Kidde
Fire Systems

Battery Energy Storage Systems (BESS)

A Comprehensive Approach to Fire Protection

KiddeFenwal

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Battery Energy Storage Systems (BESS) are fundamentally transforming the global energy landscape. By capturing and storing power from renewable sources like solar and wind, BESS provides the stability and flexibility necessary to modernize the grid—making sustainable energy both reliable and scalable. As the push for decarbonization and grid resilience intensifies, these systems have become a vital pillar of 21^{st}-century energy infrastructure.

However, as BESS installations grow in both physical scale and technical complexity, implementing a sophisticated, multi-layered fire protection strategy is no longer optional; it is a critical requirement for safe operation.

Market Trends and Drivers

The adoption of BESS is accelerating due to several key factors:

- Balancing Renewables: While solar energy follows a predictable daily cycle, wind power is inherently variable. BESS bridges this gap by "firming" renewable output—storing surplus electricity during peak production and discharging it when demand rises or natural generation drops.

- Grid Stability: Beyond simple storage, BESS acts as a buffer that helps utility providers balance supply and demand in real-time.

- Critical Infrastructure & UPS: Beyond the utility scale, BESS serves as a high-capacity Uninterruptible Power Supply (UPS). It provides essential backup protection for mission-critical facilities, such as data centers, ensuring operational continuity during grid failures.

Global Market Trends and Adoption

Data from the U.S. Energy Information Administration (EIA) highlights the extraordinary pace of BESS deployment. In the United States alone, battery storage capacity surged by 65% in Q1 2025 compared to the same period the previous year, reflecting a massive shift toward localized energy storage.

This aggressive growth is mirrored on a global scale, with many countries, especially those in the Asia-Pacific and Middle East region investing massively in infrastructure development and pushing hard for energy independence. These trends underscore a global consensus: large-scale storage is the essential catalyst for the next generation of power distribution.

Lithium-Ion Batteries (LIB)

While various energy storage technologies exist, Lithium-Ion Batteries (LIB) have emerged as the industry standard for BESS applications.

At their core, these batteries consist of an anode and a cathode, kept apart by a physical separator and submerged in a conductive liquid electrolyte. The system functions through the movement of lithium ions. When discharging, ions move through the electrolyte while electrons flow through an external circuit to provide usable power whereas when charging, the flow is reversed, and energy is pumped back into the cells, moving the ions back to their starting position for future use. This efficient cycling of chemical energy into electrical power is what makes LIBs the preferred choice for high-capacity grid storage.

Thermal Runaway and Propagation

When an anomaly, caused by factors including mechanical abuse or injury, thermal extreme, overcharging or others occur in a single cell, it creates a significant risk of cascading failure, also known as thermal runaway propagation.

Because BESS units pack thousands of cells into tight configurations, the extreme heat from one failing cell quickly overcomes the thermal insulation of its neighbors. This creates a "domino effect" where the failure spreads from cell to cell, then module to module, and eventually throughout the entire rack or container.

Key Factors in Cascading Failure:

Conductive Heating: High temperatures transfer through shared busbars and internal racking.

Radiant Heat:

The intense 1,100°F+ temperatures can ignite adjacent modules even without direct flame contact.

Vapor Cloud Risks:

As multiple cells vent simultaneously, they create a dense cloud of flammable and toxic off-gases (such as hydrogen and carbon monoxide respectively), which can lead to a deflagration or explosion if the area is not properly ventilated. This feedback loop creates a self-sustaining fire that can reach extreme temperatures—often exceeding 600°C (1,100°F) - making it incredibly difficult to extinguish using traditional methods.

Preventative Strategies and Hazard Mitigation

The most effective way to manage BESS risks is to prevent thermal runaway before it begins. By identifying and monitoring the primary catalysts for battery failure - classified into Mechanical, Electrical, and Thermal abuse - operators can intervene before a catastrophic event occurs.

1. Mechanical Abuse

Mechanical failures often stem from environmental stressors that compromise the physical integrity of the system.

The Risk: External vibrations can loosen electrical connections, while humid or corrosive environments can degrade electrical leads. These issues create high-resistance points that generate localized "hot spots."

The Solution: The Kidde Fire Systems (KFS) branded REL-iON™ sensor platform by KiddeFenwal addresses these risks by deploying vibration sensors at critical points, Infrared (IR) thermal sensors to detect overheating contacts, and environmental sensors to monitor humidity and early signs of corrosion.

2. Electrical Abuse

Electrical instability during the charging or discharging cycles can destabilize cell chemistry.

The Risk: Poor power quality or voltage spikes from the incoming supply can over-stress the battery cells.

The Solution: Continuous monitoring of incoming electrical lines allows for the detection of "dirty" power or surges, enabling the system to disconnect before the cells sustain internal damage.

3. Thermal Abuse

Thermal abuse is often a secondary failure resulting from a breakdown in the system's climate control.

The Risk: If a cooling system fails or leaks, the ambient temperature within the enclosure can rise rapidly, pushing cells past their stable operating window.

The Solution: The REL-iON™ platform mitigates this through a multi-layered approach: refrigerant leak sensors to monitor cooling loops, air temperature sensors for the battery compartment, and floor-mounted water leak sensors to detect coolant or external moisture ingress.

Early Detection and Hazard Mitigation: Off-Gas Monitoring

In cases where prevention fails, the ability to detect a cell failure in its earliest stages is the last line of defense against a full-scale event.

Before a battery enters thermal runaway, the internal pressure causes it to "vent" electrolyte vapors. Identifying these gases provides a critical window of time - often several minutes—to take corrective action.

Chemical Signatures: While gas compositions vary by manufacturer, Volatile Organic Compounds (VOCs) and Hydrogen (H2) are generally believed to be the most reliable early indicators.

KFS REL-iON™ Solution: REL-iON™ combines H2 and VOC sensing technologies. This dual-detection approach provides an early warning to the Battery Management System (BMS), allowing it to isolate the affected cells and potentially halt the transition into thermal runaway.

Managing Active Thermal Runaway

If a short circuit has already occurred within the cell, thermal runaway is inevitable for that specific unit. At this stage, the objective shifts from prevention to containment and propagation limitation.

NFPA 855 Compliance: To meet the rigorous safety standards of NFPA 855, installations must incorporate a robust suite of sensors, including:

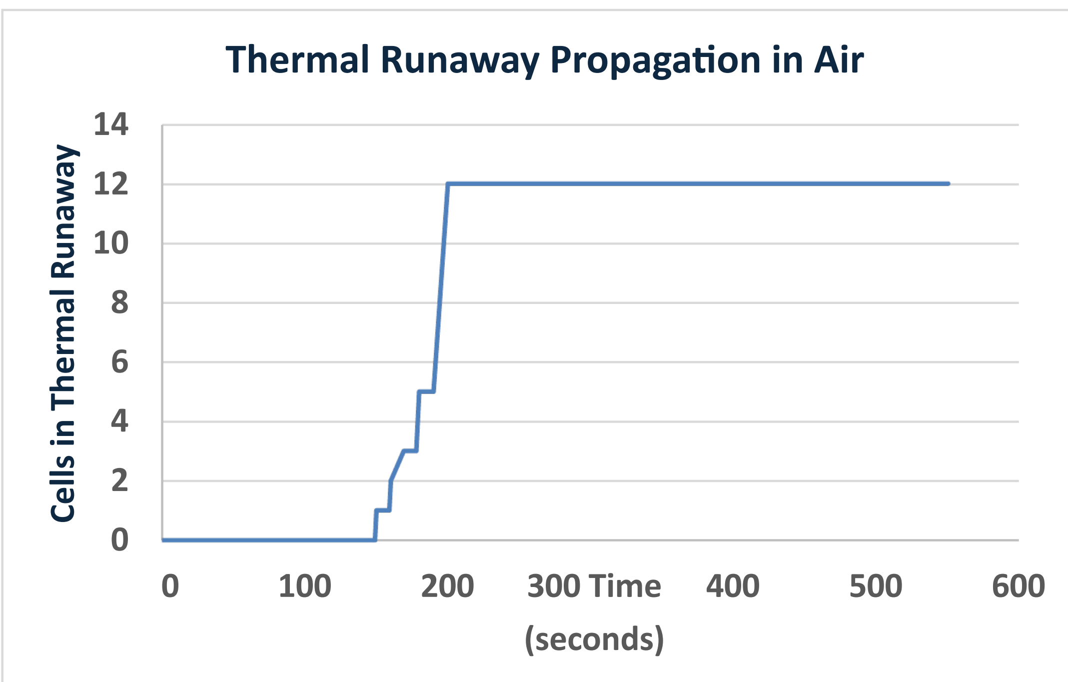
Early Warning Smoke Detection: To detect incipient smoke or smoke not visible to the eye in its earliest stage of formation, BESS should utilize air sampling smoke detection.

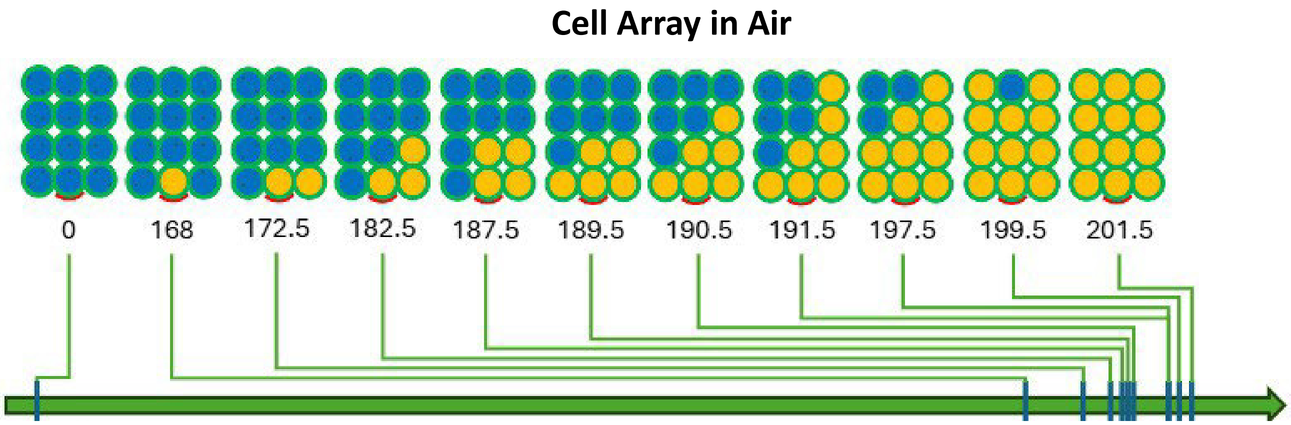
Standard Fire Detection: To detect an active event, systems should utilize traditional smoke and heat detection, including both spot and linear heat detectors.

NFPA 855 also accepts other forms of detection such as thermal imaging and radiant energy sensing. By integrating these various sensors into a system, a KiddeFenwal fire alarm-suppression control unit (FACP) such as the AEGIS™-PHX or ARIES™-SLX, can trigger immediate suppression and cooling measures to prevent the fire from spreading to adjacent battery modules.

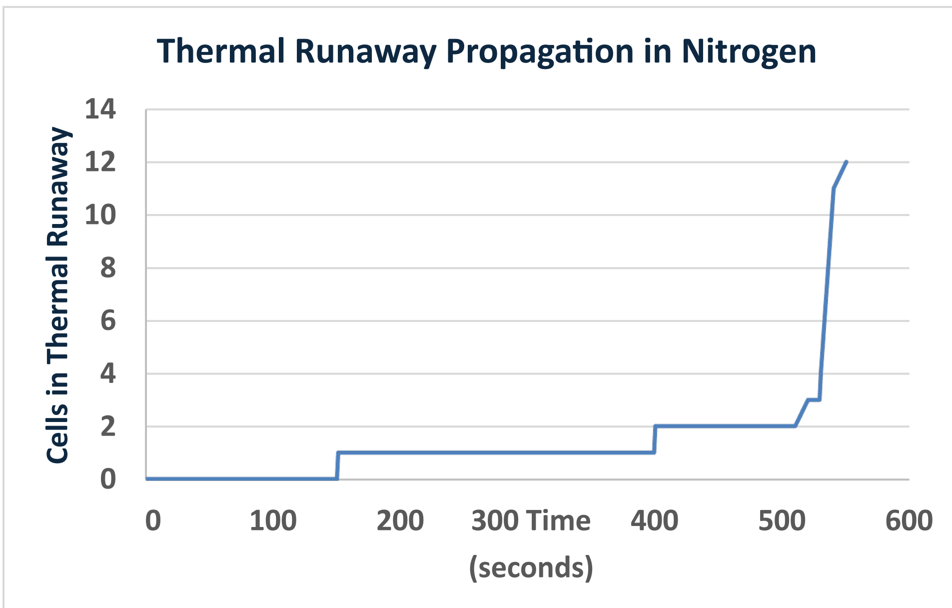
Fire Suppression and Flame Mitigation

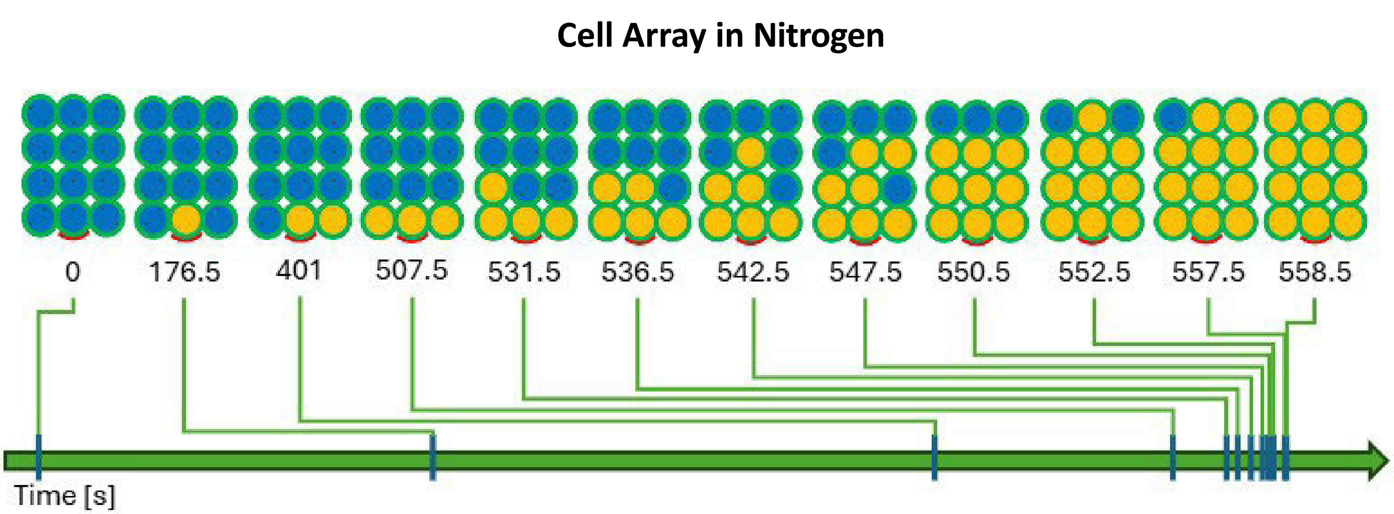
When a cell enters thermal runaway, the situation evolves rapidly. The primary objective of a suppression system is to interrupt the flaming combustion of the vented gases. If left unchecked, these gases often ignite, creating a "torch effect" that subjects neighboring cells to extreme radiant heat. The immediate deployment of a suppression system can extinguish these flames and significantly reduce the thermal load on the rest of the system. The cells start the process of thermal runaway in just under 3 minutes of the mechanical abuse. The chart shows that if left to combust in air, the number of cells in runaway jumps from 1 to 2 to 12 in just a few seconds and that these cells continue to be in thermal runaway for an extended duration thereafter.



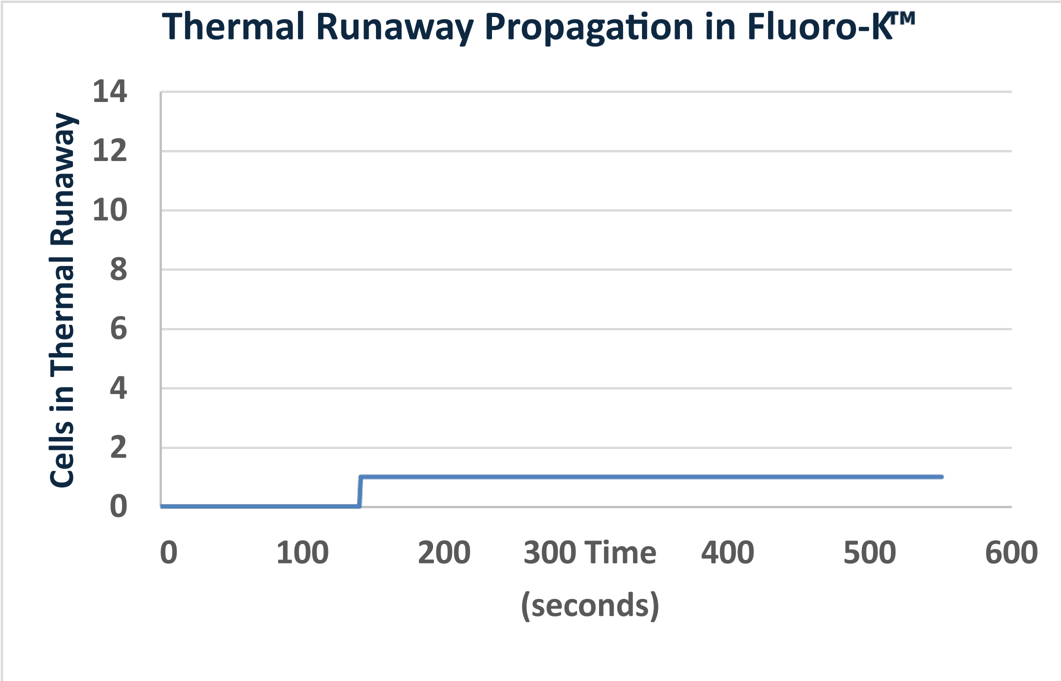


In contrast, when Nitrogen was injected into the chamber, the propagation from cell to cell drastically slowed but did not stop as seen below.



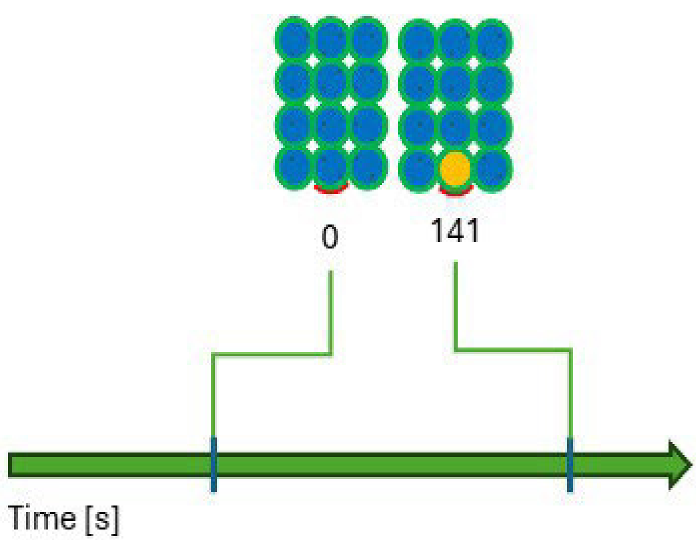


In further contrast, when Fluoro-K™ was injected into the chamber, while the one cell in thermal runaway stayed in that state, no other cells joined the first.



Research testing sponsored by KiddeFenwal and performed at University of Maryland investigated effects of Fluoro-K™ on thermal runaway propagation. The results clearly show that adding Fluoro-K™ to a battery pack under thermal runaway can eliminate the flaming combustion, cool the neighboring cells and stop cell to cell propagation.

Cell Array in Fluoro-K™



High-Performance Suppression Agents

Given the prior research, in order to determine the best practical solution for the job, KiddeFenwal collaborated with some key partners including Kidde Fire Systems engineered systems integrators and end-users to construct a live test set in a secluded and isolated desert location. As part of the test, a specific make of batteries was subjected to mechanical abuse – an action that led to a thermal runaway situation.

The team determined that the best solution to suppress the initial fire and then to prevent re-ignition was a combination of two systems acting back-to-back.

KFS Fluoro-K™ (Clean Agent): This agent is highly effective at rapidly neutralizing flames at the source. We used a minimum Design Concentration of 9% to ensure maximum suppression efficacy, and in compliance with NFPA 2001 standards, achieved it under 10 seconds and suppressed the fire before it could trigger a cascading failure in adjacent modules.

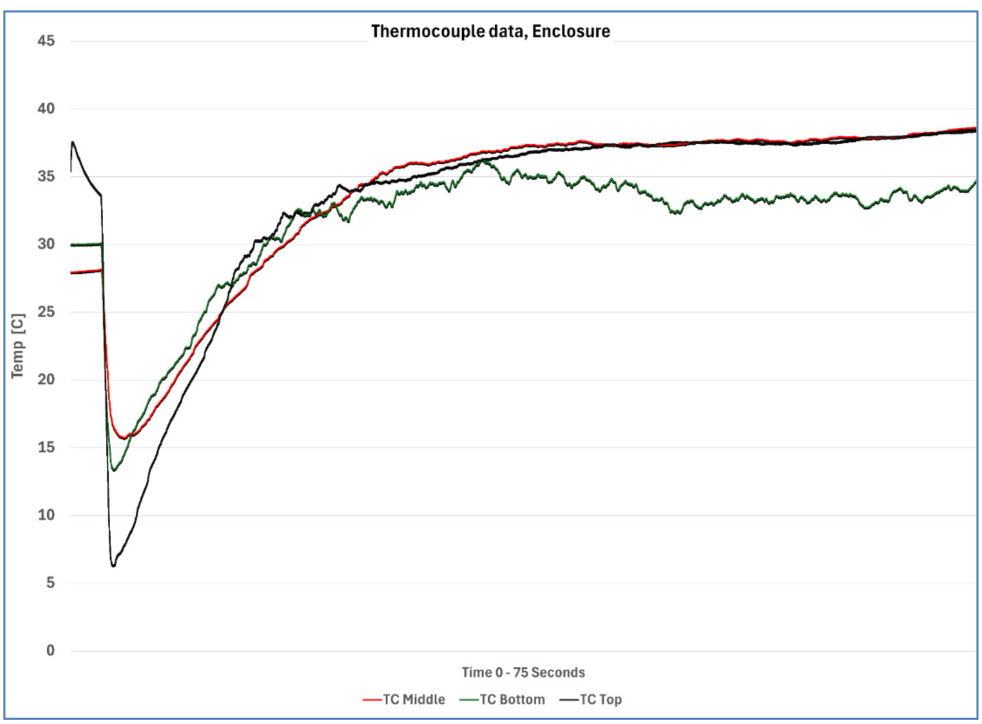
As expected, the deployment of the Fluoro-K™ agent had an immediate and positive impact by drastically reducing the temperature of the test container down to negative 2.5° C (27.5° F) as measured by thermal imaging camera and meeting the initial goal of Containment. While thermocouples in the enclosure measured slightly different temperature, that the drop is dramatic can be seen in the graph of temperature vs time below. While the agent is not expected to stop the internal chemical reaction of the primary failing cell, utilizing it is vital for extinguishing the external flames, and preventing the "torch effect" and therefore providing the critical protection needed to safeguard the surrounding batteries.

Fluoro-K™

KFS NATURA™ IG-100 (Nitrogen Inert Gas): Even after initial combustion has been successfully suppressed, the environment remains hazardous. The cells involved in the initial thermal runaway retain extreme heat and can act as persistent ignition sources for the flammable gases still present in the enclosure. To prevent re-ignition, the atmosphere must be "inerted"- a process of maintaining an oxygen-deficient environment that cannot support combustion.

NATURA™

Essentially pure nitrogen, NATURA™ IG-100 works by reducing the oxygen levels within the enclosure. We used a Minimum Design Concentration of 81% which effectively reduced the oxygen concentration below the flammability threshold of the electrolyte gases – thereby eliminating the possibility of flaming combustion. By discharging the NATURA™ IG-100 over an extended period of time, the enclosure is able to maintain a positive pressure to prevent oxygen ingress from the outside environment. The duration can be customized to specific installation requirements, but a hold time of at least 30 min is recommended. Aside from the critical inerting benefits of NATURA™ IG-100, it alone has shown to drastically increase the time it takes for thermal runaway propagation from cell to cell by as much as 277%.



Why use NATURA™ IG-100 at 81% Minimum Design Concentration

Long-term environmental stability within the BESS container is achieved through a slow, extended discharge of NATURA™ IG-100. This discharge is regulated via specialized nozzles to keep oxygen levels safely below the Limiting Oxidant Concentration (LOC). While for the typical BESS vent gases, the LOC established under ASTM E 2079 is approximately 7%, the NFPA 69 standard requires that a rigorous safety margin be used.

For systems where the LOC is below 7.5%, the standard requires operating at no more than 40% of the LOC if not continuously monitored, or maintaining a specific volume percentage below the LOC if safety interlocks are present. Following these guidelines for typical vent gases, the target oxygen concentration is reduced to 5.95%, which corresponds to an IG-100 concentration of roughly 72%, which with a 15% safety margin added, yields a design concentration of 81%.

Extended Hold Times and Leakage Compensation

Because no enclosure is perfectly airtight, the system must account for natural leakage over time. To ensure the environment remains inert for approximately 30-minute hold time—the window often required for emergency responders to assess the site—the initial discharge concentration is typically increased. Depending on the enclosure's integrity, recommendations for the starting concentration of IG-100 can be as high as 95% to compensate for oxygen ingress.

Additional Safety and Regulatory Considerations

Beyond active suppression, a robust BESS safety strategy must account for the high-pressure explosive risks created by electrolyte off gassing. When thermal runaway occurs, the sheer volume of volatile vapor can lead to a deflagration event if the infrastructure is not properly engineered to relieve pressure.

Passive Protection and Explosion Mitigation

To minimize these catastrophic risks, NFPA 855 mandates several passive protection measures. Depending on local jurisdiction and the specific Hazard Mitigation Analysis (HMA), these may include:

- Deflagration Venting: Strategically designed "blow-out" panels that safely release internal pressure, preventing the enclosure from rupturing.

- Physical Separation: Minimum spacing requirements between battery clusters and nearby structures to limit external damage.

First Responder Support and Signage

In an emergency, the safety of personnel depends on immediate, clear information. Standardized signage is required to inform first responders of the specific hazards within the unit—such as battery chemistry, voltage levels, and the presence of automated suppression systems. This ensures that emergency response plans are executed with full knowledge of the unique lithium-ion threat profile.

Conclusion: A Comprehensive Safety Ecosystem

The highest probability of operational success and site safety comes from a multi-layered, systematic approach. By integrating prevention (mechanical/electrical monitoring), early detection (off-gas sensing), active suppression, and atmospheric inerting with passive engineering (unpowered safety features and design elements), operators can ensure that their BESS infrastructure is not only efficient but fundamentally resilient.

Closing Thoughts:

Whether you are building a BESS site or expanding an existing facility, investing in a KiddeFenwal fire solution with elements including early warning detection, anomaly detection, fire alarm control unit and fire suppression kit is an essential step in safeguarding your organization's future. KiddeFenwal offers comprehensive tailored Kidde Fire Systems branded solutions that help BESS operate with confidence knowing that their critical assets are protected by the most advanced and effective fire protection systems available.

Comprehensive fire protection solutions from KiddeFenwal are not just an insurance policy; they are a fundamental component of business continuity and risk management.

Contact us at www.kiddefenwal.com to learn more about Kidde Fire Systems branded solutions.

About KiddeFenwal:

For decades, KiddeFenwal has been an industry leader in fire prevention, detection & control, and suppression. Our name is backed by a strong commitment to product quality, innovation, and expertise in system design, installation, and service. We operate across the globe through a network of trained and authorized Engineered Systems Integrators/Distributors that excel in initial hazard analysis, system design, installation, testing and commissioning as well as aftermarket service including parts, refills and code-mandated periodic testing and maintenance.

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