ABSTRACT OF THE THESIS

Flammability Limits of Lithium-Ion Battery Thermal Runaway Vent Gas in Air and the Inerting Effects of Halon 1301

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Lithium-ion (rechargeable) and lithium-metal (non-rechargeable) battery cells put aircraft at risk of igniting and fueling fires. Lithium-ion batteries can be packed in bulk and shipped in the cargo holds of both passenger and freighter aircraft; currently lithium-metal batteries are banned from bulk shipment on passenger aircraft but are permitted to be shipped in bulk on freighter aircraft [1].

The 5 %vol Halon 1301 knockdown concentration and the sustained 3 %vol Halon 1301 in a Class C cargo compartment may not be sufficient at inerting lithium-ion battery vent gas and air mixtures [2]. At 5 %vol Halon 1301 the flammability limits of lithium-ion premixed battery vent gas (Li-Ion pBVG) in air range from 13.80 %vol to 26.07 %vol Li-Ion pBVG. Testing suggests that 8.59 %vol Halon 1301 is required to render all ratios of the Li-Ion pBVG in air inert.

The lower flammability limit (LFL) and upper flammability limit (UFL) of hydrogen and air mixtures are 4.95 %vol and 76.52 %vol hydrogen respectively. With the addition of 10 %vol and 20 %vol Halon 1301 the LFL is 9.02 %vol and 45.72 %vol hydrogen respectively and the UFL is 45.72 %vol and 28.39 %vol hydrogen respectively. The minimum inerting concentration (MIC) of Halon 1301 in hydrogen and air mixtures is 26.72 %vol Halon 1301 at 16.2 %vol hydrogen.

The LFL and UFL of Li-Ion pBVG and air mixtures are 7.88 %vol and 37.14 %vol Li-Ion pBVG respectively. With the addition of 5 %vol, 7 %vol, and 8 %vol Halon 1301 the LFL is 13.80 %vol, 16.15 %vol, and 17.62 % vol Li-Ion pBVG respectively and the UFL is 26.07 %vol, 23.31 %vol, and 21.84 %vol Li-Ion pBVG respectively. The MIC of Halon 1301 in Li-Ion pBVG and air mixtures is 8.59 %vol Halon 1301 at 19.52 %vol Li-Ion pBVG.

Le Chatelier's mixing rule has been shown to be an effective measure for estimating the flammability limits of Li-Ion pBVGes. The LFL has a 1.79 % difference while the UFL has a 4.53 % difference. The state of charge (SOC) affects the flammability limits in an apparent parabolic manner, where the widest flammability limits are at or near 100 % SOC.