



#702

# ESS Safety: IntelliVent™ Explosion Control Installation Updates

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*2024 DOE OE Peer Review*



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



# Battery Safety is a Systems Approach

- Chemistry
- Cell QC
- Integration
- Workmanship
- BMS
- Communications
- Thermal Mgmt
- Fire Protection
- **Explosion Control**

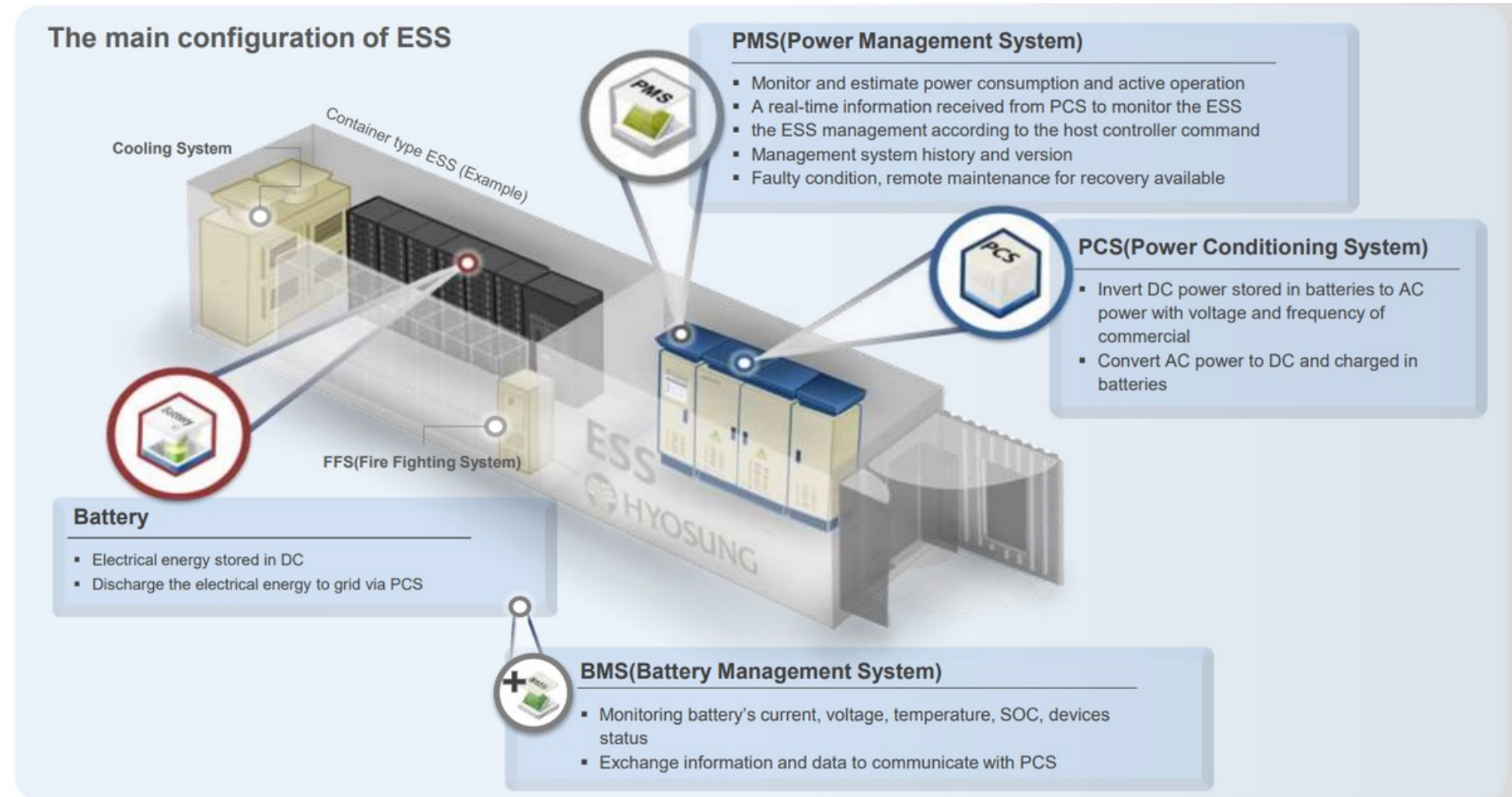


Image source: Hyosung Heavy Industries

# Mission Alignment

- OE Core Mission
  - Safe, resilient, & reliable grid
  - Utilize research, industry partnerships, and emergency response awareness to achieve safe reliable deflagration prevention system
  - Improve public confidence in ESS

**Lessons Learned:** Field failures leading to deflagrations, represented significant safety gap in early ESS designs

**Active Engagement:** Prioritize participation in development of the key ESS codes & standards

**Collaboration:** PNNL engages with community groups and first responders to provide an independent perspective on safety issues

# Project Collaboration

- ~ 15 stakeholder “Listening Sessions” to elicit critical evaluations on system features & designs
- AHJ’s, ESS manufacturers & integrators, emergency responders, fire protection engineers, battery test engineers
- Approx 15 presentations based on potential vendor/mfr inquiries
- Design based on lessons learned from field incidents



## Deflagration Risks

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

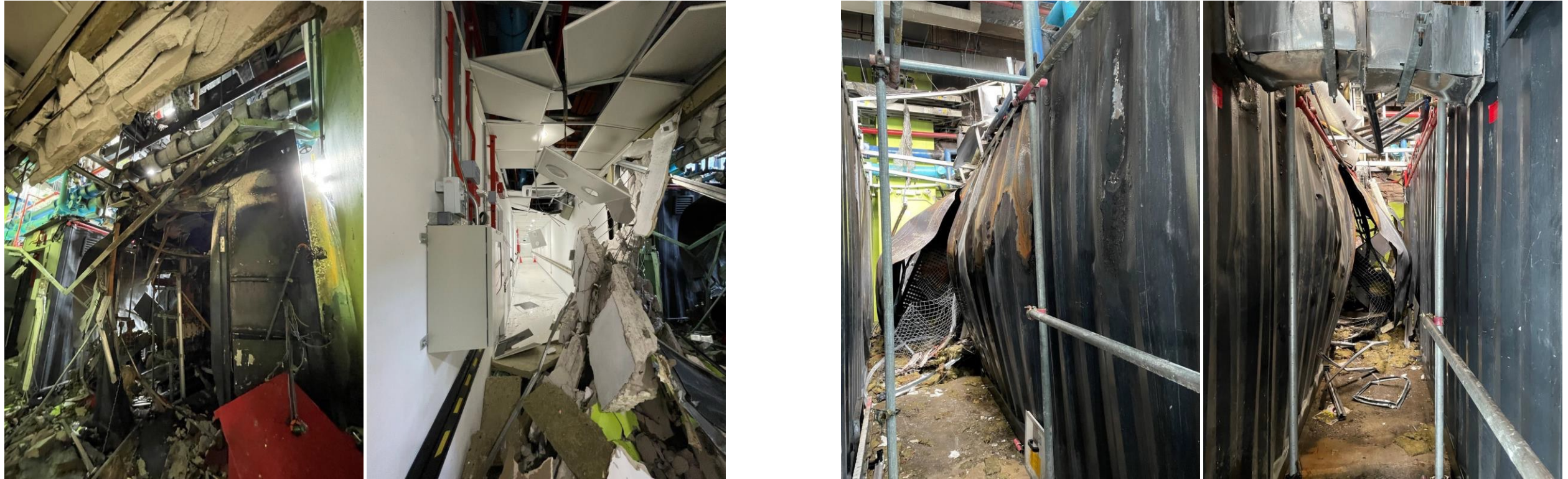


Credit: Business Korea



Credit: China Electric Power Research Institute

# Reducing Explosion Risks is Key Gap

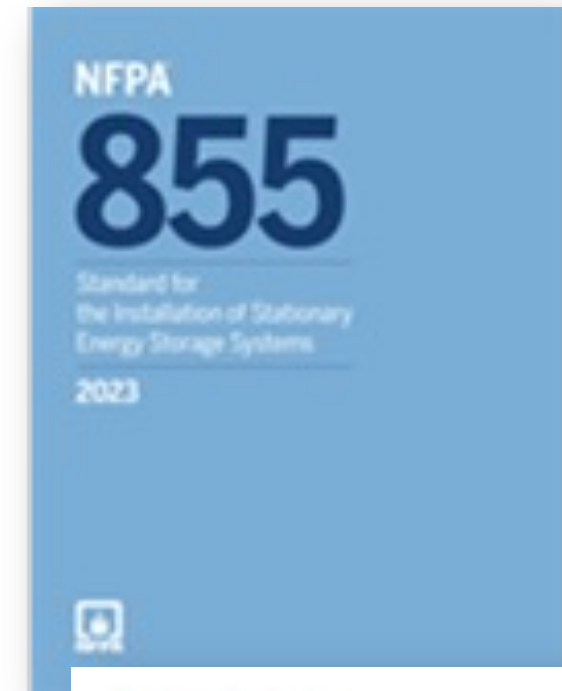


Deflagration in ISO enclosure installed indoors. Evidence of significant overpressure event.

# Explosion Control: NFPA 855 & IFC

- 2023 NFPA 855
  - Required for rooms, building, **cabinet**, walk-in unit, or non-occupiable enclosure.
  - Activation @ 10% of LFL
  - 2 hr min standby power for exhaust
  - Inclusion of Li-metal in requirements.
- 2024 IFC
  - Clarified lab use for research
  - Required for rooms, areas or walk-in units
  - Exceptions for Pb-acid & NiCd.
  - Harmonization with NFPA 855

**Retroactive HMA for unlisted ESS**



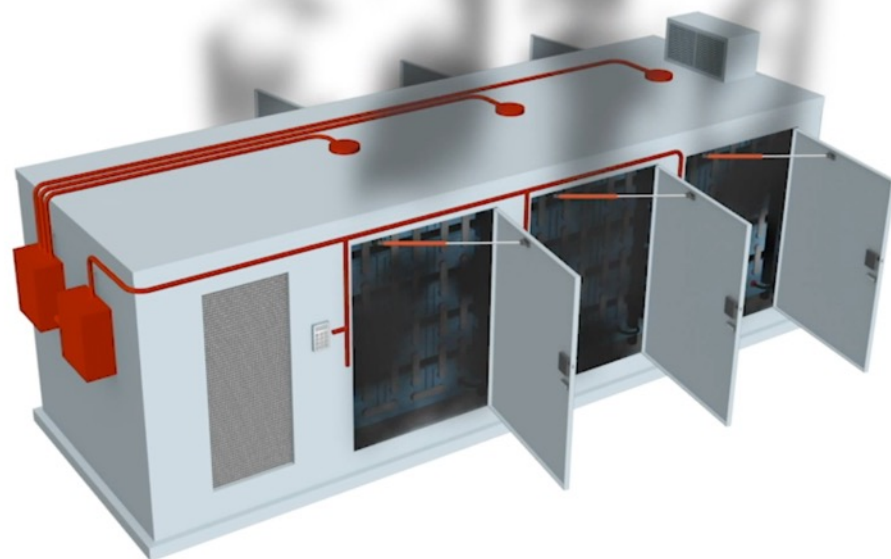
# Explosion Control Options

Three options for meeting requirement:

1. NFPA 68 – Deflagration Venting.
  - Blow-out panels to protect structure from explosion based on max gas production in module tests.
2. NFPA 69 – Deflagration Prevention.
  - Exhaust system designed to keep below 25% of LEL in area.
3. Engineered Cabinet – Based on Large Scale Fire Test has shown that no pressure waves will occur, and no projectiles can be ejected.



*Courtesy: Fike Corp.*



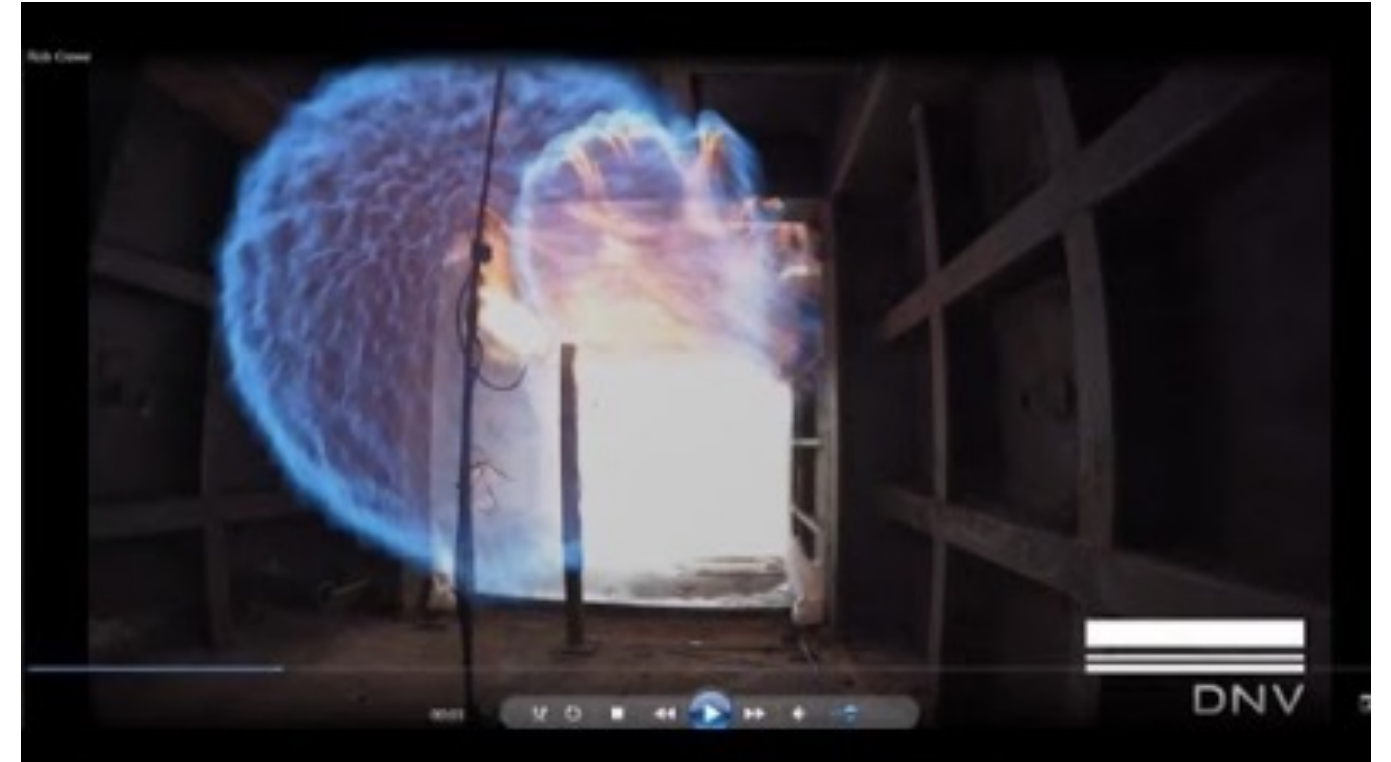
*Courtesy: LS-ES*



# NFPA 68 Deflagration Venting

## Issues

- NFPA 68 only offers protection during an explosion.
- Interior gas levels may be well above LEL
- Area needed may likely exceed available roof area of enclosure.
- **When is it safe to open?** Gas sensors may not be able to provide accurate gas measurements.
- **Who is going to open the door?** With no active exhaust, risks to anyone opening a door are too high.



*Courtesy: Dr. Paul Christensen, Rob Crew, Fraser Johnstone*

Tests on generic lithium-ion vent gas mixture (UL 9540A) in 20' shipping container w/ 380 ft<sup>3</sup> partitioned off with plastic sheet. 28.7% mix with air. Equiv to <6kWh module. Blast pressure = 7.3 psi.

## Challenges in NFPA 69 Compliance

- Cost & maintenance of gas sensors (electrochemical) can be high.
- Sensor cross-sensitivity and fouling. Not tested to function in the presence of combustion by-products.
- If fire present, damage to system likely. Long-term functionality questionable.
- NFPA 69 requires SIL-2 rating, or functional safety evaluation of system.
- If back-up power is required, must be for duration of event (>8 hrs?).

# NFPA 69 SIL-2 Requirements

## Key Requirements

**4.3.3 Prescriptive-Based Design.** A prescriptive-based design shall be in accordance with Chapters [6](#) through [15](#) of this standard.

**8.3.1 Combustible Concentration Limit.** The combustible concentration shall be maintained at or below 25 percent of the LFL for all foreseeable variations in operating conditions and material loadings, unless the following conditions apply:

(1) Where continuously monitored and controlled with safety interlocks, the combustible concentration shall be permitted to be maintained at or below 60 percent of the LFL.

**15.5.5** Instrumentation included as part of an explosion prevention or protection system shall meet the requirements of [15.5.5.1](#) through [15.5.5.4](#).

### **15.5.5.1\* Safety Instrumented Systems (SIS).**

Explosion prevention system controls installed after November 5, 2021, shall be implemented as a SIS per [15.5.5.1](#).

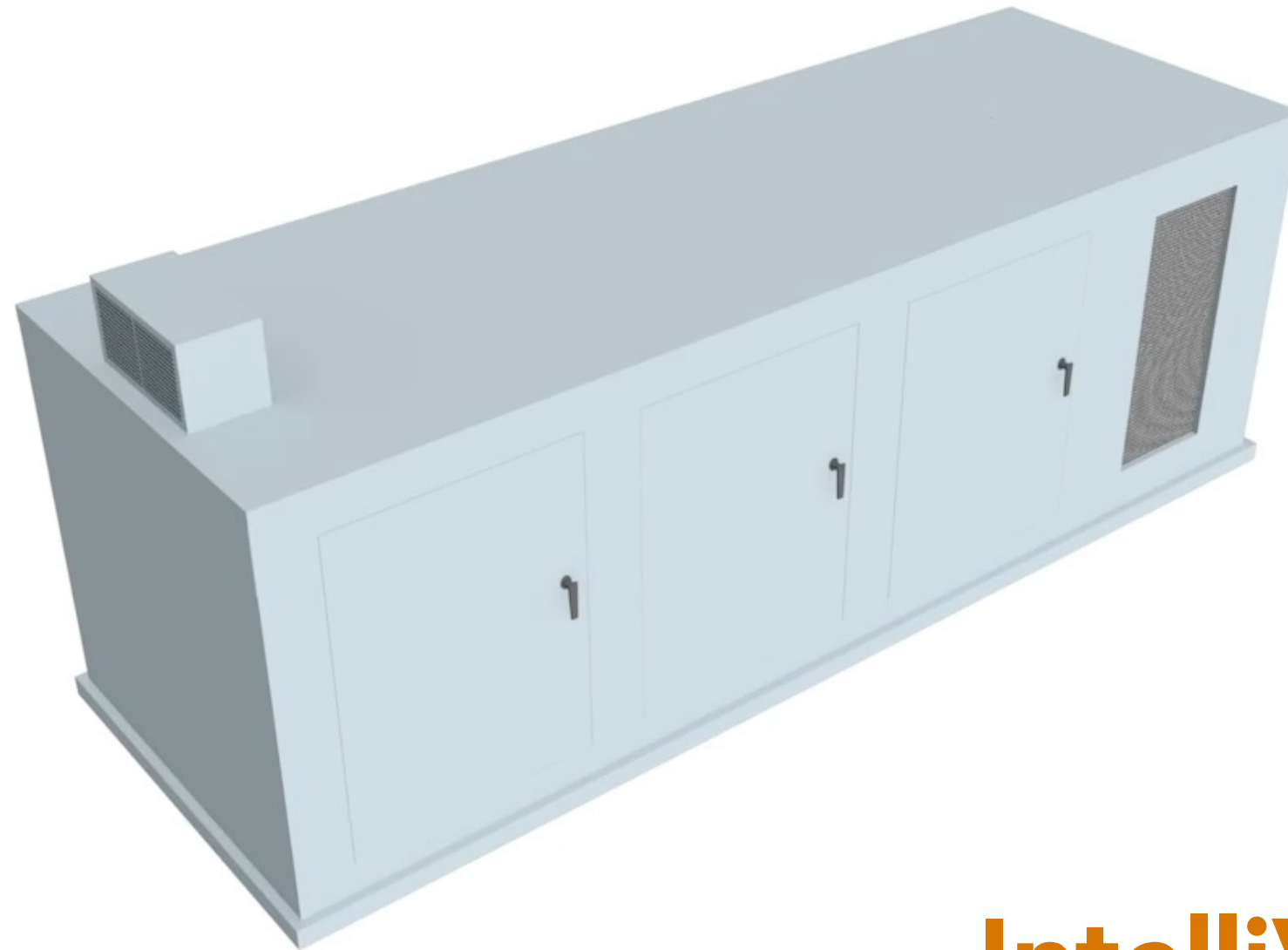
**15.5.5.1.2** Where SIS are not listed for explosion prevention service, the system consisting of a safety logic solver, sensors, and final elements used to perform safety functions shall be as follows:

**(1)\*** Certified to achieve safety integrity level 2 (SIL-2) or greater in accordance with ANSI/ISA 84.00.01, *Functional Safety: Safety Instrumented Systems for the Process Industry Sector*, or equivalent

**(2)\*** Installed and maintained to achieve at least a SIL-2 capability per the Safety Requirement Specification document

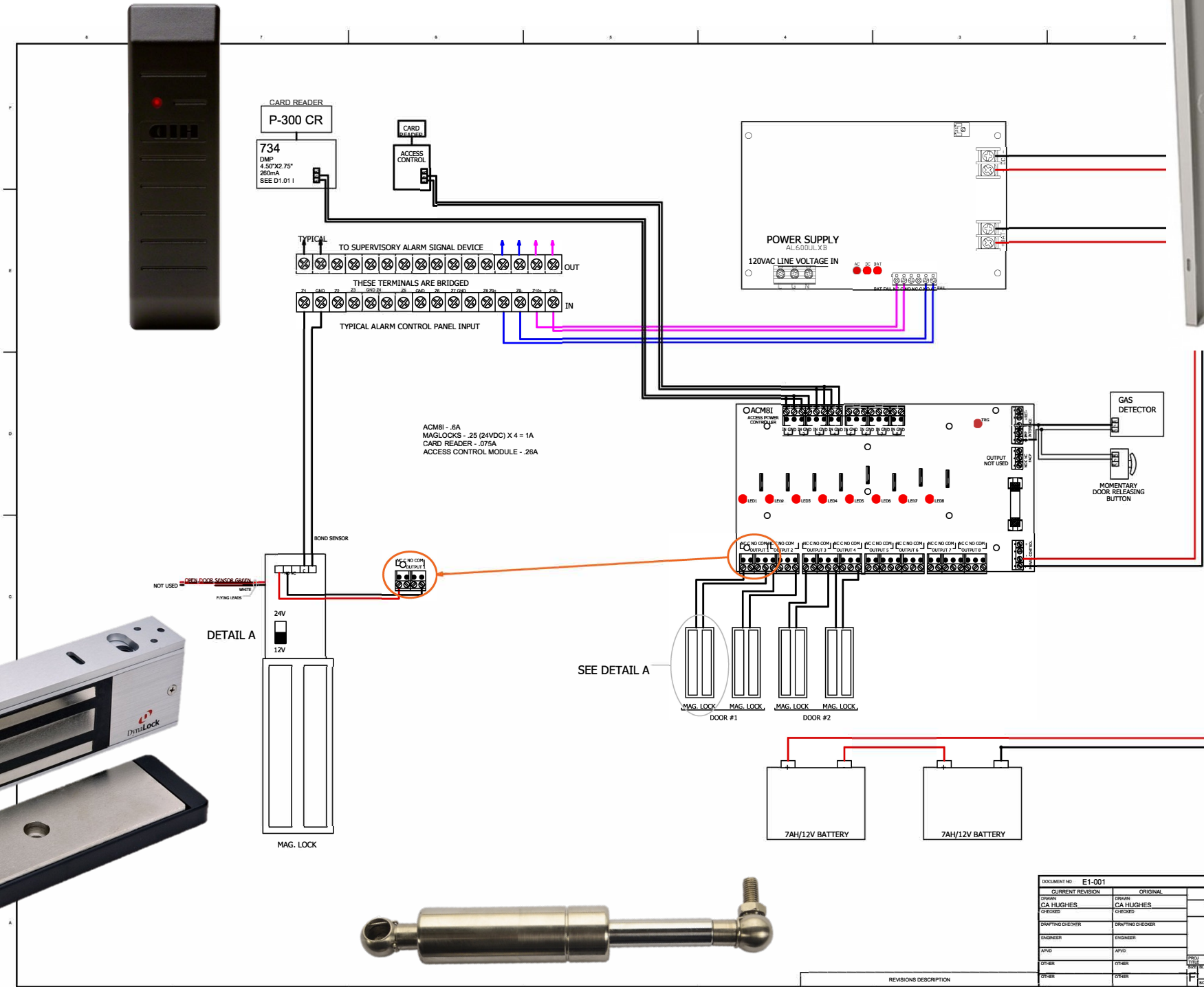
**15.5.5.1.3** Non-SIL-rated instrumentation shall be permitted to be used for implementation of Chapter [7](#) and Chapter [8](#), except when applying [8.3.1\(1\)](#)

# Deflagration Prevention Simplified



**IntelliVent™**

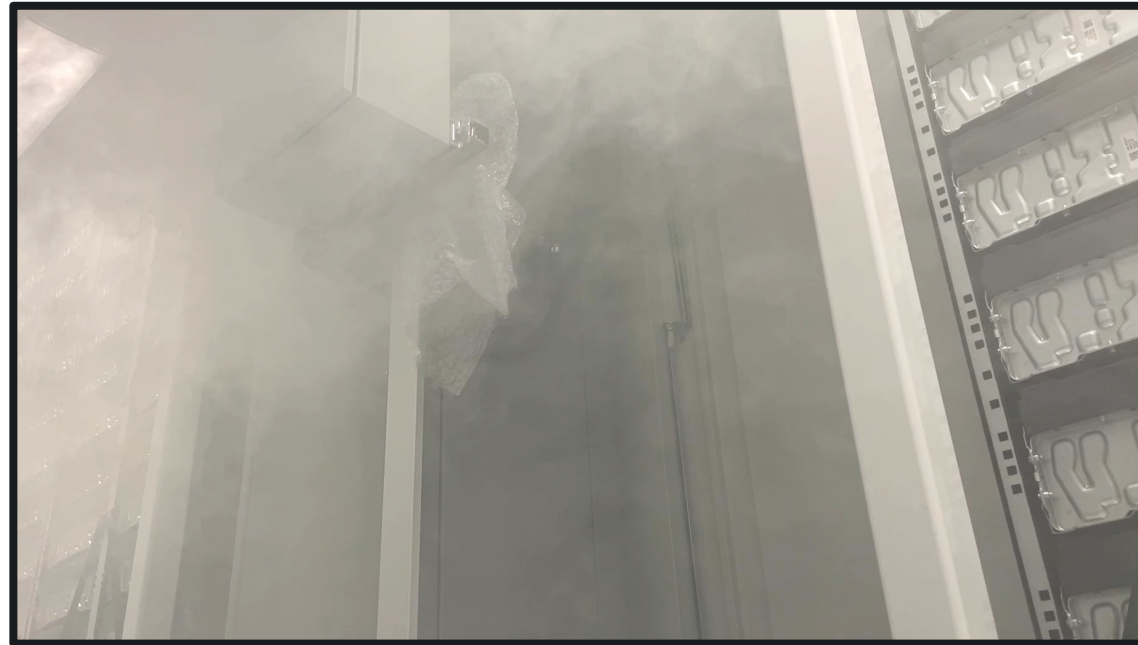
# IntelliVent™



- Fail safe design
- UL listed access control equip
- 600lb maglocks
- Increases situational awareness

DOCUMENT NO	E1-001	SERVICE REQUEST NO	
CURRENT REVISION	ORIGINAL	U. S. DEPARTMENT OF ENERGY PACIFIC NORTHWEST SITE OFFICE	
DRAWN	GA HUGHES	Pacific Northwest Division	Richland, Washington 99022
CHECKED	GA HUGHES	<b>Battelle</b>	
DRAWING CHECKER	DRAFTING CHECKER	INTELLIVENT 4 DOOR SYSTEM TYPICAL	
ENGINEER	ENGINEER	PROJECT NO	
APPD	APPD	REVISED	
OTHER	OTHER	DATE	
OTHER	OTHER	FIG NO	E1-001
REVISIONS DESCRIPTION		SCALE	NONE
		SHEET	1 OF 1

# IntelliVent™ testing at Snohomish PUD



- 1.4MWh BESS
- Part of a microgrid demonstration site
- Extensive safety systems
- Operational for 3 yrs with no activations



## PNNL 200KWh ESS

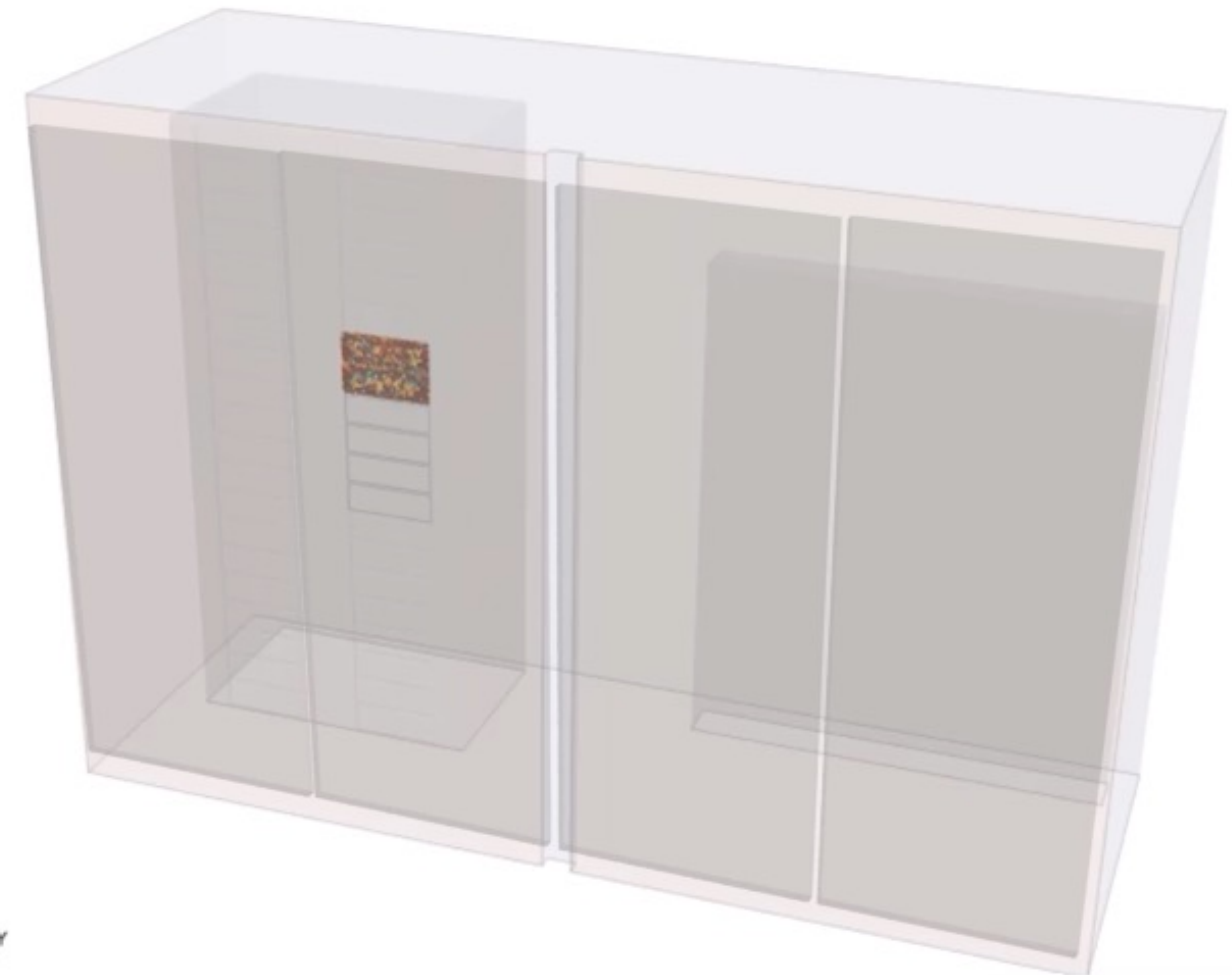
- Support for building controls modeling
- Designed prior to TIA for cabinet explosion control requirement
- PNNL driven retrofit
- Doors on front side only



## CFD Model for PNNL 200KWh ESS

- Provided to understand ventilation effects of doors on one side.
- Doors open at 8.1s

Simcenter STAR-CCM+



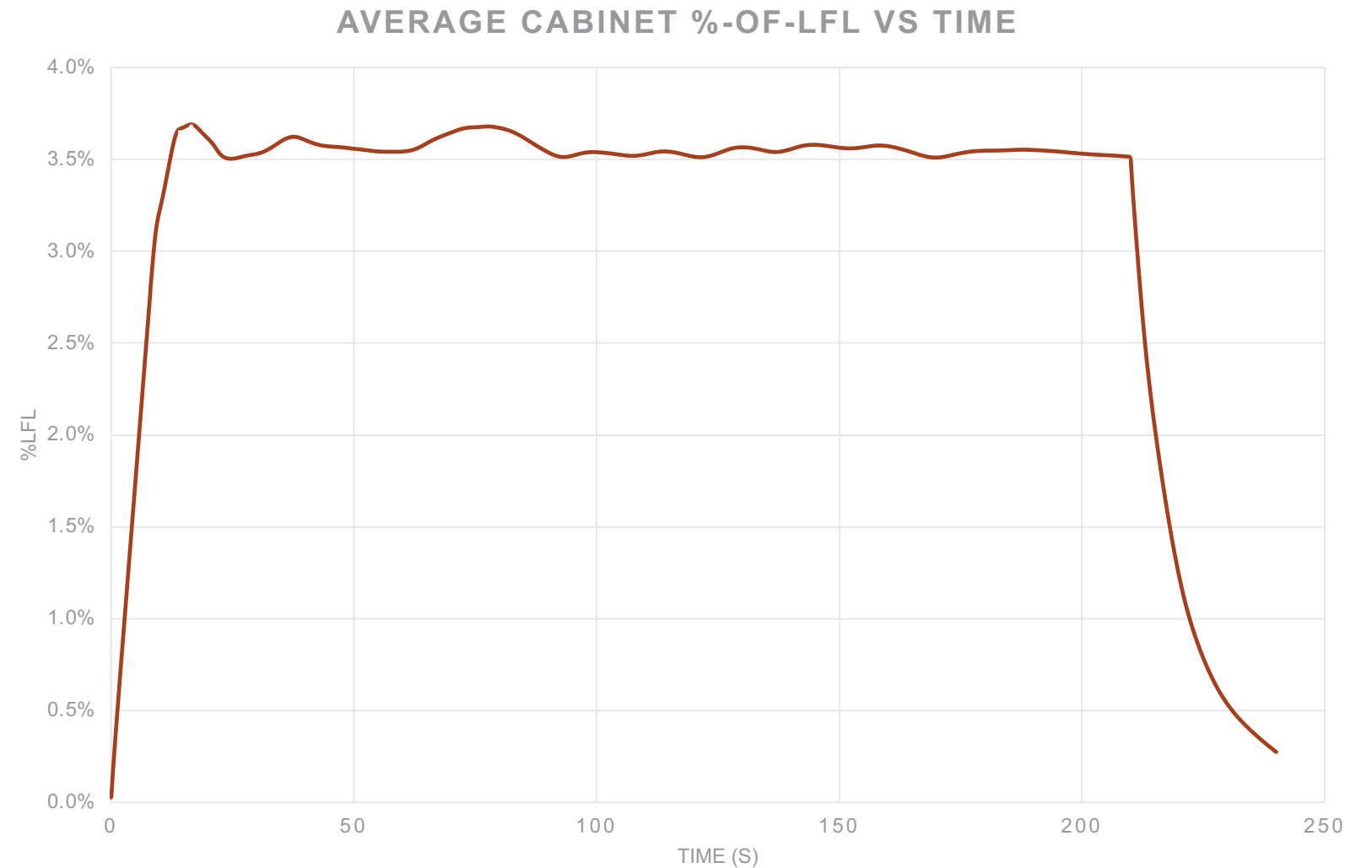
Solution Time 0.1 (s)

Mole Fraction Off-Gas  
0.03 0.0475 0.065



## Average gas volume below 4% of LFL.

- NMC Pouch cells, 137L gas per cell
- Assumption of 6 cells in TR (3x UL 9540A test results)



## IntelliVent: Installations

- 2 Retrofits
- 1 Manufacturer provided

## Remaining Development

- Work with vendor to define UL & FM standard for certification.
- Support large-scale fire testing for heat flux and spacing recommendations.





# Acknowledgement

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# Thank You!

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