CLAIMS

What is claimed is:

1. A method for extinguishing a flame and terminating thermal runaway in a device powered by a lithium ion battery, which comprises: (a) providing an enclosure; (b) providing a device positioned within the enclosure, wherein the device comprises and is powered by a lithium ion battery; (c) providing a source of a thermal runaway termination agent, wherein the source comprises a container and a two-way control valve, wherein the container contains the thermal runaway termination agent, the two-way control valve is attached to an opening in the container, and the thermal runaway termination agent comprises a nonflammable haloolefin; (d) providing a temperature sensitive tube containing an inert gas or a thermal runaway termination agent at a predetermined pressure and temperature suitable for normal operating conditions of the device, wherein the tube has two ends, wherein (i) one end is in communication with the control valve and the other end is capped, (ii) the tube is located within the enclosure and comprises a temperature sensor for detection of a threshold temperature, and (iii) the tube is disposed in proximity to the lithium ion battery; and (e) providing a heat stimulus, which generates a flame and initiates thermal runaway, whereupon the temperature sensitive tube ruptures, creating an opening in the temperature sensitive tube and causing release of the inert gas or thermal runaway termination agent within the temperature sensitive tube through the heat stimulus-created opening in the temperature sensitive tube and into the enclosure, resulting in a pressure drop within the temperature sensitive tube which actuates the control valve to deliver the thermal runaway termination agent from the storage container through the control valve to the temperature sensitive tube and out of the heat stimulus-created opening in the temperature sensitive tube and into the enclosure; wherein the delivery of the thermal runaway termination agent is characterized by a discharge time, a thermal runaway termination agent concentration, and hold time, thereby extinguishing the flame and terminating thermal runaway and preventing reignition following the extinguishment of the flame.

2. The method of claim 1, wherein the nonflammable haloolefin is chosen from one or more of *E*-HFO-1336mzz, *Z*-HFO-1336mzz, *E*-HCFO-1233zd, *Z*-HCFO-1233zd, HCFO-1233xf, *Z*-HCFO-1224yd, *E*-HCFO-1224yd, *E*-HFO-1438ezy, *Z*-HFO-1438ezy, or HBFO-1233xfB.

3. The method of claim 1 or 2, wherein the temperature sensitive tube contains an inert gas in step (d), wherein the inert gas is chosen from nitrogen, argon, helium, carbon dioxide, and mixtures thereof.

4. A method for extinguishing a flame and terminating thermal runaway in a device powered by a lithium ion battery, which comprises: (a) providing an enclosure; (b) providing a device positioned within the enclosure, wherein the device comprises and is powered by a lithium ion battery; (c) providing a source of a thermal runaway termination agent, wherein the source comprises a container and a three-way control valve, wherein the container contains the thermal runaway termination agent, the three-way control valve is attached to an opening in the container, and the thermal runaway termination agent comprises a nonflammable haloolefin; (d) providing a temperature sensitive tube containing an inert gas or a thermal runaway termination agent at a predetermined pressure and temperature suitable for normal operating conditions of the device, wherein the tube has two ends, wherein (i) one end is in communication with the three-way control valve and the other end is capped, (ii) the tube is located within the enclosure and comprises a temperature sensor for detection of a threshold temperature, and (iii) the tube disposed in proximity to the lithium ion battery; (e) providing a nozzle- connecting tube which is in communication with the three-way control valve on one end and terminates in a nozzle proximal to the lithium ion battery at the other end of the nozzle-connecting tube; and (f) providing a heat stimulus, which generates a flame and initiates thermal runaway, whereupon the temperature sensitive tube ruptures, creating an opening in the temperature sensitive tube (“heat stimulus-created opening”) and causing release of the inert gas or thermal runaway termination agent within the temperature sensitive tube through the heat stimulus-created opening in

the temperature sensitive tube and into the enclosure, resulting in a pressure drop within the temperature sensitive tube which actuates the three-way control valve to deliver the thermal runaway termination agent from the storage container through the three-way control valve to the nozzle-connecting tube, resulting in the release of the thermal runaway termination agent from the nozzle into the enclosure; wherein the delivery of the thermal runaway termination agent is characterized by a discharge time, a thermal runaway termination agent concentration, and hold time, thereby extinguishing the flame and terminating thermal runaway and preventing reignition following the extinguishment of the flame.

5. The method of claim 4, wherein the nonflammable haloolefin is chosen from one or more of *E*-HFO-1336mzz, *Z*-HFO-1336mzz, *E*-HCFO-1233zd, *Z*-HCFO-1233zd, HCFO-1233xf, *Z*-HCFO-1224yd, *E*-HCFO-1224yd, *E*-HFO-1438ezy, *Z*-HFO-1438ezy, or HBFO-1233xfB.

6. The method of claim 4 or 5, wherein the temperature sensitive tube contains an inert gas in step (d), wherein the inert gas is chosen from nitrogen, argon, helium, carbon dioxide, and mixtures thereof.

7. The method of any one of claims 1-6, wherein the lithium ion battery comprises an anode chamber comprising an anode, a cathode chamber comprising a cathode, and a semipermeable membrane, which separates the anode chamber from the cathode chamber and wherein the anode is constructed of graphite protected with a solid electrolyte interphase layer and the cathode is constructed of a lithium metal oxide chosen from $LiCoO_2$, $LiFePO_4$, $LiMn_2O_4$ or $LiNiMnCoO_2$.

8. The method of claim 7, wherein the anode chamber and cathode chamber are each filled with a liquid electrolyte which is a flammable organic carbonate chosen from ethylene carbonate or diethyl carbonate, which contains a lithium salt chosen from $LiPF_6$, $LiAsF_6$, $LiClO_4$, $LiBF_4$, or $LiCF_3SO_3$.

9. The method of any one of claims 1-8, wherein the thermal runaway termination agent comprises an amount of the nonflammable

haloolefin sufficient to provide a concentration of at least 13% v/v (volume/volume) of the nonflammable haloolefin when delivered to the enclosure.

10. The method of any one of claims 1-9, wherein the thermal runaway termination agent comprises one or more halocarbon gases, wherein the halocarbon gas is chosen from HFC-227ea, HFC-125, CF_3I, CHF_3, HFC-236fa, *E*- or *Z*-HFO-1234ze, HFO-1234yf, or FK-5-1-12.

11. A fire protection system which comprises: (a) an enclosure; (b) a device, positioned within the enclosure, wherein the device comprises and is powered by a lithium ion battery; (c) a source of a thermal runaway termination agent, wherein the source comprises a container and a two-way control valve, wherein the container contains the thermal runaway termination agent, the two-way control valve is attached to an opening in the container, and the thermal runaway termination agent comprises a nonflammable haloolefin; and (d) a temperature sensitive tube containing an inert gas or a thermal runaway termination agent at a predetermined pressure and temperature suitable for normal operating conditions of the device, wherein the tube has two ends, wherein (i) one end is in communication with the two-way control valve and the other end is capped, (ii) the tube is located within the enclosure and comprises a temperature sensor for detection of a threshold temperature, and (iii) the tube is disposed in proximity to the lithium ion battery, and the tube is burstable upon sensing a threshold temperature.

12. The fire protection system of claim 11, wherein the nonflammable haloolefin is chosen from one or more of *E*-HFO-1336mzz, *Z*-HFO-1336mzz, *E*-HCFO-1233zd, *Z*-HCFO-1233zd, HCFO-1233xf, *Z*-HCFO-1224yd, *E*-HCFO-1224yd, *E*-HFO-1438ezy, *Z*-HFO-1438ezy, or HBFO-1233xfB.

13. The fire protection system of claim 12, wherein the temperature sensitive tube of component (c) contains an inert gas,

wherein the inert gas is chosen from nitrogen, argon, helium, carbon dioxide, and mixtures thereof.

14. A fire protection system which comprises: (a) an enclosure; (b) a device, positioned within the enclosure, wherein the device comprises and is powered by a lithium ion battery; (c) a source of a thermal runaway termination agent, wherein the source comprises a container and a three-way control valve, wherein the container contains the thermal runaway termination agent, the three-way control valve is attached to an opening in the container, and the thermal runaway termination agent comprises a nonflammable haloolefin; and (d) a temperature sensitive tube containing an inert gas or a thermal runaway termination agent at a predetermined pressure and temperature suitable for normal operating conditions of the device, wherein the temperature sensitive tube has two ends, wherein (i) one end is in communication with the three-way control valve and the other end is capped, (ii) the temperature sensitive tube is located within the enclosure and comprises a temperature sensor for detection of a threshold temperature, and (iii) the temperature sensitive tube disposed in proximity to the lithium ion battery, and the temperature sensitive tube is burstable upon sensing a threshold temperature; and (e) a nozzle-connecting tube which is in communication with the three-way control valve on one end and terminates in a nozzle proximal to the lithium ion battery at the other end of the nozzle-connecting tube.

15. The fire protection system of claim 14, wherein the nonflammable haloolefin is chosen from one or more of *E*-HFO-1336mzz, *Z*-HFO-1336mzz, *E*-HCFO-1233zd, *Z*-HCFO-1233zd, HCFO-1233xf, *Z*-HCFO-1224yd, *E*-HCFO-1224yd, *E*-HFO-1438ezy, *Z*-HFO-1438ezy, or HBFO-1233xfB.

16. The fire protection system of claim 14, wherein the temperature sensitive tube of component (c) contains an inert gas, wherein the inert gas is chosen from nitrogen, argon, helium, carbon dioxide, and mixtures thereof.