ABSTRACT

Title of Document:	DYNAMICS AND HAZARDS OF CASCADING FAILURE IN LITHIUM ION CELL ARRAYS: ANALYSIS, PASSIVE MITIGATION, AND ACTIVE SUPPRESSION Ahmed O. Said, Doctor of Philosophy, 2020
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Exposure of lithium ion battery (LIB) to abnormal operating conditions may result in rapid self-heating accompanied by ejection of flammable materials, this phenomenon is referred to as thermal runaway (TR). In a multi cell array, TR of an individual cell may propagate to neighboring cells, this phenomenon is referred to as cascading failure. Cascading failure is hazardous and may cause large scale fires or explosions. In this work, a new experimental setup was developed to investigate cascading failure in arrays constructed from lithium cobalt oxide (LCO), lithium nickel manganese cobalt oxide (NMC), and lithium iron phosphate (LFP) cells of 18650 form factor. Fully charged cells were arranged in rectangular arrays: 3×4 or 3×6 with no gaps between adjacent cells and were mounted in a specially designed wind tunnel to achieve well-controlled environmental conditions. TR was initiated in one cell using an electric heater and observed to propagate through the array using temperature sensors attached to individual cells. Tests were conducted in N_2 and air to elucidate the flaming combustion impact.

In nitrogen, TR propagation speed showed no significant dependence on the

size of the array. The speed of the propagaion was found to be greater in air than in nitrogen. The LFP cells were the only cells that did not always fully propagate TR. In nitrogen, all cells produced large amounts of hydrocarbons, CO and CO_2, and minor amounts of O_2 and H_2. Total heats generated due to chemical reactions between cell components and flaming combustion of ejected materials normalized by the electrical energy stored were determined to be 3.5, 2.9, and 2.5 for LCO, NMC, and LFP cells, respectively.

Different passive mitigation strategies, including implementing 5 mm gaps between cell groups and inserting physical barrier into these gaps, were investigated. Among the barriers, ceramic fiber board was found to be the most effective, slowing down the propagation by more than a factor of 30. Lastly, the effectiveness of two fire extinguishing agents, Novec1230 and water mist, was investigated. Applying Novec1230 agent at 15.2 vol.% significantly inhibited combustion of ejected materials and prevented complete TR propagation through fully charged LCO cell arrays.