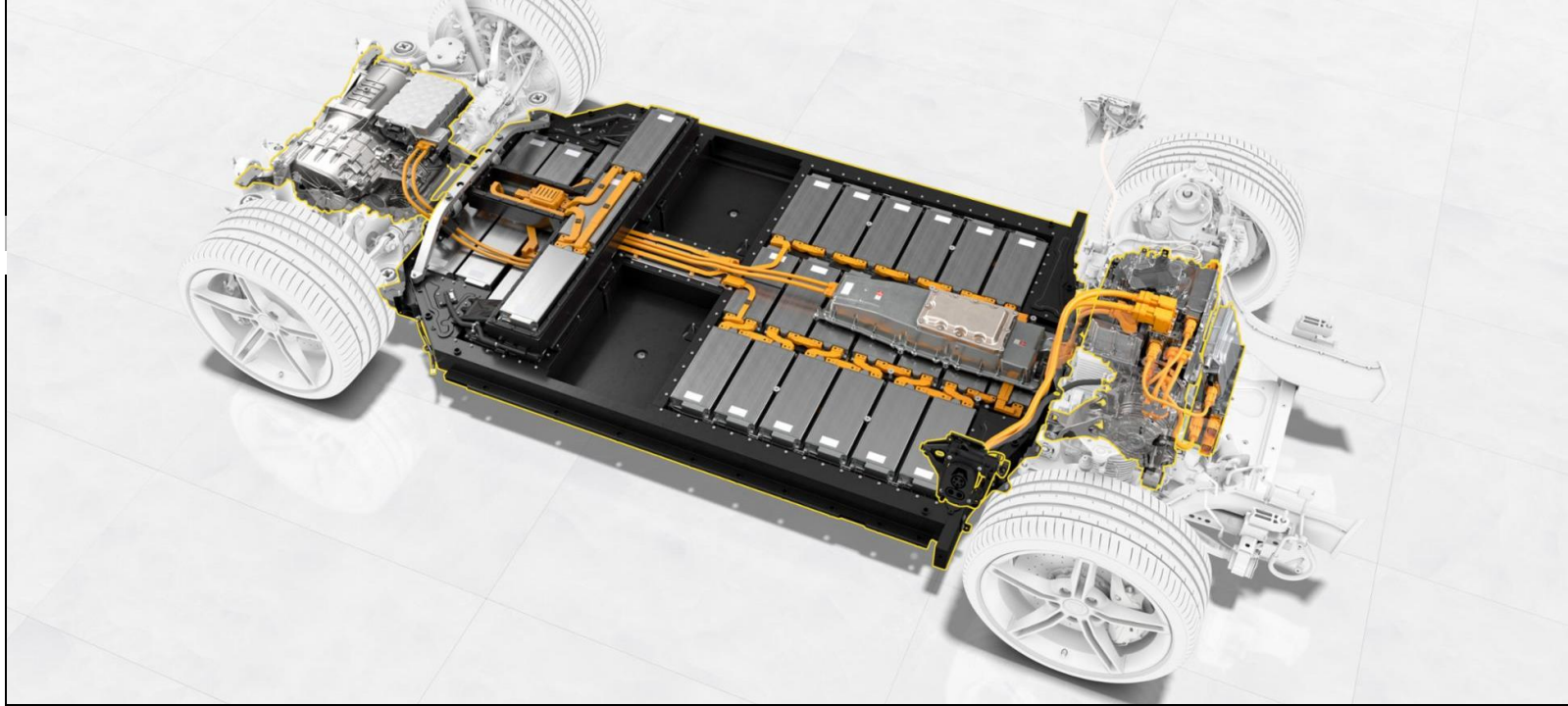
- Allow system safety devices to operate as designed.
- Monitor alarm panel and manually activate any safety devices if appropriate.
- Prevent propagation.
 - Water curtains and unstaffed lines
 - Apply from a distance and upwind if possible.
 - Protect exposed packs
 - Extinguish and protect other infrastructural exposures
 - Use 30-degree fog for water curtains to absorb heat and knock down toxic plume
- Protect other exposures.
 - Neighboring structures
 - Vegetation
- Recovery
 - Allow batteries to cool (this process may take 12-48 hours or longer).
 - Use on-site resources and manufacturer for decommissioning and recovery plans.

BESS Tactical Considerations

If Batteries Are Involved



- Resources to consider
 - BESS Personnel
 - EPA, Environmental Health, Hazmat
 - Gas/Electric



Battery Electric Vehicles (BEV)

Exponential Increase: Battery Electric Vehicles (BEV)

% of EVs Global Auto Sales

4.7% - 2020

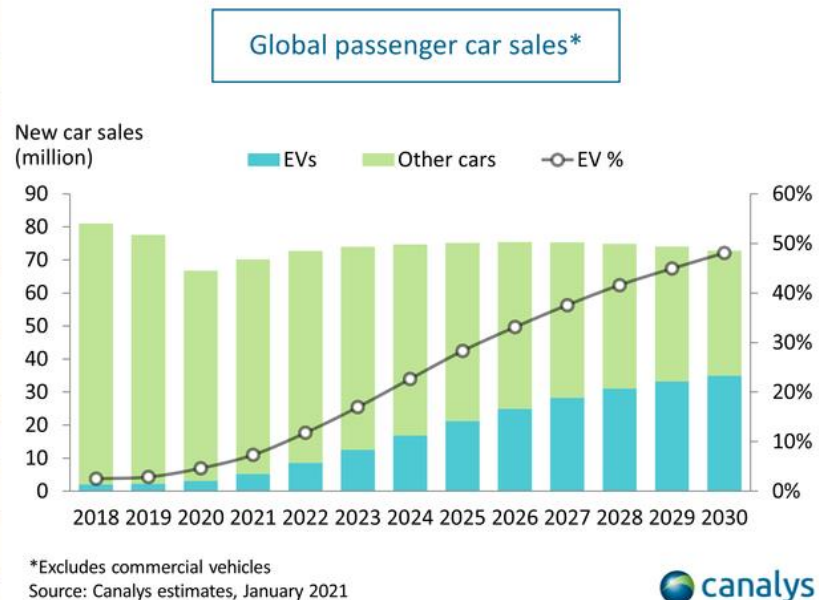
15% - 2025

48% - 2035

California forecasted to be much higher.

By 2035 100% of all vehicle sales in CA must be battery or hydrogen powered

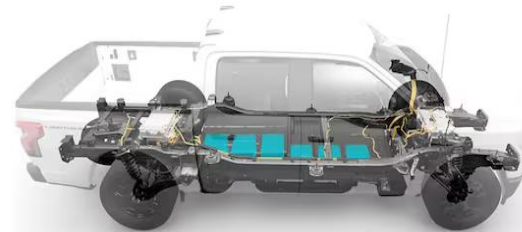
3.1 million EVs were sold in 2020, 4.7% of new passenger cars. EV sales will continue to rise, reaching 48% of passenger car sales by 2030.



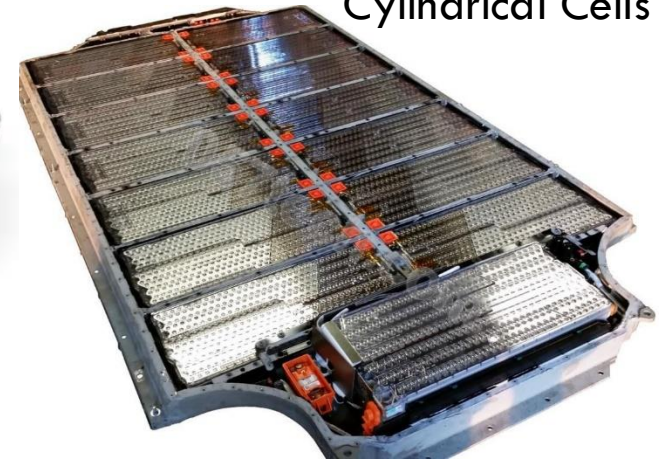
Battery Electric Vehicles (BEV) – Battery Packs



GM Battery Pack
Pouch Cells

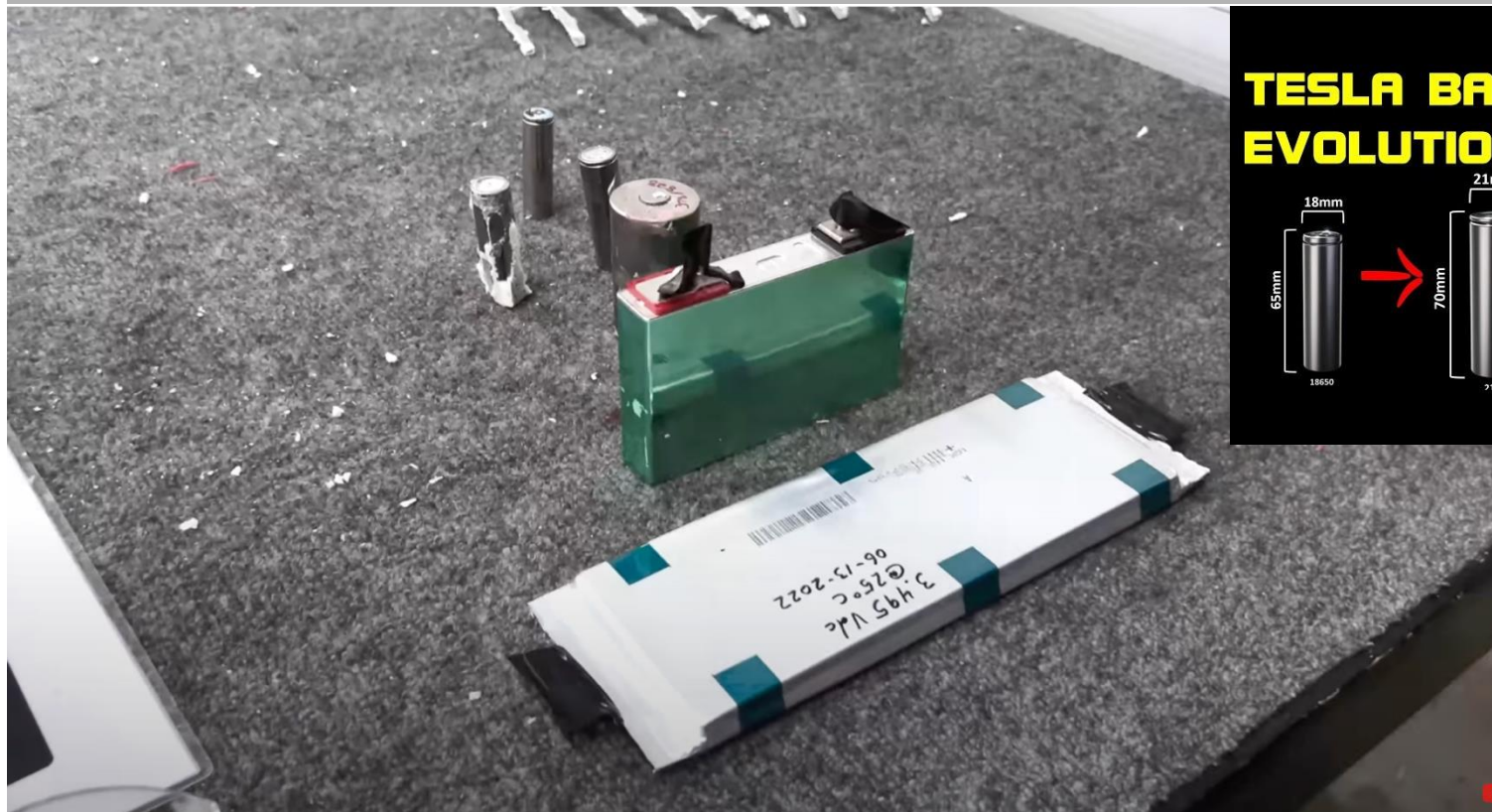


Ford Lightning Battery Pack
Pouch Cells



Tesla Battery Pack
Cylindrical Cells

Battery Electric Vehicles (BEV) – Battery Packs



TESLA BATTERY EVOLUTION



BEV Damage

- Lithium-Ion Batteries primarily located in underside of vehicle
- Identification of battery involvement is key:
 - White smoke
 - Battery cell projectiles
 - Hissing/popping sounds



Tesla – Cylindrical Cell Batteries
18650 cell generation

LOTS OF WATER

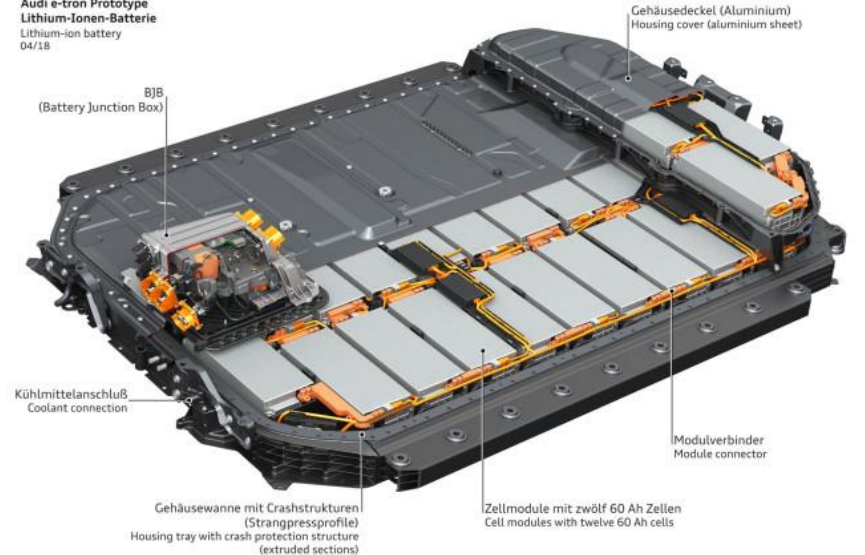
BEV – Offensive Operations

- Water is considered best cooling agent
- If offensive operation engaged:
 - Water should be applied under the vehicle and up at the batteries.
 - For pouch cell vehicles (i.e., GM), there may be access points near the wheel wells
 - Water application into access points to battery compartment can prevent propagation (manufacturer specific)

- **Thermal re-kindle can occur minutes, hours, days, weeks, months, years, later!**

Audi e-tron Prototyp

Audi e-tron Prototyp
Lithium-Ionen-Batterie
04/18



3 Keys to Success



BEV
Identification



Let it Burn
PROTECT
EXPOSURES!
(If possible)



Secure a
Water
Supply



BEV Fire Tactical Considerations

- Life safety
 - PPE
 - Rescue / Check for victims
 - Chock wheels
 - Evacuate / Shelter-in-Place
- Incident Stabilization
 - **Attack the fire like a normal vehicle fire.** Foam is NOT recommended
 - Most EV fires do not involve the batteries
 - After confirming it is an EV and batteries are involved, if possible, allow the batteries to burn and evacuate the area 330' in all directions and protect exposures.
 - Stay out of smoke, toxic.
 - Consider PPV fans to move smoke away from victims and responders.

BEV Fire Tactical Considerations

- If extinguishment/cooling is required:
 - Secure a water supply
 - Consider tilting the vehicle to gain access to the underside of the vehicle
 - This will require training prior to placing into operations
 - Lifting points must be referenced
 - Consider directing spray into side vents of battery pack
- Use a thermal imager to check for continued heating
- Never cut, crush, puncture, or open a high voltage battery to extinguish it
- If the cells are visible due to damage, you can direct a hose stream directly on the cell
- Observe the battery and watch for evidence of thermal runaway

BEV Fire Tactical Considerations



- Other considerations
 - Refer to the Emergency Response Guide (ERG) for the specific make and model of the vehicle for guidance on securing power to the lithium-ion battery.
www.NFPA.org
 - Some battery cooling mechanisms are powered by the 12-volt system
 - Once the lithium-ion battery has been cooled, stand-by at least 45 minutes and continue monitoring the lithium-ion battery using the thermal imager and observe for any other signs of thermal runaway

BEV Fire Tactical Considerations



- Tow Company
 - Make sure it's towed on a flatbed.
 - Regenerative braking sends power to batteries. This may cause a fire with rotational force on wheels
 - Non-conductive separation between vehicle and metal bed to prevent further short circuit.
 - Store 50 ft away from all exposures



EV ERG – NFPA link



Example ERG

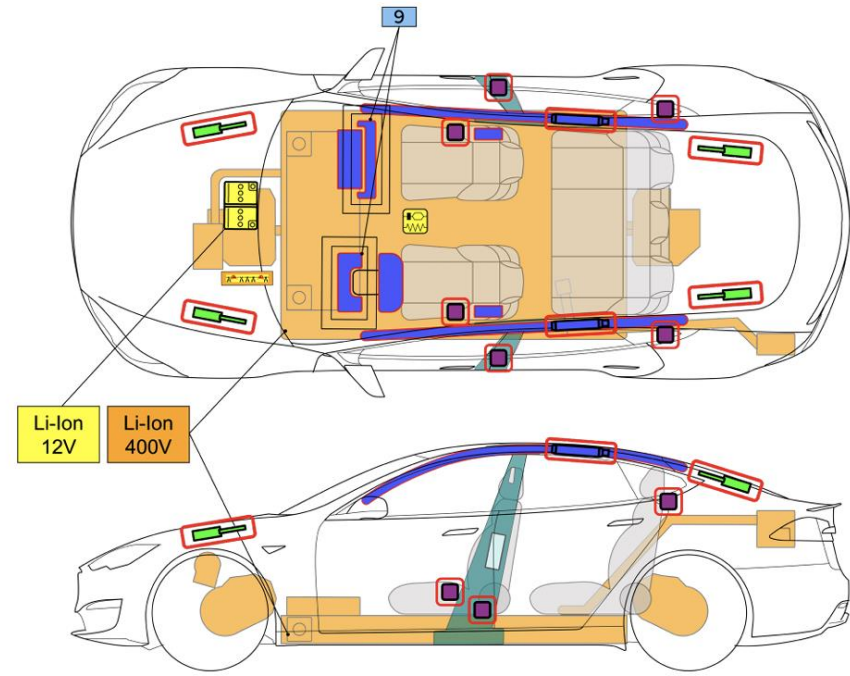
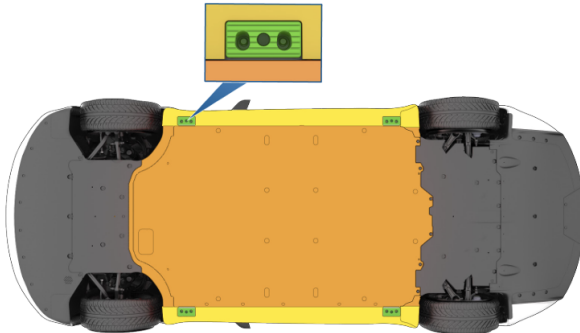
STABILIZATION / LIFTING POINTS

The high voltage battery is located under the floor pan. A large section of the undercarriage houses the high voltage battery. When lifting or stabilizing Model S, only use the designated lift areas, as shown in green.

WARNING Be careful to not damage the battery pack while stabilizing / lifting the vehicle.

WARNING The vehicle should be lifted or manipulated only if first responders are trained and equipped at the technician level per the applicable country's national fire training requirements and are familiar with the vehicle's lifting points. Use caution to ensure you never come into contact with the high voltage battery or other high voltage components while lifting or manipulating the vehicle.

WARNING DO NOT USE THE HIGH VOLTAGE BATTERY TO LIFT OR STABILIZE MODEL S.



	Airbag		Stored gas inflator		Seatbelt pretensioner		SRS Control Unit		Pedestrian protection active system
	Automatic rollover protection system		Gas strut/pre-loaded spring		High strength zone		Zone requiring special attention		
	Battery low voltage		Ultra capacitor, low voltage		Fuel tank		Gas tank		Safety valve
	High voltage battery pack		High voltage power cable/component		High voltage disconnect		Fuse box disabling high voltage system		Ultra capacitor, high voltage

	Cable cut								
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BEV Fire Tactical Considerations – Inside (underground/garage)



FSRI Demo on BESS Release Inside Garage



Courtesy: Fire Safety Research Institute



BEV Fire Tactical Considerations – Inside (underground/garage/warehouse)



■ Considerations: Garage

- Approach from a 45° angle to avoid possible door explosion/over pressurization; deflagration-detonation phenomena.
- If no active fire, be concerned with possible explosive atmosphere

■ Warehouse

- Careful cutting into rollup doors without knowing what's inside

■ Below Grade Space/Parking

- Toxic atmosphere hazard
- Explosive atmosphere less likely due to available space and good ventilation profile;

continuously assess explosion risk!

- Allowing vehicle to burn is an option, with significant consequences to the structure
 - Overall EV fires heat energy release is comparable to internal combustion engine (ICE) fires.
 - The Jet flame caused by thermal runaway accelerates fire spread to other combustibles.
- Identification of EV will be difficult, if not impossible. Follow your department SOP for underground vehicle fires
- Perform thorough PPE and personal decontamination procedures

BEV Vehicle Extrication



- Charged and STAFFED hoseline!
 - Fog pattern for hydraulic ventilation
 - Does not require full GPM
 - $\text{GPM Flow} \times \text{degree of fog pattern} = \text{CFM}$
- “RIC” Team with SCBA?
 - Consider a standby team to take over operations on SCBA

3. Disable direct hazards / safety regulations

Thermal Runaway Mitigation



The vehicle is equipped with a battery management system with internal fault detection, including thermal runaway mitigation. In the event of a “**Battery Danger Detected**” notification, **DO NOT cut or disable the 12-volt system, unless you need to disable the airbags for occupant extrication.**

Automatic safety systems are enabled when 12-volt power is available, including a battery thermal runaway mitigation system that internally cools the High Voltage battery when a thermal event is detected; this feature is available in non-crashed, static situations.



Other Battery Electric Vehicles



Micro-Mobility Devices

E-BIKES, SCOOTERS, HOVER BOARDS, ETC.

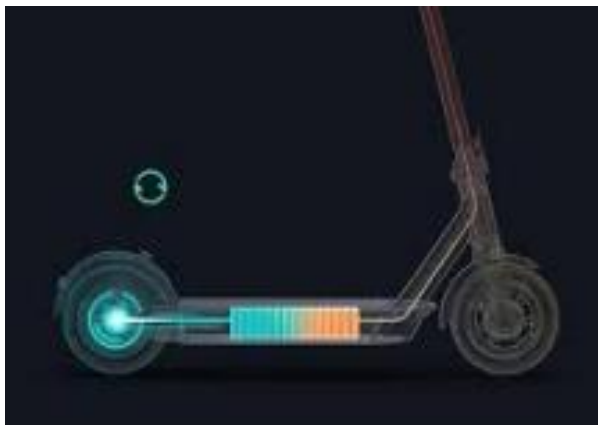
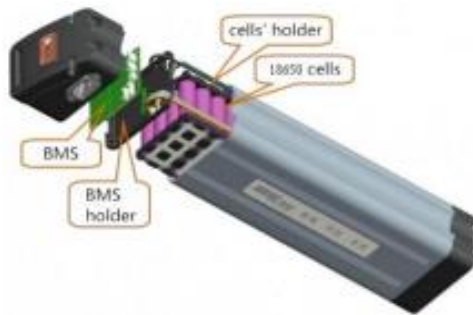
Micro-Mobility Devices



- Largest number of LIB incidents
- FDNY LIB fires:
 - 44 in 2020
 - 220 in 2022
 - 268 in 2023 (18 killed, 150 injured)
 - Now leading cause of fires and fire deaths in NY City, 2024.
- Public exposure concerns
 - Stored and charged inside occupied residences and businesses
 - Stored near entry and exit ways
 - Can ignite with little-to-no warning
 - **Rekindle is likely.**



Micro-Mobility Devices



(i) Electric Unicycle



(ii) Egret (kick electric scooter)



(iii) Electric Scooter



(iv) Three-wheeler Electric Scooter



(v) Electric Mobility Cart



(vi) Electric Bike (bicycle)



(vii) Hoverboard



(viii) Segway



(ix) Electric Caster Board



Inside View

How Many GPMs?

- Lithium-Ion batteries do not require Oxygen to burn.
- Smothering also does not work
- Inerting with clean agent may inhibit class A fire but not battery fire, where flaming combustion is suppressed, explosive and toxic gases build-up and don't burn off; Surprise, AZ.
- Cooling to prevent cell propagation may be successful if water can be placed into battery pack
 - **DO NOT** force open the battery pack



Can you have more
GPMs than this?

Micro Mobility Concerns



Elevators



"Farming"



Large volume of smoke production



Micro Mobility Concerns

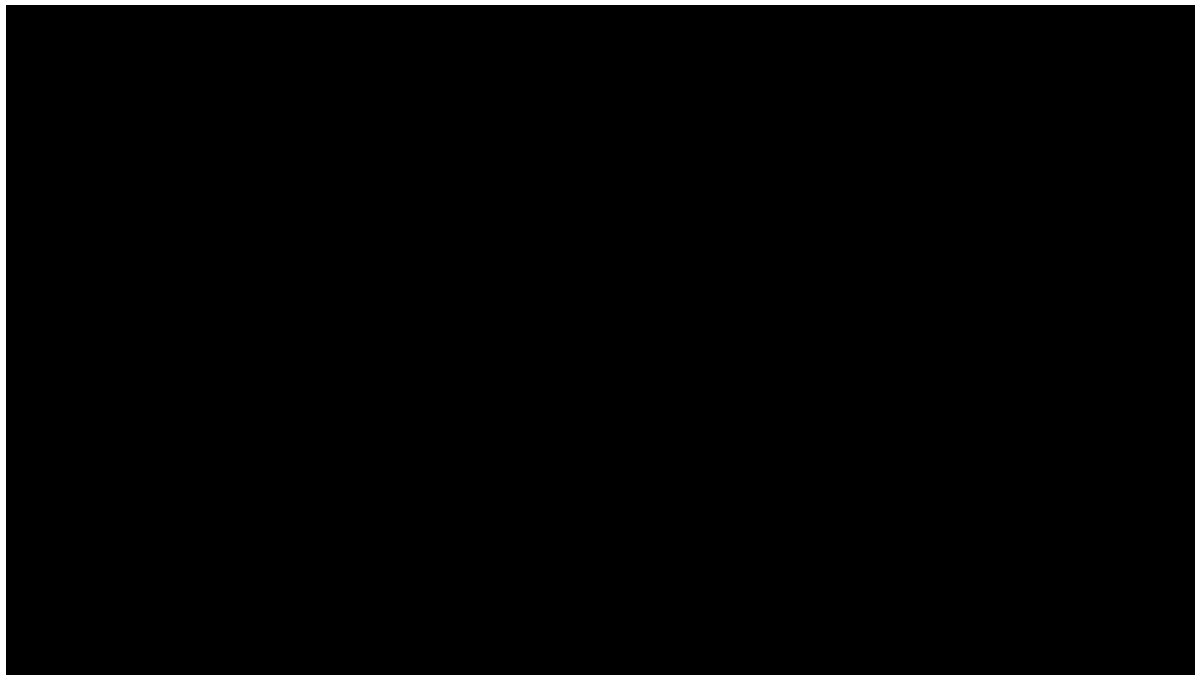
Rapid failure

Overhaul

Toxic atmosphere

Rekindle

Explosive



Micro Mobility Tactical Consideration



- Life safety
 - PPE/SCBA
 - Rescue
 - Evacuate area
- Incident Stabilization
 - If outdoors
 - Allow micro mobility to burn to completion
 - Prevent propagation to other devices/battery packs
 - If indoors
 - Attack residential fire like normal
 - **During fire attack, uninvolved micro mobility device may ignite behind you!!**

Micro Mobility Tactical Consideration



- Move all lithium-ion battery cells and devices to a safe location, away from firefighting operations, **PRIOR to overhaul**
 - Use shovel with wooden handle
 - Outside is preferred
 - Consider bathroom, bathtub, sink, or metal bucket and fill with water if outdoor not an option
- Wear SCBA during overhaul
- Advise Investigators of possible LIB presence
- Request assistance with battery stabilization, mitigation, overpacking, and disposal
- Provide protection lining during overpacking procedures



Where Do We See Them?

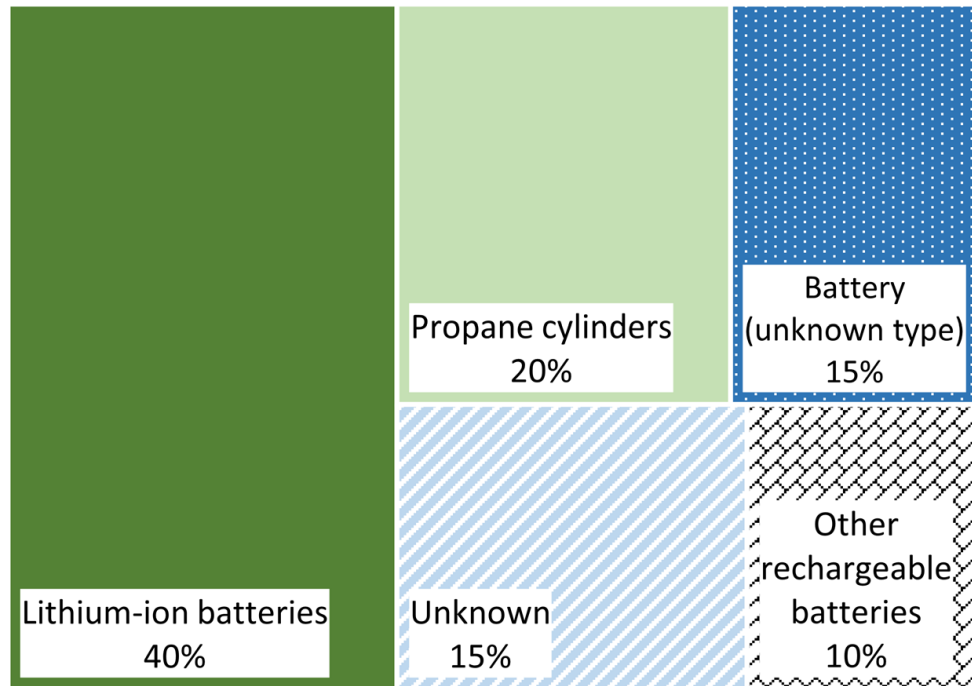
They are everywhere! Increasing fire behavior.

Disposal Challenge



- Trash trucks/recycling facilities
- 60% of trash truck load fires

Sources of Fires at Waste Management Facilities



Disposal Challenge





SAFETY AND PPE



Safety and PPE

- HazMat Size-UP, Critical Factors
- Incident Priorities L.I.P
- Recognition Prime Decision Making
- Risk Management Process: A lot, A little, Nothing
- Standard Conditions, Standard Actions, Standard Outcomes:
 - ▣ **S.I.N. C.I.A. P.C.P. D.D.D.D.**
 - Initial Action Plan: Strategy, Objectives (position and function)(use of tactics and task level work).
 - S.I.N. C.**I.A. P.C.P. D.**D.D.D.
 - ▣ **G.E.T.**
- Re-assess

Safety and PPE

- ☐ Safety
- ☐ Isolate and deny entry
- ☐ Notifications
- ☐ Command
- ☐ Identification and hazard assessment
- ☐ Action planning
- ☐ Personal Protective Equipment (PPE)
- ☐ Countermeasures-Defensive
- ☐ Protective Actions
- ☐ Decontamination
- ☐ Debrief
- ☐ Documentation!!!!
- ☐ Disposal/Recycle

Safety and PPE

- Safety
 - ▣ Front End and Back End
 - ▣ JHA-HASP (29 CFR, OSHA)
- Identification and Hazard Assessment/Analysis
 - ▣ **G**-as
 - ▣ **E**-lectrical
 - ▣ **T**-hermal

G_{AS}



E_{ELECTRICAL}



T_{THERMAL}



Safety and PPE



Personal Protective Equipment (PPE)

■ Fire/Thermal Risk

- Front End (Level D)
 - FR-Structure Fire Ensemble
 - Interior-Exterior SCBA
 - Exterior: Full-Face or Half-Face APR or PAPR with P-100 Acid Gas Cartridge
- Back End (Level D)
 - Administrative and Engineering Controls
 - FR-Ensemble
 - Interior-Exterior SCBA
 - Exterior: Full-Face or Half-Face APR or PAPR with P-100 Acid Gas Cartridge

■ No Fire/Thermal Risk at This Time?

- Back End (Level D)
 - Administrative and Engineering Controls
 - Consider particulate in air and exposure levels when selecting respiratory protection.
 - Level C
 - Interior-Exterior Full-Face APR or PAPR with P-100 Acid Gas Cartridge
 - FR-Ensemble (consider decon)
 - Interior-Exterior SCBA
 - Exterior: Full-Face or Half-Face APR or PAPR with P-100 Acid Gas Cartridge

SAN DIEGO LITHIUM-ION BATTERY FIELD STUDY DATA SUMMARY:

AIR MONITORING

Run	Test Media	Air Monitoring Data							
1	4 LiFePO4 100% SOC	O2 %	VOC	CO	LEL %	HCN	HF	Particulate	
		Min	20.9	-2.7	-1	0	0	0	0.001
		Max	20.9	0	5	0	0.8	0.58	0.707
2	4 LiFePO4 18500 SOC Unknown	O2 %	VOC	CO	LEL %	HCN	HF	Particulate	
		Min	20.9	-2.7	0	0	0	0	0
		Max	20.9	9.8	36	0	1.1	20	10.082
3	8 LiFePO4 18500 "Low SOC"	O2 %	VOC	CO	LEL %	HCN	HF	Particulate	
		Min	20.9	-2.1	0	0	0	0	0
		Max	20.9	66.5	171	2	3.9	0.95	7.567
4	8 LiFePO4 18500 100% SOC	O2 %	VOC	CO	LEL %	HCN	HF	Particulate	
		Min	20.9	-0.6	3	0	0	0	0
		Max	20.9	36.4	52	0	1.4	20	35.439
5	12 NMC (Nuon) 18650 100% SOC	O2 %	VOC	CO	LEL %	HCN	HF	Particulate	
		Min	20.9	-1.8	-2	0	-0.8	0	0
		Max	20.9	1.1	3	0	0	1.62	23.533
6	44 NMC 21700 Zhejiang Skateboard 100% SOC	O2 %	VOC	CO	LEL %	HCN	HF	Particulate	
		Min	20.9	19.4	0	0	-0.6	0	0
		Max	20.9	135	2460	5	18.2	1.08	100
7	8 NMC Mollicel ISS 21700 <100% SOC	O2 %	VOC	CO	LEL %	HCN	HF	Particulate	
		Min	20.2	0	14	0	1.6	0	0
		Max	20.9	50.5	1190	3	5.8	0	1.439
8	65 NMC KULR Ebike & Amazon 18650 SOC "as shipped"	O2 %	VOC	CO	LEL %	HCN	HF	Particulate	
		Min	20.9	0.3	5	0	0.6	0	0
		Max	20.9	26.4	206	0	1.4	0	0.188
9	18 NMC Mollicel ISS 21700 100% SOC	O2 %	VOC	CO	LEL %	HCN	HF	Particulate	
		Min	20.9	0	0	0	0	0	0.004
		Max	20.9	0.6	3	0	0.6	0	100
10	2 LiFePO4 ESS (Prismatic) 1 charged, 1 uncharged	O2 %	VOC	CO	LEL %	HCN	HF	Particulate	
		Min	20.9	2.1	3	0	0	0	NA
		Max	20.9	165	350	3	4.2	0	NA
11	48 NMC Zhejiang Skateboard 21700 <40V SOC	O2 %	VOC	CO	LEL %	HCN	HF	Particulate	
		Min	20.9	18.9	2.8	12	0	0	0.005
		Max	20.9	94.5	910	3	3	0.49	100
12	48 NMC Zhejiang Skateboard 21700 100% SOC (49.6V)	O2 %	VOC	CO	LEL %	HCN	HF	Particulate	
		Min	20.9	18.9	2.1	10	-2.6	0	0.003
		Max	20.9	87.5	1560	3	13.1	20	100
13	3 x NMC Zhejiang Skateboard in AkkuTrain Box (144 cells total) 100% SOC	O2 %	VOC	CO	LEL %	HCN	HF	Particulate	
		Min	20.9	19.1	0.4	0	0	0	0.005
		Max	20.9	780	11400	37	80.5	0	100

Yellow = over OSHA PEL, Green = H2 over MIE 4% LEL

Contaminant/Sensor	Action Level
Hydrofluoric Acid (HF)	Cal/OSHA PEL = 0.4 ppm, STEL 1 ppm
Hydrogen Cyanide (HCN)	Cal/OSHA PEL = 10 ppm, Ceiling = 4.7 ppm
Hydrogen (H2) LEL%	Minimum Ignition Energy (MIE) is 4,000 ppm or 4% by volume
Carbon Monoxide (CO)	Cal/OSHA PEL = 25 ppm, Ceiling = 200 ppm Also a 40% cross-sensitivity with H2

SAN DIEGO LITHIUM-ION BATTERY FIELD STUDY DATA SUMMARY:

AIR SAMPLING

Sampling Method	Media	Target Analytes
ASTM-D-1945	Tedlar Bag, vacuum box, pump	H2, CO, O2 ppm (v/v) and (m/m)
NIOSH 6010	Colorimetric tubes, pump	HCN
NIOSH 7902	Filter cassette, pump	HF (Fluoride ion vapor and soluble particulate)
NIOSH 7303	Filter cassette, pump	Ag, As, Ba, Be, Cd, Co, Cr, Cu, Mo, Ni, Pb, Sb, Se, Tl, V, Zn Expanded list: Al, Fe, Mn, Sr, Sn, Ti

Run #	Test Media	Air Sampling Data									
3	8 LiFePO4 18500 "Low SOC"	H2	CO	O2	HCN	HF (vapor)	Fluoride (particulate, mg/m3)				
		ppm	260	<100	277k	ND	25	0.23			
		µg/m3	Cu	Ni	Sb	Zn					
7	8 NMC Mollicel ISS 21700 <100% SOC	H2	CO	O2	HCN	HF (vapor)	Fluoride (particulate, mg/m3)				
		ppm	230	740	265K	ND	0.58	43			
		µg/m3	Ag	Ba	Co	Cu	Ni	Pb	Sb	Tl	Zn
		6	19	18000	29000	190k		570	130	9500	
		mg/m3	Al	Fe	Mn	Sr	Ti				
9	18 NMC Mollicel ISS 21700 100% SOC	H2	CO	O2	HCN	HF (vapor)	Fluoride (particulate, mg/m3)				
		ppm	400	790	255k	2.5	0.94	1.3			
		µg/m3	Ba	Co	Cu	Ni	Sb	Tl	Zn		
		3	2800	650	26000	210	20	350			
		mg/m3	Al	Mn	Sr	Ti					
11	48 NMC Zhejiang Skateboard 21700 <40V SOC	H2	CO	O2	HCN	HF (vapor)	Fluoride (particulate, mg/m3)				
		ppm	230	740	265k	ND	0.58	43			
		µg/m3	Co	Cu	Ni	Sb	Zn				
		220	43	1900	120	70					
		mg/m3	Al	Mn							
12	48 NMC Zhejiang Skateboard 21700 100% SOC (49.6V)	H2	CO	O2	HCN	HF (vapor)	Fluoride (particulate, mg/m3)				
		ppm	240	1480	247k	0.87	0.77	24			
		µg/m3	Ba	Co	Cu	Ni	Pb	Sb	Tl	Zn	
		21	7600	7500	70000	430	1400	60	1100		
		mg/m3	Al	Fe	Mn	Sr	Sn	Ti			
13	3 x NMC Zhejiang Skateboard in AkkuTrain Box (144 cells total) 100% SOC	H2	CO	O2	HCN	HF (vapor)	Fluoride (particulate, mg/m3)				
		ppm	14400	16720	264k	ND	0.56	17			
		µg/m3	Ba	Co	Cu	Ni	Pb	Sb	Zn		
		46	3600	2300	33000	220	240	470			
		mg/m3	Al	Fe	Mn	Sr	Sn	Ti			
Yellow = over OSHA PEL, Green = H2 over MIE 4% LEL											

Yellow = over OSHA PEL, Green = H2 over MIE 4% LEL



AIR SAMPLING

Sampling Method	Media	Target Analytes
ASTM-D-1945	Jedlar Bag, vacuum box, pump	H ₂ , CO, O ₂ ppm (v/v) and (m/m)
NIOSH 6010	Colorimetric tubes, pump	HCN
NIOSH 7902	Filter cassette, pump	HF (Fluoride ion vapor and soluble particulate)
NIOSH 7303	Filter cassette, pump	Ag, As, Ba, Be, Cd, Co, Cr, Cu, Mo, Ni, Pb, Sb, Se, Tl, V, Zn Expanded list: Al, Fe, Mn, Sr, Sn, Ti

Run #	Test Media	Air Sampling Data									
3	8 LiFePO4 18500 "Low SOC"	H2	CO	O2	HCN	HF (vapor)	Fluoride (particulate, mg/m3)				
		ppm	260	<100	277k	ND	25	0.23			
		µg/m3	Cu	Ni	Sb	Zn					
7	8 NMC Mollicel ISS 21700 <100% SOC	H2	CO	O2	HCN	HF (vapor)	Fluoride (particulate, mg/m3)				
		ppm	230	740	265K	ND	0.58	43			
		µg/m3	Ag	Ba	Co	Cu	Ni	Pb	Sb	Tl	Zn
9	18 NMC Mollicel ISS 21700 100% SOC	H2	CO	O2	HCN	HF (vapor)	Fluoride (particulate, mg/m3)				
		ppm	400	790	255k	2.5	0.94	1.3			
		µg/m3	Ba	Co	Cu	Ni	Sb	Tl	Zn		
11	48 NMC Zhejang Skateboard 21700 <40V SOC	H2	CO	O2	HCN	HF (vapor)	Fluoride (particulate, mg/m3)				
		ppm	230	740	265k	ND	0.58	43			
		µg/m3	Co	Cu	Ni	Sb	Zn				
12	48 NMC Zhejang Skateboard 21700 100% SOC (49.6V)	H2	CO	O2	HCN	HF (vapor)	Fluoride (particulate, mg/m3)				
		ppm	240	1480	247k	0.87	0.77	24			
		µg/m3	Ba	Co	Cu	Ni	Pb	Sb	Tl	Zn	
13	3 x NMC Zhejang Skateboard in Akkusain Box (144 cells total) 100% SOC	H2	CO	O2	HCN	HF (vapor)	Fluoride (particulate, mg/m3)				
		ppm	14400	16720	264k	ND	0.56	17			
		µg/m3	Ba	Co	Cu	Ni	Pb	Sb	Zn		
Yellow = over OSHA PEL, Green = H2 over MIE 4% LEL											

Occupational/Industrial Limits for Metals of Concern (µg/m³)

Metal	Carcinogen?	IDLH	NIOSH REL (10-hr TWA)	OSHA PEL (8-hr TWA)
Aluminum	No	-	10,000	15,000
Antimony ^a	No	50,000	500	500
Arsenic ^{a,b}	Yes	500	2b	10
Barium	No	50,000	500	500
Beryllium ^{a,c}	Yes	400	0.5	2
Cadmium ^a	Yes	900	N.E.	0.005
Chromium ^a	No	250,000	0.5	1
Cobalt ^a	No	20,000	0.05	0.1
Copper ^d	No	100,000	1	1
Iron	Yes	2,500,000	5,000	10,000
Lead ^{a,e}	No	100,000	50	50
Manganese ^{a,f}	No	500,000	1,000	5,000
Mercury ^{a,g}	No	10,000	0.1	100
Molybdenum	No	1,000,000	5,000	5,000
Nickel ^{a,h}	Yes	10,000	15	1000
Selenium ^{a,i}	No	100	200	200
Silver	No	10,000	10	10
Strontium	No	-	-	-
Thallium	No	15,000	100	100
Titanium	No	-	-	15,000
Tin	No	25,000	2,000	2,000
Vanadium ^j	No	35,000	50	50
Zinc	No	500,000	5,000	15,000

IDLH = Immediately Detrimental to Life and Health
NIOSH = National Institute of Occupational Safety and Health REL = Recommended Exposure Limit
OSHA = Occupational Safety and Health Administration PEL = Permissible Exposure Limit
a Metals designated as Hazardous Air Pollutants by the EPA.
b NIOSH REL for arsenic is a 15-minute ceiling
c OSHA PEL for beryllium has a 30-minute ceiling of 5 µg/m ³
d Additional REL of 0.1 and PEL of 0.1 for copper fume
e NIOSH REL for lead is an 8-hour TWA standard
f NIOSH short term exposure limit (STEL) for manganese is 3,000 µg/m ³ and the PEL is a
g NIOSH REL for mercury for skin is 50 µg/m ³ and the REL is a ceiling
h Nickel as Ni(CO) ₄ has an IDLH of 14,000 µg/m ³ and an REL and PEL of 7 µg/m ³
i Selenium as SeF ₆ has an IDLH of 2000 µg/m ³ and an REL and PEL of 400 µg/m ³
j NIOSH REL for vanadium is a 15-minute limit



Safety and PPE

- Decontamination
 - ▣ Field decon capability
 - ▣ Equipment decon?
 - ▣ Garment Decon-Isolation-Decon/Disposal (PPE Level and Type)
 - Metals and other toxic chemicals
 - Traditional washer extractor
 - San Diego Study (UCLA)
 - ATF-TEEX
 - ▣ FR PPE Disposal, the Future?



DE-ENERGIZING, AIR MONITORING, AND SITE CLEANUP

Li-ion Battery Fire Response Considerations



- Site Safety – Lakes Parkway
- Air Monitoring – Asset Recycling
- Shipping – Mount Horeb
- Disposal – Asset Recycling
- Expertise and Guidance



Site Safety



Lakes Parkway Fire Response, Lawrenceville, GA.

- Fire Department responded to facility, twice, three days apart and requested EPA assistance

Damaged Batteries are Unpredictable





First Fire of the Day – recently packaged bucket



Technically not a Fire?



Second Fire of the Day – bucket packaged 5 days ago







Aftermath



- Approximately 20 buckets were damaged during the second fire
- The bucket that caught fire had been packaged approximately 5 days ago and not been touched/moved for 4 days

Stop Work

Primary Goal:

- ❑ Stop calling the Fire Department

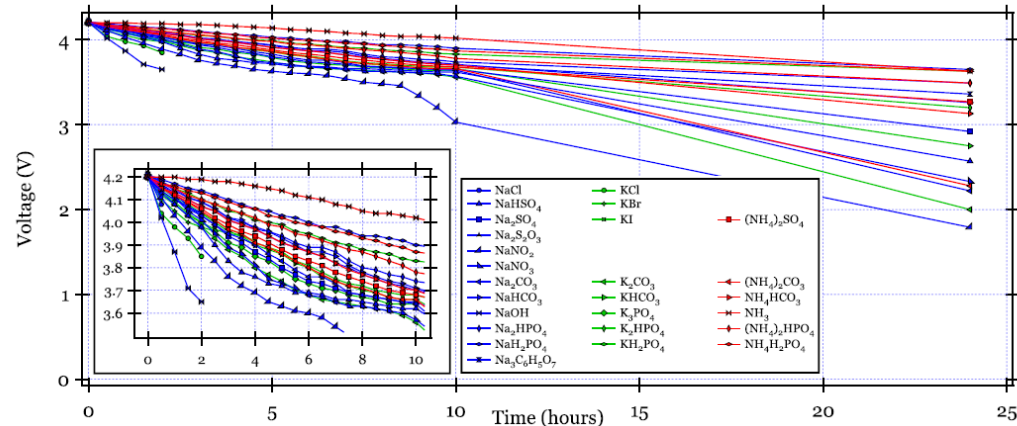
Secondary Goals:

- ❑ Stop having fires
- ❑ Find a way to safely package/ship/dispose of the DDR batteries



De-energizing Batteries

Recycling facilities regularly mentioned that prior to shredding they “soak” the batteries in salt water prior to shredding TO REDUCE EXPLOSIONS during the shredding process.



Battery De-energizing Test



- Saltwater solution – Approximately 0.5% NaCl
- 1 lb NaCl per 25 gallons water
- Soak from 3 days to 3 months
- Potentially toxic and flammable gases similar to plastic fires released during combustion
- 24-hour results indicated full discharge of test batteries



Runoff/Brine Solution Sample Results



89

- TCLP results for RCRA metals have been non-detect for disposal
- Studies show other metals may be present in high concentrations

Brine solution and runoff water are likely to be non-hazardous but should be disposed of at a POTW if possible.

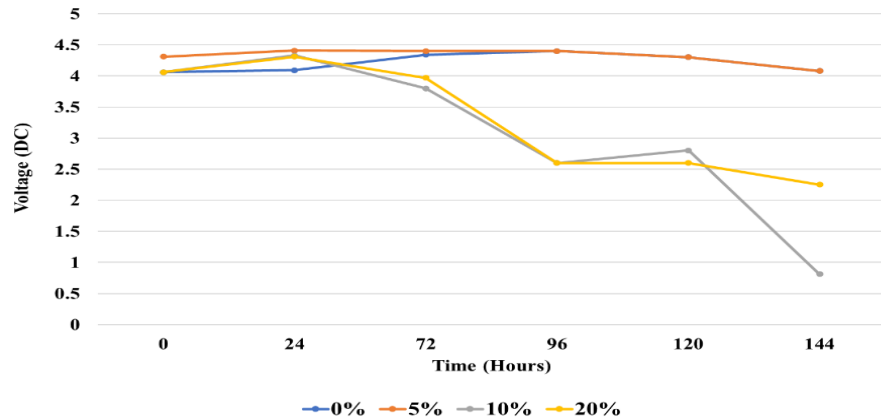
Table 13
Comparison of contamination of sprinkling and storage water with limit and background levels.

Contaminant/ Parameter	Unit	Sprinkling water	Storage water	Process water	Drinking water limit values ⁽¹⁾	Industrial effluent limit value ⁽²⁾
pH value	-	8.2	12.3	8	6.8 - 8.2	6.5 - 9.0
Chloride	mg/l	2	22	3	250	n.s.
Sulphate		34	98	2	250	n.s.
Nitrate		2	< 1	< 1	40	n.s.
Phosphate		<1	< 1	< 1	1	n.s.
Fluoride		8	330	< 1	1.5	n.s.
PAH ^(c)		0.001 ^(a) 0.36 ^(b)	0.02 ^(a) 0.02 ^(b)	0.001 ^(a) < 0.001 ^(b)	0.1	n.s.
Benzo[a]pyrene		< 0.001 ^(a) 0.07 ^(b)	0.004 ^(a) 0.01 ^(b)	< 0.001 ^(a) < 0.001 ^(b)	0.01	n.s.
Nickel	µg/l	36000 ^(a) 48400 ^(b)	55000 ^(a) 181000 ^(b)	< 700	20	2000
Cobalt		36000 ^(a) 46000 ^(b)	50000 ^(a) 181000 ^(b)	< 400	n.s. (≤ 70)	500
Manganese		36000 ^(a) 44000 ^(b)	53000 ^(a) 199000 ^(b)	< 1300	50	n.s.
Lithium		7000 ^(a) 2200 ^(b)	1460000 ^(a) 31000 ^(b)	< 1300	n.s. (≤ 40)	n.s.

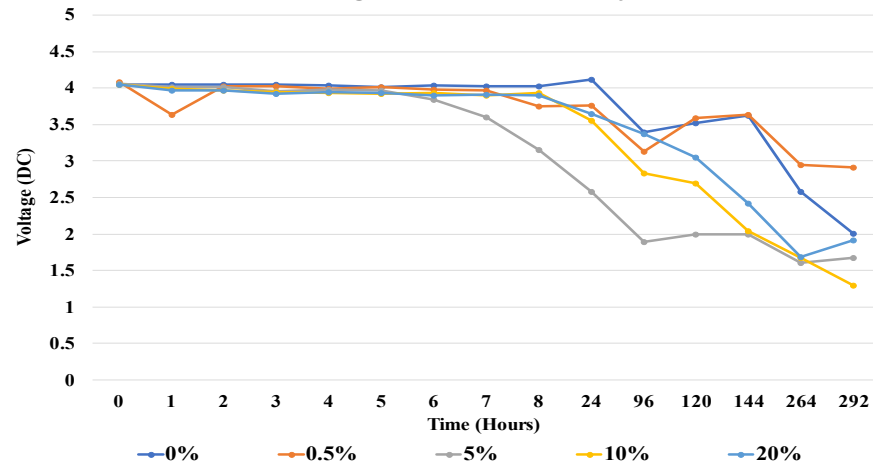
R9 Field Brine Experiments: 12th St Warehouse Fire → Duke Sauce



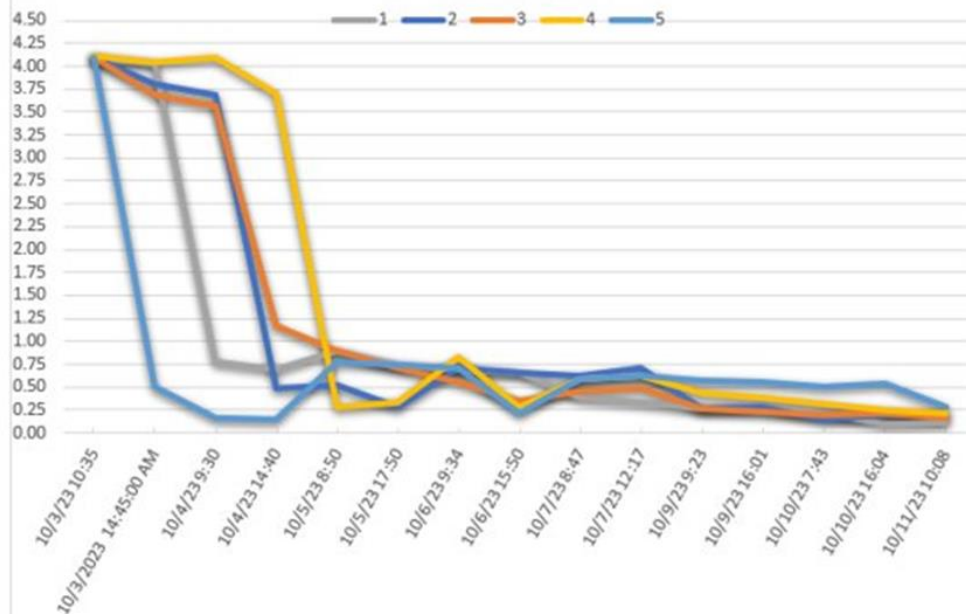
Voltage vs Time in NaCl



Voltage vs Time in NaHCO₃



NaCl (5%) & Bicarb (5%) Bucket: Battery Voltage



Field Brine Experiments: Analytical Results from Maui Brines, Sludges and Battery Materials



Early Maui Brine and Battery Material Analytics

Sample Number 09/27/2023		NaCl 20%	NaCl 6% Bicarb 5%	NaCl 6%	Bicarb 1%	Brined Battery Material Solids	Unbrined Battery Material Solids
Matrix		Liquid	Liquid	Liquid	Liquid	mg/L	mg/L
Units		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
pH		7.19	8.68	7.79	9.83		
Parameter	Reg Limits	Result	Result	Result	Result	Result	Result
CAM 17-TTLC Target Analyte List metals (EPA 6010B/7470A)							
Aluminum		2,100	2,400	3,700	16,000	32,000	22,000
Antimony	500	ND	ND	0.097	1.9	ND	12
Arsenic**	500	ND	0.012	0.017	0.15	160	66
Barium	10,000	0.079	0.035	0.062	4.8	3.0	9.7
Beryllium	75	ND	ND	ND	ND	ND	ND
Cadmium**	100	ND	ND	ND	ND	ND	38
Calcium		110,000	21,000	58,000	17,000	ND	ND
Chromium**	2,500	ND	ND	ND	ND	35	11
Cobalt	8,000	0.24	0.085	0.15	0.73	38,000	16,000
Copper	2,500	ND	0.077	0.12	3.3	110,000	410,000
Iron		4,600	5,200	2,300	5,400	960	4,500
Lead	1,000	ND	0.21	ND	0.11	82	150
Magnesium		93,000	36,000	34,000	11,000	ND	ND
Mercury	20	ND	ND	ND	ND	ND	ND
Molybdenum**	3,500	ND	ND	ND	0.087	ND	ND
Nickel	2,000	0.78	1.5	0.63	3.2	90,000	100,000
Potassium		360,000	77,000	110,000	38,000	470	1,000
Selenium	100	ND	ND	ND	ND	ND	ND
Silver	500	ND	ND	ND	ND	5.6	8.4
Sodium		76,000,000	20,000,000	27,000,000	3,400,000	ND	ND
Thallium	700	ND	ND	ND	ND	83	120
Vanadium**	2,400	ND	0.036	ND	0.065	ND	ND
Zinc	5,000	1.5	0.38	1.4	2.8	260	570
CAM 17-STLC Target Analyte List metals (EPA 6010B/7470A)							
Antimony	15					ND	6.2
Arsenic**	5.0					1.3	28
Barium	100					0.65	5.3
Cadmium**	1.0					ND	18
Chromium**	5.0					ND	5.3
Cobalt	80					120	270
Nickel	20					1,700	750
Silver	5.0					ND	2.5
Thallium	7.0					ND	52
Zinc	250					2.1	280
TCLP Target Analyte List metals (EPA 6010B/7470A)							
Arsenic**	5.0					ND	ND
Barium	100.0					ND	ND
Cadmium**	1.0					ND	ND
Chromium**	5.0					ND	ND
Lead	5.0					ND	ND
Mercury	0.2					ND	ND
Selenium	1.0					ND	ND
Silver	5.0					ND	ND
Yellow = exceedances, red = common fire contaminants, blue = common battery constituents							
** = Analytes seen in Hawaii data set but NOT the San Diego data set, indicating potential wildfire contaminants							

Battery Brine and Crushing Area Soil Analytics Post Phase 1

Sample ID 12/01/2023		Brine Solution 1	Brine Solution 2	Brine Solution 3	Brine Sludge 1	Brine Sludge 2	Brine Sludge 3	Battery Crushing Area 1	Battery Crushing Area 2	Battery Crushing Area 3
Matrix		Water	Water	Water	Sludge	Sludge	Sludge	Soil	Soil	Soil
Units		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
pH		9.0	9.2	9.2	9.7	9.9	9.5	8.4	9.1	9.2
Parameter	Reg Limits	Result	Result	Result	Result	Result	Result	Result	Result	Result
TCLP Target Analyte List metals (EPA 6010B/7470A)										
Arsenic	5.0	ND	ND	ND	ND	ND	ND	0.081	ND	ND
Barium	100.0	ND	ND	ND	0.42	0.25	0.16	0.77	0.55	0.38
Cadmium	1.0	ND	ND	ND	0.14	0.086	0.034	ND	ND	ND
Chromium	5.0	ND	ND	ND	0.16	0.16	0.13	ND	ND	ND
Lead	5.0	ND	ND	ND	ND	ND	ND	11	ND	ND
Mercury	0.2	ND	ND	ND	ND	ND	ND	ND	ND	ND
Selenium	1.0	ND	ND	ND	ND	ND	ND	ND	ND	ND
Silver	5.0	ND	ND	ND	ND	ND	ND	ND	ND	ND
Reactivity (SW-846 Ch7 9012A/Mod 9034)										
Reactive Cyanide	250	ND	ND	ND	ND	ND	ND	ND	ND	ND
Reactive Sulfide	500	ND	ND	ND	ND	ND	ND	ND	ND	ND

Exceedance for lead in Battery Crushing Area Sample likely due to high presence of lead in Pre-Staging area sampling event (see Staging Area Sample Table). Potential fire contaminant.

Arsenic and Cadmium presence may also be due to fire contaminants. Barium presence in sludge samples and crushing areas may be due to cross contamination or spillage, but levels are well below action levels.



Air Monitoring (Strategic)

- First Responder (Fire, Haz-Mat, Police):
 - ▣ Site Characterization: known, assumed, actual
 - Front end gases-materials
 - ▣ Isolation distances and site access control
 - ▣ Protective actions
- Second Responder (DOH, Environmental Response-Protection; Contractors):
 - ▣ Site Characterization: known, assumed, actual
 - Back end gases-materials
 - ▣ Isolation distances and site access control
 - ▣ Protective actions

Air Monitoring



◆ Flammable and Toxic Vapor Production

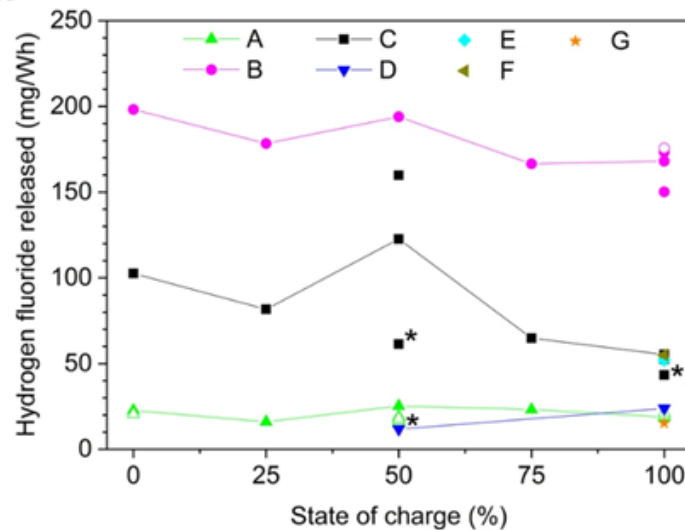
- ◆ The electrolyte in a lithium-ion battery is flammable and generally contains lithium hexafluorophosphate (LiPF₆) or other Li-salts containing fluorine.
- ◆ 6,000 L/kWh of vapors can be released during battery failure.
- ◆ Experimental data has shown that HF can be generated at concentrations between 20 mg/Wh and 200 mg/Wh

Extrapolating those experimental results....

- ◆ Electric Vehicle
(approximately 100 kWh)
 - 600,000 L of vapors
 - 2-20kg HF
- ◆ Energy Storage System
(approximately 3MWh)
 - 18,000,000 L of vapors
 - 60-600kg HF

From: [Toxic fluoride gas emissions from lithium-ion battery fires](#)

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Asset Recycling Fire, GA.



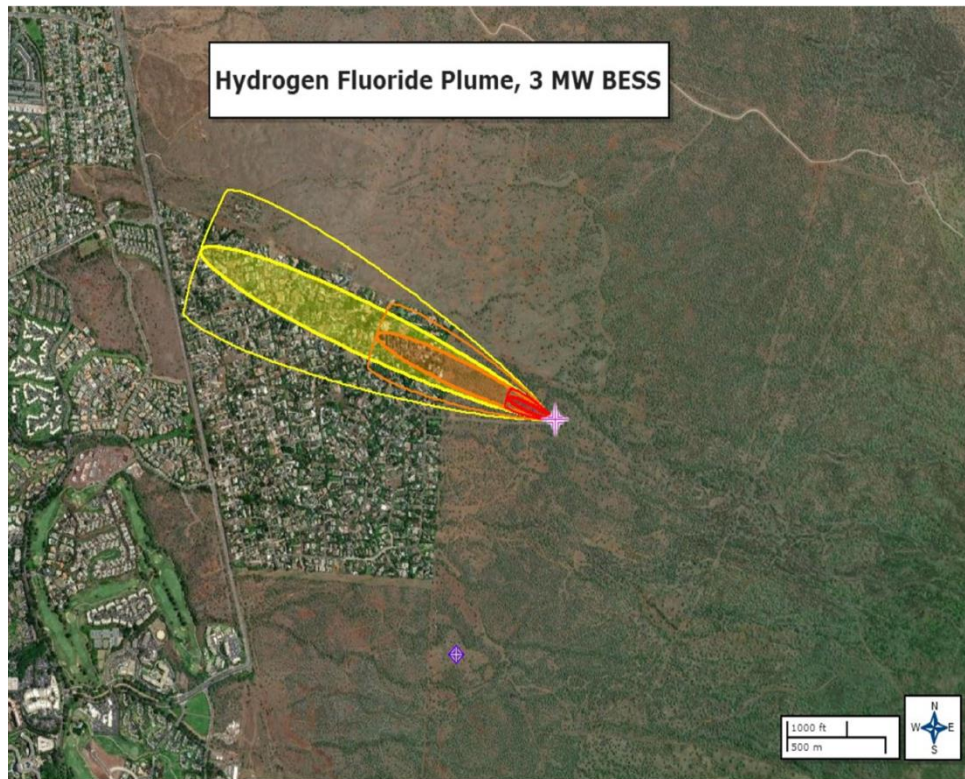
Asset Recycling – Air Monitoring



HF detections inside
the downwind building
approximately 0.5
ppm

Air monitoring capabilities and decision making (Tactical)

- Like most fires quantifying the constituents of the smoke is difficult, even with the appropriate instruments immediately available
 - ▣ Particulate monitoring may be useful to indicate direction of plume
- Typical public statement consistent with an industrial fire is appropriate for a battery fire
 - ▣ “No amount of smoke is healthy.”



Air Monitoring (Tactical)

- ▣ Site Characterization: known, assumed, actual

- | | |
|---|--|
| <ul style="list-style-type: none">▣ hydrogen▣ carbon monoxide▣ hydrogen fluoride▣ hydrogen chloride▣ hydrogen cyanide▣ phosphoryl fluoride | <ul style="list-style-type: none">▣ organic droplets▣ ethane▣ methane▣ other hydrocarbons-VOC▣ Smoke particulates / metals |
|---|--|
- Isolation distances and site access control
 - Protective actions

Air Monitoring – Potential EPA Approach



Target Compound	Equip	Sensor	Concerns
Carbon Monoxide	MultiRAE AreaRAE	CO+H2S	CO cross-sensitive to H2; H2S sensitive to SO2
Carbon Dioxide	None		
Hydrofluoric Acid (Hydrogen Fluoride)	SPM Flex	Mineral Acid	Quantity of tapes available
Sulfur Dioxide	MultiRAE Drager	SO2	SO2 sensor not always installed
Hydrogen	MultiRAE AreaRAE	H2+LEL+ CO	Reduced sensitivity in low O2
Particulates	DustTrak	PM2.5	Metals not distinguishable from smoke



Air Monitoring – RAE Sensors



Target Compound	Ionization Potential	RAE Sensor	Detection Range
Carbon Monoxide	14.01 eV	CO	0-500 ppm
Hydrofluoric Acid (Hydrogen Fluoride)	15.98 eV	HF	0.5-10 ppm
Sulfur Dioxide	12.3 eV	SO2	0-20 ppm
Hydrogen	15.43 eV	LEL H2	0-100% (0-30% O2) 0-1000 ppm



Air Monitoring – Dräger Tube



Target Compound	Tube Available	CMS Chip Available	Detection Range
Carbon Monoxide	✓	✓	.3 - 7 % Vol.
Carbon Dioxide	✓	✓	1 - 20 % Vol.
Hydrofluoric Acid (Hydrogen Fluoride)	✓		0.5-15 ppm, 10-90 ppm
Sulfur Dioxide	✓	✓	≥0.1-3 ppm
Hydrogen	✓		0.2 - 2 % Vol. 0.5 - 3 % Vol.



SAN DIEGO LITHIUM-ION BATTERY FIELD STUDY DATA SUMMARY:

AIR MONITORING

Run	Test Media	Air Monitoring Data							
1	4 LiFePO4 100% SOC	O2 %	VOC	CO	LEL %	HCN	HF	Particulate	
		Min 20.9	-2.7	-1	0	0	0	0.001	
		Max 20.9	0	5	0	0.8	0.58	0.707	
2	4 LiFePO4 18500 SOC Unknown	O2 %	VOC	CO	LEL %	HCN	HF	Particulate	
		Min 20.9	-2.7	0	0	0	0	0	
		Max 20.9	9.8	36	0	1.1	20	10.082	
3	8 LiFePO4 18500 "Low SOC"	O2 %	VOC	CO	LEL %	HCN	HF	Particulate	
		Min 20.9	-2.1	0	0	0	0	0	
		Max 20.9	66.5	171	2	3.9	0.95	7.567	
4	8 LiFePO4 18500 100% SOC	O2 %	VOC	CO	LEL %	HCN	HF	Particulate	
		Min 20.9	-0.6	3	0	0	0	0	
		Max 20.9	36.4	52	0	1.4	20	35.439	
5	12 NMC (Nuon) 18650 100% SOC	O2 %	VOC	CO	LEL %	HCN	HF	Particulate	
		Min 20.9	-1.8	-2	0	-0.8	0	0	
		Max 20.9	1.1	3	0	0	1.62	23.533	
6	44 NMC 21700 Zheiang Skateboard 100% SOC	O2 %	VOC	CO	LEL %	HCN	HF	Particulate	
		Min 19.4	0	0	0	-0.6	0	0	
		Max 20.9	135	2460	3	18.2	1.08	100	
7	8 NMC Mollicel ISS 21700 <100% SOC	O2 %	VOC	CO	LEL %	HCN	HF	Particulate	
		Min 20.2	0	14	0	1.6	0	0	
		Max 20.9	50.5	1190	3	5.8	0	1.439	
8	65 NMC KULR Ebike & Amazon 18650 SOC "as shipped"	O2 %	VOC	CO	LEL %	HCN	HF	Particulate	
		Min 20.9	0.3	5	0	0.6	0	0	
		Max 20.9	26.4	206	0	1.4	0	0.188	
9	18 NMC Mollicel ISS 21700 100% SOC	O2 %	VOC	CO	LEL %	HCN	HF	Particulate	
		Min 20.9	0	0	0	0	0	0.004	
		Max 20.9	0.6	3	0	0.6	0	100	
10	2 LiFePO4 ESS (Prismatic) 1 charged, 1 uncharged	O2 %	VOC	CO	LEL %	HCN	HF	Particulate	
		Min 20.9	2.1	3	0	0	0	NA	
		Max 20.9	165	350	3	4.2	0	NA	
11	48 NMC Zheiang Skateboard 21700 <40V SOC	O2 %	VOC	CO	LEL %	HCN	HF	Particulate	
		Min 18.9	2.8	12	0	0	0	0.005	
		Max 20.9	84.5	910	3	3	0.45	100	
12	48 NMC Zheiang Skateboard 21700 100% SOC (49.6V)	O2 %	VOC	CO	LEL %	HCN	HF	Particulate	
		Min 18.9	2.1	10	0	-2.6	0	0.003	
		Max 20.9	87.5	1560	3	13.1	20	100	
13	3 x NMC Zheiang Skateboard in Akkusmart Box (144 cells total) 100% SOC	O2 %	VOC	CO	LEL %	HCN	HF	Particulate	
		Min 19.1	0.4	0	0	0	0	0.005	
		Max 20.9	780	11400	37	80.5	0	100	

Yellow = over OSHA PEL, Green = H2 over MIE 4% LEL

Contaminant/Sensor	Action Level
Hydrofluoric Acid (HF)	Cal/OSHA PEL = 0.4 ppm, STEL 1 ppm
Hydrogen Cyanide (HCN)	Cal/OSHA PEL = 10 ppm, Ceiling = 4.7 ppm
Hydrogen (H2) LEL%	Minimum Ignition Energy (MIE) is 4,000 ppm or 4% by volume
Carbon Monoxide (CO)	Cal/OSHA PEL = 25 ppm, Ceiling = 200 ppm Also a 40% cross-sensitivity with H2

SAN DIEGO LITHIUM-ION BATTERY FIELD STUDY DATA SUMMARY:

AIR SAMPLING

Sampling Method	Media	Target Analytes
ASTM-D-1945	Tedlar Bag, vacuum box, pump	H2, CO, O2 ppm (v/v) and (m/m)
NIOSH 6010	Colorimetric tubes, pump	HCN
NIOSH 7902	Filter cassette, pump	HF (vapor and soluble particulate)
NIOSH 7303	Filter cassette, pump	Ag, As, Ba, Be, Cd, Co, Cr, Cu, Mo, Ni, Pb, Sb, Se, Si, Ti, V, Zn Expanded list: Al, Fe, Mn, Sr, Sn, Ti

Run #	Test Media	Air Sampling Data											
3	8 LiFePO4 18500 "Low SOC"	H2	CO	O2	HCN	HF (vapor)		HF (particulate, mg/m3)					
		ppm	260	<100	277k	ND	25		0.23				
		µg/m3	Cu	Ni	Sb	Zn							
7	8 NMC Mollicel ISS 21700 <100% SOC	H2	CO	O2	HCN	HF (vapor)		HF (particulate, mg/m3)					
		ppm	230	740	265K	ND	0.58		43				
		µg/m3	Ag	Ba	Co	Cu	Ni	Pb	Sb	Tl	Zn		
9	18 NMC Mollicel ISS 21700 100% SOC	H2	CO	O2	HCN	HF (vapor)		HF (particulate, mg/m3)					
		ppm	400	790	255k	2.5	0.94		1.3				
		µg/m3	Ba	Co	Cu	Ni	Sb	Tl	Zn				
11	48 NMC Zhejiang Skateboard 21700 <40V SOC	H2	CO	O2	HCN	HF (vapor)		HF (particulate, mg/m3)					
		ppm	230	740	265k	ND	0.58		43				
		µg/m3	Co	Cu	Ni	Sb	Zn						
12	48 NMC Zhejiang Skateboard 21700 100% SOC (49.6V)	H2	CO	O2	HCN	HF (vapor)		HF (particulate, mg/m3)					
		ppm	240	1480	247k	0.87	0.77		24				
		µg/m3	Ba	Co	Cu	Ni	Pb	Sb	Tl	Zn			
13	3 x NMC Zhejiang Skateboard in Akkusmart Box (144 cells total) 100% SOC	H2	CO	O2	HCN	HF (vapor)		HF (particulate, mg/m3)					
		ppm	14400	16720	264k	ND	0.56		17				
		µg/m3	Ba	Co	Cu	Ni	Pb	Sb	Zn				
Yellow = over OSHA PEL, Green = H2 over MIE 4% LEL													

Yellow = over OSHA PEL, Green = H2 over MIE 4% LEL



Air monitoring capabilities and decision making (Tactical)



ONE TO SIX GAS PORTABLE MONITOR

Gas Detection For Life

EAGLE 3 Model



Features

- Monitor up to 6 different gases
- PPM, % LEL, or % Vol. auto-ranging combustibles
- EC / PID / TC / CAT / IR Sensor technologies
 - Standard 4 Gases (LEL, O2, H2S, CO)
 - Toxic Gases
 - 10.6 eV, 10.0 eV and 11.7 eV PID
- Powerful long-life pump up to 125' range
- Low flow pump shut off and alarm
- Methane elimination for environmental use
- Li-ion rechargeable battery pack
- Internal hydrophobic dust filter
- External probe with hydrophobic filter
- RFI / EMI / chemical / weather resistant enclosure
- Intrinsically safe design
- Datalogging standard
- Bluetooth communication





IR-hydrocarbons Auto Range: TC-Cal to H2 Non-Auto Range:

Not With Eagle 3

[illegible]



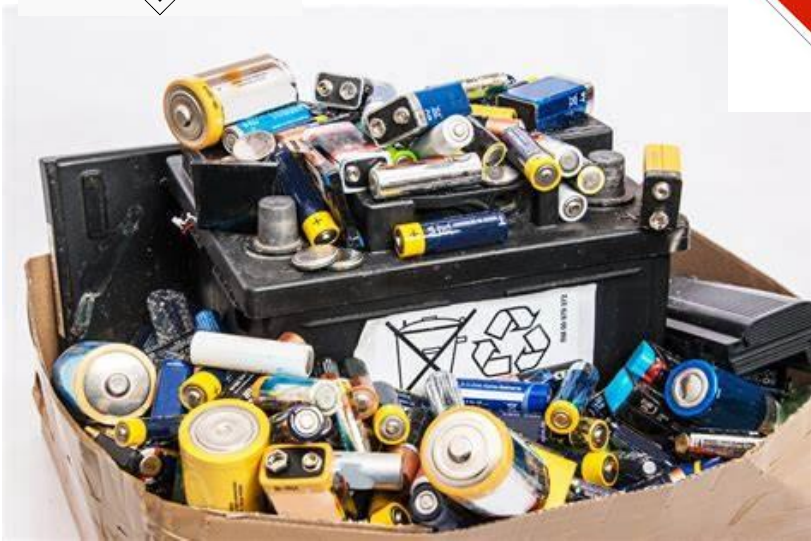
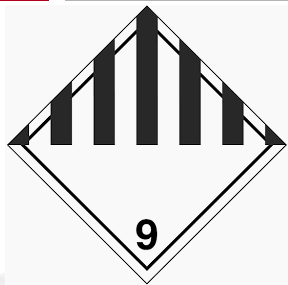
Air Monitoring and Sampling

- **Air Monitoring (Real-time/Near real-time):**
 1. Smoke plume modeling (IMAAC: Inter Agency Modeling and Atmospheric Assessment Center, (877) 240-1187), down range monitoring.
 2. Particulate/vapor real-time air monitoring (Dust Trak, Multi-RAE, Real-time instruments)
 3. Field Portable GC/MS, MS, GAS ID
 4. Dust concentration in air calculations (concentration in soil, dust, air)

- **Air Sampling (Not real-time requires laboratory analysis):**
 1. Air sampling: pump to cassette for perimeter
 2. Air sampling: pump to cassette for personnel
 3. Summa Canister or Tedlar bags

What is it?:

Battery? Battery Debris? Hazardous? Non-Hazardous? Scrap Metal? Regulated?



- Background
 - Lithium-ion Batteries present various hazards during use and at end of life
 - DOT damaged battery (DDR, 49 CFR 173.185 (f) Regs burdensome, expensive and ineffective to address safety concerns.
 - Alternative techniques have been developed on Maui; however, required changes/updates to 40 CFR and 49 CFR are needed.

Shipping – DOT Restrictions for DDR Batteries, 49 CFR 173.185 (f)



- (f) *Damaged, defective, or recalled cells or batteries.* Lithium cells or batteries that have been damaged or identified by the manufacturer as being defective for safety reasons, that have the potential of producing a dangerous evolution of heat, fire, or short circuit (e.g., those being returned to the manufacturer for safety reasons) may be transported by highway, rail or vessel only, and must be packaged as follows:
- (1) Each cell or battery must be placed in individual, non-metallic inner packaging that completely encloses the cell or battery;
 - (2) The inner packaging must be surrounded by cushioning material that is non-combustible, electrically non-conductive, and absorbent; and
 - (3) Each inner packaging must be individually placed in one of the following packagings meeting the applicable requirements of part 178, subparts L, M, P, and Q of this subchapter at the Packing Group I level:

DOT Special Permits



- Allow for operations outside of the Hazardous Materials Regulations, providing a similar level of security can be met
- Require a submittal for approval and can take 7-90 days to be approved
- Can be issued to a company
 - ▣ Special permits using special packages and special cushioning!!!
 - ▣ These will be limited to certain circumstances/use cases
- Can be issued to a site
 - ▣ EPA R4 requested a permit that was site-specific at the Lakes Parkway Site

DOT Special Permits



1200 New Jersey Avenue, SE
Washington, DC 20590

SPECIAL PERMIT AUTHORIZATION

DOT-SP 16532

EXPIRATION DATE: 2025-12-31

GRANTEE: Call2recycle, Inc.
Atlanta, GA

In response to your January 19, 2024, application for party status to DOT-SP 16532, Call2recycle, Inc. is hereby granted party status to DOT-SP 16532 as a shipper only in accordance with 49 CFR 107.113.

Copies of this special permit may be obtained by accessing the Office of Hazardous Materials Safety Homepage at <https://www.phmsa.dot.gov/approvals-and-permits/hazmat/special-permits-search>. The most recent revision of the special permit supersedes all previous revisions of the special permit. Photo reproductions and legible reductions of this special permit are permitted. Any alteration of this special permit is prohibited.

If you have questions regarding this action please call the Office of Hazardous Materials Safety, General Approvals and Permits Branch at (202) 366-4535.

Issued in Washington D.C. on January 25, 2024.

A handwritten signature in blue ink, appearing to read 'William Schoonover'.

for William Schoonover
Associate Administrator for Hazardous Materials Safety

Tracking Number: 2024015356

DUNS Number on file: 867231110



U.S. Department
of Transportation

Pipeline and Hazardous
Materials Safety Administration

East Building, PHH-30
1200 New Jersey Avenue S.E.
Washington, D.C. 20590

September 04, 2019

DOT-SP 16532
(SECOND REVISION)

(FOR RENEWAL, SEE 49 CFR § 107.109)

1. GRANTEE: (see individual authorization letter)

2. PURPOSE AND LIMITATION:

a. This special permit authorizes the transportation in commerce of certain damaged, defective, or recalled lithium ion cells and batteries and lithium metal cells and batteries in alternative packaging. This special permit provides no relief from the Hazardous Materials Regulations (HMR) other than as specifically stated herein. The most recent revision supersedes all previous revisions.

b. The safety analyses performed in the development of this special permit only considered the hazards and risks associated with the transportation in commerce.

c. Unless otherwise stated herein, this special permit consists of the special permit authorization letter issued to the grantee together with this document.

DOT Special Permits



U.S. Department of Transportation
**Pipeline and Hazardous Materials
Safety Administration**

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Show 10 entries

SP Number	Tracking Number	Company	City	State	Application Date	Granted Date	Expiration Date
SP16532	2023054219	Energy Security Agency, Inc.	Galena	Oh	05/05/2023	05/25/2023	04/30/2025
SP16532	2023074040	Environmental Quality Management, Inc.	Cincinnati	Oh	06/30/2023	07/12/2023	06/30/2025
SP16532	2023074309	Battalion Response Consulting LLC	Highland	Il	11/03/2023	12/08/2023	10/31/2025
SP16532	2023094159	Union Battery Disposal Inc	Ontario	Ca	09/05/2023	11/16/2023	10/31/2025
SP16532	2023104634	Rivian Automotive, LLC	Plymouth	Mi	10/12/2023	10/18/2023	09/30/2025
SP16532	2023124013	Cascade Asset Management, LLC	Madison	Wi	11/29/2023	12/08/2023	11/30/2025
SP16532	2023124595	Alliance Fulfillment LLC	Marietta	Ga	12/11/2023	01/17/2024	12/31/2025
SP16532	2024015356	Call2recycle, Inc.	Atlanta	Ga	01/19/2024	01/25/2024	12/31/2025
SP16532	2024024350	Federal Prison Industries, Inc.	Marianna	Fl	02/08/2024	02/26/2024	01/31/2026
SP16532	2024034647	Amazon.com, Inc.	Seattle	Wa	03/25/2024	03/28/2024	02/29/2028

Showing 41 to 50 of 55 entries

[Previous](#) [1](#) [2](#) [3](#) [4](#) [5](#) [6](#) [Next](#)

DOT Special Permits



Continuation of DOT-SP 16532 (2nd Rev.) Page 2

September 04, 2019

6. HAZARDOUS MATERIALS (49 CFR § 172.101):

Hazardous Materials Description			
Proper Shipping Name	Hazard Class/Division	Identification Number	Packing Group
Lithium ion batteries*	9	UN3480	N/A
Lithium ion batteries contained in equipment*	9	UN3481	N/A
Lithium ion batteries packed with equipment*	9	UN3481	N/A
Lithium metal batteries*	9	UN3090	N/A
Lithium metal batteries contained in equipment*	9	UN3091	N/A
Lithium metal batteries packed with equipment*	9	UN3091	N/A

*Only damaged, defective, or recalled lithium cells and batteries are authorized under the terms of this special permit.

7. SAFETY CONTROL MEASURES:a. PACKAGING:

(1) Each damaged, defective, or recalled lithium cell or battery, including those packed with equipment, or each piece of equipment containing such cells or batteries must be individually packed in individual, non-metallic inner packaging that completely encloses the cell, battery, or equipment, as applicable.

(2) Each cell, battery, or equipment inside the inner packaging must be surrounded:

(i) With non-combustible, non-conductive, and inert absorbent material sufficient to absorb any release of electrolyte; or

Continuation of DOT-SP 16532 (2nd Rev.)

Page 3

September 04, 2019

(ii) Completely with at least 2 inches of a thermally insulating fire suppressant surrounding each cell, battery, or equipment as described in the April 9, 2019 supplemental information which is on file with the Office of Hazardous Materials Safety Approvals and Permits Division. The thermally insulating fire suppressant must be in a sufficient quantity to absorb all of the potential release of electrolyte; suppress lithium cell/battery fires, heat and smoke; absorb the smoke, gases and flammable vapors and electrolytes during a thermal runaway incident; and will protect from the effects of shock and vibration and prevent movement of the cells, batteries and/or the equipment, and that is sufficient to absorb any release of electrolyte.

(3) The inner packaging containing the damaged, defective, or recalled lithium cell or battery or those contained in or packed with equipment must be placed in a 55-gallon, 30-gallon or 5-gallon metal or plastic drum meeting the Packing Group I performance level.

(4) The inner packaging or outer packaging must be leak-proof to prevent the potential release of electrolyte.

(5) Non-combustible, non-conductive, and absorbent cushioning material must fill the void spaces within the outer packaging to protect from the effects of shock and vibration and to prevent movement of the inner packagings containing cells, batteries and equipment, as applicable.

(6) If cells or batteries must comply with paragraph 7.b.(4), a venting device must be used for leaking cells or batteries.

(7) The gross weight of a 55-gallon, 30-gallon or 5-gallon drum may not exceed 181 kg (400 pounds), 91 kg (200 pounds) or 16 kg (35 pounds), respectively.

b. OPERATIONAL CONTROLS:

(1) Each cell and battery must be protected against short-circuiting.

DOT Special Permits



Continuation of DOT-SP 16532 (2nd Rev.)

Page 4

September 04, 2019

(2) A lithium metal cell or battery individually or contained in equipment in an inner packaging may not exceed 5 g or 25 g in lithium metal content, respectively. Each inner packaging may contain no more than 5 g or 25 g of lithium content for cells or batteries, respectively.

(3) A lithium ion cell or battery individually or contained in equipment in an inner packaging may not exceed 60 Wh or 300 Wh in energy content, respectively. Each inner packaging may contain no more than 60 Wh or 300 Wh of energy content for cells or batteries, respectively.

(4) Cells or batteries liable to rapidly disassemble, dangerously react, produce a flame or a dangerous evolution of heat or a dangerous emission of toxic, corrosive or flammable gases or vapors under normal conditions of transport may not be transported except under paragraph 7.b.(4) of this special permit. The damaged or defective cell or battery may be transported if for a period of at least seven (7) days prior to transport there is no evidence of venting, leakage, heat, smoke, fire or other adverse reaction.

(5) MARKING: Each package shipped under the terms of this special permit must be durably and legibly marked and displayed on a contrasting background in proximity to the markings and labels required by the HMR with the following:

(i) "DOT-SP 16532";

(ii) "Damaged/Defective Lithium Ion Batteries" or "Damaged/Defective Lithium Metal Batteries," as appropriate.

8. SPECIAL PROVISIONS:

a. A person who is not a holder of this special permit who receives a package covered by this special permit may reoffer it for transportation provided no modification or change is made to the package and it is reoffered for transportation in conformance with this special permit and the HMR.

Continuation of DOT-SP 16532 (2nd Rev.)

Page 5

September 04, 2019

b. A current copy of this special permit must be maintained at each facility where the package is offered or reoffered for transportation.

9. MODES OF TRANSPORTATION AUTHORIZED: Motor vehicle and rail freight.

10. MODAL REQUIREMENTS: A current copy of this special permit must be carried aboard each motor vehicle used to transport packages covered by this special permit.

11. COMPLIANCE: Failure by a person to comply with any of the following may result in suspension or revocation of this special permit and penalties prescribed by the Federal hazardous materials transportation law, 49 U.S.C. 5101 et seq:

- o All terms and conditions prescribed in this special permit and the Hazardous Materials Regulations, 49 CFR Parts 171-180.
- o Persons operating under the terms of this special permit must comply with the security plan requirement in Subpart I of Part 172 of the HMR, when applicable.
- o Registration required by § 107.601 et seq., when applicable.

Each "Hazmat employee", as defined in § 171.8, who performs a function subject to this special permit must receive training on the requirements and conditions of this special permit in addition to the training required by §§ 172.700 through 172.704.

No person may use or apply this special permit, including display of its number, when this special permit has expired or is otherwise no longer in effect.

Under Title VII of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU)–"The Hazardous Materials Safety and Security Reauthorization Act of 2005" (Pub. L. 109-59), 119 Stat. 1144 (August 10, 2005), amended the Federal hazardous materials transportation law by changing the term "exemption" to "special permit" and authorizes a special

DOT Special Permits



Continuation of DOT-SP 16532 (2nd Rev.)

Page 6

September 04, 2019

permit to be granted up to two years for new special permits and up to four years for renewals.

12. **REPORTING REQUIREMENTS:** Shipments or operations conducted under this special permit are subject to the Hazardous Materials Incident Reporting requirements specified in 49 CFR §§ 171.15 - Immediate notice of certain hazardous materials incidents, and 171.16 - Detailed hazardous materials incident reports. In addition, the grantee(s) of this special permit must notify the Associate Administrator for Hazardous Materials Safety, in writing, of any incident involving a package, shipment or operation conducted under terms of this special permit.

Issued in Washington, D.C.:

A handwritten signature in blue ink, appearing to read "W. Schoonover".

for William Schoonover
Associate Administrator for Hazardous Materials Safety

Address all inquiries to: Associate Administrator for Hazardous Materials Safety, Pipeline and Hazardous Material Safety Administration, U.S. Department of Transportation, East Building PHH-30, 1200 New Jersey Avenue, Southeast, Washington, D.C. 20590.

Copies of this special permit may be obtained by accessing the Hazardous Materials Safety Homepage at http://hazmat.dot.gov/sp_app/special_permits/spec_perm_index.htm. Photo reproductions and legible reductions of this special permit are permitted. Any alteration of this special permit is prohibited.

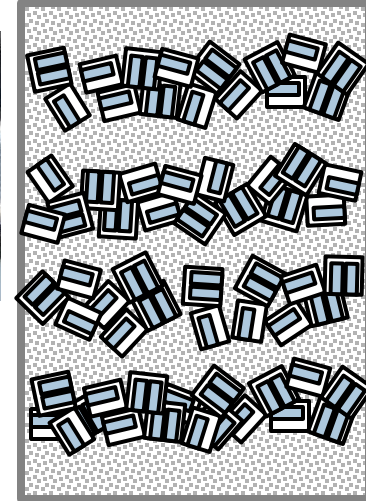
PO: Steve H

DOT SP-16532:

Held by cleanup company - not site specific



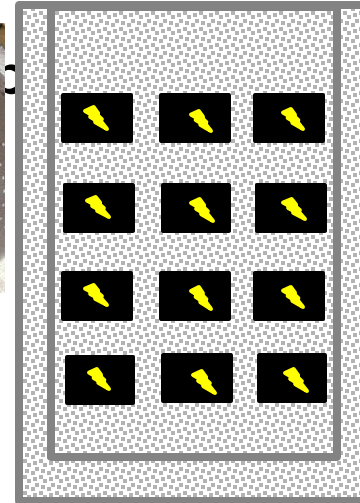
- Special Permit to package multiple “small” lithium ion batteries



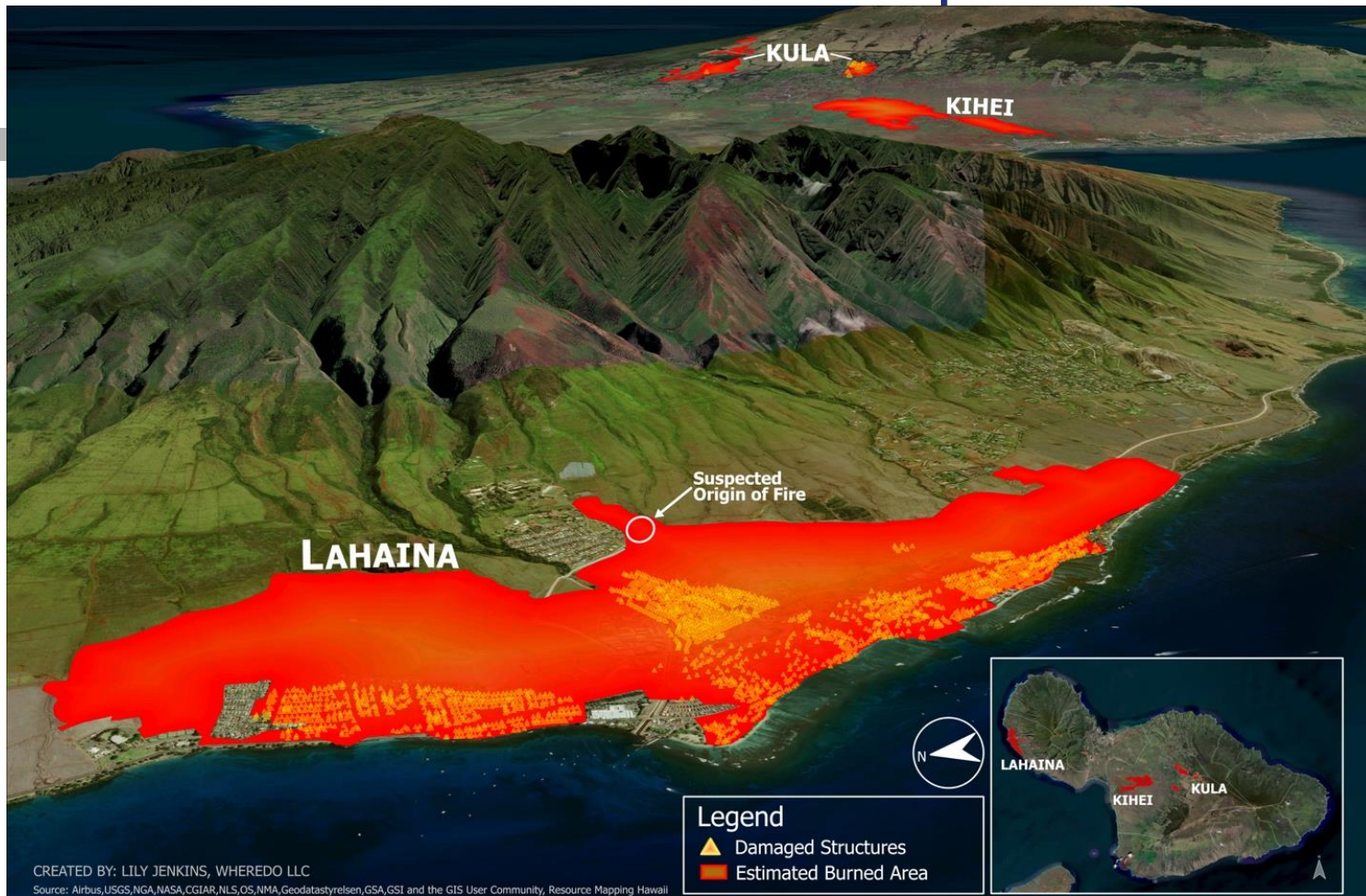
DOT SP-21329 – held by R4, site specific



- Special Permit to package multiple “large” lithium-ion batteries (>300Wh, 14 lbs)



Maui Waste Determination and Transportation



Waste Determination and Transportation



- Maui Problem
 - Damaged, defective or recalled lithium-ion battery have special packaging that was intended to mitigate hazards but effectively does not prevent build-up/release of toxic and explosive gases; and is expensive.
 - Shipping of material is cost prohibitive and subject to risk- based acceptance procedures of carriers.
 - Shippers/carriers do not prefer to accept fire impacted batteries (DDR).
 - Without additional material processing, the general industry expectation is that fire impacted batteries will move as hazardous waste due to reactivity (DDR).

Waste Determination and Transportation



- Actions (Maui)
 - Crush/destroy/de-construct (No longer meets definitions)
 - 40 CFR 273.9 *Battery* means a device consisting of one or more electrically connected electrochemical cells which is designed to receive, store, and deliver electric energy. An electrochemical cell is a system consisting of an anode, cathode, and an electrolyte, plus such connections (electrical and mechanical) as may be needed to allow the cell to deliver or receive electrical energy. The term battery also includes an intact, unbroken battery from which the electrolyte has been removed.
 - 49 CFR 171.8 *Lithium ion cell or battery* means a rechargeable electrochemical cell or battery in which the positive and negative electrodes are both lithium compounds constructed with no metallic lithium in either electrode. A lithium ion polymer cell or battery that uses lithium ion chemistries, as described herein, is regulated as a lithium ion cell or battery.

Waste Determination and Transportation



Waste Determination and Transportation



- Actions (Maui)
 - Material still observed to generated very limited toxic and flammable gases (Electrolysis, hydrolysis, oxidation, and/or decomposition)
 - UN Test

33.5.4 *Test N.5: Test method for substances which in contact with water emit flammable gases*

33.5.4.4.4 Packing group III/Category 3 should be assigned to any substance which reacts slowly with water at ambient temperatures such that the maximum rate of evolution of flammable gas is greater than 1 litre per kilogram of substance per hour, and which does not meet the criteria for packing groups I or II/Categories 1 or 2.

Waste Determination and Transportation

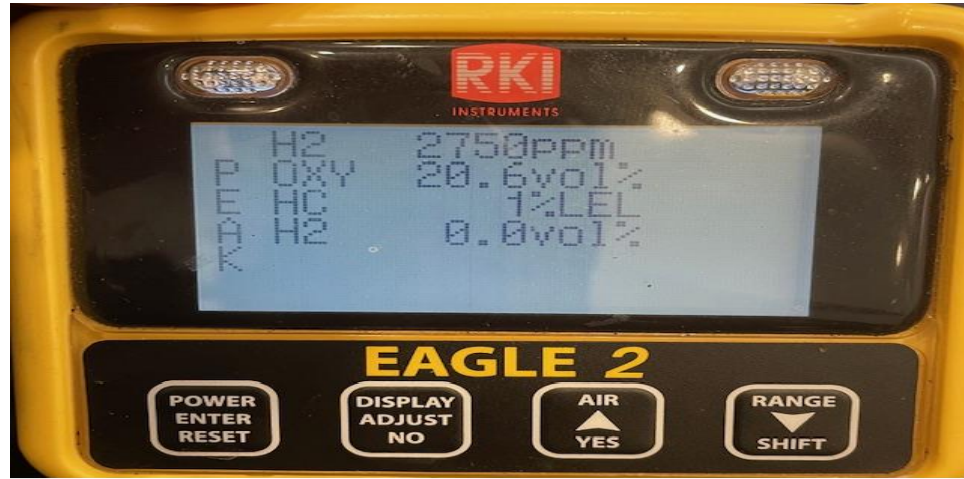


Actions (Maui)

- Material moved in packaging that provides:
 - Ventilation (Highest Readings Taken)
 - CO sensor is a 40% H₂ Sensor
 - 400 PPM of CO=1000 PPM of Hydrogen or .1%v
 - LEL of H₂ is 4% so .1%v= 2.5% of LEL
 - Particulate Control
 - Water Intrusion Control
- Packaging transported in open top containers



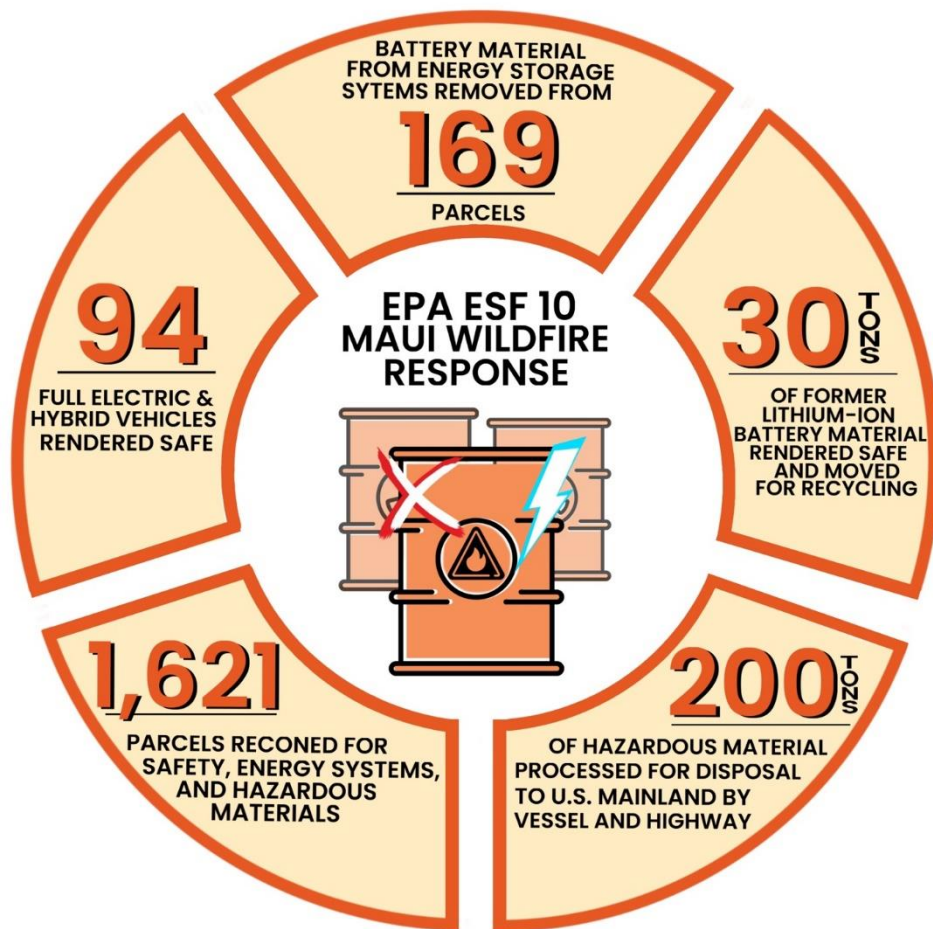
Waste Determination and Transportation: H2 Management



Carrier to West Coast to Recycler



Waste Determination and Transportation



Disposal



- End-Point Recycling Facilities offer the best option for disposal?
- Risk? \$Cost? Efficient?

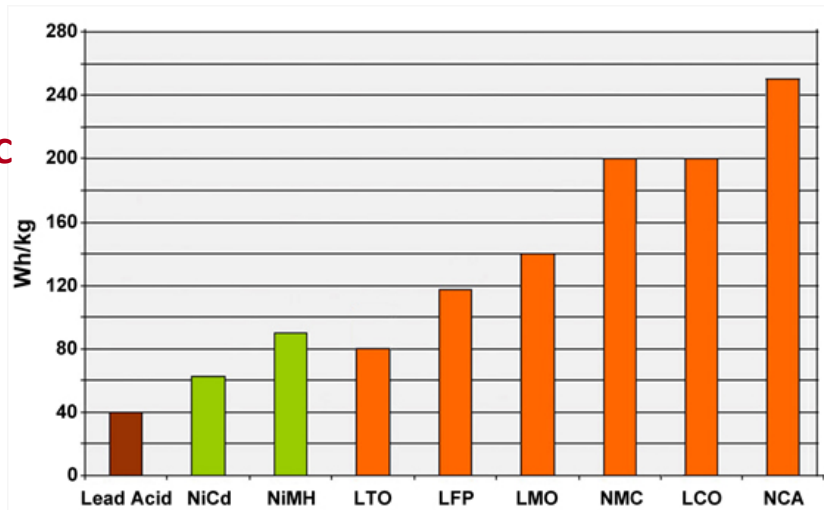


- Discharge battery (3 days in brine)
- Aqueous grind battery to 0.5" or less pieces
- Extract metals?
- Dispose of remaining mash?

Li-ion Battery Chemistries

- Lithium Cobalt Oxide(LiCoO_2) — LCO
- Lithium Nickel Cobalt Aluminum Oxide (LiNiCoAlO_2) — NCA
- Lithium Nickel Manganese Cobalt Oxide (LiNiMnCoO_2) — NMC
- Lithium Manganese Oxide (LiMn_2O_4) — LMO
- Lithium Iron Phosphate(LiFePO_4) — LFP
- Lithium Titanate (Li_2TiO_3) — LTO

Different chemistries cannot all be recycled together (depends upon recycler)



Involve Recycling Facilities Early



- Tour the site
- Advise on potential chemistries
- Rent drums
 - ▣ \$100 to rent
 - ▣ \$800-1200 to buy new
- Special Permits?
- RFP, large incident.
- Do not try to do on-site grinding yet
- **Regulations and Choices**





TRANSPORT AND DISPOSAL



Lithium Battery Incident

PHMSA – 2023



U.S. Department of Transportation
**Pipeline and Hazardous Materials
Safety Administration**



PHMSA Understanding DDR Batteries



Houston TX – April 23, 2017



Shipping
container exploded
while in transportation
by rail.

There was no warning
or indication that
lithium batteries were
involved.

San Antonio, TX – February 10, 2022



Use of black shrink-wrap made it difficult to see damage that impacted the cellphones/batteries in the packages.

Port – L.A. Long Beach – March 4, 2022



- Shipper described the contents as **Synthetic Resins N.O.S.**
- Many other containers were found in the port and loaded on ships with the same description

Port – L.A. Long Beach – March 4, 2022



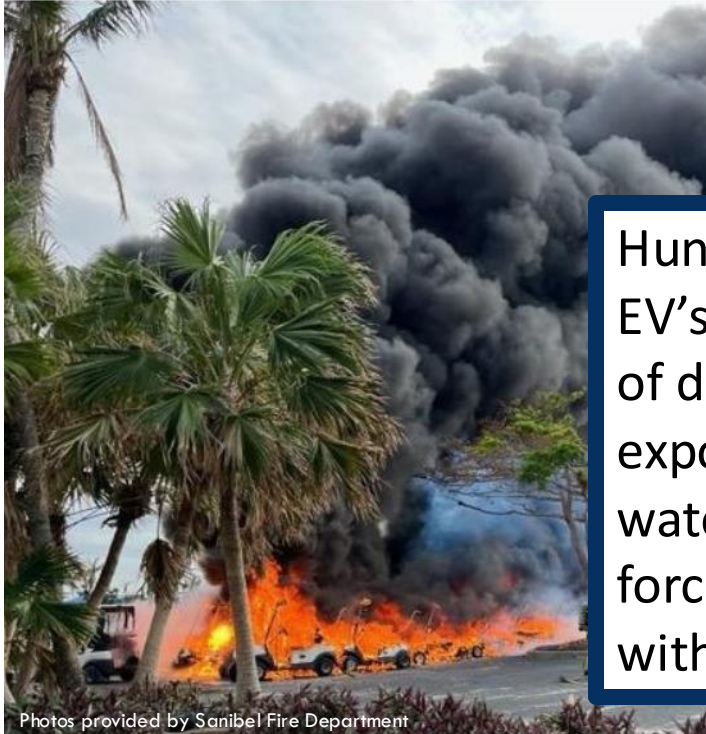
Port – L.A. Long Beach – March 4, 2022



Container of undeclared li batteries involved associated with the previous container contains laptop batteries.



Hurricanes – September 28, 2022



Photos provided by Sanibel Fire Department



Hundreds of EV's and thousands of devices exposed to sea water and other forces associated with hurricanes.

Hurricanes – September 28, 2022



Photos provided by Sanibel Fire Department



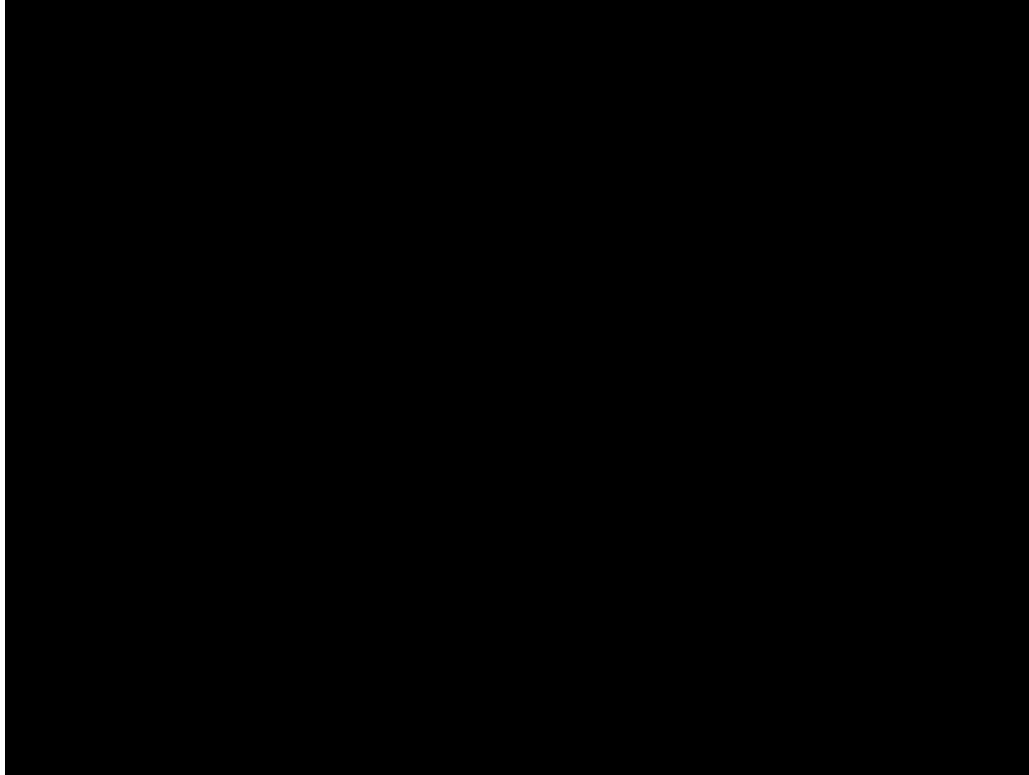
Birmingham, AL– March 31, 2023



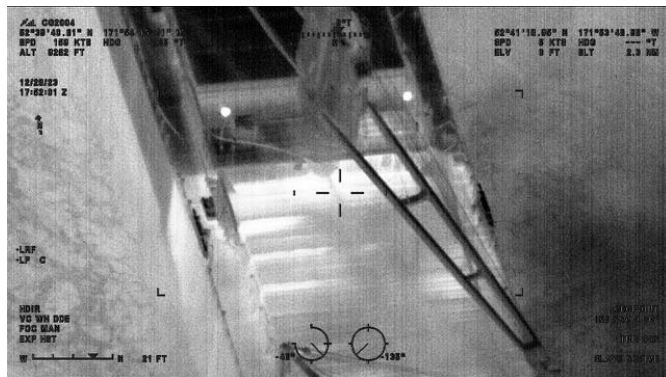


Genius Star XI, December 25, 2023

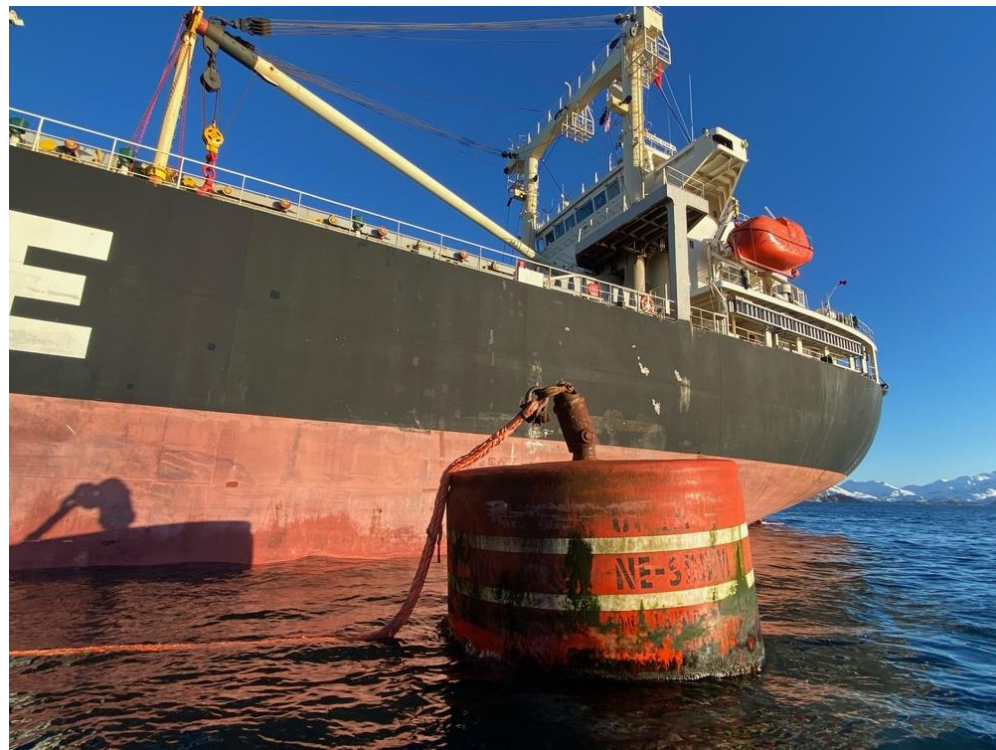
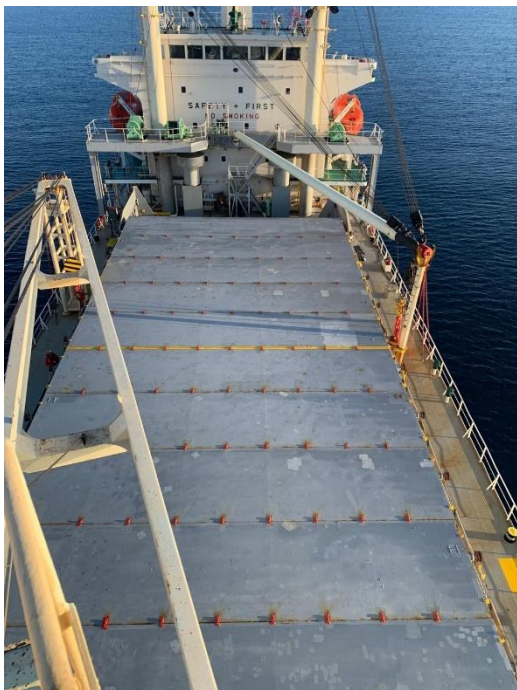
Genius Star IX



Genius Star IX



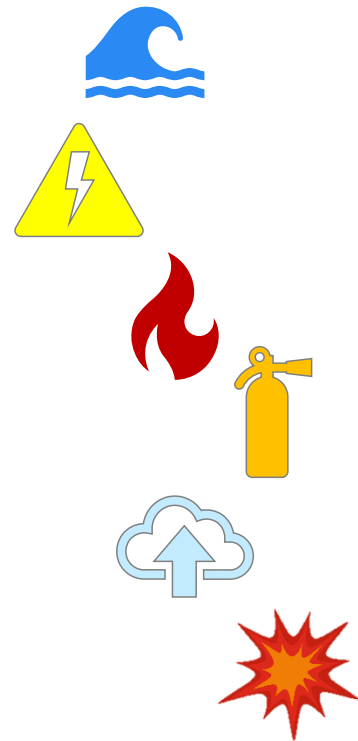
Genius Star XI



Genius Star XI



Genius Star XI



Genius Star XI



10 cells
x
3 modules
x
28 packs
x
180 stacks
=
>150k cells

Genius Star XI





M/V Magellan

M/V Magellan



M/V Magellan



M/V Magellan



Photo by Fairmont City FD Facebook

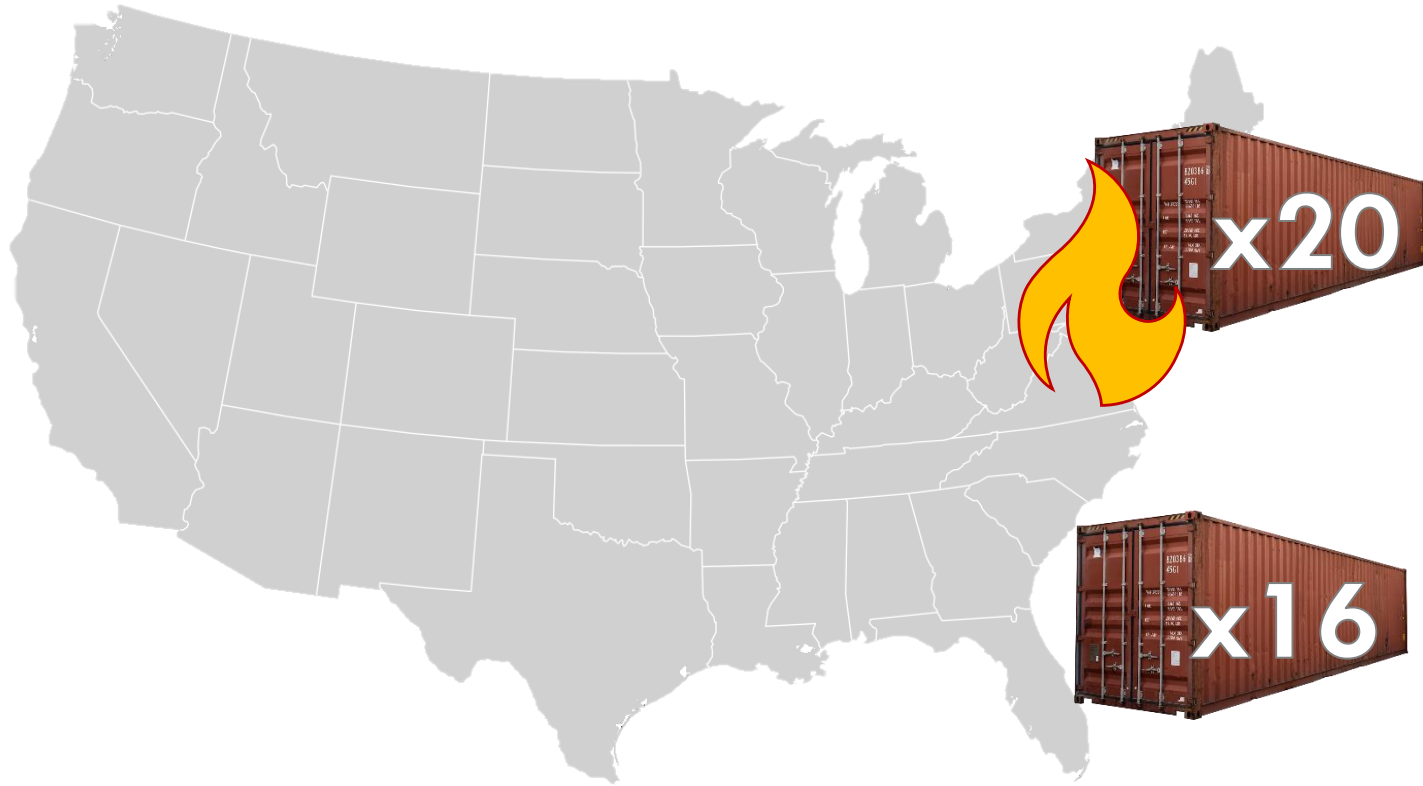
M/V Magellan



M/V Magellan



M/V Magellan

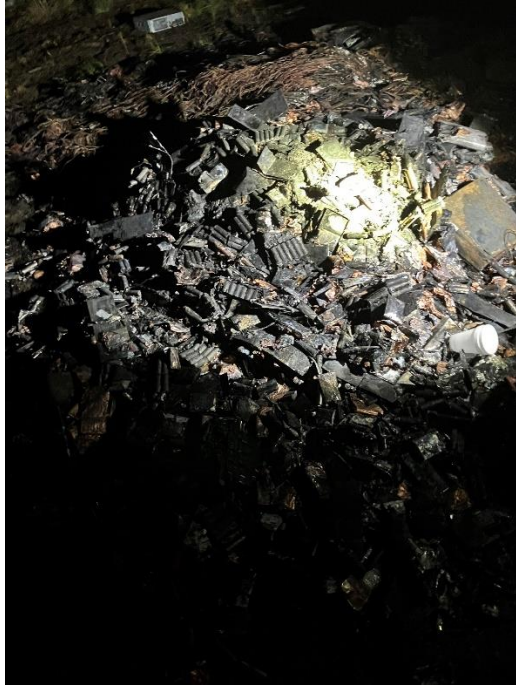


Port of Oakland Fire – May 12, 2024



Fire near Port of Oakland spreads dark smoke plume along the bay

I-75 Explosion – June 29, 2024



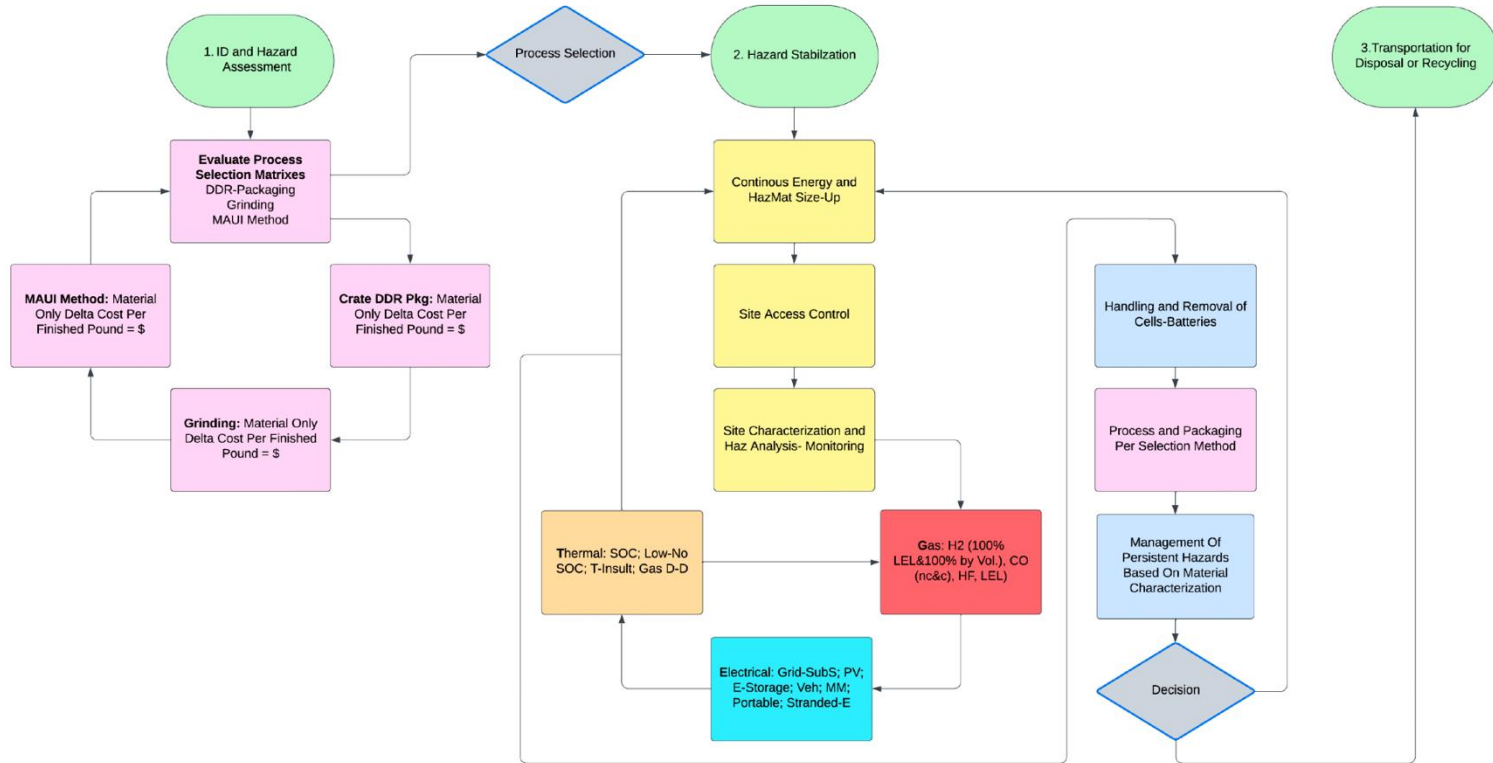
LIB Transport – Review

- ❑ Poor battery handling
 - ❑ Poor and inconsistent packaging
 - ❑ Mis-declared and mislabeled
 - ❑ Unprotected Damaged, Defective, Recalled (DDR)
 - ❑ Poor management of End-Of-Life (EOL)
 - ❑ Mixing DDR and EOL batteries
- ❑ Incidents can be new batteries, not just DDR and EOL
- ❑ Current domestic shipping regulations and SP are not fully protective and are slow/difficult to change



MISSION ACTION PLANNING

Mission Action Planning – Decision Tree



Mission Action Planning – Cost Projection



PROCESS SELECTION MATRIX

	Method	Grinding	Maui Method "Knuckle Dragger"	DDR PKG
	Mass per hour	5000 lbs		5000 lbs
	DOT SP			
	Cost to Buy Equip	2,000,000.00	N/A	\$5000 each (x813 or 975) \$4 Million- \$4.9Million
	Cost to Rent Equip	N/A	30000	
Notes:				
samsungs				
120kg cs112 batt module				
nmc				
10 banks batt ? Lg vs Sam				
	Cost Maint per Month	?	N/A	N/A
	Labor Cost per Week (x6 x105/hr)	30K-40K	30K-40K	30K-40K
	Labor Cost per Month (Days)	170K-180K	170K-180K	170K-180K
	Package Type	Drums	Drums	5000# Rated 49 CFR 173.185 (f) CFR DDR Crate Vessel, Rail ,and Hwy
	KWh per Kg	9 KWh per Kg	N/A	N/A
	kWh per Package Type	N/A	N/A	N/A
lg jh3 jh4s 100lbs	Mass per Wh per Package Type	N/A	N/A	N/A
avgs 2.5-3.0 lbs per build. X1	Mass per Package Type		1700 lbs avg	5000 lbs
	Regulated Material per 49 CFR Y or N	No	No	Yes
	Reactive Waste per UN and 40 CFR Y or N	No	No	Yes
3075 lbs per hour	Cost Package Type	\$81.00 CleanPak	\$81.00 CleanPak	\$5,000
2,500,000./3075lbs=813 hrs/50 hrwk	Number of Packages for Total Mass	1470 -1765	1470 -1765	813-975
or 16.26 wks/4.5 wks/mo = 3.61 Mos	Total Cost Per Finished Pound	\$0.85-\$0.71	\$0.05	\$1.60 - \$1.63
	Cost Disposal/Pound	?	?	?
3075 lbs per hour	Cost Recycle/Pound	\$.95 /lb	\$.95/lb	\$.95//lb
3,000,000/3075lbs=975.6 hrs/50 hrwk	Cost of Shipping	?	?	?
or 19.51 wks/4.5 wks/mo = 4.34 Mos	Sampling and Anylsis	?	?	?
!!!				
Key is DDR package type and cost per lb and Wh total per package for total unit Cost	Total Amount of Material lbs	3,000,000.00	3,000,000.00	3000000
	Estimated De-energizing Equipment Cost per month	\$ 50,000.00	\$ 50,000.00	
	Deenergizing Throughput (lbs/day)	50,000.00	50,000.00	
	Deenergizing Labor Timeframe	60.00	60.00	
	Deenergizing Labor Cost (3 people for 10 hrs/day \$105/hr)	\$ 189,000.00	\$ 189,000.00	
	Denergezing Total Costs	\$ 289,000.00	\$ 289,000.00	
	Equipment Costs for Packaging Method	\$ 2,142,941.18	\$ 342,941.18	\$ 3,000,000.00
	Packaging Throughput (lbs/hour)	5,000.00	1,500.00	3,075.00
	Packaging Labor Timeframe (hrs)	600.00	2,000.00	975.61
	Packaging Labor Timeframe (10 hour days)	60.00	200.00	97.56
	Packaging Labor Costs (6 people for 10 hrs/day \$105/hr)	\$ 189,000.00	\$ 630,000.00	\$ 307,317.07
	Total Packaging Costs	\$ 2,331,941.18	\$ 972,941.18	\$ 3,307,317.07
	Recycling Costs (\$1.00 per lb)	\$ 3,000,000.00	\$ 3,000,000.00	\$ 3,000,000.00
	Waste Transport (\$2000 per truck. 40,000 lbs/truck)	\$ 150,000.00	\$ 150,000.00	\$ 150,000.00
	Total Project Costs	\$ 5,770,941.18	\$ 4,411,941.18	\$ 6,457,317.07