NEXCERIS
where energy meets environment

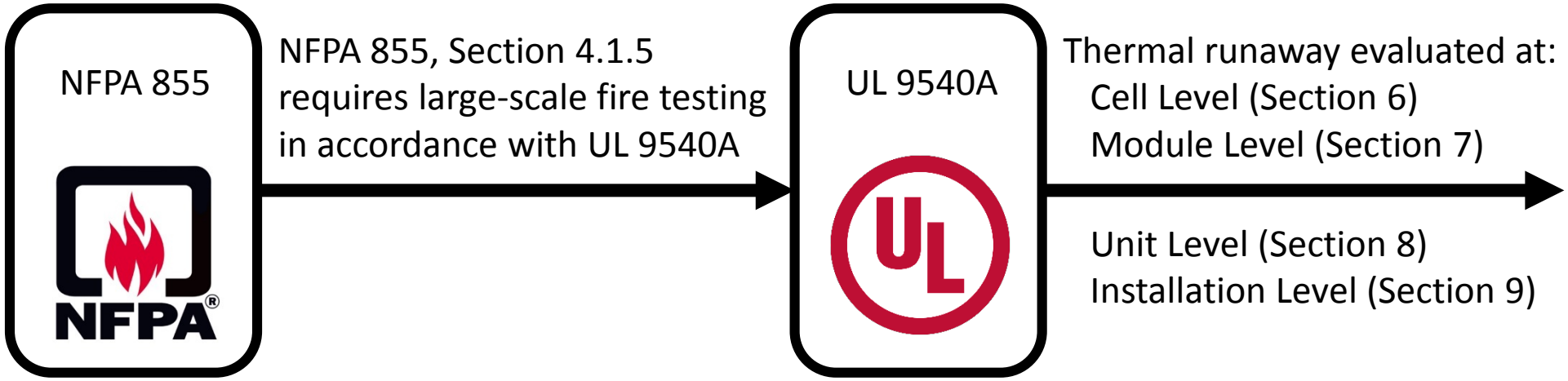
Data Pack for NFPA 855 Committee

Off-gas Detection for Lithium-ion Battery Systems

Nexceris, LLC

July 11, 2018

Thermal Runaway Propagation



Two distinct points will be recorded during UL 9540A Cell Level test

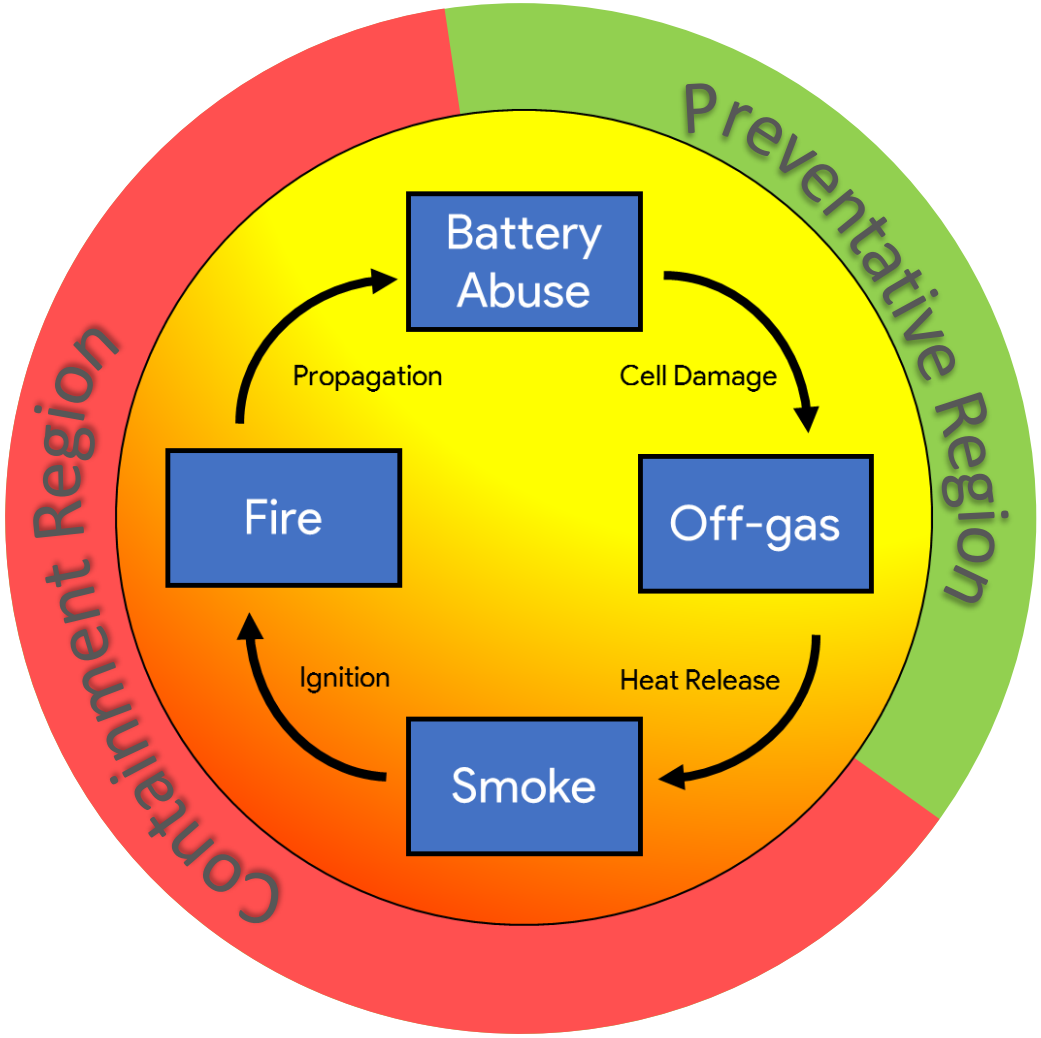
6.2.5 The temperature at which the cell case vents due to internal pressure rise shall be documented. ← **off-gas event**

6.2.6 The temperature at the onset of thermal runaway shall be documented. ← **thermal runaway**

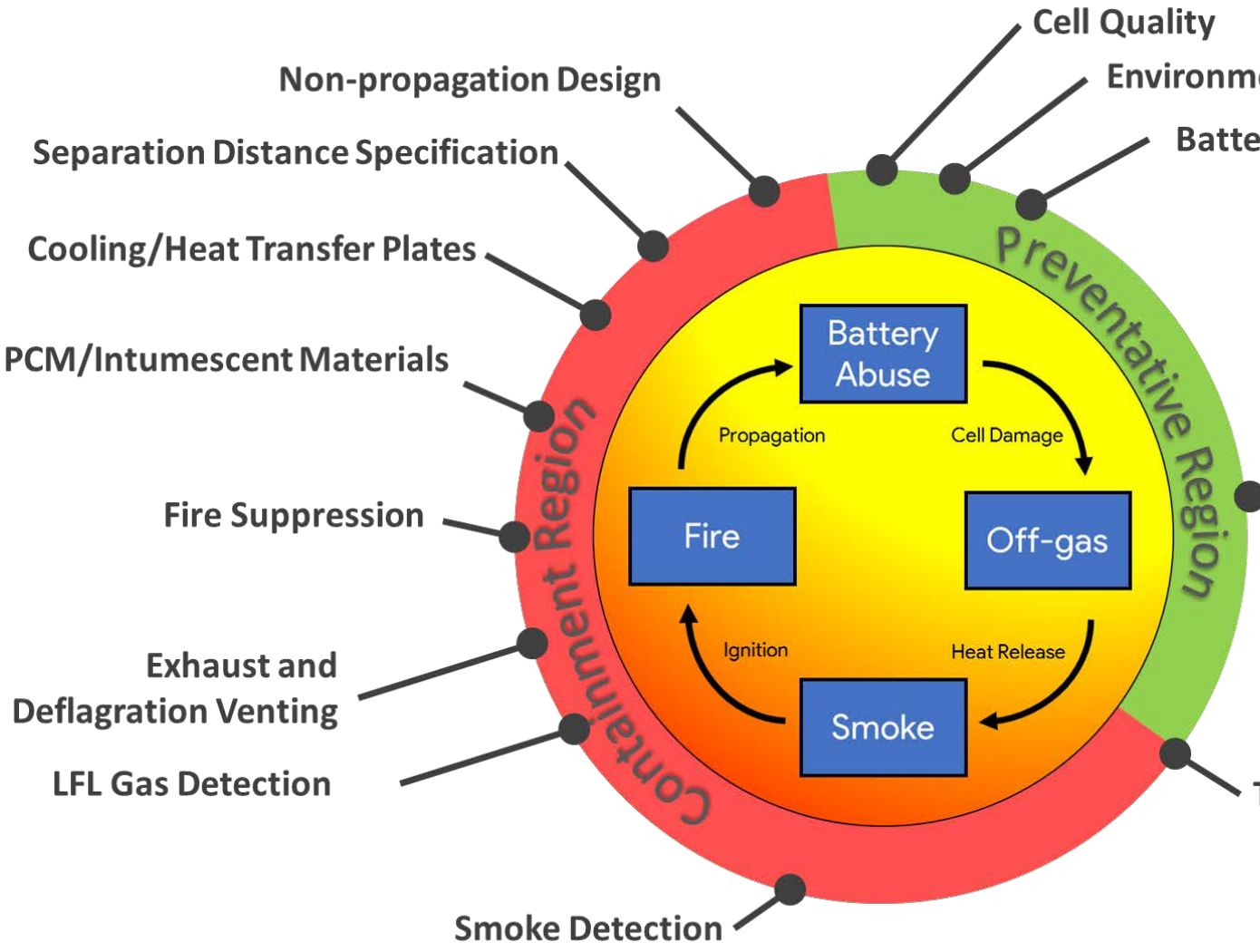
UL 9540A test report will indicate if off-gas event occurs prior to thermal runaway

Stages of a Battery Failure

1. **Battery Abuse**
   - Thermal, electrical or physical abuse
   - Leads to *Cell Damage*
   - *PREVENTATIVE REGION:* BMS is the primary defense against cell abuse
2. **Off-gas**
   - The event in which the cell case vents due to a rise in internal pressure of the cell
   - If left unchecked, *Heat Release* will continue toward thermal runaway
   - *PREVENTATIVE REGION*: Detecting off-gas from a cell provides enough time prevent thermal runaway (data on subsequent slides)
3. **Smoke**
   - Catastrophic failure is imminent
   - Likely to quickly lead to *Ignition*
   - *CONTAINMENT REGION:* Cell has entered thermal runaway and the failure must be contained.
4. **Fire**
   - Thermal runaway is fully developed
   - Likelihood of failure *Propagation* drastically increases
   - *CONTAINMENT REGION:* Cell has entered thermal runaway and the failure must be contained.



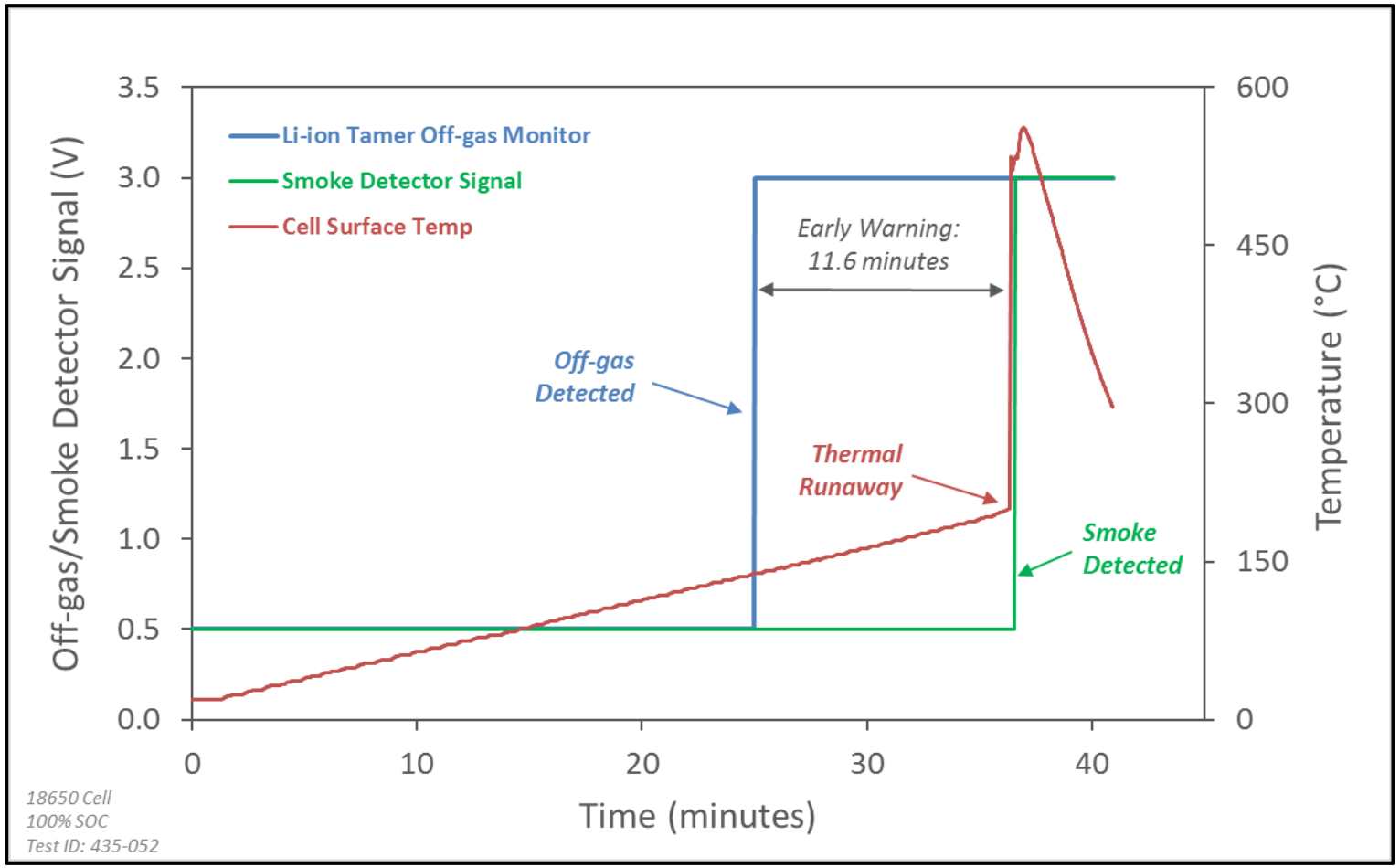
Protection Methods for Stages of Battery Failure



LI-ION TAMER®

Off-gas detection should be included in NFPA 855 if UL 9540A test report indicates that cells vent prior to TR

Off-gas Detection vs Smoke Detection



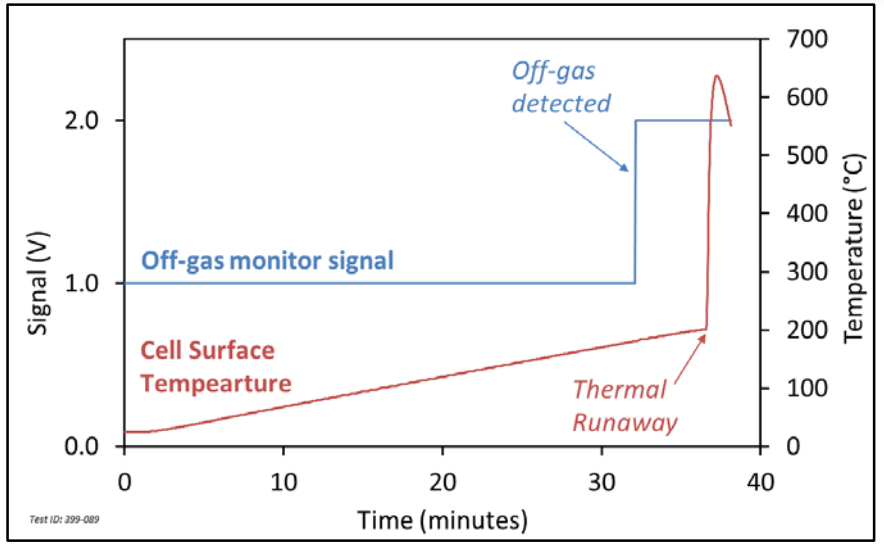
Off-gas can be detected *prior* to thermal runaway

Smoke detector provides *no* early warning of failure

Battery Failure Data

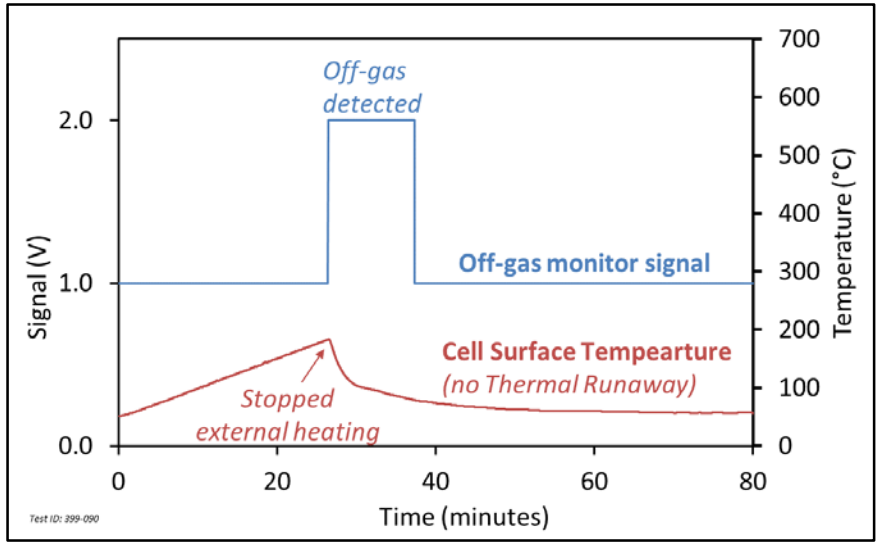
Battery Fault Detection

- Thermal abuse of a lithium ion cell
- Off-gas is detected minutes prior to thermal runaway
- Detection of off-gas can provide early warning of pending thermal runaway



Battery Fault Mitigation

- Identical test as above, but thermal abuse removed when off-gas detected
- Demonstrates that off-gas can be detected prior to onset of thermal runaway and provide enough time to prevent it



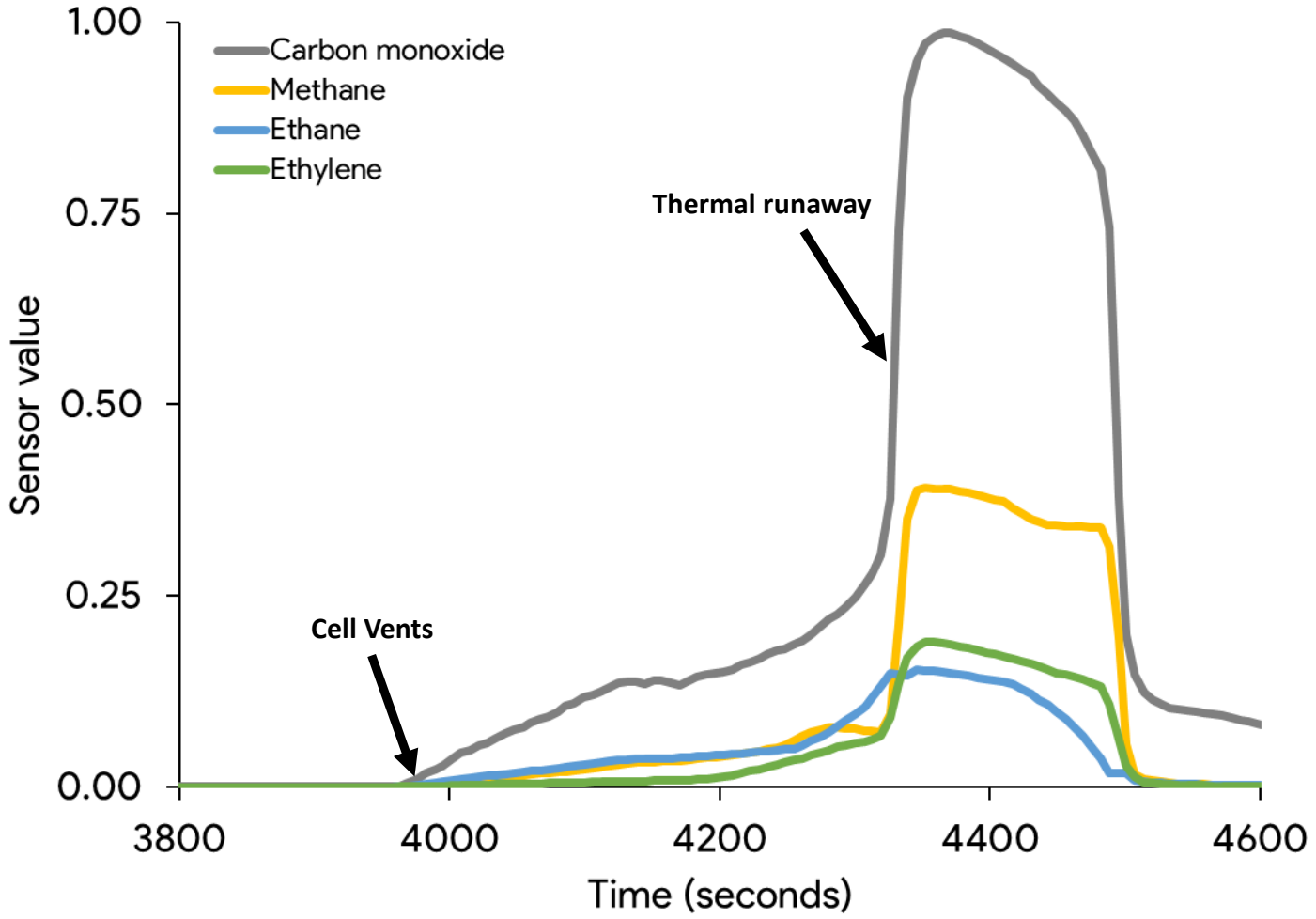
Off-gas Generation and Detection (1 of 3)

Test #1 conditions

- 63 Ah pouch cell
- Overcharged at 50A (0.8C)
- FTIR data gathered during failure (plus H_2 and LEL monitors)
- Third-party data (DNV-GL)

Remarks

- Low-level off-gassing occurs early, prior to thermal runaway



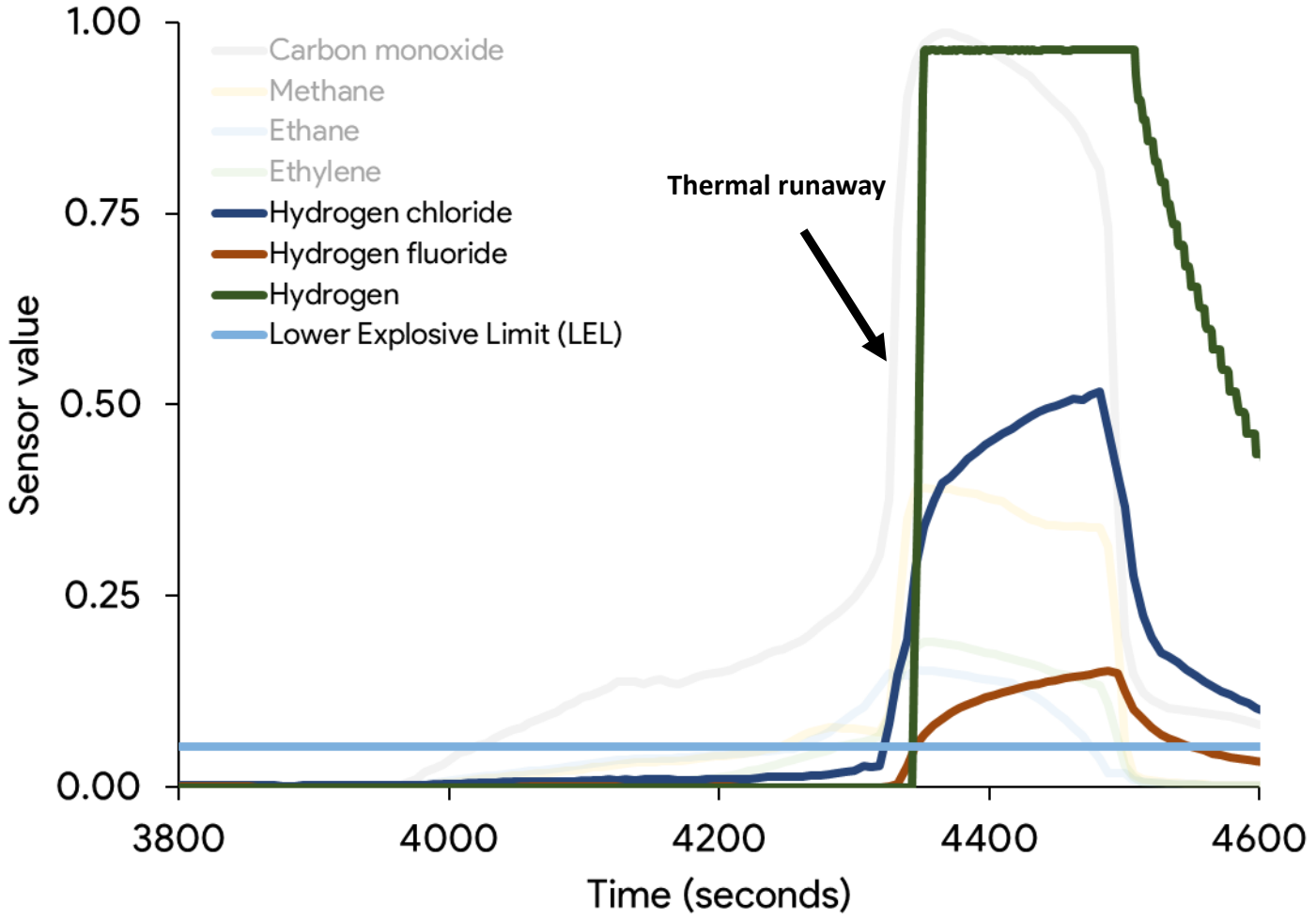
Off-gas Generation and Detection(2 of 3)

Test #1 conditions

- 63 Ah pouch cell
- Overcharged at 50A (0.8C)
- FTIR data gathered during failure (plus H_2 and LEL monitors)
- Third-party data (DNV-GL)

Remarks

- Low-level off-gassing occurs early, prior to thermal runaway
- H_2, HCl, and HF generated during thermal runaway
- LEL monitor does not alarm



Off-gas Generation and Detection(3 of 3)

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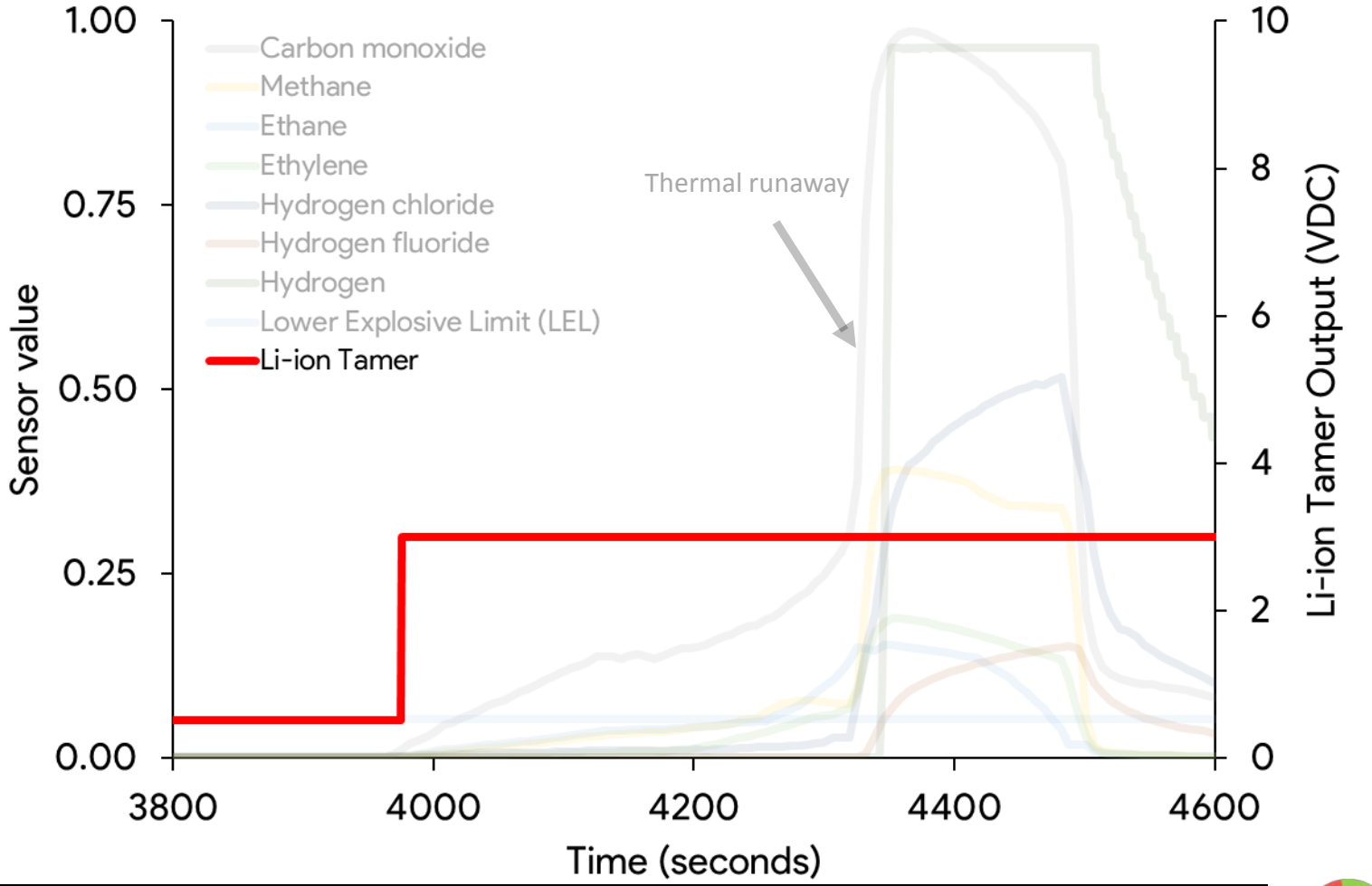
- Li-ion Tamer correlates to initial gas detection from FTIR

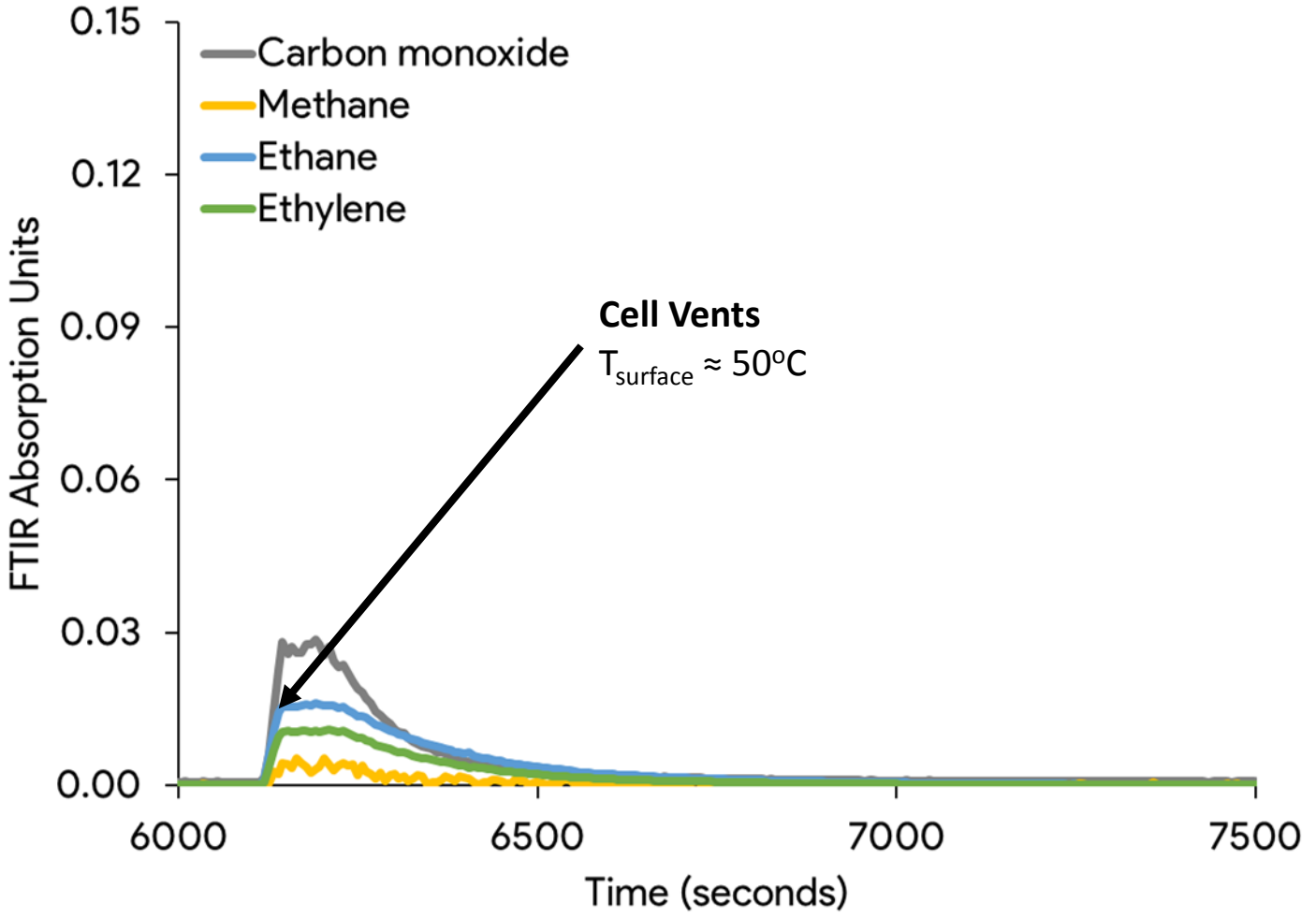


Li-ion Tamer® provided 6.4 minutes of early warning prior to thermal runaway

Off-gas Used to Prevent Thermal Runaway (1 of 2)

Test #2 conditions

- 63 Ah pouch cell
- Overcharged at 50A (0.8C)
- Charge is stopped when Li-ion Tamer detects off-gas
- Third-party data (DNV-GL)



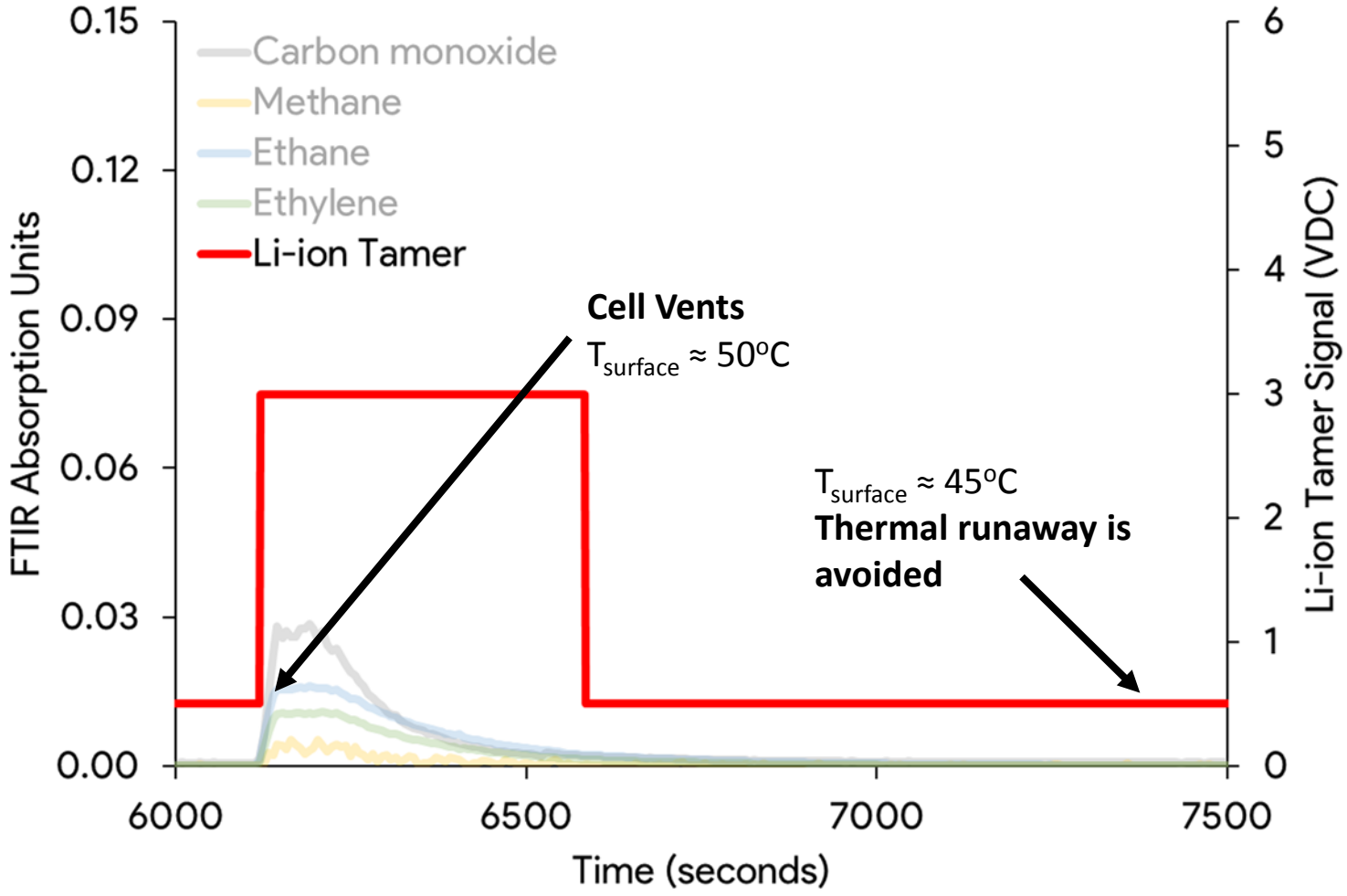
Off-gas Used to Prevent Thermal Runaway (2 of 2)

Test #2 conditions

- 63 Ah pouch cell
- Overcharged at 50A (0.8C)
- Charge is stopped when Li-ion Tamer detects off-gas
- Third-party data (DNV-GL)

Remarks

- Li-ion Tamer correlates to initial gas detection from FTIR
- Thermal runaway of cell was avoided by removing charge at Li-ion Tamer signal
- Gas concentraitons never build to high levels as thermal runaway is prevented



Li-ion Tamer® enables mitigation of thermal runaway

Links to Content

Summary Video

Video produced to explain the value of off-gas monitoring. Li-ion Tamer® is a new line of products designed to stop lithium ion battery thermal runaway before it ever gets started. Based on technology developed for the U.S. Navy, Li-ion Tamer has been demonstrated detect battery failure prior to thermal runaway and prevent fires.

LINK: https://youtu.be/fqq5Tq5hFxo

ARPA-E Video

ARPA-E held their annual Energy Innovation Summit in March in Washington, DC. This meeting draws nearly 1,800 energy innovators and industry experts to discuss the latest in energy related technologies. Nexceris' Li-ion Tamer® off-gas monitoring technology was selected from a very competitive pool of new innovations to be highlighted as a cutting-edge technology that has led to strategic partnerships with the US Navy. You can watch the video below to learn more about how the Navy is using this game changing technology to enhance the safety of their lithium ion battery system. We would like to provide the same level of protection for your energy storage systems.

LINK: https://youtu.be/A3Y_cpMnk58