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~~).~~

~~4. The method of claim 3),~~ wherein the inert gas is chosen from nitrogen, argon, helium, carbon dioxide, and mixtures thereof.

~~5. The method of claim 4 wherein the inert gas further comprises the thermal runaway termination agent.~~

~~6. The method of any of claims 1 to 5 wherein the temperature sensitive tube contains a thermal runaway termination agent in step (d).~~

~~7. The method of any one of claims 1 to 6 wherein the two-way control valve has at least three ports.~~

~~8. The method of claim 7 wherein the two-way control valve has a third port which provides an option for withdrawing a sample from the container contents.~~

~~9~~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.

~~10~~5. The method of claim ~~9~~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.

~~11~~6. The method of claim ~~9~~4 or ~~10~~5, wherein the temperature sensitive tube contains an inert gas in step (d~~).~~

~~12. The method of claim 11),~~ wherein the inert gas is chosen from nitrogen, argon, helium, carbon dioxide, and mixtures thereof.

~~13. The method of claim 12 wherein the inert gas further comprises the thermal runaway termination agent.~~

~~14. The method of any of claims 9-13, wherein the temperature sensitive tube contains a thermal runaway termination agent in step (d).~~

~~15. The method of any one of claims 9-14, wherein the three-way control valve has at least four ports.~~

~~16. The method of claim 15 wherein the three-way control valve has a fourth port which provides an option for withdrawing a sample from the container contents.~~

~~17~~7. The method of any one of claims 1-~~16, wherein the device is chosen from datalogger, telecommunication equipment, personal electronic equipment, power tool, energy storage system, data center, electric motor vehicle, and electric bicycle.~~

~~18. The method of claim 17, wherein the device is personal electronic equipment chosen from cell phone, laptop computer and gaming system.~~

~~19. The method of any one of claims 1-18~~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 $LiNiMnCoO_2$.

~~20~~8. The method of claim ~~19~~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 $LiCF_3SO_3$.

~~21~~9. The method of any one of claims 1-~~20~~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.

~~22. The method of claim 21 wherein the thermal runaway termination agent comprises an amount of the nonflammable haloolefin sufficient to provide a concentration of at least 18% v/v of the nonflammable haloolefin when delivered to the enclosure.~~

~~23~~10. The method of any one of claims 1-~~22, wherein the thermal runaway termination agent comprises one or more inert gas chosen from nitrogen, argon, helium, carbon dioxide, and mixtures thereof.~~

~~24. The method of any one of claims 1-23~~9, wherein the thermal runaway termination agent comprises one or more halocarbon gases~~.~~

~~25. The method of claim 24,~~ 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.

~~26. The method of any one of claims 1-25, wherein the heat stimulus is the result of applied heat to the enclosure from an external source.~~

~~27. The method of any one of claims 1-25, wherein the heat stimulus is the result of applied heat to the enclosure from an internal source.~~

~~28. The method of claim 27 wherein the internal source is due to the LIB overheating due to a mechanical event or electrical event or a defect event.~~

~~29. The method of claim 28 wherein two or more of a mechanical event, a thermal event, an electrical event or a defect event are coupled causing the heat stimulus.~~

~~30. The method of any one of claims 1-29, wherein the thermal runaway termination agent comprises an amount of the nonflammable haloolefin sufficient to provide a concentration of 13% to 30% v/v of the nonflammable haloolefin when delivered to the enclosure.~~

~~31. The method of claim 30, wherein the thermal runaway termination agent comprises an amount of the nonflammable haloolefin sufficient to provide a concentration of 18% to 28% v/v of the nonflammable haloolefin when delivered to the enclosure.~~

~~32. The method of claim 28, wherein the thermal runaway termination agent comprises an amount of the nonflammable haloolefin sufficient to provide a concentration of 20% to 25% v/v of the nonflammable haloolefin when delivered to the enclosure.~~

~~33. The method of any one of claims 1-30, wherein the discharge time ranges from 18 seconds to 180 seconds.~~

~~34. The method of claim 31 wherein the discharge time ranges from 25 to 120 seconds.~~

~~35. The method of claim 31 wherein the discharge time ranges wherein the discharge time ranges from 45 to 120 seconds.~~

~~36. The method of any one of claims 1-34, wherein the hold time ranges from 10 to 15 minutes.~~

~~37. The method of claim 34 wherein the hold time ranges from 15 to 30 minutes.~~

~~38. The method of claim 34 wherein the hold time ranges from 30 to 60 minutes.~~

~~39. The method of any of claims 1-38, wherein discharge time is at least 18 seconds and the thermal runaway termination agent comprises at least 13% v/v of the haloolefin to provide flame extinguishment,~~

~~terminating thermal runaway in single or multiple cell configurations and cooling sufficient to prevent reignition.~~

~~40~~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.

~~41~~12. The fire protection system of claim ~~40~~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.

~~42~~13. The fire protection system of claim ~~41~~12, wherein the temperature sensitive tube of component (c) contains an inert gas~~.~~

~~43. The fire protection system of claim 42,~~ wherein the inert gas is chosen from nitrogen, argon, helium, carbon dioxide, and mixtures thereof.

~~44. The fire protection system of claim 42, wherein the inert gas further comprises the thermal runaway termination agent.~~

~~45. The fire protection system of claim 41, wherein the temperature sensitive tube of component (c) contains a thermal runaway termination agent.~~

~~46~~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.

~~47~~15. The fire protection system of claim ~~46~~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.

~~48~~16. The fire protection system of claim ~~46~~14, wherein the temperature sensitive tube of component (c) contains an inert gas~~.~~

~~49. The fire protection system of claim 48~~, wherein the inert gas is chosen from nitrogen, argon, helium, carbon dioxide, and mixtures thereof.

~~50. The fire protection system of claim 48, wherein the inert gas further comprises the thermal runaway termination agent.~~

~~51. The fire protection system of claim 46, wherein the temperature sensitive tube of component (c) contains a thermal runaway termination agent.~~

~~52. The fire protection system of any of claim 40-51, wherein the device is chosen from datalogger, telecommunication equipment, personal electronic equipment, power tool, energy storage system, data center, electric motor vehicle, and electric bicycle.~~

~~53. The fire protection system of claim 52, wherein the device is personal electronic equipment chosen from cell phone, laptop computer and gaming system.~~