



Facility Design for Thermal Runaway– PNNL Grid Storage Launchpad

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PNNL is operated by Battelle for the U.S. Department of Energy



Introduction and Agenda



- Adam Jivelekas, Nuclear Engineer and Facility Safety Analyst
- ME, Fire Protection  BS, Mechanical Engineering 
- 10+ years of facility safety analysis and design of complex systems for hazard mitigation

- Grid Storage Launchpad (GSL) Overview and Capabilities
- Design of the “kW Test Lab” for flammable gas safety
 - Unique Challenges for Research
 - Code of Record and Hazard Analysis Process
 - ★ **Challenges of Safety System Design for Li-ion Thermal Runaway**

GSL Overview and Capabilities

- Material synthesis, prototyping, and cell assembly, up to 5kW
- Cell-level testing
- Realtime “In-operando” characterization and quiet suite
- **kW Test Lab – ESS grid simulations up to 100kW/400kW-hr**



kW Test Lab - Unique Challenges for Research

- Wide flexibility in BESS types
 - Organic-based electrolyte (Li-Ion)
 - Aqueous electrolyte (Lead Acid)
 - REDOX Flow
 - Molten Salt
- Undefined configurations, systems, controls, interfaces,.....
- Designing for Safety : Performance-based design, without well-defined hazard criteria



Facility Design for World-Class Safety

- US Department of Energy facility design life is nominally 40 years
- Risk tolerance and safety culture are rooted in nuclear facility operations
 - Design for the “unmitigated” scenarios
 - What is the worst-case?
- Code and standards-based design
 - Understanding the relative youth of the industry and technology
 - Forward looking to new technologies and known unknowns

Evaluating Hazards: Industry Perspective

- PNNL GSL Design Team toured multiple testing facilities across the country to understand hazard mitigation strategies used in similar facilities



General Motors 100kW Test Lab –
Commercial Off-The-Shelf Testing
Chambers



Naval Surface Warfare Center – Standard industrial
construction for battery storage and cycle-testing
operations

Evaluating Hazards : Code Perspective

- NFPA 855, *Standard for the Installation of Stationary Energy Storage Systems*
 - Broad applicability to GSL; limited nuance for research facility
 - Guidance and scope for Hazard Mitigation Analysis (4.1.4.1)
- DOE Standards
 - DOE O 413.3B, *Program and Project Management for the Acquisition of Capital Assets*
 - ✓ Formal Hazard Analysis Requirements
 - DOE-STD-1066-2016, *Fire Protection*
 - ✓ Control of flammable gasses
- NFPA Explosion Prevention and Mitigation Standards (NFPA 69 and NFPA68)

kW Test Lab Flammable Gas Control Strategy

Planning and Prevention

1. Battery system acceptance evaluation (protect facility operating envelope)
2. Conduct of Operations/Maintenance
3. Battery management system interlocks
4. Battery cyler or grid simulator interlocks
5. Facility interlocks (room temperature, loss of HVAC)
6. Local off gas detection interlock
7. **Room off gas detection and interlock**

Hazard Management

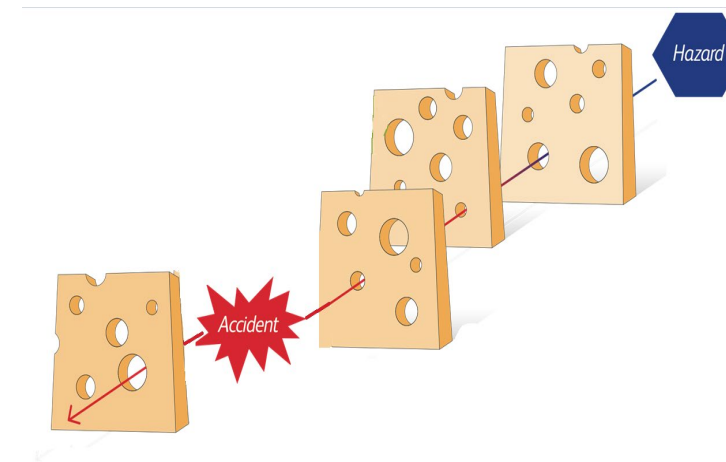
1. Early warning alarms and staff response
2. **Emergency exhaust, NFPA compliant SIS**
3. Fire suppression system

Mitigate

Post-incident Mitigation

1. **Passive deflagration venting**
2. Robust separation of test rooms
3. Emergency response procedures

Prevent



The Devil is in the Details – NFPA 69

- NFPA 69, *Standard on Explosion Prevention Systems*

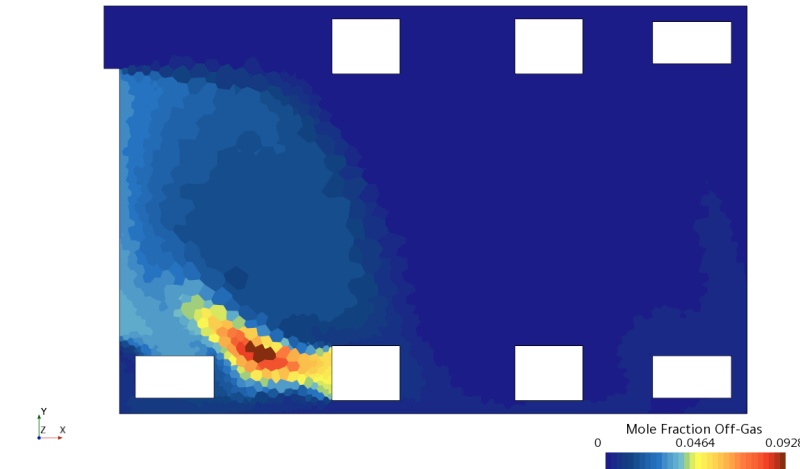
- Chapter 8, “Deflagration Prevention by Combustible Concentration Reduction”
- ‘Detect & Exhaust’ - Sounds simple?



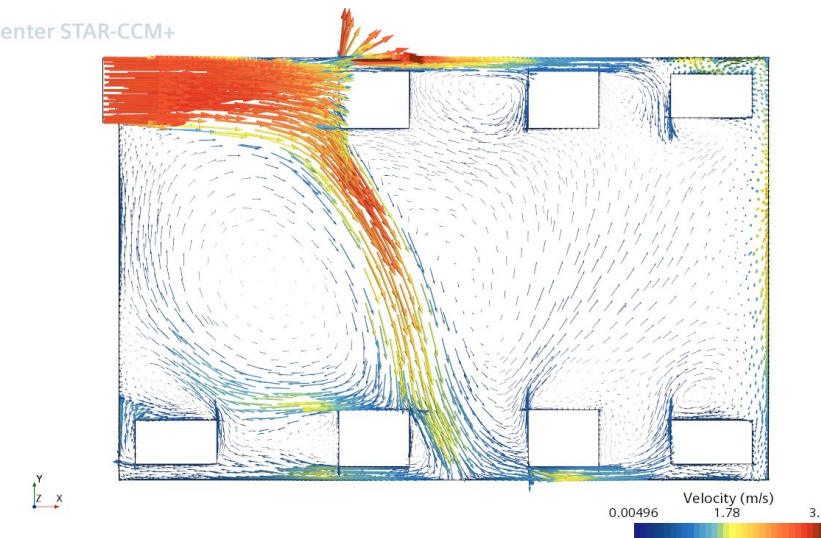
- Design Challenges

- System capability
 - ✓ Estimation of maximum rate of gas release
 - ✓ Conservative design margin (@GSL, 256ACH for 32CFM of off gas)
- System Reliability - ANSI/ISA–84.00.01, SIL-2
 - ✓ PLC-based control system
 - ✓ Redundancy and fault tolerance
 - ✓ Equipment pedigree
- Long-term Maintenance
 - ✓ Tight configuration management and maintenance program to maintain SIL rating

Simcenter STAR-CCM+



Simcenter STAR-CCM+



The Devil is in the Details – NFPA 68

- NFPA 68, *Standard on Explosion Protection by Deflagration Venting*
 - Chapter 7.2, “Venting by Means of Low Inertia Vent Closures”
 - ‘Install a few rated relief panels’ – Sounds simple?
- Design Challenges
 - A.7.1.1 - For fast burning gasses NFPA 69 should be used.
 - Massive vent areas for full-volume stoichiometric (505 m²)
 - ✓ How to define a more realistic partial-volume event?
 - Wall strength to minimize vent area
 - Fireball hazards
 - Unintended pressure relief pathways

Take Aways

- ESS hazards are well understood, yet unique and complex
- Hazard mitigation strategies are available through codes and standards
- Consider the safety posture of your facility early and often during project development
- Take the time to consider the likely end points for safety system design early and plan accordingly



ESS Fire Aftermath Near Seoul, SK, 2021

Thank you

