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Lithium Ion Battery Off-Gas Sensor for Battery Health and Safety Monitoring

Joint Service Power Expo

Cincinnati, OH
August 27, 2015

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About NexTech

NexTech Materials, Ltd.

- Founded in 1994, privately held
- Technology Developer – advanced ceramics, electrochemical devices
- Product Developer – fuel cells, catalysts and sensors
- Manufacturer/Distributor – fuel cells and related products, sensors
- ISO 9001:2008 certification – covers all products and operations

www.nextechmaterials.com

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Lithium Ion Battery Off-Gas Sensor

Project History

2010-2011: Launch of NexTech hydrogen safety sensor product

2010-2011: Phase I NAVSEA project on battery off-gas sensor

2012: Launch of hydrogen alarm product for lead acid batteries

2012-2015: ARPA-e project on lithium ion battery off-gas sensor for stationary battery management systems

2015: Initiated Phase II of NAVSEA project, targeting ship service applications

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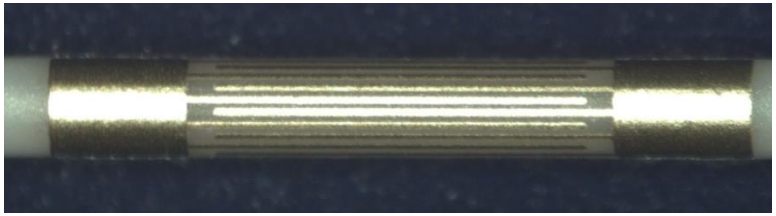
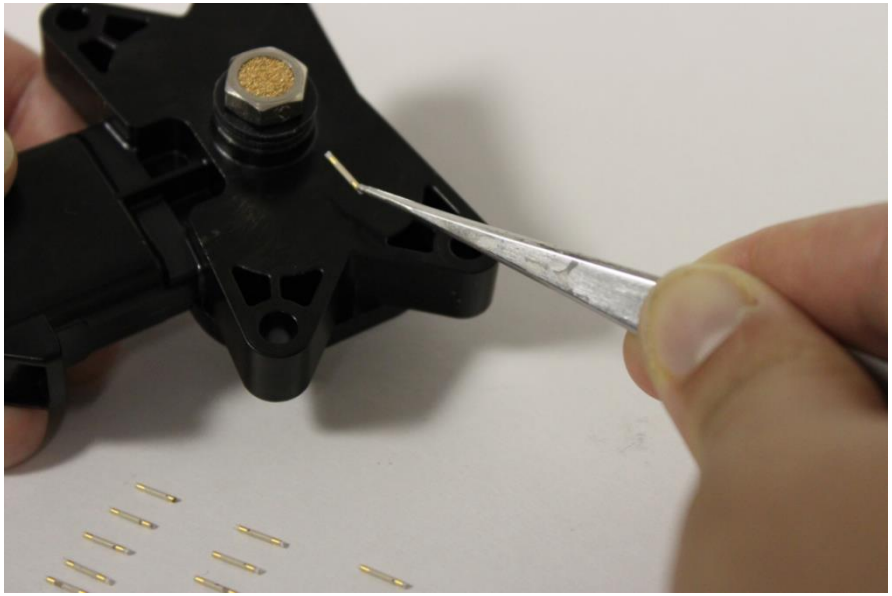
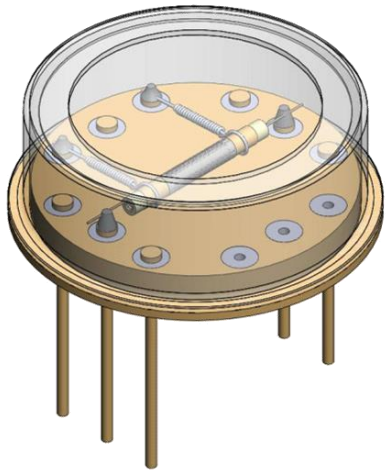
Sensor Device Platform







Features

- Chemi-resistive sensor element
- Small mass and efficient heating for low power draw
- Robust device platform with integrated electronics

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First Generation Product

NTM SenseH_2®

Standard Device Characteristics	
Calibration Range	0.25 to 4% H_2 in air
Response Time (t_{90})	< 5 sec
Recovery Time (t_{10})	< 5 sec
Humidity Range	5 to 95% RH
Temperature Range	-20 to 80°C
Power Draw	< 2 watts at 20°C
Insensitive to:	CO, CH_4, VOCs
Robust to continuous H_2 exposure (no signal saturation)	
UL listed for hazardous locations	

Starting-point platform for lithium ion battery off-gas sensor development

NexTech's Phase I NAVSEA Project

NAVSEA Contract No. N65538-10-C-0035

Phase I NAVSEA Project

Project Goal: Tailor and optimize NexTech's hydrogen sensor technology for detecting gases released from deteriorated lead acid, nickel-cadmium, silver-zinc, and lithium ion batteries

Objectives

- Define requirements for battery monitoring applications
- Enhance sensitivity at low H_2 concentrations (lead-acid batteries)
- Refine formulations for detecting CO, CH_X and VOCs (lithium ion batteries)
- Performance qualification (target gas detection range, response time, recovery time, operating temperature, baseline stability)

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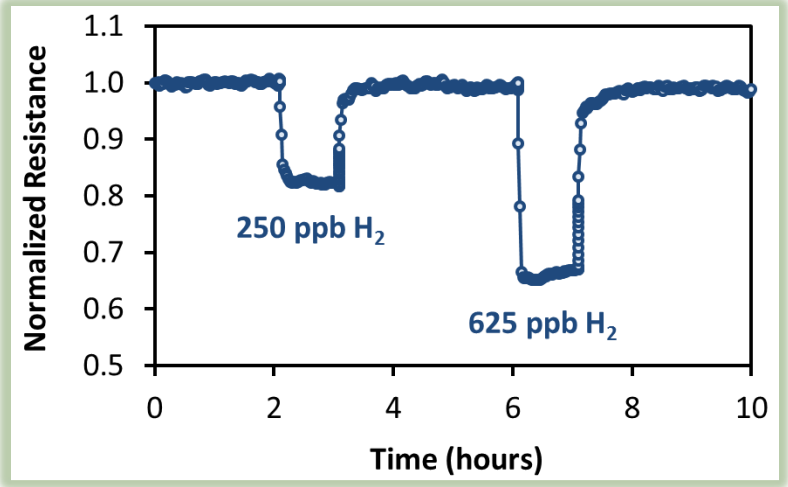
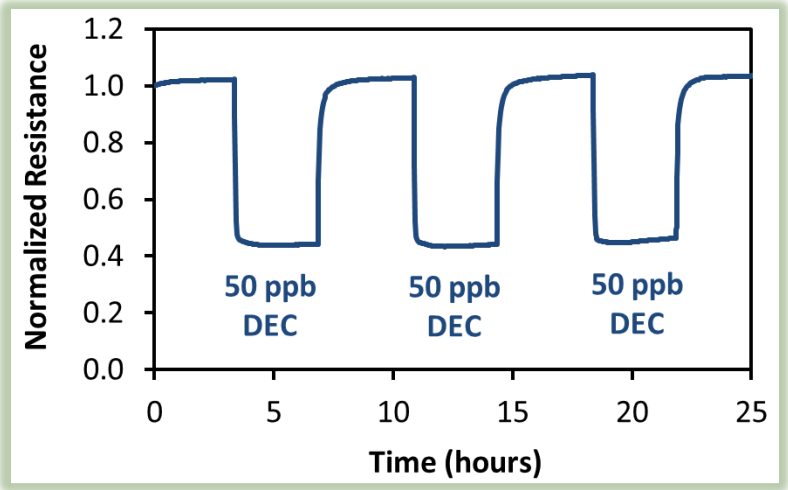
Phase I NAVSEA Project

Key Accomplishments

- Defined requirements for lead acid and lithium ion battery monitoring applications
- Modified sensor formulations for low level detection of hydrogen, hydrocarbons and VOCs
- Demonstrated ppb level detection of hydrogen for lead acid battery monitoring
- Demonstrated ppb level detection of lithium ion battery electrolytes (DMC and DEC)





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Battery Off-Gas Sensor

Target Requirements	
Gases to be detected	Battery electrolytes (e.g., DEC, DMC, MEC)
Cross-sensitivity	No false positives to paint fumes, diesel fuel, HF
Durability	Robust to environment (shock, vibration, salt air, etc.)
Lifetime	> 5 years
Calibration Interval	> 1 year
Response Time	< 18 seconds to any gas
Recovery Time	< 1 minute
Temperature	-40°C to +80°C
Size (fully packaged)	Less than 36 cubic inches (2” x 3” x 6”)
Weight (fully packaged)	< 900 grams
Audible Alarm	Piercing (>85 dB at 1 meter)
Visible Alarm	Verification of operation, fault, and presence of gas

DNV's ARPA-e AMPED Project

DOE Contract No. DE-AR00002765

ARPA-e Project

Project Goal: Develop sensor technology for safety and health monitoring of lithium ion batteries

Objectives

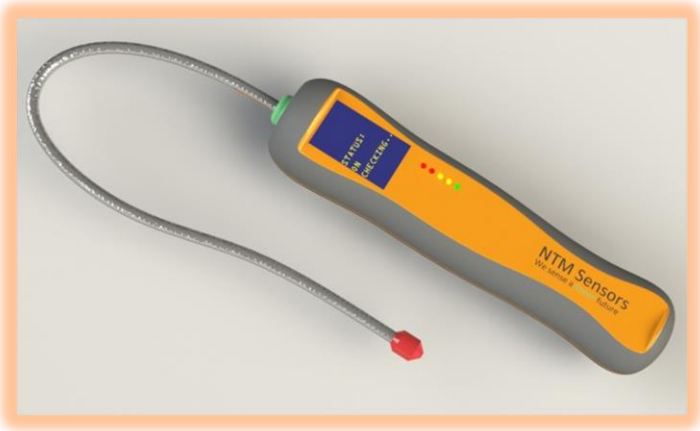
- Tailor NexTech's sensor for detection of lithium ion battery electrolytes (the primary off-gassing species in degraded or damaged batteries)
- Explore the feasibility of this technology for second-life battery applications, such as community energy storage.
- Build prototypes and conduct field testing with NexTech's sensor integrated with battery management systems.

Project Team: Det Norske Veritas (project prime), NexTech Materials, Beckett Energy Systems

ARPA-e Project

Key Accomplishments

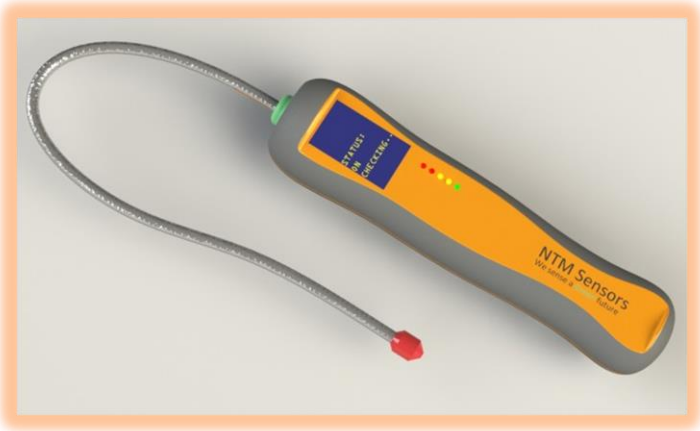
- Developed capability for testing cells under a range of abuse conditions
- Characterized battery off-gassing under normal and abusive conditions
- Quantified off-gas constituents for thermal runaway conditions
- Developed a hand-held sniffer to support customer demonstrations
- Conducted field tests on returned battery packs and punctured pouch cells
- Installed sensors in Beckett's community storage system and analyzed responses to simulated off-gas events
- Quantified sensor response time and off-gas detection capability



Battery Off-Gas Sensor

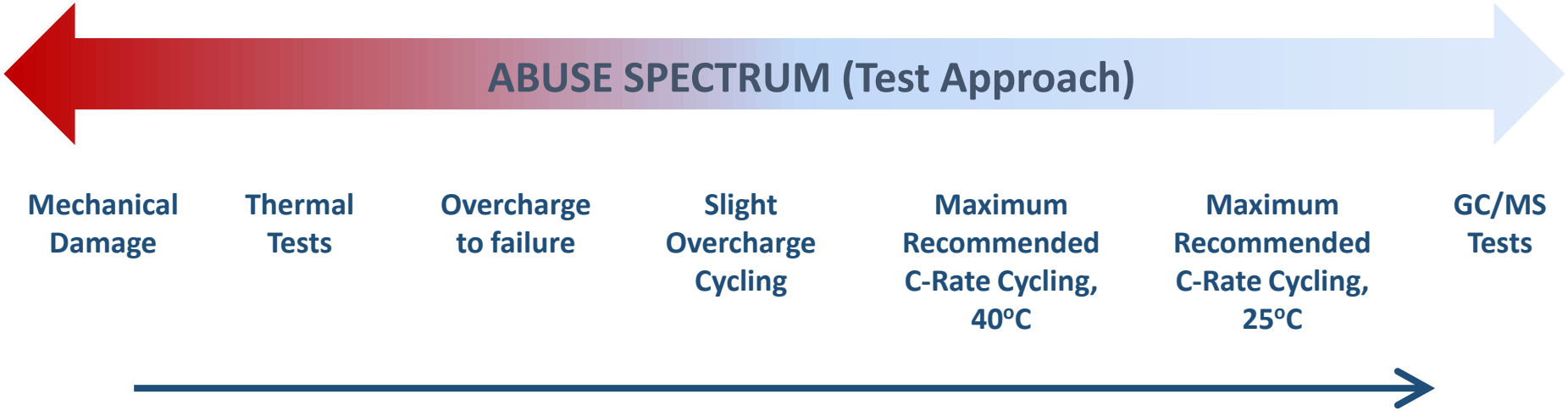
Product Concepts

- Sensor modules that will integrate with the BMS to identify electrolyte leaks from battery packs or modules
- Stand-alone battery safety monitoring devices that can provide safety monitoring of a battery system, particularly during times when the BMS is off-line, such as during storage or transport.
- A hand-held leak detector to check battery integrity during installation or prior to conducting maintenance on or near battery systems.

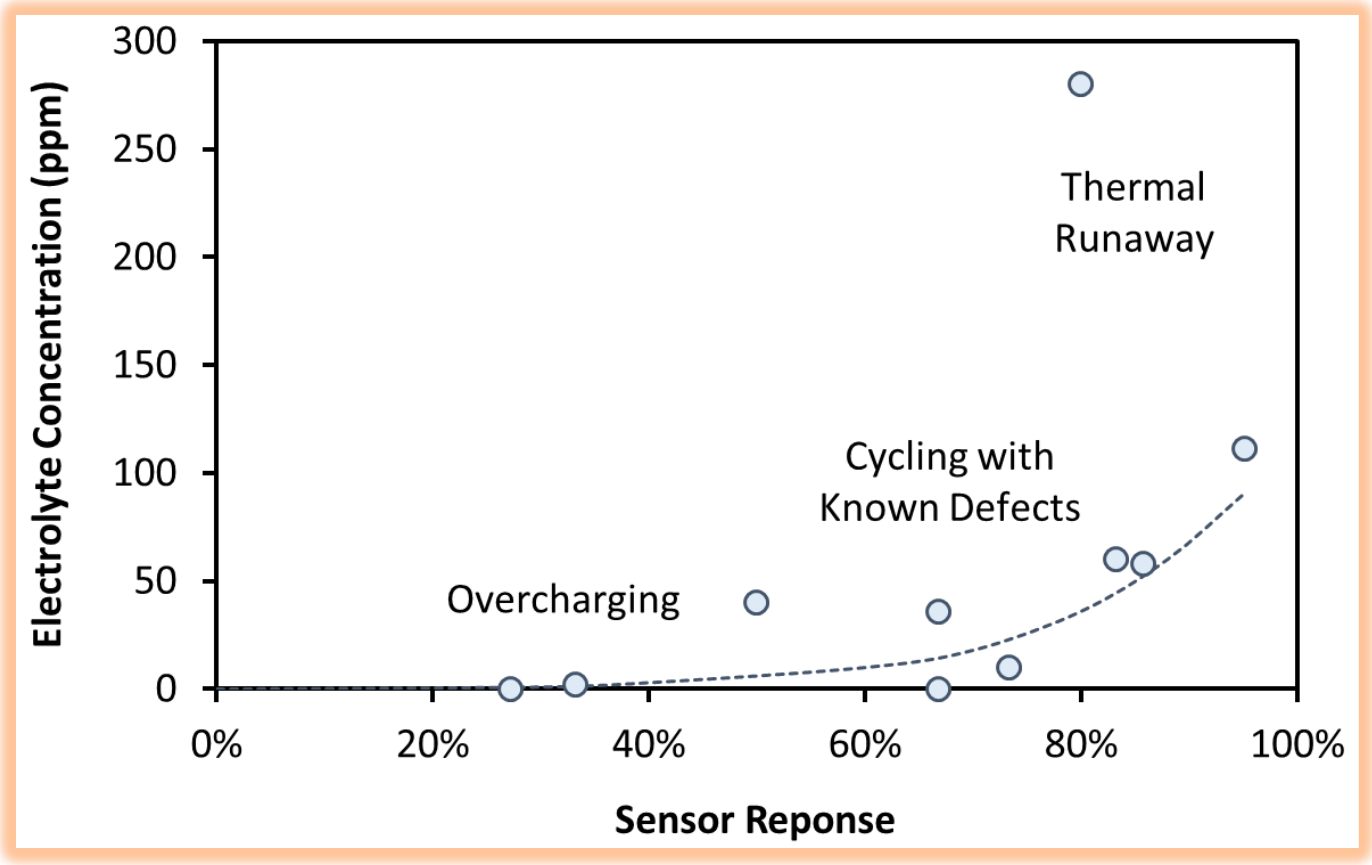


Testing Focus

Project plan structured to focus first on most aggressive abuse conditions, then stepping down to normal use conditions:

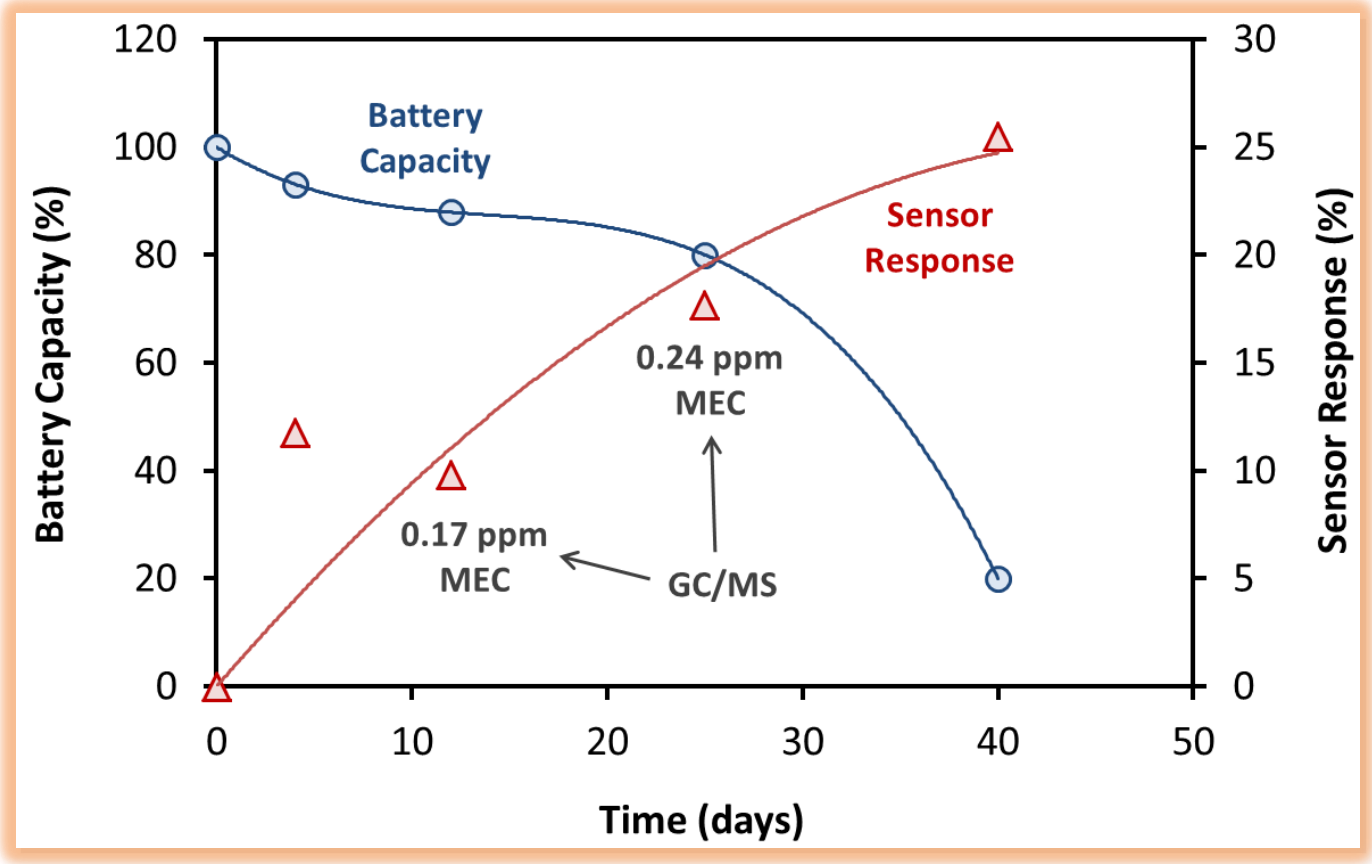


Sensor Reponses to Different Scenarios



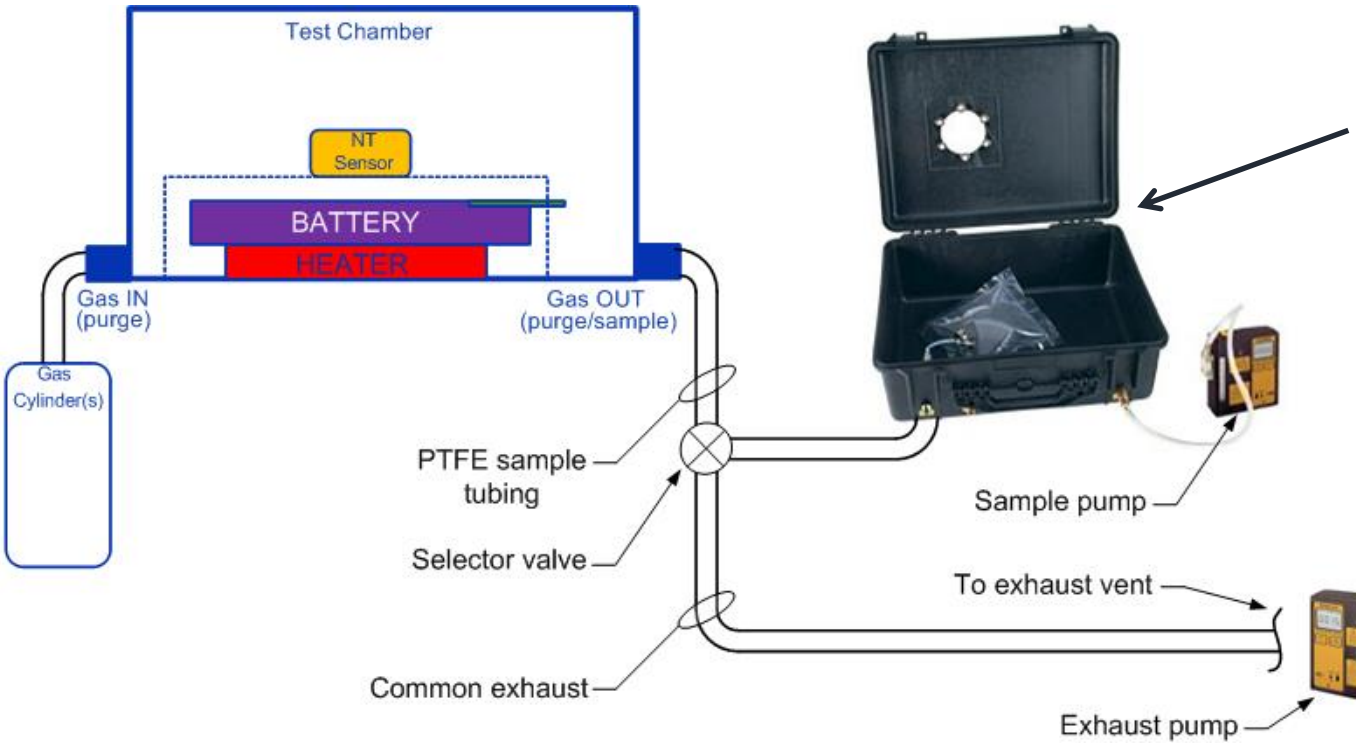
- NexTech's sensor can detect a wide range of electrolyte off-gas events caused by different failure modes.

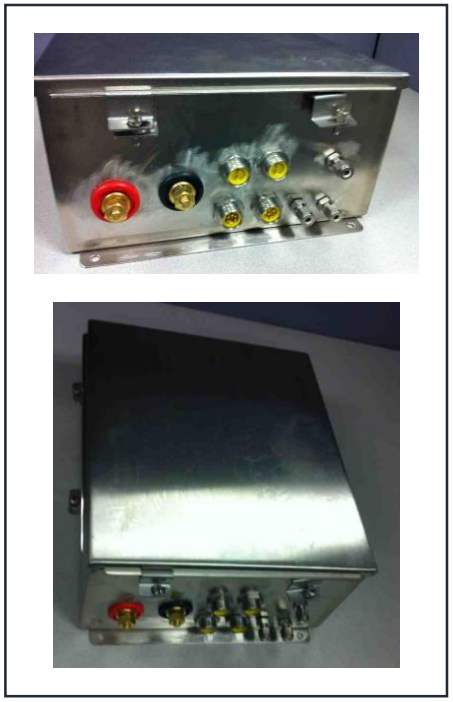
Non-Abusive Cell Cycling



- Sub-ppm level electrolyte detected with NexTech's sensor
- Not all batteries offgas – appears to be related to manufacturing quality

Sampling Set-up

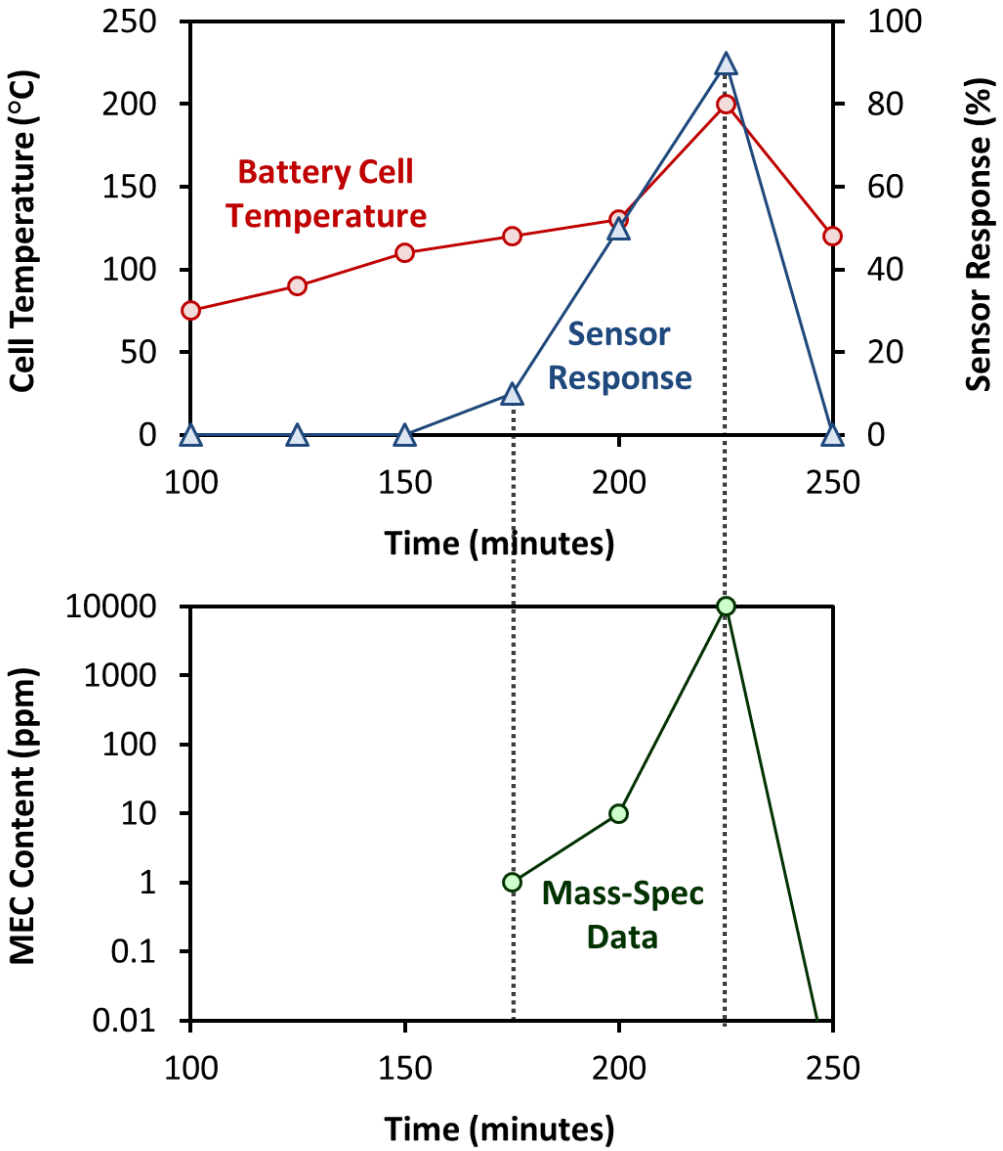




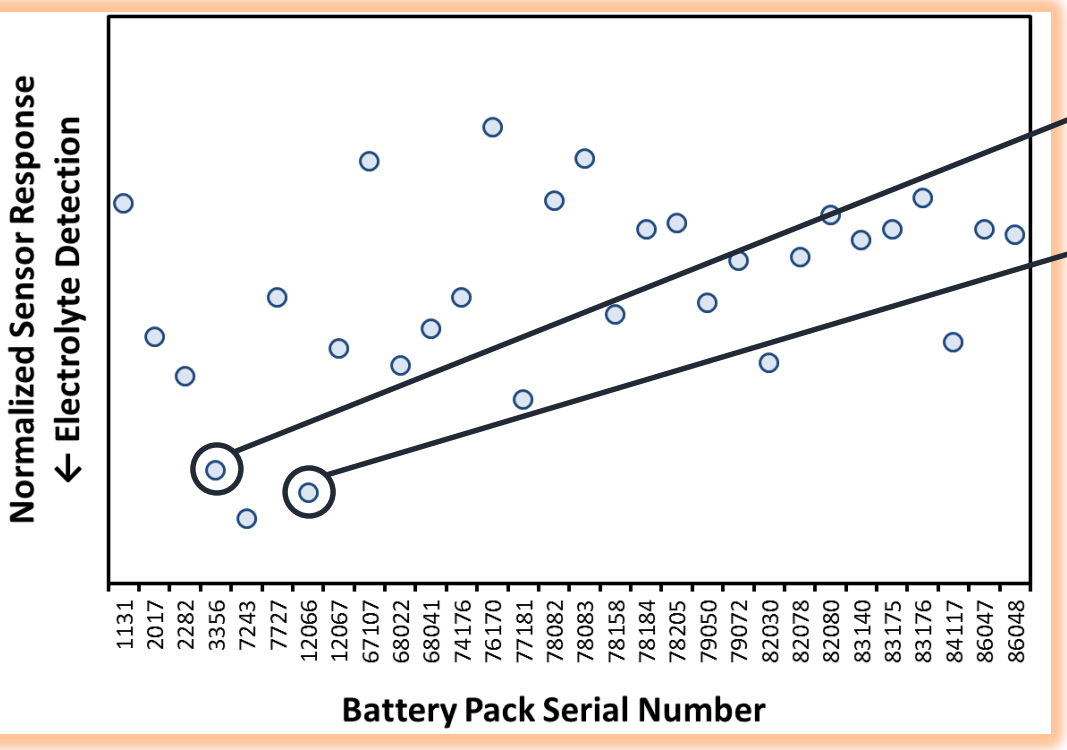
- Each test chamber requires one vacuum chamber and one sample pump
- All chambers connected to common exhaust line through a selector valve

Thermal Abuse Testing

Sensor response climbs 10% prior to temperature spike by 10-20 minutes under thermal runaway test conditions



Hand-Held "Sniffer"



Passed electrical test and visual inspection

Failed electrical test and has visible corrosion

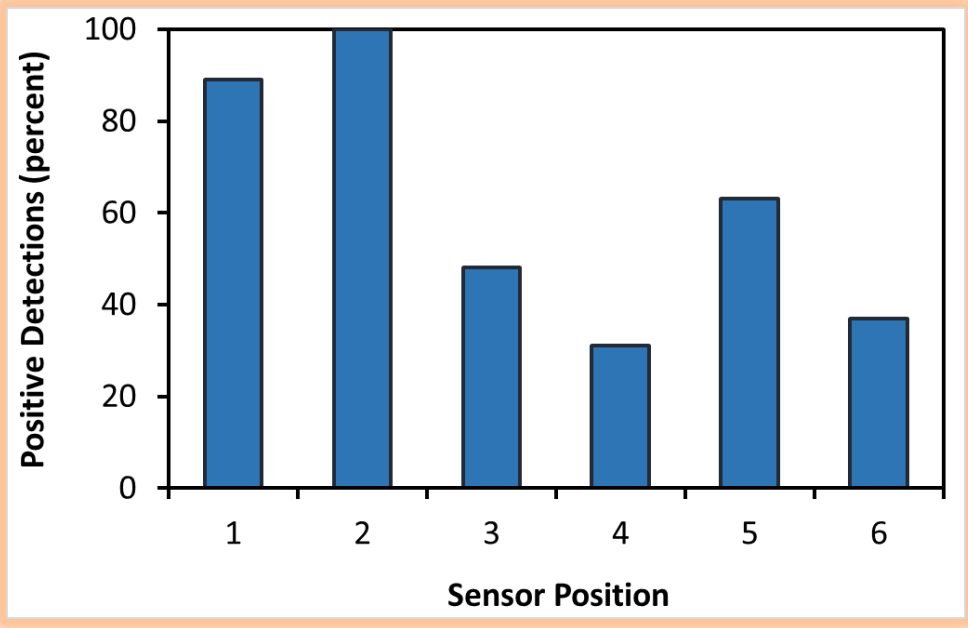
Sensor may provide additional diagnostic capability and identify battery issues not detectable with current methods

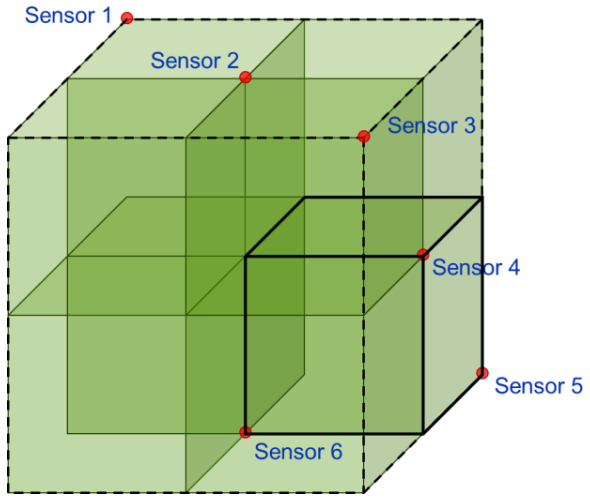
New Technologies

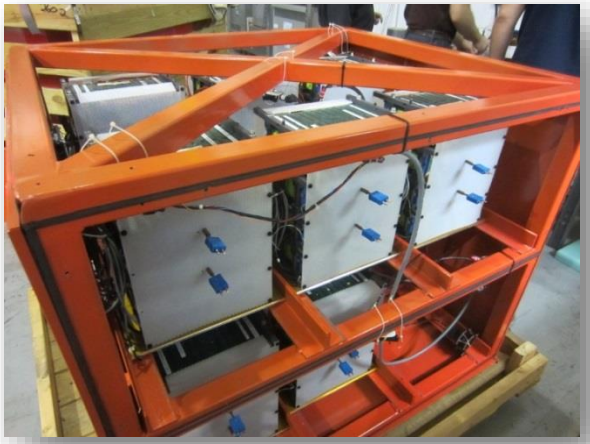
Off-Gas Sensor for BMS Diagnostics

Details of Test

- Tests conducted on a 25-kW SCALE Beckett system
- Six sensors map full range of placement options
- Quantified sensor responses with simulated off-gas
- Shows single sensor can identify off gas in system
- Offers redundant, independent monitor to BMS







Beckett DESS System

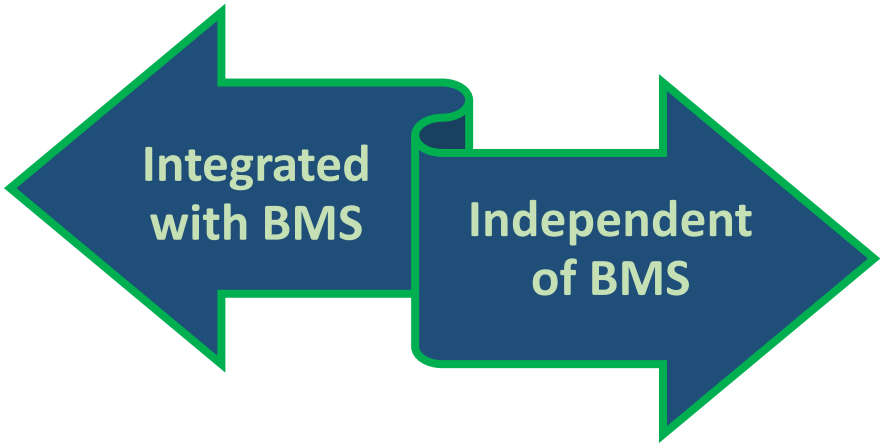
Utilization Scenarios

Expanded Operation

"Pull Back" from Extremes

Redundancy in Shut Down

Bypassable Modules



Automated Class D Extinguisher

Redundancy

Maintenance Alarms

Distinguish Cell Anomaly from Catastrophic Failure

NexTech's Phase II NAVSEA Project

NAVSEA Contract No. N00024-15-C-4002

NAVSEA Phase II Project

Objectives

- Identify key performance requirements
- Continue maturation of core battery electrolyte sensor technology
- Optimize the prototype device design to meet ambient temperature variation requirements
- Demonstrate prototype device performance through field testing
- Improve robustness of the sensor for military deployment (Option)
- Conduct military application demonstrations (Option)

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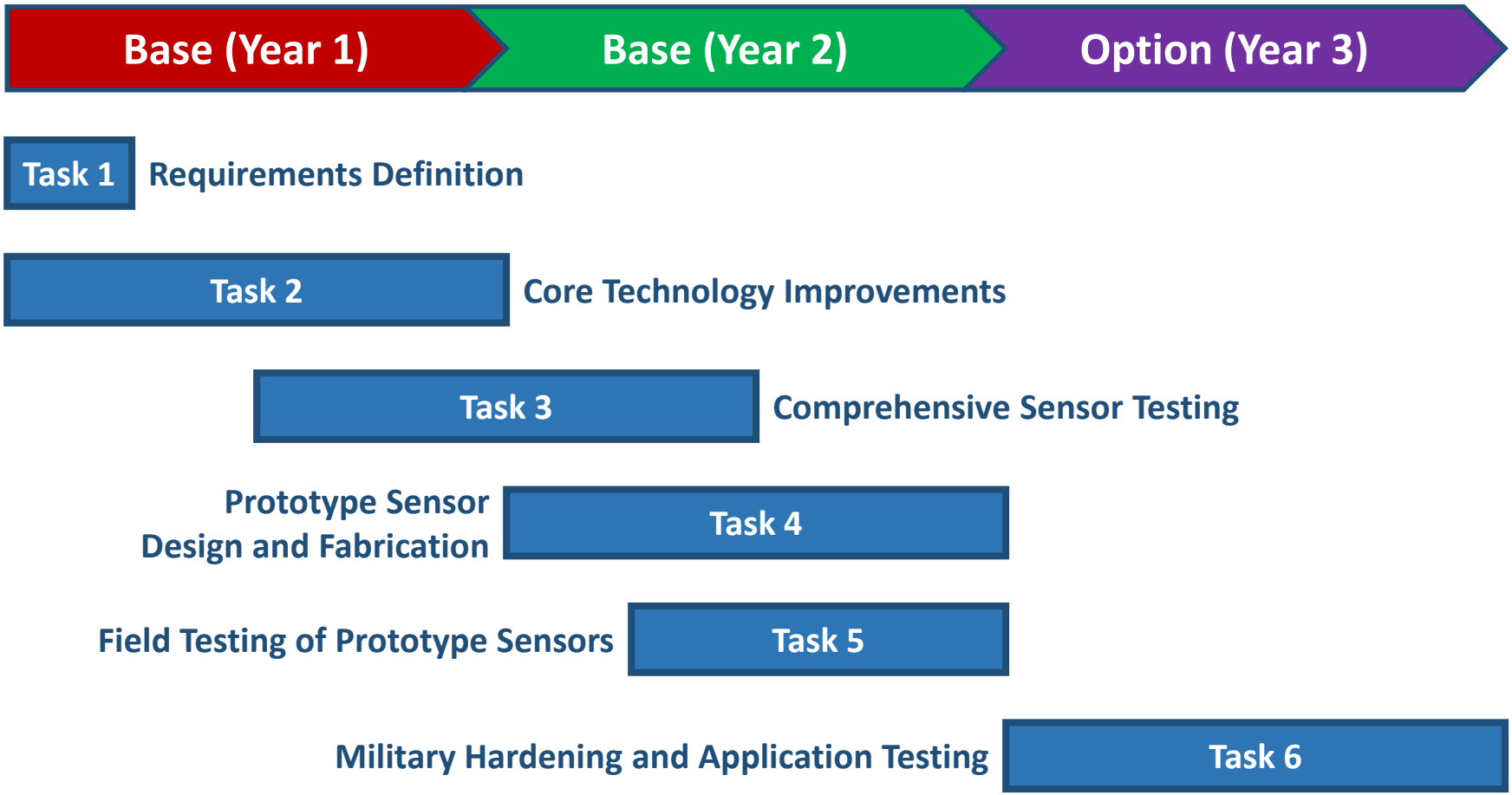
Phase II Work Plan



Testing Plan

NexTech Laboratory Testing

- Evaluation of sensor response characteristics in headspace gas of typical battery electrolytes (DEC, DMC, MEC)
- Cross-sensitivity testing to wide range of gases (HF, CO, CO_2, H_2O, other HCs)
- Response and recovery time characterization
- Long-term stability testing

Field Testing

- Sensor evaluation in relevant application environments (collaboration with Navy-selected test partners)
- Prototype device testing on military hardened optimized designs during the Option phase

Acknowledgments

NAVSEA
NAVAL SEA SYSTEMS COMMAND

arpa·e
CHANGING WHAT'S POSSIBLE

PEO SHIPS

DNV

Beckett
ENERGY SYSTEMS

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Questions?

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