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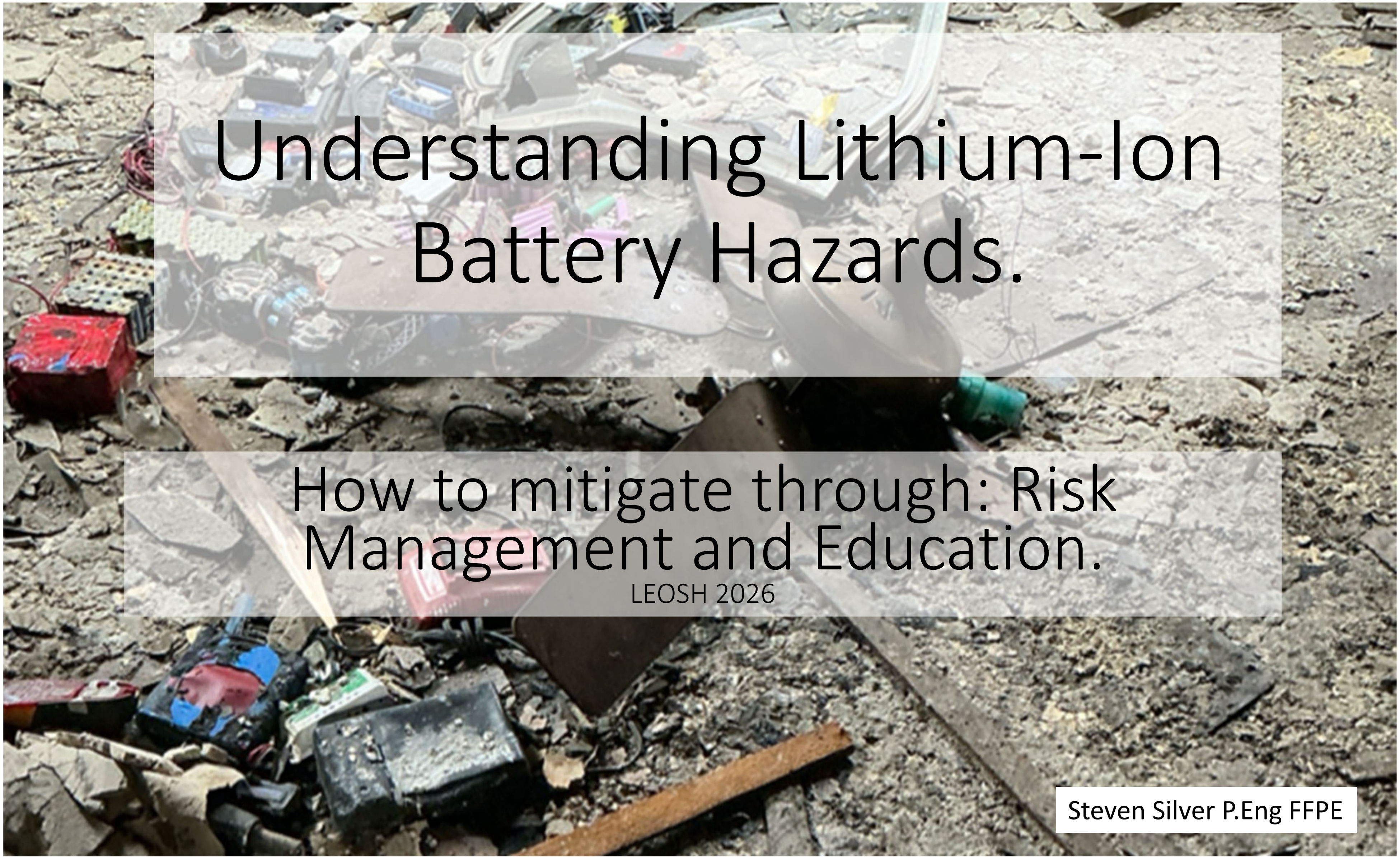

Understanding Lithium-Ion Battery Hazards.

How to mitigate through: Risk Management and Education.

LEOSH 2026

Steven Silver P.Eng FFPE

Lithium-Ion batteries store electrical energy

- Cell phones
- Tablets
- Computers
- Video Games
- Tablets
- Cameras
- Power tools
- Toys
- Electric toothbrushes
- Electric razors

- Electric razors
- Flashlights
- E-cigarettes
- Vehicle starting batteries
- Vehicle primary power
- Industrial machinery
- Telecommunications
- Aerospace
- Military
- Emergency power supplies
- Pacemakers

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- Come in many shapes and sizes

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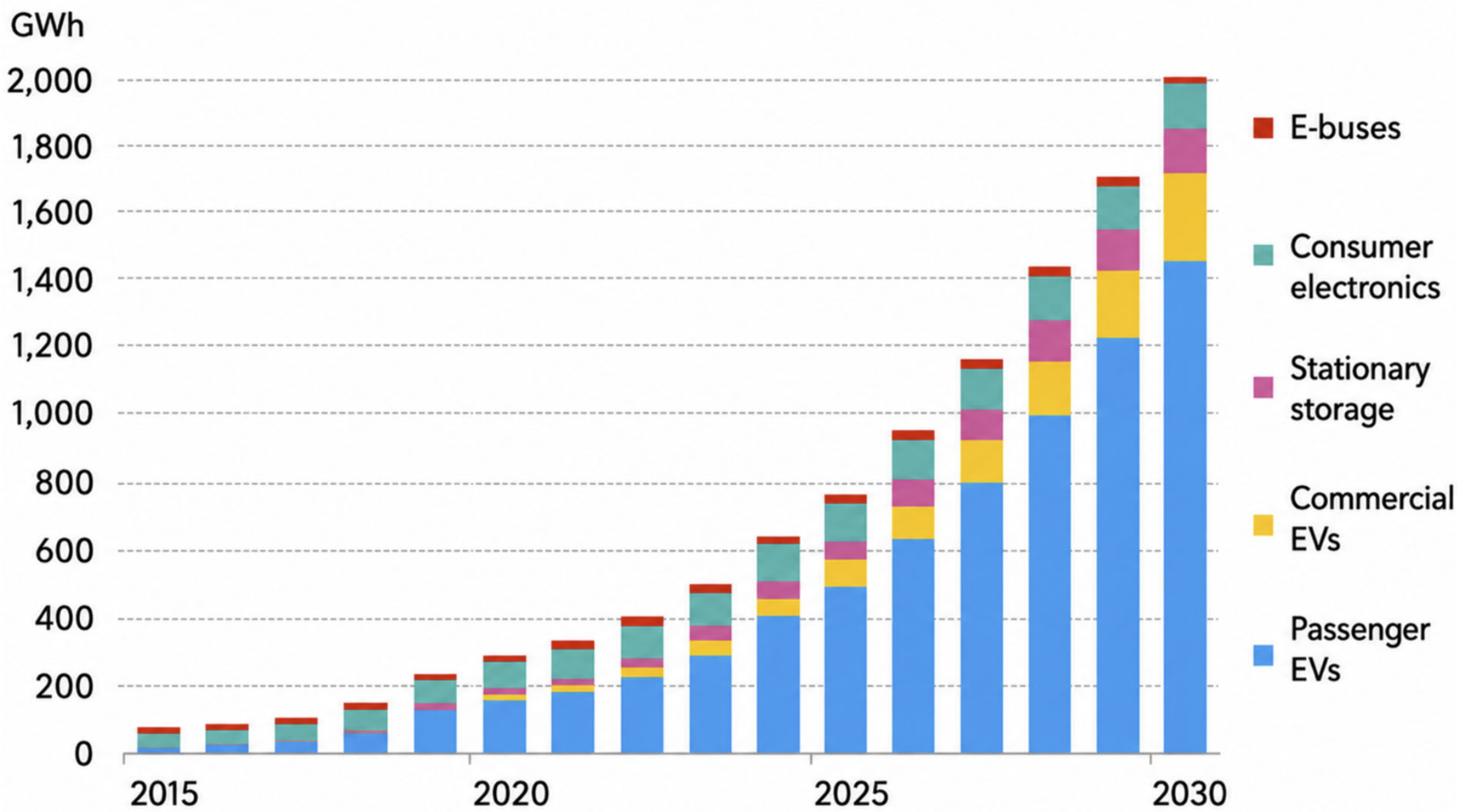

Lithium-ion battery global market size, GWh. ***Source:*** *Bloomberg New Energy Finance (BNEF)*

Found in Billion of Devices

- ChatGPT says
  - Lithium-ion batteries are extraordinarily safe, with a proven safety record of 99.999% to 99.9999% per individual cell. But manufacturers produce billions of units, even a minuscule defect or failure rate of 0.0001% can still lead to a common failures.

  - Damage to batteries increases this rate substantially

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Presentation Overview

What is Risk Management

- – Brief overview

Understanding Lithium Ion Hazards

- Electrical
- Fire
- How do these hazards effect our workplace

Applying principles of risk management to these hazards

- Real world examples – Case studies

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Risk Management

Risk management is the process of identifying, analyzing, and controlling potential problems (risks) that could negatively affect an organization, project, or individual.

Four main steps:

1. **Identifying risks** – what hazards do lithium batteries bring
2. **Assessing risks** – evaluating how likely they are and how serious their impact could be
3. **Mitigating risks** –what actions can we take to reduce or prevent them
4. **Monitoring and reviewing** – continuously checking and updating risk strategies

Risk Management

Lithium ion battery hazards are a dynamic hazard

- Hazards can increase
- Hazards can decrease
- Require continuous re-assessment

Our understanding of these hazards is also changing

- Recommend working committees to monitor

The first step in safety is education

Lithium Ion Hazards are Dynamic

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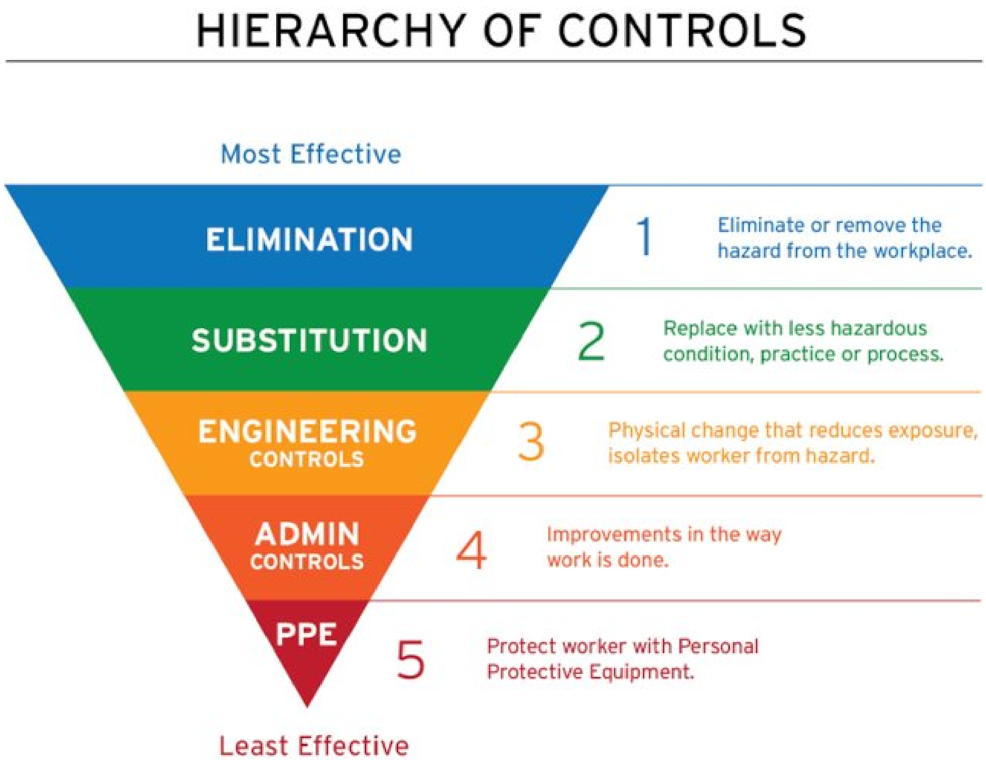
Risk Management – control the hazard



Remove the batteries/devices from scene or our workplace

Define your work area so that it excludes the batteries – use of barriers

Batteries remain in place but procedures are implemented

Gas monitors, appropriate clothing, PAPR, IR cameras

Understanding Lithium-Ion Battery Hazards

- What hazards do they present?
  - Electrical
  - Fire
    - Gases
    - Explosion
    - Liquids
    - Re-ignition

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What Electrical risks exist

1. **Identifying risks** – How does electricity harm us. What roll does the size of battery (quantity), specifically voltage of batteries play
2. **Assessing risks** – What is the state of the battery

Understanding the difference between items damaged and undamaged

Quantity and Condition

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Wide range of sizes and shapes – Size and voltage relationship

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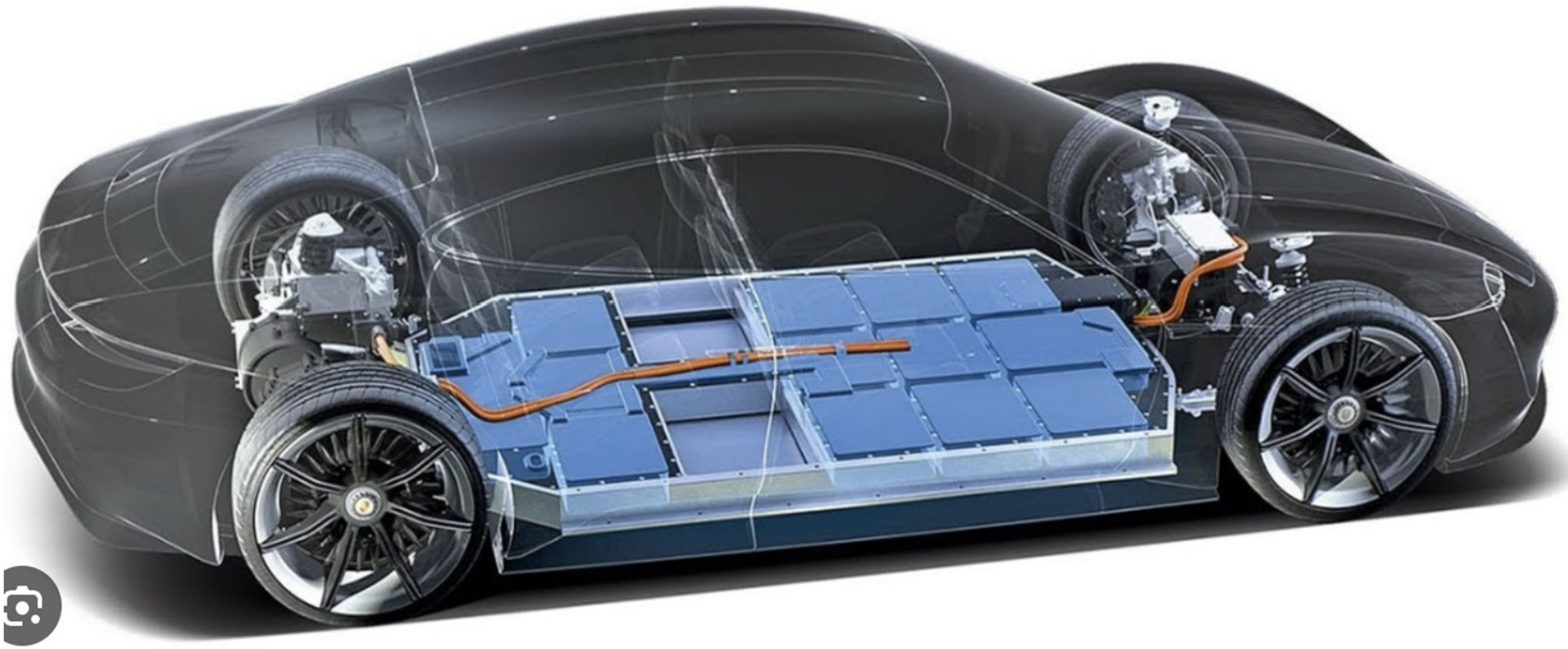

300-1000 V

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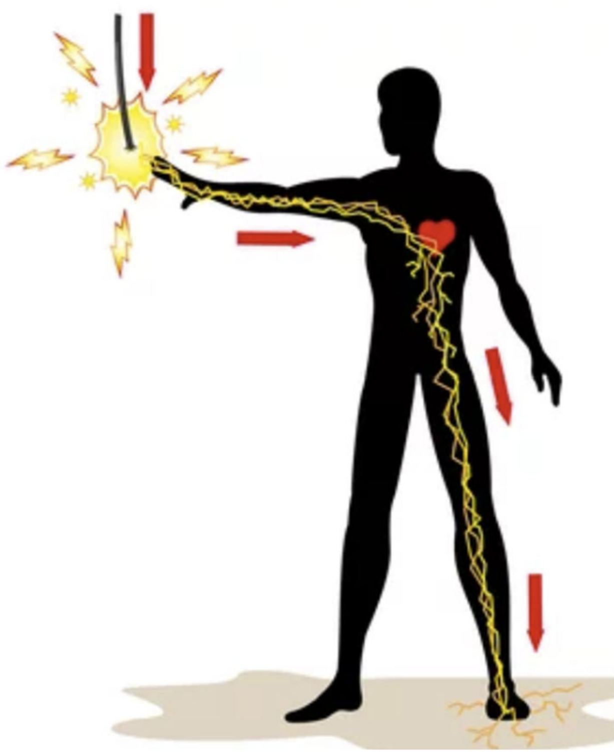
UNITED ENERGY

Battery voltage levels by device

0-60/100 Volts	60/100 – 300 Volts	300 Volts and greater
Individual cells	DIY batteries	Power banks
Power tool batteries	Power banks	Electric vehicles
Most e-bikes	E-mobility ?	DIY batteries
DIY batteries		BESS
Vape pens		
Cell phones		
Laptops		

How electricity can harm us



Three hazards of electricity—shock, thermal (burn) and arc flash

Shock hazard: electric current passes through a person (minor to lethal)

Shock fatalities cause the heart to go into fibrillation

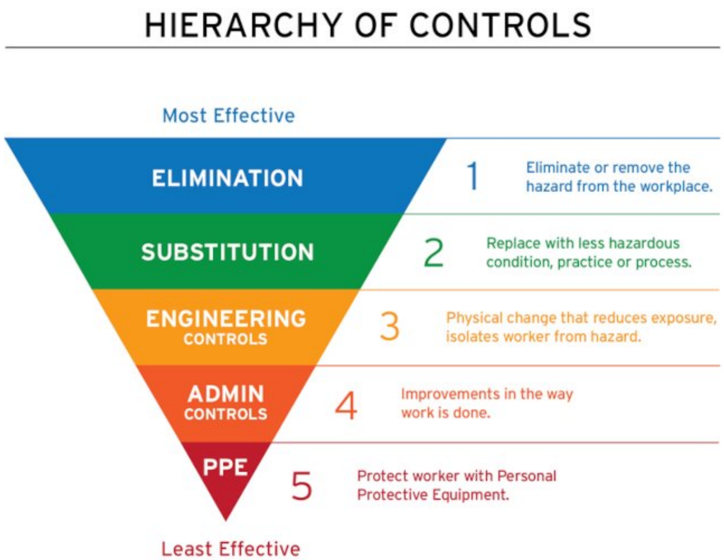
Contact with electric voltage can cause current to flow through the body. If two conductors have different voltages, current can flow through them if they are connected.

The human body can be that conection

Thermal is the heat generated when electricity passes through a person

Arc Flash - The person does not become part of the circuit. A powerful electrical explosion occurs in front of the person and they are exposed to high temperatures and pressures

Electrical remediation – control the hazard



- <u>Remove, Isolate, Protect against</u>
- Removing the batteries from scene
  - The ability to remove the hazard is dependent on battery size, and energy capacity.
  - CSA standard Z462 – Workplace Electrical Safety give us guidance
- Isolate
  - Batteries remain in place but procedures are implemented
  - As per CSA Z462
- Protect against
  - PPE, gas monitors, IR cameras
  - Special contractors might be needed for this

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Isolate and Protect

CSA Z462 – Workplace Electrical Safety

4.3.4.6 Limited approach boundary

4.3.4.6.1 Approach by unqualified persons

Unless permitted by Clause 4.3.4.6.3, no unqualified person shall be permitted to approach nearer than the limited approach boundary of energized conductors and circuit parts.

4.3.4.6.2 Working at or close to the limited approach boundary

Where one or more unqualified persons are working at or close to the limited approach boundary, the alerting methods in Clause 4.3.8.15 shall be applied to advise the unqualified person(s) of the electrical hazard and warn such persons to stay outside of the limited approach boundary.

4.3.4.6.3 Entering the limited approach boundary

Where there is a need for an unqualified person(s) to cross the limited approach boundary, a qualified person shall warn workers of the possible hazards and continuously escort the unqualified person(s) while inside the limited approach boundary. Under no circumstance shall unqualified person(s) be permitted to cross the restricted approach boundary.

4.3.4.7 Restricted approach boundary

Qualified persons shall not approach or bring conductive objects closer to exposed energized electrical conductors or circuit parts operating at voltages greater than 30 V ac or 60 V dc than the restricted approach boundary specified in Tables 1A and 1B unless at least one of the following applies:

a) The qualified person is insulated or guarded from the energized electrical conductors or circuit parts operating at voltages greater than 30 V ac or 60 V dc. Rubber insulating gloves and sleeves shall be considered insulation only with regard to the energized parts on which work is being performed.

b) The energized electrical conductors or circuit parts are insulated or guarded by a barrier in accordance with Clause 4.3.7.4.8 from the qualified person and from any other conductive object at a different potential.

Table 1A
Shock protection approach boundaries to exposed energized electrical conductors or circuit parts for ac systems*
(See Clauses 4.1.8.1.2, 4.3.4.5, 4.3.4.7, 4.3.7.4.11, 4.3.9.5, 4.3.9.6.1, 6.2.4.1, C.2, C.2.1, and R.2.2.)

(1) Nominal system voltage range, phase to phase†	(2) Limited approach boundary: Exposed movable conductor‡	(3) Limited approach boundary: Exposed fixed circuit part	(4) Restricted approach boundary (includes inadvertent movement adder)
Less than or equal to 30 V	Not specified	Not specified	Not specified
31–150 V§	3.0 m (10 ft 0 in)	1.0 m (3 ft 6 in)	Avoid contact
151–750 V	3.0 m (10 ft 0 in)	1.0 m (3 ft 6 in)	0.3 m (1 ft 0 in)
751 V–15 kV	3.0 m (10 ft 0 in)	1.5 m (5 ft 0 in)	0.7 m (2 ft 2 in)

(Continued)

Table 1A (Continued)

(1) Nominal system voltage range, phase to phase†	(2) Limited approach boundary: Exposed movable conductor‡	(3) Limited approach boundary: Exposed fixed circuit part	(4) Restricted approach boundary (includes inadvertent movement adder)
15.1–36 kV	3.0 m (10 ft 0 in)	1.8 m (6 ft 0 in)	0.8 m (2 ft 9 in)
36.1–46 kV	3.0 m (10 ft 0 in)	2.5 m (8 ft 0 in)	0.8 m (2 ft 9 in)
46.1–72.5 kV	3.0 m (10 ft 0 in)	2.5 m (8 ft 0 in)	1.0 m (3 ft 6 in)
72.6–121 kV	3.3 m (10 ft 8 in)	2.5 m (8 ft 0 in)	1.0 m (3 ft 6 in)
138–145 kV	3.4 m (11 ft 0 in)	3.0 m (10 ft 0 in)	1.2 m (3 ft 10 in)
161–169 kV	3.6 m (11 ft 8 in)	3.6 m (11 ft 8 in)	1.3 m (4 ft 3 in)
230–242 kV	4.0 m (13 ft 0 in)	4.0 m (13 ft 0 in)	1.7 m (5 ft 8 in)
345–362 kV	4.7 m (15 ft 4 in)	4.7 m (15 ft 4 in)	2.8 m (9 ft 2 in)
500–550 kV	5.8 m (19 ft 0 in)	5.8 m (19 ft 0 in)	3.6 m (11 ft 8 in)
765–800 kV	7.2 m (23 ft 9 in)	7.2 m (23 ft 9 in)	4.9 m (15 ft 11 in)

** See the "Boundary" definitions in Clause 3. See Clause 4.3.4 and Annex C.*
† For single-phase systems above 250 V, select the range that is equal to the system's maximum phase-to-ground voltage times 1.732.
‡ A condition in which the distance between the conductor and a person is not under the control of the person. The term is normally applied to overhead line conductors supported by poles.
§ This includes circuits where the exposure does not exceed 120 V.

Notes:
1) *All dimensions are distance for exposed energized electrical conductors or circuit parts to the worker.*
2) *For the arc flash boundary, see Clause 4.3.5.5.*

Table 1B
Shock protection approach boundaries to exposed energized electrical conductors or circuit parts for dc systems*
(See Clauses 4.1.8.1.2, 4.3.4.5, 4.3.4.7, 4.3.7.4.11, 4.3.9.5, 4.3.9.6.1, C.2.1, R.2.2, W.7.1, and W.7.2.)

(1) Nominal voltage conductor to ground	(2) Limited approach boundary: Exposed movable conductor†	(3) Limited approach boundary: Exposed fixed circuit part	(4) Restricted approach boundary (includes inadvertent movement adder)
Less than or equal to 60 V	Not specified	Not specified	Not specified
61–300 V	3.0 m (10 ft 0 in)	1.0 m (3 ft 6 in)	Avoid contact
301 V–1 kV	3.0 m (10 ft 0 in)	1.0 m (3 ft 6 in)	0.3 m (1 ft 0 in)

(Continued)

machines located outside the cell line working zone shall be barricaded to prevent workers from touching the welding machine and ground simultaneously where the welding cables are in the cell line working zone.

6.2.5.5 Portable test equipment

Test equipment in the cell line working zone shall be suitable for use in areas of large magnetic fields and orientation.

Note: *Test equipment that is not suitable for use in such magnetic fields can provide false results. When such equipment is removed from the cell line working zone and its performance returns to normal, the user can be misled to believe that the false results were correct.*

6.2.6 Maintenance of electrolytic cells

6.2.6.1 General

The electrical components and accessory equipment of electrolytic cells covered by Clause 6.2 shall be kept in safe and proper working condition.

6.2.6.2 Ground faults

A ground fault shall be investigated and a plan for its removal shall be implemented.

6.3 Safety requirements related to batteries and battery rooms or battery enclosures

6.3.1 General

Clause 6.3 covers electrical safety requirements for the practical safeguarding of workers while working with exposed stationary storage batteries that exceed 100 V, nominal, or exceed a short-circuit power of 1000 W.

Clause 6.3 does not apply to mobile applications or primary storage battery applications in which batteries are discharged only and not recharged.

6.3.2 Safety procedures

6.3.2.1 Energy thresholds

Energy exposure levels shall not exceed those identified in the following list unless appropriate controls are implemented:

a) ac: 50 V and 5 mA;
b) dc: 100 V; and
c) thermal: 1000 W short-circuit power.

Notes:

1) *Available short-circuit power is calculated by multiplying the battery's nominal voltage by its available short-circuit current at the battery terminals then dividing the result by two.*
2) *This information is extracted from DOE-HDBK-1092.*

6.3.2.2 Battery risk assessment

Prior to any work on a battery system, a risk assessment shall be performed to identify the chemical, electrical shock, and arc flash hazards and assess the risks associated with the type of tasks to be performed.

Note: *For additional information on performing a battery risk assessment, see Clause F.8*

6.3.2.3 Battery rooms or battery enclosures

6.3.4 Tools and equipment

The following shall apply to the use of tools and equipment during battery maintenance and testing:

a) Handles: Tools and equipment for work on batteries shall be equipped with insulated handles rated for the voltages on which they will be used in accordance with Clause 4.3.7.4.2.
b) Contact: Battery terminals and all electrical conductors shall be kept clear of unintended contact with tools, test equipment, liquid containers, and other foreign objects. The length and insulation of tools for work on batteries shall be selected to minimize the likelihood of inadvertent contact.
c) Non-sparking tools: Additional requirements for tools and equipment, including the use of non-sparking tools, shall be based on the risk assessment required by Clause 4.1.7.8.

6.3.5 Cell flame arresters and cell ventilation

When present, battery cell ventilation openings shall be unobstructed.

Cell flame arresters shall be inspected for proper installation and unobstructed ventilation and shall be replaced when necessary in accordance with the manufacturer's instructions.

6.4 Safety-related work practices for use of lasers

6.4.1 General

Clause 6.4 applies to safety-related work practices for maintaining lasers and their associated equipment.

Notes:

1) *For recommendations on laser safety requirements for laser use, see ANSI Z136.1.*
2) *For laser product requirements for laser manufacturers, see 21 CFR Part 1040,* Performance Standards for Light-Emitting Products, *Sections 1040.10, "Laser products"; and 1040.11, "Specific purpose laser products."*
3) *For guidance on the safety of laser products, see CSA E60825-1.*
4) *For guidance on the safe use of lasers in healthcare, see CSA Z386.*

6.4.2 Hazardous energy

6.4.2.1 Electrical hazard thresholds

Exposure levels shall not exceed those identified in the following list unless appropriate controls are implemented:

a) AC: 50 V and 5 mA;
b) DC: 100 V and 40 mA; and
c) capacitor stored energy
   i) less than 100 V and greater than 100 J of stored energy;
   ii) greater than or equal to 100 V and greater than 1.0 J of stored energy; and
   iii) greater than or equal to 400 V and greater than 0.25 J of stored energy.

Notes:

1) *See DOE-HDBK-1092 for information on electrical safety thresholds.*
2) *See Clause 6.7 and Annex W for information on capacitor hazards and controls.*

6.4.2.2 Stored energy

For the purpose of this Clause, hazardous stored energy shall be considered greater than or equal to 0.25 J at 400 V or greater, or 1 J at greater than 100 V up to 400 V.

Isolate and Protect

CSA Z462 – Workplace Electrical Safety

Table 1B
Shock protection approach boundaries to exposed energized electrical conductors or circuit parts for dc systems*
(See Clauses 4.1.8.1.2, 4.3.4.5, 4.3.4.7, 4.3.7.4.11, 4.3.9.5, 4.3.9.6.1, C.2.1, R.2.2, W.7.1, and W.7.2.)

(1)	(2)	(3)	(4)
	Limited approach boundary		Restricted approach boundary (includes inadvertent movement adder)
Nominal voltage conductor to ground	Exposed movable conductor†	Exposed fixed circuit part	
Less than or equal to 60 V	Not specified	Not specified	Not specified
61–300 V	3.0 m (10 ft 0 in)	1.0 m (3 ft 6 in)	Avoid contact
301 V–1 kV	3.0 m (10 ft 0 in)	1.0 m (3 ft 6 in)	0.3 m (1 ft 0 in)

(Continued)

Isolate and Protect

CSA Z462 – Workplace Electrical Safety

6.3.2.1 Energy thresholds

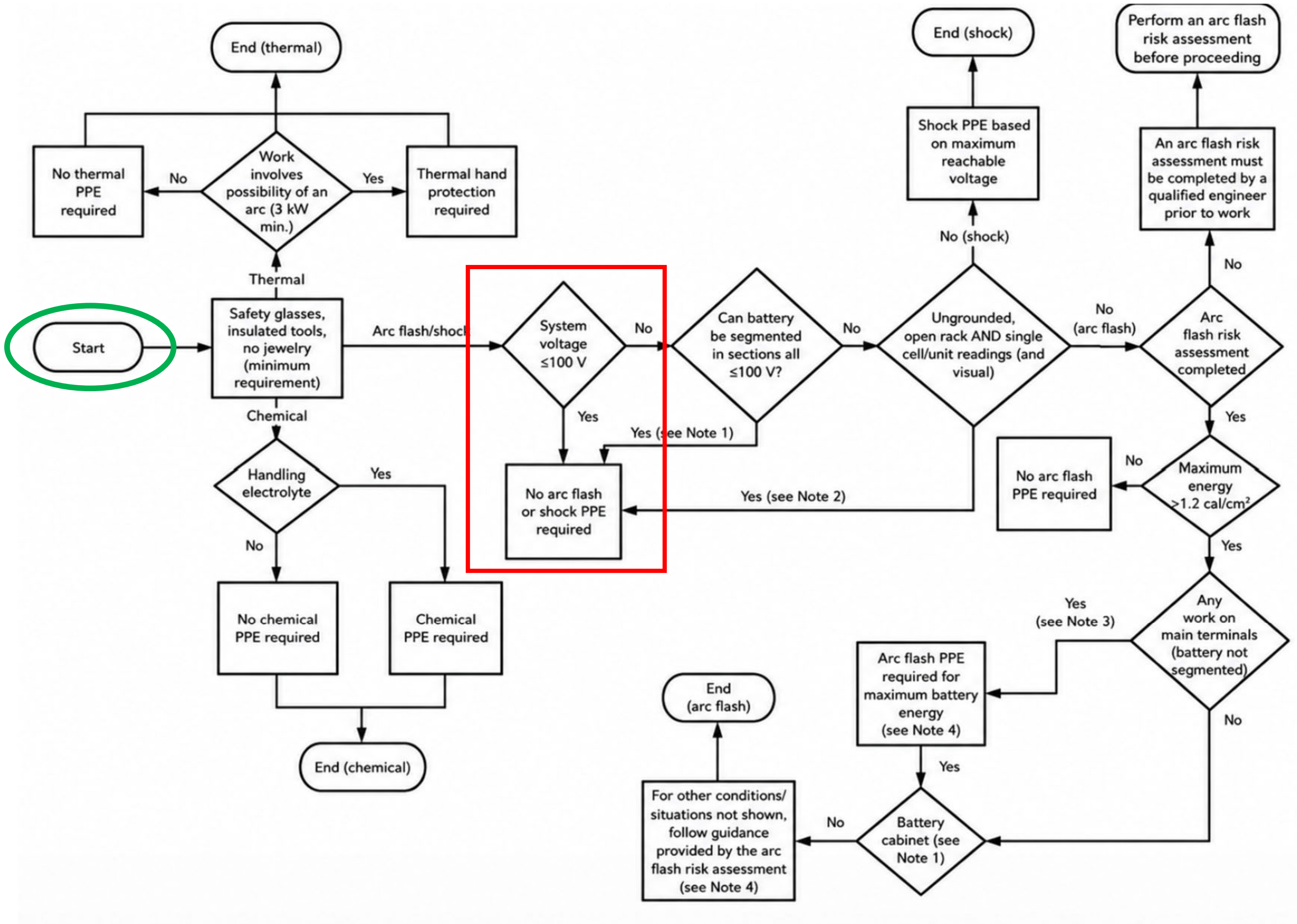
Energy exposure levels shall not exceed those identified in the following list unless appropriate controls are implemented:

a) ac: 50 V and 5 mA;

b) dc: 100 V; and

c) thermal: 1000 W short-circuit power.

CSA Z462 – Workplace Electrical Safety



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Electrical Protection

- Below 100 V; no shock or arc flash protection required.
- Above 100V; PPE required to protect from both Arc Flash and Electrical Shock
- When working above these an Electrical Hazard assessment must be conducted in accordance with CSA z462

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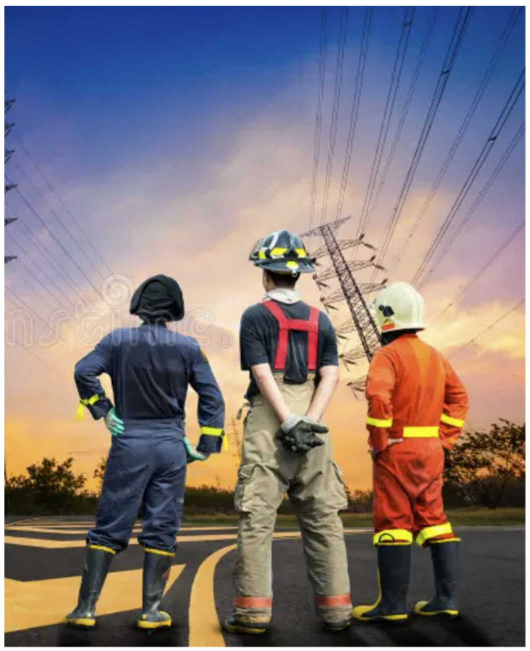
Electrical Hazard Summary



- Lithium batteries found in many devices.
- We can use the voltage rating to follow safety guidelines
- Below 100V – does not pose an electrical safety hazard
- Above 100V – special PPE and precautions
- Above 60 V – we can use safety barriers to work safely around

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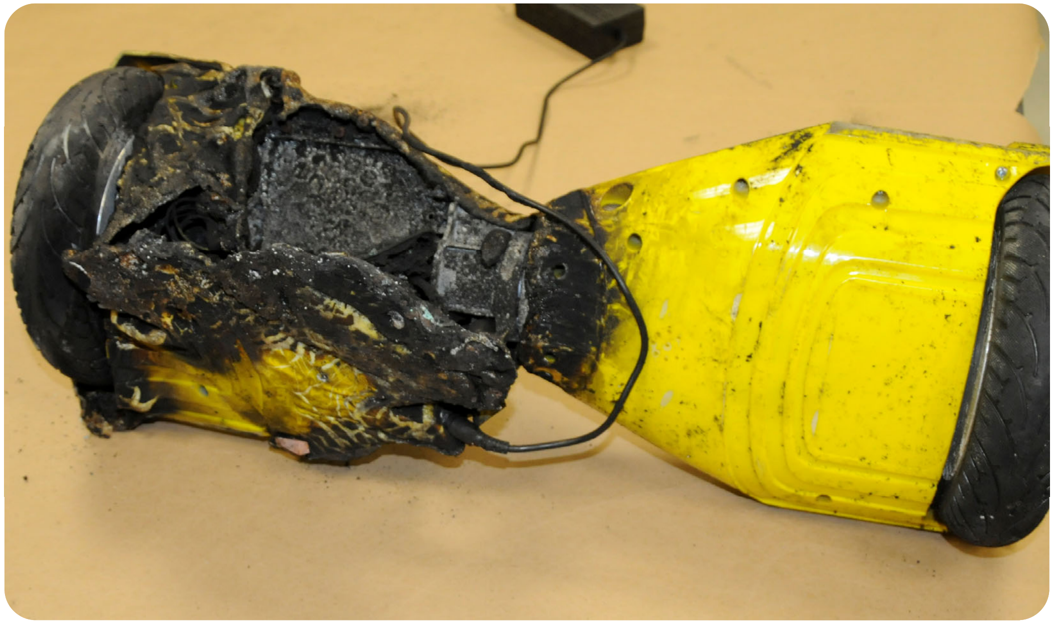
What fire risks exist

1. **Identifying risks** – what thermal risks do batteries pose. With fire and damage what other risks develop
    1. Gases – toxic
        1. Toxic
        2. Explosive
    2. Liquids
    3. Re-ignition
2. **Assessing risks** – What is the condition, size and location of the batteries. What would happen if a fire was to happen to occur
    1. Risk to workers
    2. Risk to property
    3. Risk to evidence

FIRE INVESTIGATIONS



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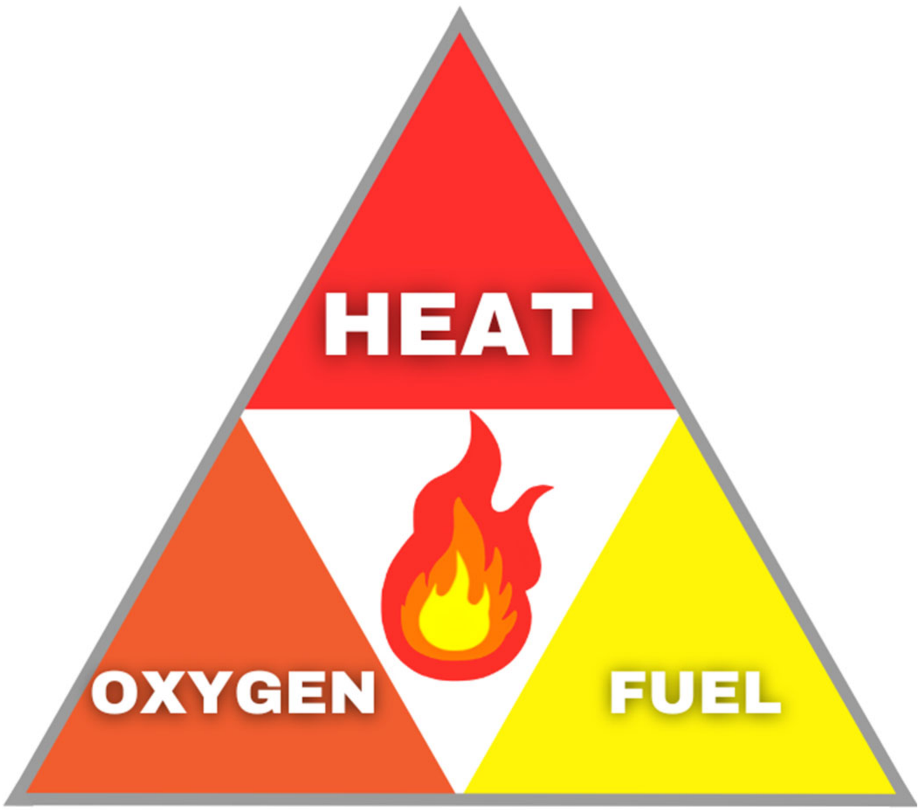
UNDERSTANDING FIRE



Definition:

Fire: the rapid oxidation of a material in the exothermic chemical process of combustion, releasing heat, light, and various reaction products.

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WHAT CAUSES LITHIUM-ION BATTERY FIRES?

Heat Generation

Chemically

Electrically

Thermal Runaway

Resistance Heating

Physical Damage

Poor Design/Manufacturing

Improper Use

Improper Charging

Improper Storage

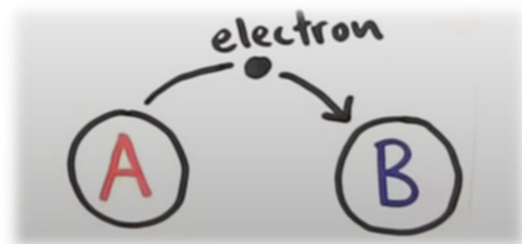
FIRE & BATTERY RELATIONSHIP

Key Concepts

1. Rate of Reaction

2. Oxidation & Reduction = Redox Reaction

Redox Reactions:
Electrons Moving Between Atoms

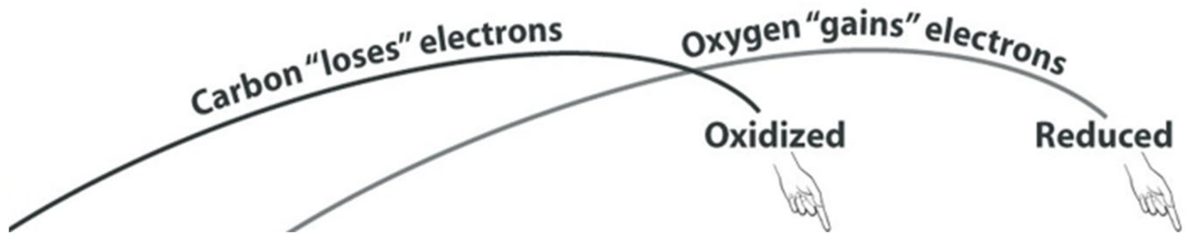


Reduction = Electrons Gained

Oxidation = Electrons Lost

METHANE COMBUSTION

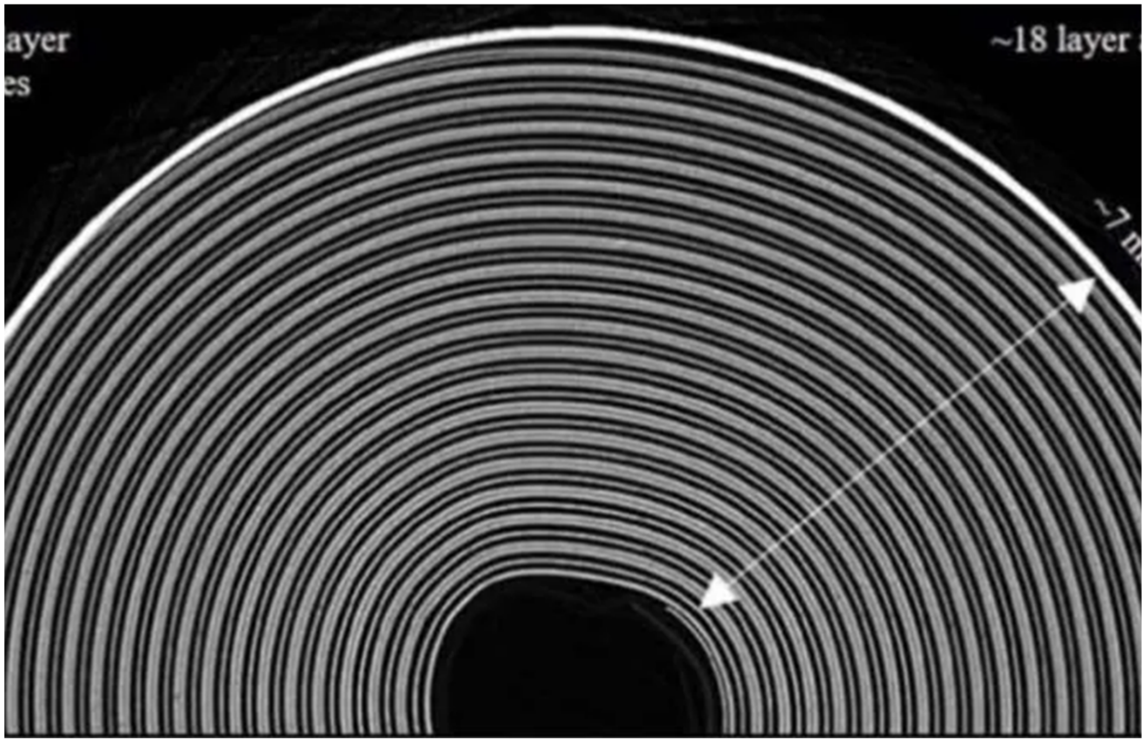
Oxidation Reduction

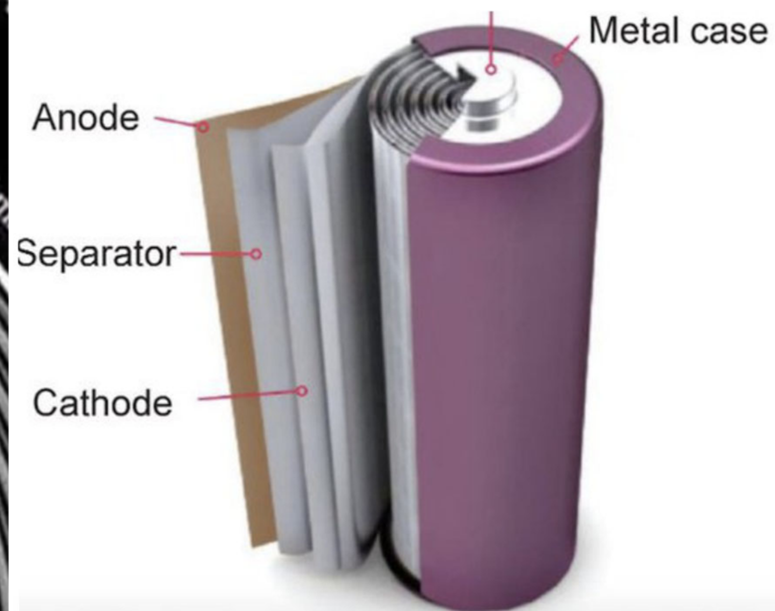


Methane + Oxygen Produces Carbon Dioxide + Water

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

LITHIUM-ION BATTERY





Redox Reactions occur between these layers

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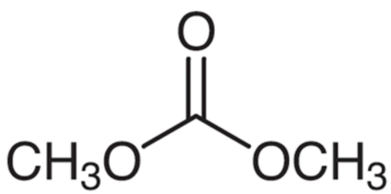
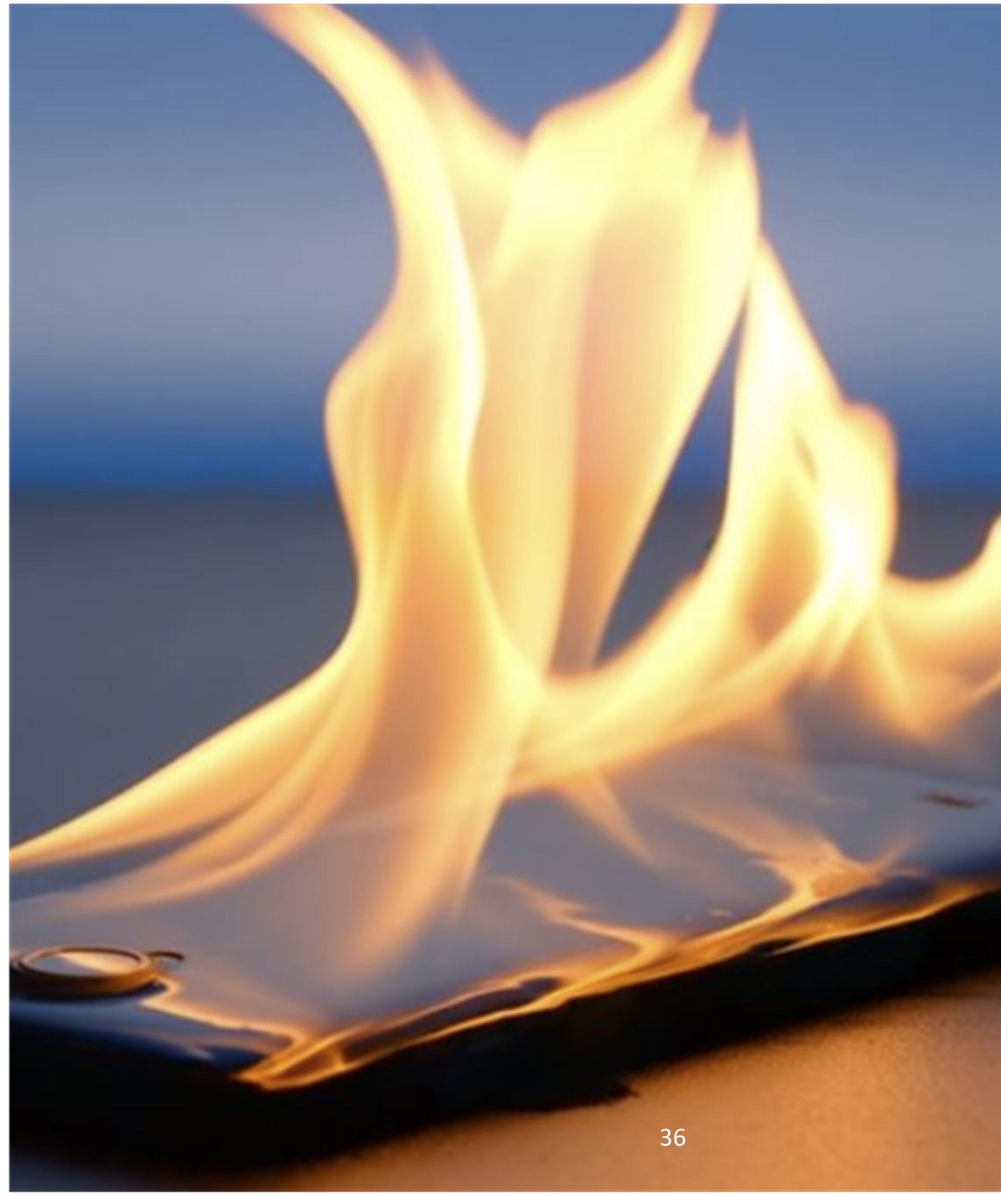
WHAT MAKES LI-ION BATTERIES UNIQUE?

Electrolyte

Dimethyl Carbonate



Decomposes into combustible gases



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Fires & Batteries – What’s The Difference?

Difference:

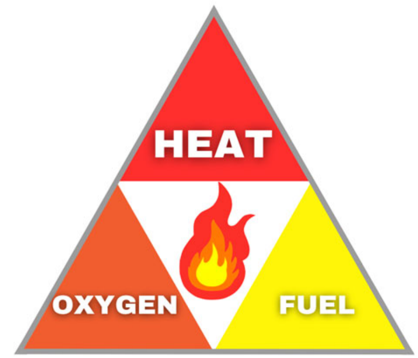
Rate and control of Reaction

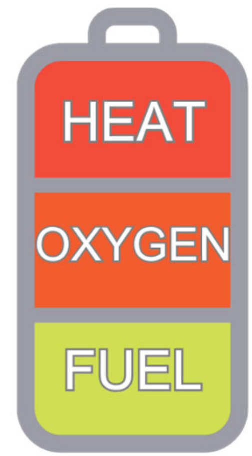
Fire:

Rate of reaction unhindered

Battery:

Rate Of Reaction Controlled by Design & System





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KEY MESSAGING

Lithium-ion batteries are a fire hazard when mishandled or physically damaged.

Never attempt to modify, tamper with, or build your own lithium-ion batteries.

Only use lithium-ion batteries and charging cords designed and approved by the manufacturer of the device. If replacing use a manufacture recommended product

When charging lithium-ion batteries, keep an eye on them, follow all recommended safety instructions, and never exceed the suggested charge time.

Never use batteries that are swollen or dented. Dispose of batteries at designated waste management facilities

Summary fire risks

Under the right conditions (wrong conditions) Lithium-ion batteries can initiate fires.

Damaged batteries can thermally decompose

Creating harmful gases, both toxic and potentially explosive. Typically, there are visual signs

Re-ignition can occur

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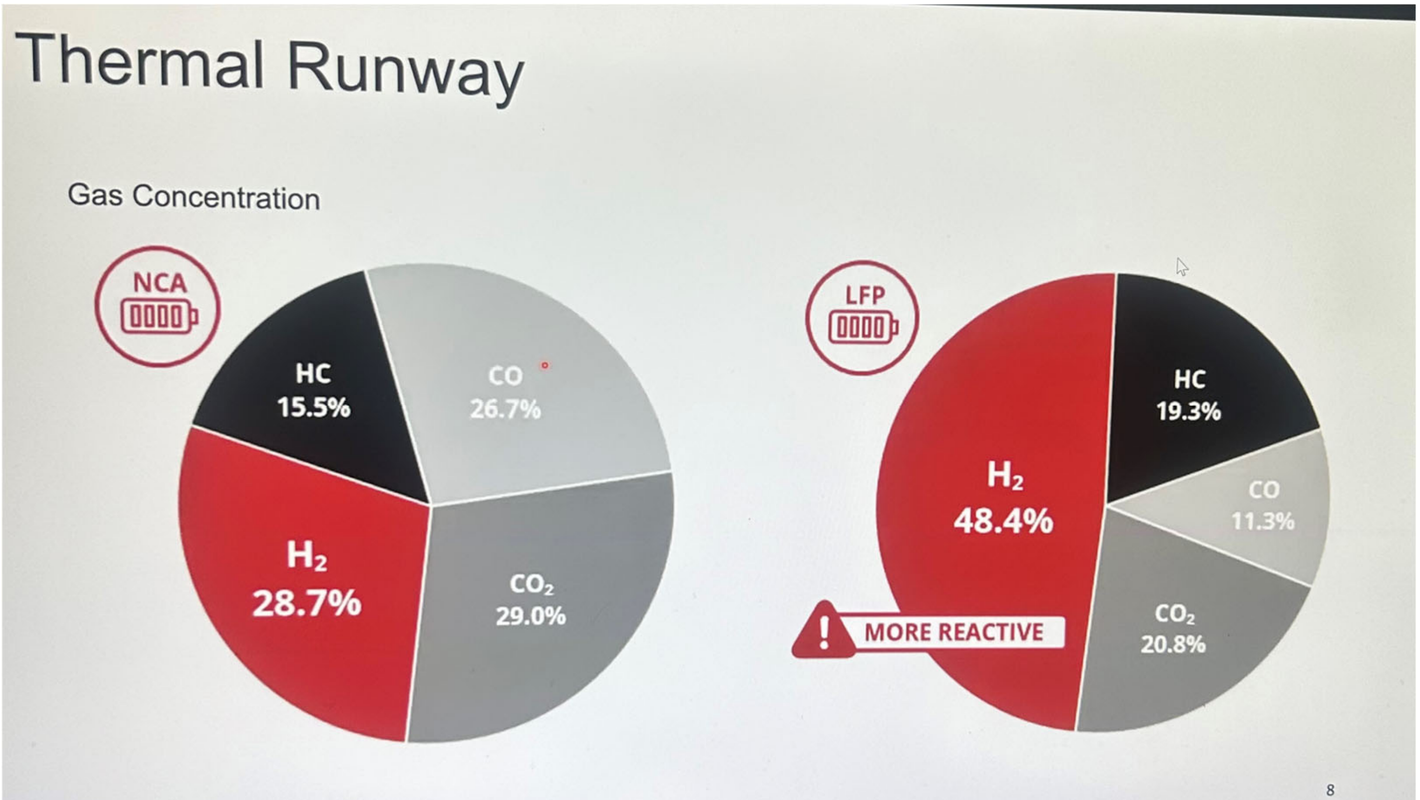
Gases

Produced during battery decomposition



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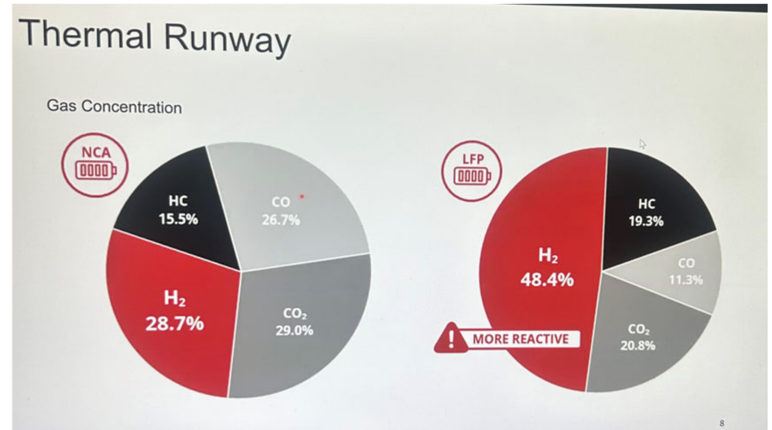
Gases

Produced during battery decomposition

The Institution of Fire Engineers
Canada Branch



Assessment

- Visual – do you see smoke venting?
- Air monitors
- Are they hot? – An infrared camera can tell if a battery is warmer than the environment
- Continuous scene assessment

Control (Remove, Isolate, Protect)

- Respirators and air monitors protect from toxic gases
- Ensure ventilation is adequate
- Remove/isolate batteries before they have a thermal runaway**
- If in thermal runaway, evacuate the scene, call 911

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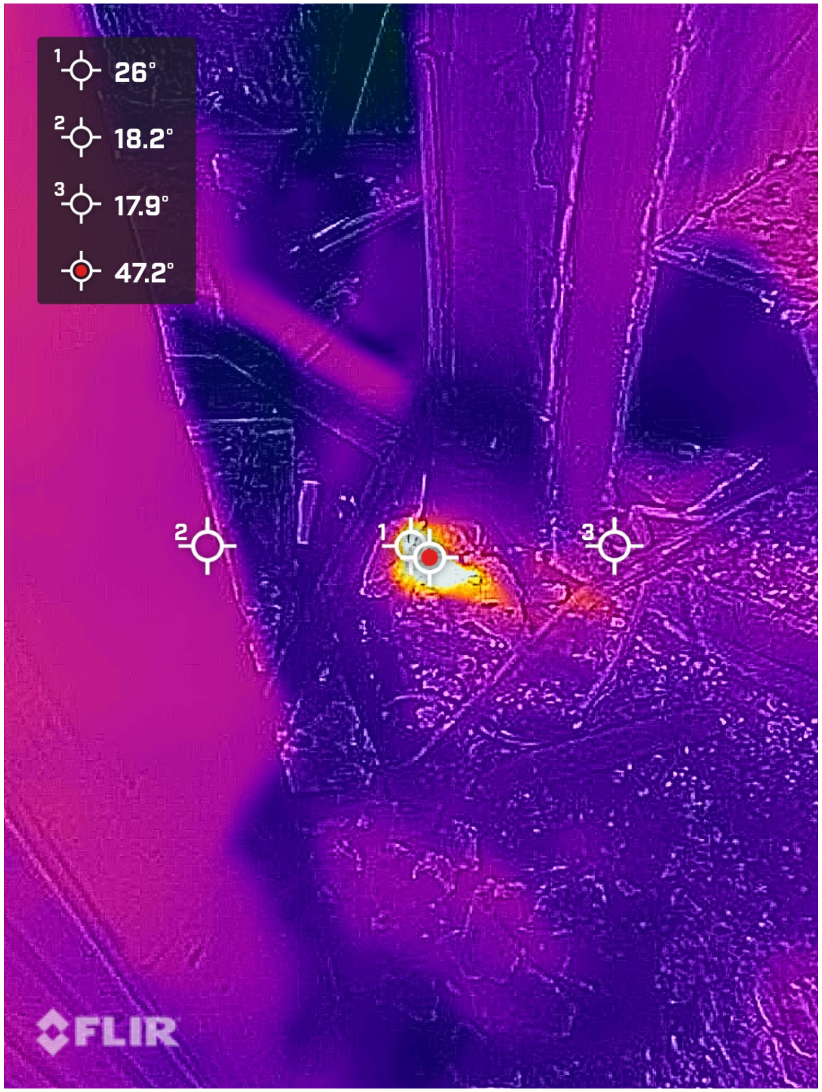
Thermal Cameras



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Gases

- First incidents of explosions occurring when fire fighters attend.
- No recorded accounts of post scene explosions
  - The hazard of combusted gases could persist.
  - Be aware of what a fire blanket used at your scene could mean

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Liquids

The battery electrolyte is an acid after a fire

Assessment

- Degree of fire damage?
- Risk is low with small battery packs
- Vehicles and BESS can be a concern
- What direction is the run-off from the batteries?

Control (Remove, Isolate, Protect)

- Use PPE
- Handling of electrolyte is a special case
- Avoid liquid run-off
- Excess water dilutes the hazard
- Special contractors

Re-ignition or thermal runaway

The end phase of a thermal runaway can be emission of flames

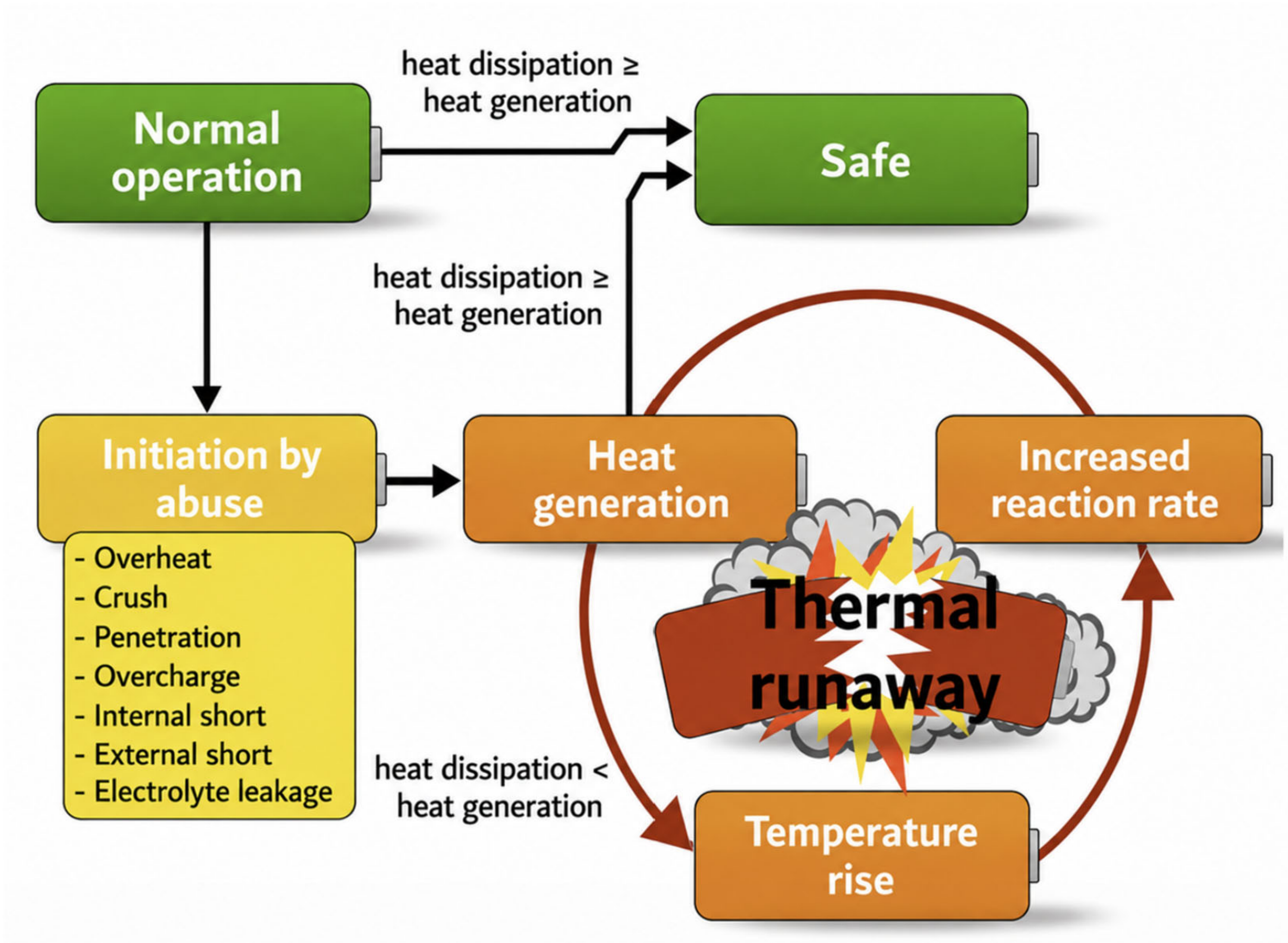
Assessment

- Risk even from single cell
- Visual - degree of fire/water/mechanical damage? Is it venting?
- Gas monitor detection?
- thermal imagers?

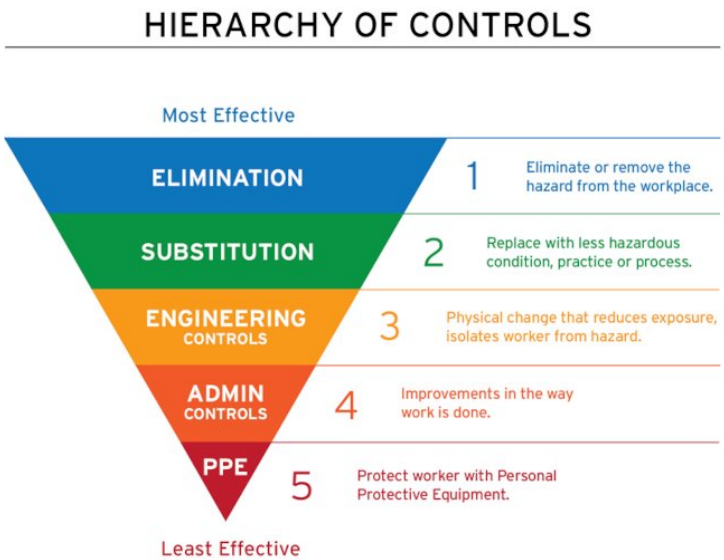
Control (Remove, Isolate, Protect)

- Removal from scene before a thermal runaway**
- Fire department – special contractors
- If in thermal runaway, evacuate the scene, call 911
- Consider a Fire Watch

Thermal Runaway



Fire remediation – control the hazard



- Remove, Isolate, Protect against
- Removing the batteries from scene
  - The ability to remove the hazard is dependent on size and degree of damage.
  - CSA standard Z462 – Workplace Electrical Safety give us guidance
  - Utilize Fire Department
- Isolate
  - Batteries remain in place, but procedures are implemented
  - As per CSA Z462
- Protect against
  - PPE, gas monitors, IR cameras
  - Special contractors might be needed for this

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Evidence

- Small Scale and Large scale

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Evidence

- Evidence containing Li-Ion batteries need considerations
  - Risk to life
  - Risk to property
  - Risk to other evidence

- Consider separating these items from other types of exhibits

- Consider using specialty cabinets

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Evidence

- EVs and Hybrids require special precautions.
- Hazards
  - Electrical
  - Re-ignition
  - toxic gases

The National Fire Protection Association (NFPA) recommends:

- Treating damaged electric vehicles (EVs) as high-risk
- Advising that submerged or crashed EVs be towed to an open, secure area at least 50 feet from buildings and other vehicles due to delayed, severe fire risks.

Case examples

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EV hazards

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Garage house fire - Isolate

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Garage House fire - Remove

Scene examples

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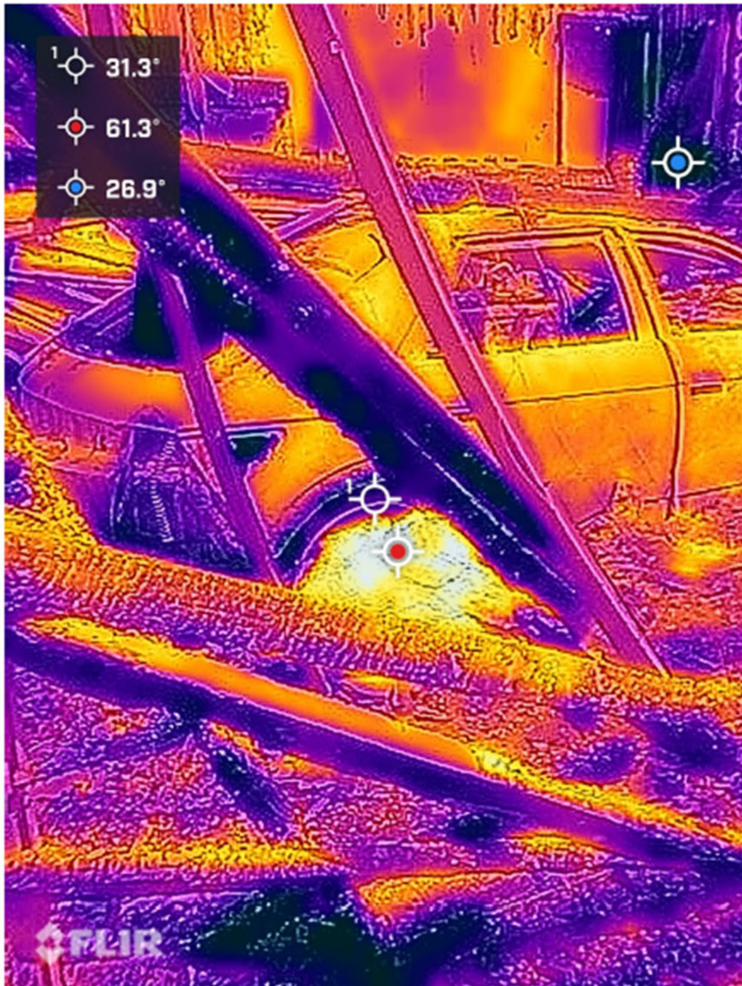

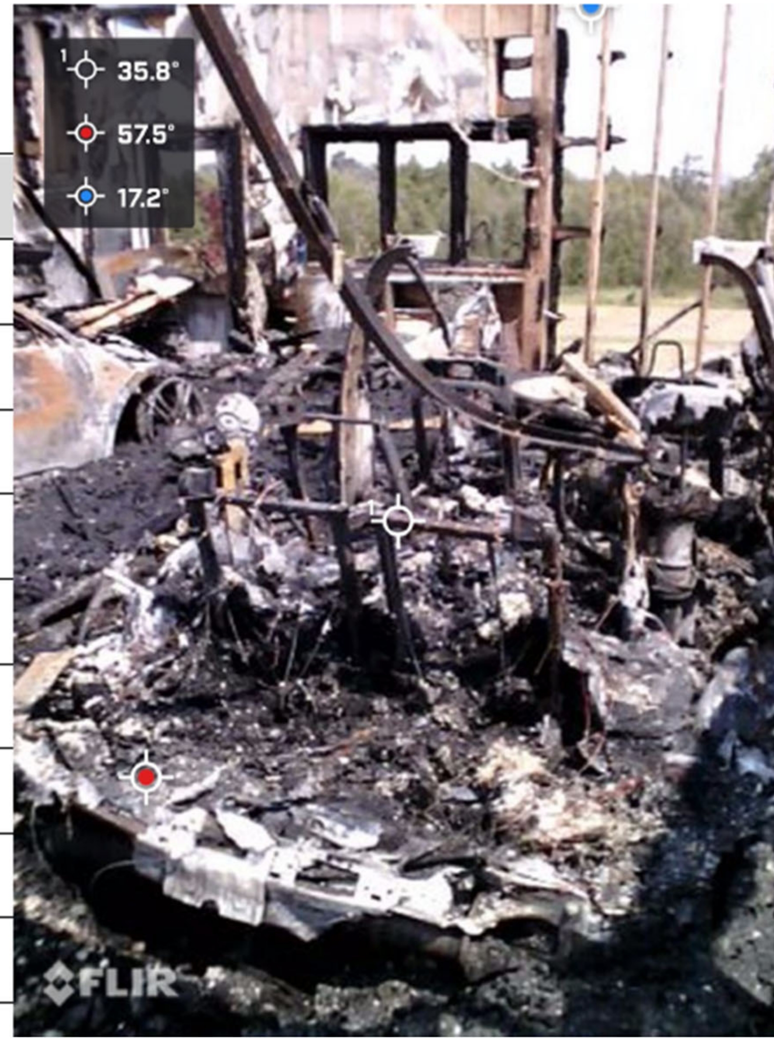

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Rav 4 Vehicle collision


POLICE

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Training – Niagara College

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nc
Automotive
Motive Power
AST Apprenticeship

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DANGER
HIGH VOLTAGE


DANGER


APPLIED DREAMS.

Are batteries still a hazard

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Thank you

- Questions?

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