Development of Protection Recommendations for Li-ion Battery Bulk Storage: Sprinklered Fire Test

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Extended Abstract

Fire protection guidance for warehouse storage of lithium ion (Li-ion) batteries presently remains a relatively unexplored topic within the fire protection community. At the same time, demand for Li-ion batteries continues to grow for applications such as electric and hybrid electric vehicles, consumer electronics, and energy storage systems. This is highlighted by a 2013 report that forecasted the global Li-ion battery market will increase from US$11.7 billion in 2012 to US$33.1 billion by 2019 [1]. As manufacturing capacity grows to meet the new global demand, so too will the volume of batteries stored in warehouses.

The fire hazards inherent to Li-ion battery technology are well documented in many overview documents [2, 3, 4, 5] and through experimental studies [6, 7, 8, 9, 10, 11, 12, 13]. The unique potential for thermal runaway reactions to spread a fire differentiates Li-ion batteries from typical ordinary combustible materials found in warehouse storage. As a result, neither *FM Global Property Loss Prevention Data Sheets* nor National Fire Protection Association Standard 13, “Standard for the Installation of Sprinkler Systems,” [14] currently contain specific, research based, sprinkler installation recommendations or requirements for Li-ion battery storage. Consequently, the existing approach for sprinkler protection often relies on designs for high-hazard commodities, *e.g.,* automatic in-rack sprinklers [15].

A multi-phase project was undertaken in conjunction with the Property Insurance Research Group (PIRG) and in collaboration the Fire Protection Research Foundation (FPRF). The previous two phases of the project included a use and hazard assessment report [16] and a series of reduced-commodity fire tests comparing the flammability characteristics of several Li-ion batteries and FM Global standard cartoned commodities [15, 17]. These tests showed that bulk storage of small-format Li-ion batteries (*i.e.*, 2.6 Ah) exhibits similar fire growth leading to first sprinkler operation as cartoned commodities. Further, it

was determined that the time required for significant involvement of Li-ion batteries was slower than the typical sprinkler response. These conclusions provided the basis for sprinkler protection recommendations for small-format Li-ion batteries in bulk storage, with the goal of suppressing the fire before the anticipated time of involvement of Li-ion batteries.

The current project enhances the ceiling-only sprinkler protection options following large-scale sprinklered fire test experience of cartoned Li-ion batteries. Protection recommendations for warehouse storage of cartoned Li-ion batteries have been developed through fire testing and comparison to analogous commodities with similar hazard characteristics. A unique approach was developed that incorporated four different fire test evaluations, ranging from small- to large-scale, with the goal of extending the application of a successful large-scale fire test to additional types of Li-ion batteries. A reduced-commodity test evaluated the flammability characteristics of large-format, 20 Ah Li-ion polymer batteries, compared to FM Global's standard commodities and previously tested small-format Li-ion batteries.

The performance of ceiling-level sprinkler protection was then assessed with a large-scale sprinklered fire test of the large-format 20 Ah polymer pouch batteries. Two supplemental tasks reinforced the sprinkler protection guidance resulting from the large-scale fire test. The impact of internal ignition within a pallet load of batteries versus the external ignition typically used in large-scale fire testing was assessed through small-scale testing. Finally, the effectiveness of sprinkler water at suppressing a fire at a later stage of battery involvement than could be achieved in the large-scale test was assessed through intermediate-scale testing.

Based on the experimental results, adequate protection can be achieved for storage of cartoned Li-ion batteries stored solid pile, palletized, or in racks up to 4.6 m (15 ft) under a ceiling up to 12.2 m (40 ft) high. Ceiling-level sprinkler protection options include K320 or K360 L/min/bar$^{1/2}$ sprinklers (K22.4 or K25.2 gpm/psi$^{1/2}$) @ 2.4 bar (35 psi). Sprinklers should be quick-response, pendent, and have a 165^{o}F (74^{o}C) nominal temperature rating. This guidance applies to all small- and large-format batteries testing throughout this project.

The full technical report can be download at www.fmglobal.com/researchreport. A summary report is also available at http://www.nfpa.org/lithiumbatteryhazards.

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