LITHIUM-ION BATTERY EMERGENCIES

Training Outline

- Battery Basics
- Firefighting Operations and Tactics
  - Maritime Focus
- 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.

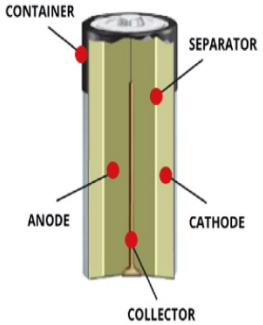
Cathode A combo of manganese dioxide and carbon, cathodes are the electrodes reduced by the electrochemical reaction.

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

Anode Made of powered 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 iconic 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

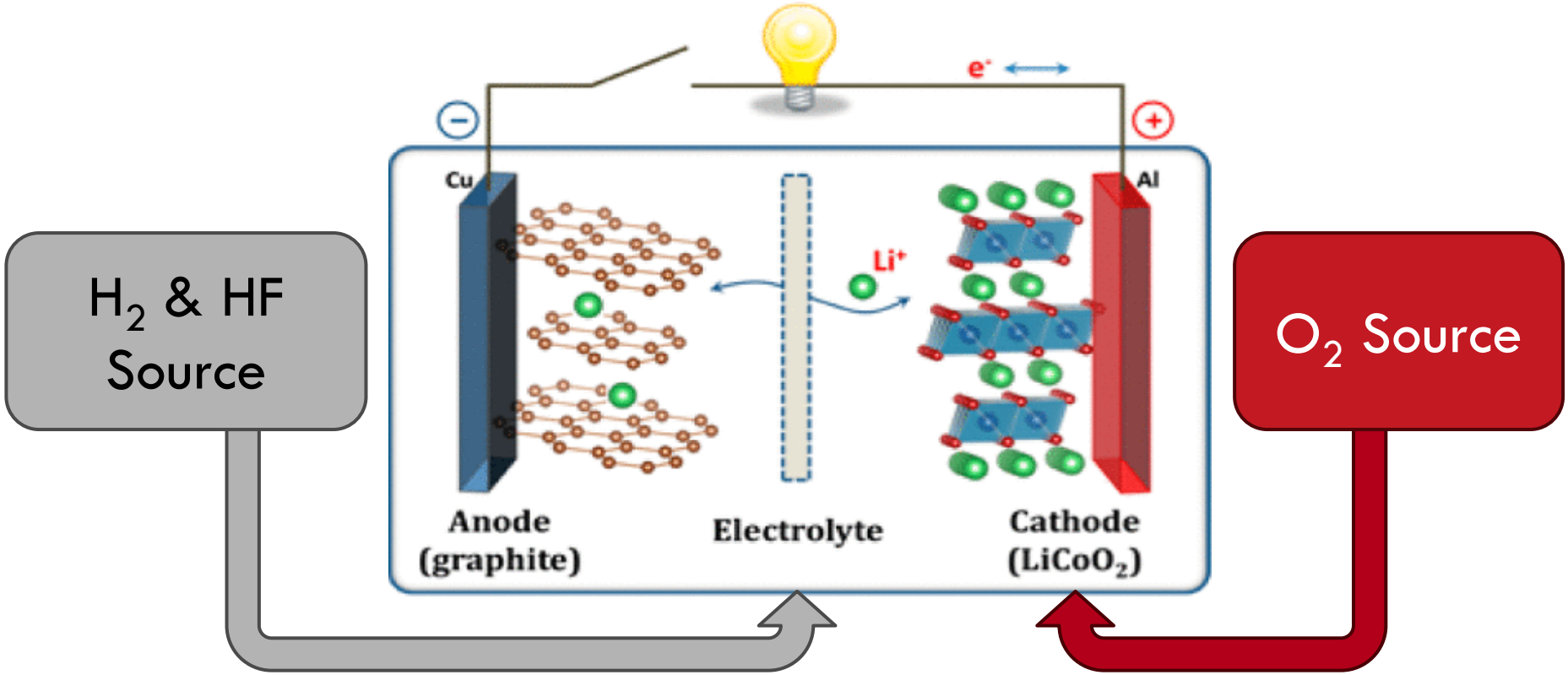
Pouch
Cell

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

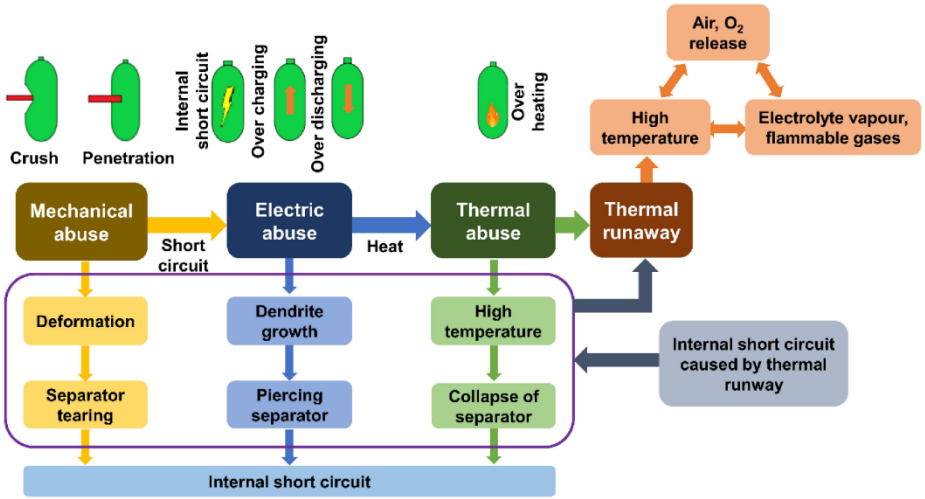


Li-Ion Battery Hazards and Failure

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!

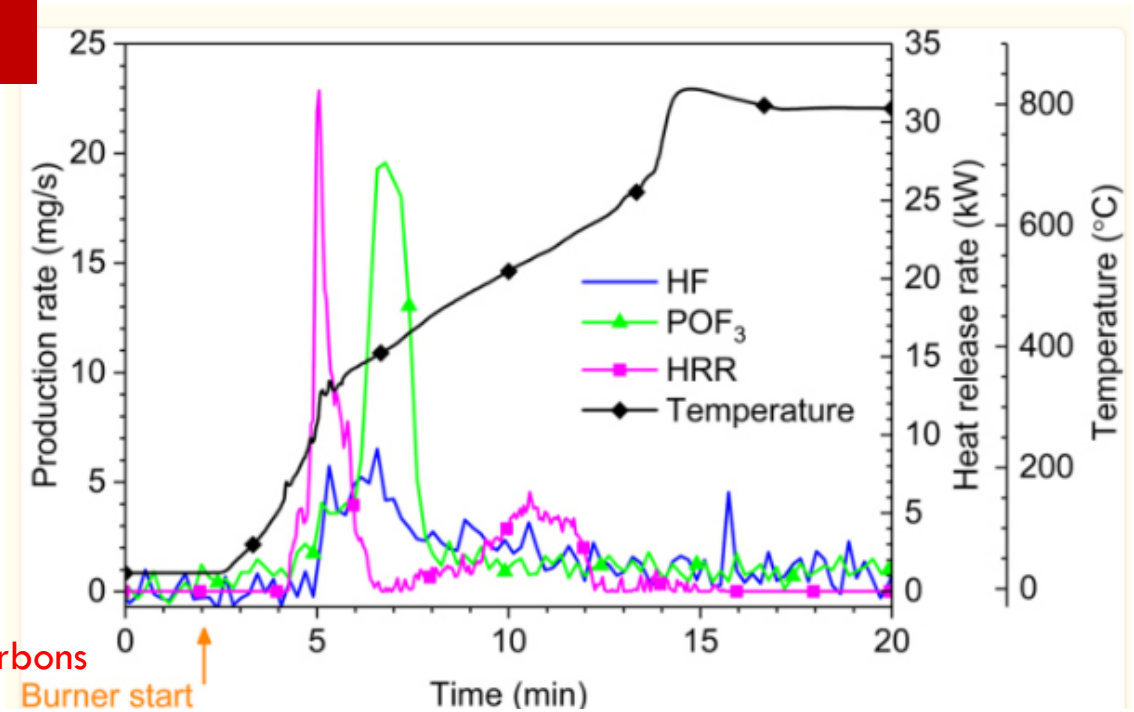
Additive Mechanism



Li-Ion Battery Toxic/Flammable Vapors

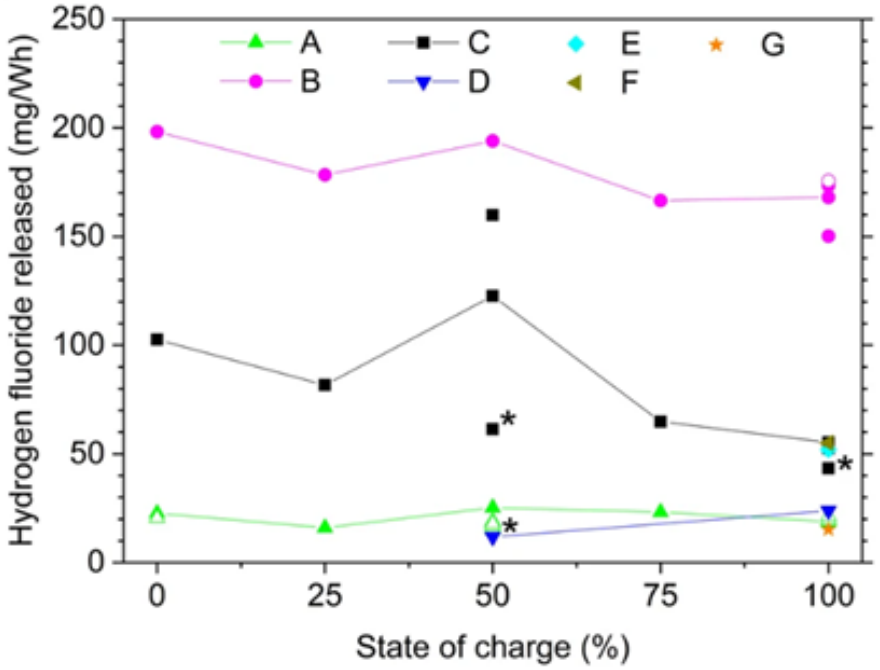
Toxic/Flam Vapors

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



Source: Toxic fluoride gas emissions from lithium-ion battery fires. Larsson F, Andersson P, Blomqvist P, Mellander BE. Sci Rep. 2017 Aug 30;7(1):10018. doi: 10.1038/s41598-017-09784-z. Erratum in: Sci Rep. 2018 Mar 22;8(1):5265. PMID: 28855553; PMCID: PMC5577247.

Li-Ion Battery Toxic/Flammable Vapors



Vapor Production

6,000 L/kWh of vapors can be released during battery failure

Electrolyte is flammable, usually contains lithium hexafluorophosphate (LiPF6) 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**

Source: Toxic fluoride gas emissions from lithium-ion battery fires. Larsson F, Andersson P, Blomqvist P, Mellander BE. Sci Rep. 2017 Aug 30;7(1):10018. doi: 10.1038/s41598-017-09784-z. Erratum in: Sci Rep. 2018 Mar 22;8(1):5265. PMID: 28855553; PMCID: PMC5577247.

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

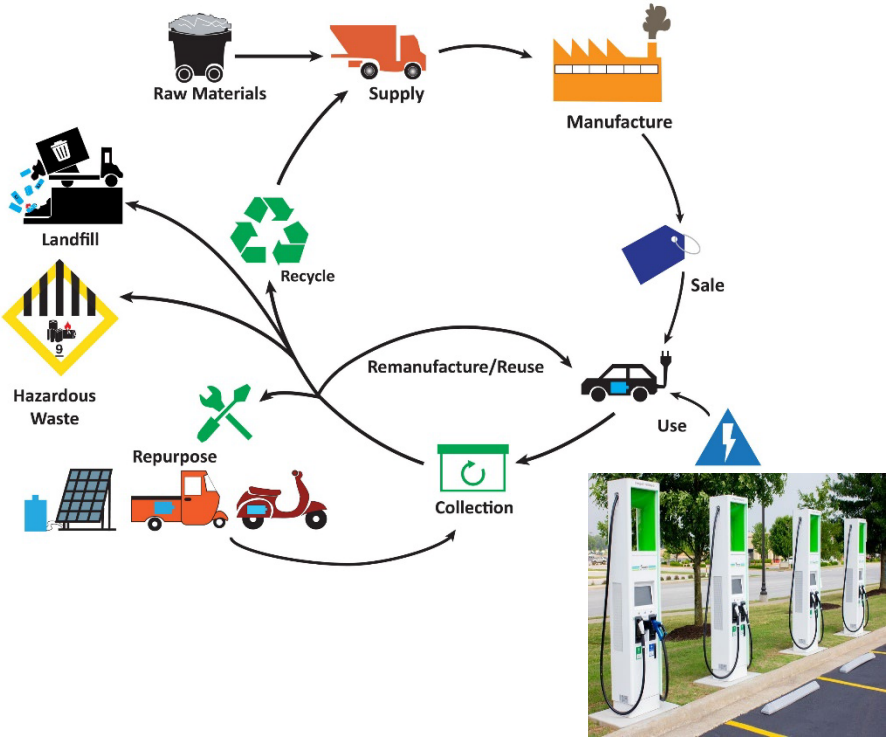
Tesla Truck = 800V (reported)

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

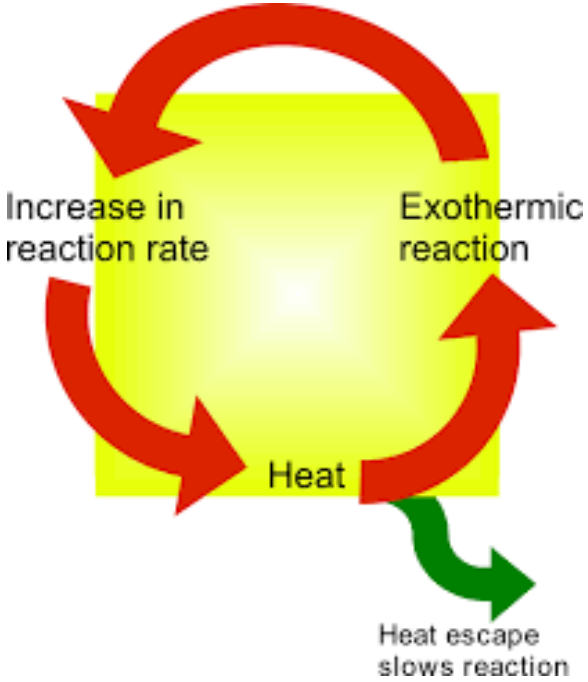


School Buses?

Rapid smoke and flame production

Differences in Lithium-Ion Battery Fires

- Very toxic atmospheres
- Burn temperatures are higher than normal
- Fires at cell level can burn without external oxygen – can't smother!
- Explosive potential – 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
  - Could initiate in seconds or days
- Thermal re-kindle is common – <u>minutes, hours, days, weeks, months, years!</u>

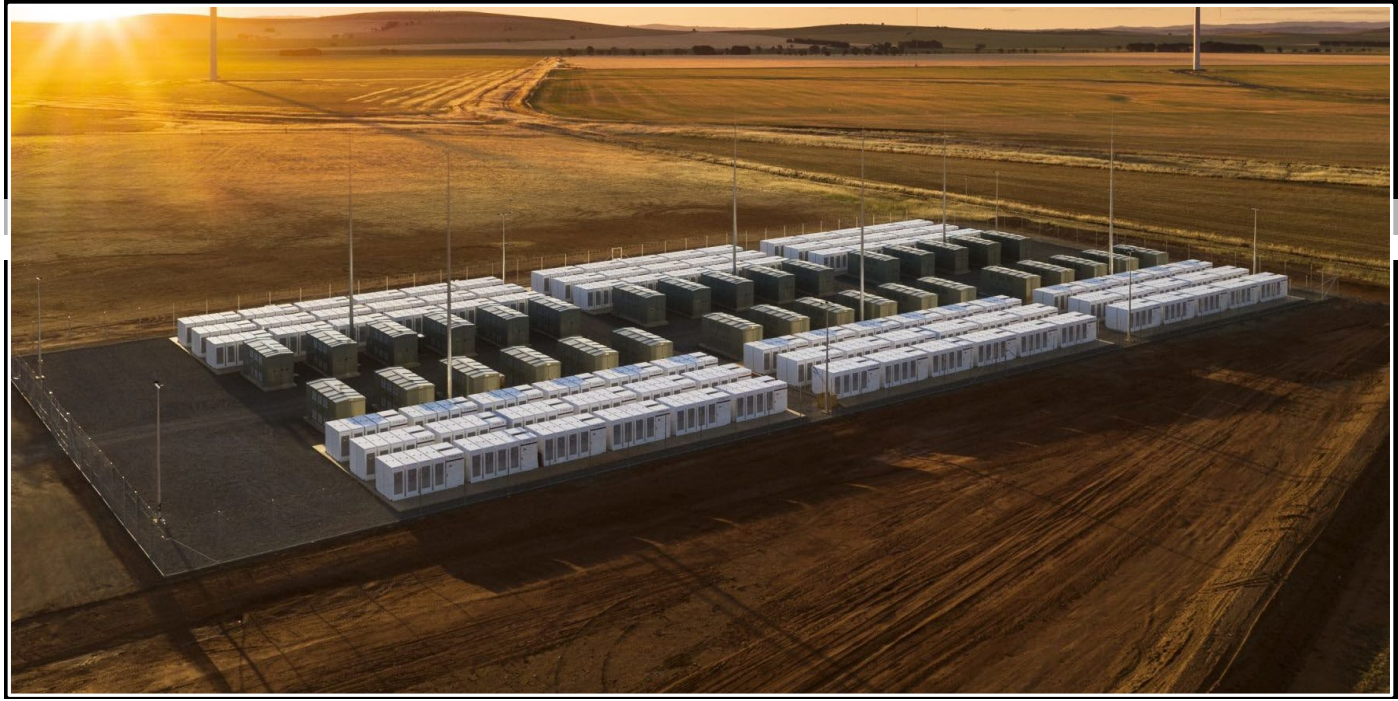


Propagation

- Propagation
  - Domino effect
  - Thermal Runaway heat from one battery-cell is likely to trigger Thermal Runaway in neighboring battery-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



Battery Energy Storage System (ESS)

KEY TAKEAWAYS FROM APS EXPLOSION REP

SEVERAL VALLEY FIREFIGHTERS HURT IN 2019 BLAST

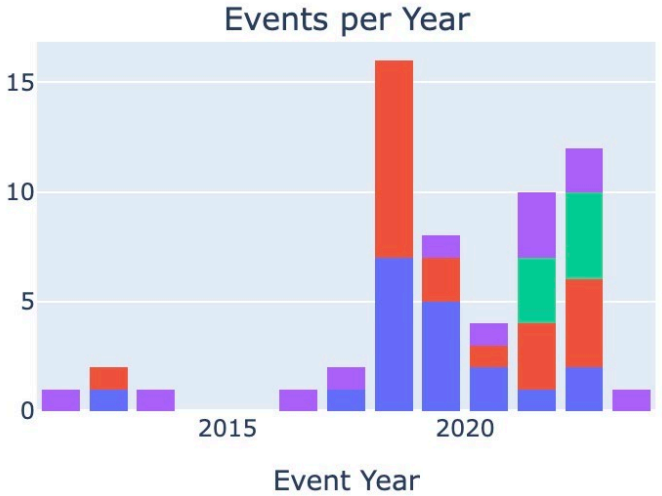
abc 15 ARIZONA

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
- Otay Mesa, San Diego, CA



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

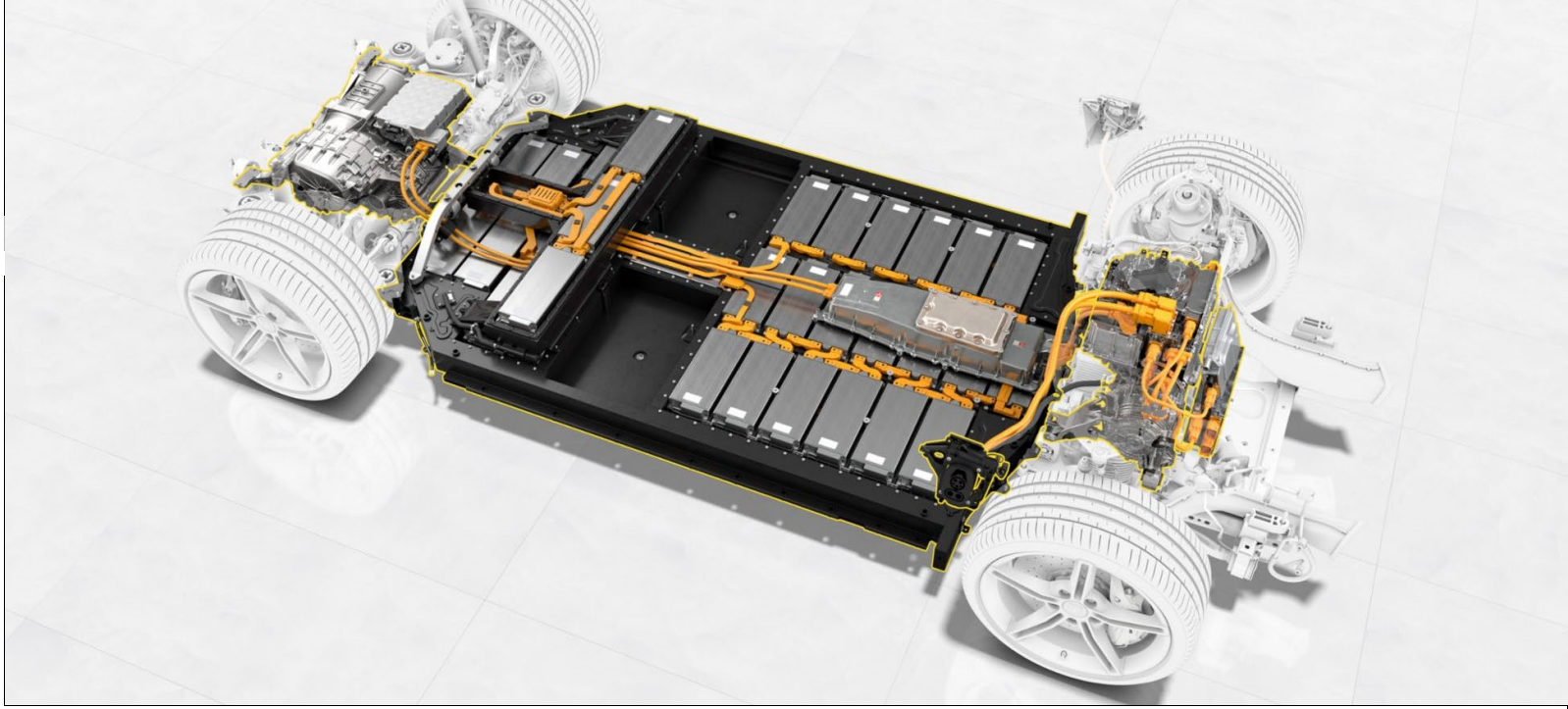
- #2-Incident Stabilization
  - Let it burn!
    - Applying water to the burning unit will only delay the event.
    - May take multiple operational periods.
    - During periods of module propagation, there may be no sign of fire, but the event can still be active and flare up can still occur.
  - Environmental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

BESS Tactical Considerations
If Batteries Are Involved

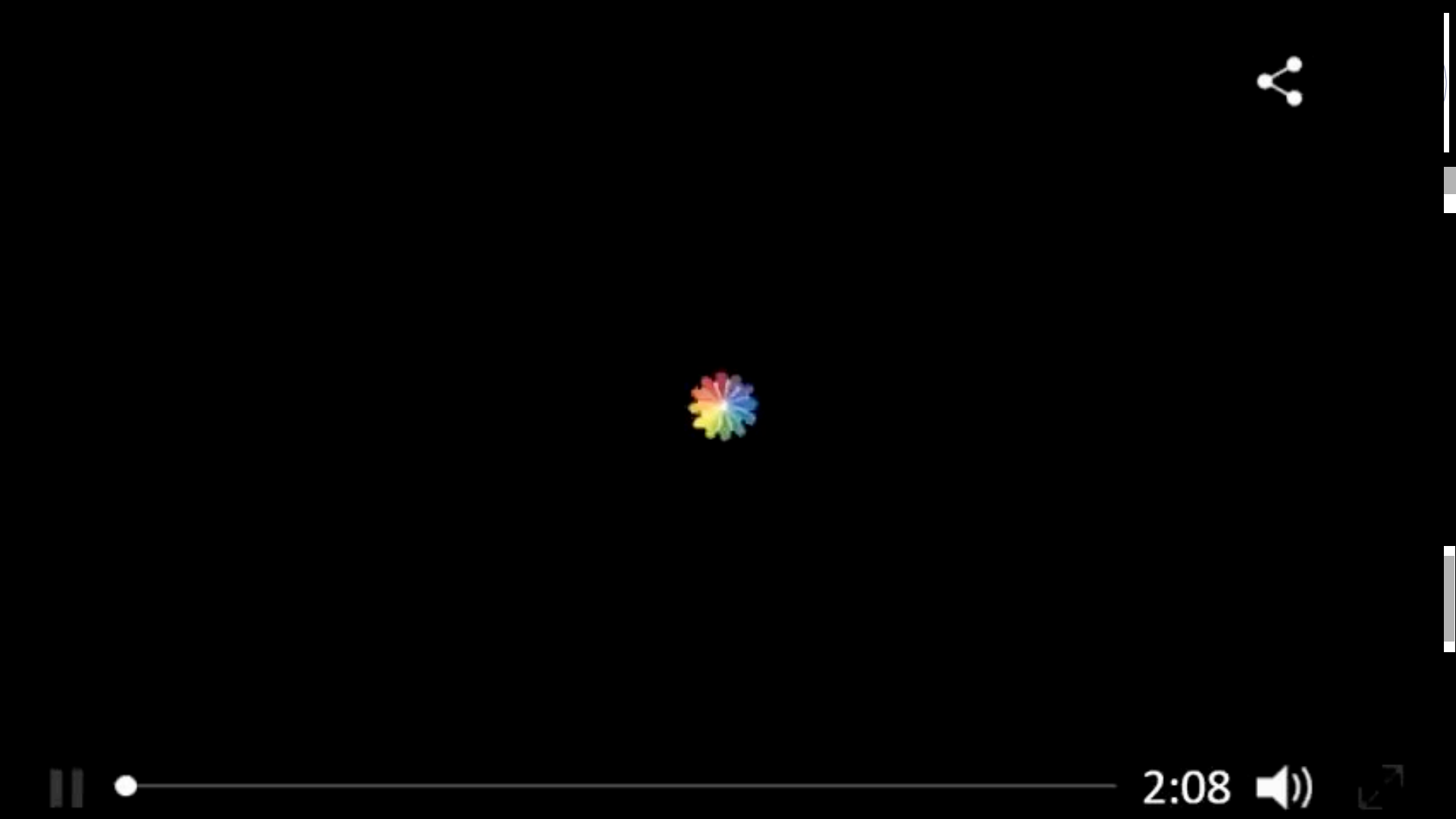
- #3-Property Conservation
  - Allow system safety devices to operate as designed.
  - Monitor alarm panel and manually activate any safety devices if appropriate.
  - Prevent propagation.
    - Water curtains and unstaffed lines
    - Apply from a distance and upwind if possible.
      - Protect exposed 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)


2:08

Exponential Increase: Battery Electric Vehicles (BEV)

% of EVs Global Auto Sales

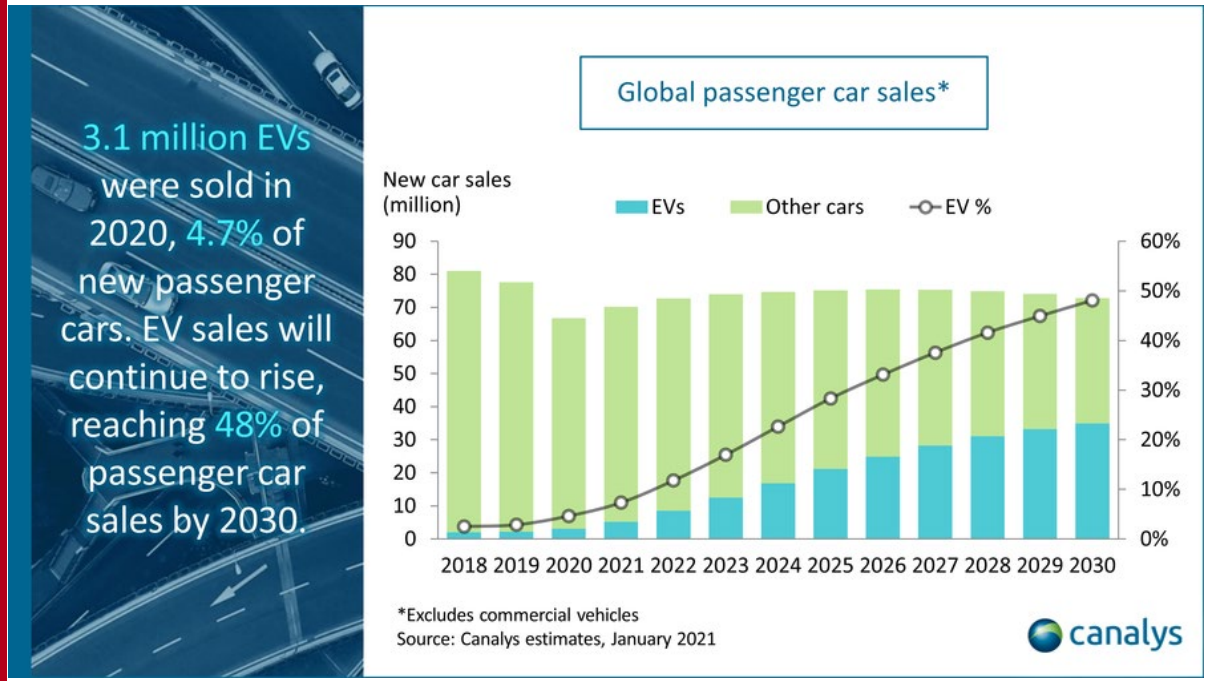
4.7% - 2020

15% - 2025

48% - 2035

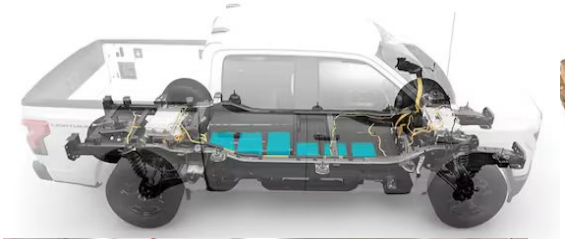
California forecasted to be much higher.

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



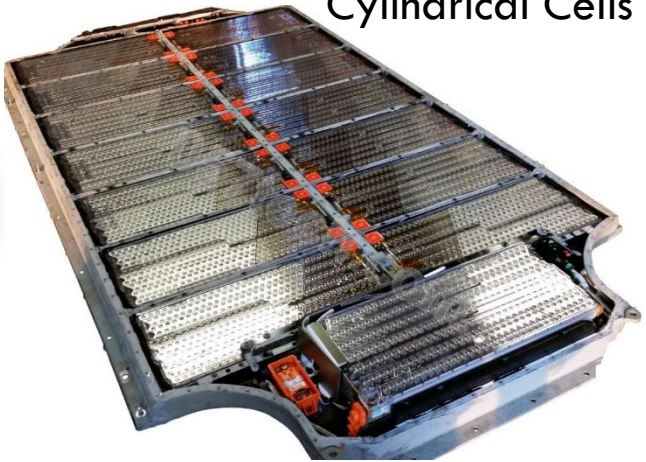
Battery Electric Vehicles (BEV) – Battery Packs

GM Battery Pack
Pouch Cells

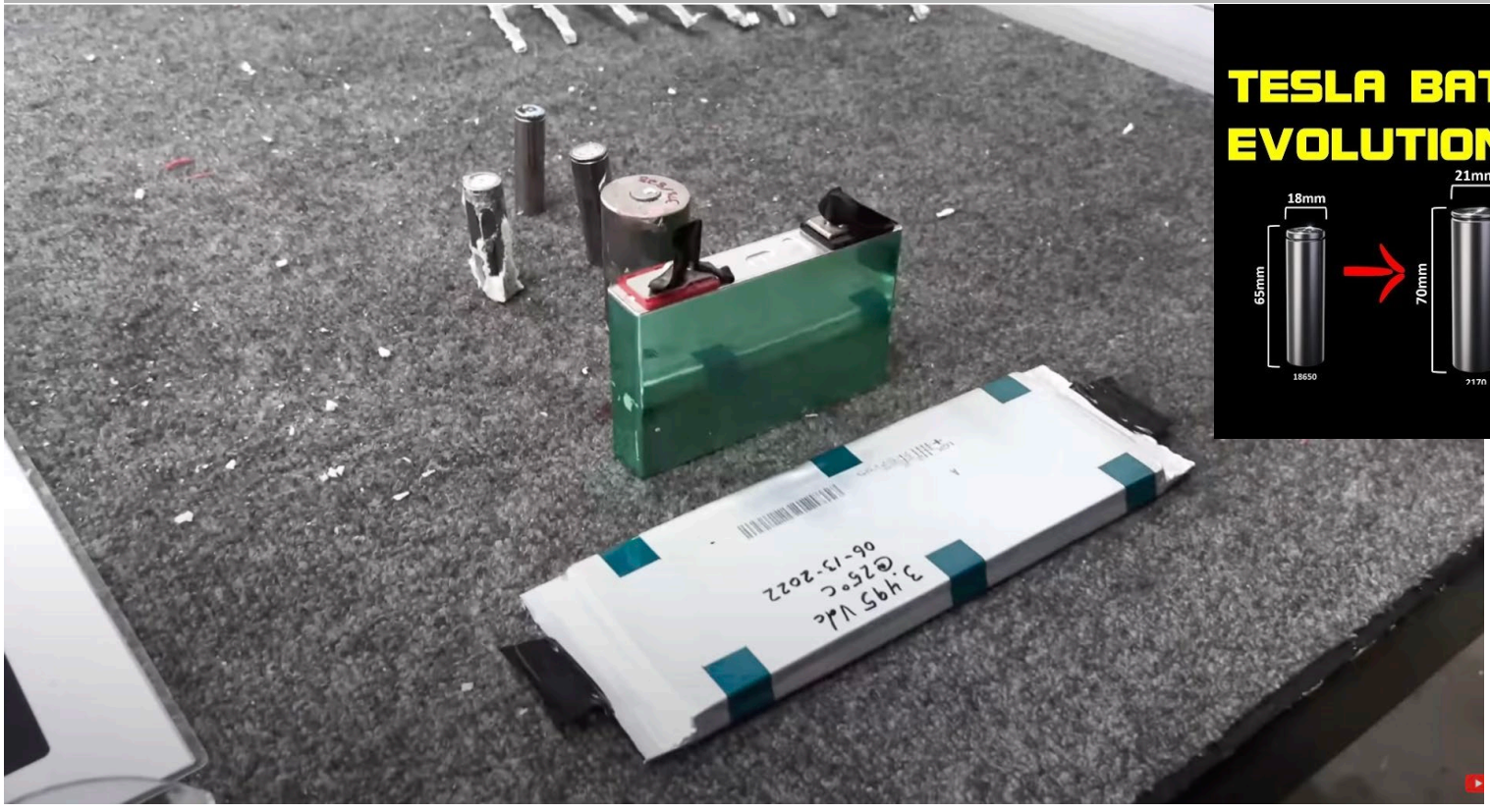


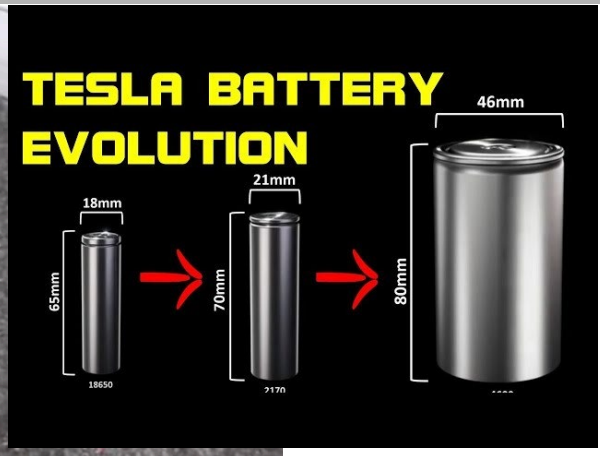
Ford Lighting Battery Pack
Pouch Cells

Tesla Battery Pack
Cylindrical Cells



Battery Electric Vehicles (BEV) – Battery Packs





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

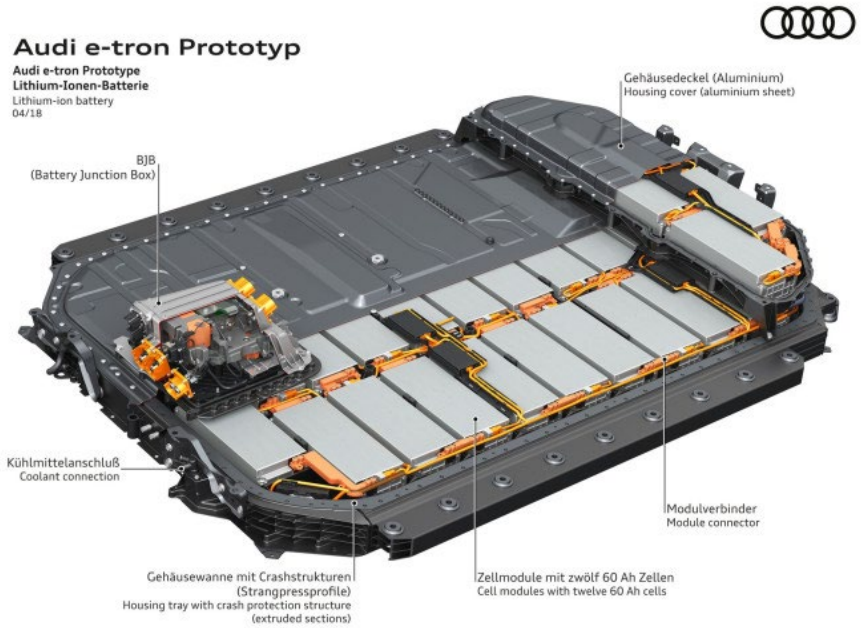
Tesla – Cylindrical Cell Batteries

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)
- **<u>Thermal re-kindle can occur minutes, hours, days, weeks, months, years, later!</u>**



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
  - **<u>Attack the fire like a normal vehicle fire.</u>** 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

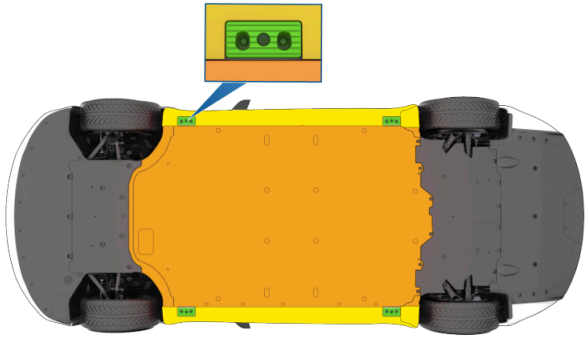
STABILIZATION / LIFTING POINTS

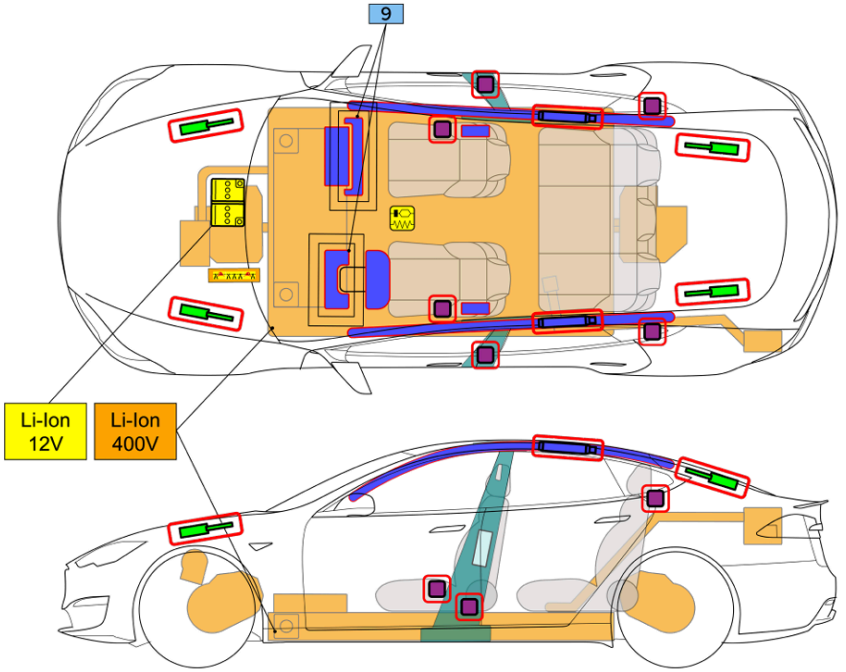
The high voltage battery is located under the floor pan. A large section of the undercarriage houses the high voltage battery. When lifting or stabilizing Model S, only use the designated lift areas, as shown in green.

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								

BEV Fire Tactical Considerations – Inside (underground/garage)

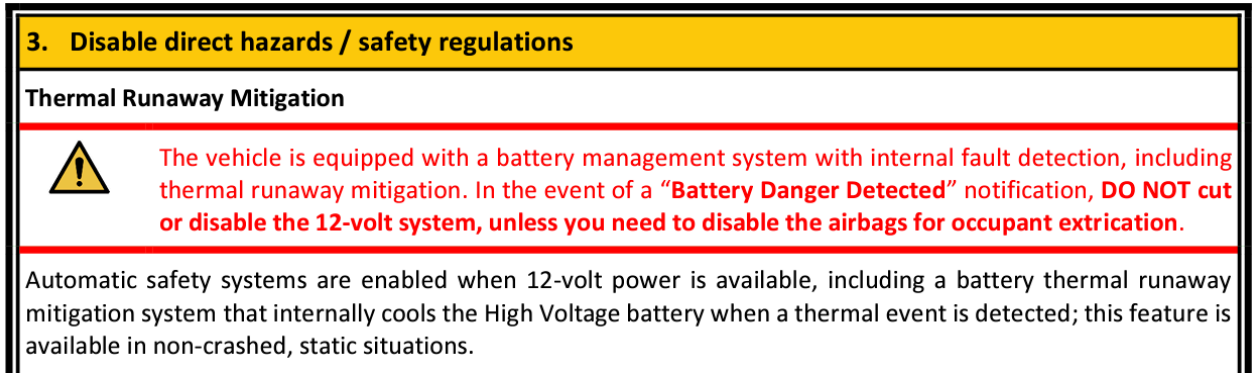
FSRI Demo on BESS Release Inside Garage

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
- Underground 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
    - GPM Flow x degree of fog pattern = 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

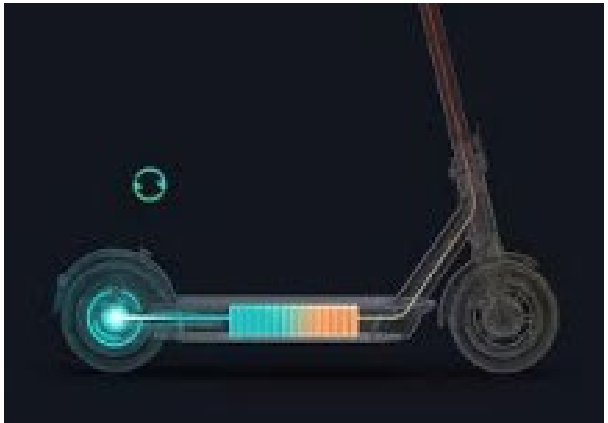
Micro-Mobility Devices

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

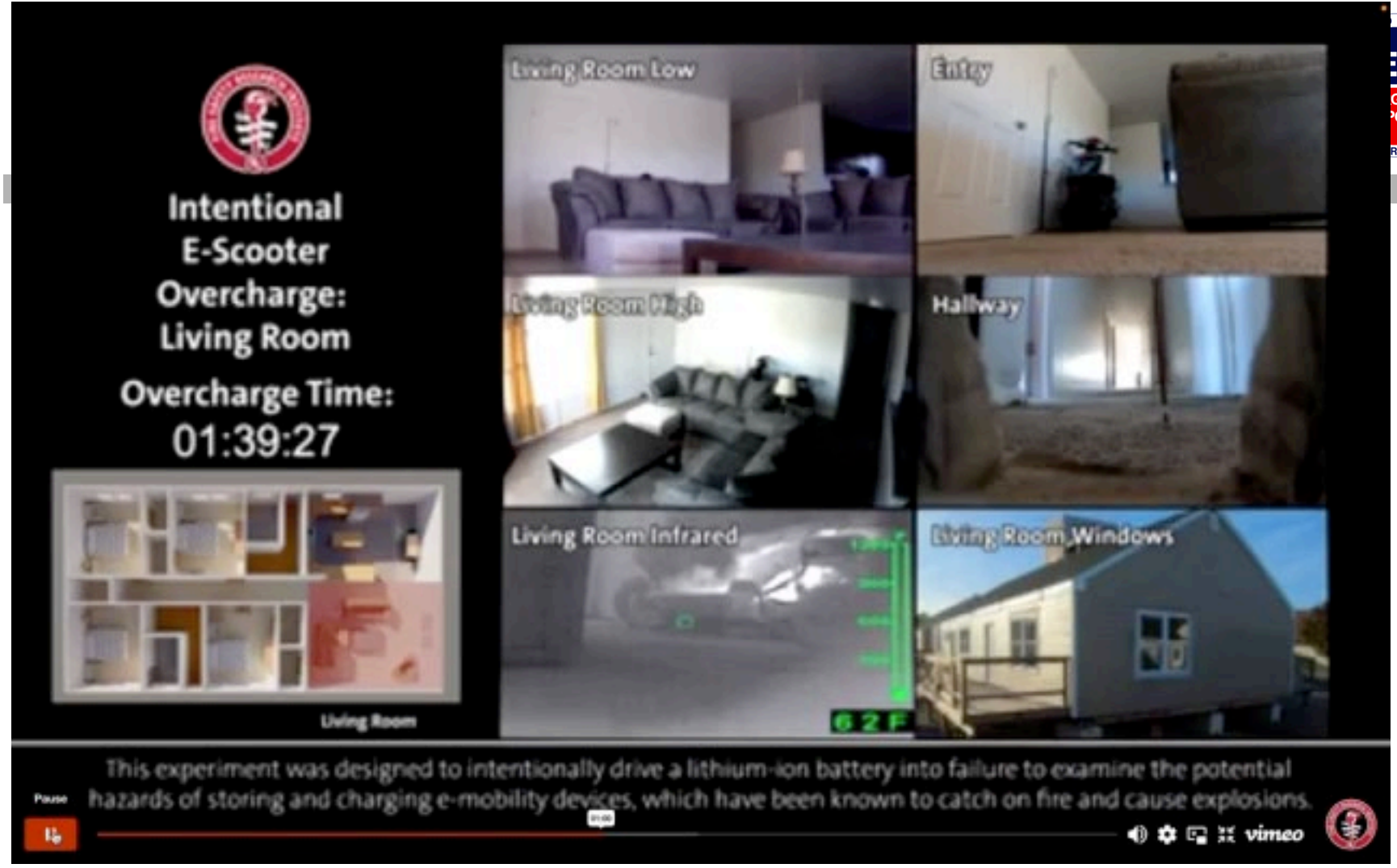
(v) Electric Mobility Cart

(vi) Electric Bike (bicycle)

(vii) Hoverboard

(viii) Segway

(ix) Electric Caster Board


Intentional
E-Scooter
Overcharge:
Living Room
Overcharge Time:
01:39:27
Living Room
Living Room Low
Entry
Living Room High
Hallway
Living Room Infrared
62 F
Living Room Windows
This experiment was designed to intentionally drive a lithium-ion battery into failure to examine the potential hazards of storing and charging e-mobility devices, which have been known to catch on fire and cause explosions.
Pause
vimeo

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

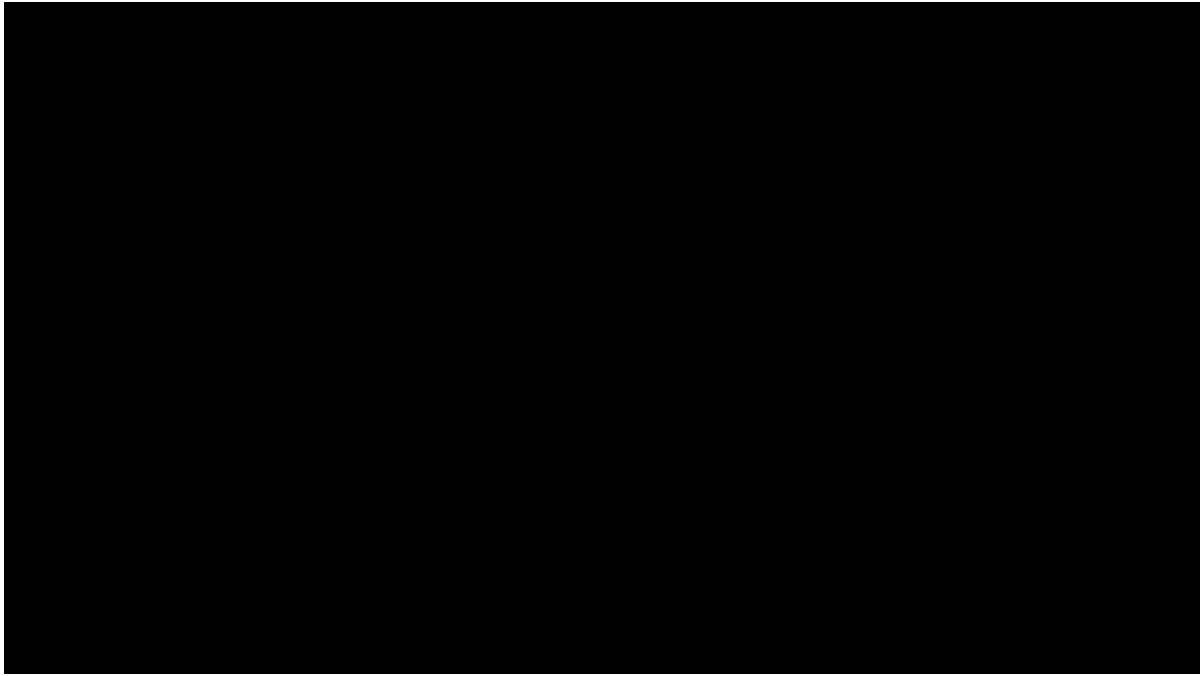
Elevators

"Farming"

Large volume of smoke production

Micro Mobility Concerns

- Rapid failure
- Overhaul
- Toxic atmosphere
- Rekindle
- Explosive



Micro Mobility Tactical Considerations

- 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
    - **<u>During fire attack, uninvolved micro mobility device may ignite behind you!!</u>**

Micro Mobility Tactical Considerations

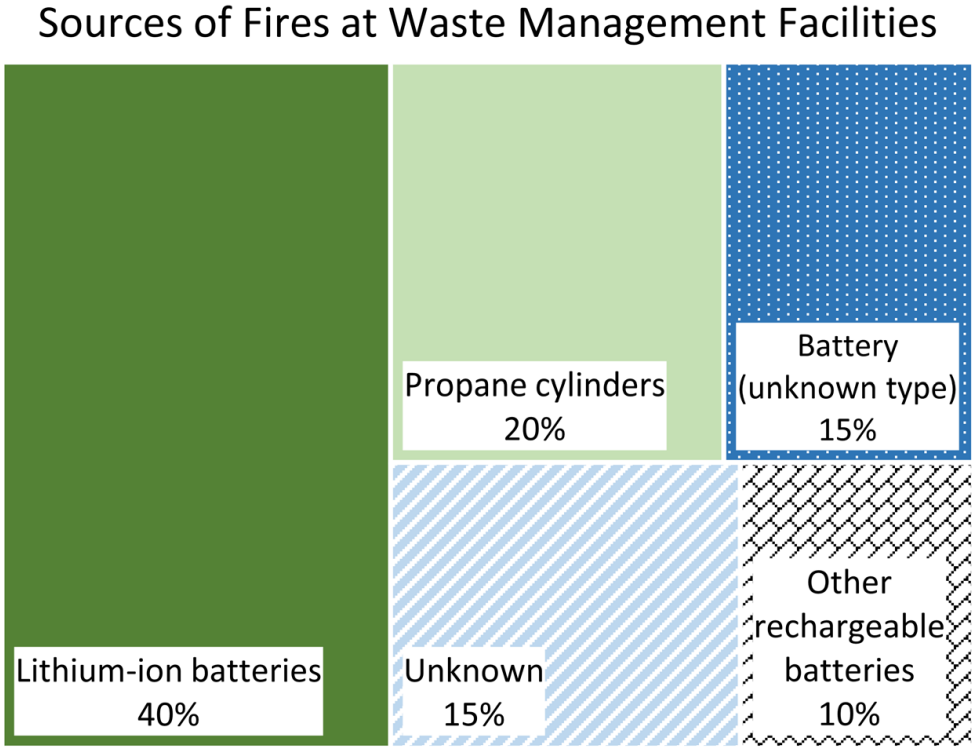
- Move all lithium-ion battery cells and devices to a safe location, away from firefighting operations, **PRIOR to overhaul**
  - Use shovel with wooden handle
  - Outside is preferred
  - Consider bathroom, bathtub, sink, or metal bucket and fill with water if outdoor not an option
- Wear SCBA during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



Disposal Challenge

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

- S-aftey
- I-solate and deny entry
- N-otifications

- C-ommand
- I-dentification and hazard assessment
- A-ction planning

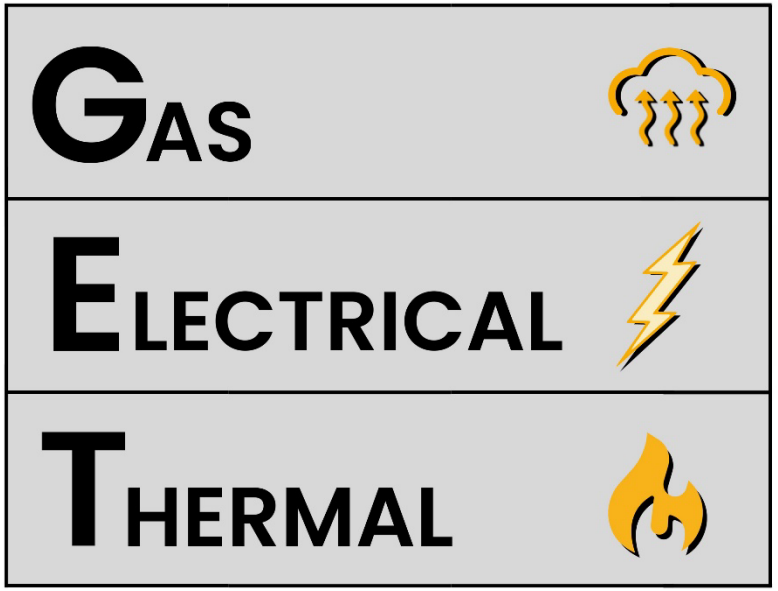
- P-ersonal Protective Equipment (PPE)
- C-ountermeasures-Defensive
- P-rotective Actions

- D-econtamination
- D-ebrief
- D-ocumentation!!!!
- D-isposal/Recycle

Safety and PPE

- Safety
  - Front End and Back End
  - JHA-HASP

- I-dentification and Hazard Assessmment/Analysis
  - **G**-as
  - **E**-lectrical
  - **T**-hermal



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

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

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

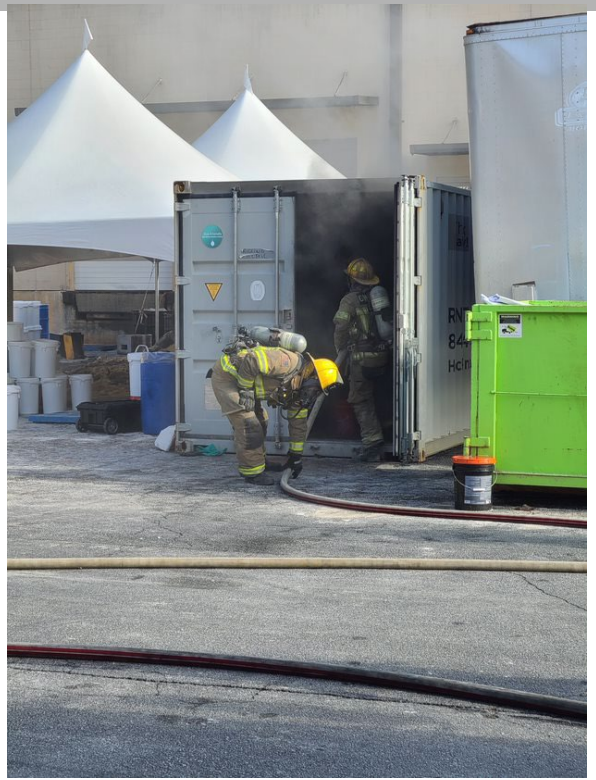
Damaged Batteries are Unpredictable


UNITED STATES
EPA
EMERGENCY
RESPONSE
ENVIRONMENTAL PROTECTION AGENCY

First Fire of the Day – recently packaged bucket

Technically not a Fire?

Second Fire of the Day – bucket packaged 5 days ago




JACKSON

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:

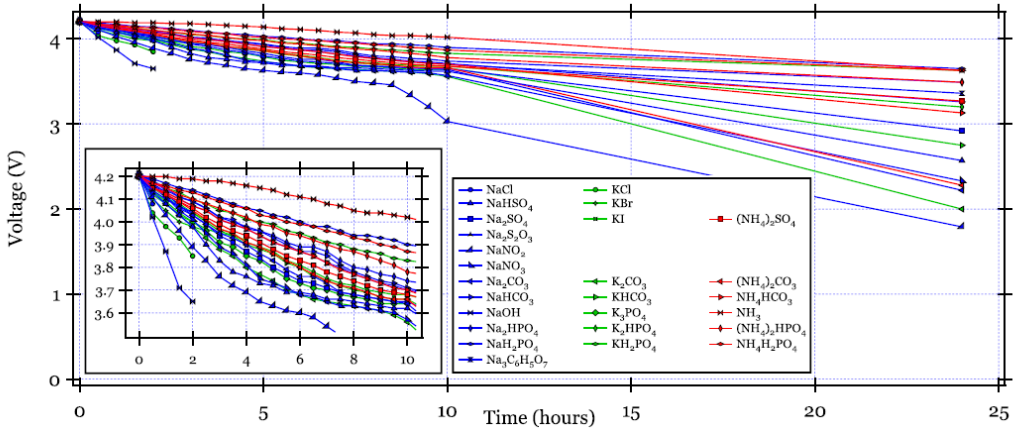
- Stop calling the Fire Department

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

- 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]	µg/l	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		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.

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

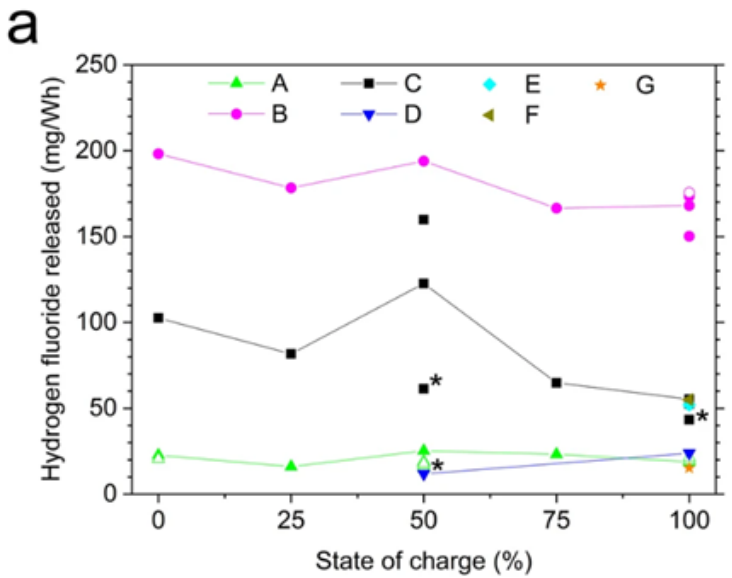
Flammable and Toxic Vapor Production

- 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 cam 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



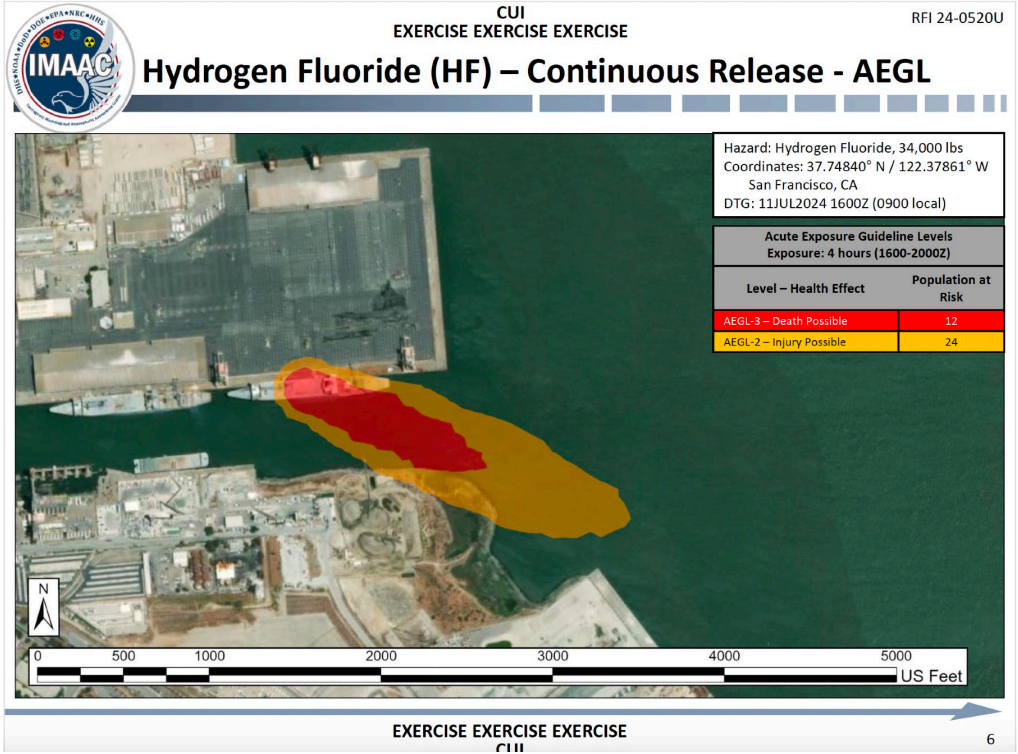
Asset Recycling Fire

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
  - hydrogen
  - carbon monoxide
  - hydrogen fluoride
  - hydrogen chloride
  - hydrogen cyanide
  - phosphoryl fluoride
  - 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 – SPM Flex

Target Compound	SPM Flex Tape	Detection Range
Hydrofluoric Acid (Hydrogen Fluoride)	Mineral Acid	0.4-20 ppm
Sulfur Dioxide	Sulphur Dioxide	0.01-2.5 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.

Air monitoring capabilities and decision making (Tactical)

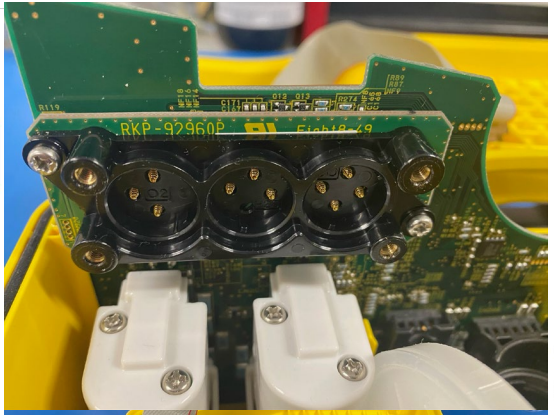
RKI INSTRUMENTS

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



Air Monitoring

RKI SENSORS EAGLE 2-3

	LEL	O2	H2	IR-hydrocarbons	TC-Cal to H2	CO non-compensated	CO compensated	HCN	PID-VOC	H2S	HF
hydrogen	Y	N	Y	N	Y	Y	N	Slight Resp.	N	Slight Resp.	N
carbon monoxide	Y	N	N	N	Y >80% LEL	Y	Y	Slight Resp.	N	Slight Resp.	N
hydrogen fluoride	N	N	N	N	N	N	N	Slight Resp.	N	Slight Resp.	Y 1:1
hydrogen chloride	N	N	N	N	N	N	N	Y	N	Y	Y
hydrogen cyanide	Y	N	N	N	Y >80% LEL	Slight Resp.	Slight Resp.	Y 1:1	N	Slight Resp.	Slight Negative Resp.
phosphoryl fluoride	N	N	N	N	N	N	N	N	N	N	Y
organic droplets	Y	N	N	Y >80% LEL	Y >80% LEL	Slight Resp.	Slight Resp.	Slight Resp.	Y	Slight Resp.	Slight Resp.
ethane	Y	N	N	Y	Y >80% LEL	N	N	N	N	N	N
methane	Y	N	N	Y	Y >80% LEL	N	N	N	N	N	N
other hydrocarbons-VOC	Y	N	N	Y	Y >80% LEL	Y >80% LEL	Y >80% LEL	Slight Resp.	Y	Slight Resp.	Slight Resp.
smoke particulates/metals	N	N	N	N	N	N	N	N	N	N	N
metals	N	N	N	N	N	N	N	N	N	N	N
corrosive gases and vapors	?	?	?	?	?	?	?	?	?	?	?

Air Monitoring (Tactical? VS Post Exposure Lab Analysis)

- Particulate Monitoring Respirable Dust Evaluation:
  1. High volume sampling: pump to cassette for perimeter
  2. Personal Low volume sampling: pump to cassette
  3. Summa Canister or Field Portable GC/MS, MS, GAS ID
  4. Dust Trak
  5. Allowable dust concentration in air calculations (concentration in soil, dust, air)
  6. Direct sample collection
  7. Smoke plume modeling, down range monitoring.

Air Monitoring

RUN 12

Date: 2/22/24
Time to 1st Rxn: 1:34
Official Run Time: 1221 - 1234 (13 mins)
5-Gas Meter Run Time: 1221 - 1251 (30 min)
HF/Particulate Run Time: 1221 - 1251 (30 min)
Sample Run Time: 1215 - 1235 (20 mins)
Test Media:
48 NMC Zhejang 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	4	13.1	20	100
Sensor Peak Time	--	12:31:24	12:31:46	12:31:28	12:31:46	12:27:15	12:22:47

ASTM-D-1945 - Tedlar Bag Samples

Property:	Units:	SDFE-02224-1945-05A	SDFE-02224-1945-05B
Hydrogen	ppm (v/v)	240	<100
Carbon Monoxide	ppm (v/v)	1480	560
Oxygen	ppm (v/v)	215890 #	247050 #
Hydrogen	ppm (m/m)	<100	<100
Carbon Monoxide	ppm (m/m)	1350	500
Oxygen	ppm (m/m)	282370 #	317830 #

- Result is outside of test method limits and/or analytical range used in method precision study
*Note that two Tedlar Bag samples were taken per run to ensure sufficient volume for analysis

HCN - NIOSH 6010 - Colorimetric (Plus Duplicate)

Sample ID	Lab ID	Air Vol liter	Front ug	Back ug	Total ug	Conc mg/m3	ppm
SDFE-022224-6010-05	L618635-7	3.86	3.7	<2.6 ND	3.7	0.96	0.87
SDFE-022224-6010-D	L618635-2	4	3.7	<2.6 ND	3.7	0.92	0.83

HF - Fluoride Vapor - NIOSH 7902

Sample ID	Lab ID	Air Vol liter	Total ug	Conc mg/m3	ppm
SDFE-022224-7902-05	L618635-15	39.5	25	0.63	0.77

HF - Soluble Particulate - NIOSH 7902

Sample ID	Lab ID	Air Vol liter	Total ug	Conc mg/m3
SDFE-022224-7902-05	L618635-15	39.5	940	24

METALS - NIOSH METHOD 7303

Sample Number	Lab Number	Volume	Analyte	Result	Result Units	Reporting Limit
SDFE-022224-7303-05	LM267284	79 L	Ag	< 4 ND	ug/m3	4.0
	LM267284	79 L	As	< 8 ND	ug/m3	8.0
	LM267284	79 L	Ba	21	ug/m3	6.0
	LM267284	79 L	Be	< 1 ND	ug/m3	1.0
	LM267284	79 L	Cd	< 8 ND	ug/m3	8.0
	LM267284	79 L	Co	7600	ug/m3	4.0
	LM267284	79 L	Cr	< 20 ND	ug/m3	20.0
	LM267284	79 L	Cu	7500	ug/m3	6.0
	LM267284	79 L	Mo	< 20 ND	ug/m3	20.0
	LM267284	79 L	Ni	70000	ug/m3	80.0
	LM267284	79 L	Pb	430	ug/m3	10.0
	LM267284	79 L	Sb	1400	ug/m3	6.0
	LM267284	79 L	Se	< 20 ND	ug/m3	20.0
	LM267284	79 L	Tl	60	ug/m3	40.0
	LM267284	79 L	V	< 6 ND	ug/m3	6.0
	LM267284	79 L	Zn	1100	ug/m3	10.0

ADDITIONAL ANALYSIS - NIOSH 7303

Sample Number	Lab Number	Volume	Analyte	Result	Result Units	Reporting Limit	Concentration
SDFE-022224-7303-05	L621801-7	79.2L	Aluminum	1000	mg/m3	7.5	13
	L621801-7	79.2L	Iron	12	mg/m3	7.5	0.16
	L621801-7	79.2L	Manganese	6.9	mg/m3	0.15	0.088
	L621801-7	79.2L	Strontium	0.83	mg/m3	0.15	0.01
	L621801-7	79.2L	Tin	21	mg/m3	3.0	0.27
	L621801-7	79.2L	Titanium	4.2	mg/m3	0.75	0.053

RUN 13

Date: 2/22/24
Time to 1st Rxn: 00:52
Official Run Time: 1430 - 1450 (20 mins)
5-Gas Meter Run Time: 1431 - 1501 (30 min)
HF/Particulate Run Time: 1431 - 1501 (30 min)
Sample Run Time: 1430 - 1450 (20 mins)
Test Media:
3 x NMC Zhejang Skateboard in Akkugrain Box
100% SOC, 144 cells total

	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
Sensor Peak Time	--	14:39:02	14:39:04	14:39:02	14:39:25	--	14:49:40

ASTM-D-1945 - Tedlar Bag Samples (Plus Duplicates)

Property:	Units:	SDFE-02224-1945-06A	SDFE-02224-1945-06B	SDFE-02224-1945-06AD	SDFE-02224-1945-06BD
Hydrogen	ppm (v/v)	358	12500	14400	13200
Carbon Monoxide	ppm (v/v)	840	13770	16720	14220
Oxygen	ppm (v/v)	247560 #	263540 #	255580 #	245290 #
Hydrogen	ppm (m/m)	290	1000	1160	1070
Carbon Monoxide	ppm (m/m)	740	12770	14930	13120
Oxygen	ppm (m/m)	318450 #	333070 #	330880 #	330310 #

- Result is outside of test method limits and/or analytical range used in method precision study
*Note that two Tedlar Bag samples were taken per run to ensure sufficient volume for analysis

HCN - NIOSH 6010 - Colorimetric

Sample ID	Lab ID	Air Vol liter	Front ug	Back ug	Total ug	Conc mg/m3	ppm
SDFE-022224-6010-06	L618635-8	3.84	<2.6 ND	<2.6 ND	<2.6 ND	<0.67 ND	<0.61 ND

HF - Fluoride Vapor - NIOSH 7902

Sample ID	Lab ID	Air Vol liter	Total ug	Conc mg/m3	ppm
SDFE-022224-7902-06	L618635-16	39.25	18	0.45	0.56

HF - Soluble Particulate - NIOSH 7902

Sample ID	Lab ID	Air Vol liter	Total ug	Conc mg/m3
SDFE-022224-7902-06	L618635-16	39.25	650	17

METALS - NIOSH METHOD 7303

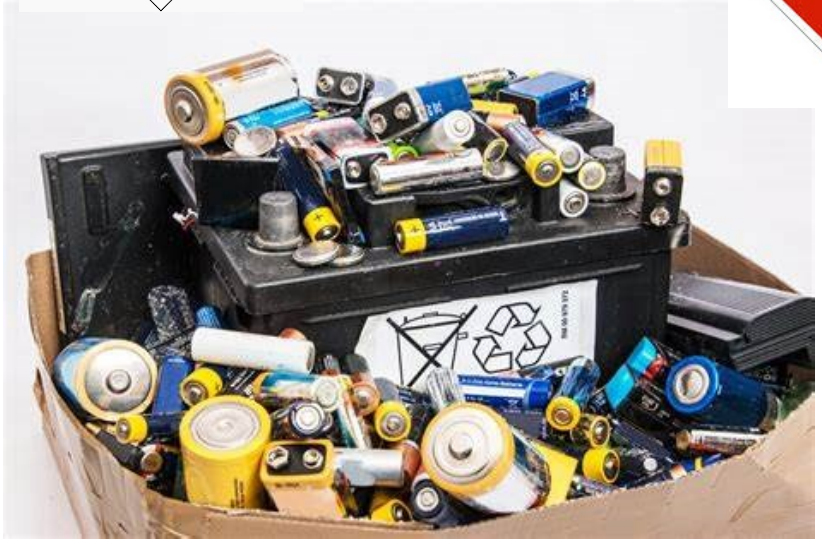
Sample Number	Lab Number	Volume	Analyte	Result	Result Units	Reporting Limit
SDFE-022224-7303-06	LM267285	78 L	Ag	< 4 ND	ug/m3	4.0
	LM267285	78 L	As	< 8 ND	ug/m3	8.0
	LM267285	78 L	Ba	46	ug/m3	6.0
	LM267285	78 L	Be	< 1 ND	ug/m3	1.0
	LM267285	78 L	Cd	< 8 ND	ug/m3	8.0
	LM267285	78 L	Co	3600	ug/m3	4.0
	LM267285	78 L	Cr	< 20 ND	ug/m3	20.0
	LM267285	78 L	Cu	2300	ug/m3	6.0
	LM267285	78 L	Mo	< 20 ND	ug/m3	20.0
	LM267285	78 L	Ni	33000	ug/m3	8.0
	LM267285	78 L	Pb	220	ug/m3	10.0
	LM267285	78 L	Sb	240	ug/m3	6.0
	LM267285	78 L	Se	< 20 ND	ug/m3	20.0
	LM267285	78 L	Tl	< 40 ND	ug/m3	40.0
	LM267285	78 L	V	< 6 ND	ug/m3	6.0
	LM267285	78 L	Zn	470	ug/m3	10.0

ADDITIONAL ANALYSIS - NIOSH 7303

Sample Number	Lab Number	Volume	Analyte	Result	Result Units	Reporting Limit	Concentration
SDFE-022124-7303-01	L621801-8	78.0L	Aluminum	650	mg/m3	7.5	8.4
	L621801-8	78.0L	Iron	13	mg/m3	7.5	0.16
	L621801-8	78.0L	Manganese	0.54	mg/m3	0.15	0.0069
	L621801-8	78.0L	Strontium	0.15	mg/m3	0.15	0.002
	L621801-8	78.0L	Tin	21	mg/m3	3.0	0.27
	L621801-8	78.0L	Titanium	1.8	mg/m3	0.75	0.022

What is it?:

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



Waste Determination and Transportation

- 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

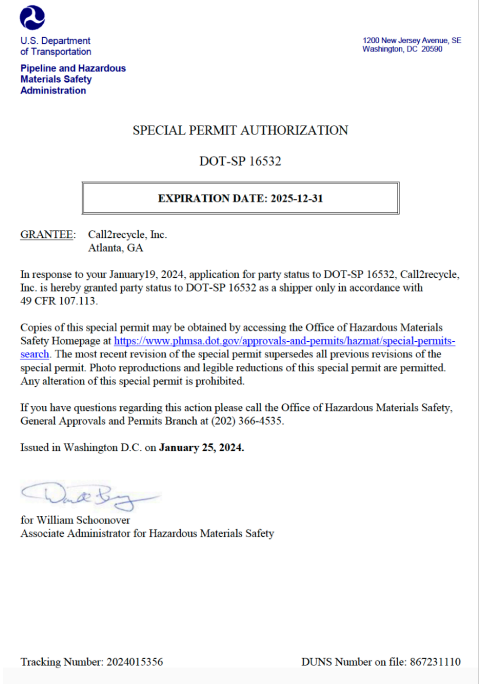
(3) Each inner packaging must be individually placed in one of the following packagings meeting the applicable requirements of part 178, subparts L, M, P, and Q of this subchapter at the Packing Group I level:

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



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

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 January19, 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.

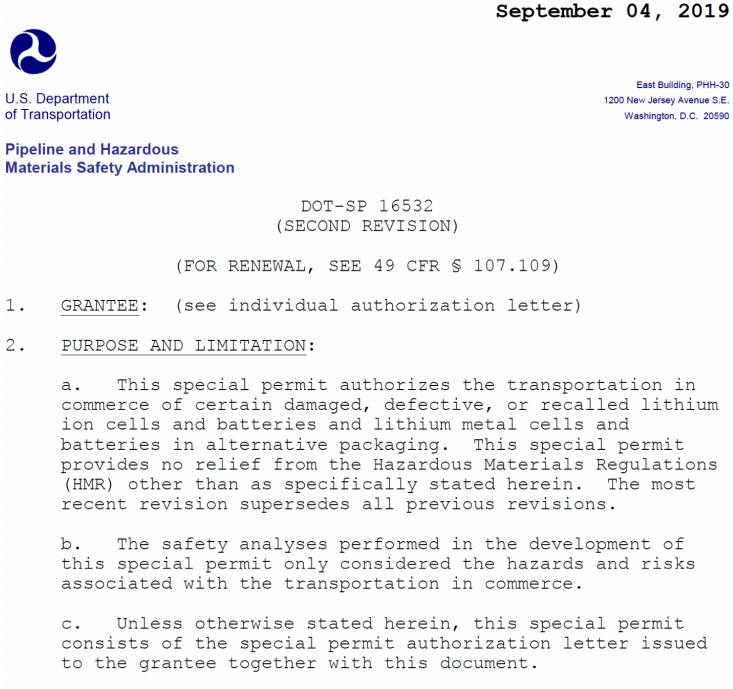
Copies of this special permit may be obtained by accessing the Office of Hazardous Materials Safety Homepage at https://www.phmsa.dot.gov/approvals-and-permits/hazmat/special-permits-search. The most recent revision of the special permit supersedes all previous revisions of the special permit. Photo 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.**

for William Schoonover
Associate Administrator for Hazardous Materials Safety

Tracking Number: 2024015356 DUNS Number on file: 867231110



September 04, 2019

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

DOT-SP 16532
(SECOND REVISION)

(FOR RENEWAL, SEE 49 CFR § 107.109)

1. GRANTEE: (see individual authorization letter)

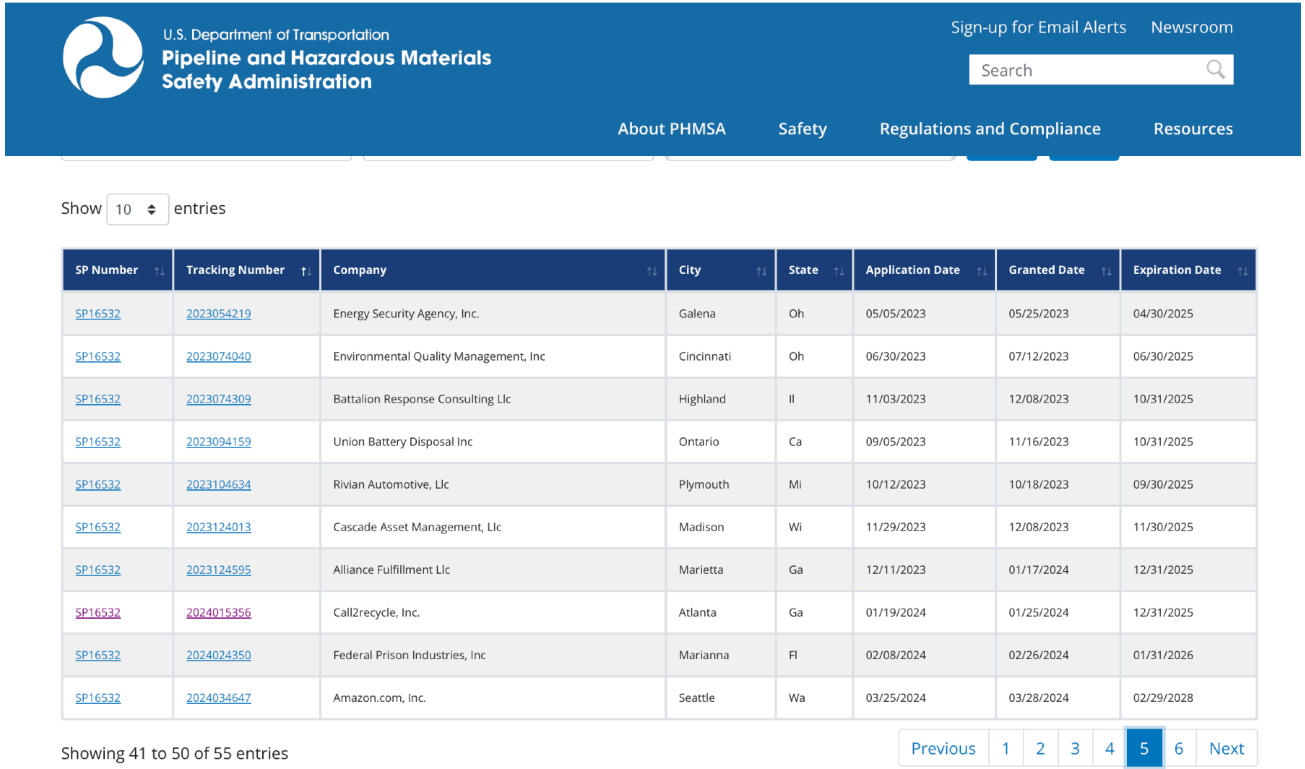
2. PURPOSE AND LIMITATION:

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

Sign-up for Email Alerts Newsroom

Search

About PHMSA Safety Regulations and Compliance Resources

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

6. HAZARDOUS MATERIALS (49 CFR § 172.101):

Hazardous Materials Description			
Proper Shipping Name	**Hazard Class/ Division**	**Identi-fication 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

(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

(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.

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:

- All terms and conditions prescribed in this special permit and the Hazardous Materials Regulations, 49 CFR Parts 171-180.
- 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.
- 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

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.:

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

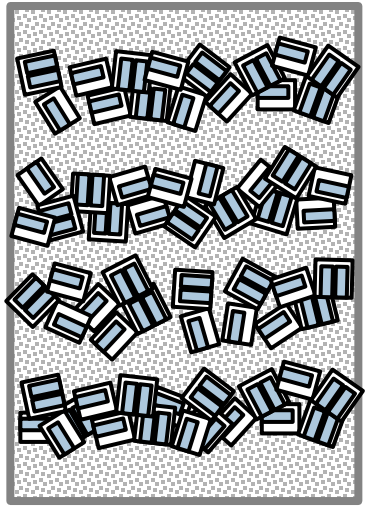
DOT SP-16532:
Held by cleanup company - not site specific

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







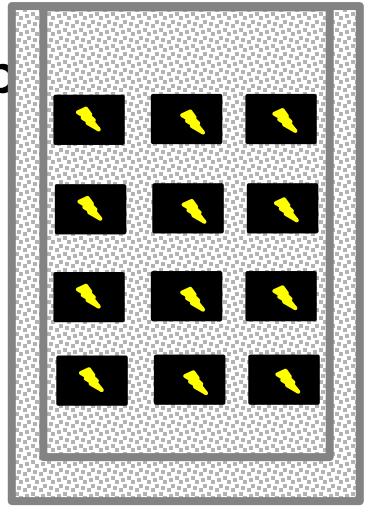



DOT SP-21329 – held by R4, site specific

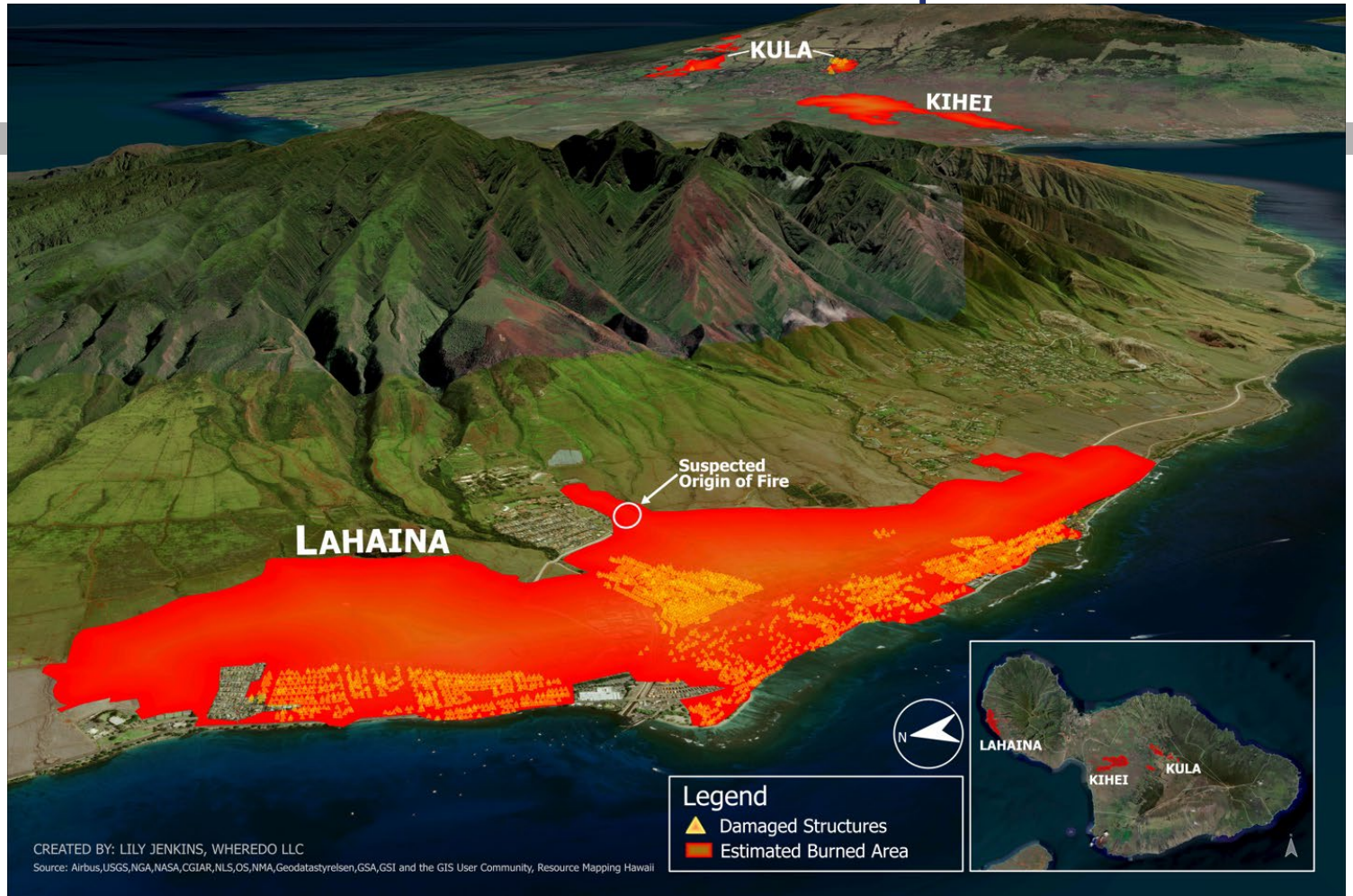
- Special Permit to package multiple “large” lithium-ion batteries (>300Wh, 14 lbs)








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

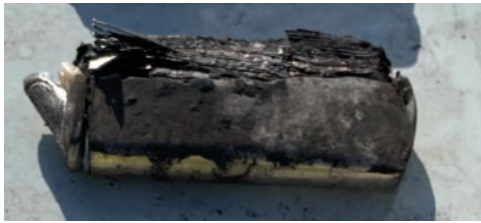
- Actions (Maui)
  - Crush/destroy/de-construct (No longer meets definitions)
    - 40 CFR 273.9

> *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***

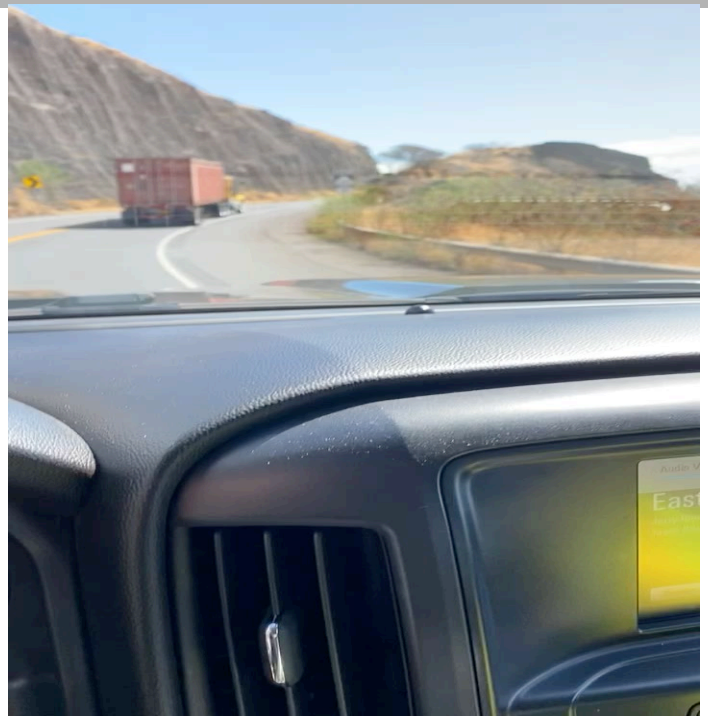
33.5.4.4.4 Packing group III/Category 3 should be assigned to any substance which reacts slowly with water at ambient temperatures such that the maximum rate of evolution of flammable gas is greater than 1 litre per kilogram of substance per hour, and which does not meet the criteria for packing groups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

Waste Determination and Transportation

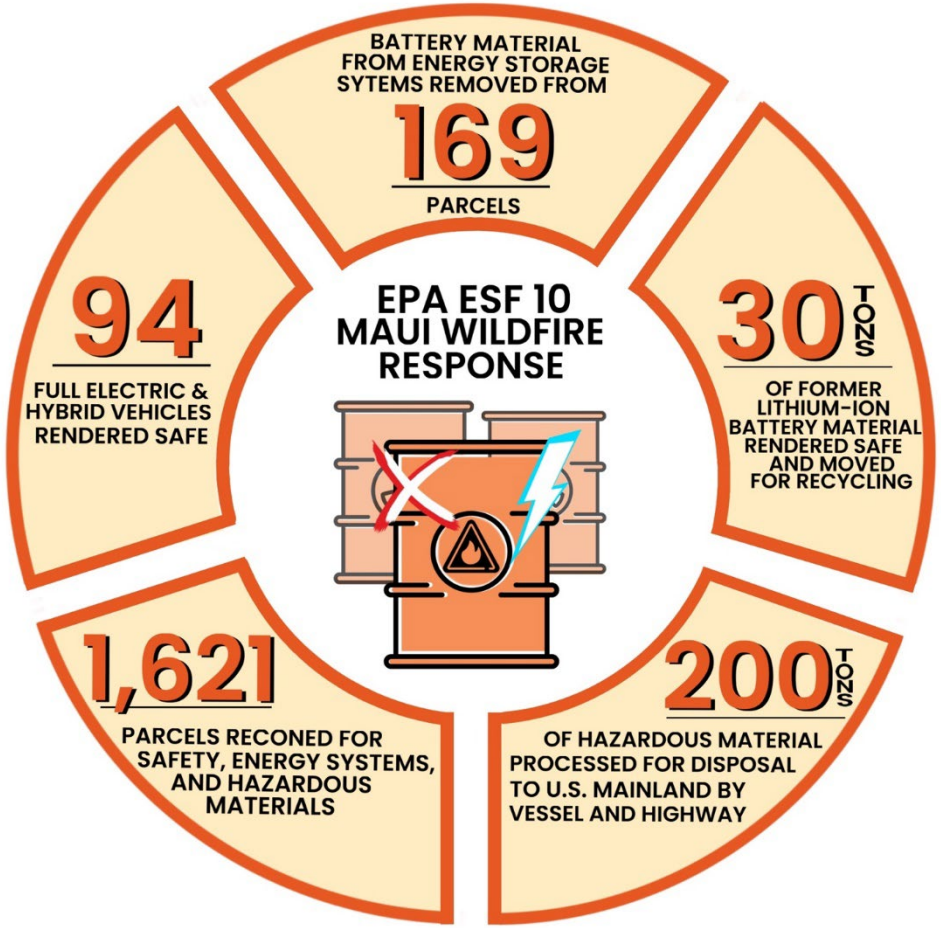
Actions (Maui)

- 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
      - (Drager Tubes: .2%, very light colored green)
  - Particulate Control
  - Water Intrusion Control
- Packaging transported in open top containers

Carrier to West Coast to Recycler



Waste Determination and Transportation



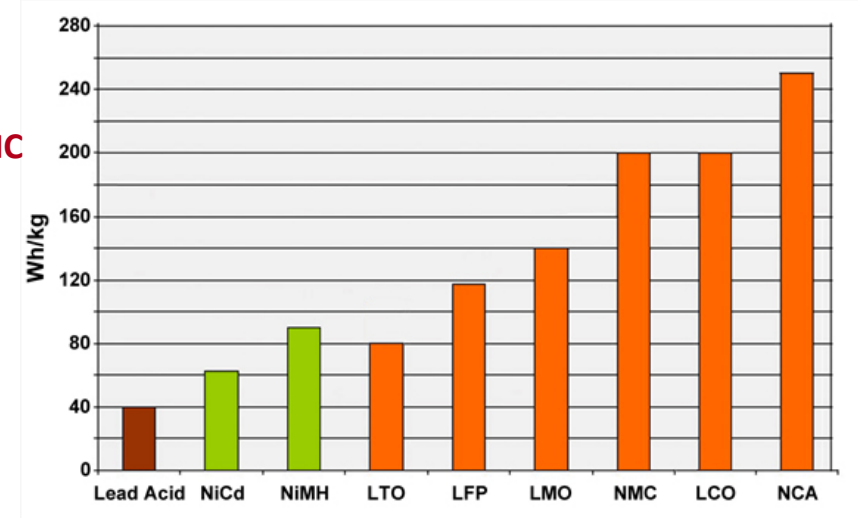
Disposal

- 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 (Li2TiO3) — LTO

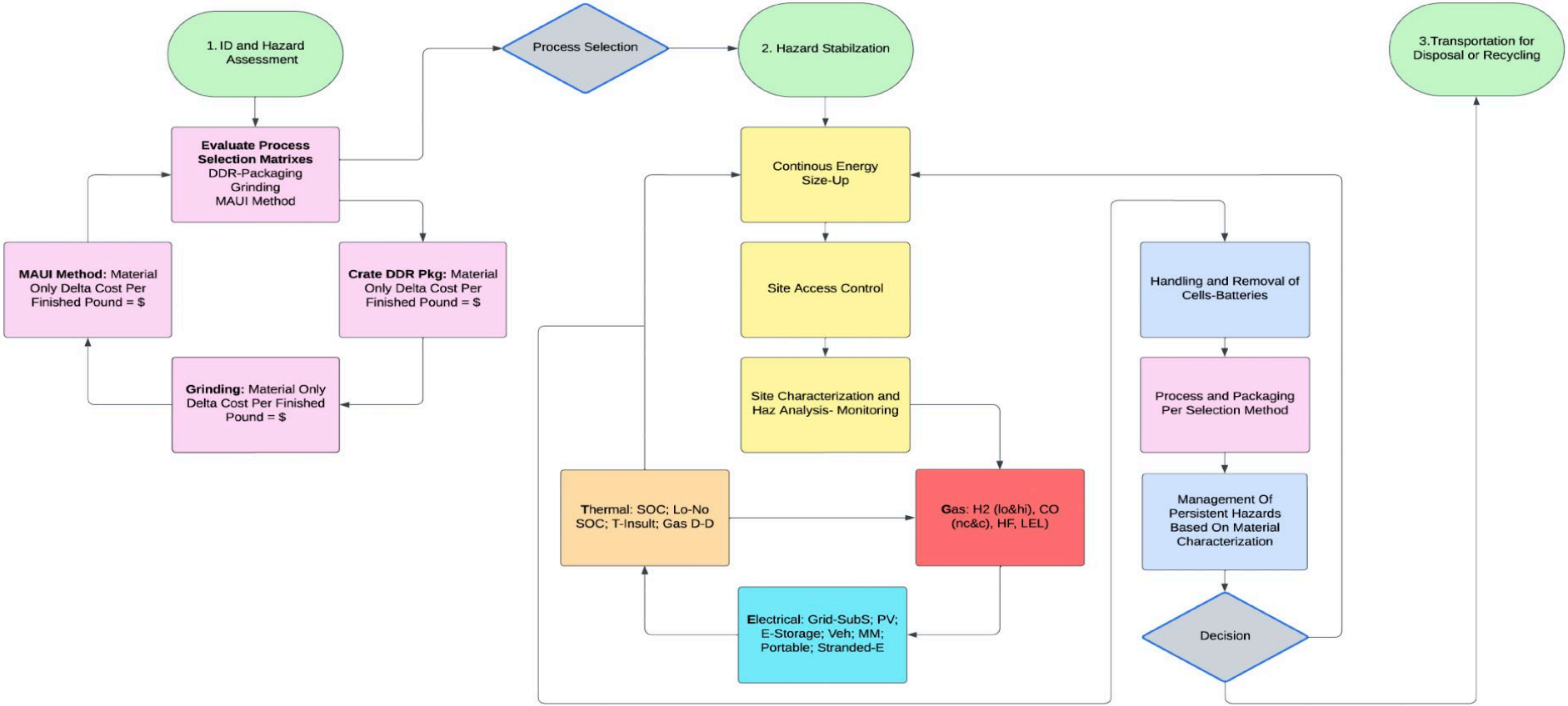


Different chemistries cannot all be recycled together (depends upon recycler)

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**

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

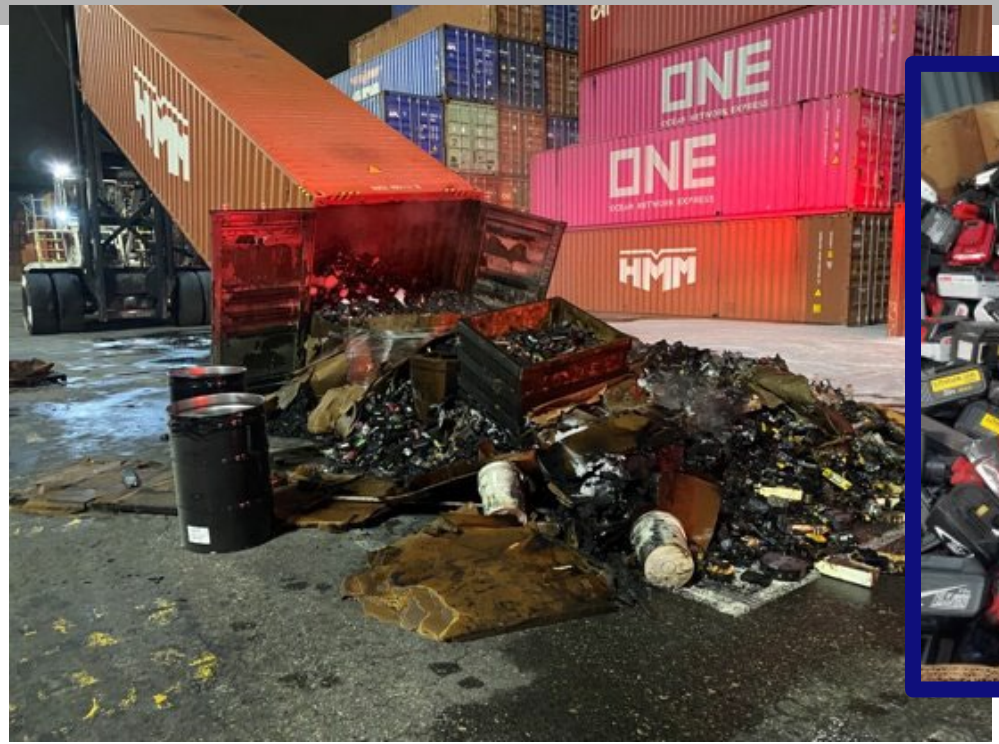
Use of black shrink-wrap made it difficult to see damage that impacted the cellphones/batteries in the packages.

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

- Shipper described the contents as **Synthetic Resins N.O.S.**

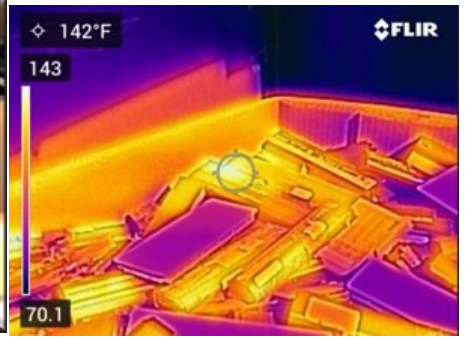
- Many other containers were found in the port and loaded on ships with the same description

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

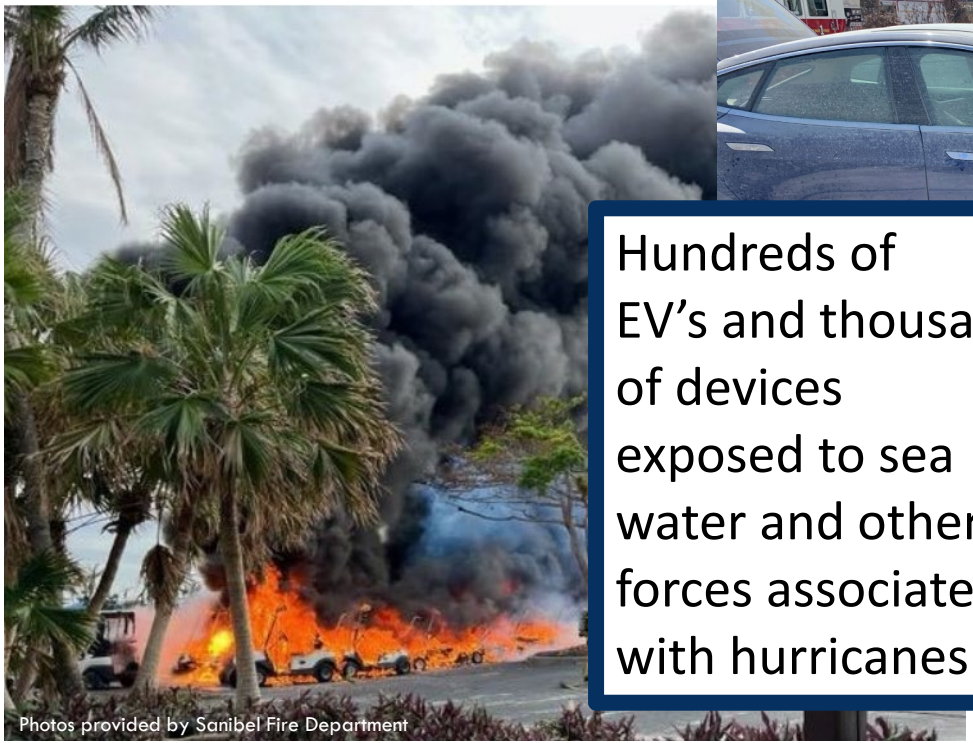


Port – L.A. Long Beach – March 4, 2022

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

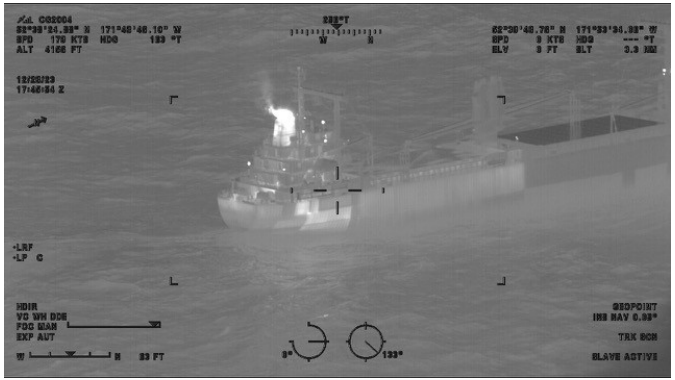
Photos provided by Sanibel Fire Department

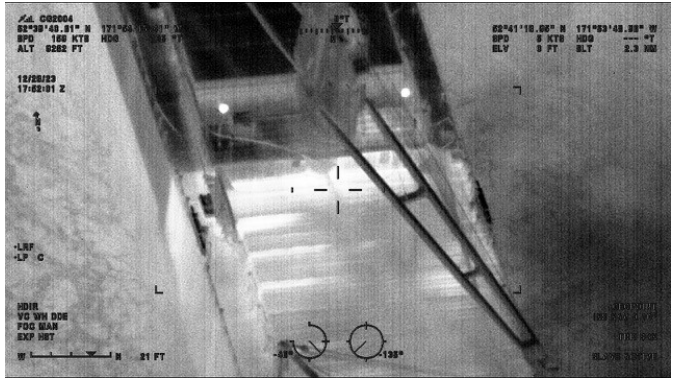
Birmingham, AL– March 31, 2023

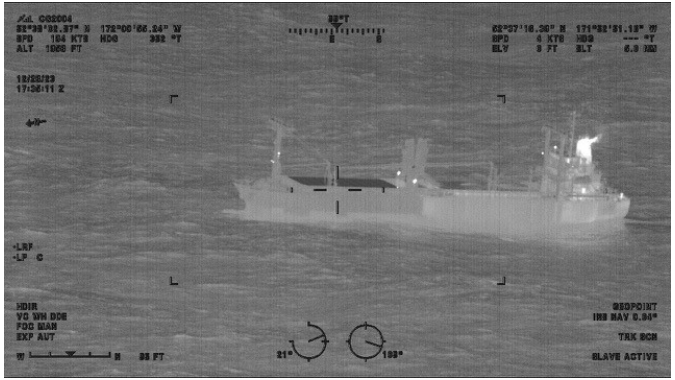
Genius Star IX, December 25, 2023

Genius Star IX

Genius Star IX







Photos by Lt. Cmdr Michael Salerno, USCG D17

Genius Star IX

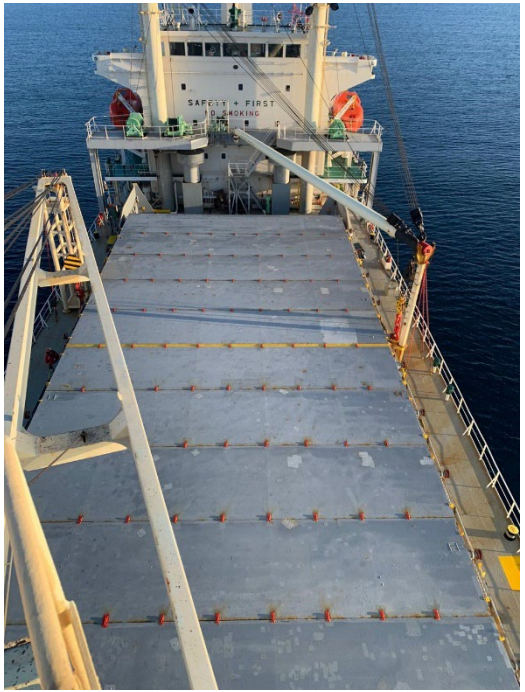
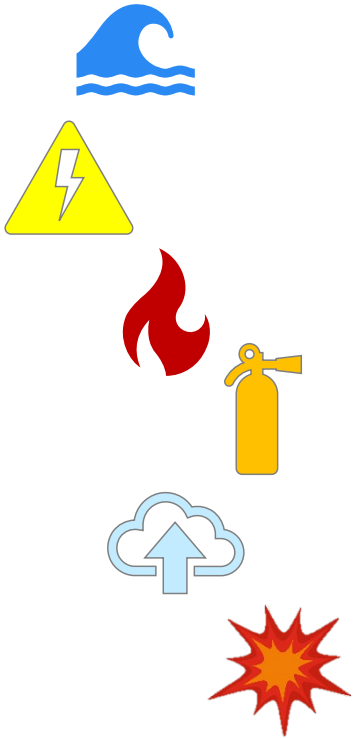


Photo by T&T Salvage and Marine Firefighting

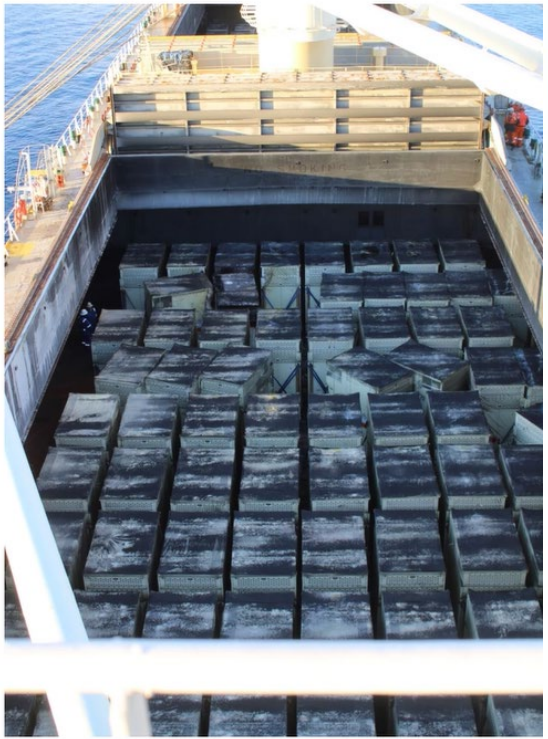
Genius Star IX

Photo by Petty Officer 1st Class Melissa McKenzie, USCG

Genius Star IX



Genius Star IX



10 cells

x

3 modules

x

28 packs

x

180 stacks

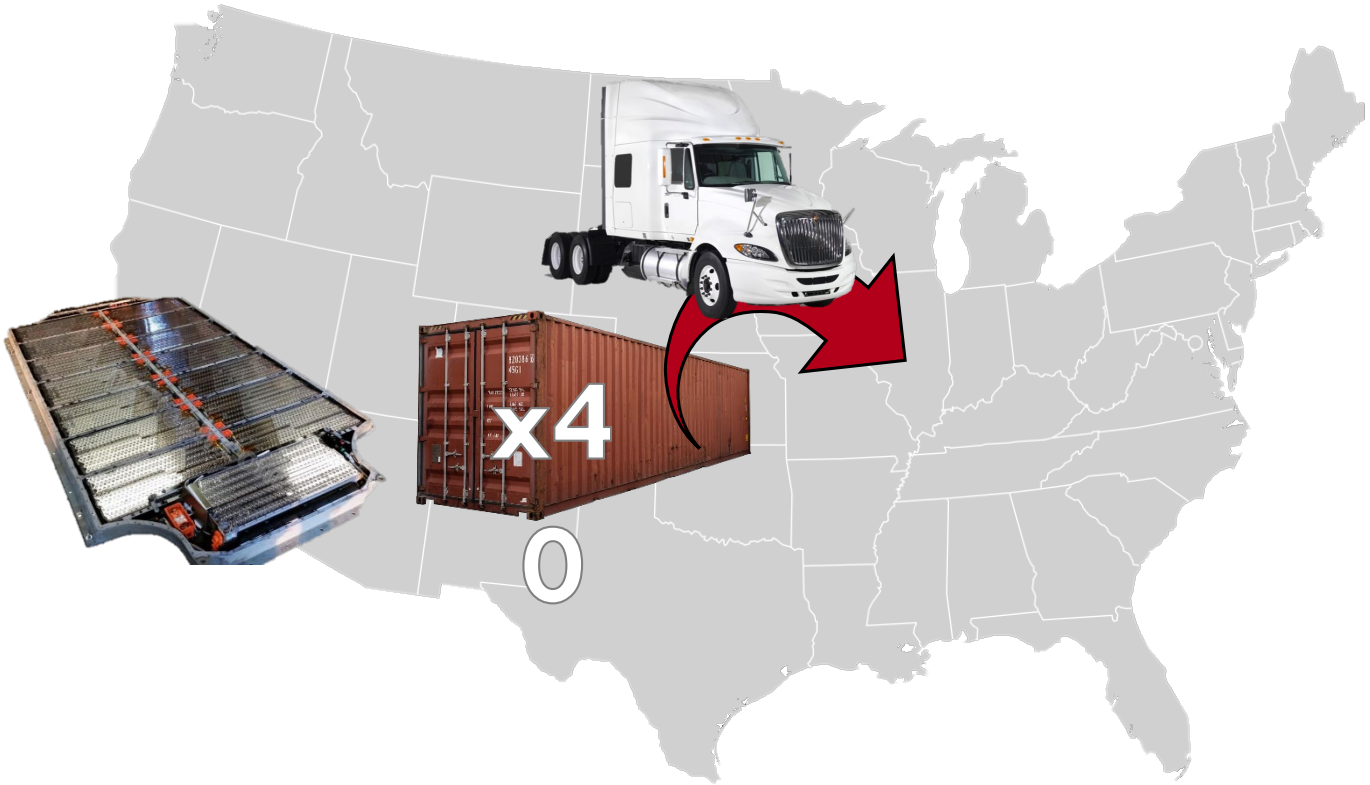
=

>150k cells

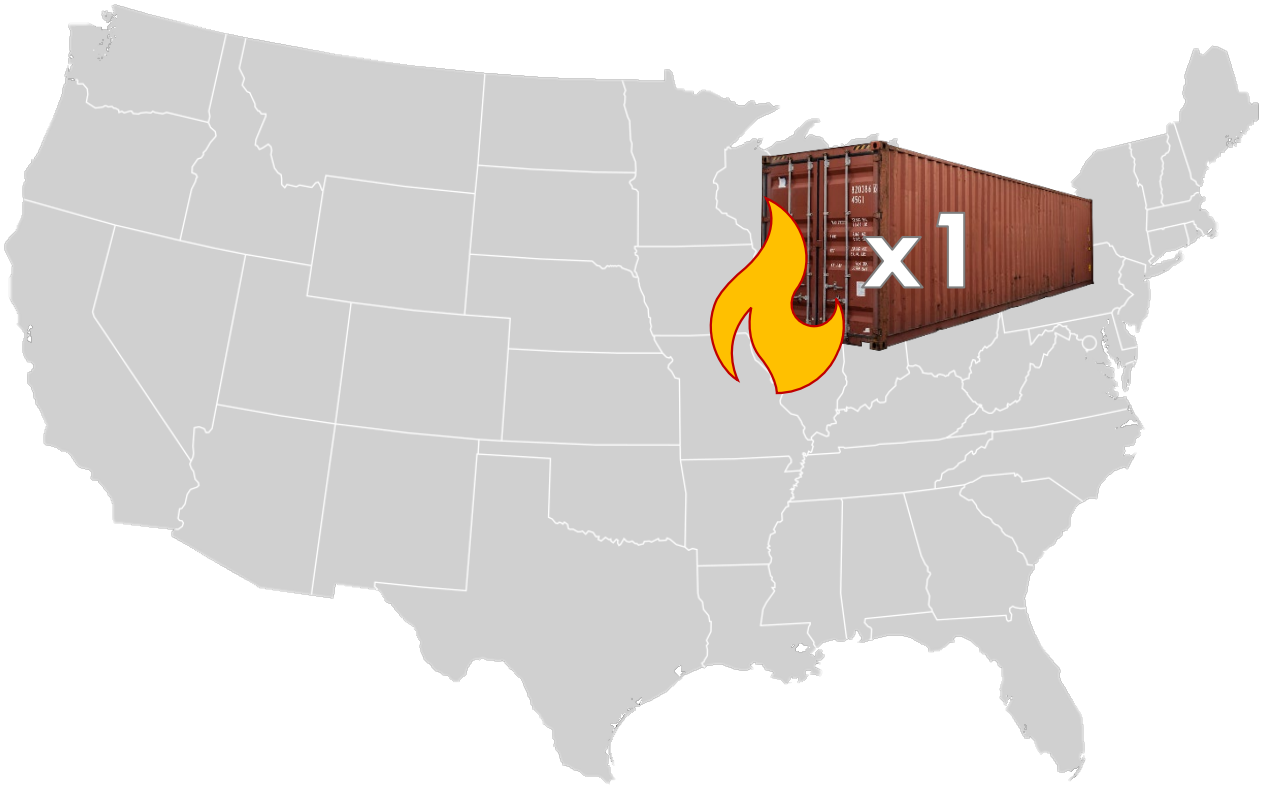
Genius Star IX

M/V Magellan

M/V Magellan



M/V Magellan



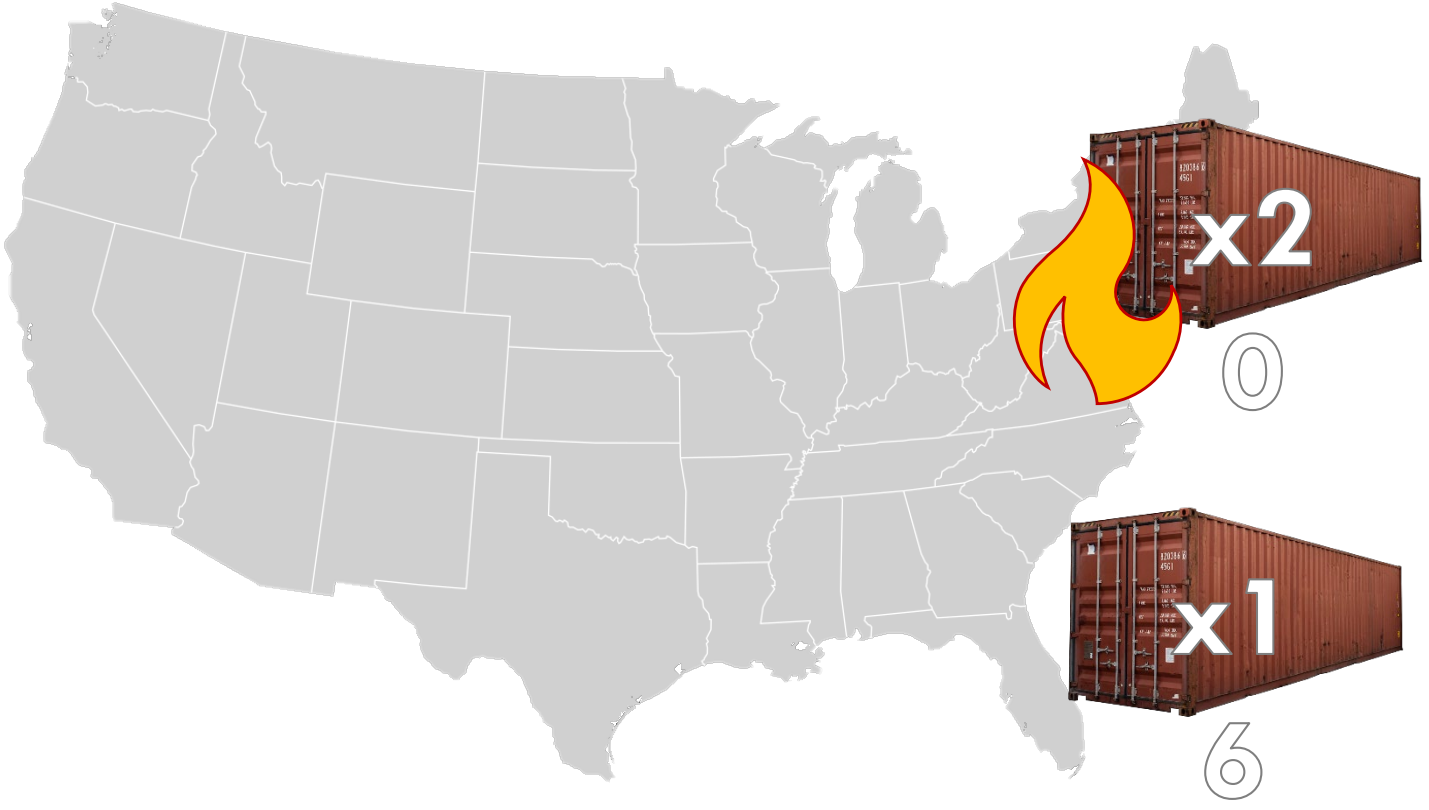
M/V Magellan

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

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

- 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