

Preface

This book gives a comparison of cartoned lithium-ion (Li-ion) batteries and FM Global standard commodities in a rack storage configuration. Subsequent large-scale fire tests were conducted by FM Global to assess the effectiveness of ceiling level only sprinkler protection. All data, test descriptions, data analysis, and figures in this report were graciously provided by FM Global. Exponent has relied on the FM Global testing report entitled, “Flammability Characterization of Lithium-ion Batteries in Bulk Storage,” as a basis for this report [1].

This project was conducted in conjunction with the Property Insurance Research Group (PIRG) and was directed through FPRF.

Small format Li-ion battery commodities were selected to represent commercially available battery formats and Li-ion battery containing devices. The selected Li-ion battery types were individual 18,650 format cylindrical cells, power tool packs comprising 18,650 format cells, and polymer cells. The selected comparison commodities were the FM Global standard Class 2 and Cartoned Unexpanded Plastic (CUP). Two independent test series were conducted by FM Global. These tests represented a unique approach to hazard evaluation with limited commodity and were necessary due to the inordinate cost associated with Li-ion batteries.

The first test series evaluated the flammability characteristics of small format Li-ion batteries and the FM Global standard cartoned commodities in a three-tier high, single row, open frame, rack storage array. All tests conducted were free burn tests. In each test, cartoned commodity was only located in a portion of the rack where the initial fire growth was expected to lead to sprinkler operation (i.e., at the flues). The first test series was used to estimate the fire hazard from the cartoned commodity present at the time of the predicted first sprinkler operation.

A total of 13 tests were conducted. Ignition was achieved using an external fire. The key findings reported by FM Global included:

- The fire growth characteristics for the Li-ion batteries and the FM Global standard commodities that were evaluated exhibited similar fire development leading to the estimated time of first sprinkler operation.
- Commodity containing densely packed Li-ion batteries and minimal plastics (i.e., cylindrical and polymer cells) exhibited a delay in the battery involvement. For the Li-ion batteries used in this project, significant involvement was observed within 5 min after ignition.

- Commodity containing a significant quantity of loosely packed plastics (i.e., CUP and power tool packs) exhibited a rapid increase in the released energy due to plastics involvement early in the fire development. Battery involvement was not observable due to the contribution from the plastics.
- The CUP commodity exhibited a fire hazard leading to initial sprinkler operation that was similar or greater than the Li-ion battery products tested. Therefore, the CUP commodity was chosen as a suitable surrogate for Li-ion batteries in a bulk-packed rack storage test scenario, provided the fire protection system suppresses the fire prior to the time of significant Li-ion battery involvement.
- Without full-scale sprinklered testing experience with Li-ion batteries, protection system performance must preclude Li-ion battery involvement.

The second test series evaluated the level of protection provided by ceiling level only sprinklers. Two large-scale fire sprinkler tests were conducted with CUP commodity and were based on the reduced commodity testing approach data. Full-scale tests were conducted with CUP commodity due to the costs associated with purchasing Li-ion cells and/or battery packs.

In both large-scale fire tests, the CUP commodity cartons were breached by the fire before initial sprinkler operation, resulting in persistent, deep-seated flames beyond the predicted time of battery involvement. At this time, the adequacy of ceiling level sprinkler protection cannot be established without repeating the large-scale fire sprinkler tests using bulk-packed Li-ion cells and/or battery packs.

Reference

1. B. Ditch et al., *Flammability Characterization of Lithium-ion Batteries in Bulk Storage* (FM Global, Norwood, 2013)

Flammability of Cartonned Lithium Ion Batteries

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2014, XX, 31 p. 13 illus., Softcover

ISBN: 978-1-4939-1076-2