Global Membership Council Webinar Series:

Lithium-ion Battery Energy System Storage: Connecting Building Codes, Design, Technology & Fire Department Response

17 January 2023

Welcome & Housekeeping

- This webinar will be recorded
- We will have time at the end for questions and discussion
- Audience members are muted with videos off by default
- If you have a question, please use the Q&A function at any time to submit the question or indicate your interest in being recognized
  - We will unmute you or ask your question during the Q&A period at the end of the webinar session

The ICC Global Membership Council connects building safety professionals from outside the United States with US-based professionals who have an interest in advancing the cause of building safety internationally.

- Membership in ICC not required
- Initiatives include:
  - Webinar series
  - Annual Conference events, including the Global Building Safety Forum
  - Networking opportunities

ICC GLOBAL MEMBERSHIP COUNCIL

For more information visit www.iccsafe.org/membership/membership-councils/icc-global-membership-council/

The Fire Service Membership Council (FSMC) is a forum for concerns and issues that are of particular interest to the fire service, to assist ICC in increasing participation of such individuals in the ICC Code development process, and to advise ICC on programs and policies, legislative matters, code adoption issues and such other matters as the Council deems appropriate.

ICC FIRE SERVICE MEMBERSHIP COUNCIL

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City of Olathe, Kansas

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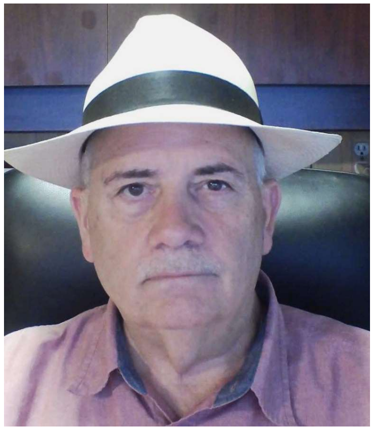

Robert J. Davidson
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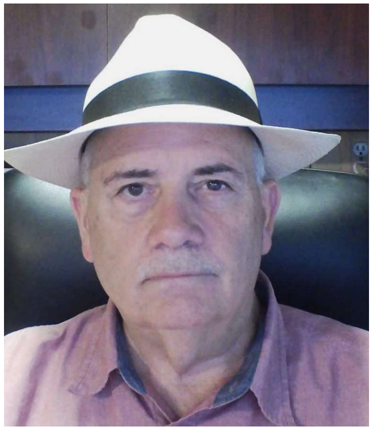

Robert J. Davidson
Davidson Code Concepts

Emerging Fire Technologies:

Adapting when technology development outpaces code development

Codes &
Standards

Code History

- 1997 Uniform Fire Code
  - Stationary Lead-Acid Battery Systems
- 2000 International Fire Code
  - Stationary Lead-Acid Battery Systems
- 2003 International Fire Code and NFPA 1 Fire Code
  - Stationary Lead-Acid Battery Systems
  - Section 608 vented (flooded) lead-acid batteries
  - Section 609 valve-regulated lead-acid (VRLA) battery systems

Codes & Standards

History

- 2006 International Fire Code
  - Stationary Storage Battery Systems
  - Reorganized into one section
  - Added Lithium-ion; Only the IFC signage, seismic protection and smoke detection requirements applied to the Lithium-Ion batteries
  - NFPA 1 Fire Code No Change
- 2009 International Fire Code and NFPA 1 Fire Code
  - Stationary Storage Battery Systems
  - IFC Added Lithium Metal Polymer (including thermal runaway protection)
  - NFPA 1 added both Lithium-ion and Lithium Metal Polymer
  - IBC limited Incidental Uses to 10% of floor area

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Codes & Standards

History

2012-2015 International Fire Code and NFPA 1 Fire Code

- Stationary Storage Battery Systems
- No significant changes

2018 International Fire Code and NFPA 1 Fire Code

- Electrical Energy Storage Systems
- Extensive re-write
- Cycling as compared to stand-by
- Recognition of hazards of thermal runaway

2020 NFPA 855 and 2021 International Fire Code

- Electrical Energy Storage Systems
- Extensive re-write recognizing additional installation locations
- No longer an incidental use. All indoor require 2-hour separation

Codes & Standards

1207.1.3 Construction documents. The following information shall be provided with the permit application:

1. Location and layout diagram of the room or area in which the ESS is to be installed.
2. Details on the hourly fire-resistance ratings of assemblies enclosing the ESS.
3. The quantities and types of ESS to be installed.
4. Manufacturer's specifications, ratings and listings of each ESS.
5. Description of energy (battery) management systems and their operation.
6. Location and content of required signage.
7. Details on fire suppression, smoke or fire detection, thermal management, ventilation, exhaust and deflagration venting systems, if provided.
8. Support arrangement associated with the installation, including any required seismic restraint.
9. A commissioning plan complying with 1207.2.1.
10. A decommissioning plan complying with 1207.2.3.

Codes & Standards

Key requirements

1207.1.4 Hazard mitigation analysis

- 1207.1.4.3 Additional protection measures. Construction, equipment and systems that are required for the ESS to comply with the hazardous mitigation analysis, including but not limited to those specifically described in Section 1207 shall be installed, maintained and tested in accordance with nationally recognized standards and specified design parameters

1207.1.5 Large scale fire test (UL 9540A)

1207.2.2 Operation and maintenance

1207.1.6 Fire remediation

- 1207.1.6.1 Fire mitigation personnel

1207.3.2 Equipment listing (UL 9540)

Authority

Chapter 1 Code Application

2021 IBC (*previous editions similiar*)

[A] 101.3 Purpose.

The purpose of this code is to establish the minimum requirements to provide a reasonable level of safety, health and general welfare through structural strength, means of egress, stability, sanitation, light and ventilation, energy conservation, and for providing a reasonable level of life safety and property protection from the hazards of fire, explosion or dangerous conditions, and to provide a reasonable level of safety to fire fighters and emergency responders during emergency operations

Authority

IBC 2015-2021

[A] 101.4.5 Fire prevention.

The provisions of the International Fire Code shall apply to matters affecting or relating to structures, processes and premises from the hazard of fire and explosion arising from the storage, handling or use of structures, materials or devices; from conditions hazardous to life, property or public welfare in the occupancy of structures or premises; and from the construction, extension, repair, alteration or removal of fire suppression, automatic sprinkler systems and alarm systems or fire hazards in the structure or on the premises from occupancy or operation.

Authority

2015-2021 IFC

[A] 102.8 Subjects not regulated by this code.

Where applicable standards or requirements are not set forth in this code, or are contained within other laws, codes, regulations, ordinances or bylaws adopted by the jurisdiction, compliance with applicable standards of the National Fire Protection Association or other nationally recognized fire safety standards, as approved, shall be deemed as prima facie evidence of compliance with the intent of this code. Nothing herein shall derogate from the authority of the fire code official to determine compliance with codes or standards for those activities or installations within the fire code official's jurisdiction or responsibility

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Authority

2015-2021 IFC

[A] 102.9 Matters not provided for.

Requirements that are essential for the public safety of an existing or proposed activity, building or structure, or for the safety of the occupants thereof, that are not specifically provided for by this code, shall be determined by the fire code official.

[A] 102.10 Conflicting provisions.

Where there is a conflict between a general requirement and a specific requirement, the specific requirement shall be applicable. Where, in a specific case, different sections of this code specify different materials, methods of construction or other requirements, the most restrictive shall govern.

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Authority

Authority

Chapters 1 of the IBC and the IFC provide you the authority to use other standards and newer code language to address recognized hazards your current code does not provide guidance on.

Codes & Standards

Thank-you

Robert J Davidson, Fire Marshal (Ret)

Managing Partner Davidson Code Concepts, LLC

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Dr. Francisco Joglar
Jensen Hughes, Inc.

ENERGY STORAGE SYSTEM (BESS) RISK ASSESSMENTS
An Introduction

Agenda

- Code Requirements for a Risk Assessment
- Discuss a Strategy for ESS Risk Assessments
- Available Guidance
- About Fire Risk
  - Frequency and Consequences
- Hazards and Mitigation Strategies
- Accident Progression

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Background

Background

- Battery Energy Storage Systems (BESS)
  - Lithium-ion batteries are a popular choice for energy storage systems
  - Li-ion technology is also benefiting from increased economies of scale and technological maturity
  - Used in a variety of applications, including energy storage, electric vehicles, and consumer electronics.

- Thermal Runaway- Key hazard to manage
  - Thermal runaway is the condition that occurs when an electro-chemical cell increases its temperature through self-heating in an uncontrollable fashion
  - Progresses when the cell's heat generation is at a higher rate than it can dissipate,
  - Potentially leading to off-gassing, fire, or explosion. At some lower energy cells,
  - Thermal runaway consequences range from:
    - Local heating and pouch swelling.
    - At higher energy levels, this may lead to fire and or explosions.
  - Thermal runaway can be caused by physical damage (puncture, crushing), electrical issues (deep discharge, overcharging), exposure to elevated ambient temperatures, and by manufacturer defects (imperfections, contaminants).

Codes Requirements

- NFPA 1, NFPA 855 and Local Fire Codes* may require a **Hazard Mitigation Analysis**
  - HMA- An evaluation of potential energy storage system failure modes and the safety-related consequences attributed to the failures. (Chapter 3 of NFPA 855)
  - Provide an FMEA or other approved hazard mitigation analysis to AHJ when:
    - Certain battery technologies are used
    - More than one battery technology is provided in a room or area where there is a potential for adverse interaction
    - When allowed as a basis for increasing the maximum allowable quantities (Most Common)
  - Analysis may need to consider the following failure modes
    - Thermal runaway condition
    - Failure of energy management system
    - Voltage surges
    - Short circuits
    - Failure of smoke detection, fire extinguishing, or gas detection systems
    - Spill neutralization

*e.g., Section 1206.2.3 of the 2019 California Fire Code

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Risk Assessment Strategy

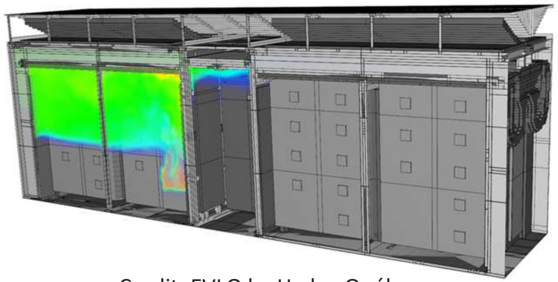
Risk Assessment Strategy for Energy Storage Systems (ESS)

- Risk assessment includes
  - Failure modes & hazard identification (Part of the HMA!)
  - Mitigating strategies (Part of the HMA!)
  - Assessment of potential consequences (Part of the HMA!)
- Analysis Approach
  - Event tree analysis to assess the risk impact of mitigation strategies. Provides a detailed chronology of the event
- Results of analysis are used to:
  - Inform pre-fire plans & emergency response
  - Inform fire protection systems design and maintenance
  - Inform facility oversight (e.g., Interactions with AHJ)
  - Risk Communication
- References:
  - SFPE Engineering Guide for Fire Risk Assessment
  - NFPA 550, Guide for the Evaluation of Fire Risk Assessments

Risk Modeling Approach

Risk Modeling Approach

- Based on **event-tree analysis**
  - Defined as a graphical logic model that identifies and quantifies possible outcomes following an initiating event (e.g., a failure mode, thermal runaway)
- With this method
  - Scenario frequencies are calculated using the event tree
  - Consequence level is mapped to each end state
- Requires an understanding of the scenarios including the
  - Hazards
  - Mitigation Strategies
    - BMS & EMS
    - Gas Detection
    - Smoke and Fire Detection
    - Suppression (Water, Gas)
    - Environmental impact control (e.g., water runoff)
    - Explosion Prevention (NFPA 69)
    - Deflagration Venting (NFPA 68)
    - Fire Brigade or Fire Department



Credit: EVLO by Hydro-Québec

Test Requirements

The following test data, evaluation information, and calculations shall be provided:

- Fire and explosion testing data (e.g., UL 9540A)
  - Data supports engineering design in terms of spacing, design of ventilation systems, modeling, etc.
- Hazard mitigation analysis (HMA) in accordance
- Calculations or modeling data to determine compliance with NFPA 68 and NFPA 69 in accordance
- Other test data, evaluation information, or calculations as required
  1. Performance of detection and suppression
  2. Performance of explosion prevention
  3. Performance of deflagration venting

Site Walkdowns

Walkdowns

- Battery mfg., system integrator, AHJ
- Site Description
  - Exposures
  - Location of potential public impacts
- ESS Enclosure Geometry
- Signage
- Physical/Impact protection
- Ventilation / Climate Control including AHU size / redundancy
- Presence of storage (i.e., transient combustibles)
- Fire Detection, Suppression, and Other Mitigation
  - System Type and Layout
  - Maintenance Records
  - Sequence of Operations

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Definition of Risk

Guidance for Fire Risk Assessments

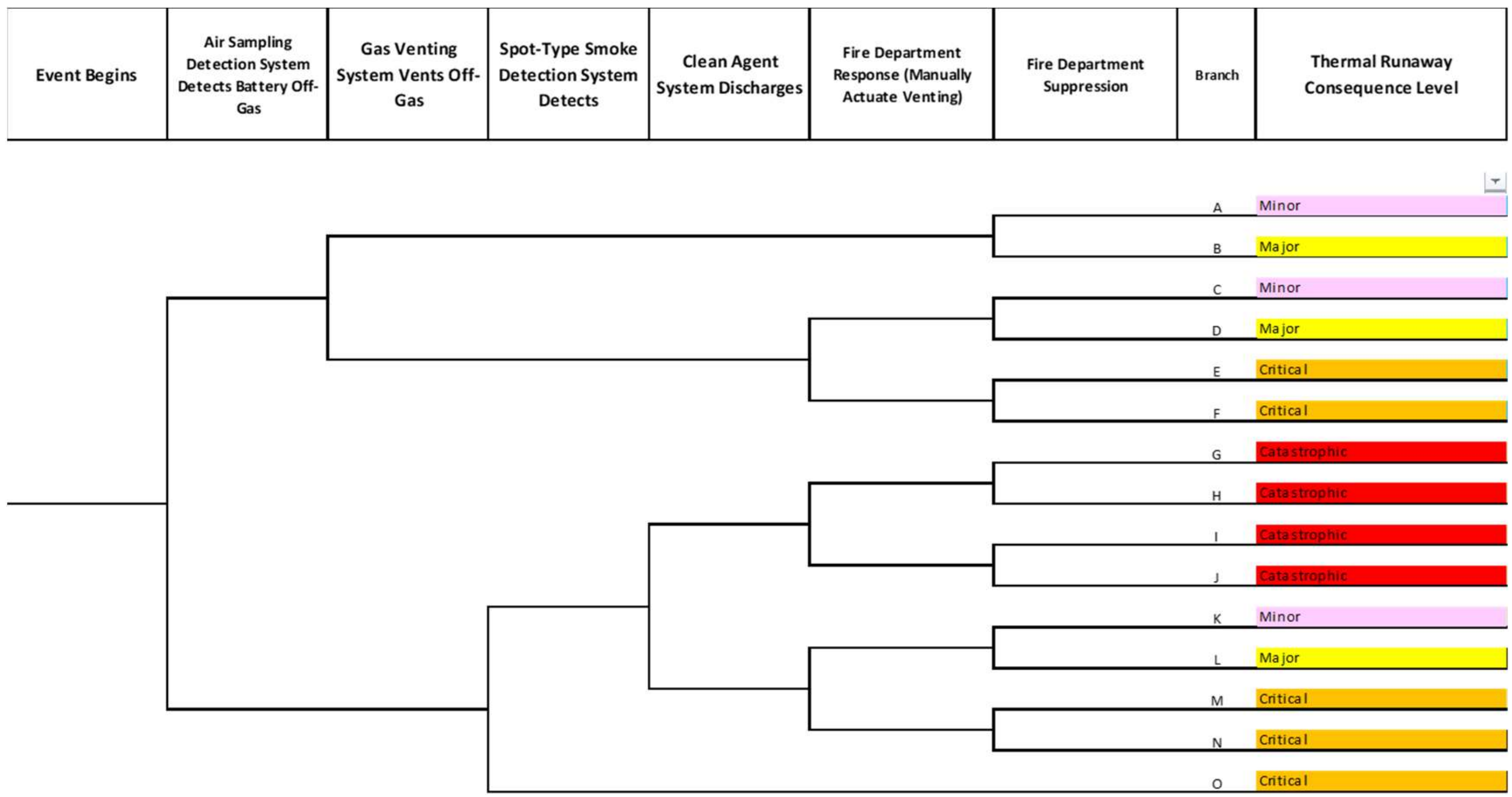
- Frequency*, λ
  - Events/Unit Time
  - Classifications ranging from “Frequent” to “Incredible”
- Consequences, C
  - Impacts of the Event
  - Range from Negligible to Catastrophic

Fire Risk Matrix

Scenario Frequency (/yr)						
Frequent >	1.0E+00	5.0E-04	5.0E-03	5.0E-02	5.0E-01	1.0E+00
Probable	1.0E+00	5.0E-04	5.0E-03	5.0E-02	5.0E-01	1.0E+00
	1.0E-01	5.0E-05	5.0E-04	5.0E-03	5.0E-02	1.0E-01
Occasional	1.0E-01	5.0E-05	5.0E-04	5.0E-03	5.0E-02	1.0E-01
	1.0E-02	5.0E-06	5.0E-05	5.0E-04	5.0E-03	1.0E-02
Remote	1.0E-02	5.0E-06	5.0E-05	5.0E-04	5.0E-03	1.0E-02
	1.0E-04	5.0E-08	5.0E-07	5.0E-06	5.0E-05	1.0E-04
Improbable	1.0E-04	5.0E-08	5.0E-07	5.0E-06	5.0E-05	1.0E-04
	1.0E-06	5.0E-10	5.0E-09	5.0E-08	5.0E-07	1.0E-06
Incredible <	1.0E-06	5.0E-10	5.0E-09	5.0E-08	5.0E-07	1.0E-06
		Negligible	Minor	Major	Critical	Catastrophic
		5.00E-04	5.00E-03	5.00E-02	5.00E-01	1.00E+00
		Consequence				

Fire Event Tree

Simplified Fire Event Tree (Thermal Runaway)



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Thank you!

Hazard Focus:
Battery Energy Storage Systems, Lithium Ion Batteries

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Battery Failure Cycle & Stages

Stage 1: Abuse Occurs

- Thermal, Electrical or Mechanical
- Internal Failure Process Begins

Stage 2: Internal Reaction Generates Heat, increasing cell surface temperature

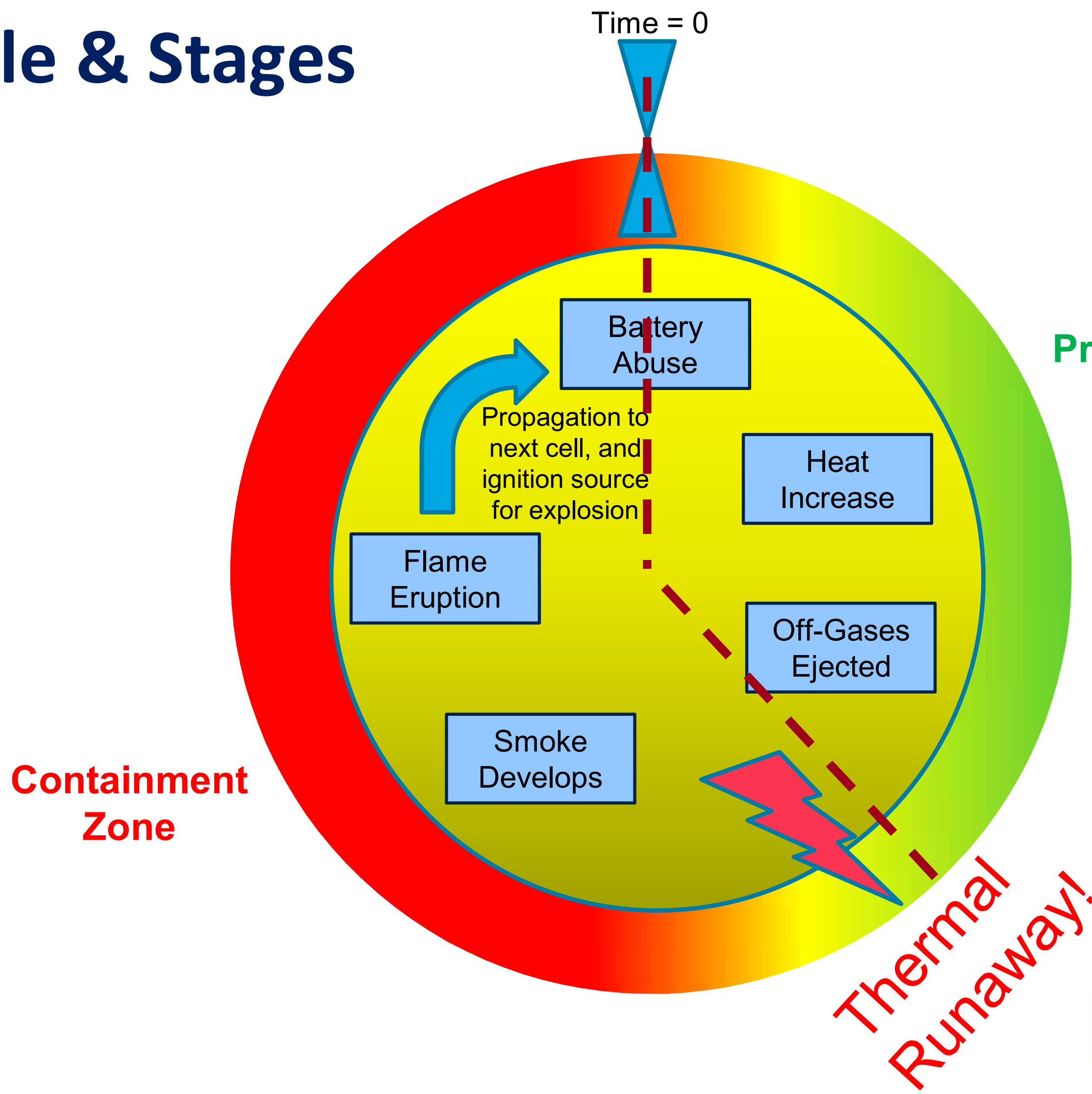
Stage 3: Off-Gas Generation and Ejection from Cell during initial "heat up"

Stage 4: Thermal Runaway

Stage 5: Smoke Expulsion

- Catastrophic failure is imminent

Stage 6: Flame Eruption



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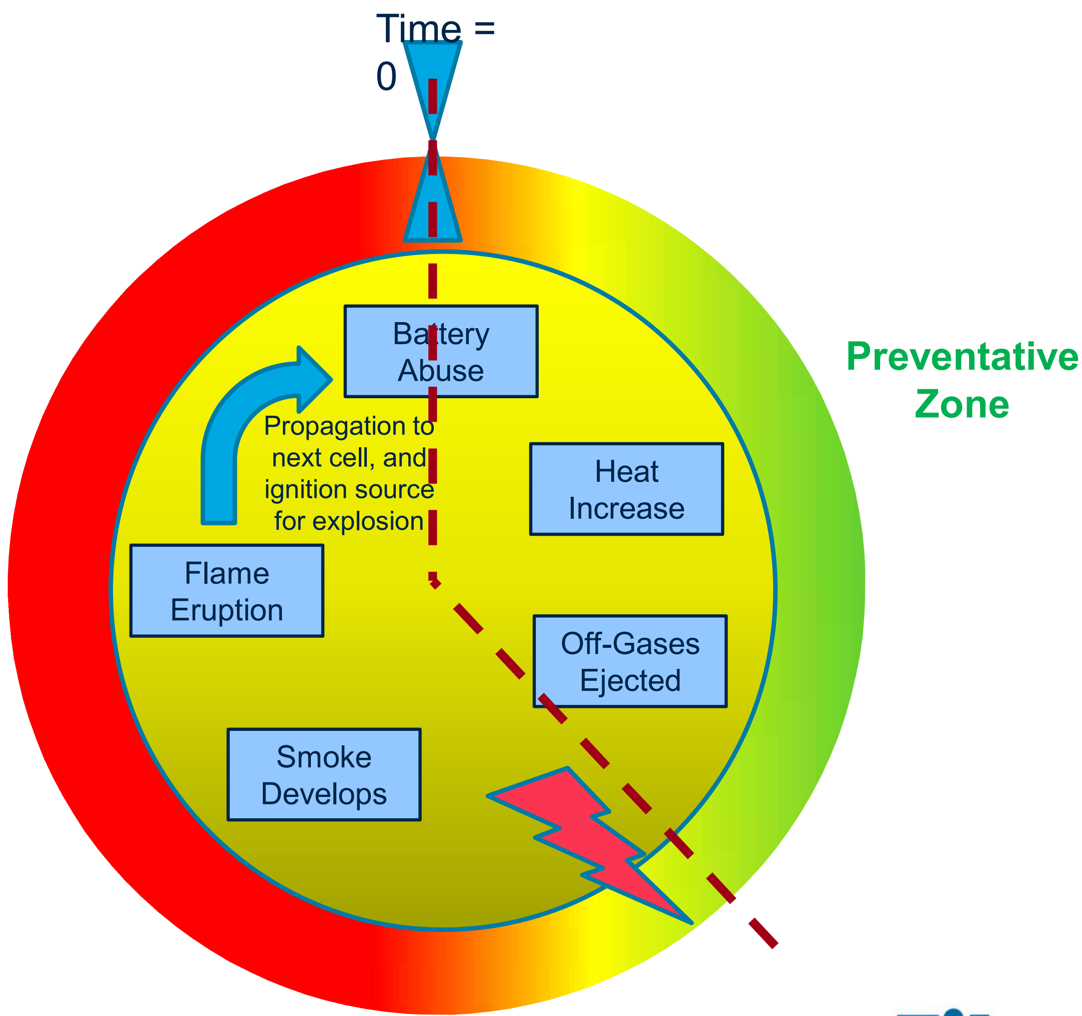
Preventative Zone

From Time "Zero" (normal operation) to BEFORE Thermal Runaway starts

Window of time to DETECT and RESPOND to PREVENT Uncontrollable situation of thermal runaway and propagation

Requires EARLY DETECTION of either the Cell Surface Temperature increase or the Off-Gas

And the INTEGRATION of the Detection system to the Battery Management System (BMS) to "disconnect" and isolate the affected cell/module/rack from the system and adjacent cells



Containment Zone

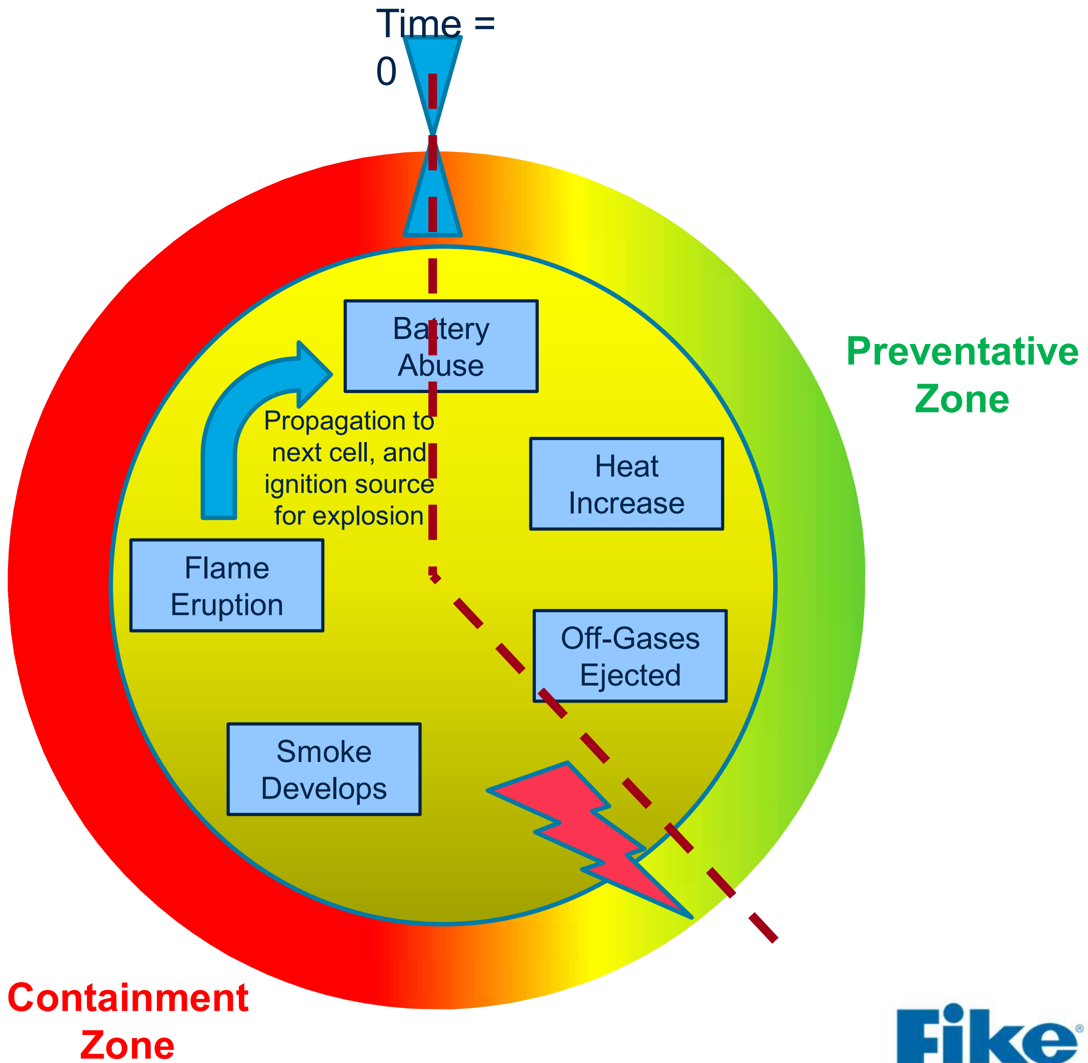
Every Second AFTER Thermal Runaway starts

Nothing can be done to STOP Thermal Runaway once it starts, or extinguish the Lithium electrolyte combustion

Heat is Increasing and Radiating, Smoke develops as Class A combustibles begin to smolder and ignite

Flames/Sparks erupt as adjacent cells/batteries fail and ignite

Can only take measures to Contain the combustion zone and prevent further propagation



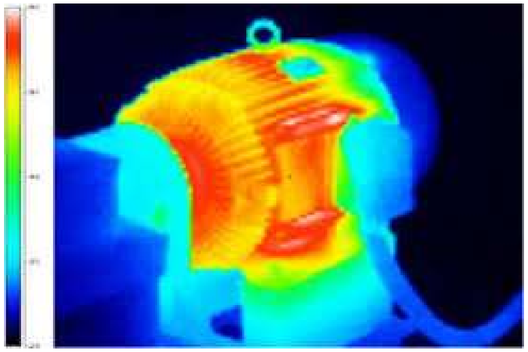
Preventative Zone Detection Techniques

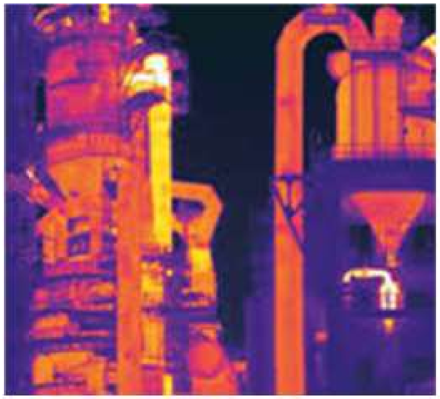
Thermal Image Monitoring

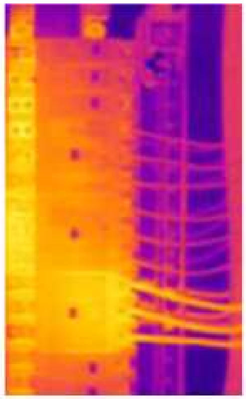
Extremely customizable and programmable within any sensor's field of view

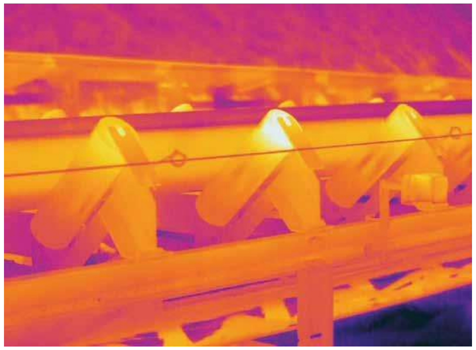
Extremely Accurate and Localized readings

Will provide very early warning and notification of developing "hot spots"









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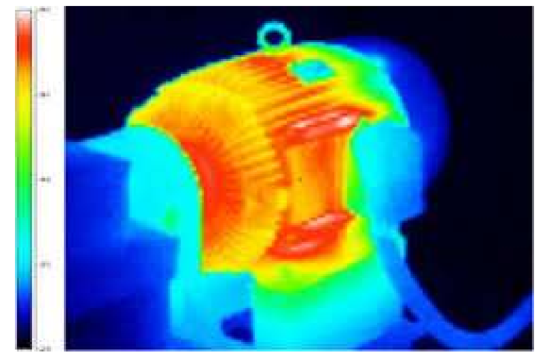
Preventative Zone Detection Techniques

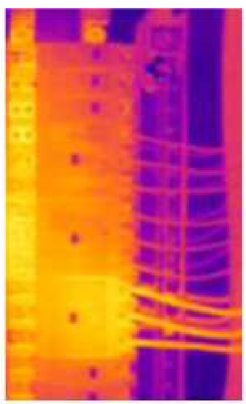
Thermal Image Monitoring

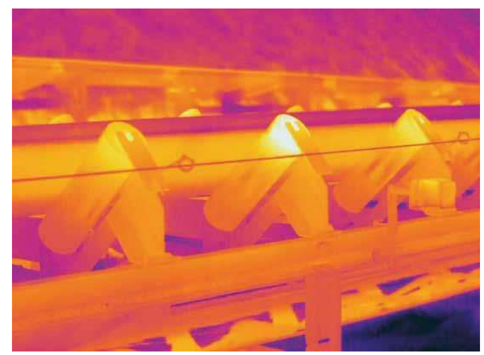
Would tie directly into the BMS

Could not be used to activate an extinguishing system or signal to BFA

Line of Sight dictates how many sensors required





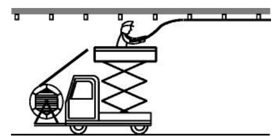


Preventative Zone Detection Techniques

FiberOptic Linear Heat Detection

Sensor Fiber Characteristics

- Simple fiber optic cable: flexible and light – Easy to install
- Mechanically robust
- Completely passive sensor cable
- Inherently safe against electromagnetic disturbance
- Immune to dirt, dust, humidity and corrosive environments
- Explosion Proof
- Long product lifetime, maintenance free
- Operating temperature -40C to +85C (-40F to +180F)
- Fast detection (10 seconds measurement time)
- Precise localization (<1 m (3.3’) spatial resolution)
- Long reach (up to 10 km (6.2 miles!))
- Wide range of certification (VdS EN54-22, UL 521, ULC-S530, FM 3210)



VdS SIGNALING c UL us LISTED FM APPROVED EX

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FiberOptic Linear Heat Detection

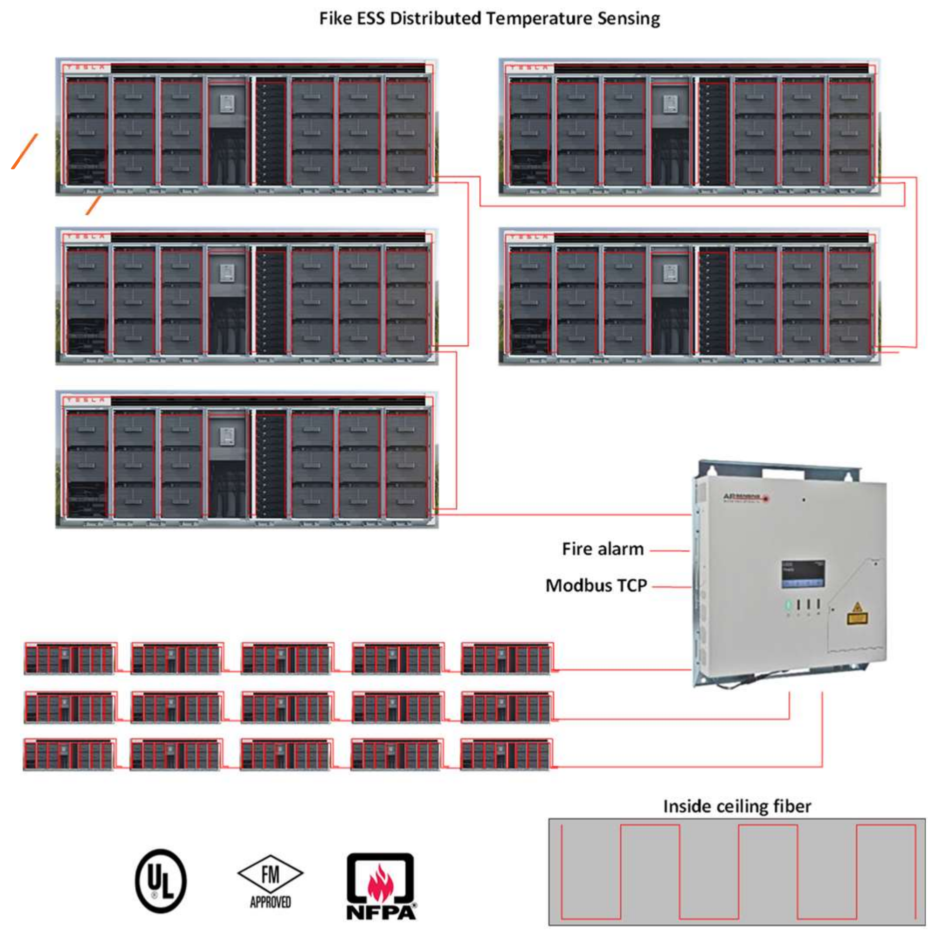
Can Monitor Several Battery Storage Containers with One System

Can interface directly with BMS

Listed and Approved to initiate BFA system and release suppression

Through the software can identify exactly where the upset condition has occurred:

- Fixed Threshold Exceeded
- ROR Exceeded
- Deviation from Average



Preventative Zone Detection Techniques

Off-Gas Monitoring

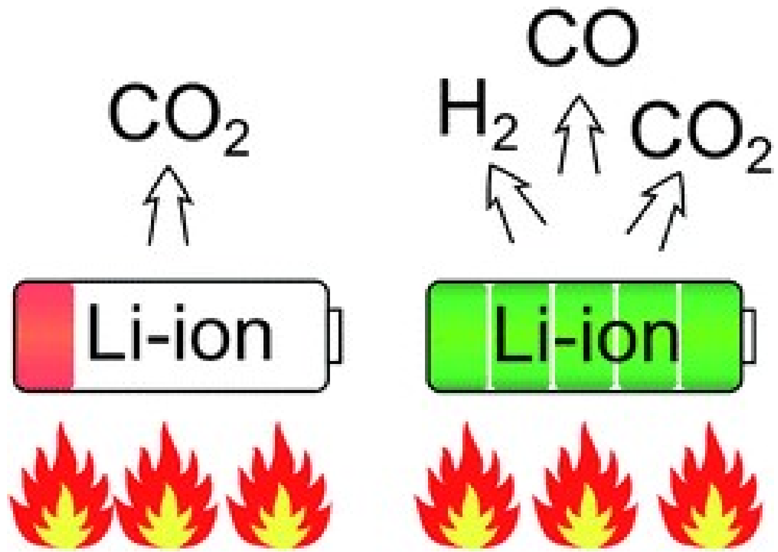
An Air Sampling product that specializes in detecting an off-gas event from lithium-ion batteries. It is a unique protection technology that offers early warning to avoid catastrophic events specifically in Li-ion ESS environments.

What gases do we monitor?

- Manufacturers are constantly improving lithium-ion. New and enhanced chemical combinations are introduced every six months or so. With such rapid progress, it is difficult to assess how well the revised battery will perform or what specific gases it will emit during a thermal runaway.

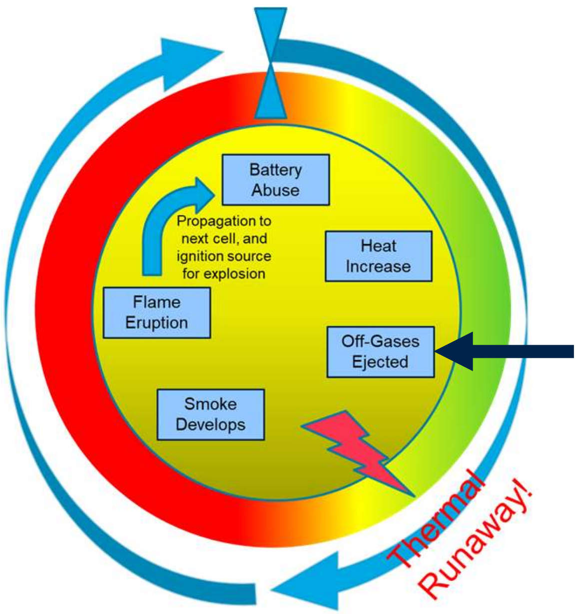
- To detect Li-ion off-gases, we must be capable of detecting a very trace amount of a blend of different gases.

- Focusing on any one gas is not effective.



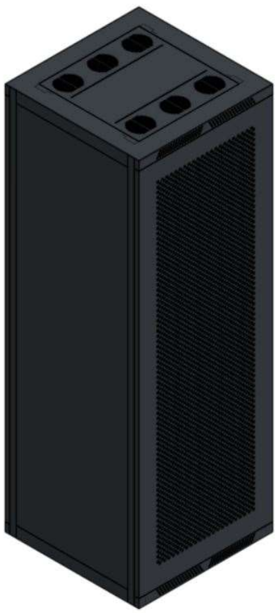
Not all batteries are made equal

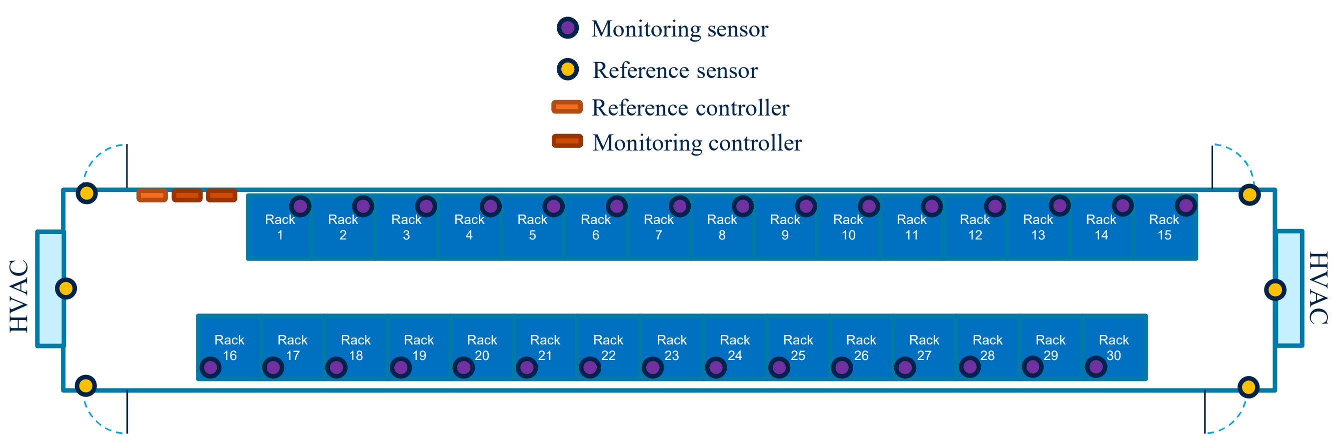
OFF GAS VIDEO



Off-Gas Monitoring

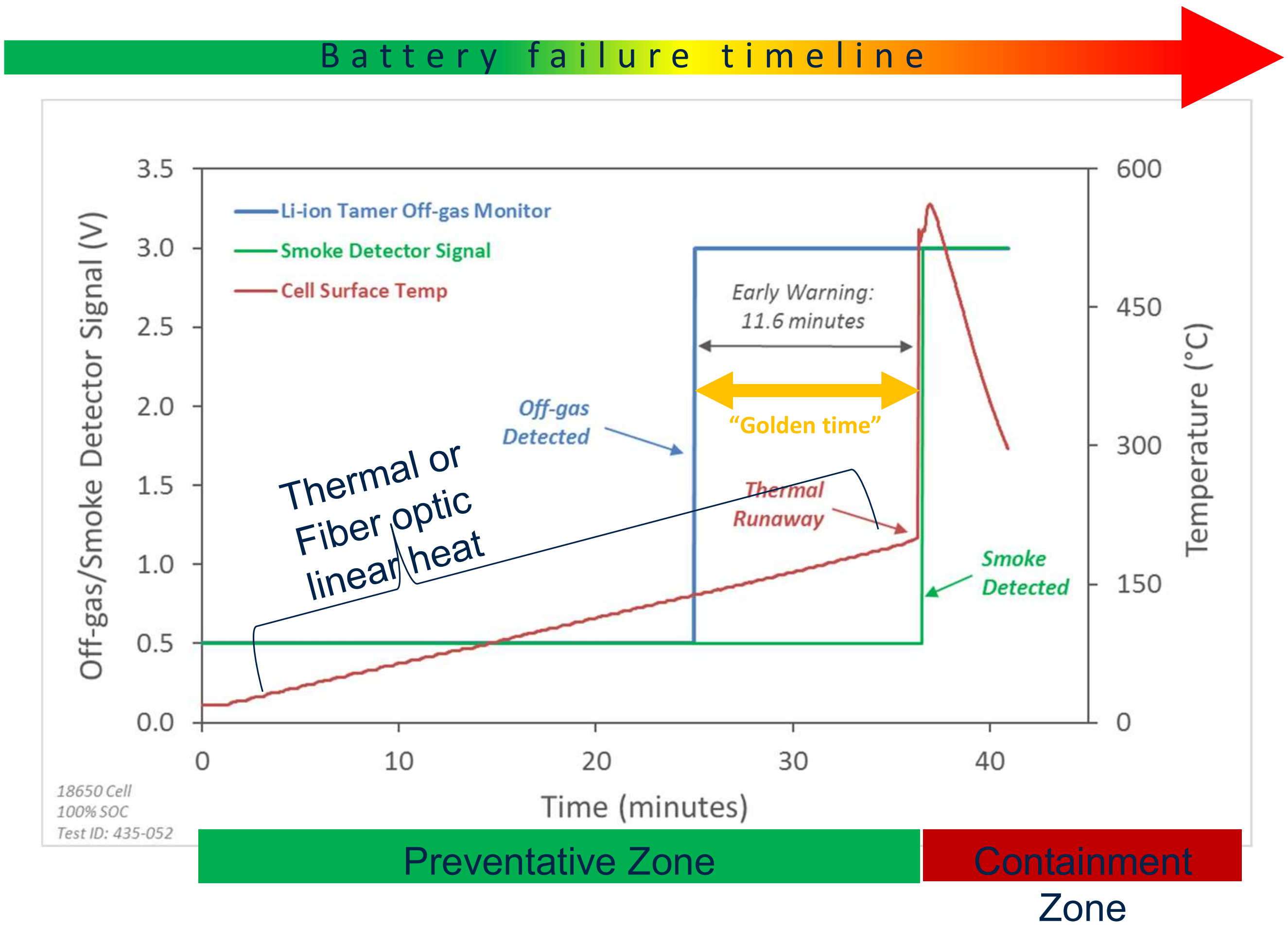
Typical ESS Container with Battery Racks





Preventative Zone Detection Techniques

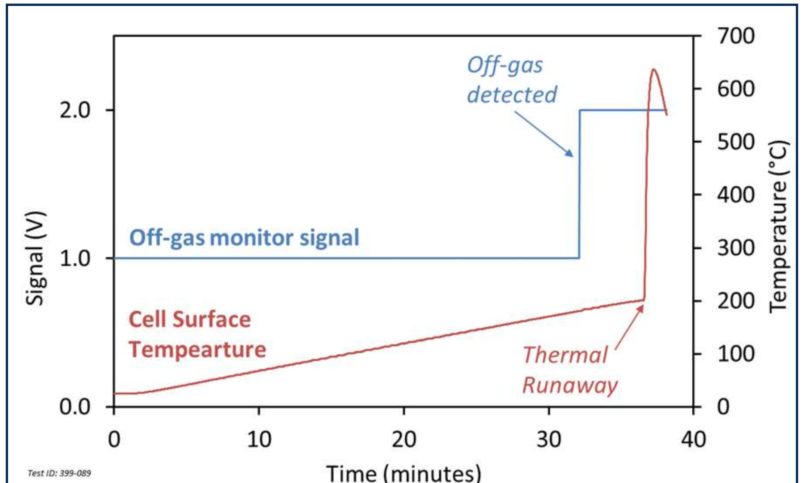
Battery Failure Timeline



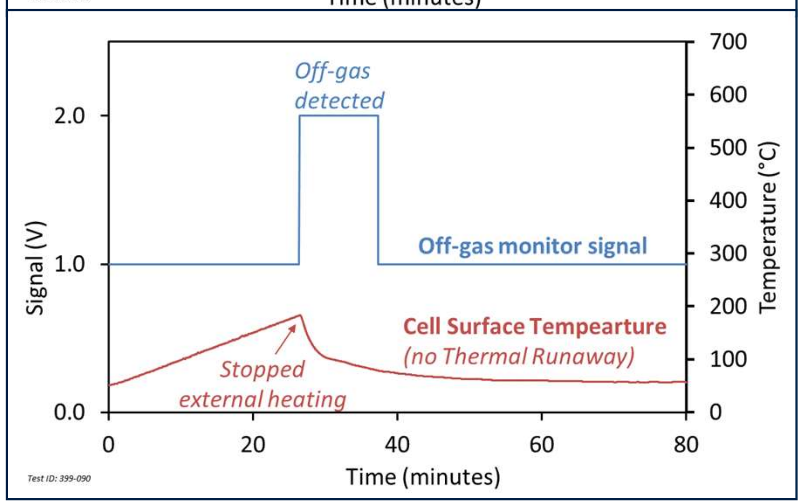
PREVENTATIVE ZONE

Battery Failure Timeline

- Off-gas and surface temperature increase are precursors to battery failure
- Identification of either will provide early warning and notification



- Isolating/disconnecting affected cells upon detection can PREVENT thermal runaway
- Additional Suppression/Extinguishing should also be utilized as additional safeguard to surroundings, and help prevent escalation of the event. (more info on these options in the Containment Section)



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Containment Zone

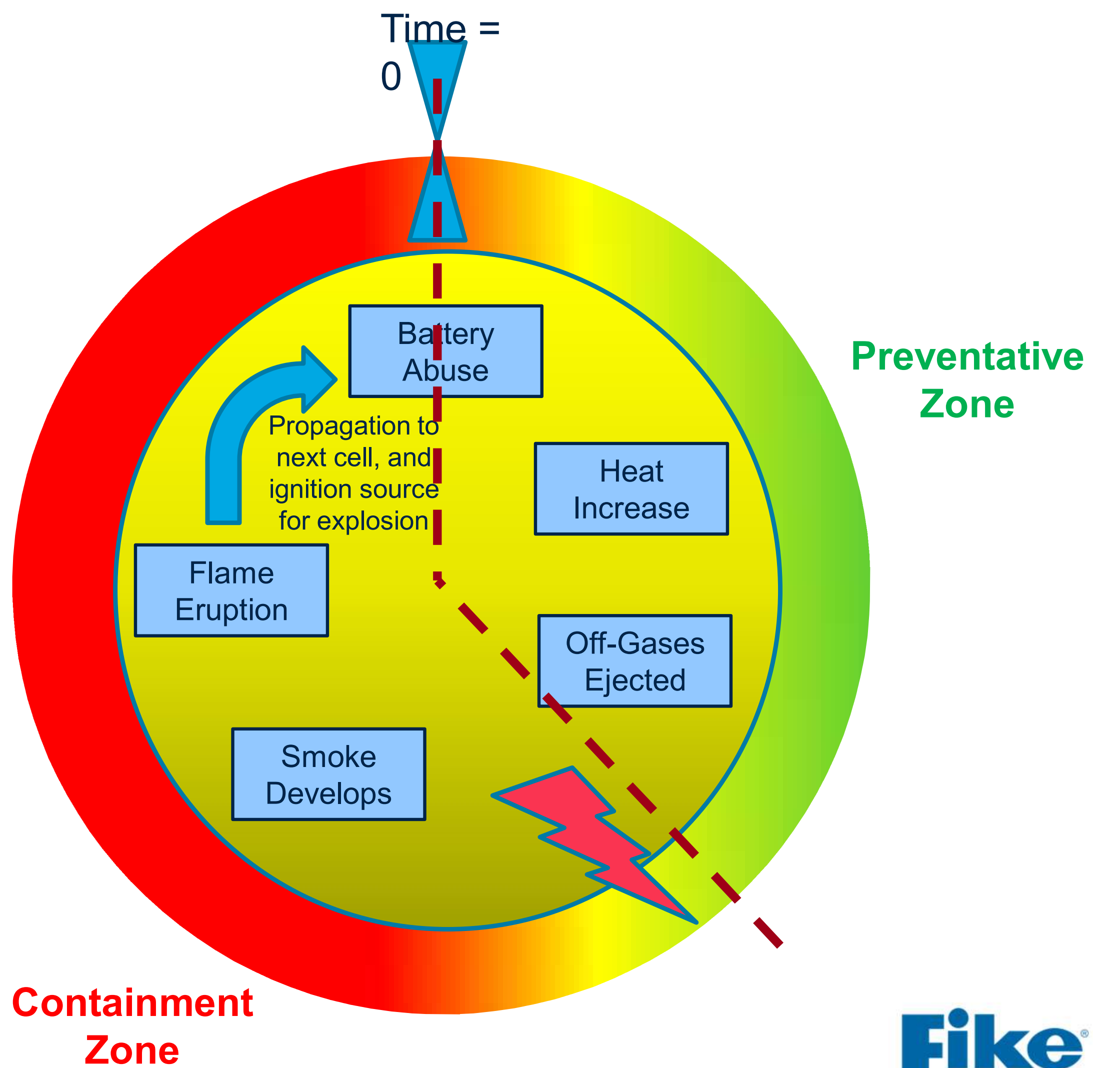
Containment Attempt Measures Available or typically applied:

Sprinkler Head

Traditional smoke/heat/flame detection integrate with BMS to disconnect charge/draw from the affected zone, and initiate discharge of a special hazard suppression system:

Clean Agent Extinguishing System
Inert Gas System
Water Mist

None of the above will extinguish thermal runaway, but all attempt to contain the event and minimize damage to adjacent areas



CONTAINMENT ZONE PROTECTION TECHNIQUES

CLEAN EXTINGUISHING AGENTS

NFPA

- As Defined by NFPA 2001, Standard on Clean Agent Fire Extinguishing Systems:
  - *Odorless and Colorless, Electrically nonconducting gaseous fire extinguishant that does not leave a residue upon evaporation.*

- *Primarily Preferred in Mission Critical Areas to Prevent Business Disruptions due to Fires, and Promote and Enhance Business Continuity via:*
  - *Valuable Asset Protection*
  - *Minimizing Downtime*
  - *Fast, Effective, 3-Dimensional Extinguishment*
  - *Safe for People and Occupied Spaces at Approved Concentrations**

FM-200®

HFC-227ea

ECARO 25

3M Novec™ Brand

FK-5-1-12

PROINERT 2

Fike®

Containment Zone Protection Techniques

Regardless of Clean Agent Utilized:

- Must be partnered with a Pre Thermal Runaway Detection method to be most effective. (Fiberoptic linear heat is preferred)
- Will not damage any unaffected servers, drives, or cells
- Safe to breathe for anyone nearby or exposed

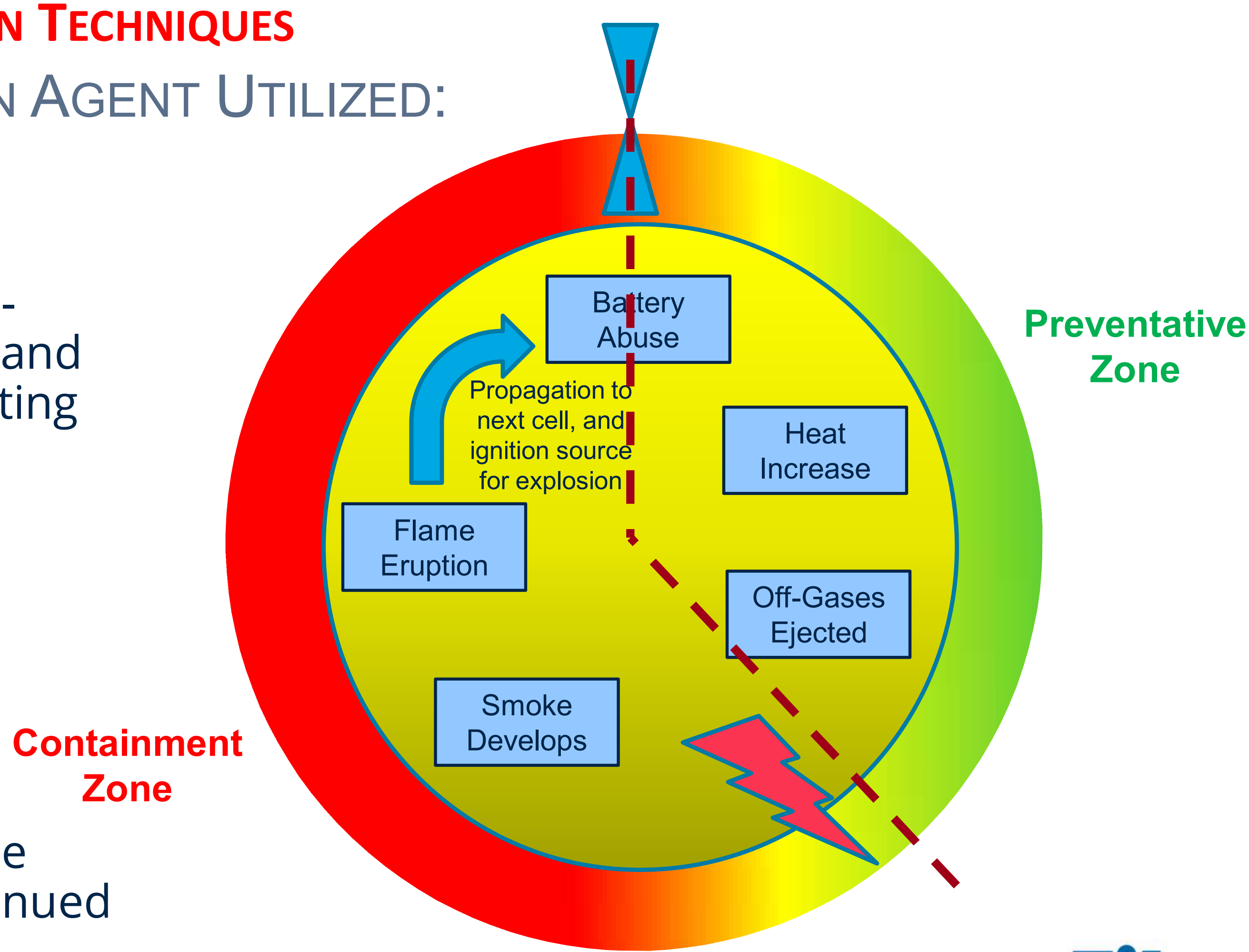
- Amount of agent provided will be specific to volume protected
- Requires the enclosure to be "airtight"
- Agent lost through leakage (or continued ventilation) lowers duration and effectiveness of system, "one shot deal"

- If discharged AFTER Thermal Runaway, Chemical Agents can break down into additional flammable/toxic gases (Inert will not)
- No Agent will extinguish Thermal Runaway

CONTAINMENT ZONE PROTECTION TECHNIQUES

REGARDLESS OF CLEAN AGENT UTILIZED:

- If Discharged in the Preventative Zone;
  - Will extinguish any non-lithium electrolyte fire, and absorb and block radiating heat.
- If Discharged in the Containment Zone;
  - May initially extinguish the Class A, B, or C Combustibles, but effectiveness likely to be short-lived due to continued and evolving Thermal Runaway and leakage



Fike

WATER MIST

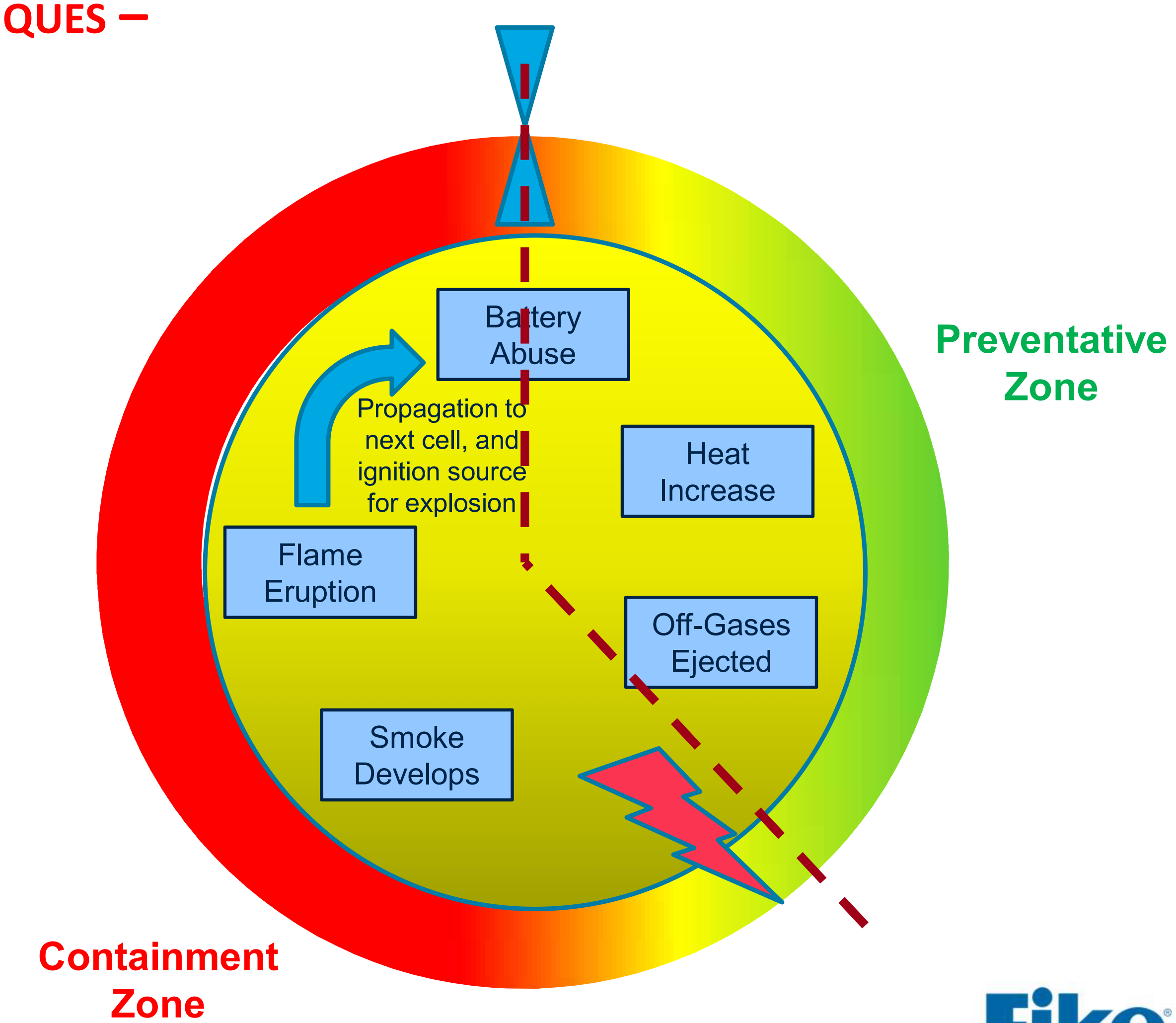
- As Defined by NFPA 750, Standard on Water Mist Fire Protection Systems:
  - Extinguish fire using a very fine water spray with droplets <1,000µm.
  - Primarily via Heat Absorption and Localized Oxygen Displacement at transition point from solid (droplet) to gas (steam)
- Designated for use in Class A, B, and C Hazards

- Room Integrity (airtight) not as critical as with gaseous systems
- Will discharge much longer than gaseous systems
  - Fixed Water Supply and Pressurized cylinders for 10-20 minutes
  - Continuous Water Supply driven by pump = “unlimited duration”

Fike

Containment Zone Protection Techniques – Water Mist

- If Discharged in the Preventative Zone;
  - Will extinguish any non-lithium electrolyte fire, and absorb and block radiating heat.
- If Discharged in the Containment Zone;
  - Extended /Continued / “Unlimited” discharge provides constant supply of water vapor to absorb and block radiating heat as long as it is being generated



Hazard Focus:
Battery Energy Storage Systems, Lithium Ion Batteries

Several different options and configurations and combinations of detection and protection available, when do we do what?

Answer depends on what level of protection you need or desire, and what is driving the need?
(and of course budget)

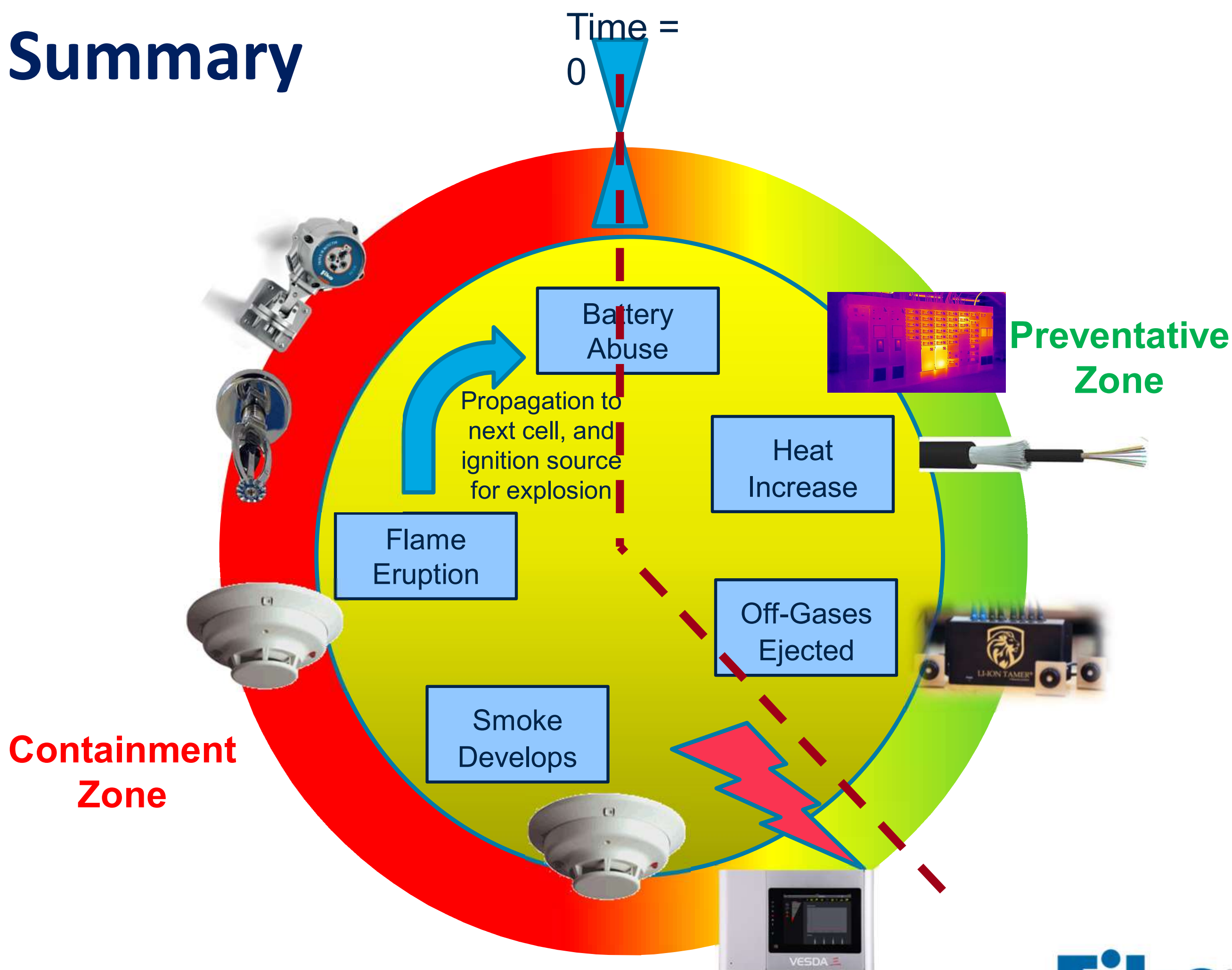
Detection Option Summary

Detection in the Preventative Zone offers the best chance and the most time to respond to avoid a catastrophic event.

Detection in the Containment Zone prompts you to respond as best as possible.

Fire Suppression Response options:

Clean Extinguishing Agent
Inert Gas
Water Mist



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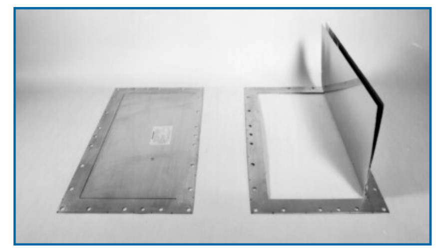
Protection Options Summary

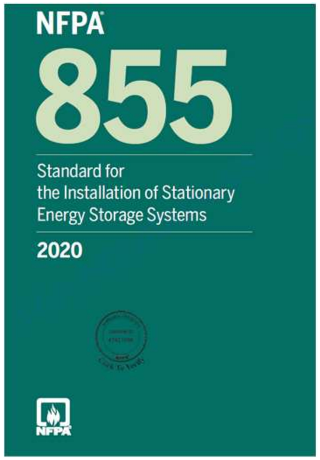
Detection & Control

- Traditional Smoke/Heat Detection
- Thermal Imaging
- Xtralis Air Sampling (Smoke & Gas Detection)
- Fiber Optic Linear Heat
- Li-ion Tamer (Off-gas detection)

Suppression / Protection

- **Good** - Explosion Venting
- **Better** - Gaseous Agent or Water Mist
- **Best** - Gaseous Agent + Water Mist





What does NFPA 855 require for my BESS unit?

#1 – You must have Combustible Gas Detection to alert at >25% LFL
AND
#2 – You must have Explosion Protection (NFPA 69) or Explosion Venting (NFPA 68)

Can the Gas Detection system tie into the BMS to automatically initiate mechanical exhaust fans upon LFL > 25%?

YES → Explosion Protection may be omitted (AHJ)

NO → Explosion Protection Required

#3 – You must have Smoke & Fire Detection and Suppression

Where is the Unit going to be Located?

Indoors → Is the Building "Dedicated" to Just the ESS Equipment?
- YES → Is it "remote", ie: >100' away from any "nearby exposures"?
  - YES → Suppression may be omitted by AHJ, but still need smoke & Fire Detection
  - NO → #3 – You must have Smoke & Fire Detection and Suppression
- NO → #3 – You must have Smoke & Fire Detection and Suppression

Outdoors → Is the ESS unit "remote", ie: >100' away from any "nearby exposures"?
- YES → Suppression may be omitted by AHJ, but still need smoke & Fire Detection
- NO → #3 – You must have Smoke & Fire Detection and Suppression

Rooftop / **Parking Garage** → Must also have "Radiant Energy Sensing" Equipment (Fiberoptic Linear Heat or Thermal Imaging) → #3 – You must have Smoke & Fire Detection and Suppression

*In a Parking Garage: you can omit smoke detection if you have radiant energy sensing equipment

*In a Parking Garage: you can omit suppression IF a fire is proven to present no threat to nearby vehicles or means of egress

Mobile Unit → Can you "Walk In" the unit?
- YES → #3 – You must have Smoke & Fire Detection and Suppression
- NO → Suppression may be omitted by AHJ, but still need smoke & Fire Detection

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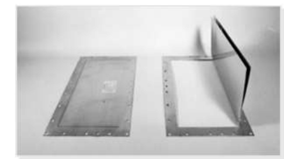

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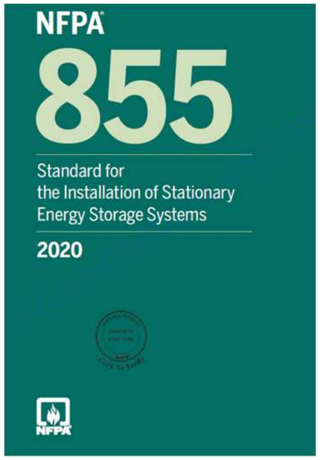

What seems to be the "preferred", most accepted approach in the market?

Testing with ESS manufacturers has led to a preference of Intelligent Fiber Linear Heat Detection Cable and Water Mist for suppression.

Intelligent Fiber LHD cable can provide early warning of thermal upsets to respond and potentially avoid Thermal Runaway, and is listed to release Water Mist suppression.

Water Mist is listed for Class A, B, C fires, and when continuously discharged will provide an extremely effective heat absorbing barrier between Thermal Runaway sources and surrounding fuels. Water Mist is a very suitable means of protection before and/or after Thermal Runaway.

What is the Most Code Compliant Protection System Configuration for my BESS?

1. **Off-Gas Detection Tied into BMS to shutdown rack and initiate mechanical ventilation fan.**
2. **Fiber Optic Linear Heat that shuts off exhaust and seals enclosure to initiate Clean Agent* and/or Water Mist discharge.**
3. **Spot-type or Air Sampling Smoke Detection that shuts off exhaust and seals enclosure to initiate Clean Agent* and/or Water Mist discharge if not previously initiated.**
4. **Explosion Vents to expel flame and gases should a deflagration occur**
5. **Flame Detection external to unit to alarm upon visible flame outside of the unit**

*** Clean Agents should only be discharged BEFORE Thermal Runaway.**

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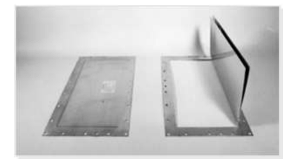

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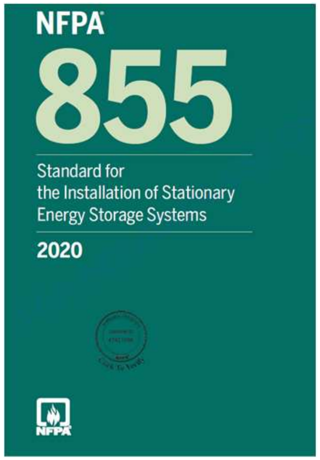
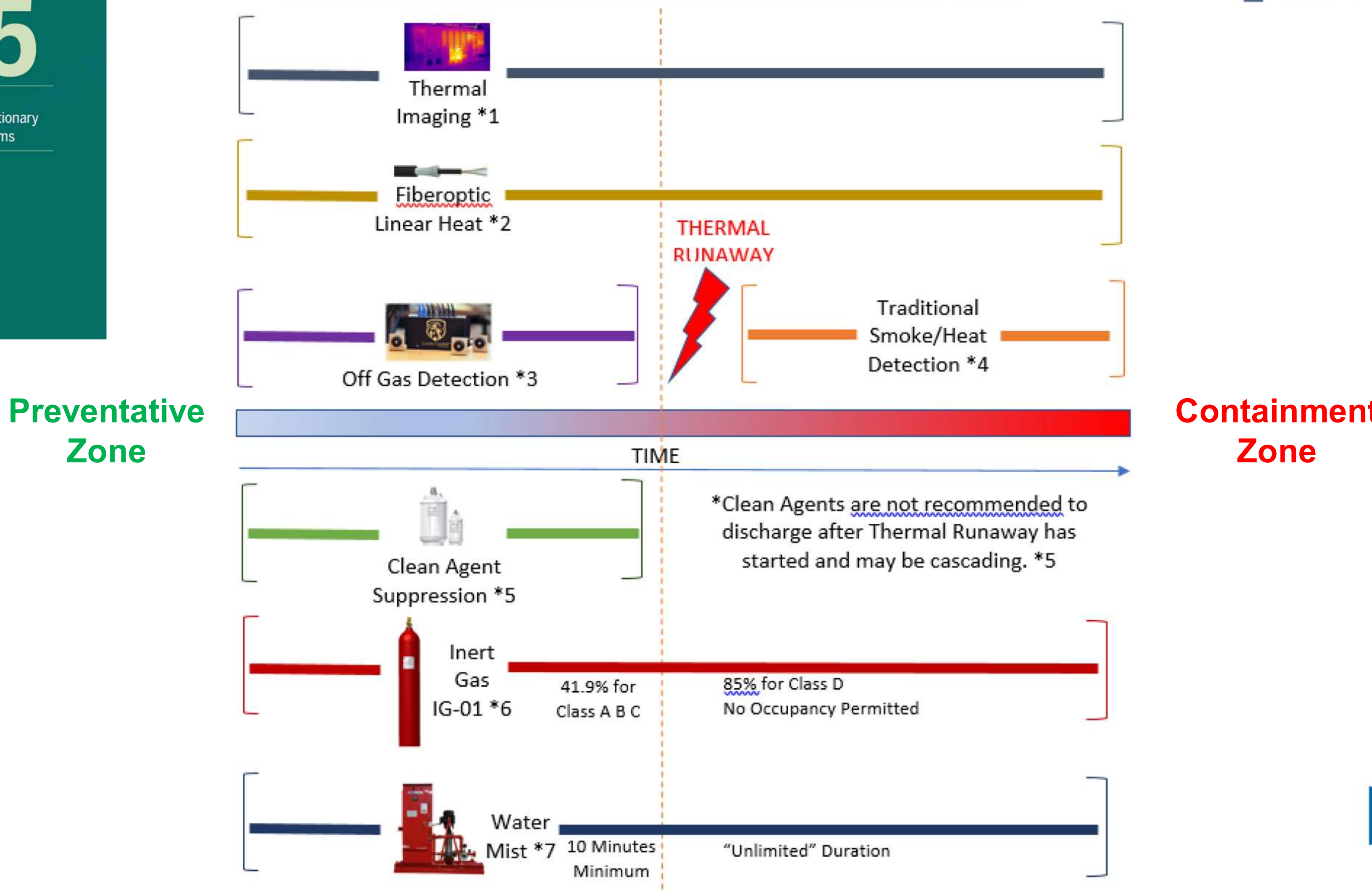


When is Which Detection & Suppression Technology Appropriate?



Thank you for your time!

Rick Seidel
Regional Sales Manager – Northeast USA
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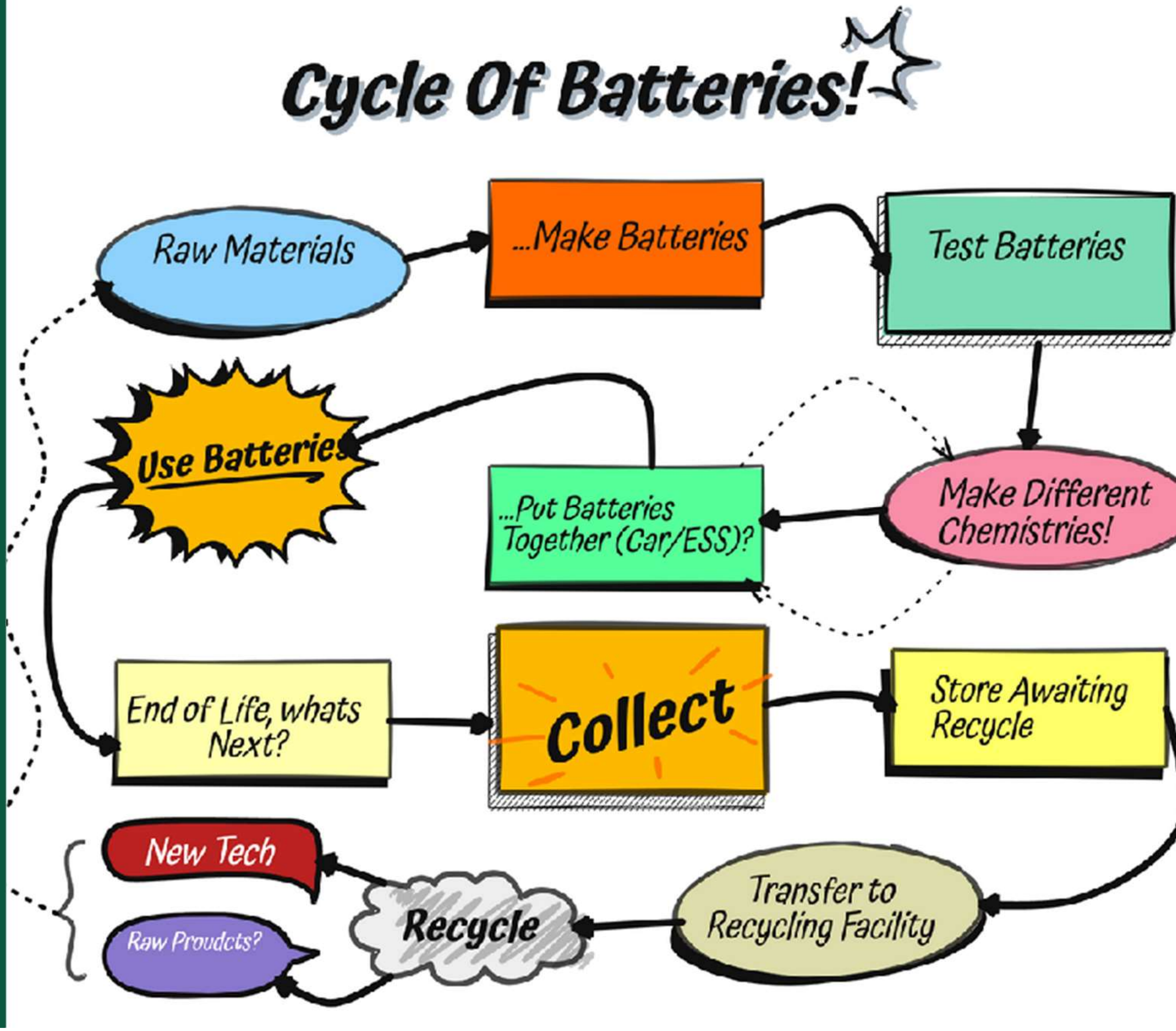
Chief Michael O’Brien

Brighton Area Fire Authority

Response to Energy Storage Systems:

The collective community developing resources based on best practices

The Current Cycle on Batteries



Battery Responses Are In Multiple Categories

- Mobility/Consumer grade (ebikes, scooters, hover boards etx)
- Electrical /Hybrid Vehicle (Car/Bus/Vehicle)
- Recycling (hauling, storing, moving, in waste stream
- ESS (Energy Storage Systems)
- Storage/Manufacture

Previous Work

What the International Association of Fire Chiefs (IAFC) has done

-Work Group dedicated to response of batteries

IAFC BULLETIN

October 19, 2021

Fire Department Response to Electrical Vehicle Fires

Adapting our response plans through training, research, and experience is critical in the Fire Service. As sales of Electric and Hybrid vehicles increase, the fire service must continue to modify our tactics to properly respond and protect our firefighters. Fighting vehicle fires is inherently dangerous. When responding to a Electric or Hybrid vehicle fire there are additional challenges responding crews must consider.

Additional response-specific information can be found on most automobile manufacture web pages. NFPA Quick Vehicle Response Guide

Pre-Incident

Modify or establish your department policy or standard response guideline to vehicle fires and ensure it includes practices for electrical vehicle fires. Include guidelines for limited interaction and when crews should allow the vehicle to burn.

When working on roadways protect the work area per department policy. Staff should consider that this may include a vehicle fire or extrication. Staff operating on roadways should anticipate possibly longer timeframes to manage/control EV vehicle fires and maintain heightened situational awareness.

NFPA has a full series of documents on various EV safety response (including emergency response guides by manufacturer).

Review response and post incident procedures with law enforcement and towing companies.

INCIDENT ACTIONS

When arriving on scene, the first arriving company should perform a proper size up This includes the extent of the fire and if it is a compartment fire or includes the electric components of the car. Similar to other vehicle fires, is the "engine" compartment or the passenger compartment on fire? The best method for managing or controlling a battery fire is with water. Battery fires will initially show from under the vehicle.

- Protect your work area through established department policy and establish tactical priorities (fire, extrication, victim care) and ensure the vehicle is in park and off, if possible.
- Wear full PPE with SCBA with face-piece and establish an appropriate command structure.
- Consideration and tactics may be categorized in offensive or defensive mode. This may be based on exposures and the extent of fire which may include actions to let the vehicle burn. Use a thermal imaging camera to help with the 360 size-up
- Secure a large, continuous and sustainable water supply from one or more fire hydrants or multiple water tenders (3,000-8,000 gallons)
- Where safe, consider chocking the wheels. EVs move silently, so never assume it is powered off. Never assume that an EV will not move.
- Extinguish small fires that do not involve the high voltage battery using typical vehicle firefighting procedures
- When attacking the vehicle fire, understanding that once the contents of the fire are extinguished, sustained suppression on the battery pack may be necessary. Use a large volume of water such as multiple 1¾-inch hand-lines to suppress and cool the fire and the battery. Put water on the burning surfaces
- Have sufficient fire personnel and apparatus on scene for an extended operation to monitor the battery's heat or possible secondary ignition. The heat from the

IAFC Response Guideline

Pre-Incident, Pre-Plan, Response

IAFC BULLETIN

August 1, 2022

Recommended Fire Department Response to Energy Storage Systems (ESS) Part 1

Events involving ESS Systems with Lithium-ion batteries can be extremely dangerous. All fire crews must follow department policy, and train all staff on response to incidents involving ESS. Compromised lithium-ion batteries can produce significant amounts of flammable gases with potential risk of deflagration and fire.

1. **If a commercial or utility install, follow pre-plan and do not enter structure.**
2. **Residential setting response, control power to the unit, ventilate the area, and protect exposures.**
3. **In all cases contact manufacture technical support as soon as possible.**

This guide serves as a resource for emergency responders with regards to safety surrounding lithium ion Energy Storage Systems (ESS). Each manufacturer has specific response guidelines that should be made available to first responders prior to activation.

...s and sizes. They may be affiliated with renewable systems (wind, photovoltaic systems, etc) or used as standby ...led in single family homes too large commercial and utility applications.

...officials including Building, Fire, and Electrical

ESS systems must be installed per

INCIDENT ACTIONS

The fire crew should allow the battery to burn itself out, during which it is recommended to apply water spray to neighboring battery enclosures and exposures to further mitigate the spread of the hazards rather than directly onto the burning unit.

Applying water directly to the affected enclosure will not stop the thermal runaway event, as the fire will be located behind several layers of steel material, and direct application of water has shown to only delay the eventual combustion of the entire unit.

- Firefighters must wear full personal protective equipment, including SCBA with face-piece.
- If identified in pre-incident plan, shut off the unit/system by operating any visible disconnects or E-stops (shutting off the disconnect does not remove the energy from the battery). To isolate any PV system and ESS in an emergency, multiple disconnects may need to be shut off. This could include circuit breakers, knife-blade disconnects, or other switches.
- Lithium ion batteries that are in thermal runaway or off gasing will create hazardous atmospheres. Firefighters must stay out of the vapor cloud and not rely on gas monitors (without consideration of cross contamination of the gas sensors)
- Due to construction of the unit, thermal imaging cameras may not give true thermal conditions.

Incident Response

The fire crew should allow the battery to burn itself out, during which it is recommended to apply water spray to neighboring battery enclosures and exposures to further mitigate the spread of the hazards rather than directly onto the burning unit.

Applying water directly to the affected enclosure will not stop the thermal runaway event, as the fire will be located behind several layers of steel material, and direct application of water has shown to only delay the eventual combustion of the entire unit.

Best Practices

- Firefighters must wear full personal protective equipment, including SCBA with face-piece.
- If identified in pre-incident plan, shut off the unit/system by operating any visible disconnects or E-stops (shutting off the disconnect does not remove the energy from the battery). To isolate any PV system and ESS in an emergency, multiple disconnects may need to be shut off. This could include circuit breakers, knife-blade disconnects, or other switches.
- Lithium ion batteries that are in thermal runaway or off gasing will create hazardous atmospheres. Firefighters must stay out of the vapor cloud and not rely on gas monitors (without consideration of cross contamination of the gas sensors)
- Due to construction of the unit, thermal imaging cameras may not give true thermal conditions.

Venting ESS

- Evacuate the area. Never open any doors or remove panels to ESS units.
- Contact vendor-specific technical support for assistance including BMS data.
- Residential units that are located inside a dwelling unit or garage, the space should be properly ventilated with charged hand-lines in place.
- Maintain a safe distance from the ESS and monitor. A remote FDC may be present on larger commercial or utility ESS to support a sprinkler system inside the enclosure.
- Each manufacturer will have a recommended time for a battery pack to cool down. This can be near a full work cycle of 12 hours or more.

Defensive Firefighting

- Water spray is the preferred agent for response to lithium-ion battery fires (Lithium-ion is not water reactive).
- If a fire has not developed and only smoke is visible, take a defensive stance toward the system and be prepared to apply water spray.
- If a fire develops, take a defensive stance toward the burning unit and apply water spray to neighboring battery enclosures and exposures.
- Maintaining a safe distance from the unit involved (large commercial systems, at least 300').
- Response crews should allow the battery to burn out. Water should be applied to adjacent battery enclosures and exposures (building).

Patience During the Response

- What is happening
  - Fire that is treating an ESS installation
  - Fire that is a result of an ESS installation
- Ventilation is key (Basement/Garage Installations)
- Cool exposures
- Get resources at our finger tips
- Time

POWERWALL

MEGAPACK

POWERPACK

Lithium-Ion Battery Emergency Response Guide

For Tesla Energy Products Powerwall, Powerpack, and Megapack

to a Tesla product fire or hazardous event, contact Tesla Energy Technical Support for guidance (*Identification of Company and Contact Information on page 4*).

5.1 Responding to a Venting Tesla Energy Product

Smoke or suspicious odor emanating from a Tesla Energy Product can be an indication of an abnormal and hazardous condition. Battery thermal runaway fires are preceded by a period of smoke. The smoke is likely flammable and may ignite at any time. If fire, smoke, or suspicious odor is observed emanating from a Tesla Energy Product at any time, the following should be performed:

1. If possible, **shut off the unit/system** (see *Shutting Down in an Emergency on page 25*).
2. **Evacuate the area.**

> **WARNING:** When responding to a fire event with the **Powerpack System**, do not approach the Powerpack units from the front (door-side) or the rear. Perform all incident response from the sides of the units. Do not attempt to open the enclosure doors or come in contact with the units.

> **WARNING:** When responding to a fire event with **Megapack**, do not approach the unit and attempt to open any doors. The doors are designed to remain shut, and built-in deflagration vents in the roof of the unit will vent any smoke and flame out of the top of the unit and front thermal system intake louvers.

3. If not already done, **contact Tesla Energy Technical Support** for assistance (*Identification of Company and Contact Information on page 4*).
4. **Maintain a safe distance from the unit and monitor** (*Defensive Firefighting on page 24*) for evidence of continued smoke venting or fire.

> **WARNING:** There may be periods of up to three hours at a time during which the thermal runaway propagates from battery modules to battery modules. During such time, the battery may not generate visible signs of thermal event although the event can still be active and the battery can flare up.

   a. **If a fire has not developed** and only smoke is visible, take a defensive stance toward the system and be prepared to apply water spray **to neighboring exposures and neighboring battery enclosures.**

   b. **If a fire develops:**

      - **Continue to take a defensive stance toward the burning unit.** Applying water to the burning unit will only slow its eventual combustion (see *Defensive Firefighting on page 24*).
      - **If advised by Tesla, apply water to neighboring battery enclosures.** If communication cannot be established with Tesla, apply water at the discretion of first responders.
      - **At the discretion of first responders, apply water to other neighboring exposures.**

5. **Allow the battery pack to cool down** for a minimum of 12 hours after all fire and smoke has visibly subsided.
6. **Monitor the temperature** of the battery pack using a thermal imaging camera to determine if it is safe to interact with the unit.
7. Contact Tesla Energy Technical Support for next steps (*Identification of Company and Contact Information on page 4*).

5.2 Defensive Firefighting

Tesla's recommendation is to fight a Tesla Energy Product fire defensively. The fire crew should maintain a safe distance in any direction of at least:

- 5 m from Powerwall
- 10 m from Powerpack
- 20 m from Megapack

> **WARNING:** Depending on the conditions of the event (such as location of the burning battery, wind speed and direction) a safe distance may be higher than those prescribed above.

As outlined in the procedure above, **the fire crew should allow the battery to burn itself out.** To further mitigate the spread of the hazards, Tesla may recommend the application of water spray to neighboring battery enclosures, and first responders may apply water spray to neighboring exposures. **Applying water directly to the affected enclosure will not stop the thermal runaway event, as the fire will be located behind several layers of steel material, and direct application of water has shown to only delay the eventual combustion of the entire unit.**

> **WARNING: In confined spaces,** if water is used directly on the enclosure that is burning, electrolysis of water (splitting of water into hydrogen and oxygen) may contribute to the flammable gas mixture formed by venting cells, burning plastic, and burning of other combustibles.

Water spray has been deemed safe as an agent for use on exposed Tesla Energy Products. Water is considered the preferred agent for managing lithium-ion battery fires. Gaseous agents such as CO2, Halon, or dry chemical suppressants may temporarily suppress flaming of lithium-ion battery packs, but they will not cool lithium-ion batteries and will not limit the propagation of cell thermal runaway reactions. Metal fire suppressants such as LITH-X, graphite powder, or copper powder are not appropriate agents for suppressing fires involving lithium-ion battery packs as they are unlikely to be effective.

A battery fire may continue for several hours and it may take 24 hours or longer for the battery pack to cool after it has been fully consumed by a thermal runaway event. After all fire and smoke has visibly subsided for at least 12 hours, a thermal imaging camera can be used to actively measure the temperature of the unit and determine if it is safe to interact with.

5.3 Firefighter PPE

Firefighters should wear self-contained breathing apparatus (SCBA) and fire-protective turnout gear. Regulatory testing has shown that the products of combustion of Tesla Energy Products can include flammable and nonflammable gases. Based on those regulatory tests, the flammable gases were found to be below their lower flammable limit (LFL) and would not pose a deflagration or explosion risk to first responders or the general public. The nonflammable gases were found to be comparable to the smoke encountered in a typical Class A structure fire and do not contain any unique, or atypical, gases beyond what you would find in the combustion of modern combustible materials.

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Questions/Discussion

DURING THE WEBINAR: please utilize Q&A function to be recognized or ask a question to be read aloud to the panel

AFTER THE WEBINAR: We will email responses to the anyone who has entered a question into the chat box but did not receive a response during the webinar. Email new or follow-up questions to jzakreski@iccsafe.org.