Pacific Northwest
NATIONAL LABORATORY

ES Safety & Reliability Session

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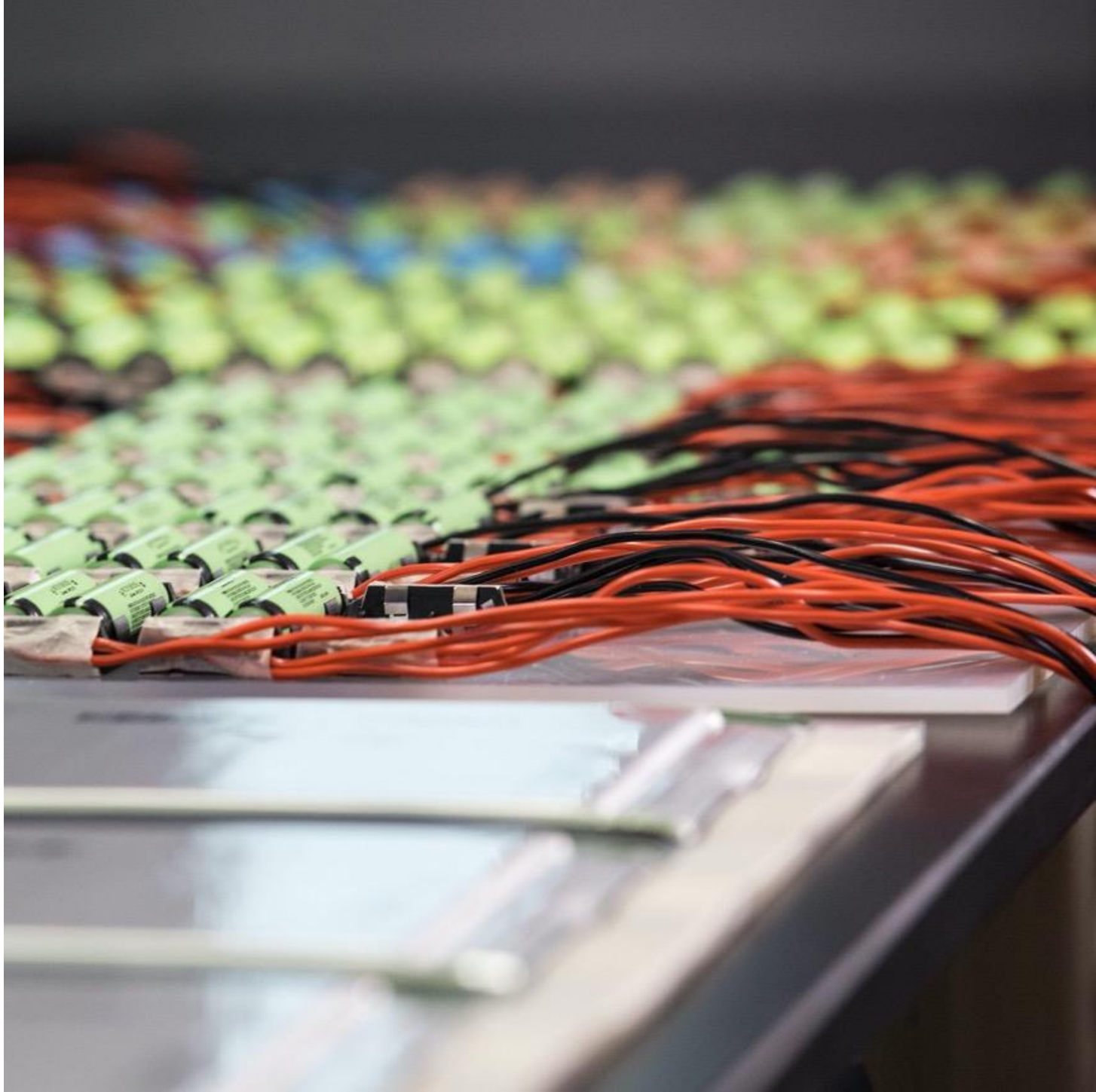
Session Lead



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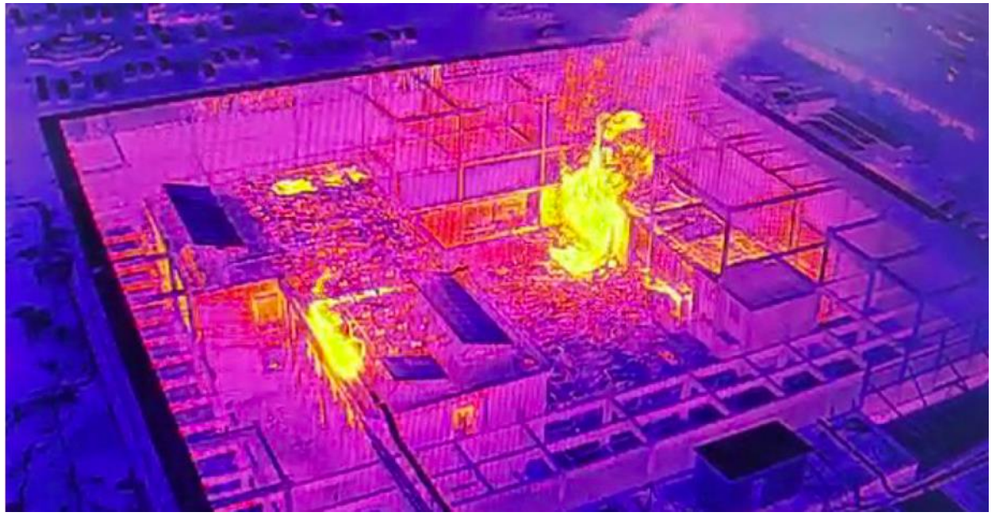
OE Lab Efforts in Safety & Reliability

- Safety has been in the spotlight with several significant ESS failures
  - Explosions in Liverpool & Beijing
  - Recalls of residential ESS and EV's
  - Thermal Runaway prevention, detection, and suppression remain critical gaps
- Continued developments by National labs in the areas of battery degradation modeling and predictive analytical tools such as:
  - Battery Archive by SNL
  - Thermal runaway risk database by ORNL
  - Lithium-ion Modeling with 1-D Thermal Runaway by SNL
  - Developing 2nd Life validation protocols by PNNL
- Updates on safety and reliability codes & standards efforts:
  - Program metrics & milestones
  - Future work including update to the DOE ES Safety Strategy

Deflagration Risks

- Explosions in Li-ion BESS have resulted in 3 fatalities (Beijing) and 2 serious injuries (Arizona).
- With limited fire suppression capabilities, a defensive firefighting approach is warranted while preventing for deflagration.

Credit: Business Korea



Credit: China Electric Power Research Institute

Background

- Lack of exhaust ventilation was identified as leading gap in APS incident. Other explosions will occur in similarly designed systems.
- Deflagration prevention lacking in most systems.
- Listing to 9540 costly for large systems due to 9540a fire testing.

Credit: APS

Explosion Control Gaps

- Providing deflagration venting is a late-stage measure. Does not eliminate flammable gases prior to explosion
- Deflagration **prevention** is the key!
- But…smaller volume cabinets make exhaust ventilation even more challenging
- Exhausting must occur rapidly

Credit: Merseyside Fire & Rescue

ESS Cabinets Becoming Common

Credit: Tesla Energy

Advantage:

- Trending due to modular design flexibility for smaller projects
- Safer installation due to less on-site connections
- Listing Requirements

Challenges:

- Difficult to provide deflagration prevention due to small air volume
- Lower energy density for larger projects

Credit: Fluence

Deflagration Challenges

- System with clean agent suppression system.
- TR continued after deployment
- Deflagration occurred @ 44min
- Event required direct water application.

Demonstration 2 – Timeline of Major Events

Smoke accumulation at second smoke detector activation [TR + 00:00:55]

Novec 1230 discharge [TR + 00:00:58]

Smoke stratification before ignition [TR + 00:26:51]

Ignition [TR + 00:28:32]

Partial volume deflagration [TR + 00:44:39]

Continued thermal runaway propagation [TR + 00:46:26]

Smoke plume from open door [TR + 02:09:27]

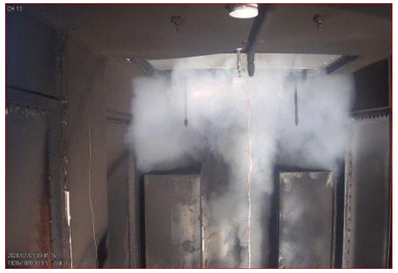
Flashover and flaming from open door [TR + 02:09:48]

https://ulfirefightersafety.org/docs/UL9540AInstallationDemo_Report_Final_4-12-21.pdf

Deflagration Challenges

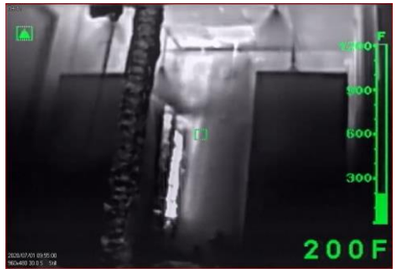
- System with 0.5 gpm sprinkler system.
- Deflagration 30 min post water application.
- UL demonstration of deflagration risks highlights that no matter what the suppression system – **deflagration still occurs**.

Demonstration 3 – Timeline of Major Events



Smoke accumulation and first response of LEL at the ceiling [TR + 00:00:29]

Ignition leading to sustained flaming [TR + 00:08:49]



Water flow initiated at 0.5 gpm/ft^2 [TR + 00:10:13]

Smoke and gas release from TR propagation [TR + 00:30:49]

Deflagration vent operation [TR + 00:42:02]

Water flow discontinued [TR + 01:05:55]

Thermal runaway propagation after end of water flow [TR + 01:13:05]

TR propagation continues after water flow restarted [TR + 01:49:54]

https://ulfirefightersafety.org/docs/UL9540AInstallationDemo_Report_Final_4-12-21.pdf

UL Demonstration Summary

Performance – Deflagration Protection

- The deflagration venting successfully vented overpressure, potentially preventing dangerous loss of integrity/rupture of the ISO container.
- Flames emitted from the deflagration vents indicate the need to site and orient the ISO container to mitigate secondary ignition/life safety hazards.
- Compartment filled to approximately 40-60% battery gas
- Flammable gas mixtures at elevated temperatures in all demonstrations
- Gas accumulation not prevented by clean agent or water suppression

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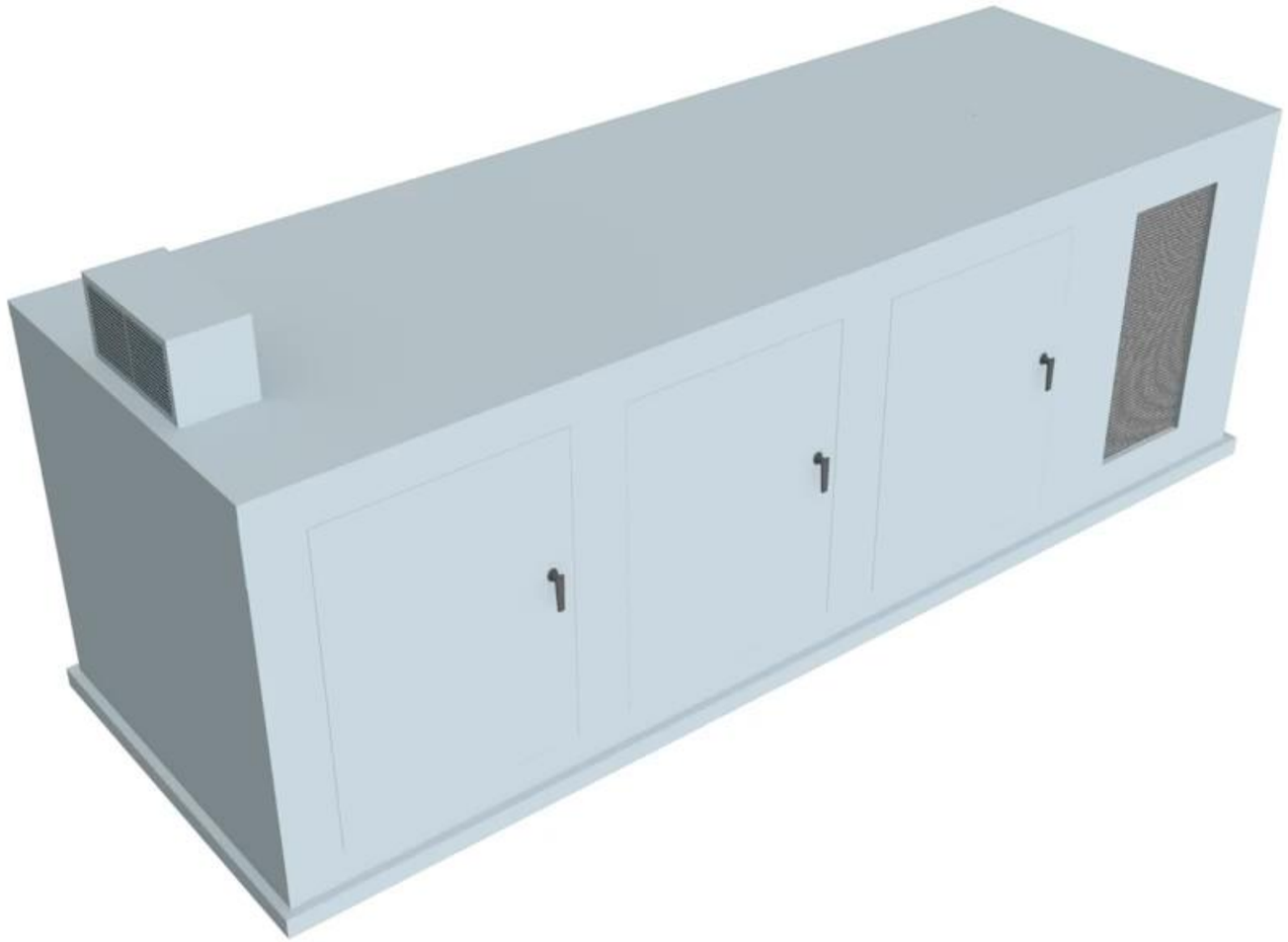

PNNL available technology

INTELLIVENT

Available Technology

- Initial development license with Snohomish PUD and currently being installed.
- Other licenses in development

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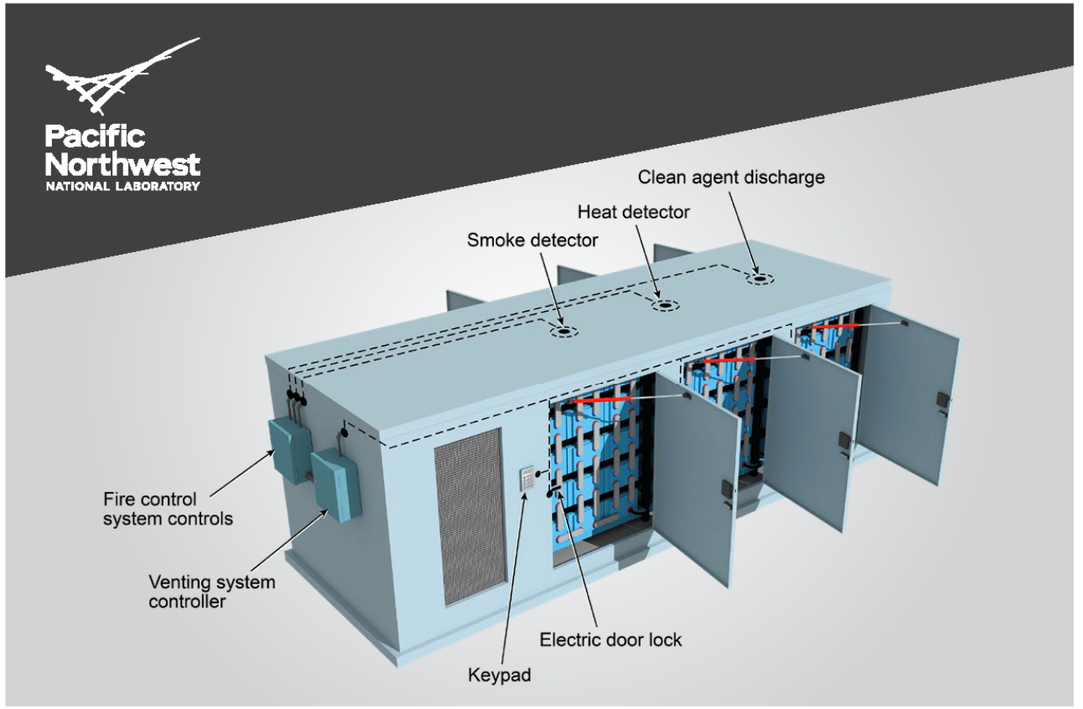

INTELLIVENT: A SAFETY VENTING SYSTEM FOR ENERGY STORAGE SYSTEM ENCLOSURES

Minimizing explosion risk in energy-storage-system cabinet enclosures

MAXIMUM BATTERIES, NO ROOM FOR FANS

Energy storage systems (ESS) with cabinet-type enclosures are becoming more common in industry because they allow for maximum battery capacity and smaller footprints, while still providing easy access to the interior space. However, the cabinets leave little room for the traditionally used exhaust fans that vent flammable gases that can result from cell failure.

INTELLIGENTLY OPENING THE DOOR TO VENTILATION

Scientists at the Pacific Northwest National Laboratory developed this patent-pending deflagration prevention system for cabinet-style battery enclosures. Intellivent is designed to intelligently open cabinet doors to vent the cabinet interior at the first sign of explosion risk. This functionality provides passive dilution of accumulated flammable gases, minimizing the potential for catastrophic explosion and reducing the risk of personnel injury.

SYSTEM BENEFITS

- Minimizes explosion risk in cabinet-type ESS enclosures
- Protects nearby building structures, equipment, and personnel from sudden explosions
- Helps meet industry codes and standards
- Enables fire fighters to access cabinet interior in case of battery failure
- Supports widespread acceptance of new ESS installations as well as retrofit needs

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Thank you

DOE - Office of Electricity
Dr. Imre Gyuk

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