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*Report to:*  
**Carver Fire**

# Technical Opinion & Report (TO&R): ELSA Fire Protection System Used in Battery Applications



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## 1 OVERVIEW

This Technical Opinion & Report evaluates the ELSA fire suppression system in lithium-ion battery applications. The ELSA system is a fire suppression system that uses cryogenic slurry of dry ice and liquid nitrogen to prevent propagation of thermal runaway in battery energy storage systems (BESS).

## 2 GENERAL

This report is prepared in accordance with IFC provisions for alternative materials and methods and evaluates equivalency with respect to life safety, property protection, fire spread, and fire department safety.

## 3 APPLICABLE CODES AND STANDARDS

- ◆ 2024 International Fire Code
- ◆ NFPA 13-2025 “Standard for the Installation of Sprinkler Systems”
- ◆ NFPA 855-2026 “Standard for the Installation of Stationary Energy Storage Systems”

## 4 BESS FIRE PROBLEM

Battery Energy Storage System (BESS) deployment is accelerating globally, quickly outpacing existing fire suppression technologies and the standards that govern their use. As systems grow larger, more energy dense, and more widely deployed near critical infrastructure and populated areas, the limitations of traditional fire protection approaches have become increasingly clear.

In many BESS fire scenarios today, particularly once thermal runaway is fully established, incident commanders are faced with a lack of effective and safe suppression options.

As a result, controlling exposures while allowing the fire to burn has often become the safest available course of action. This approach is not a strategy of choice, but rather a risk management decision driven by responder safety, gas toxicity, deflagration risk, and the limited leverage that conventional suppression methods may offer late in an event.

One reason this gap exists is that the core problem in BESS fires is not flame, as in most traditional fire scenarios.

Instead, it is thermal runaway — a series of exothermic reactions occurring inside battery cells that generate extreme heat along with large volumes of flammable and toxic gases. Once initiated, this process can sustain itself independently, shifting suppression strategies toward rapid cooling as the most effective means of intervention.

Many existing fire suppression standards were developed around flame-based fire models and were appropriate for the hazards they were designed to address.

However, they do not fully account for sustained internal heat generation, gas production, deflagration risk and the potential for re-ignition that define BESS fire events.

As battery systems have continued to scale, this mismatch between hazard and response has become increasingly difficult to ignore.

In response, standards organizations and risk engineering bodies such as UL, CSA Group and FM Global are actively working to develop updated frameworks that better reflect the realities of BESS fire behavior.

While prevention and early detection remain central to these efforts, there is growing recognition that suppression and intervention must also address the underlying failure mechanisms involved, rather than treating battery fires as conventional flame events.

The objective is to provide guidance and tools that will enable earlier, safer and more effective intervention, reducing reliance on “let it burn” outcomes.

## 5 BESS FIRE SUPPRESSION PERSCRIPTIVE REQUIREMENTS

Current model codes and standards (International Fire Code, NFPA 855, etc.) require BESS containers to have an automatic sprinkler system or alternative automatic fire-extinguishing system installed to protect the batteries. However, none of these traditional extinguishing agents have adequate cooling capacity to stop thermal runaway in BESS applications.

Several early research papers from multiple organizations have shown that battery cells must be cooled to terminate the thermal runaway process. Currently, the agent of choice is water, yet system cabinet design poses a significant barrier to the efficient application of water while simultaneously allowing the free movement of fire and combustion gases. [2]. It has been proven in real world scenarios that water does not have sufficient cooling capacity to prevent thermal runaway propagation in BESS applications.

## 6 ELSA SYSTEM

### 6.1 General:

The ELSA system uses a mixture of two suppression agents; carbon dioxide and nitrogen. Nitrogen is stored as liquid nitrogen and solid CO<sub>2</sub> (dry ice) pellets are suspended in liquid nitrogen to form a cryogenic slurry (70% dry ice, 30% liquid nitrogen). The cryogenic slurry is approximately -324 °F. The liquid nitrogen keeps the dry ice pellets from fusing together.

The cryogenic slurry is discharged through hoses between 5-60 psi, depending on application, directly onto the battery module when activated. Upon discharge, the liquid nitrogen and dry ice mixture absorbs large amounts of heat and starts to form an ice film on the surfaces the liquid comes in contact with. The slurry rapidly cools the components and electrolytes internal to the battery.

The slurry is sprayed onto the battery surface and expands approximately 800 times its volume at a temperature much colder than the surrounding air and displaces oxygen near the surfaces of the liquid slurry.

As a result, an ice layer forms and completely covers the battery module and stops thermal propagation to other battery modules. The dry ice will continue to absorb the heat for many hours. This is extremely beneficial in battery fires due to the stranded energy increasing the risk of reignition.

## 6.2 Thermal Runaway Propagation Prevention

The ELSA fire suppression system has been proven to prevent propagation of thermal runaway in a thermal runaway event in multiple small-scale fire tests.

The ELSA system cools the internal battery components and creates a cooling “barrier” between cells to prevent thermal propagation. The liquid nitrogen provides immediate quenching and the dry ice particles offer sustained cooling and stability, without over-freezing cores. Once the electrolyte reaches its freezing temperature, the cells are effectively inert.[1]. This cooling barrier makes it extremely difficult for heat to spread to adjacent cells, thereby preventing thermal propagation. The cryogenic slurry keeps the battery cooled for hours allowing the safe removal of damaged batteries without damaging any battery components.

A small-scale fire test was performed at the CSA Group Energy Storage Lab in Independence, OH on October 30, 2024 on a custom cube of 75 cylindrical 21700 cells (three 25-cell packs side by side) fully charged. The battery pack was ignited with a torch until 50% consumed. The ELSA system discharged at 30 psi through a 1” hose for 30 seconds. The preliminary findings were that the flames were extinguished immediately and no further venting occurred after discharge. The battery module was allowed to thaw over two days without re-ignition. The electronic devices, hoses, and cables placed around the module were unaffected and worked after thawing. This demonstrates flame extinguishment and thermal propagation prevention validates there was no damage to nearby equipment. The full CSA report is pending and will further quantify performance data.

A full-scale fire test was performed at Stress Engineering in Waller, TX on February 6, 2025. The test was supervised by Underwriters Laboratory. A battery module of 324 cylindrical 18650 cells with a lid in place was placed inside a cargo container. The preliminary analysis was that the battery was overcharged until ignition occurred. The fire was allowed to propagate for 30 seconds before suppression. The ELSA discharged at 30 psi through a 1 inch hose for 90 seconds. Upon activation of the ELSA system, the flames extinguished immediately. 300 lbs of dry ice accumulated beneath the suspended rack; only a few inches built up on top of the module. This demonstrates rapid flame knockdown and sustained cooling of the ELSA system. The final UL report is pending and will further quantify performance data.

## 6.3 Deflagration-Mitigation

During thermal runaway, battery cells release significant quantities of flammable gases. These gases often exceed the lower flammability limits of the gases and become flammable when an ignition source is present. In a thermal runaway event, ignition sources are highly likely to be present creating a deflagration hazard. The types of deflagration hazards that could exist include the following: overpressure of the container creating structural damage and doors, panels, and lids become projectiles as well as flames extending through doors, hatches, and vents. These deflagration hazards make it extremely dangerous for firefighters and emergency responders. In fact, the hazard is so dangerous that most fire departments will not fight the fire and let BESS container burn itself out, which can take multiple days.

In addition, when a deflagration event occurs a complex toxic plume is released into the atmosphere. Corrosive and toxic chemicals can collect on soil, vegetation, and water surfaces. The fine particulates can travel miles downwind often triggering shelter-in-place orders.

The ELSA system introduces liquid nitrogen and dry ice into the container. The liquid nitrogen starts to boil upon release and creates a vapor with an expansion ration of 1:700. This means for every gallon of liquid nitrogen introduced creates approximately 93 cubic ft of inert nitrogen vapor. Dry ice sublimates with a 1:790 expansion ratio. 1 lb of dry ice creates approximately 9 cubic ft of carbon dioxide gas.

The liquid nitrogen and dry ice mixture absorbs large amounts of heat cooling the flammable gases and introduces inert gas into the system diluting the flammable gases below the lower flammability limit.

## **7 RISKS & LIMITATIONS**

Introducing liquid nitrogen and dry ice inside a sealed container will create overpressure inside the container causing structural damage and potential projectile hazards. Any BESS container should have adequate overpressure protection.

In addition, an oxygen-deficiency hazard is created by the introduction of dry ice. In a completely airtight enclosure, the oxygen levels could reach the fatal range causing asphyxiation. The cryogenic slurry should not be introduced into an occupied enclosure.

Early detection of thermal runaway is critical, as BESS fires can escalate rapidly once thermal runaway starts.

## **8 PROFESSIONAL ENGINEERING OPINION**

It is my professional opinion that the proposed ELSA system is superior to any other current fire suppression systems that are currently available for fire protection. The ELSA system is the only system currently offered that has been proven to prevent thermal runaway propagation.

## **9 REFERENCES**

[1] Nathaniel Sutherland, Andrew Colclasure, Chuanbo Yang, Joshua Major, Kae Fink, Aron Saxon, Matthew Keyser. "Effects of cryogenic freezing upon lithium-ion battery safety and component integrity", Journal of Energy Storage, Volume 63 (2023) <https://doi.org/10.1016/j.est.2023.107046>

[2] NFPA 855, "Standard for the Installation of Stationary Energy Storage Systems", 2026 ed., Annex C, National Fire Protection Association