NYSERDA / Consolidated Edison Battery Energy Storage Safety Testing Program

Conducted by DNV GL

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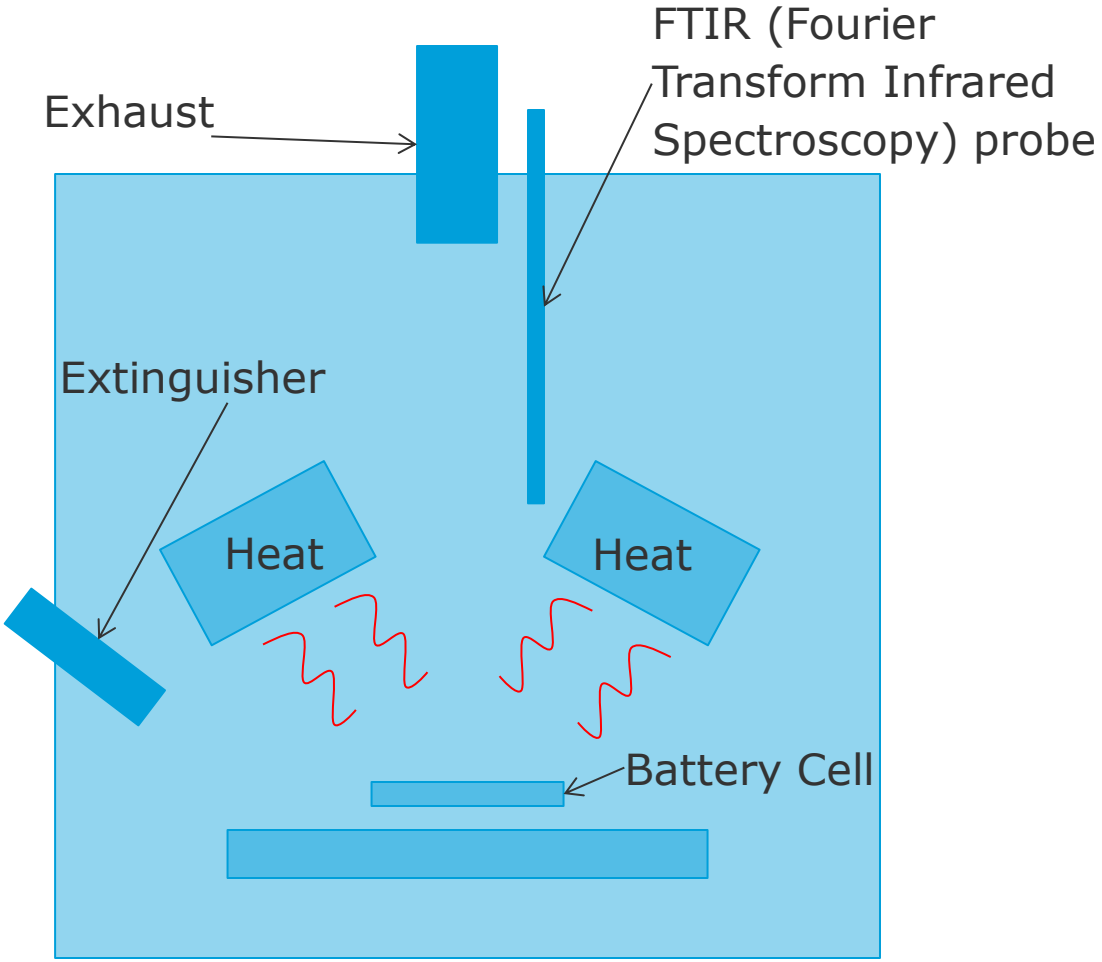
Work Scope

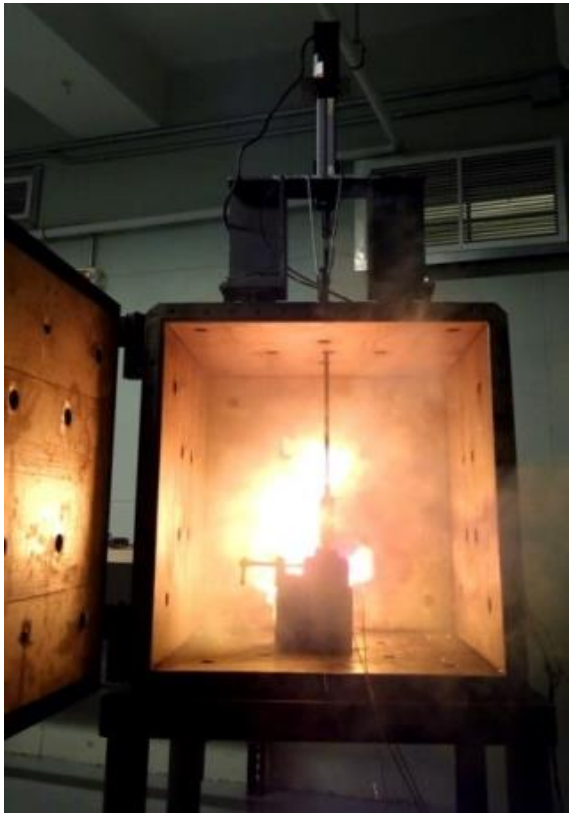
1. Literature Review and Background
   - Precedents
   - Incidents
   - Toxicity for multiple chemistries
2. Chemistries to undergo testing
   - 4 Li-ion NCM
   - 1 Pb Acid
   - 1 Li-ion Titanate
   - 1 Li-ion Iron Phosphate
   - 1 Vanadium Redox
3. Lab Testing, Module Testing
   - Cell level tests for SOC, heat production, extinguisher variables
   - Module tests to confirm lab tests and models at scale
4. Models (heat and plume at scale)
   - FEA
   - DNV GL PHAST
5. Final Report

Important Distinction for the purpose and context of testing:

Battery as *fuel*, not battery as *cause*

Lab Testing



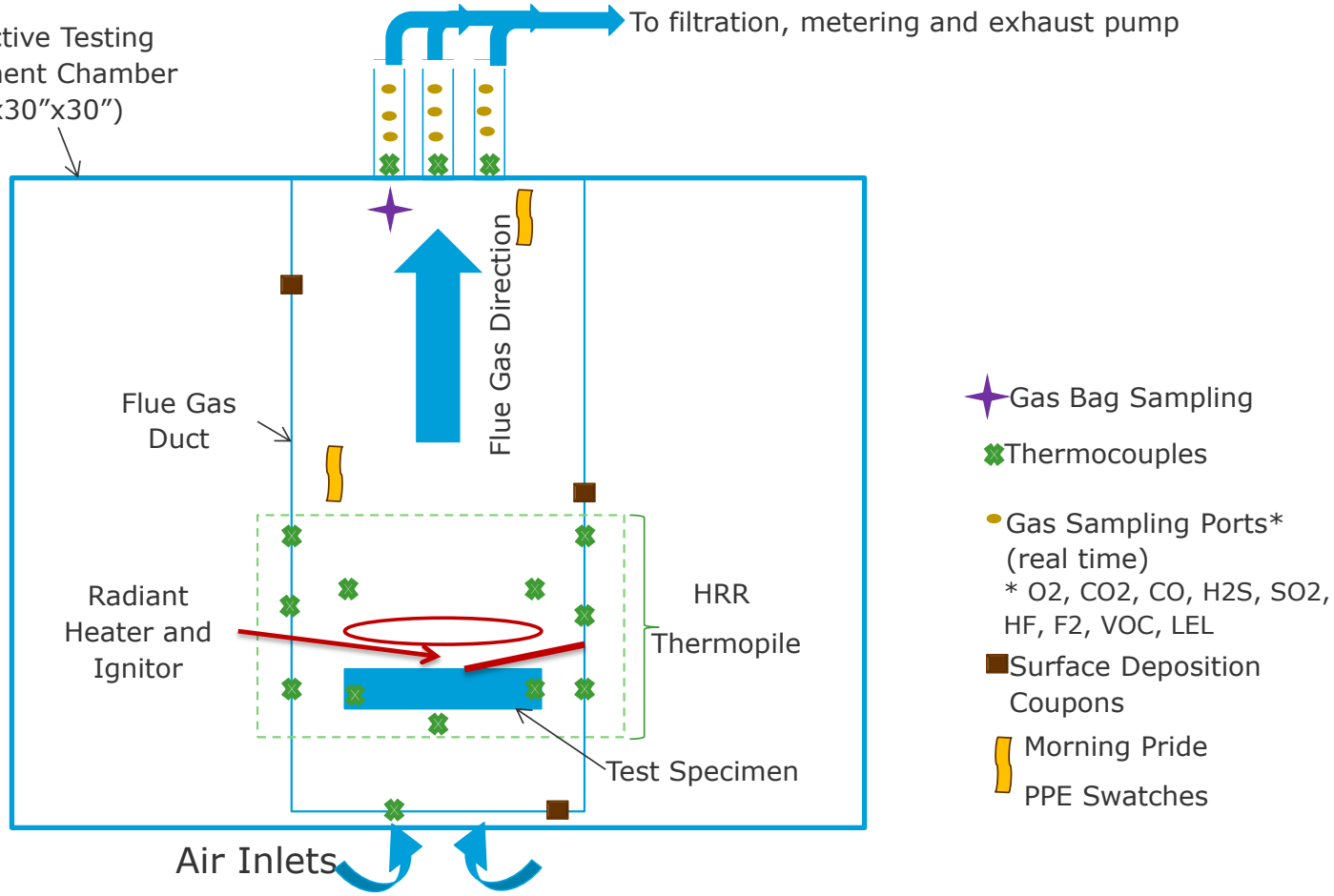


Large Battery Abuse Chamber

- configurable to test conditions
- Steel with stainless liner
- Multi-sensor array

Swatches and Coupon Sampling

- **Degradation of swatch materials**
- **HAZMAT information for toxicity of dust/particulate**



Combustion Gas Analysis

- **Flammable Gases**
  - CO
  - H_2
  - CH_4 and other hydrocarbons

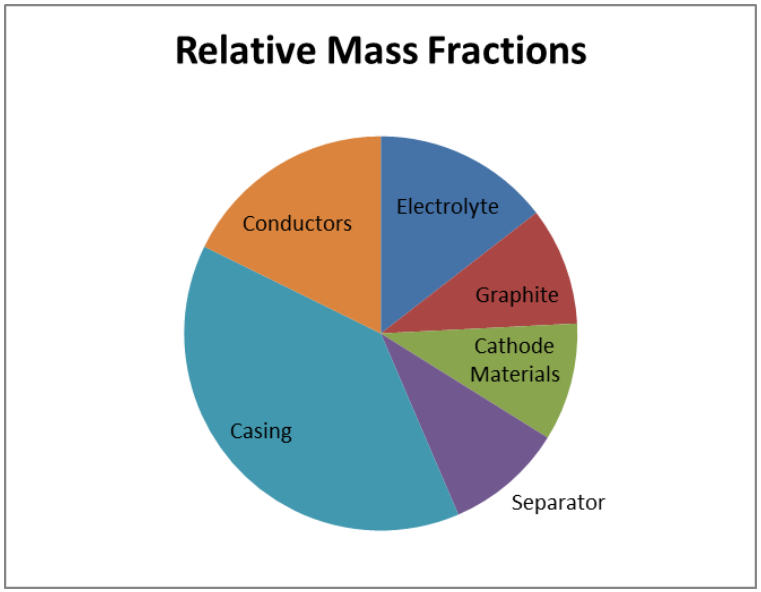
- **Common irritants and asphyxiants**
  - CO
  - HCl
  - HCN
  - HF
  - No_x
  - SO_2

Heat Release, Flammability, Smoke and Toxic Hazard of Various Aircraft Insulated Wires

Lawrence D. Schwartz, Raychem Corporation, Menlo Park, CA
Richard H. Whiteley, Raychem Ltd., UK
Peter J. Elliot, Raychem Ltd., UK
Arthur F. Grand, Omega Point Laboratories, Elmendorf, TX

Sources of Gases

- Electrolyte solvents
- Cathode binders and active materials
- Polymer separators and casing



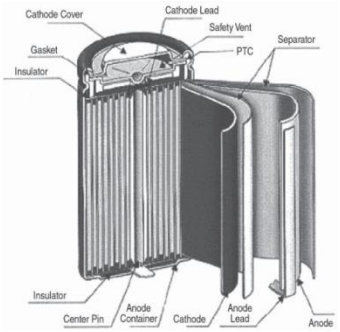
Battery Form Factors

- Pouches
- Cans
- AGM (Pb Acid)
- Electrolyte (Vanadium Redox)

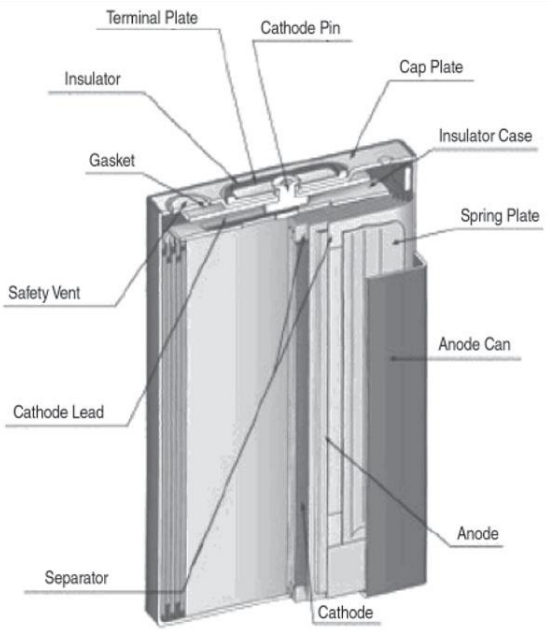
Images reference:

(Cylindrical and Can) Materials and Processing for Lithium-Ion Batteries, Claus Daniel JOM Sept 2008

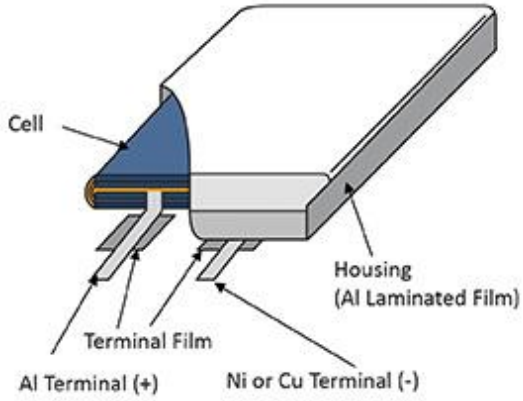
Pouch: Targray



Li-ion cylindrical cell



Li-ion "Can" cell



Li-ion pouch cell

Heat Release Rate

- ASTM 906 and ASTM 1354 with modifications
  - Oxygen measured to quantify O_2 consumption
  - Temperature monitored in multiple locations
  - Aggregate thermal conductivity of battery mass measured
  - Heat rise as a function of battery mass and active material

Objective:

Determine how much heat is released during exothermic reactions, ignition temperatures, and how this may scale

Generalized Test Procedure

- **Steps 1-3:** Collect background gas baselines, begin heating and video
- **Step 4-6:** Monitor heat rise, gas levels, and oxygen until heat peaks. Monitor for exothermic heat release.
- (Extinguishing occurs at this step in extinguisher tests)
- **Step 7-8:** monitor decreasing heat rate or cooling rate from extinguishing
- **Step 9:** Collect debris, deposition coupons, PPE swatches for particulates, carcinogenic elements
- **Step 10:** Monitor for reignition, reignite if possible.

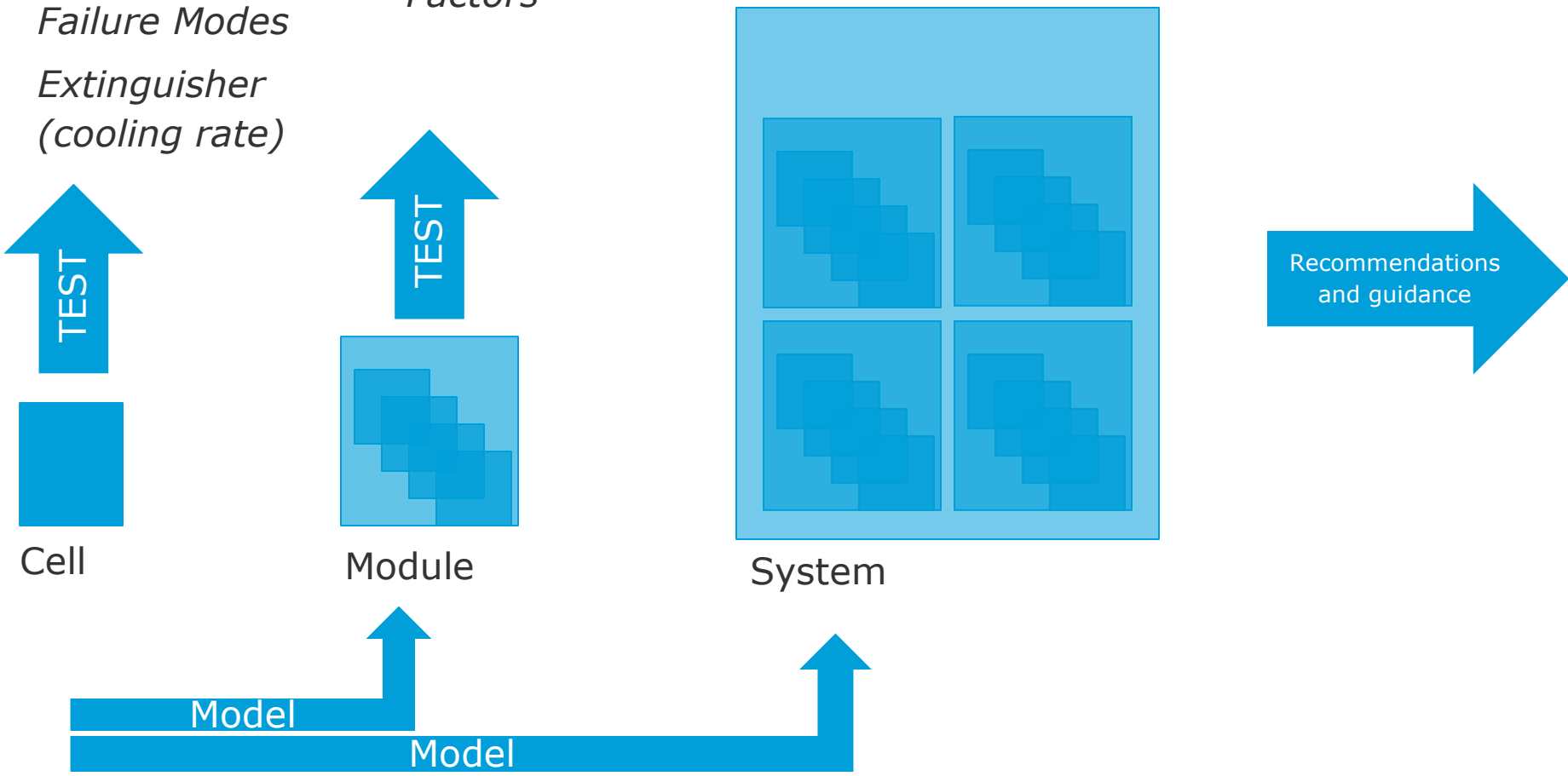
Considerations for Pb-Acid, Vanadium Redox:

- Testing electrolytes separately, heating and monitoring gases in headspace

Modeling Strategy

- *HRR*
- *Toxicity*
- *Failure Modes*
- *Extinguisher (cooling rate)*

- *Validates Scaling Factors*



Test Plan and FAQ Available upon Request

CONSOLIDATED EDISON - NYSERDA TESTING SCOPE FOR BESS PROGRAM

The total project scope for the Consolidated Edison-New York Energy Research and Development Authority (NYSERDA) BESS program is shown below. It includes four project tasks with a final report, which also includes the development of guidelines and training materials.

CONSOLIDATED EDISON – NYSERDA BESS FAQ

In response to battery manufacturer and other stakeholder inquiries, DNV GL[1] wishes to answer questions and provide direct insight into the testing being performed in the Consolidated Edison - NYSERDA BESS program. The following pages summarize answers to common questions[2] about what is being performed in this program.

Timeline

1. Cell testing is underway presently
2. Extinguisher testing (cells) about to commence
3. Module testing (with project partner Rescue Methods) will occur in Delaware, OH in the July-August (pending EPA permit timing)
4. Modeling occurring in parallel as data is produced
5. Periodic reporting to Con Ed / NYSERDA
6. Stakeholder engagement guided by Con Ed and NYSERDA
7. Draft Report in early Fall
8. Final report before end 2016

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