Energy Storage

Large-Scale Fire Testing of Battery Energy Storage Systems

Background

The large-scale fire test (LSFT) for battery energy storage system (BESS) enclosures is a new requirement in the 2026 National Fire Protection Association (NFPA) 855, *Standard for the Installation of Stationary Energy Storage Systems*. The new LSFT addresses the potential for complete combustion of an energy storage system enclosure, a major step up from combustion testing required by previous standards. Following the NFPA standard's test method, recent changes, and LSFT-specific provisions is key to compliance under this comprehensive new measure, and understanding the drivers behind the LSFT requires understanding the history of BESS fire testing.

LSFT Standards History

The NFPA Standards Council approved the development of NFPA 855 in April 2016. An initial draft was released in 2017, and after a public comment period, first (2020) edition was published in late 2019. In parallel, Underwriters Laboratories (UL) began work on UL 9540A, *Standard for Test Method for Evaluating Thermal Runaway Propagation in Battery Energy Storage Systems*, publishing the first edition in November 2017. Somewhat confusingly, that first edition of NFPA 855 referred to UL 9540A testing as 'large-scale fire testing,' although this designation was changed in the 2023 edition to 'fire and explosion testing.'

In late 2024, the Canadian Standards Association (CSA) published CSA TS-800:24, *Large-scale fire test (LSFT) procedure*. While this first CSA publication was not a consensus standard and the LSFT procedure lacked the detail of Annex G, this test was then incorporated into the consensus-based CSA/ANSI C800:25, *Testing protocol for energy storage system reliability and quality assurance program*. In February 2025, the Second Draft Report of NFPA 855 (2026 edition) mandated the LSFT for compliance as well as introduced guidance on implementing an LSFT in informative Annex G. More recently, in March 2026, UL published the 6th edition of UL 9540A with modifications to include the LSFT.

UL 9540A

Testing under the first five editions of UL 9540A (released 2017-2025) involved sequential testing at the cell, module, unit (typically a representative battery rack), and installation levels. The module-level test establishes the number of initiating cells that must be driven into thermal runaway to propagate thermal runaway in one or more neighboring cells. This propagating test is repeated at the unit level to see if propagation occurs between modules, and testing proceeds at the installation level depending on the unit-level results.

The UL 9540A test method is predicated on an individual internal cell failure that could propagate to adjacent cells and to the larger system. However, internal cell failures are quite rare. As far back as 2012, Sandia National Laboratories[1] cited cell failure rates ranging from less than 1 in 10 million to 1 in 40 million cells, and Contemporary Amperex Technology Co., Limited recently reduced its failure rate to one part per billion.[2] In a 2024 white paper,[3] the Electric Power Research Institute (EPRI) examined available root cause data for BESS failure events and found that the majority had initiating component failures outside of the cells or modules. For example, root causes could often be attributed to stormwater intrusion or coolant leaks resulting in multi-cell arcing events, which UL 9540A did not address in its first five editions. Instances of fires in BESS products that had achieved favorable UL 9540A test results were the main driver behind the introduction of the LSFT.

1 A General Discussion of Li Ion Battery Safety, Doughty and Roth, https://www.sandia.gov/app/uploads/sites/213/2022/08/Doughty_2012_Electrochem._Soc._Interface_21_37.pdf

2 https://www.catl.com/en/news/6285.html

3 Insights from EPRI's Battery Energy Storage Systems (BESS) Failure Incident Database Analysis of Failure Root Cause, https://www.epri.com/research/products/000000003002030360

Changes to UL 9540A

The 6th edition of the UL9540 modifies the installation-level test to incorporate the LSFT. With the implementation of a mandatory LSFT for the installation-level test, it is no longer necessary to perform unit-level tests for most lithium-ion batteries. The cell- and module-level tests are still mandatory.

The LSFT procedure in the new edition of UL 9540A is much more detailed than the CSA C800, spanning 30 pages of the document compared to CSA's two pages. The test uses one of a variety of ignition sources, including a propane burner, to establish an involved fire condition in the initiating enclosure. It also tests the consumption of a majority of potential fuel sources, including cells, plastics, and other combustibles. Target enclosures are installed around the initiating unit at the minimum spacing recommended by the manufacturer and must be instrumented to detect thermal runaway or potentially hazardous temperatures.

Photo credit: AES

What Does the New LSFT Tell Us?

While satisfactory results under past editions of UL 9540A involved limiting the extent of an incident, the new LSFT assumes a worst-case event in which complete combustion of an energy storage system enclosure occurs. For each potential BESS installation, the LSFT results are evaluated by a registered design professional for the anticipated wind conditions at the spacing recommended by the manufacturer. This evaluation is to validate that complete combustion of one enclosure will not result in propagation of thermal runaway in adjacent units.

The LSFT treats the battery as a fuel source in a developed fire, rather than just a potential initiator of a combustion event. One shortcoming in the UL LSFT procedure is that mandatory data gathering is based mainly on temperature readings. The document is very detailed on placement of thermocouples, but treats all other data as optional. Temperature readings are required for product listing under UL 9540, but there are other submissions under NFPA 855, such as the hazard mitigation analysis and emergency response plan.

Under some jurisdictions, there are requirements informed by more extensive data acquisition in the LSFT. For example, some jurisdictions require plume modeling for toxic emissions, and modeling gas and smoke emissions in the LSFT can help to ensure that the results are as realistic as possible. Characterizing these emissions is required by NFPA 855 but not by UL 9540A. Also, heat flux measurements should be gathered to assess the potential impact of a BESS fire on adjacent equipment, such as oil-filled transformers. Additional data required by CSA C800 is recommended, including peak heat release rate, battery management system data, timelines for activation of critical safety systems, fire and damage impacts on critical safety systems, and viability of communication pathways.

With the high cost of performing the LSFT, ACP strongly advocates that BESS manufacturers and test labs capitalize on the data-gathering opportunity presented by these tests to gather as much of this 'optional' information as possible.