


Paul Combs,
Fire Engineering.
Used by permission
of the artist.

VERMONT
FIRE ACADEMY
DIVISION OF FIRE SAFETY

VERMONT
FIRE ACADEMY
DIVISION OF FIRE SAFETY

# Lithium Ion Batteries

## Safety and Tactical Considerations for Firefighters

Version 1.3 | February 2025





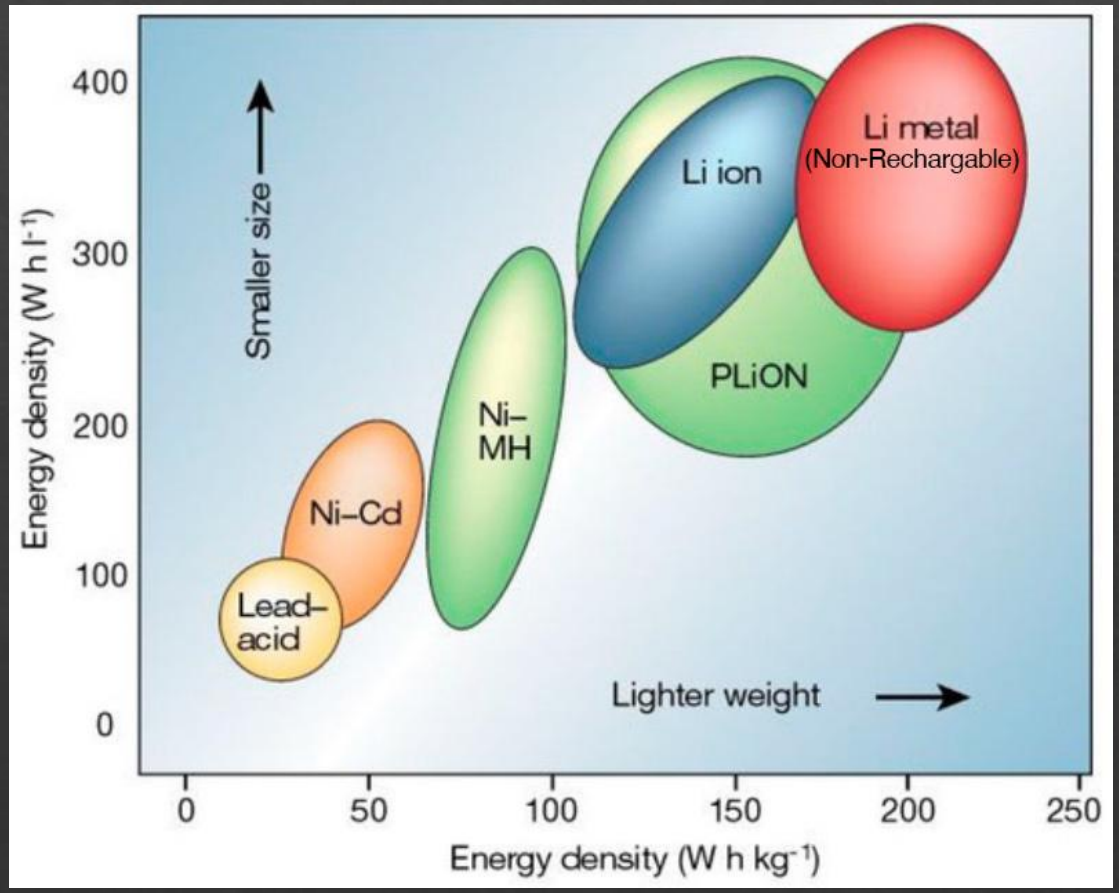

# Part 1:
# Lithium Batteries 101

What are lithium batteries, and what is the nature of the hazard lithium batteries pose to the fire service?

VERMONT
FIRE ACADEMY
DIVISION OF FIRE SAFETY

# Why Lithium Ion Batteries?

- Lithium provides an extremely high ratio of power to weight and size
- Makes these batteries suitable for applications where weight matters
  - Portable electronic devices
  - Tools
  - Cars & trucks
  - "e-mobility" devices: Scooters, mopeds, battery-assisted bicycles, hoverboards, etc.




VERMONT FIRE ACADEMY
DIVISION OF FIRE SAFETY

# Lithium Ion Battery Chemistries

- **Various chemistries** used in different batteries
- Each has different characteristics in terms of:
  - Specific energy
  - Specific power
  - Performance
  - Lifespan
  - Cost
  - **SAFETY**

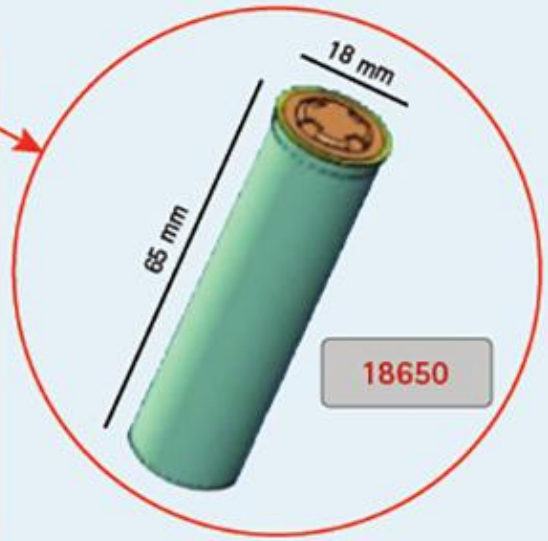
- Lithium Cobalt Oxide
- Lithium Manganese Oxide
- Lithium Iron Phosphate
- Lithium Nickel Manganese Cobalt Oxide
- Lithium Nickel Cobalt Aluminum Oxide
- Lithium Titinate



# How do Lithium-ion batteries work?

# 18650:Workhouse of e-Mobility Devices

Li battery types




Battery of choice for TESLA and 99.9% of all micro-mobility devices
Length/width

Cylindrical cell

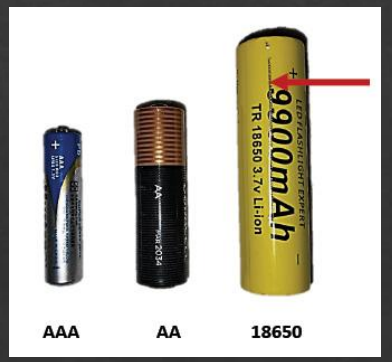
Pros: Compact size, hard casing—impact resistant, least expensive production costs. Some built-in safety features to resist thermal breakdown. Tesla uses 3K–7K cylindrical cells to power vehicle; if one cell fails, there is little impact on overall performance.

Cons: Most difficult to regulate and prone to quality control issues.




**18650 =**
**18**mm wide **65.0**mm tall

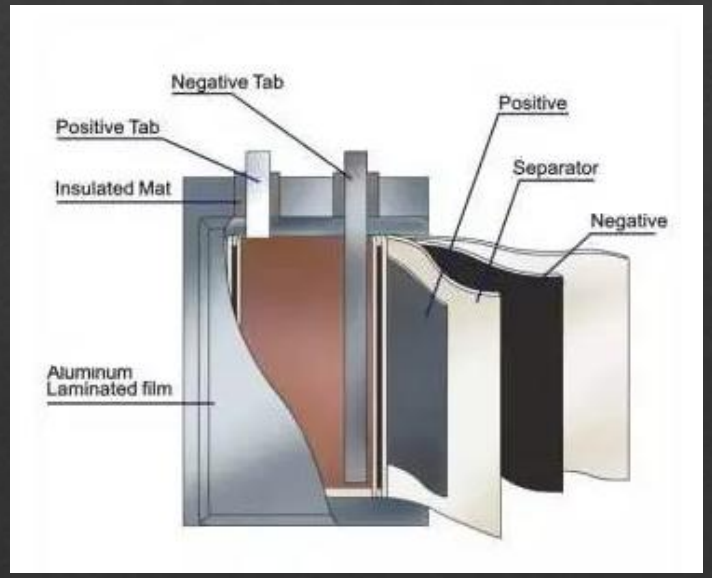


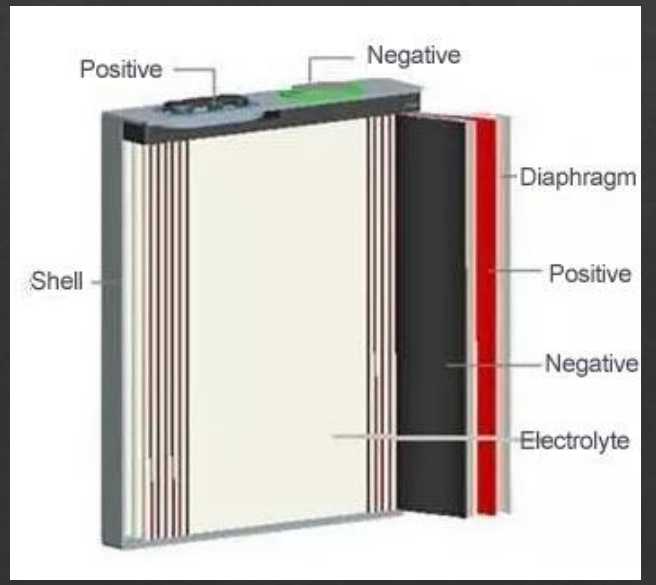

VERMONT FIRE ACADEMY
DIVISION OF FIRE SAFETY

# Lithium Ion Battery Construction

- **Pouch Cell**
  - Flat configuration, flat form factor
  - Common in phones, laptops, small electronics

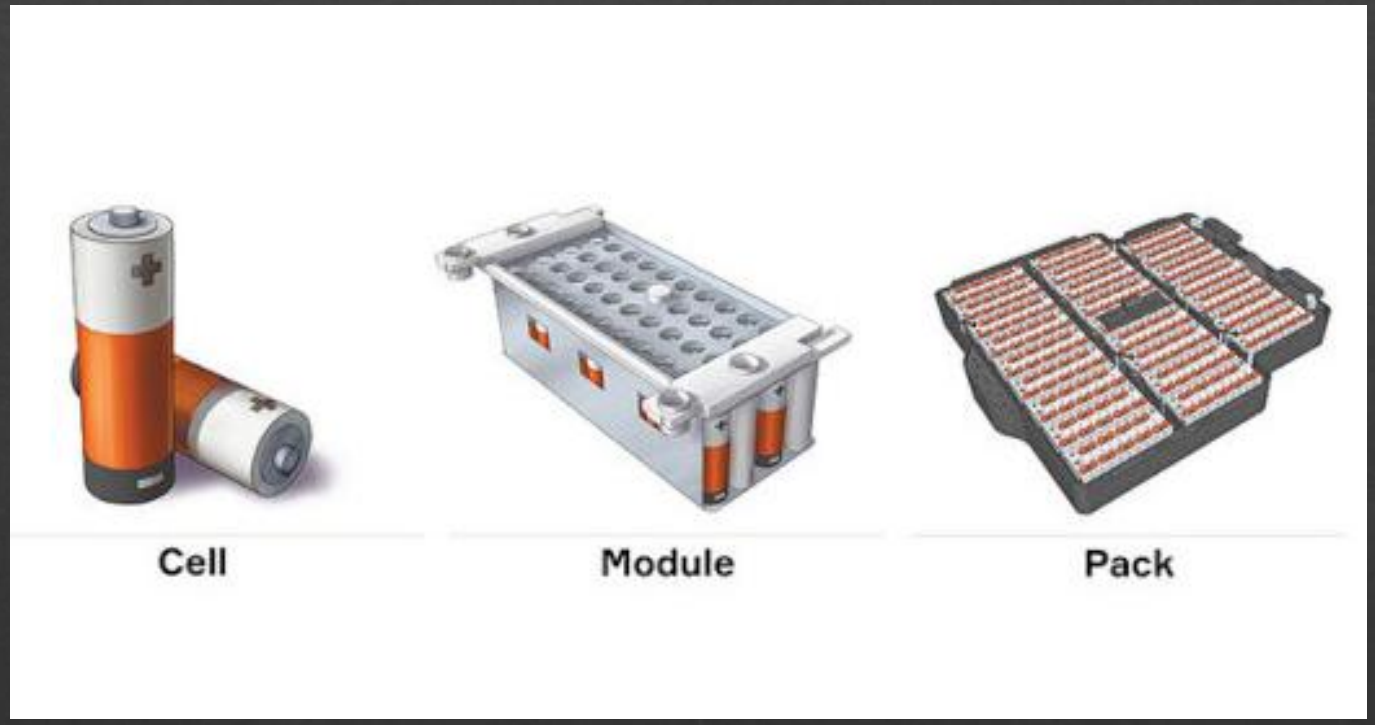



- **Prismatic Cell**
  - Z or C-fold configuration, rectangular form factor
  - Used in some electric vehicles




VERMONT FIRE ACADEMY
DIVISION OF FIRE SAFETY

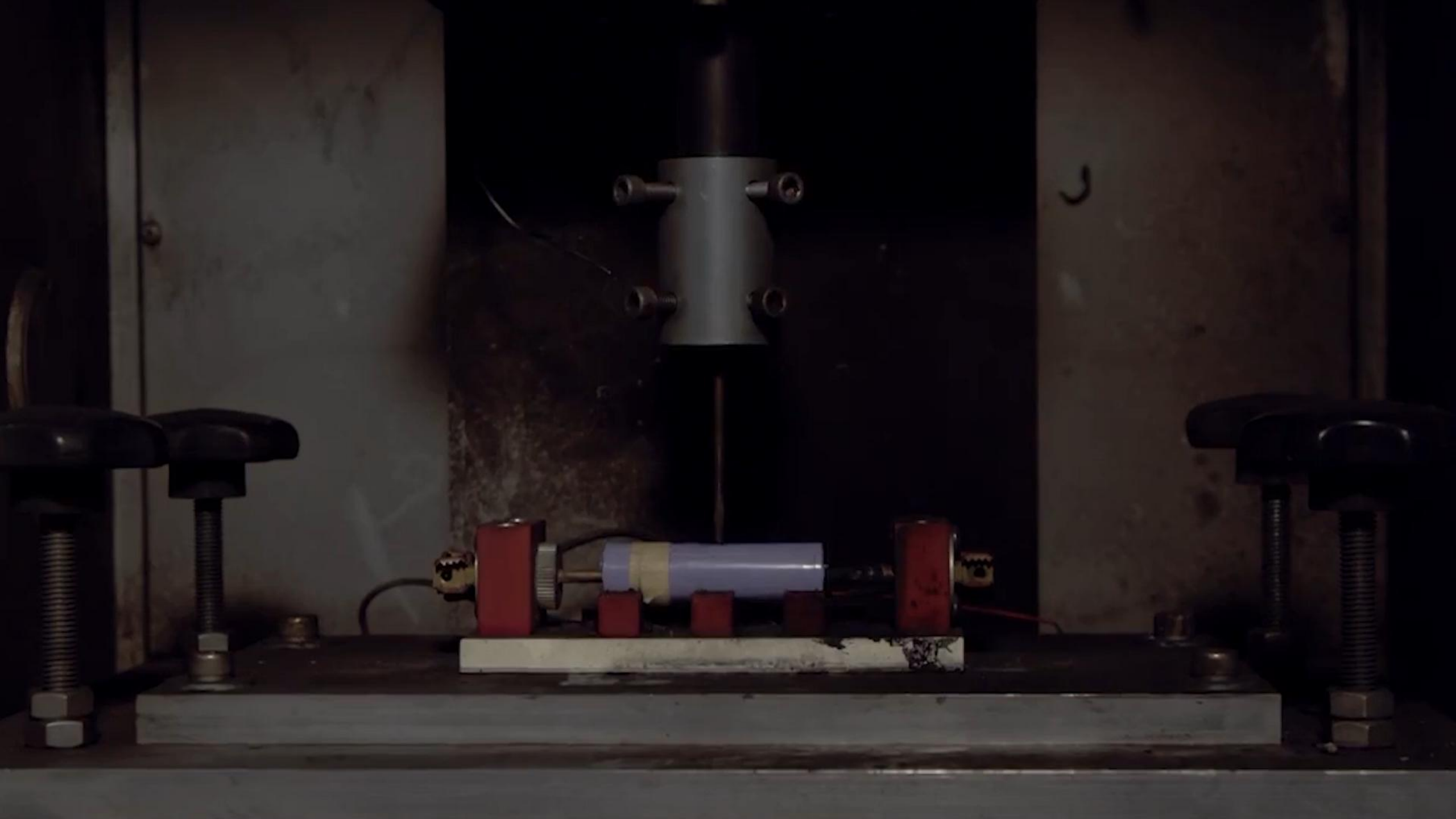
# Making Big Batteries Out of Small Ones






Tesla Model S battery = 7,104 18650 cells in 16 modules of 444 cells each, capable of storing up to 85 kWh of energy

VERMONT FIRE ACADEMY
DIVISION OF FIRE SAFETY



# Thermal Runaway

## Typical Causes

- Physical abuse (drop, crush, penetration)
- Thermal abuse (overheating)
- Electrical abuse (overcharging)
- Manufacturing defects
- Modifications
- Mismatched parts

## Typical Effects

- Rapid release of gasses
  - Acute toxic hazard
  - Extremely flammable
- Autoignition of electrolyte
  - Rapid combustion
  - High heat release

VERMONT FIRE ACADEMY
DIVISION OF FIRE SAFETY

# Not Just Electric Vehicles

- Thermal runaway can occur in:
  - Cell phones
  - Laptops
  - e –Mobility devices
  - Energy storage systems
  - Power tools
  - **ANY device with a lithium-ion battery**









VERMONT FIRE ACADEMY
DIVISION OF FIRE SAFETY

# Threats Posed by Thermal Runaway

- High heat
- Massive evolution of toxic, flammable gas
- Flame jetting
- Explosive ejection of battery parts

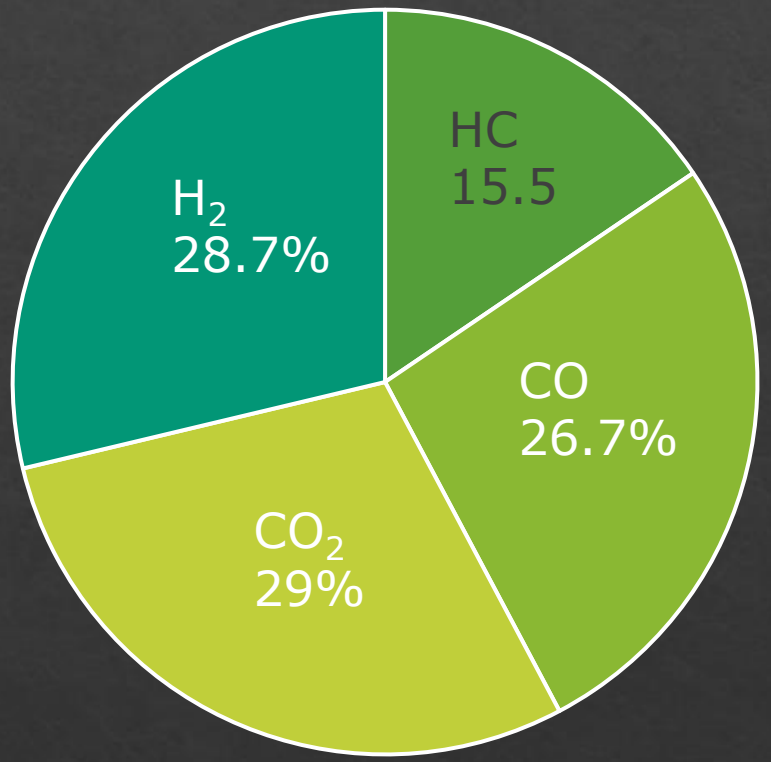


Youtube @Batteryman1952

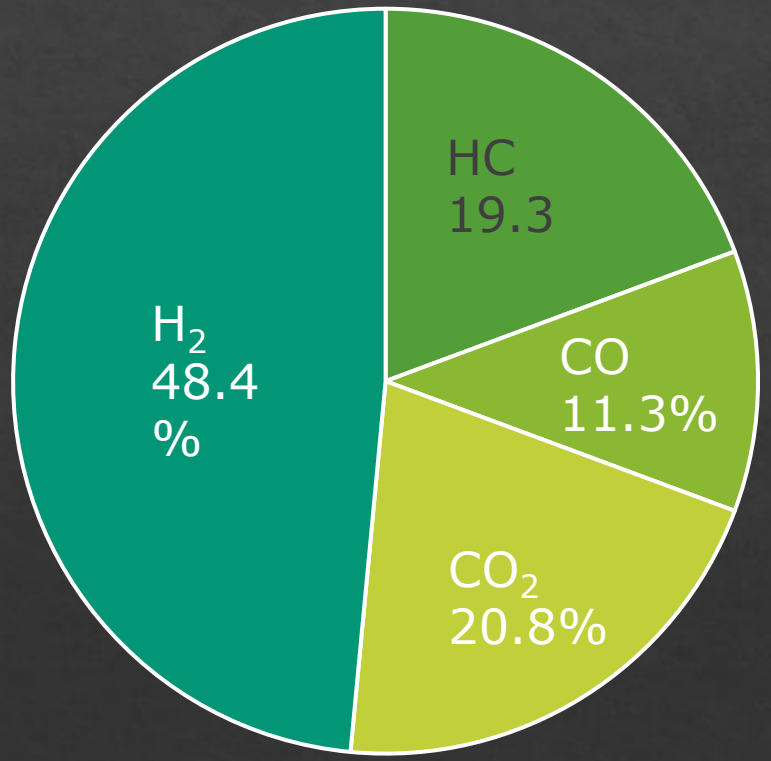
VERMONT FIRE ACADEMY
DIVISION OF FIRE SAFETY

# Gas Concentration

## Li Nickel Cobalt Oxide




## Li Iron Phosphate




VERMONT
FIRE ACADEMY
DIVISION OF FIRE SAFETY

# Inhalation Threats

- Hydrogen (4% - 75 % flammable range)
- Hydrogen Fluoride
- Carbon Dioxide
- Dimethyl Carbonate
- Ethane
- Ethylene
- Methane
- Ethyl Methyl Carbonates
- FAA Study: One 18650 cell at 100% SOC releases **8 liters of gas**

VERMONT FIRE ACADEMY
DIVISION OF FIRE SAFETY


2021 05 23 星期日 08:21:50
newsflare
KINEMASTER
Camera 01


N
3
mph


WWW.WIONEWS.COM
LOCATION:
BEIJING,CHINA
SOURCE: CCTV / REUTERS


31/12/2021 06:16:44
CAM 3




2023-04-11 08:30:46 -0600
AXON BODY 3 X60AC497T

# Part 2:
# Dealing with Lithium-Ion Battery Fires

Tactical considerations for fires involving lithium batteries

VERMONT FIRE ACADEMY
DIVISION OF FIRE SAFETY

# Initial Fire Suppression: Water Helps

- Water must be applied to the battery pack to get the desired cooling effect
- Can be easier said than done







# Water Stops Propagation, Not Thermal Runaway

- Lithium-ion batteries will burn underwater
- Some of the gasses released in failure are water soluble but some are not and can pose toxic inhalation and flammable hazards



Youtube @kisssys5414

VERMONT FIRE ACADEMY
DIVISION OF FIRE SAFETY

# EV Battery Fire Tactics









- Extinguishers are ineffective on lithium battery fires

VERMONT FIRE ACADEMY
DIVISION OF FIRE SAFETY



Youtube
@eco_maine

VERMONT
FIRE ACADEMY
DIVISION OF FIRE SAFETY

# Overhaul Considerations

- Cells can be ejected from the module explosively
  - May be found in areas remote from the original device
- All cells must be accounted for – leaving cells in fire debris poses a rekindle hazard
- Stranded energy and damaged equipment pose a shock risk to responders

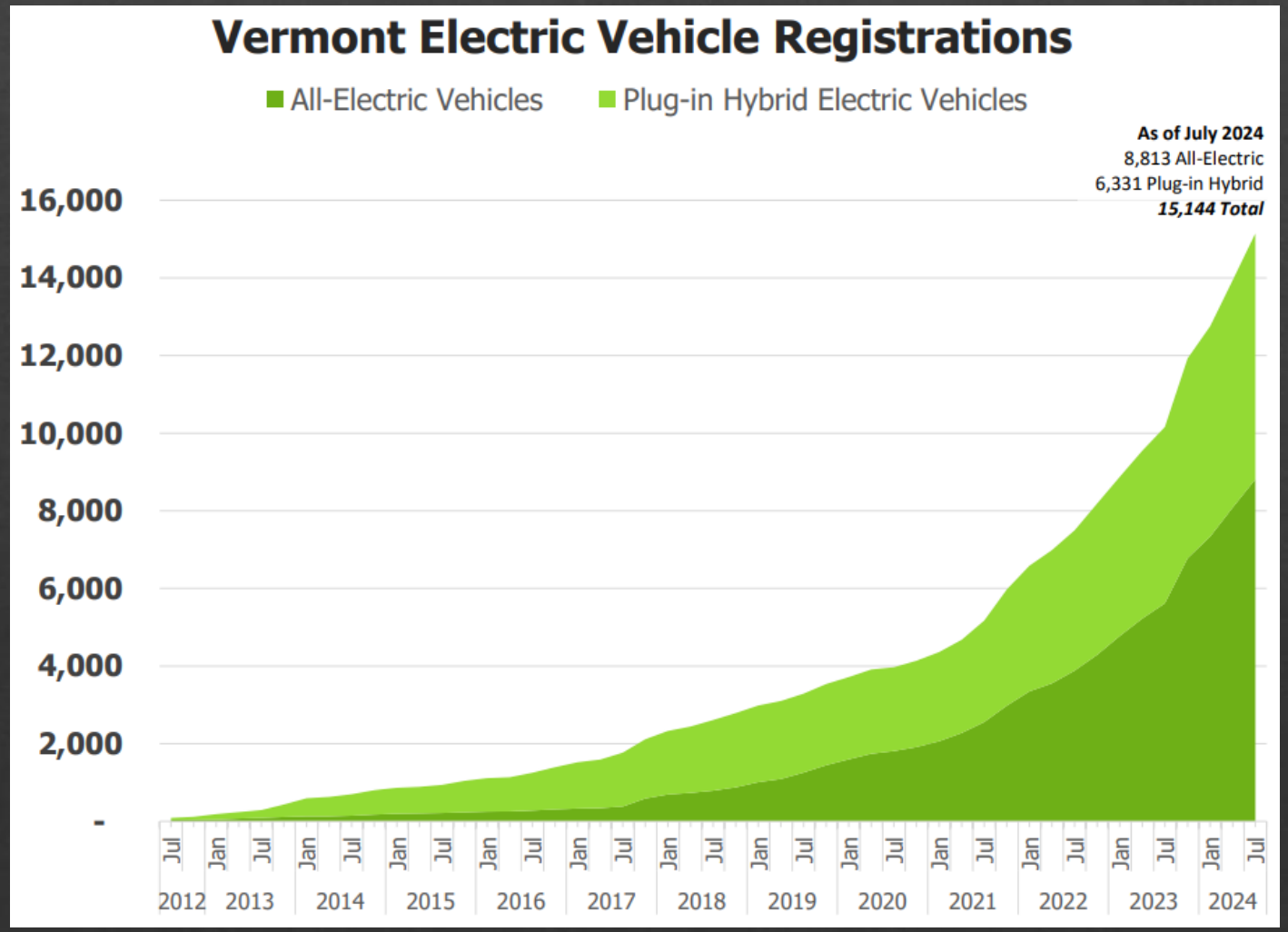


# Part 3:
# Electric Vehicle Fires

Tactical considerations for emergencies involving EV’s

VERMONT
FIRE ACADEMY
DIVISION OF FIRE SAFETY

# EV’s on the Roads




Drive Electric Vermont



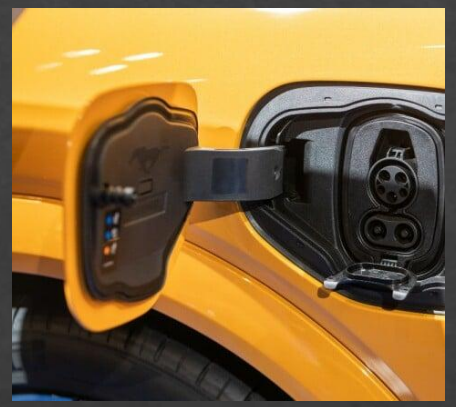
- Nothing new, but coming back into style
- 8.7% of new cars sold in the US in Q4 of 2024 were EV’s
- 15,144 registered in Vermont, 49% increase in 2024 alone

VERMONT FIRE ACADEMY
DIVISION OF FIRE SAFETY

# Identifying Electric Vehicles

- Ask the Driver
- External Vehicle Badging
- No Front Grille
- No Exhaust Pipe
- Presence of a Charge Port
- High Voltage Component Stickers












VERMONT FIRE ACADEMY
DIVISION OF FIRE SAFETY


Youtube @TheGrandTourFans
The Grand Tour
Fans
PED XING
PED XING

# EV Battery Fire Tactics

- Use water to cool the cells
- Consider non-intervention
  - Probably not an option in urban areas
  - May be the best option in rural areas



FSRI

VERMONT FIRE ACADEMY
DIVISION OF FIRE SAFETY

# Effective Tactics Using Water

- Objective is to stop propagation. You will not be able to stop those cells that are in thermal runaway
- Full PPE and SCBA a must
- Establish water supply and expect to need up to 3,000 gallons
- Check temperatures with a TIC
  - Direct water on areas where temperature is above ambient.



Marietta (GA) FD

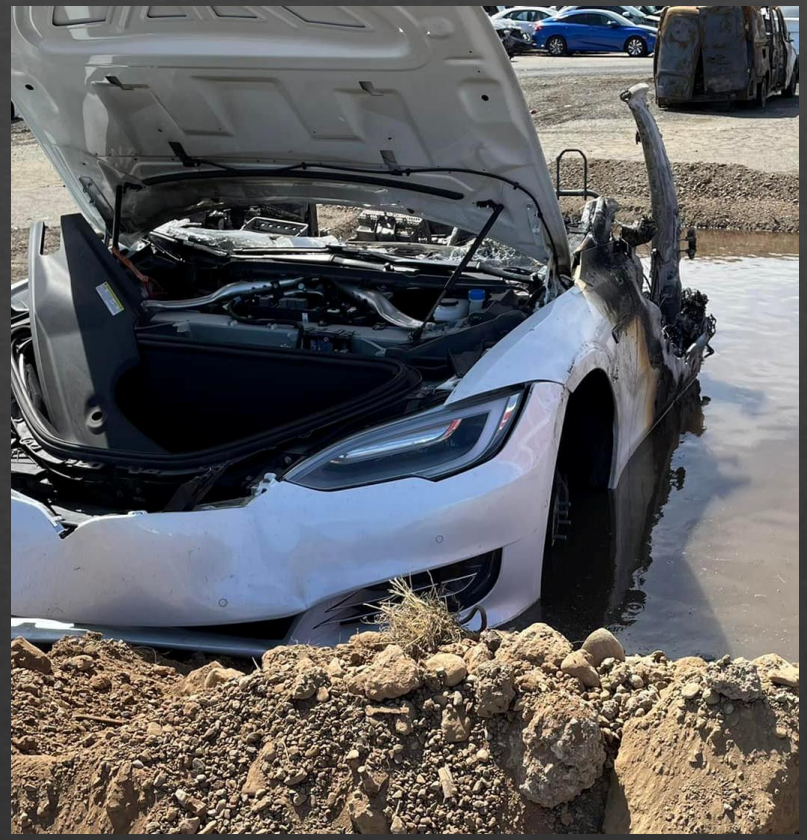
VERMONT FIRE ACADEMY
DIVISION OF FIRE SAFETY

# Submersion




Hulpverleningszone Oost (Herent, Belgium)

- **Pros:**
  - Partially removes hazard
- **Cons:**
  - Cost & availability
  - Proximity
  - Logistics
  - Time
  - Environmental issues



Sacramento (CA) Metropolitan Fire District

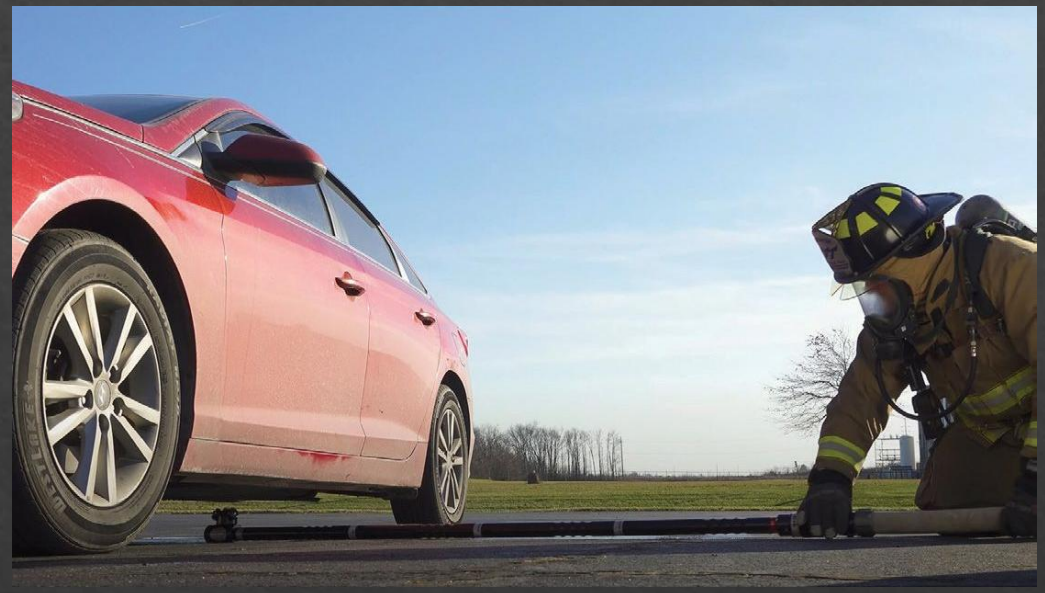
VERMONT FIRE ACADEMY
DIVISION OF FIRE SAFETY

# Specialty Under-Car Nozzles

- **Pros:**
  - Unmanned once deployed
  - May provide easier way to get water on battery
  - Low water volume
- **Cons:**
  - Proximity
  - Cost & availability
  - Less effective cooling than a handline




Toxic Suppression Firefighter Safety Solutions



Task Force Tips



Turtle Fire Systems

VERMONT FIRE ACADEMY
DIVISION OF FIRE SAFETY

# Specialty Fire Blankets

- **Pros:**
  - Buys time
  - Application is quick
  - Containment
  - Exposure protection
- **Cons:**
  - Proximity
  - Cost & availability
  - Does not extinguish batteries




W. S. Darley & Company

VERMONT FIRE ACADEMY
DIVISION OF FIRE SAFETY


fedex.com

# Post-Operation Considerations

- Unless it has burned completely, thermal runaway risk remains




VERMONT FIRE ACADEMY
DIVISION OF FIRE SAFETY

# Part 4:
# Energy Storage System (ESS) Fires

Tactical considerations for emergencies involving Lithium ESS

VERMONT FIRE ACADEMY
DIVISION OF FIRE SAFETY

# Fixed-Site ESS in Vermont




Green Mountain Power

- As of 9/23, GMP owns or operates ESS facilities in Panton, Essex, Ferrisburg, Milton, Rutland, Georgia, Springfield, and Barre
- These units are Tesla's commercial ESS product, called Powerpack
- Hydro Quebec is also in the ESS game in Vermont, with 16 ESS systems planned for Troy area in the next few years (Orleans County NEK)

VERMONT FIRE ACADEMY
DIVISION OF FIRE SAFETY

# Transportable ESS in Vermont






- GMP also owns a 1000kW transportable ESS
- They expect to have another 8 similar units distributed throughout the state by 2025

VERMONT FIRE ACADEMY
DIVISION OF FIRE SAFETY

# Tactics for Fires Involving ESS

- Non-intervention may be the best tactic for fires involving ESS batteries
- In the event of thermal runaway and fire, Tesla instructions are:
- **"Allow the affected unit to consume itself as it is designed to do. Applying water to the unit will only slow its eventual combustion"**
- Protect exposures if it can be safely done

VERMONT FIRE ACADEMY
DIVISION OF FIRE SAFETY




# Thank you!

Robert.Morlino@Vermont.gov

Samatha.Slayton@Vermont.gov