L3 LimitLess Lithium Series
Battery Energy Storage System

Aerosol Fire Suppression System Overview

Author: Liam O'Brien, *Sr. Staff Engineer - C&I Products*

1. Product Overview

The Sol-Ark L3 LimitLess Lithium series, comprised of the HV-40, L3 HV-60, and L3 HVR-60 lithium-iron-phosphate BESS (battery energy storage system) is listed to *UL9540 Ed. 2-2021* and has completed *UL9540a Ed. 4-2019* unit-level testing for "Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems" with no external flames, flying debris, or explosion observed with thermal runaway contained by the unit's integral design features.

The L3 Series battery packs utilize Tier-1 lithium cells based on lithium iron phosphate (LFP) chemistry. Unlike other compositions used in consumer and grid batteries such as nickel manganese cobalt oxide (NMC) or lithium nickel cobalt aluminum oxide (NCA), LFP offers key safety advantages.

1. **Thermal Runaway Resistance** - LFP has strong internal chemical bonds that resist breaking down and releasing large amounts of heat, even when damaged. This minimizes the risk of thermal runaway.
2. **High Ignition Temperature** - LFP cells have a higher runaway initiation threshold of over 180°C [1] before entering thermal runaway and potential ignition, as compared to NCM chemistries which begin around 120-130°C. This allows more time to prevent or manage overheating situations.
3. **Low Operating Voltage** - LFP operates at lower cell voltages than other lithium-ion chemistries, resulting in lower energy potential that is less likely to fuel fires in a fault condition.

[1] Shen et al., "Thermal Runaway Characteristics and Gas Composition Analysis of Lithium-Ion Batteries with Different LFP and NCM Cathode Materials under Inert Atmosphere."

2. Aerosol-Based Fire Suppression System

The L3 Series features an integrated aerosol-based fire suppression system at the battery module and cabinet (for L3 HVR) level. In the rare event of a thermal runaway, the aerosol canister would rapidly deploy, filling the battery module or cabinet interior with non-toxic agent to suppress any potential fire before spreading. This unique, industry-leading safety capability from Sol-Ark ensures maximum protection for commercial and industrial users.

This proprietary system activates automatically in two different ways depending on the product:

Module Level – For L3 HV and L3 HVR: Contained in each battery module is a 12-gram aerosol agent canister (shown in Fig 1) with a thermal deployment mechanism which activates automatically when heat inside the module reaches potentially unsafe levels due to thermal runaway or external fires (185°C ±10°C). By building the suppression system directly into the battery next to the cells, the system is able suppress fires right where needed, rather than external to the module as with a water-based sprinkler system in a battery room.

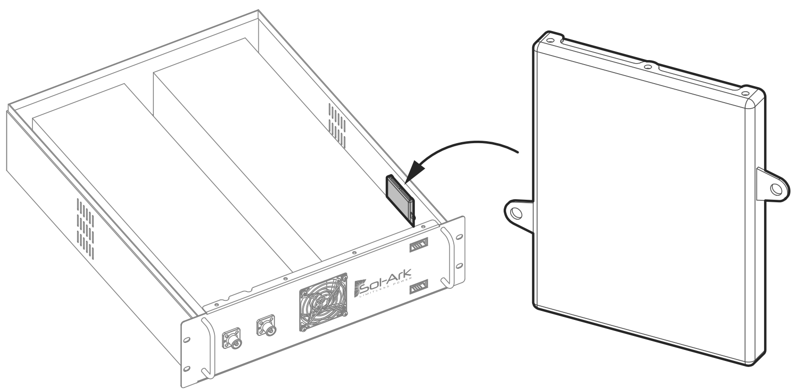

Figure 1: Module level aerosol agent canister

Cabinet Level – For L3 HVR Only: Inside each L3 HVR cabinet is a larger 300-gram aerosol canister located in the top right corner. This unit is electronically activated based on signals from the fire detection sensors inside the cabinet. Smoke, heat, and CO2/gas sensors will detect abnormal operating conditions and deploy the aerosol from the canister, filling the inside of the cabinet.

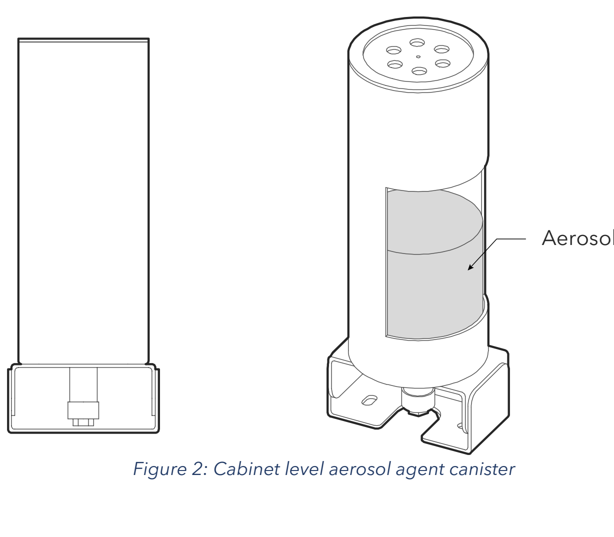

Figure 2: Cabinet level aerosol agent canister

3. Module Level Photos:

The following photos depict the location of the aerosol canister inside the battery cabinet or module.

Figure 3: External View the L3 HV Battery Module

Figure 4: Closeup of the L3 HVR Aerosol Canister

Figure 5: Closeup of the Module Aerosol Canister

4. Aerosol Suppression Agent Operating Theory

The following content is excerpted from the aerosol manufacturer (JIANDUN) Installation and Operation Manual for the Aerosol Fire Extinguishing Device, Model: QRR0.012G/S-QT-003 used inside the battery modules.

Cooling and Extinguishing Effect of Endothermic Decomposition

The cooling effect of aerosol fire extinguishing agents mainly relies on the endothermic decomposition of metal oxides and carbonates. The heat released by any fire in a short period of time is limited. If the solid particles in the aerosol can absorb some of the heat released by the fire source in a short period of time, the temperature of the flame will be lowered and radiated to the burning surface. And the heat for cracking the gasified combustible molecules into free radicals will be reduced, and the combustion reaction will be inhibited to a certain extent.

Gas-phase Chemical Inhibition

Under the action of heat, vaporized metal ions such as Sr, K, Mg or electron-losing cations decomposed by aerosol fire extinguishing agents exist in the form of steam, which interact with the active groups H•, •OH and O • in combustion. Secondary chain reaction, take Sr as an example below:

$$Sr+2\bullet OH \rightarrow Sr(OH)_2 \quad Sr+O\bullet \rightarrow SrO \quad Sr(OH)_2+2H\bullet \rightarrow Sr+2H_2O$$

Repeatedly, the active groups in the combustion are consumed in large quantities, the concentration is continuously reduced, and the combustion is suppressed.

Solid-phase Chemical Inhibition

The solid particles in the aerosol fire extinguishing agent can adsorb the chain reaction intermediates • OH, H• and O•, and catalyze their reorganization into stable molecules, thereby interrupting the branched chain reaction of the combustion process. Take K as an example:

$$K2O(s)+2H(g) \rightarrow 2KOH(s) \quad KOH(s)+OH(g) \rightarrow KO(s)+H2O(g) \quad K2O(s)+O(g) \rightarrow 2KO(s) \quad KO(s)+H(g) \rightarrow KOH$$

In the above-mentioned fire-extinguishing effects, several fire-extinguishing mechanisms interact and work synergistically, but the gas transport and the endothermic and cooling effects of metal oxides or carbonates are only auxiliary effects, and the main fire-extinguishing effect still relies on gas The chemical inhibition of the solid phase.