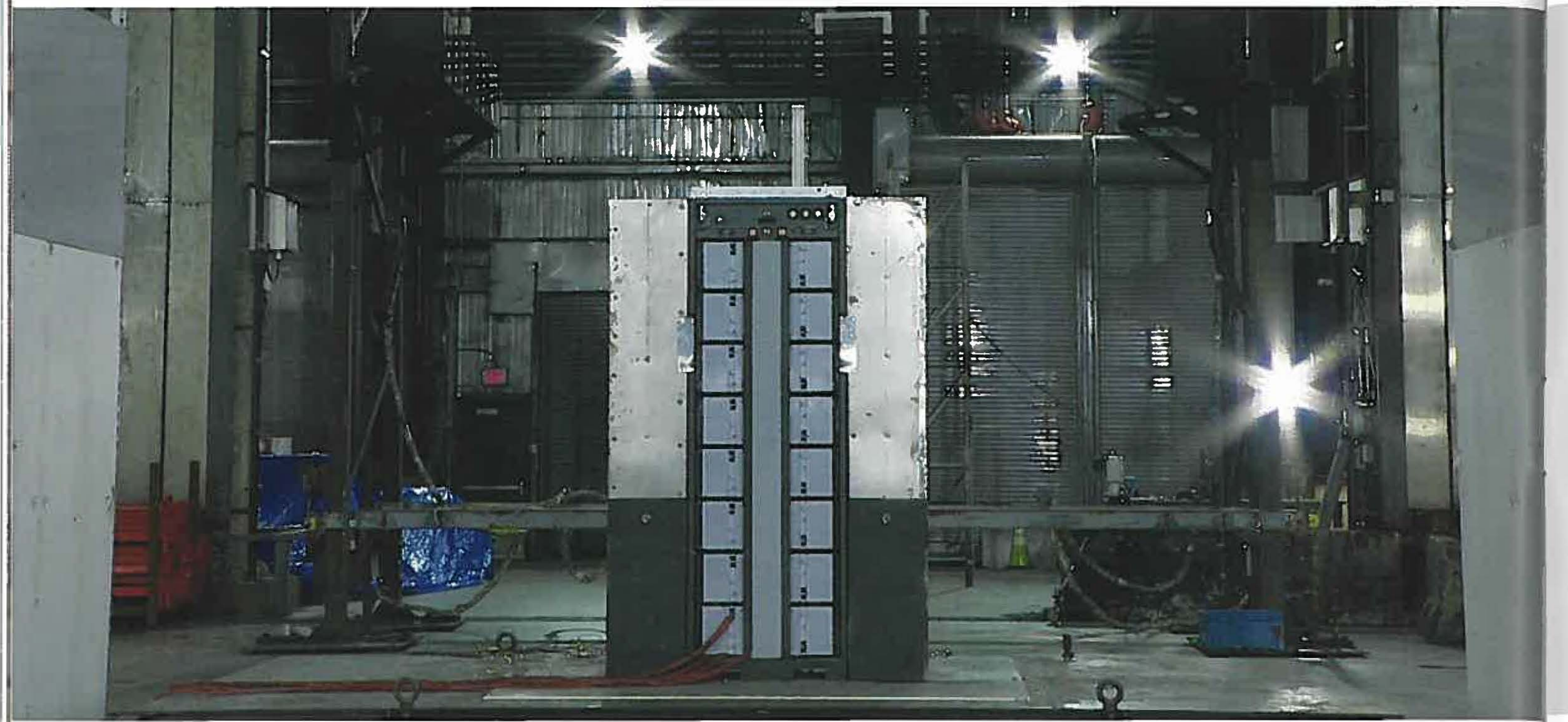

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ENERGY STORAGE SYSTEMS AND FIRE PROTECTION

With demand rising for lithium-ion battery-based energy storage systems, new recommendations have been released for their protection from fire.

FIGURE 1. Example of full-scale free burn test set-up for the NMC module. Mock racks are located on either side of the ESS rack to measure the exposure hazard to adjacent equipment, and representative structure walls are located across a 2.7 m separation to measure the exposure to surrounding objects.

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Lithium-ion battery-based energy storage systems (ESS) are in increasing demand for supplying energy to buildings and power grids. However, they are also under scrutiny after a number of recent fires and explosions. It has become clear that lithium-ion batteries are vulnerable to thermal runaway, leading to a venting of flammable gases and subsequent combustion, and creating new fire protection challenges.

To increase awareness of what can be done to improve safety around this technology, mutual insurance company FM Global has publicly released first-of-its-kind research and recommendations. These are based on small to large-scale fire tests recently conducted on ESS sized for commercial applications, such as manufacturing, office buildings, power generation and utility use.

The good news is that the research shows that ESS deployments can be made safer through the combination of automatic sprinklers and the careful spacing of ESS racks.

Determining the fire hazard

From a fire protection standpoint, the overall fire hazard of any ESS is a combination of all the combustible system components, including battery chemistry, battery format (for example, cylindrical, prismatic or polymer pouch), electrical capacity and energy density. Materials of construction and the design of components such as batteries and modules also play a part in determining hazard levels.

The fire testing was conducted at the FM Global Research Campus in Rhode Island, US, and the ESS comprised of either iron phosphate (LFP) or nickel manganese cobalt oxide (NMC) batteries. Both of the ESS tested had solid metal side and back walls, an open front, and contained 16 modules of prismatic batteries arranged in eight levels of two modules. The LFP system had a rating of 83.6 kilowatt hours, while the NMC system had a rating of 125 kWh. Figures 1 and 2 show the arrangement and results of a large-scale free burn test on an NMC system.

At all test scales, which ranged from a single-battery module to full ESS racks containing 16 modules each, the ESS comprised of LFP batteries was found to have a lower overall fire hazard. In the sprinklered tests where a single sprinkler operation was sufficient to contain the fire to the rack where it ignited, the fire did not significantly affect any of the modules in the adjacent rack.

Under the same conditions, a test involving a system comprised of NMC batteries resulted in the fire spreading to an adjacent rack, and the number of sprinkler operations represented a demand area greater than 230 square metres.

Delay or prevent

Despite the design of the racks effectively shielding the fire from sprinkler water, the fire tests proved that sprinklers could delay or prevent fire spread to adjacent racks. Coupled with adequate separation from nearby combustibles and the addition of thermal barriers between racks, the hazard can be reduced even more. However, without a protection system that can suppress the fire in the early stages, a prolonged burn, high water demand and damage to surroundings are likely.

We recommend protection coupling sprinkler system design and ESS installation guidance, such as the appropriate separation distance, to keep the fire hazard within acceptable levels.

Current understanding tells us that the best protection recommendations are as follows:

- the sprinkler system should provide a minimum discharge density of 12 millimetres per minute using sprinklers with a K-factor of 81 litres/min/bar$^{1/2}$ or greater
- a nominal 74 degrees Celsius temperature rating and RTI of 27.6 m$^{1/2}$s$^{1/2}$
- for ceiling heights in the range of 3.0 metres to 7.6 m, the ceiling construction should have a minimum one-hour fire rating.

The protection recommendations for this type of LFP system should include:

- Without fire protection: the minimum space separation from any part of the ESS should be 1.2 m from non-combustible objects and 1.8 m from combustible objects, including adjacent ESS racks.
- With sprinkler protection: the minimum space separation from any part of the ESS should be 0.9 m from non-combustible objects and 1.5 m from combustible objects. The sprinkler system water supply should be designed for a minimum 230 m^2 demand area and a duration of at least 90 minutes.

Protection recommendations for this type of NMC system:

- Without fire protection: the minimum space separation from any part of the ESS should be 2.4 m from non-combustible objects and 4.0 m from combustible objects, including adjacent ESS racks.
- With sprinkler protection: the minimum space separation from any part of the ESS should be 1.8 m from non-combustible objects and 2.7 m from combustible objects. The sprinkler system water supply should be designed for the total room area where the ESS is located, and the water supply should be calculated as 45 minutes times the number of adjacent racks, but no less than 90 minutes.
- For ESS comprised of multiple racks, without large-scale fire testing, each individual rack should be separated like combustibles at the distances outlined above.

For ESS that represents a different kind of fire hazard to those already listed, due to design features and/or power rating, appropriate large-scale fire testing is recommended to determine if a more robust protection scheme is needed.

As fires involving lithium-ion batteries are known to reignite at any time—from minutes to days after the initial event—a fire watch should be present until all potentially damaged ESS equipment containing lithium-ion batteries is removed from the area. Adequate cooling of the batteries is necessary in order to prevent reignition.

The results show that properly designed sprinklers can be effective in delaying or preventing fire spreading to adjacent ESS racks and that separation between ESS and other combustibles is essential to effective fire protection. ■

To learn more, download the full research report from the FM Global website at www.fmglobal.com/researchreports.

FIGURE 2. NMC fire development during large-scale free burn test: near time of ignition (left), near time of predicted sprinkler operation (centre), peak heat release rate (right).