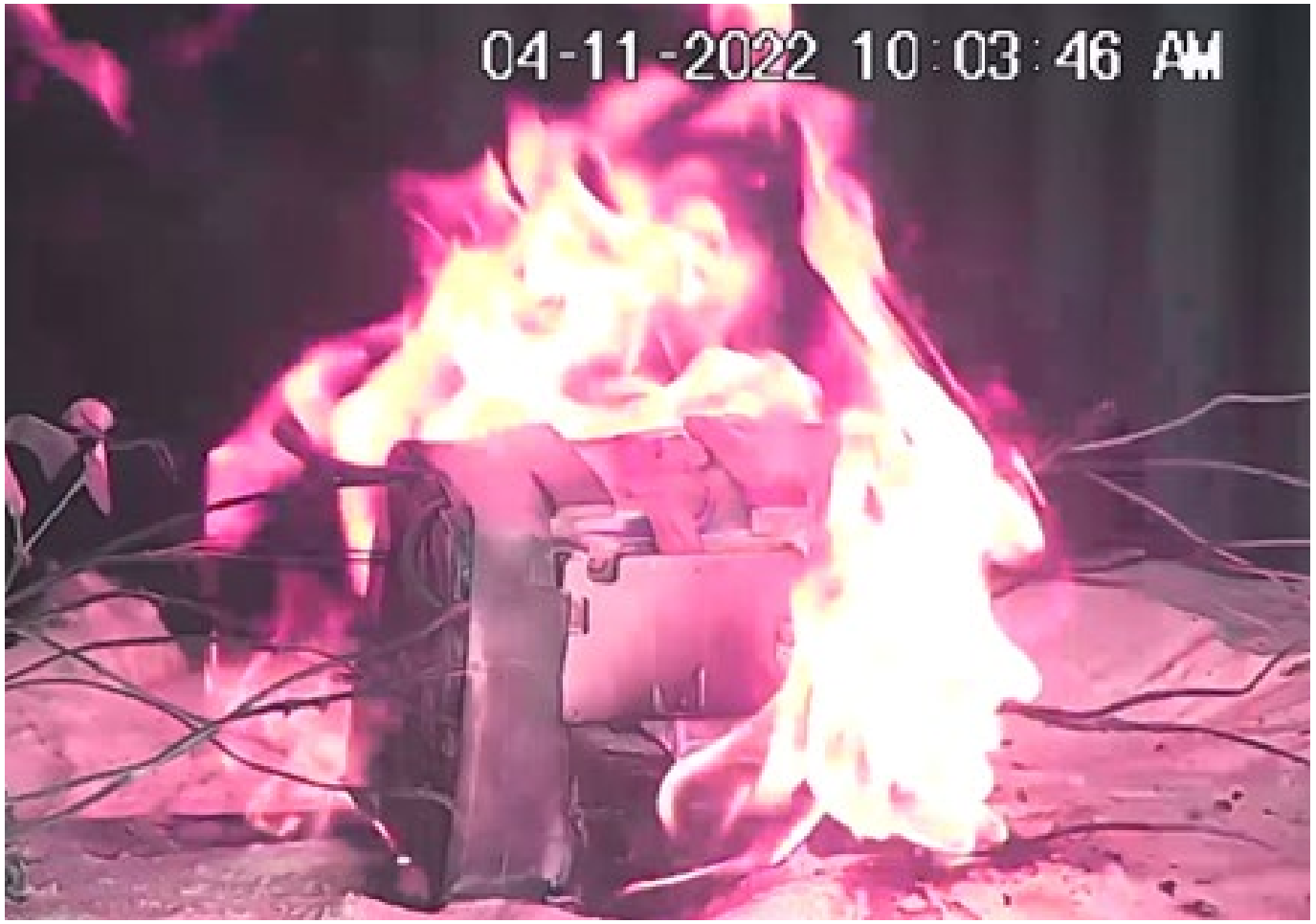
NIOSH Lithium-Ion Battery Research



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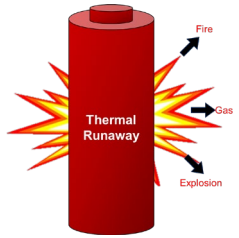
Occupational Safety and Health

Mine Automation and Emerging Technologies Health and Safety Partnership Meeting

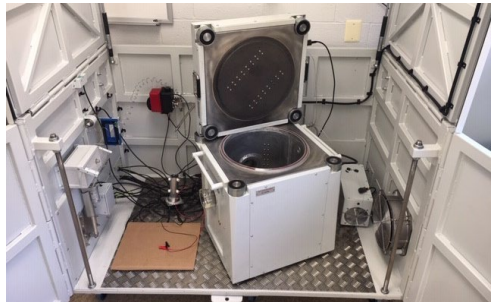
September 20, 2023

Presentation topics

Lithium-ion battery (LIB) thermal runaway (TR)



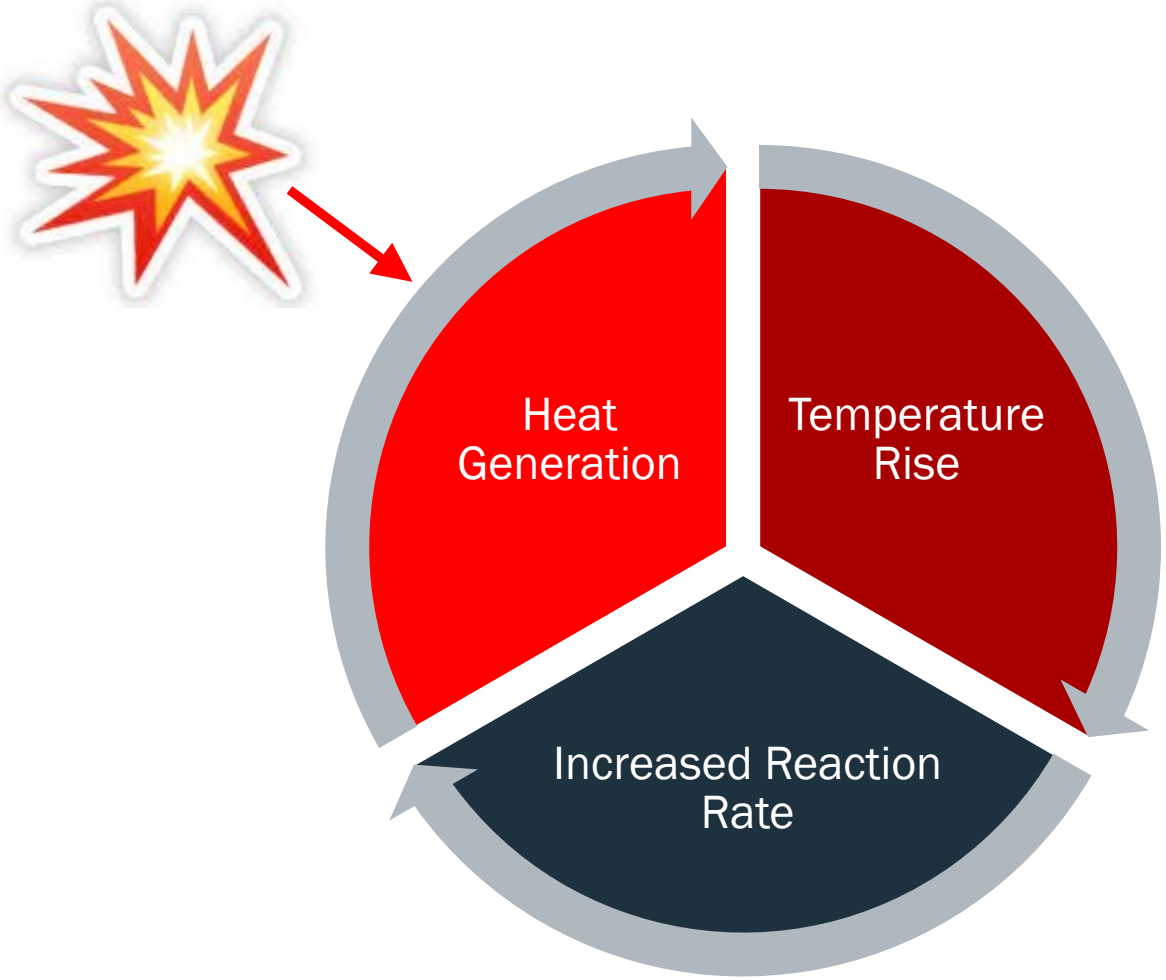
Prior NIOSH LIB research



New NIOSH LIB research projects

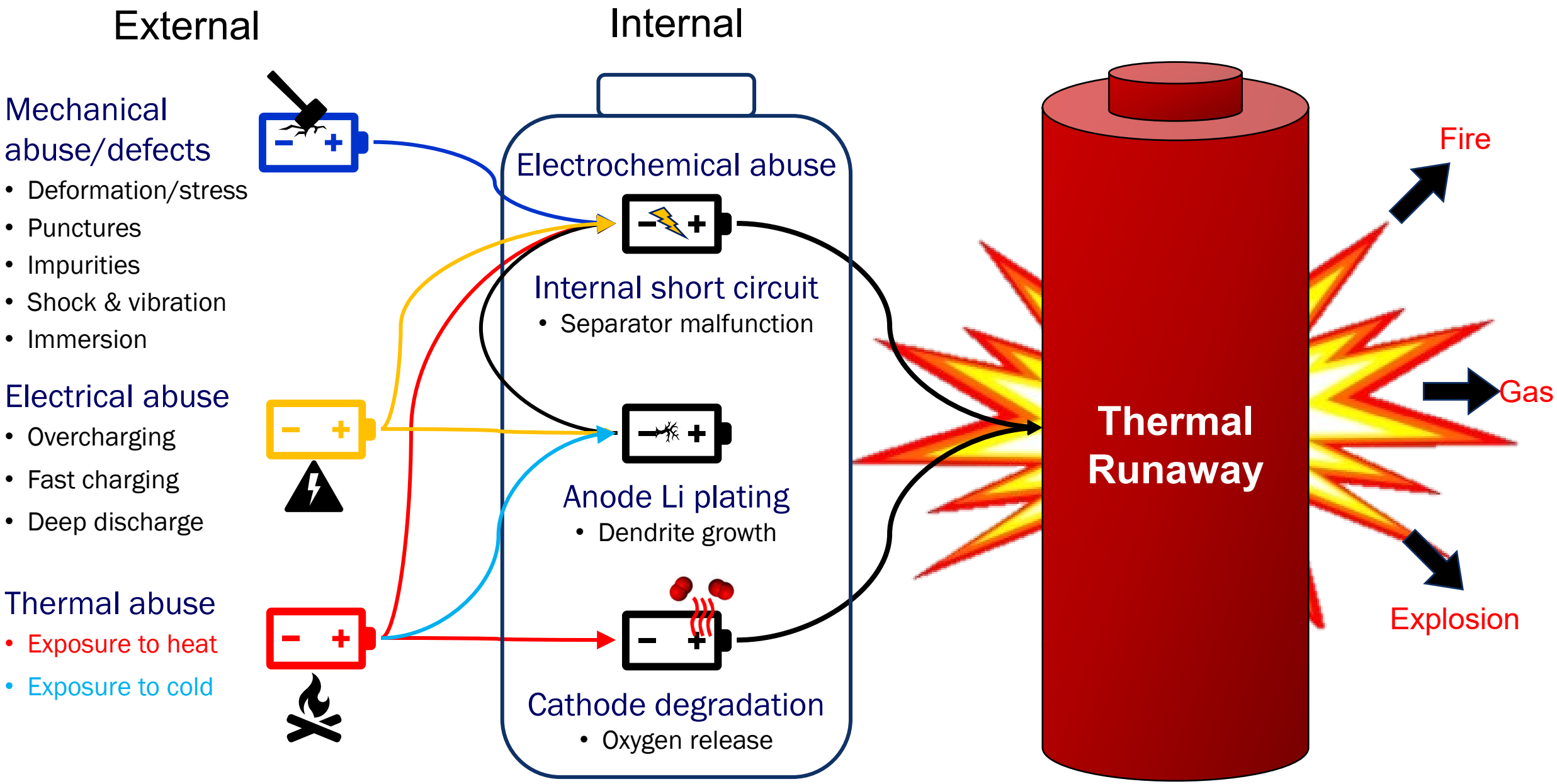
One serious concern with LIBs is thermal runaway (TR) — a chemical reaction that can lead to fires, explosions, & harmful gas emission

initiation event



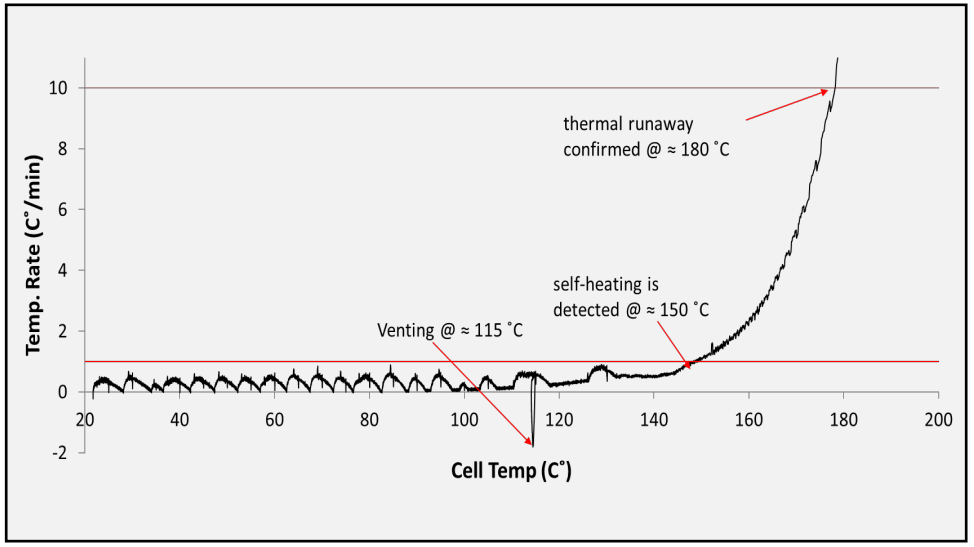
- The chemical rxn generates oxygen
- Gas generation increases pressure
- Pressure buildup can cause an explosion and release of gas

TR can be initiated by external or internal factors

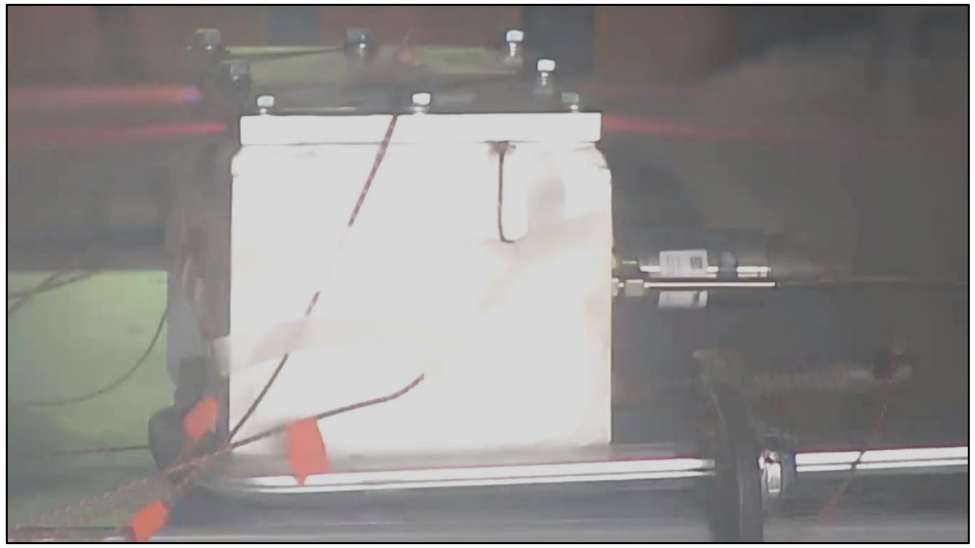


Recently, NIOSH performed LIB-TR-related research in several areas ...

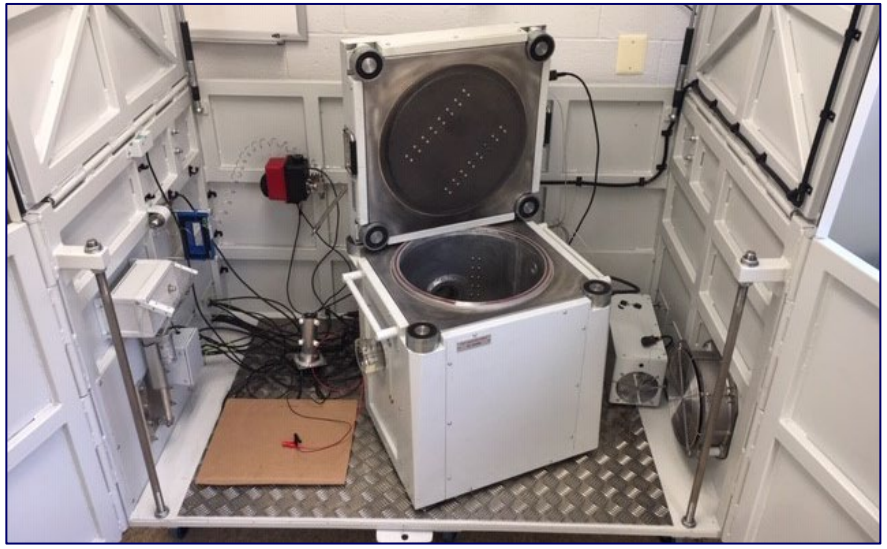
LIB Thermal Stability Tests



LIB XP Enclosure Tests



LIB Cell Heating & Gas Emission

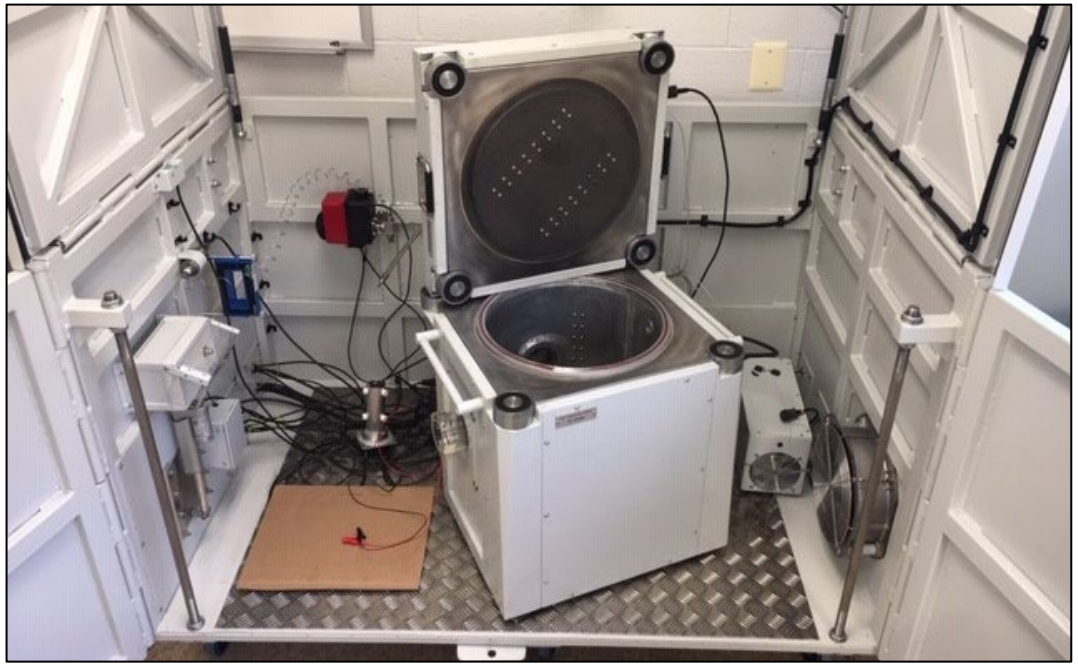


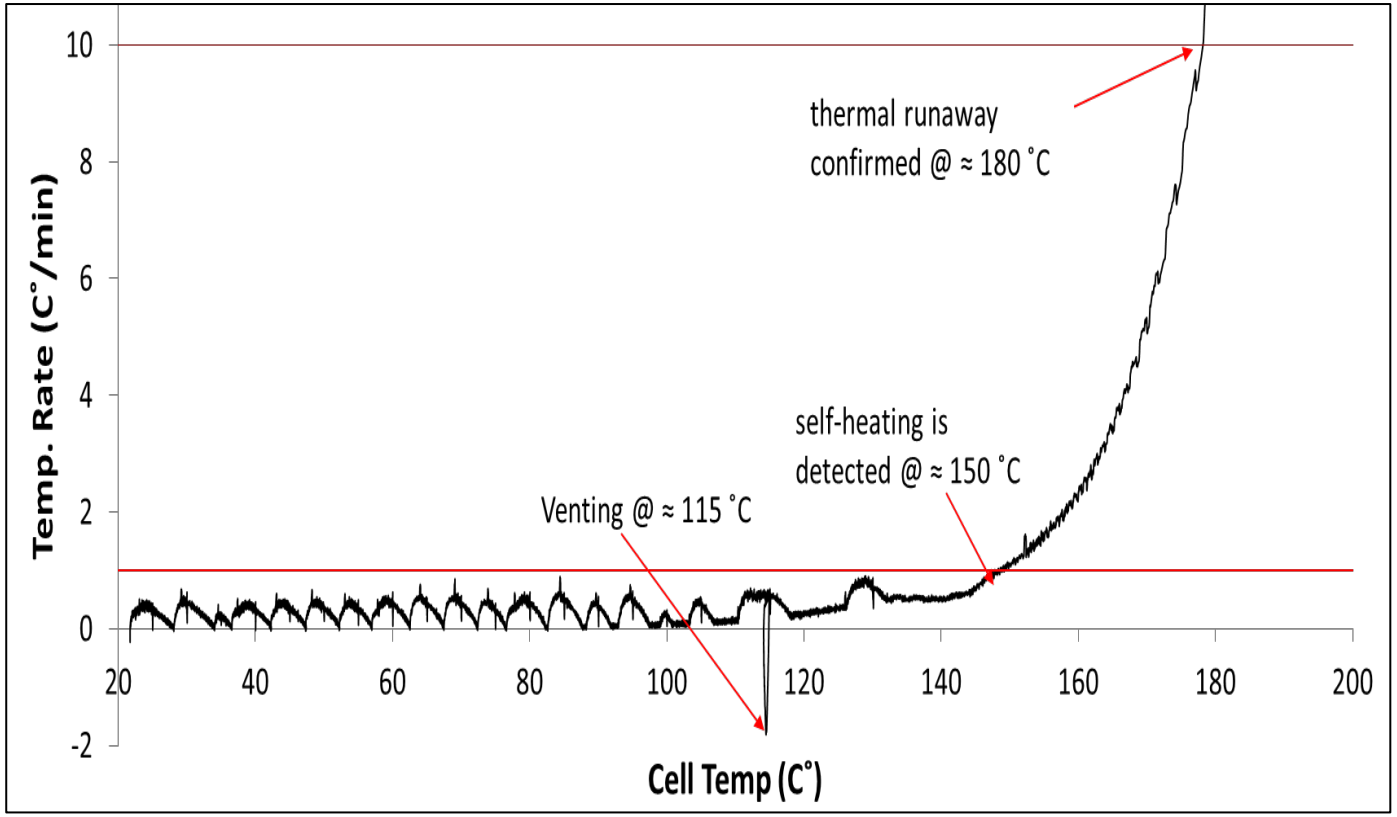
LIB Fire Suppression

NIOSH conducted trial thermal stability tests—aka HWS tests

- Follows SAE J2464
- Subject cells to a constant temperature w/ 30-min hold, monitor cell thermal response
- Test cells across a range of temperatures from 25°C to 300°C, or when TR occurs
- Determine the temperatures for venting, self-heating, and TR

accelerating rate calorimeter (ARC)





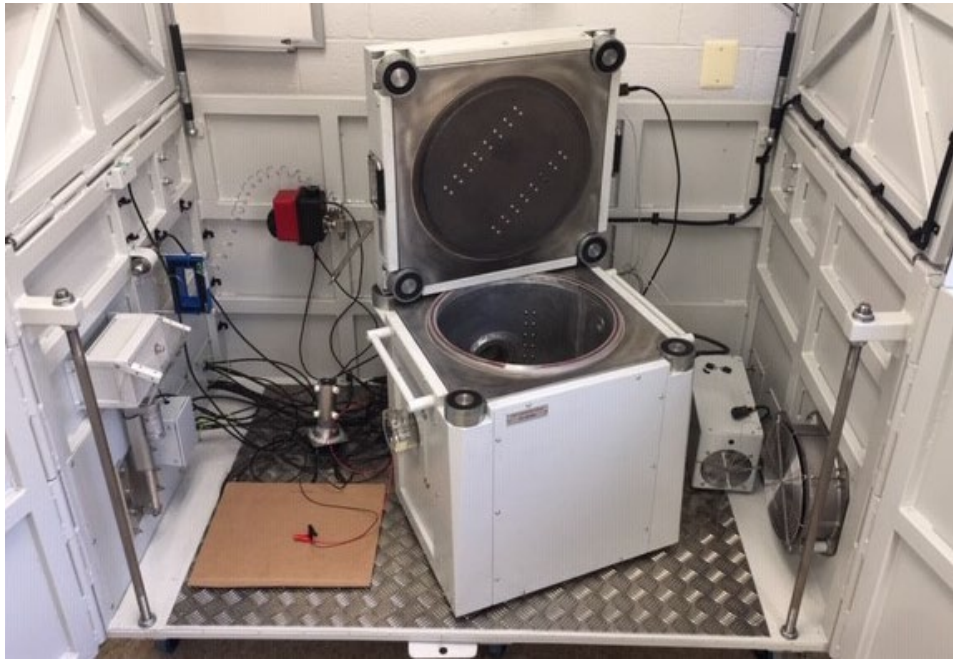
NIOSH tested LIB TR in an *explosion-proof (XP) battery enclosure*

- Depending on free space, LIB cells can generate pressures exceeding 3,000 psi during TR
- The pressure inside an XP enclosure reached ~700 psi and flames/hot gases leaked out

NIOSH conducted cell heating & gas emission tests on LFP, LTO, and NMC cells

- Cell surface temperatures (T) measured and gas samples analyzed
- NMC surface T > 800°C;
  LFP & LTO surface T < 400°C
- Primary gases generated were H_2, CO, CO_2, & CH_4
- Gas concentrations depended on cell chemistry
  - Some gas concentrations were above the lower explosive limit (LEL)
- Gas volume generated depended on cell chemistry
  - NMC cells generated 3x–4x the gas volume of the LFP and LTO cells (~10 L vs ~3 L)

accelerating rate calorimeter (ARC)

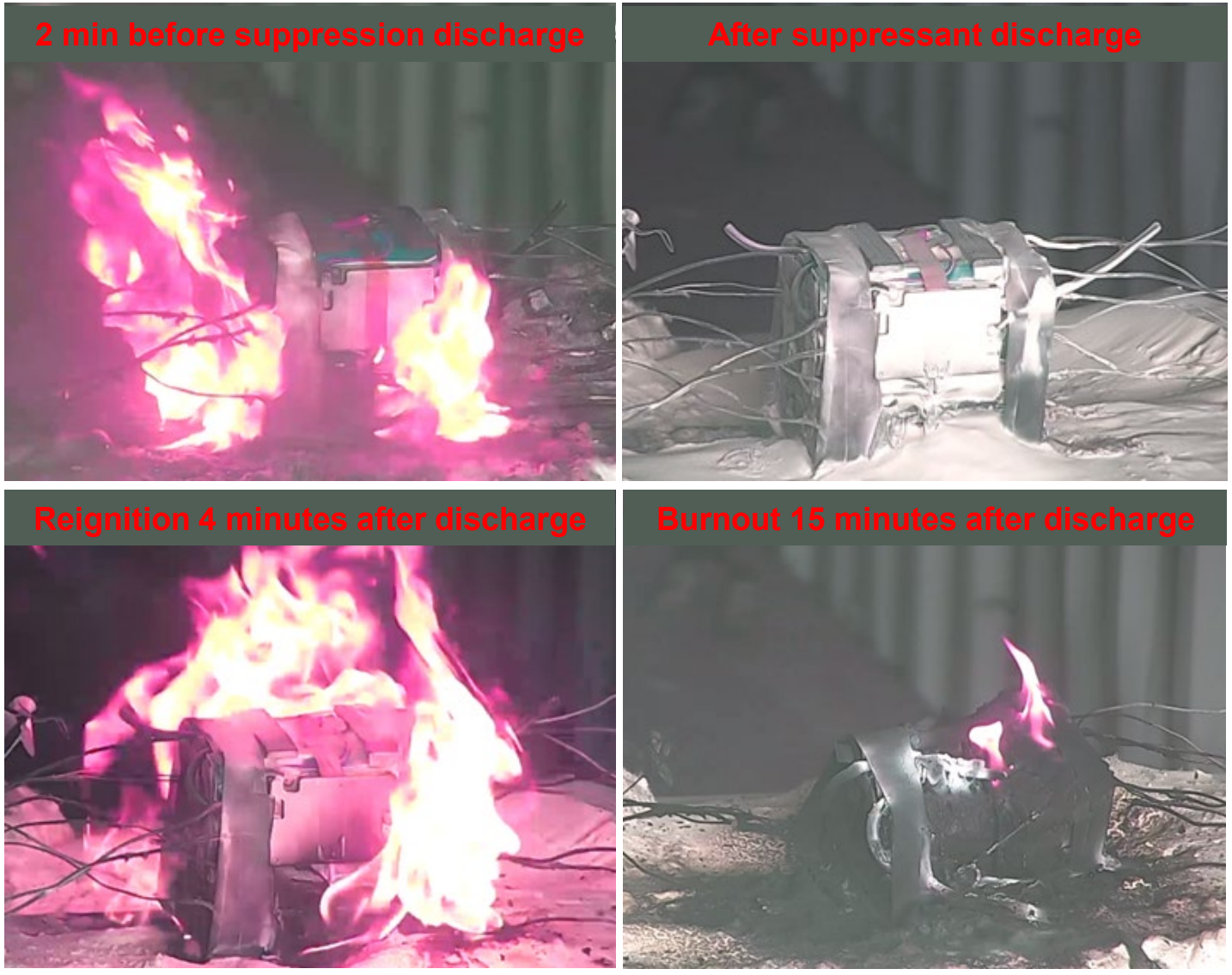


Yuan L. et al. (2020). Experimental study on thermal runaway and vented gases of lithium-ion cells. Process Safety and Environmental Protection, 144, 186-192.

NIOSH performed fire suppression tests on LFP and NMC LIB packs to assess the ability of fire suppression systems and agents to extinguish LIB fires

- Dry chemical and Class D powder temporarily put out the fire, but reignition occurred
- Water was more effective at extinguishing LIB pack fires; reignition did not occur

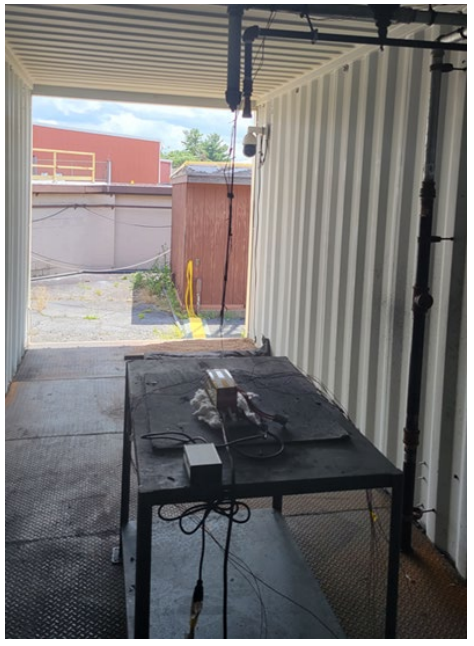
Dry Chemical Test



Yuan, L., Tang, W., Thomas, R., Soles, J. (2023). Evaluation of different suppression techniques for lithium-ion battery fires. Proceedings of the 19th North American Mine Ventilation Symposium, Edited by Purushotham Tukkaraja, pp. 384-392.

NIOSH has two new LIB-related projects that start in October 2023

Characterizing the Generation and Mitigation of Hazardous Gases During Lithium-ion Battery Failure Events



Environmental Susceptibility of Mine Utility Vehicle (MUV) and Rubber-Tired Mantrip (RTM) Lithium-ion Batteries (LIBs)

The *Environmental Susceptibility of Mine Utility Vehicle (MUV) and Rubber-Tired Mantrip (RTM) Lithium-ion Batteries (LIBs)* project will examine the effects of mechanical shock, vibration, temperature, and moisture on LIBs

The MUV/RTM LIB project consists of several tasks with the goal of preventing adverse LIB events caused by environmental conditions

1. Collect operating data to understand the environmental conditions
2. Develop a rigorous test procedure for LIBs used on MUVs and mantrips
3. Conduct laboratory testing on MUV/mantrip LIB cells, modules, and packs
4. Design LIB installation methods to protect them from environmental effects









Field data collection is an essential element of understanding the complexities of the mine environment

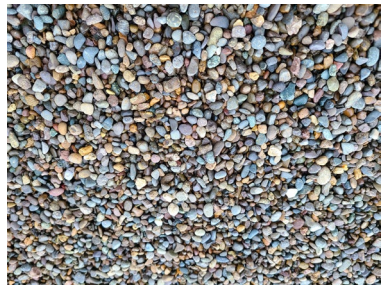
- Goal is to collect data near MUV and RTM battery compartments at underground and surface mines in all commodities

The field and in-house data will be used to develop a rigorous test procedure to evaluate reliability of LIBs

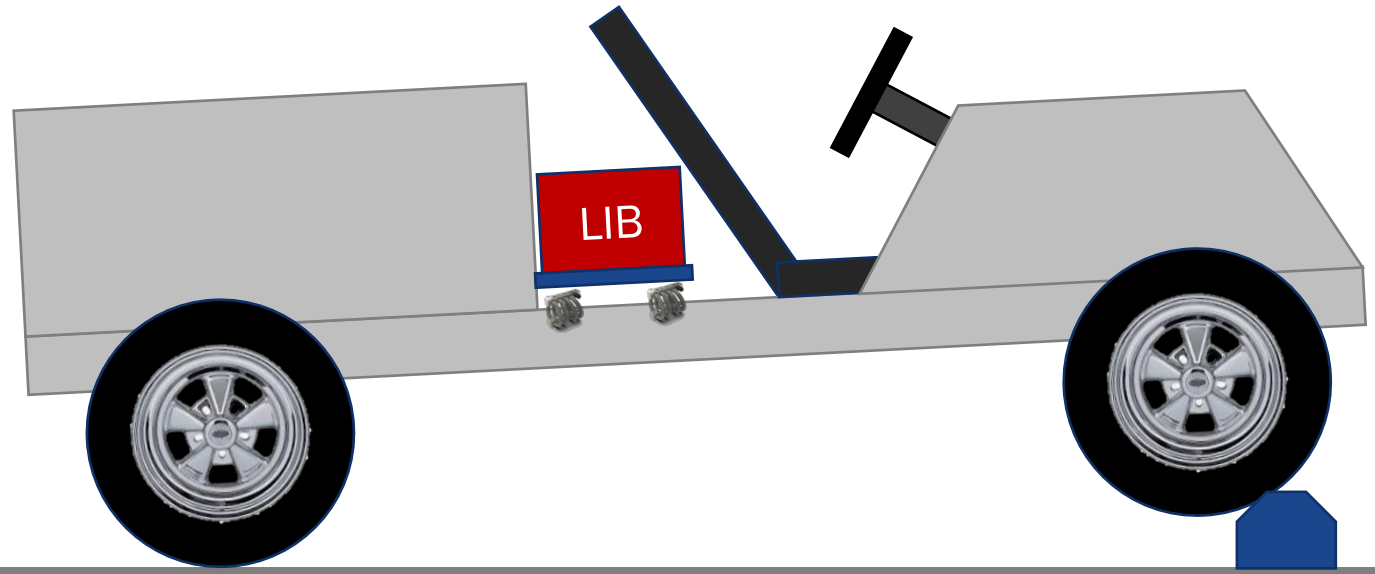
- Mechanical shock and vibration data will be scaled to reduce time needed for life cycle testing
- Multiple parts to the test
  1. Drop test
  2. Mechanical shock and vibration tests at various T and SOC
  3. Battery immersion test
     - Go to #2

Field shock and vibration data will be used to develop an internal test track in the NIOSH Experimental Mine

- Replicate field measurements
- Collect additional data with varying speed, terrain, mild collisions, etc.
- Prove out LIB installation methods

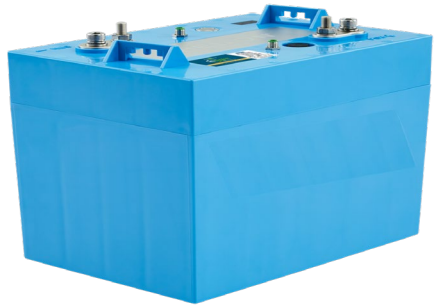


To reduce transmitted mechanical shock and vibration, we will design and test battery isolation systems

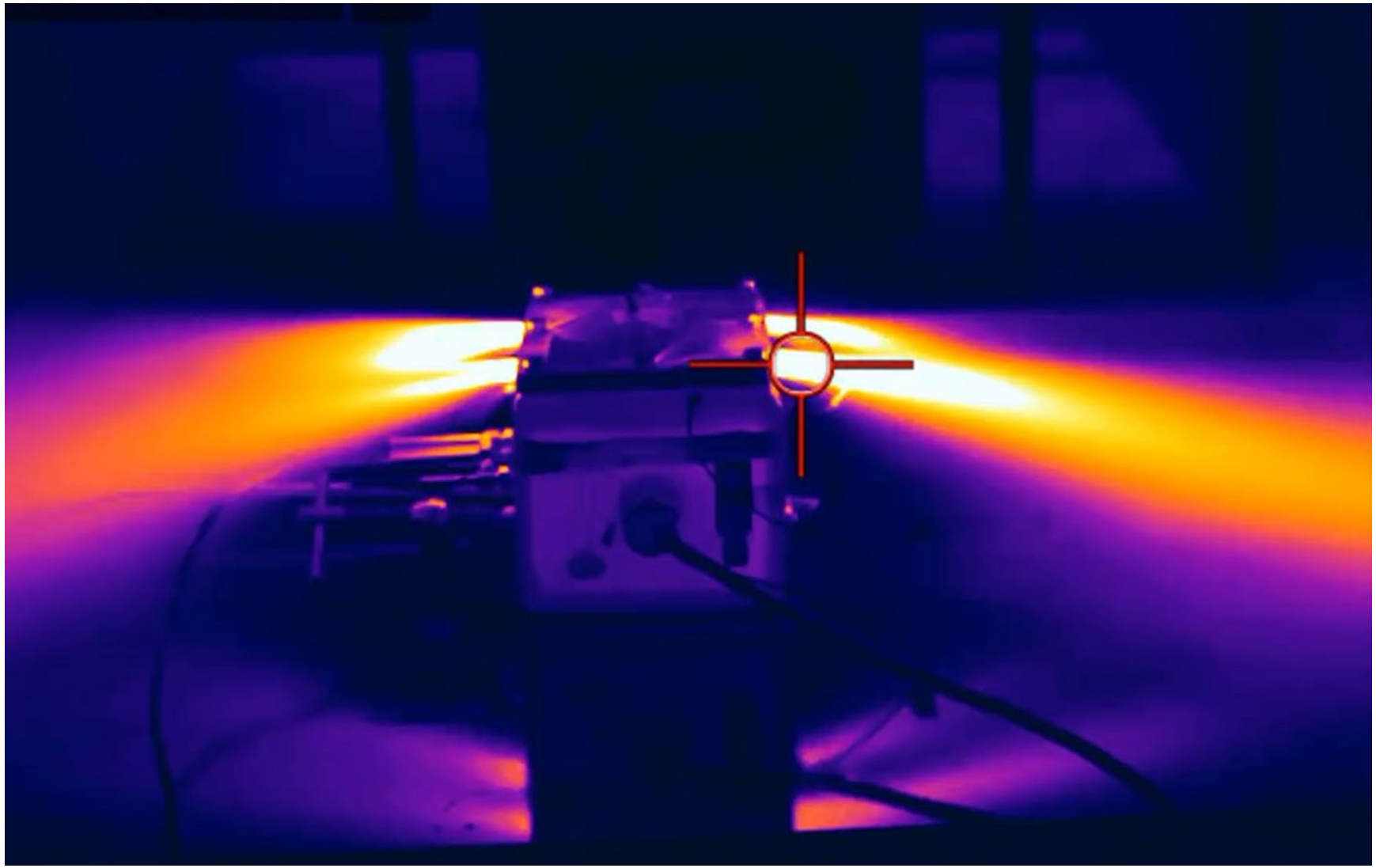


The project will have multiple benefits to MUV and mantrip manufacturers, battery suppliers, mines, and regulatory agencies

- Knowledge of the operating conditions for MUVs/mantrips
- Improved LIB safety and durability
- Reduced risk of LIB thermal runaway



Questions?



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