# Low-Temperature Thermal Method to Preprocess the End-of-Life Lithium-Ion Batteries from Consumer Devices

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REACTION ENGINEERING INTERNATIONAL

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## Overview

**Timeline**
- Start date: 10/1/2024
- End date: 9/30/2027
- Project complete: 16%

**Budget**
- U.S. DOE: $5,543,221
- Cost share: $1,678,851
- Total: $7,222,072

**Barriers and Technical Targets**
- Cost, Safety, Clean

**Project Goal**
- Develop a clean and affordable low-temperature thermal method to preprocess the end-of-life lithium-ion batteries from consumer electronics.
- Utilize knowledge and matured technologies in the process and thermal industries to solve problems in the battery industry.

## Relevance

- 'Preprocessing' a battery before it is transported to a recycling facility so that it is no longer classified as hazardous material.
- Reducing environmental impact and improve worker safety throughout the recycling process.
- Promoting the design and production of batteries that reduce thermal run-away conditions and enable easier recycling of battery components and materials.

## Key Technologies Expected

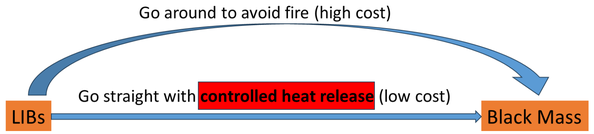
- A novel dry discharge technology that involves no comminution, no disassembly, no chemicals, and no resistors.
- A Low-temperature process to extract black mass that utilizes existing technology in the process and thermal industries.
- An integrated mobile system capable of processing various lithium-ion batteries that includes advanced processing technologies and convenient enough to provide community education regarding battery recycling.
- Fundamental understanding of battery thermal behavior that can provide valuable insight to help eliminate battery fires.

## Milestones

| Technical Milestone Description | Target Date | Status |
|---|---|---|
| Set up the thermal property database for LIB materials in SGE (>30 materials). | 06/2025 | On schedule |
| Determine the strategy for dry discharge, staged decomposition strategy (<300 °C), and black mass separation strategy (>95% black mass recovery rate). | 09/2025 | On schedule |
| Finish the design of the pilot-scale facility module. | 09/2025 | On schedule |

## Approach

- Lithium-Ion Batteries (LIBs) Fire Hazard Investigation
- LIBs Dry Discharge Investigation
- LIBs Staged Decomposition Investigation
- Black Mass Separation Investigation
- TEA/LCA Analysis
- Pilot-Scale Facility Continuous System Setup and Demonstration



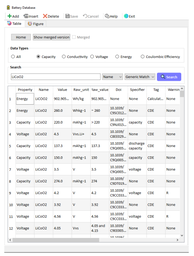

## Technical Accomplishment and Progress

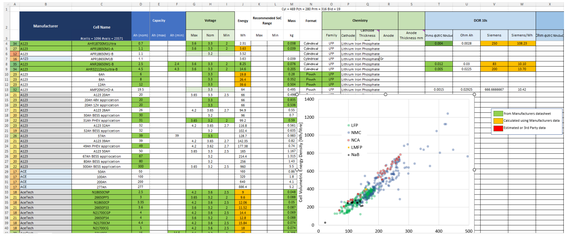
### *Executive Summary*

- In the first two quarters of the program, in addition to establishing contractual agreements with all project partners, the team has focused on developing the capability to estimate the mass of key components in LIBs, as well as designing and constructing various bench-scale systems for upcoming tests.

### *LIB Thermal Properties*

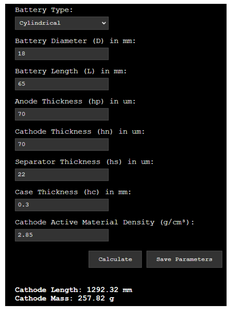
- A battery materials property database has been identified, which contains 210,416 records of chemical-property data including capacity, voltage, conductivity, Coulombic efficiency, and energy. Extracted from 223,877 scientific until the year 2021.
- A cell database has been identified, which contains 1107 cells and 23,711 datapoints of cell capacity, energy, dimension, electrode chemistry, and charge/discharge data.





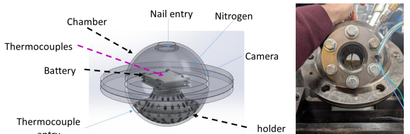
### *LIB Material Mass Estimation*

- Developed a python-based program to calculate the masses of individual component in a specific LIB cell.
- User inputs: cell shape, capacity, cathode chemistry, overall dimensions.
- Outputs: masses of electrodes, separator, electrolyte, casing, etc.

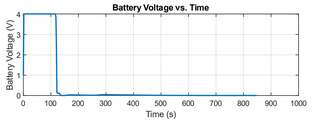


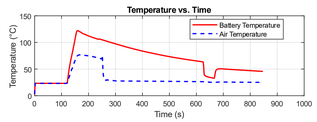

### *LIB Dry Discharging - Intermediate System*

- Designed and manufactured an intermediate-scale system to investigate battery dry discharging, featuring real-time monitoring of battery voltage, battery temperature, and ambient temperature.



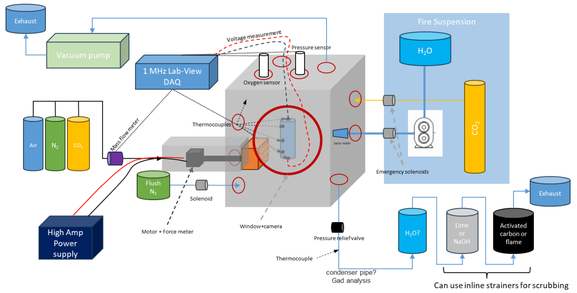


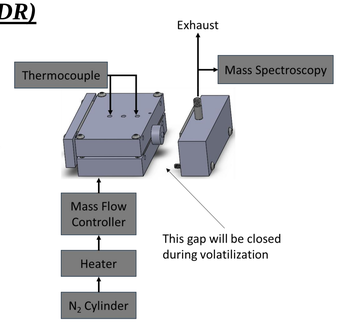

### *LIB Dry Discharging - Bench Scale System*

- Designed and built a bench-scale system to investigate battery dry discharging, enabling improved control and measurement capabilities. The system is currently undergoing safety evaluation.




### *LIB Disfunction Reactor (LDR)*

- Designed a LIB disfunction reactor capable of performing battery opening, disfunction testing, decomposition analysis, and perforation tests. The LDR enables precise control of temperature and atmospheric conditions, with integrated measurement capabilities for temperature, gas composition, and battery voltage.




## Collaboration and Coordination with Other Institutions

- *Massachusetts Institute of Technology*, subcontractor, leads LIBs dry discharge investigation.
- *Brigham Young University*, subcontractor, leads LIBs staged decomposition investigation.
- *Utah San Rafael Energy Lab*, subcontractor, leads black mass separation investigation.
- *Lion Energy*, subcontractor, provides LIBs and technical support.
- *American Battery Factory*, subcontractor, subcontractor, provides technical support.

## Remaining Challenges and Barriers

- The team has been focusing on system design and fabrication, and is now preparing to initiate experimental testing. It is anticipated that the tests will proceed smoothly without requiring significant modifications to the system.

## Proposed Future Research

- The team is finalizing the manufacturing and assembly of the bench-scale reactors and will soon initiate testing for LIB fire hazard, discharging, staged decomposition, and black mass separation.

## Summary

- Identified the LIB thermal properties database.
- Developed a program to calculate the masses of key LIB components.
- Designed and manufactured an intermediate system and conducted a few preliminary tests.
- Designed a bench scale system for LIB dry discharging.
- Designed a LIB disfunction reactor that is capable for LIB opening, disfunction test, decomposition test, perforation test.

** Future work is subject to change based on funding levels.*