DOCKETED

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Filer:	Doug Urry
Organization:	Tetra Tech
Submitter Role:	Applicant Consultant
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Data Request Response #6

Corby Battery Energy Storage System Project (24-OPT-05)

April 2026

Prepared for

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Acronyms and Abbreviations

Applicant	North Bay Interconnect, LLC and Corby Energy Storage, LLC
Application	Opt-in Application
BESS	battery energy storage system
CEC	California Energy Commission
FLACS	FLame ACceleration Simulator
GHG	greenhouse gas
kV	kilovolt
NFPA	National Fire Protection Association
PG&E	Pacific Gas and Electric
POCO	point of change of ownership
Project	Corby Battery Energy Storage System Project
SDR	Supplemental Data Request
SF_6	sulfur hexafluoride
UL	Underwriters Laboratories

1.0 INTRODUCTION

This Data Request Response #6 to North Bay Interconnect, LLC and Corby Energy Storage, LLC's (Applicant)[1] Opt-in Application (Application) for the Corby Battery Energy Storage System Project (Project) (24-OPT-05) responds to supplement data requests (SDR) that California Energy Commission (CEC) Staff have made as a result of their review of Project Description Update #2, including SDR GHG-1, SDR GHG-2, and REV2 DR FP-5. These SDRs were received via email on February 20, 2026, which is provided in Appendix 1-A.

Each data request is presented below in its entirety, followed by the Applicant's response to the information requested. All figures referenced in responses are provided following the set of responses for the technical discipline. If the response requires additional appended material, it is included in numbered appendices at the end of the document.

2.0 GREENHOUSE GAS EMISSIONS

2.1 Data Request SDR GHG-1

SDR GHG-1. Can you please confirm whether the construction and operations emissions from the New Corby substation and the PCOC (including SF6 leakage) are already included in the emissions estimates provided in the most current docketed filing (TN 263284)?

- If they are included, simple confirmation would be sufficient.
- If they are not included, we will need those estimates to finalize our analysis.

Response: The construction emissions analysis provided in the May 2025 Air Quality and Greenhouse Gas Technical Report (TN# 263284) included estimated emissions from construction of the point of change of ownership (POCO), full length of the generation tie line, and New Corby Bay at the Pacific Gas and Electric (PG&E) Vaca-Dixon Substation. Upon further review, it was determined that the New Corby Bay will include sulfur hexafluoride (SF_6) containing equipment that was not included in the previous operational emissions analysis. PG&E will be adding one 230-kilovolt (kV) circuit breaker containing 186 pounds of SF_6. The following text and table provide updated greenhouse gas (GHG) emission estimates in underline/~~strikeout~~ format relative to the May 2025 report (TN# 263284).

> GHG emissions are associated with fugitive emissions of SF_6 from gas-insulated switchgear equipment, such as the high voltage circuit breakers at the on-site substation. The SF_6 global warming equivalence is 22,800 times that of CO_2. The Project substation will have four 245-kV voltage circuit breakers, each with 125 pounds of SF_6 for a total of 500 pounds~~, and~~. Additionally, the New Corby Bay at PG&E's Vaca-Dixon Substation will include one 230-kV circuit breaker with 186 pounds of SF_6, for a Project total of 686 pounds. Each circuit breaker

[1] North Bay Interconnect, LLC and Corby Energy Storage, LLC are both wholly-owned subsidiaries of NextEra Energy Resources. North Bay Interconnect, LLC will own and operate the interconnection facilities for the Project; and Corby Energy Storage, LLC will own and operate the BESS components of the Project.

<u>has</u> a maximum leak rate of 0.5 percent per year. CO_2e resulting from SF_6 gas leakage can be represented by the following equation:

$$CO_2e \text{ Emissions} = SF_6 \text{ gas contained in equipment (lbs)} \times 0.5\% \text{ leak rate per year} \times 0.0004536 \text{ MT/lb} \times 22{,}800$$

The updated estimated operational GHG emissions from the Project are shown in Table 2-1[2].

Table 2-1. Estimated Annual Operational Greenhouse Gas Emissions[1/]

Annual	CO_2	CH_4	N_2O	SF_6	R
	Emissions (Metric tons)				
Operational GHG Emissions	3.42	0.0003	0.0002	~~0.0011~~ <u>0.0016</u>	0.0770
Global Warming Equivalence Factor	1	25	298	22,800	573
Equivalent CO_2e Emissions[2]	3.42	0.01	0.06	~~25.86~~ <u>35.47</u>	44.10
Total Operational GHG Emissions	~~73~~ <u>83</u>				
Total Operational GHG Emissions + Amortized Construction GHG Emissions	*~~196~~ <u>206</u>*				

1/ Replaces Table 15 in the May 2025 Air Quality and Greenhouse Gas Technical Report (TN# 2693284)
2/ Equivalent CO_2e Emissions = Operation GHG Emissions x Global Warming Equivalent Factor
CO_2 – carbon dioxide; CO_2e – carbon dioxide equivalent; CH_4 – methane; GHG – greenhouse gas; N_2O – nitrogen oxides, R – R-513a

As shown in Table 2-1, the estimated annual Project-operational GHG emissions will be approximately ~~73~~ <u>83</u> MT CO_2e per year as a result of Project operation. Estimated maximum annual operational emissions and amortized construction emissions will be approximately ~~196~~ <u>206</u> MT CO_2e per year. As shown, the total annual emissions will not exceed the proposed interim GHG significance threshold of 900 MT CO_2e per year. Because the Project's GHG emissions will not result in a cumulatively considerable contribution, the Project will result in a less than significant cumulative impact in terms of climate change.

2.2 Data Request SDR GHG-2

DR GHG-2. Can you please confirm whether both R-513a and HFC-32 would be used in the BESS thermal management system?

Response: Both refrigerants will be used in the LG DC LINK enclosures; R-513a is used in the heating, ventilation, and air conditioning system while HFC-32 is used within the coolant chiller.

3.0 FIRE PROTECTION

3.1 REV2 DR FP-05

CEC staff needs clarification regarding how the BESS enclosure addresses flammable gas accumulation and deflagration hazards, as required by NFPA 855 (edition 2026). The Explosion Prevention System Design Report (TN268433, Appendix 3.9-D) concludes that the ventilation system

[2] Replaces Table 15 in the May 2025 Air Quality and Greenhouse Gas Technical Report (TN# 263284)

prevents the formation of flammable gas mixtures; however, the role and design basis of the partial deflagration panels are not described nor evaluated.

The recently submitted DRR Set 5, SDR FP-4, describes the partial deflagration panels as "*although not necessary to meet NFPA 69 compliance, the enclosure features six partial deflagration panels engineered to provide structural pressure relief (see pg. 6 of Appendix 3-C). These panels complement the NFPA 69 active prevention system by functioning as a secondary mitigation measure to protect the enclosure's integrity by providing a controlled path for pressure discharge in the event of an internal pressure rise, ensuring installation aligns with the mandatory hazard mitigation objectives of the 2026 NFPA 855.*" Because the ventilation system requires approximately 35.9 seconds to open the vent doors (TN268433, PDF page 255, paragraph 2), a delay or failure could allow flammable conditions to develop during that period. Clarification is needed to understand whether the deflagration panels function within the overall explosion protection strategy regardless of any requirement that they do so. CEC staff needs to know why they are there and what is their function.

REV2 DR FP-05. Please describe the design basis, function, and performance criteria of the passive deflagration panel system and how it operates in conjunction with the active ventilation system. Explain how the panels are incorporated into the overall explosion protection approach, including their role under delayed or failed ventilation conditions. Provide supporting calculations, modeling, or test data demonstrating that the combined system adequately mitigates deflagration hazards in accordance with NFPA 855 and NFPA 69.

Response: The design basis, function and performance criteria of the passive deflagration system is provided in the LG Energy Solution JF2 DC LINK Battery Energy Storage System FLame ACceleration Simulator (FLACS) Deflagration Analysis (Appendix 3-A). The deflagration system is evaluated per National Fire Protection Association (NFPA) 68-2023. The FLACS modeling evaluated the maximum simulated pressure under worst-case conditions using Underwriters Laboratories (UL) 9540A cell and module-level gas compositions, single and dual release points, and ignition at peak flammable concentration. The supporting analysis demonstrates the pressure on the internal walls of the container under worst-case conditions would not exceed 2.132 pounds per square inch (psi), which is approximately within the threshold limit of what typical BESS enclosure, without deformation, damage or disintegration, and therefore the system design meets the intent of NFPA 68 for a limited gas volume accumulation and subsequent deflagration scenario before the activation of the forced emergency ventilation system. Further detail is provided in the FLACS report (Appendix 3-A); see the analysis and conclusions associated with Scenario 5 which simulates the worst-case gas accumulation scenario. Therefore, as demonstrated by the FLACS analysis, the deflagration protection system does not rely on or require passive deflagration panels.

As an additional layer of deflagration protection, the JF2 DC LINK enclosure incorporates passive deflagration vent panels to provide additional mitigation if deflagration occurs under delayed or failed venting conditions. The container design includes two deflagration panels on the roof of each M-Link, totaling six passive deflagration panels across the entire roof of each container. Each panel is 0.275 meter by 0.460 meter (0.127 square meter opening area). The deflagration panels are designed to open when the container pressure reaches or exceeds 1.45 psi; refer to the deflagration panel specifications provided in Appendix 3-B.

The active ventilation system and deflagration panels are independent separately functioning systems. The JF2 DC LINK includes an active ventilation system that detects flammable gas accumulation and activates full ventilation to prevent deflagration from occurring, in compliance with NFPA 69. NFPA 69 is a standard for an active ventilation system that provides deflagration prevention, whereas the passive deflagration panel system provides deflagration protection. Under NFPA 69, deflagration vent panels are not required; the active ventilation system alone satisfies the code's explosion prevention requirements. **However, LG chose to add the passive vent panels voluntarily as an additional layer of protection. In the extremely unlikely scenario of the active ventilation system being delayed or failing entirely during a thermal event, the passive vent panels independently provide deflagration protection.** Please refer to the NFPA 69 Explosion Prevention System Design Report provided in Project Description Update #2, Part 2, Appendix 3.9-D (TN# 268433) for more details regarding the active ventilation system.

4.0 REFERENCES

NFPA (National Fire Protection Association). 2023. NFPA 68: Standard on Explosion Protection by Deflagration Venting.

NFPA. 2024. NFPA 69: Standard on Explosion Prevention Systems.

APPENDIX 1-A: CEC DATA REQUESTS

From:	Longman, Renee@Energy
To:	Syed, Qaim; Omercajic, Nadan
Cc:	Qian, Wenjun@Energy; Record, Jacquelyn@Energy; Jiang, Tao@Energy; Chang, Kaycee@Energy
Subject:	Corby BESS: Air Quality and GHG Questions
Date:	Tuesday, March 24, 2026 4:52:29 PM
Attachments:	image001.png

Hi Qaim and Nadan,

CEC staff has follow-up questions regarding Air Quality and GHG provided below. Please let us know if you have any questions. Thank you!

1. **New Corby Substation and POCO Emissions** Can you please confirm whether the construction and operations emissions from the New Corby substation and the PCOC (including SF6 leakage) are already included in the emissions estimates provided in the most current docketed filing (TN 263284)?
    - If they **are included**, simple confirmation would be sufficient.
    - If they **are not included**, we will need those estimates to finalize our analysis.
2. **BESS Thermal Management System** Can you please confirm whether both R-513a and HFC-32 would be used in the BESS thermal management system?

Renee Longman AICP, LEED AP BD+C
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Website: www.energy.ca.gov

From:	Longman, Renee@Energy
To:	Syed, Qaim; Omercajic, Nadan
Cc:	Chang, Kaycee@Energy
Subject:	Corby BESS: Fire Protection Supplemental Data Request
Date:	Tuesday, March 24, 2026 4:11:23 PM
Attachments:	image001.png

Hi Qaim and Nadan,

Provided below is an additional data request based upon the recent Data Request Response Set #5. Responses should be filed to the project docket. Please let us know if you have any questions. Thank you!

Fire Protection

CEC staff needs clarification regarding how the BESS enclosure addresses flammable gas accumulation and deflagration hazards, as required by NFPA 855 (edition 2026). The Explosion Prevention System Design Report (TN268433, Appendix 3.9-D) concludes that the ventilation system prevents the formation of flammable gas mixtures; however, the role and design basis of the partial deflagration panels are not described nor evaluated.

The recently submitted DRR Set 5, SDR FP-4, describes the partial deflagration panels as "*although not necessary to meet NFPA 69 compliance, the enclosure features six partial deflagration panels engineered to provide structural pressure relief (see pg. 6 of Appendix 3-C). These panels complement the NFPA 69 active prevention system by functioning as a secondary mitigation measure to protect the enclosure's integrity by providing a controlled path for pressure discharge in the event of an internal pressure rise, ensuring installation aligns with the mandatory hazard mitigation objectives of the 2026 NFPA 855.*" Because the ventilation system requires approximately 35.9 seconds to open the vent doors ((TN268433, PDF page 255, paragraph 2), a delay or failure could allow flammable conditions to develop during that period. Clarification is needed to understand whether the deflagration panels function within the overall explosion protection strategy regardless of any requirement that they do so. CEC staff needs to know why they are there and what is their function.

REV2 DR FP-05. Please describe the design basis, function, and performance criteria of the passive deflagration panel system and how it operates in conjunction with the active ventilation system. Explain how the panels are incorporated into the overall explosion protection approach, including their role under delayed or failed ventilation conditions. Provide supporting calculations, modeling, or test data demonstrating that the combined system adequately mitigates deflagration hazards in accordance with NFPA 855 and NFPA 69.

Renee Longman AICP, LEED AP BD+C

Project Manager

Siting and Environmental Branch

Siting, Transmission and Environmental Protection Division

1-916-937-3538

California Energy Commission

APPENDIX 3-A: FLACS DEFLAGRATION ANALYSIS

LG Energy Solution JF2 DC LINK Battery Energy Storage System FLACS Deflagration Analysis

Issued Report | Rev 1 | July 01, 2025

Prepared for:

LG Energy Solution
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Date	Revision	Reason for Issue	Developed By	Reviewed By	Approved by
07/01/2025	Rev 1	Updated Report	DKB	MHR/MK	-
06/18/2025	Rev 0	Issued Report	DKB	MHR/MK	-

REVISION CONTROL SHEET

REVISION	SECTION	CHANGE NOTED
Rev 1	Exec Summary, Section 2, Section 4, Conclusion	Updated report with comments based on LG email dated 06/25/2025

EXECUTIVE SUMMARY

Fire & Risk Alliance, LLC (FRA), performed a deflagration analysis for JF2 DC LINK Lithium-ion Battery Energy Storage System (BESS) manufactured by LG. This analysis applies to a fully populated (28 modules) model JF2 DC LINK BESS enclosure consisting of two battery racks of 14 battery modules each (Model Number NR27N414L_P15190NB3). Flammable gas explosion analysis was conducted for the BESS enclosure using the consequence modelling computational fluid dynamics (CFD) tool FLACS (FLame ACceleration Simulator) to determine the impact of a deflagration occurring in the enclosure.

The BESS enclosure has interior dimensions of 2.4 m x 1.9 m x 2.5 m (width x depth x height). Two deflagration vent panels are provided on the roof, each measuring 0.275 m x 0.46 m (0.127 m^2) with a total venting area of 0.254 m^2. The analysis examined the maximum pressure observed in the enclosure due to a deflagration event. Constituents of the battery gas mixture used for this analysis were obtained from UL9540A failure characterization tests. The following tables show the results of the maximum average pressure on the internal walls of the enclosure for various scenarios.

The NFPA 69 analysis performed by Jensen Hughes indicated a detection time of 9 seconds and the total time for complete open vents of 36 seconds, which were assumed for all the FLACS CFD scenarios. However, for the 197 LPM venting rate, the anticipated detection is quicker than 9 seconds, which would lead to different gas accumulation and overpressure conditions that are lower than those observed at 9 seconds and at 36 seconds.

Table E1. Average pressure at enclosure internal walls (in bar-g) (Scenario 1 and Scenario 2)

Wall	197 LPM Cell Gas Comp 9s, 2 Release Points (Scenario 1) (100022)	197 LPM Cell Gas Comp 36s, 2 Release Points (Scenario 1) (100023)	107 LPM Cell Gas Comp 9s, 2 Release Points (Scenario 2) (200021)	107 LPM Cell Gas Comp 36s, 2 Release Points (Scenario 2) (200022)
Doors	-0.005	-0.018	-0.003	-0.011
Backwall	0.009	0.035	0.007	0.021
X-Min Wall	-0.009	-0.034	-0.006	-0.020
X-Max Wall	0.009	0.034	0.006	0.020
Roof	0.010	0.037	0.007	0.022
Maximum (bar-g)	**0.010**	**0.037**	**0.007**	**0.022**
Maximum (psig)	**0.145**	**0.537**	**0.102**	**0.319**

Table E2. Average pressure at enclosure internal walls (in bar-g) (Scenario 3 and Scenario 4)

Wall	197 LPM Module Gas Comp 9s, 2 Release Points (Scenario 3) (300021)	197 LPM Module Gas Comp 36s, 2 Release Points (Scenario 3) (300022)	197 LPM Cell Gas Comp 9s, 1 Release Point (Scenario 4) (400021)	197 LPM Cell Gas Comp 36s, 1 Release Point (Scenario 4) (400022)
Doors	-0.013	-0.026	-0.006	-0.017
Backwall	0.025	0.049	0.012	0.033
X-Min Wall	-0.024	-0.047	-0.012	-0.032
X-Max Wall	0.024	0.047	0.012	0.032
Roof	0.027	0.053	0.013	0.035
Maximum (bar-g)	**0.027**	**0.053**	**0.013**	**0.035**
Maximum (psig)	**0.392**	**0.769**	**0.189**	**0.508**

Table E3. Average pressure at enclosure internal walls (in bar-g) (Scenario 5)

Wall	197 LPM Module Gas Comp 9s, 1 Release Point (Scenario 5) (500021)	197 LPM Module Gas Comp 36s, 1 Release Point (Scenario 5) (500022)
Doors	-0.016	-0.073
Backwall	0.031	0.138
X-Min Wall	-0.030	-0.132
X-Max Wall	0.030	0.132
Roof	0.033	0.147
Maximum (bar-g)	**0.033**	**0.147**
Maximum (psig)	**0.479**	**2.132**

The important findings of the analysis presented in the tables can be summarized as follows:

- **Scenario 5** demonstrates a worst-case scenario, with a 197 LPM venting rate, gas composition from the UL 9540A module level test, single release location, and gas accumulation of up to 36s. The peak simulated average vented overpressure on the internal walls of the enclosure was **0.147 bar-g (2.132 psig**) with deflagration vent panel activation.

As per NFPA 68 6.3.1.1 "*P_{red} (reduced pressure) shall not exceed two-thirds of the ultimate strength for the vented enclosure, provided deformation of the equipment can be tolerated*." A strength analysis for the enclosure was not performed by LG, and in the absence of that data, external references were considered. Factory Mutual datasheet FMDS 07-76 Appendix C §C.3.1 states that when structural strength data for vessels is not available, a 3.0 psig maximum allowable pressure (P_{red}) for typical design vessels (eg. bag-type dust collectors) can be assumed for vent sizing with a note that vessel likely will not be deformed or some vessel deformation may happen (or is tolerable). As such, we can define the P_{red} (reduced pressure or enclosure design strength) in the following ways:

- 0.2 bar-g (3.0 psig) – Enclosure deformation is tolerable. Deformation may likely occur, but the enclosure is not expected to rupture in a way that creates projectile hazards.
- 0.133 bar-g (2.0 psig) – Enclosure deformation is tolerable. Deformation will likely occur, but the enclosure is not expected to rupture in a way that creates projectile hazards. Includes a safety factor multiplier of 2/3 applied for consistency with the intent of NFPA 68.

The maximum simulated pressure with vent panel activation in the DC LINK enclosure is **0.147 bar-g (2.132 psig)**, corresponding to a venting rate source term of 197 LPM and gas composition based on UL 9540A module level testing. This assumes conservative conditions that include gas accumulation for 36 seconds, without accounting for immediate emergency ventilation system activation upon gas detection. The resulting peak overpressure from the deflagration simulation is approximately within the threshold limit of a typical BESS enclosure, without deformation, damage, or disintegration and therefore the vent panel design meets the intent of NFPA 68 for a limited gas volume accumulation and subsequent deflagration scenario before the activation of the forced emergency ventilation system. Based on the analysis conducted, FRA advises that a suitable emergency response plan (ERP) and training be provided to cover the full range of scenarios that may be encountered.

DISCLAIMER

This report and its contents are provided for informational purposes only and are based on the specific conditions, data, and product specifications available at the time of its preparation. The recommendations, designs, and conclusions presented herein are applicable solely to the specific product, site, or application described in this report.

The results presented in this report do not constitute a guarantee or warranty of performance in the field. All designs, calculations, and recommendations should be verified through appropriate field testing and site-specific evaluations. The accuracy and applicability of this report's findings may be subject to changes in conditions, technology, and standards that are beyond the scope of this analysis.

It is the responsibility of the owner, contractor, or designated party to conduct comprehensive testing and obtain all necessary approvals to confirm the validity of the design in the field. The authors, engineers, and firms involved in the creation of this report assume no liability for performance, errors, omissions, or failures that may arise during construction or operation, and no warranty of fitness for a particular purpose is implied

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1 INTRODUCTION

Fire & Risk Alliance, LLC (FRA) performed a deflagration analysis for JF2 DC LINK Lithium-ion Battery Energy Storage System (BESS) manufactured by LG. This analysis applies to a fully populated (28 modules) model JF2 DC LINK BESS enclosure consisting of two battery racks of 14 battery modules each (Model Number NR27N414L_P15190NB3). Flammable gas explosion analysis was conducted for the BESS enclosure using the consequence modeling computational fluid dynamics (CFD) tool FLACS (FLame ACceleration Simulator) to determine the impact of a deflagration occurring in the enclosure.

The main objective of the analysis was to determine the overpressure levels on the DC LINK enclosure walls from an internal explosion, based on performance-based criteria and guidance from the NFPA 68-2023 Edition, *Standard on Explosion Protection by Deflagration Venting*. The analysis examined the maximum pressure observed in the enclosure due to a deflagration event. Constituents of the battery gas mixture used for this analysis were obtained from UL9540A failure characterization tests.

This analysis is intended to be used as a tool for a Fire Code Official (FCO), an Authority Having Jurisdiction (AHJ), or other project stakeholders to assist in their review of an DC LINK BESS installation.

1.1 Scope

The scope of this project was limited to conducting dispersion and deflagration analysis. Battery gas chemistry was considered from the UL 9540A test reports and served as inputs to the FLACS model. Source terms for this analysis were based on the UL 9540A test reports as well as the NFPA 69 analysis performed by others for LG. Analysis of structural failure or damage to the enclosure due to simulated overpressures is not a part of the scope of work and thus was not performed.

1.2 Applicable Codes and Standards

The following codes and standards were used in performing this analysis:

- NFPA 68, Standard on Explosion Prevention by Deflagration Venting (NFPA 68) – 2023 Edition.

Other codes and standards relevant to this analysis are:

- UL 9540A, Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems (UL 9540A) – 2019 4th Edition.
- NFPA 69, Standard on Explosion Prevention Systems (NFPA 69) – 2019 Edition.

1.3 Reference Material

The following reference materials were reviewed as part of this analysis:

- UL 9540A Cell Level Fire Test Report (4791256609), UL Solutions Korea, Dated 2024.10.09.
- UL 9540A Module Level Fire Test Report (4791519232), UL Solutions Korea, Dated TBD.
- UL 9540A Unit Level Fire Test Report (4791516927), UL Solutions Korea, Dated TBD.
- Factory Mutual Loss Prevention Datasheet (FMDS) 07-76, Combustible Dusts.
- LG Energy Solution Battery Energy Storage System – Explosion Prevention System Design Report (NFPA 69), Rev0, Dated 05/14/2025

1.4 Acronyms and Abbreviations

Authority Having Jurisdiction	AHJ	Fire Code Official	FCO
Battery Energy Storage System	BESS	Fire & Risk Alliance, LLC	FRA
Battery Management Module	BMM	Heating, Ventilation, and Air Conditioning	HVAC
Battery Management System	BMS	Lower Flammable Limit	LFL
Computational Fluid Dynamics	CFD	National Fire Protection Association	NFPA
Emergency Response Plan	ERP	Reduced Pressure	P_{red}
FLame ACceleration Simulator	FLACS	Underwriters Laboratory, LLC	UL

1.5 Nomenclature

Ampere-hour	Ah	Megawatt-hour	MWh
Centimeter	cm	Meter	m
Cubic Feet Per Minute	CFM	Millimeter	mm
Cubic Meters	m3	Pascal	Pa
Degree Celsius	°C	Pounds per square inch gauge	psig
Degree Fahrenheit	°F	Square meters	m2

2 JF2 DC LINK DESIGN SUMMARY

The JF2 DC LINK is a non-walk-in type BESS with all equipment accessible from the exterior. The BESS cabinet has internal dimensions of 2.4 m x 1.9 m x 2.5 m (width x depth x height). Two deflagration vent panels, each measuring 0.275 m x 0.46 m (0.127 m^2), are provided on the roof of the cabinet, providing a total venting area of 0.254 m^2. The BESS enclosure is equipped with 2 units/racks mounted on metal frames. The cabinet contains 28 modules, and each module contains 120 cells. The total energy capacity of M-LINK which is one JF2 DC LINK enclosure is approximately 1.711 megawatt hours (MWh).

Each enclosure is also equipped with a combustible gas detector. The DC LINK is an energy storage device that includes battery modules, a core component of ESS. It contains 2 battery racks including BPU, BMS, liquid cooling system of battery packs, chiller, HVAC, and ventilation door. A typical LG DC LINK BESS enclosure in a power block configuration is shown in Figure 1.

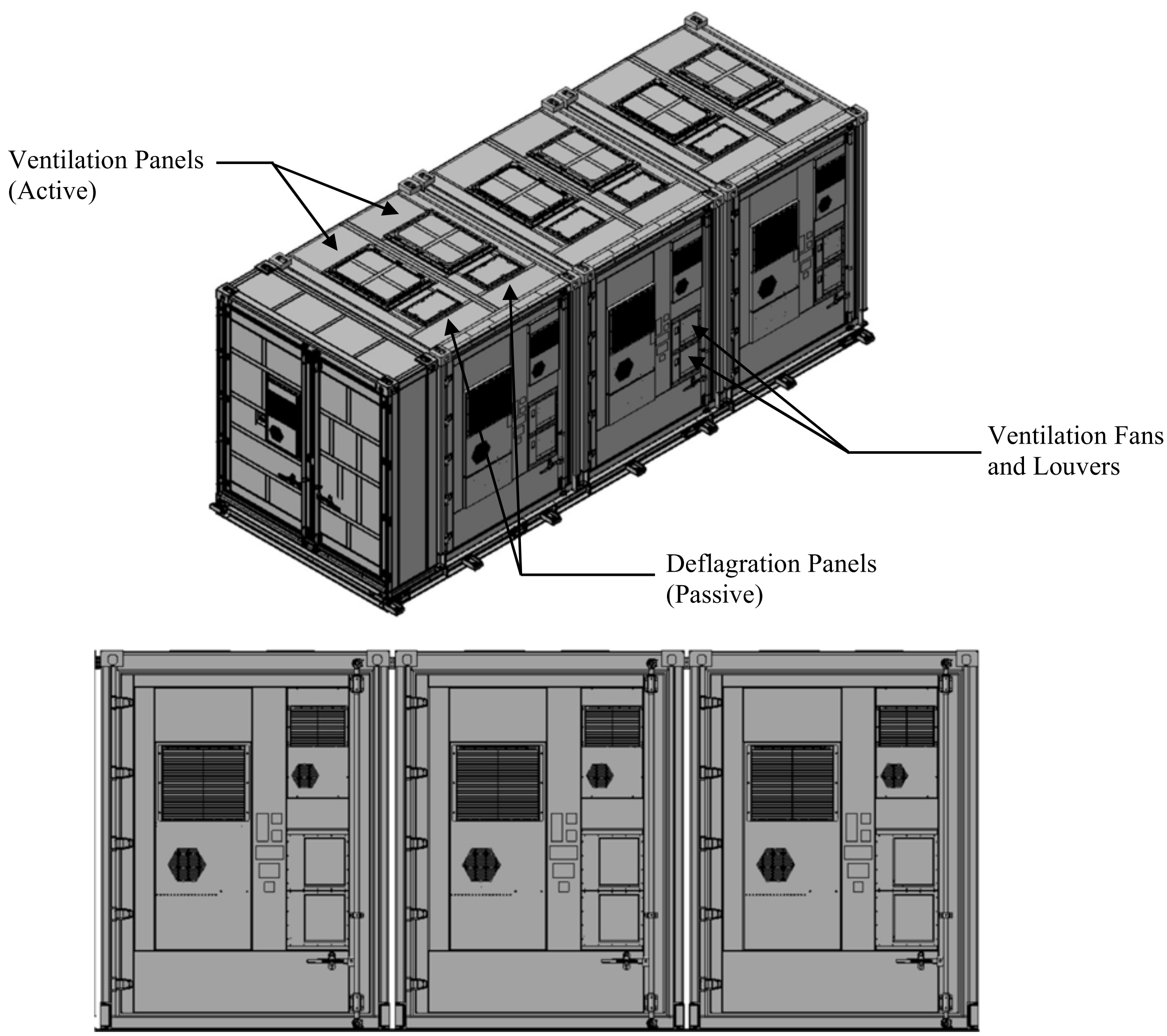


Figure 1. LG DC LINK System ESS

3 UL 9540A TEST SUMMARY

UL9540A, 4th Edition testing was performed on the lithium-ion phosphate ($LiFePO_4$) model JF2-159.2 Ah prismatic battery cells[1]. The cell vent gas compositions for the cells are provided in Table 1 and the flammability characteristics are provided in Table 2.

Table 1. Cell vent gas compositions for the cells (from UL9540A cell level test report)

Gas Constituent		Measured (%)
Carbon Monoxide	CO	0.1000
Carbon Dioxide	CO_2	0.2240
Hydrogen	H_2	0.5930
Methane	CH_4	0.0368
Acetylene	C_2H_2	0.0016
Ethylene	C_2H_4	0.0253
Ethane	C_2H_6	0.0053
Propene	C_3H_6	0.0026
Propane	C_3H_8	0.0012
-	C_4 (Total)	0.0040
-	C_5 (Total)	0.0012
-	C_6 (Total)	0.0039
-	C_7 (Total)	0.0004
-	C_8 (Total)	0.0006
Benzene	C_6H_6	0.0009
Toluene	C_7H_8	0.0001
Total		**1.0000**

Table 2. Cell flammability properties for the cells (from UL9540A cell level test reports)

Gas Constituent	Value
Average cell surface temperature at gas venting, °C	128
Average cell surface temperature at thermal runaway, °C	209.6
Gas volume	64 L
Lower flammability limit (LFL), % volume in air at the ambient temperature	7.4
Lower flammability limit (LFL), % volume in air at the venting temperature	6.6
Burning velocity (S_u) m/s	0.856
Maximum pressure (P_{max}) psig	98.9

[1] UL9540A 4*th* Edition, Cell Level Test Report Project # 4791256609, Dated 09/10/2024

Module level (Model EP096636PFB1) testing performed in accordance with the fourth edition of UL 9540A[2] indicated that 1345.31 L of gas was produced. Figure 2 and Figure 3 shows the venting rate (LPM) during the module level testing for the four main gas components (CO, CO_2, H_2 and THC). Table 3 shows the gas volume produced for each of the four main components and their gas composition in the total gas volume produced.

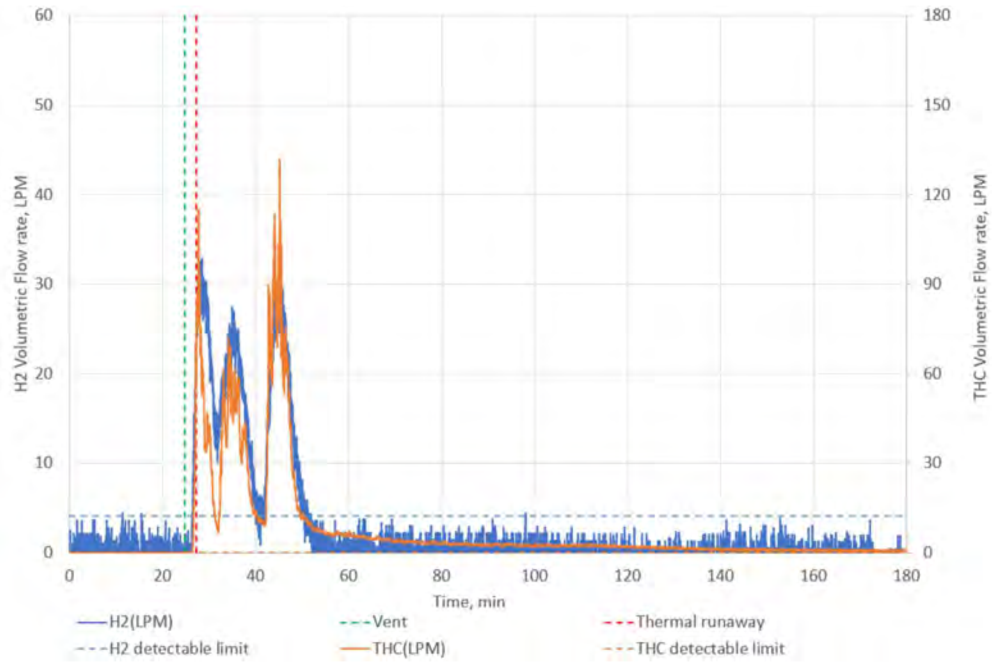


Figure 2. UL 9540A Module Level Test report H2 and THC gas venting rate plots

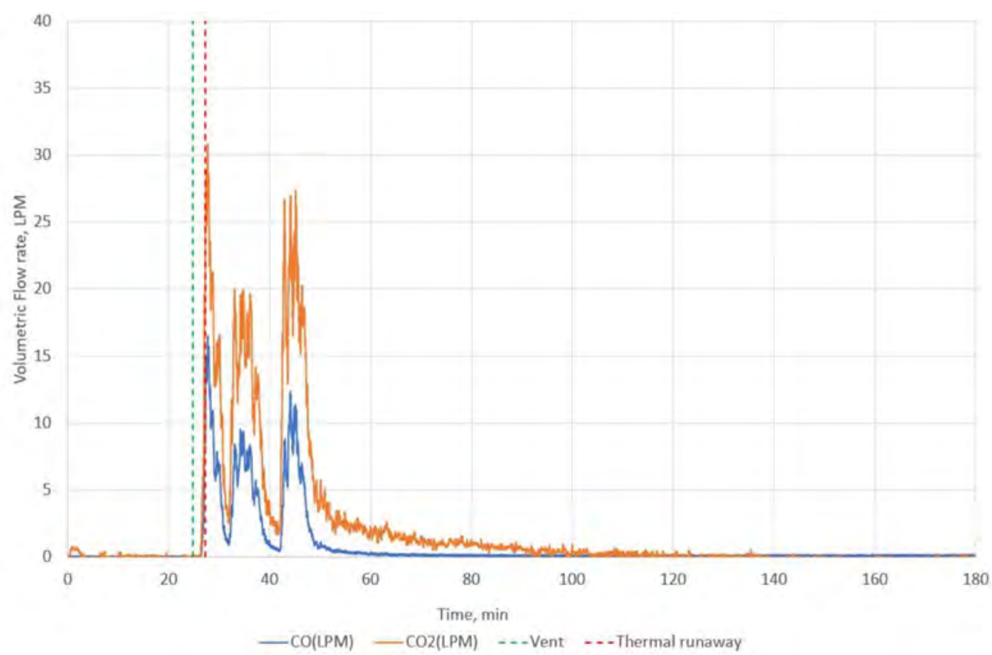


Figure 3. UL 9540A Module Level Test report CO and CO2 gas venting rate plots

[2] UL9540A 4*th* Edition, Module Level Test Report Project # 4791519232, Dated TBD

Table 3. Total gas generation and gas composition from UL 9540A Module Level Test

Module Level Gas Composition	Gas Volume	Gas Concentration
CO	134.14 L	9.97%
H_2	422.97 L	31.44%
THC (Propane Equivalent)	435.21 L	32.35%
CO_2	352.99 L	26.24%
Total	1,345.31 L	

The total peak gas generation rate for the four main gas components (CO, CO_2, H_2 and THC), soon after thermal runaway was initiated, totaled 197 LPM based on the summation of the peak venting rates for each of those components. The FLACS analysis detailed in this report is performed to demonstrate the overpressure conditions within the enclosure during the initial time before the activation of the ventilation system. Therefore, the total gas generation rate calculated above was considered for this analysis since that represents the conditions that would exist in the enclosure during the initial moments soon after thermal runaway and before the ventilation system activates.

4 FLACS CFD ANALYSIS & APPROACH

4.1 FLACS CFD Dispersion and Explosion Modeling

FLACS CFD analysis was performed to determine the overpressures developed in the enclosure due to an internal explosion of the battery gas released. The simulations were performed using version 25.1 of FLACS, a CFD tool developed by Gexcon. FLACS is widely used to perform simulations involving gas dispersion and deflagration. It is designed to perform consequence modeling assessment of deflagration scenarios involving gases, such as could be generated within the BESS cabinet. FLACS has been subjected to extensive and ongoing validation efforts, details of which can be found on the Gexcon website.

4.2 Model Geometry in FLACS

The nominal dimensions of the cabinet are 2.4 m x 1.9 m x 2.5 m (width x depth x height) and an approximate free air space of 4.78 m^3, based on 3D CAD model provided by the Client. An DC LINK is an energy storage device that includes battery modules, a core component of ESS. It contains 2 battery racks including BPU, BMS, liquid cooling system of battery packs, chiller, HVAC, and ventilation door. The ventilation panels (active) were modeled in geometry; however they were just a geometric feature and did not participate in any of the simulations.

The BESS is equipped with 2 units/racks mounted on metal frames. The enclosure contains 28 modules, and each module contains 120 cells. Each enclosure is equipped with a combustible gas detector. The CAD 3D model and the model generated in FLACS are shown in Figure 4.

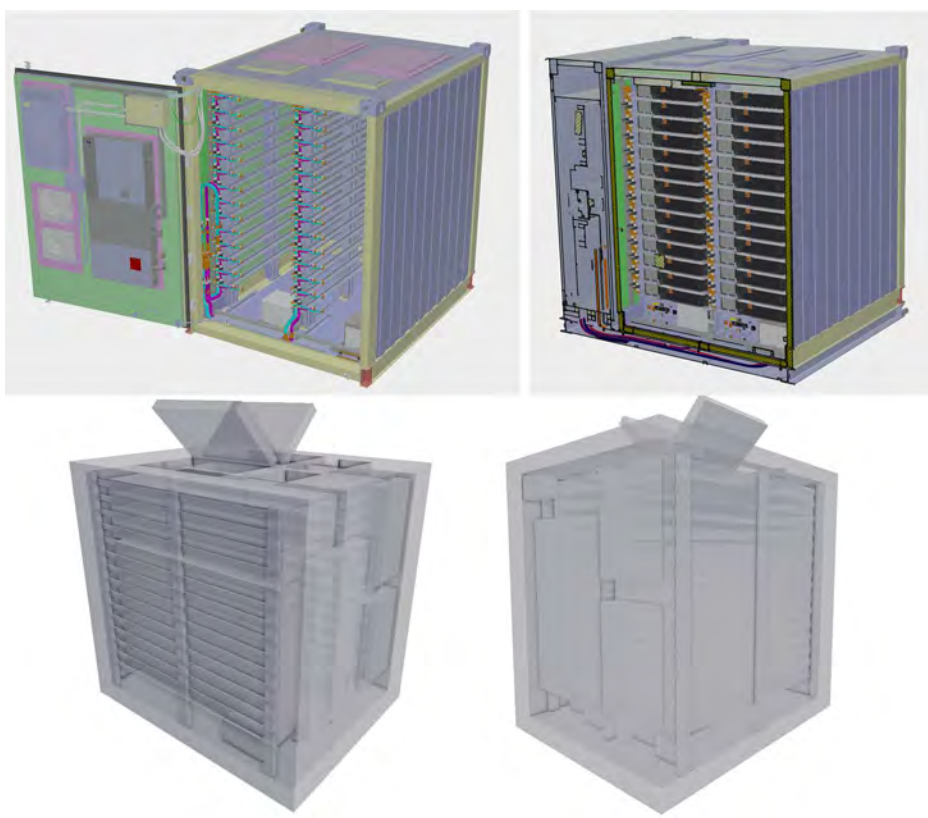


Figure 4. 3D CAD (Top) and FLACS geometry (Bottom) of the LG JF2 DC LINK BESS enclosure

Overpressure on the internal walls of the unit was monitored throughout the simulation using inactive pressure panels in FLACS. The walls were named in the model as “X-Min Wall”, “X-Max Wall”, “Doors”, “Back Wall”, and “Roof”, as shown in Figure 5.

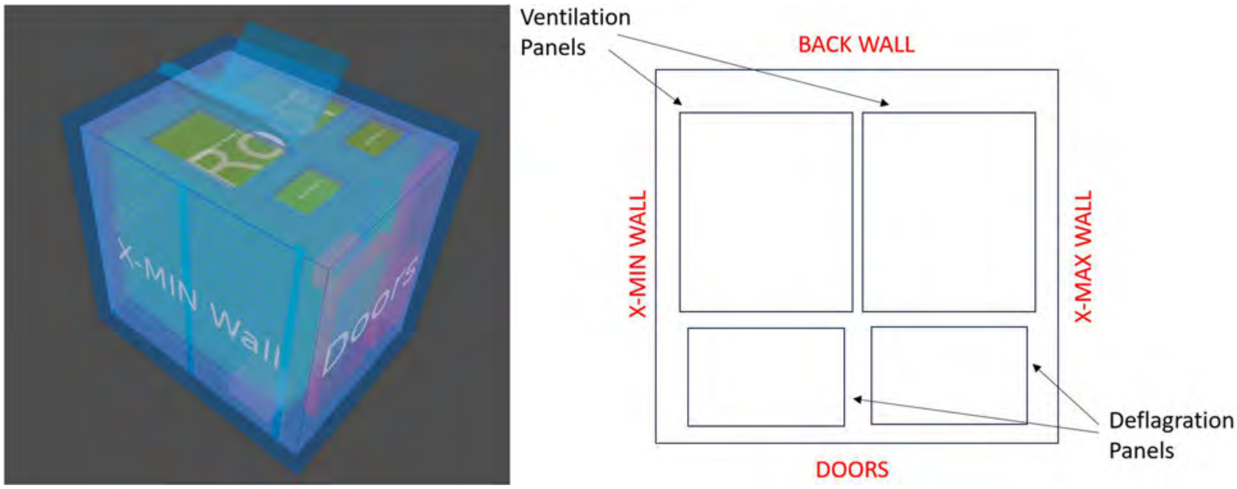


Figure 5. Location of BESS wall pressure panels for monitoring overpressure at the enclosure walls

Based on the deflagration vent panel spec sheet provided by the Client, the maximum effective venting area is approximately 0.254 m^2, with each deflagration vent panel measuring 0.275 m x 0.460 m (0.127 m^2). The activation pressure (P_{stat}) for the deflagration vent panel was 1.45 psi (0.10 bar), which is the pressure at which the deflagration vent panel open and pressurized gases and flame escape. The deflagration vent panel weight was assumed to be 10 kg/m^2.

4.3 Modeled Scenarios

Five gas dispersion scenarios and ten deflagration scenarios (two deflagration scenarios for each dispersion scenario) were modeled and set up in FLACS. The scenarios that were simulated assumed that failure was based on a single battery module.

The enclosure ventilation system was analyzed by Jensen Hughes, per the NFPA 69 performance requirements. The venting rate (source term) for the ventilation system analysis was determined to be 107 LPM, and the detection time was observed to be 9s (including a 20% safety factor) based on the FDS modeling and simulation results. Information provided by LG indicates that the ventilation system takes 27 seconds to ramp up after gas detection. This ramp-up time includes the ventilation fan on the door and ventilation panels at the ceiling.

Therefore, as a conservative approach for this analysis, the two deflagration scenarios’ dispersion cases included gas cloud accumulation up to 9 seconds for the first simulation and up to 36 seconds for the second simulation. It should be noted that the ventilation system does activate starting at 9 seconds, which would result in some gas to escape. However, the analysis assumed that the ventilation system does not activate during the entirety of the dispersion simulation, and the 36 seconds deflagration simulation provided the worst-case gas volume released up to that duration limit.

4.3.1 Dispersion & Deflagration Simulation Scenario 1

The battery vent gas dispersion for scenario 1 is based on the venting rate data from the module level test (as shown in Figure 2 and Figure 3) and gas composition from the cell level test as described in Table 1. The scenario modeled the dispersion of flammable gas from two release locations on the module that would partially fill the free air volume inside the enclosure, Figure 6. The flammable vent gas is released into the ambient air inside the enclosure at a constant rate of 197 LPM (0.00219 kg/s using the calculated density of gas from cell level testing) based on the summation of peak venting rates for CO, CO_2, H_2, and THC shown in Figure 2 and Figure 3. The gas release progressively took up a portion of the free/open air volume inside the enclosure as the duration increased. The total release duration for the flammable vent gas from the initiating module was 40 seconds. At the end of the release duration, a gas cloud concentration above the LFL was attained within the enclosure. At this point, ignition was initiated just above the release location, which was modeled in the two explosion scenarios.

a. Scenario 1 – Deflagration Case 1: For the first deflagration scenario, the gas accumulation data up to a duration of 9 seconds from the dispersion simulation was used as input. The simulation was then performed to determine the overpressures generated within the enclosure due to gas cloud ignition.

b. Scenario 1 – Deflagration Case 2: For the second deflagration scenario, the gas accumulation data up to a duration of 36 seconds from the dispersion simulation was used as input. The simulation was then performed to determine the overpressures generated within the enclosure due to gas cloud ignition.

Only a single ignition location was considered for the deflagration simulations, as the gas cloud accumulation over 100% LFL was insignificant at the roof of the enclosure. Hence, a top ignition case (closer to the roof) was not performed.

4.3.2 Dispersion & Deflagration Simulation Scenario 2

The battery vent gas dispersion for scenario 2 is based on the venting rate data from the NFPA 69 analysis and gas composition from the cell level test that would partially fill the free air volume inside the enclosure, as described in Table 1. Scenario 2 modeled the dispersion of flammable gas from two release locations on the module as shown in Figure 6. Per the Jensen Hughes NFPA 69 analysis, flammable vent gas is released into the ambient air inside the enclosure at a constant rate of 107 LPM (0.00119 kg/s using the calculated density of gas from cell level testing). The gas release progressively took up a portion of the free/open air volume inside the enclosure as the duration increased. The total release duration for the flammable vent gas from the initiating module was 40 seconds. At the end of the release duration, a gas cloud concentration above the LFL was attained within the enclosure. At this point, ignition was initiated just above the release location, which was modeled in the two explosion scenarios.

a. Scenario 2 – Deflagration Case 1: For the first deflagration scenario, the gas accumulation data up to a duration of 9 seconds from the dispersion simulation was used as input. The simulation was then performed to determine the overpressures generated within the enclosure due to gas cloud ignition.

b. Scenario 2 – Deflagration Case 2: For the second deflagration scenario, the gas accumulation data up to a duration of 36 seconds from the dispersion simulation was used as input. The simulation was then performed to determine the overpressures generated within the enclosure due to gas cloud ignition.

Only a single ignition location was considered for the deflagration simulations, as the gas cloud accumulation over 100% LFL was insignificant at the roof of the enclosure. Hence, a top ignition case (closer to the roof) was not performed.

4.3.3 Dispersion & Deflagration Simulation Scenario 3

The battery vent gas dispersion for scenario 3 is based on the venting rate data from the module level test (as shown in Figure 2 and Figure 3) and gas composition from the module level test as well, as shown in Table 3. The scenario modeled the dispersion of flammable gas from two release locations on the module, as shown in Figure 6, that would partially fill the free air volume inside the enclosure. The flammable vent gas is released into the ambient air inside the enclosure at a constant rate of 197 LPM (0.0038 kg/s using the calculated density of gas from module level testing) based on the summation of peak venting rates for CO, CO_2, H_2 and THC as shown in Figure 2 and Figure 3. The gas release progressively took up a portion of the free/open air volume inside the enclosure as the duration increased. The total release duration for the flammable vent gas from the initiating module was 40s. At the end of the release duration, a gas cloud concentration above the lower flammability limit (LFL) was attained within the enclosure. At this point, ignition was initiated just above the release location, which was modeled in the two explosion scenarios.

a. Scenario 3 – Deflagration Case 1: For the first deflagration scenario, the gas accumulation data up to a duration of 9s from the dispersion simulation was used as input. The simulation was then performed to determine the overpressures generated within the enclosure due to gas cloud ignition.

b. Scenario 3 – Deflagration Case 2: For the second deflagration scenario, the gas accumulation data up to a duration of 36s from the dispersion simulation was used as input. The simulation was then performed to determine the overpressures generated within the enclosure due to gas cloud ignition.

Only a single ignition location was considered for the deflagration simulations as the gas cloud accumulation over 100% LEL was insignificant at the roof of the enclosure and hence a top ignition case (closer to the roof) was not performed.

4.3.4 Dispersion & Deflagration Simulation Scenario 4

The battery vent gas dispersion for scenario 4 is based on the venting rate data from the module level test (as shown in Figure 2 and Figure 3) and gas composition from the cell level test, as shown in Table 1. The scenario modeled the dispersion of flammable gas from a single release location on the module, as shown in Figure 6, that would partially fill the free air volume inside the enclosure. The flammable vent gas is released into the ambient air inside the enclosure at a constant rate of 197 LPM (0.00219 kg/s using the calculated density of gas from cell level testing) based on the summation of peak venting rates for CO, CO_2, H_2 and THC as shown in Figure 2 and Figure 3. The gas release progressively took up a portion of the free/open air volume inside the enclosure as the duration increased. The total release duration for the flammable vent gas from the initiating module was 40s. At the end of the release duration, a gas cloud concentration above the lower flammability limit (LFL) was attained within the enclosure. At this point, ignition was initiated just above the release location, which was modeled in the two explosion scenarios.

a. Scenario 4 – Deflagration Case 1: For the first deflagration scenario, the gas accumulation data up to a duration of 9s from the dispersion simulation was used as input. The simulation was then performed to determine the overpressures generated within the enclosure due to gas cloud ignition.

b. Scenario 4 – Deflagration Case 2: For the second deflagration scenario, the gas accumulation data up to a duration of 36s from the dispersion simulation was used as input. The simulation was then performed to determine the overpressures generated within the enclosure due to gas cloud ignition.

Only a single ignition location was considered for the deflagration simulations as the gas cloud accumulation over 100% LEL was insignificant at the roof of the enclosure and hence a top ignition case (closer to the roof) was not performed.

4.3.5 Dispersion & Deflagration Simulation Scenario 5

The battery vent gas dispersion for scenario 5 is based on the venting rate data from the module level test (as shown in Figure 2 and Figure 3) and gas composition from the module level test as well, as shown in Table 3. The scenario modeled the dispersion of flammable gas from a single release location on the module, as shown in Figure 6, that would partially fill the free air volume inside the enclosure. The flammable vent gas is released into the ambient air inside the enclosure at a constant rate of 197 LPM (0.0038 kg/s using the calculated density of gas from module level testing) based on the summation of peak venting rates for CO, CO_2, H_2 and THC as shown in Figure 2 and Figure 3. The gas release progressively took up a portion of the free/open air volume inside the enclosure as the duration increased. The total release duration for the flammable vent gas from the initiating module was 40s. At the end of the release duration, a gas cloud concentration above the lower flammability limit (LFL) was attained within the enclosure. At this point, ignition was initiated just above the release location, which was modeled in the two explosion scenarios.

a. Scenario 5 – Deflagration Case 1: For the first deflagration scenario, the gas accumulation data up to a duration of 9s from the dispersion simulation was used as input. The simulation was then performed to determine the overpressures generated within the enclosure due to gas cloud ignition.

b. Scenario 5 – Deflagration Case 2: For the second deflagration scenario, the gas accumulation data up to a duration of 36s from the dispersion simulation was used as input. The simulation was then performed to determine the overpressures generated within the enclosure due to gas cloud ignition.

Only a single ignition location was considered for the deflagration simulations as the gas cloud accumulation over 100% LEL was insignificant at the roof of the enclosure and hence a top ignition case (closer to the roof) was not performed.

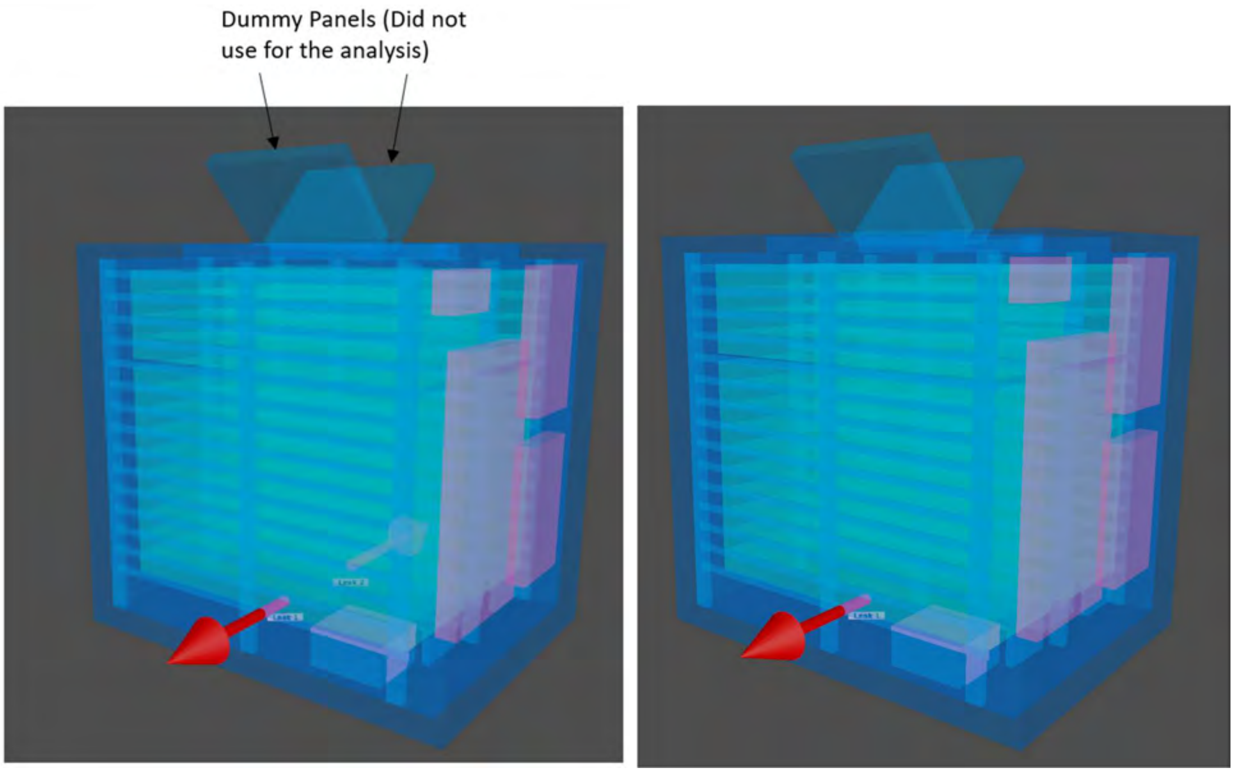


Figure 6. FLACS model setup for dispersion simulations with two location release (left) and a single location release (right)

Table 4. Summary for scenarios and model setup in FLACS

Simulation Number	Simulation Type	Gas Venting Rate	Gas Composition	Gas Venting Duration	Release Location Details
Scenario 1 100001	Dispersion	197 LPM		40s	Bottom module, 2 release points on both sides of the module
Scenario 1 100022	Deflagration	-	Cell Level Gas Composition	-	Deflagration simulation at 9s data from dispersion simulation
Scenario 1 100023	Deflagration	-		-	Deflagration simulation at 36s data from dispersion simulation
Scenario 2 100002	Dispersion	107 LPM		40s	Bottom module, 2 release points on both sides of the module
Scenario 2 200021	Deflagration	-	Cell Level Gas Composition	-	Deflagration simulation at 9s data from dispersion simulation
Scenario 2 200022	Deflagration	-		-	Deflagration simulation at 36s data from dispersion simulation

Simulation Number	Simulation Type	Gas Venting Rate	Gas Composition	Gas Venting Duration	Release Location Details
Scenario 3 100003	Dispersion	197 LPM	Module Level Gas Composition	40s	Bottom module, 2 release points on both sides of the module
Scenario 3 300021	Deflagration	-		-	Deflagration simulation at 9s data from dispersion simulation
Scenario 3 300022	Deflagration	-		-	Deflagration simulation at 36s data from dispersion simulation
Scenario 4 100004	Dispersion	197 LPM	Cell Level Gas Composition	40s	Bottom module, 1 release points on wall facing side of the module
Scenario 4 400021	Deflagration	-		-	Deflagration simulation at 9s data from dispersion simulation
Scenario 4 400022	Deflagration	-		-	Deflagration simulation at 36s data from dispersion simulation
Scenario 5 100005	Dispersion	197 LPM	Module Level Gas Composition	40s	Bottom module, 1 release points on wall facing side of the module
Scenario 5 500021	Deflagration	-		-	Deflagration simulation at 9s data from dispersion simulation
Scenario 5 500022	Deflagration	-		-	Deflagration simulation at 36s data from dispersion simulation

5 FLACS CFD MODELING RESULTS

5.1 Dispersion Results

Figure 7 through Figure 11 shows the results for the five dispersion simulations performed with different venting rate terms, gas compositions, and venting locations.

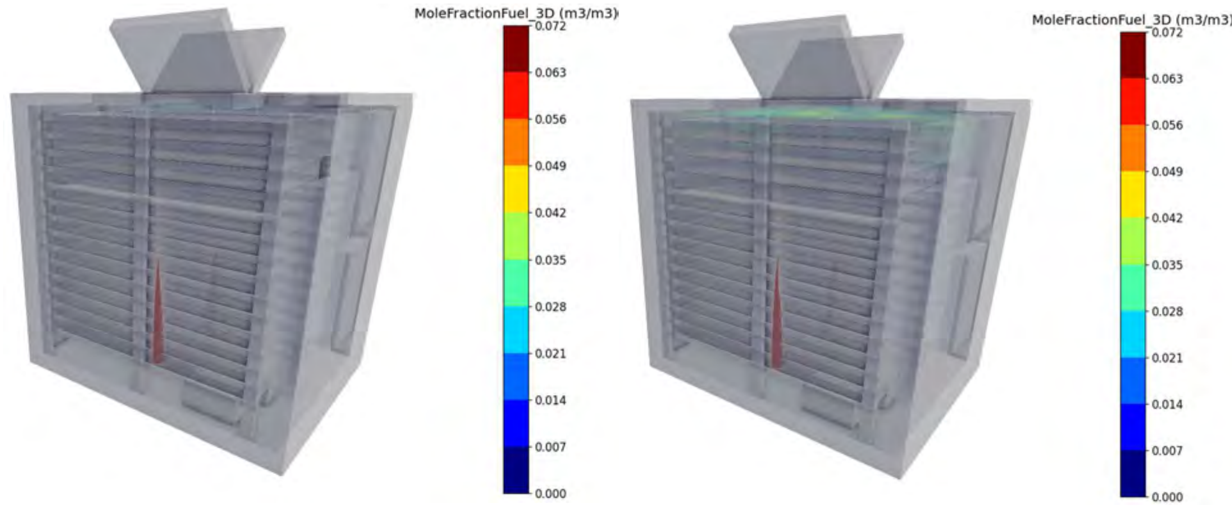


Figure 7. Dispersion results for dispersion scenario 1 with vent gas release and gas cloud accumulation within the enclosure at 9 seconds (left) and 36 seconds (right)

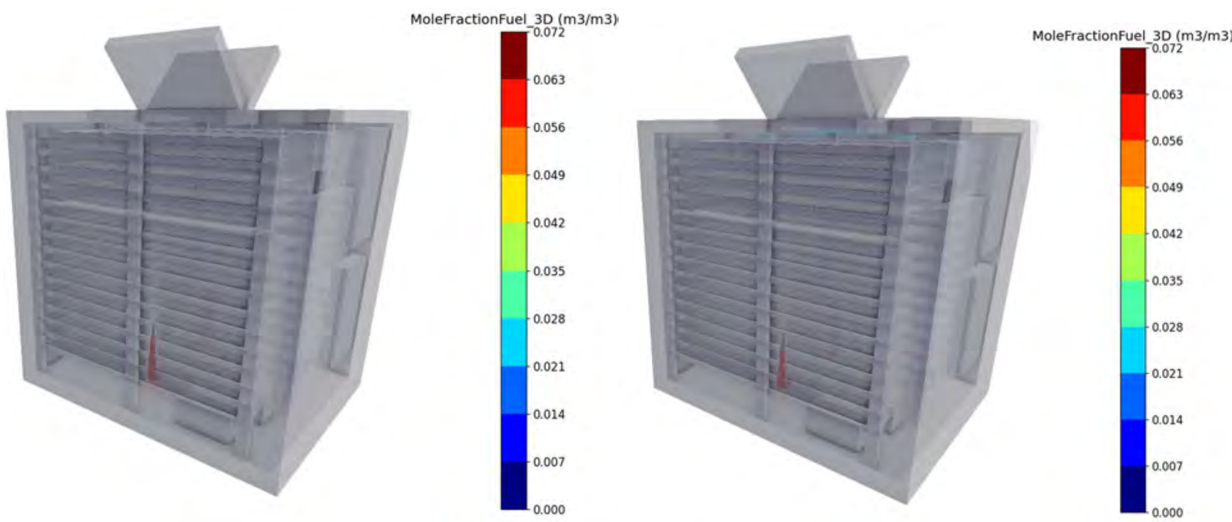


Figure 8. Dispersion results for dispersion scenario 2 with vent gas release and gas cloud accumulation within the enclosure at 9 seconds (left) and 36 seconds (right)

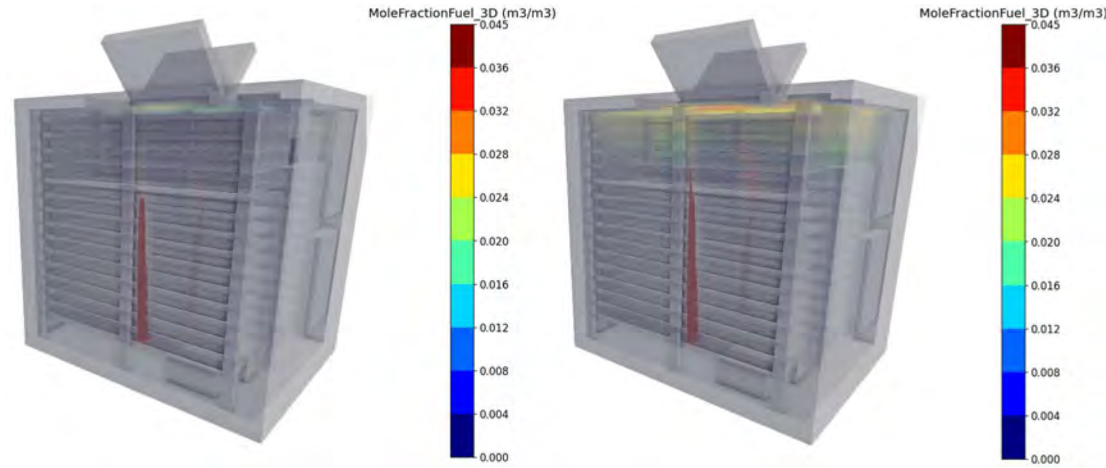


Figure 9. Dispersion results for dispersion scenario 3 with vent gas release and gas cloud accumulation within the enclosure at 9 seconds (left) and 36 seconds (right)

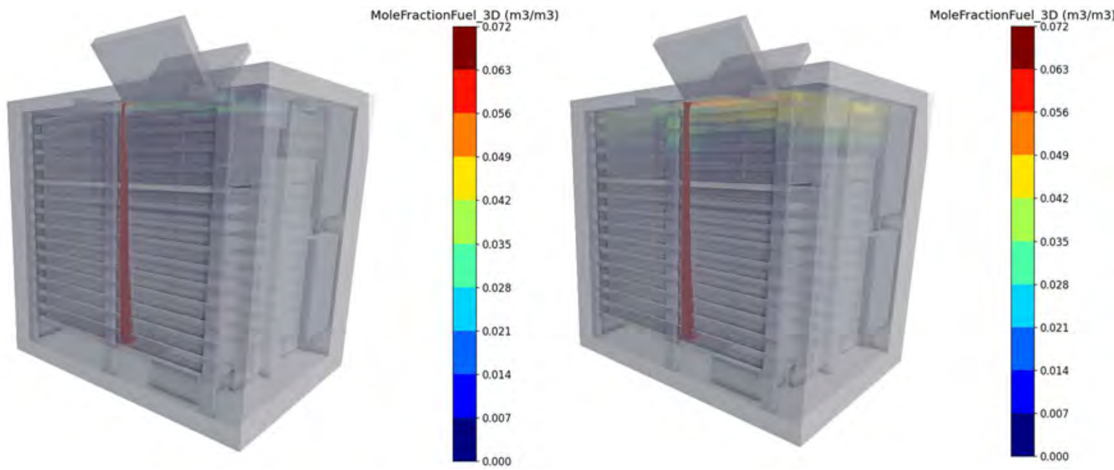


Figure 10. Dispersion results for dispersion scenario 4 with vent gas release and gas cloud accumulation within the enclosure at 9 seconds (left) and 36 seconds (right)

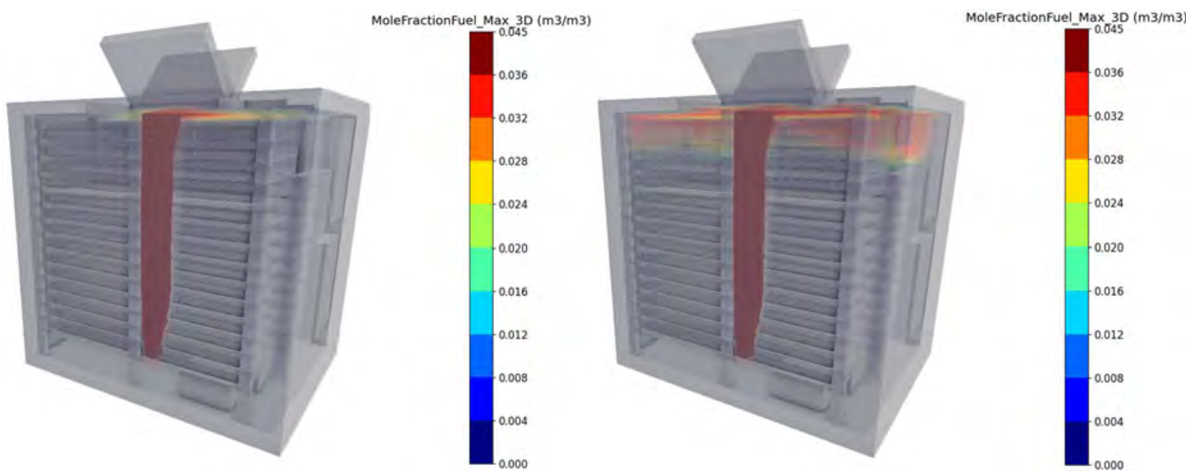


Figure 11. Dispersion results for dispersion scenario 5 with vent gas release and gas cloud accumulation within the enclosure at 9 seconds (left) and 36 seconds (right)

5.2 Overpressure

The average pressures recorded at the internal walls for the various simulation scenarios are summarized in Table 5 through Table 7. The negative/positive sign simply indicates the direction in which the pressure was acting, relative to the FLACS Cartesian grids.

The overall peak average wall pressures of up to 0.147 bar-g (2.132 psig) were recorded for the 197 LPM, module level test gas composition, single release location, and gas accumulation up to 36 seconds in the presence of the two deflagration vents.

Table 5. Average pressure at enclosure internal walls (in bar-g) (Scenario 1 and Scenario 2)

Wall	197 LPM Cell Gas Comp 9s, 2 Release Points (Scenario 1) (100022)	197 LPM Cell Gas Comp 36s, 2 Release Points (Scenario 1) (100023)	107 LPM Cell Gas Comp 9s, 2 Release Points (Scenario 2) (200021)	107 LPM Cell Gas Comp 36s, 2 Release Points (Scenario 2) (200022)
Doors	-0.005	-0.018	-0.003	-0.011
Backwall	0.009	0.035	0.007	0.021
X-Min Wall	-0.009	-0.034	-0.006	-0.020
X-Max Wall	0.009	0.034	0.006	0.020
Roof	0.010	0.037	0.007	0.022
Maximum (bar-g)	**0.010**	**0.037**	**0.007**	**0.022**
Maximum (psig)	**0.145**	**0.537**	**0.102**	**0.319**

Table 6. Average pressure at enclosure internal walls (in bar-g) (Scenario 3 and Scenario 4)

Wall	197 LPM Module Gas Comp 9s, 2 Release Points (Scenario 3) (300021)	197 LPM Module Gas Comp 36s, 2 Release Points (Scenario 3) (300022)	197 LPM Cell Gas Comp 9s, 1 Release Point (Scenario 4) (400021)	197 LPM Cell Gas Comp 36s, 1 Release Point (Scenario 4) (400022)
Doors	-0.013	-0.026	-0.006	-0.017
Backwall	0.025	0.049	0.012	0.033
X-Min Wall	-0.024	-0.047	-0.012	-0.032
X-Max Wall	0.024	0.047	0.012	0.032
Roof	0.027	0.053	0.013	0.035
Maximum (bar-g)	**0.027**	**0.053**	**0.013**	**0.035**
Maximum (psig)	**0.392**	**0.769**	**0.189**	**0.508**

Table 7. Average pressure at enclosure internal walls (in bar-g) (Scenario 5)

Wall	197 LPM Module Gas Comp 9s, 1 Release Point (Scenario 5) (500021)	197 LPM Module Gas Comp 36s, 1 Release Point (Scenario 5) (500022)
Doors	-0.016	-0.073
Backwall	0.031	0.138
X-Min Wall	-0.030	-0.132
X-Max Wall	0.030	0.132
Roof	0.033	0.147
Maximum (bar-g)	**0.033**	**0.147**
Maximum (psig)	**0.479**	**2.132**

The average pressures recorded at the internal walls of the cabinet are shown in Figure 12 through Figure 21 for all simulated scenarios.

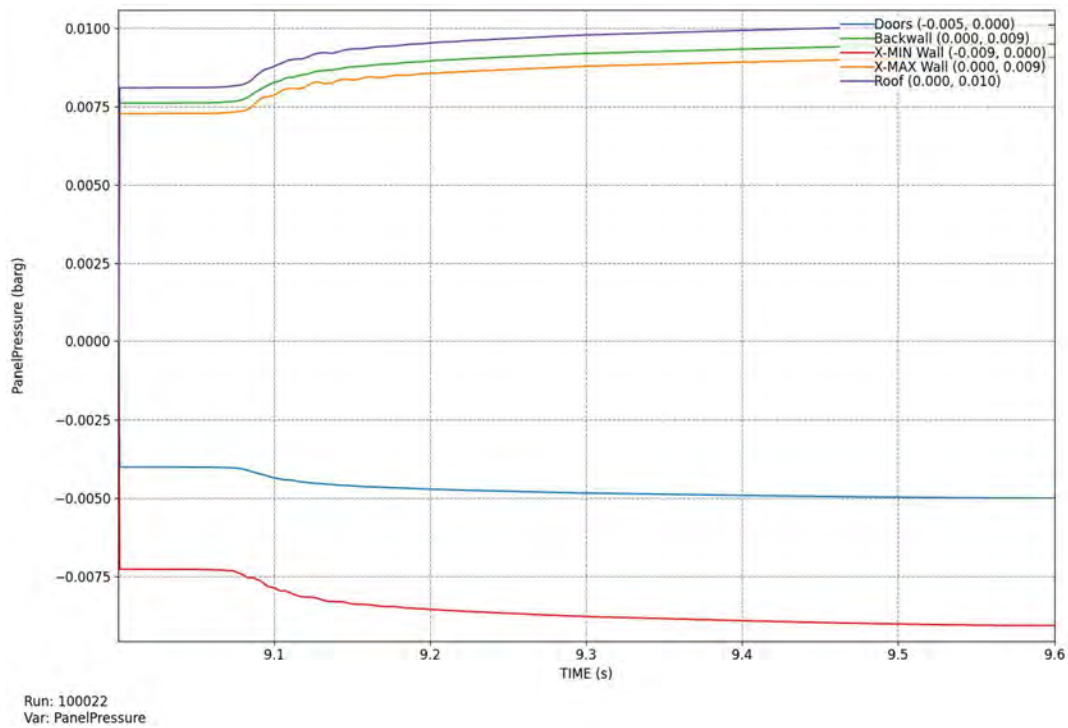


Figure 12. Average panel pressure profiles at enclosure internal walls (197 LPM, cell level gas composition, 9 seconds, 2 release points) (Scenario 1) (100022)

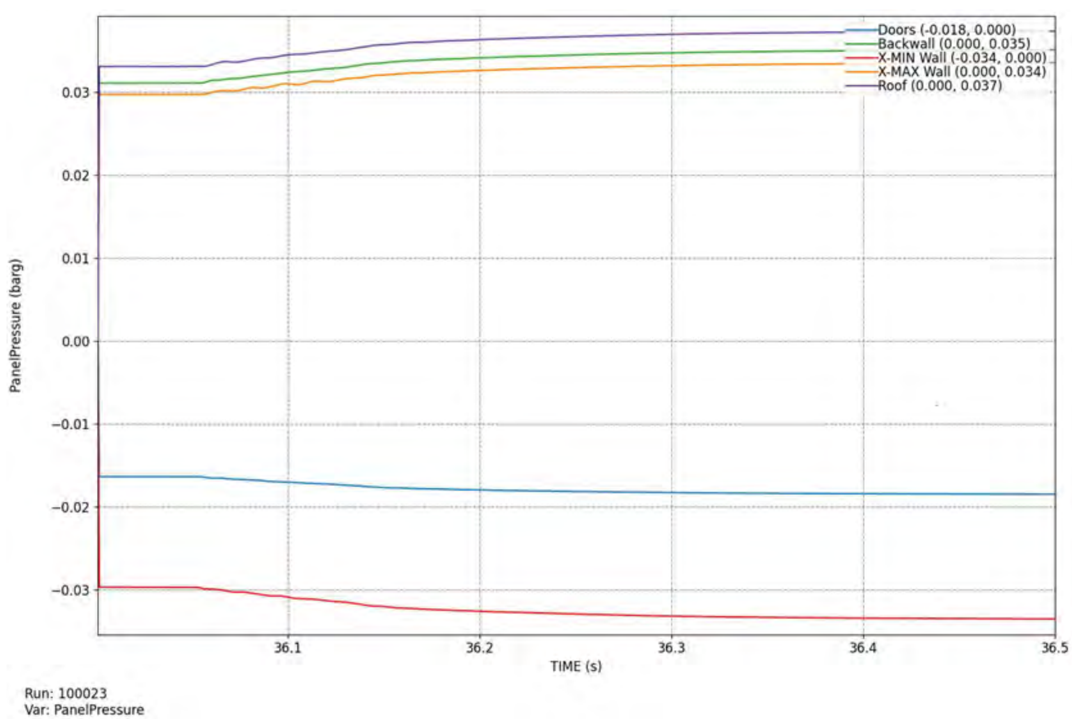


Figure 13. Average panel pressure profiles at enclosure internal walls (197 LPM, cell level gas composition, 36 seconds, 2 release points) (Scenario 1) (100023)

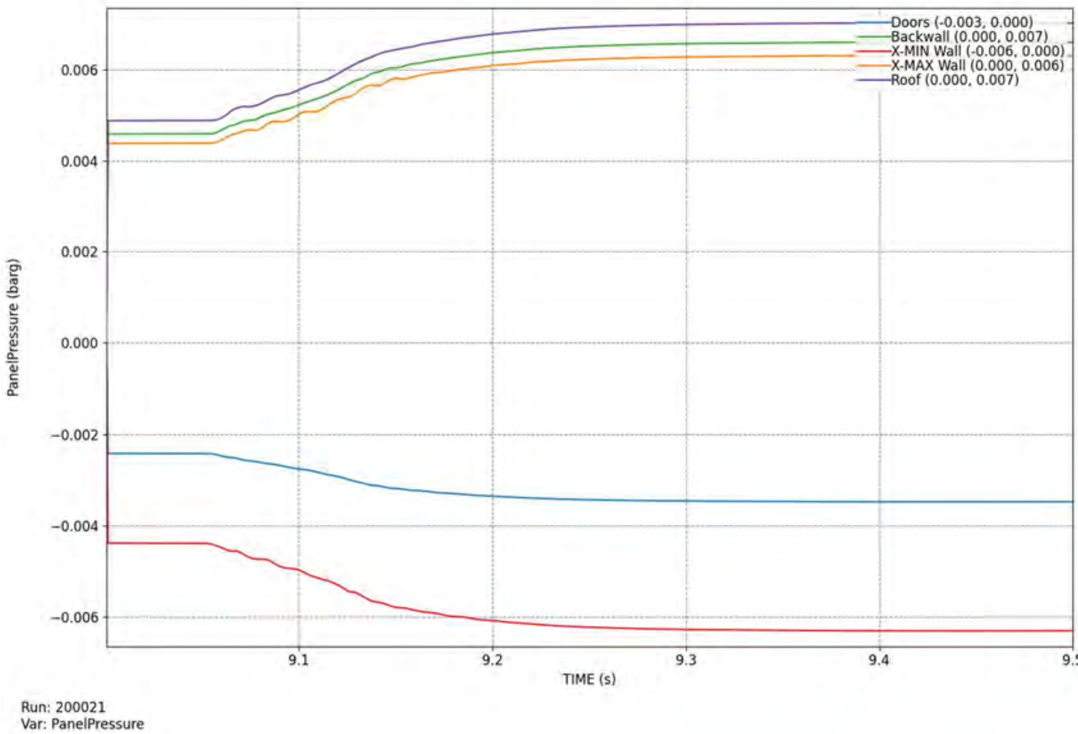


Figure 14. Average panel pressure profiles at enclosure internal walls (107 LPM, cell level gas composition, 9 seconds, 2 release points) (Scenario 2) (200021)

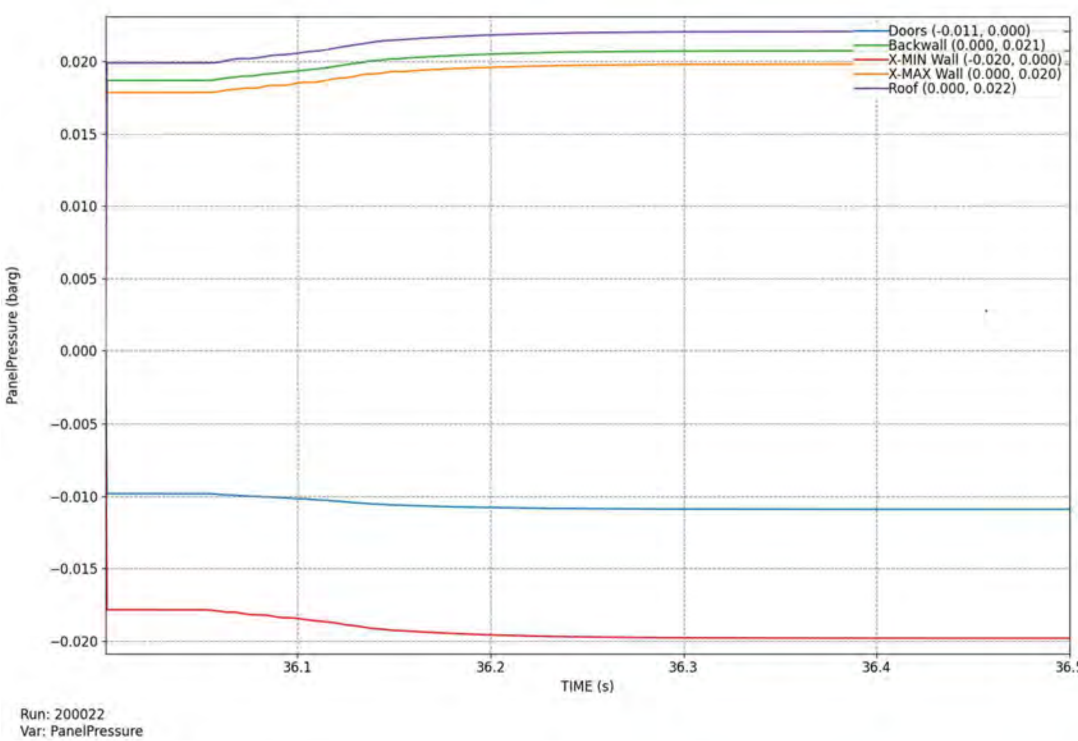


Figure 15. Average panel pressure profiles at enclosure internal walls (107 LPM, cell level gas composition, 36 seconds, 2 release points) (Scenario 2) (200022)

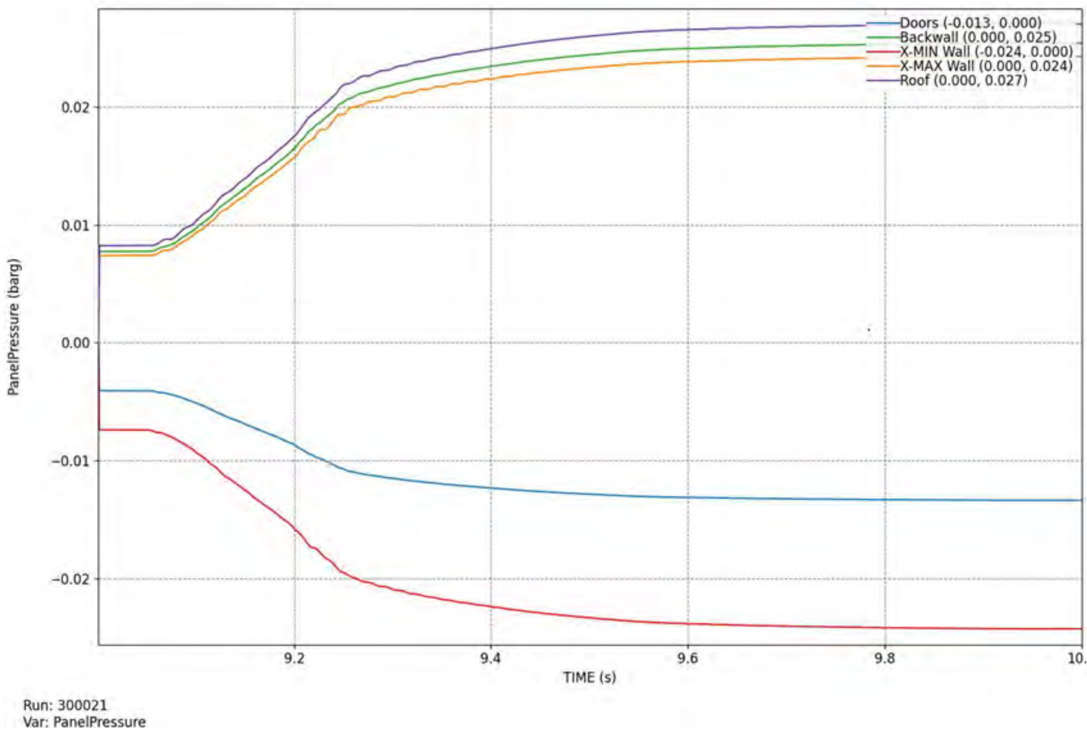


Figure 16. Average panel pressure profiles at enclosure internal walls (197 LPM, module level gas composition, 9 seconds, 2 release points) (Scenario 3) (300021)

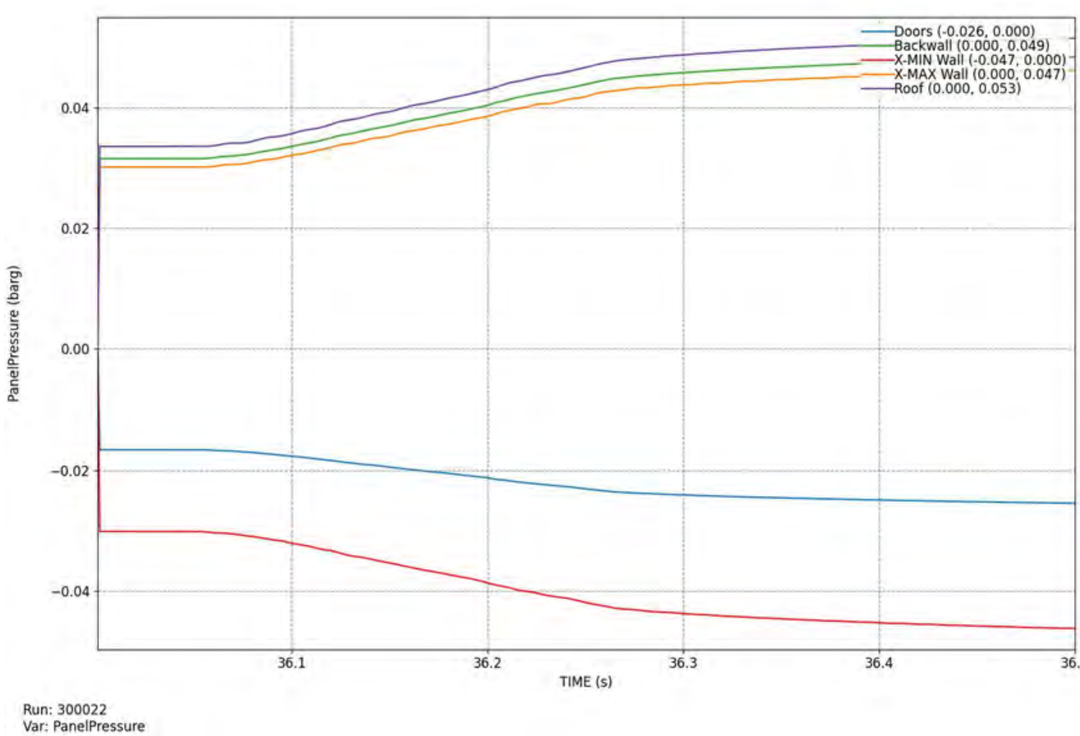


Figure 17. Average panel pressure profiles at enclosure internal walls (197 LPM, module level gas composition, 36 seconds, 2 release points) (Scenario 3) (300022)

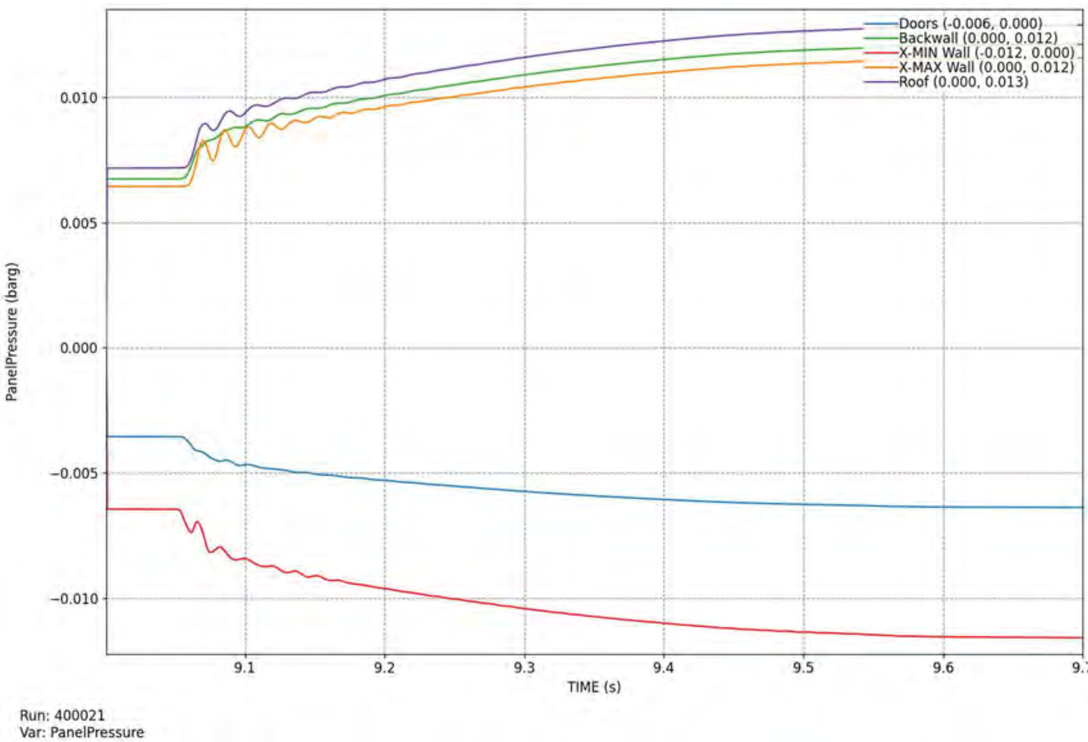


Figure 18. Average panel pressure profiles at enclosure internal walls (197 LPM, cell level gas composition, 9 seconds, 1 release point) (Scenario 4) (400021)

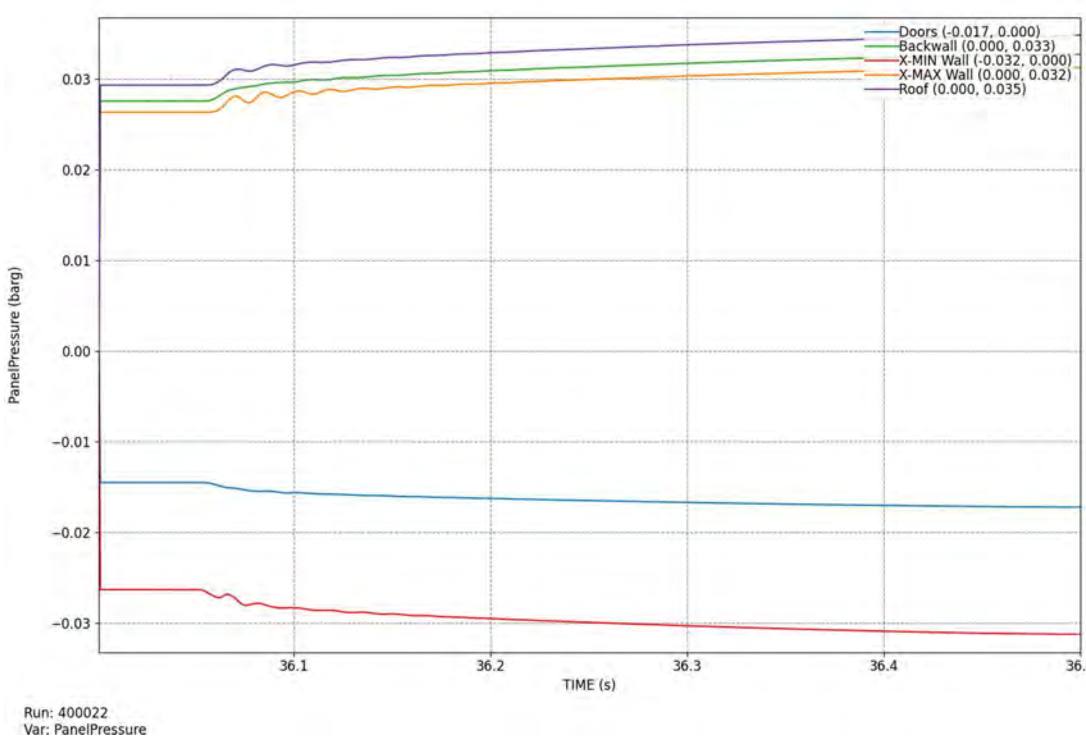


Figure 19. Average panel pressure profiles at enclosure internal walls (197 LPM, cell level gas composition, 36 seconds, 1 release point) (Scenario 4) (400022)

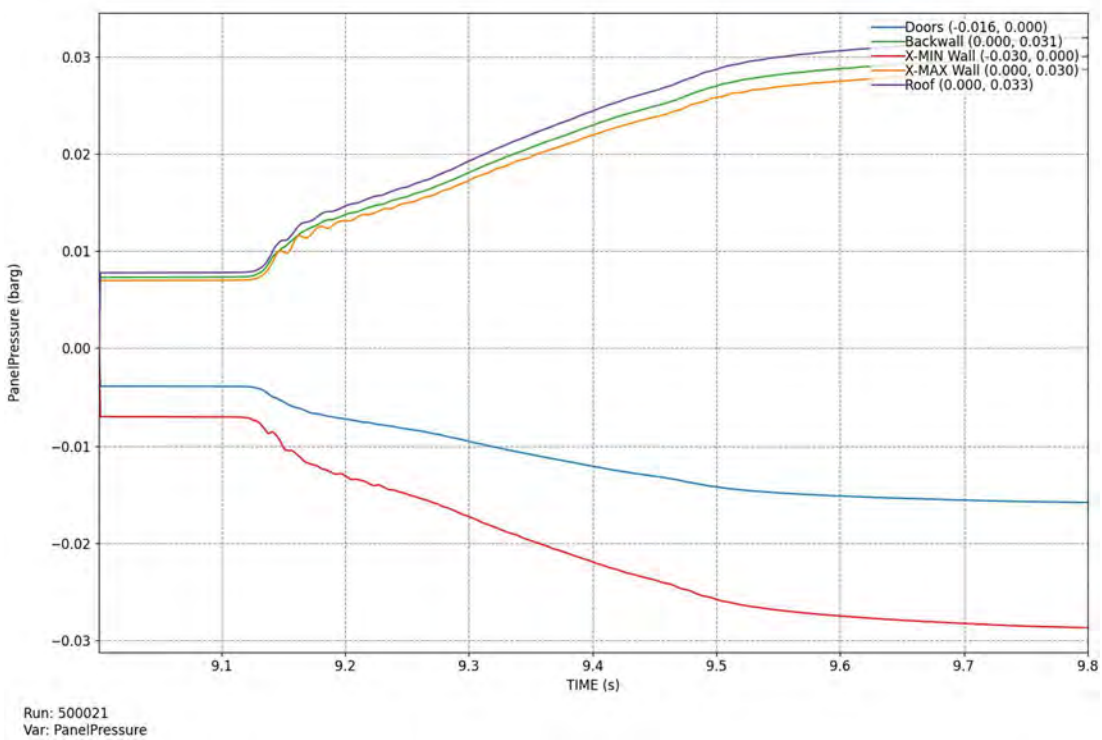


Figure 20. Average panel pressure profiles at enclosure internal walls (197 LPM, module level gas composition, 9 seconds, 1 release point) (Scenario 5) (500021)

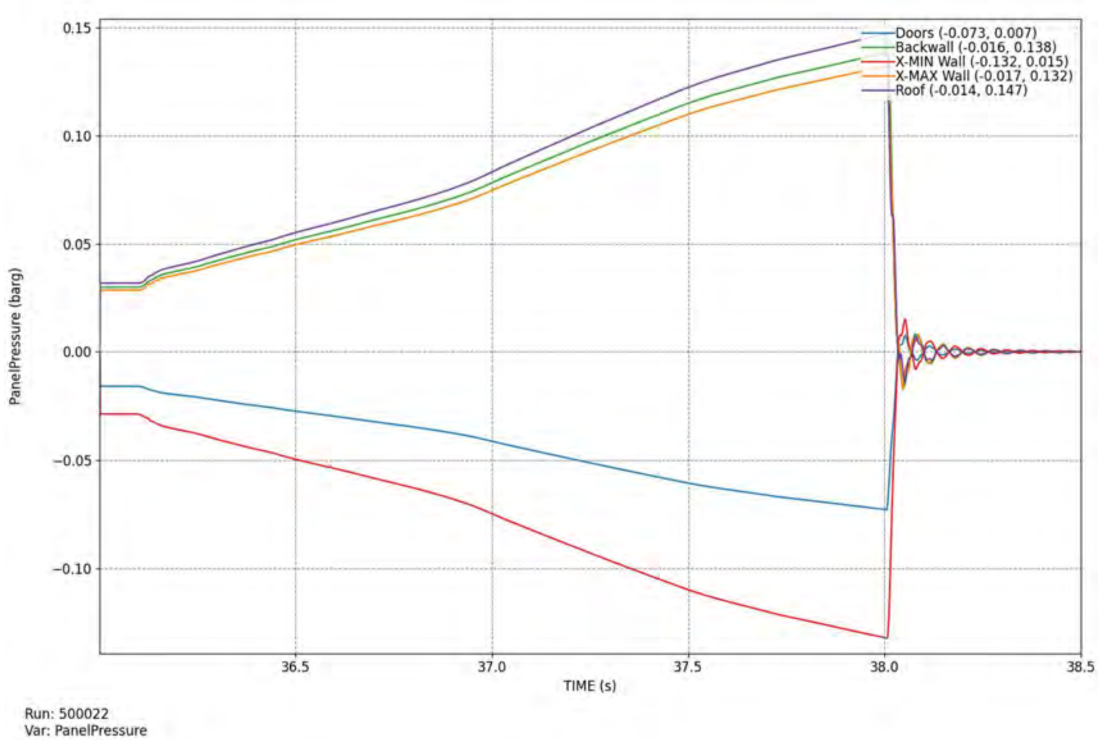


Figure 21. Average panel pressure profiles at enclosure internal walls (197 LPM, module level gas composition, 36 seconds, 1 release point) (Scenario 5) (500022)

6 SUMMARY OF FINDINGS

Flammable gas explosion analysis was conducted for the LG JF2 DC LINK BESS enclosure using the computational fluid dynamics tool FLACS CFD to determine the impact of a deflagration occurring in the cabinet under three scenarios. The two deflagration vent panels located on the roof of the cabinet provide an effective vent area of 0.254 m^2.

Important findings of the analysis presented in this report can be summarized as follows:

Scenario 5 demonstrates the worst-case, with 197 LPM venting rate, gas composition from the UL 9540A module level test, single release location and gas accumulation of up to 36s, the peak simulated average pressure on the internal walls of the cabinet was **0.147 bar-g (2.132 psig).**

Average pressure at enclosure internal walls (in bar-g) (Scenario 1 and Scenario 2)

Wall	197 LPM Cell Gas Comp 9s, 2 Release Points (Scenario 1) (100022)	197 LPM Cell Gas Comp 36s, 2 Release Points (Scenario 2) (100023)	107 LPM Cell Gas Comp 9s, 2 Release Points (Scenario 2) (200021)	107 LPM Cell Gas Comp 36s, 2 Release Points (Scenario 2) (200022)
Doors	-0.005	-0.018	-0.003	-0.011
Backwall	0.009	0.035	0.007	0.021
X-Min Wall	-0.009	-0.034	-0.006	-0.020
X-Max Wall	0.009	0.034	0.006	0.020
Roof	0.010	0.037	0.007	0.022
Maximum (bar-g)	**0.010**	**0.037**	**0.007**	**0.022**
Maximum (psig)	**0.145**	**0.537**	**0.102**	**0.319**

Average pressure at enclosure internal walls (in bar-g) (Scenario 3 and Scenario 4)

Wall	197 LPM Module Gas Comp 9s, 2 Release Points (Scenario 3) (300021)	197 LPM Module Gas Comp 36s, 2 Release Points (Scenario 3) (300022)	197 LPM Cell Gas Comp 9s, 1 Release Point (Scenario 4) (400021)	197 LPM Cell Gas Comp 36s, 1 Release Point (Scenario 4) (400022)
Doors	-0.013	-0.026	-0.006	-0.017
Backwall	0.025	0.049	0.012	0.033
X-Min Wall	-0.024	-0.047	-0.012	-0.032
X-Max Wall	0.024	0.047	0.012	0.032
Roof	0.027	0.053	0.013	0.035
Maximum (bar-g)	**0.027**	**0.053**	**0.013**	**0.035**
Maximum (psig)	**0.392**	**0.769**	**0.189**	**0.508**

Average pressure at enclosure internal walls (in bar-g) (Scenario 5)

Wall	**197 LPM Module Gas Comp 9s, 1 Release Point (Scenario 5) (500021)**	**197 LPM Module Gas Comp 36s, 1 Release Point (Scenario 5) (500022)**
Doors	-0.016	-0.073
Backwall	0.031	0.138
X-Min Wall	-0.030	-0.132
X-Max Wall	0.030	0.132
Roof	0.033	0.147
Maximum (bar-g)	**0.033**	**0.147**
Maximum (psig)	**0.479**	**2.132**

7 CONCLUSION

Based on the results of the current FLACS analysis, the maximum simulated pressure in the DC LINK enclosure is 0.147 bar-g (2.132 psig), corresponding to a venting rate source term of 197 LPM and gas composition based on UL 9540A module level testing. This assumes conservative conditions that include gas accumulation for 36s without accounting for immediate emergency ventilation system activation upon gas detection. The resulting peak overpressure from the deflagration simulation case is approximately within the threshold limit of what typical BESS enclosure, without deformation, damage or disintegration and therefore the vent panel design meets the intent of NFPA 68 for a limited gas volume accumulation and subsequent deflagration scenario before the activation of the forced emergency ventilation system. Based on the analysis conducted, FRA advises that a suitable emergency response plan (ERP) and training be provided to cover the full range of scenarios that may be encountered.

As per NFPA 68 6.3.1.1 *"P_{red} (reduced pressure) shall not exceed two-thirds of the ultimate strength for the vented enclosure, provided deformation of the equipment can be tolerated."* A strength analysis for the enclosure was not performed by LG and in absence of that data, external references were considered. Factory Mutual datasheet FMDS 07-76 Appendix C §C.3.1 states that when structural strength data for vessels is not available, a 3.0 psig maximum allowable pressure (P_{red}) for typical design vessels (eg. bag-type dust collectors) can be assumed for vent sizing with a note that vessel likely will not be deformed or some vessel deformation may happen (or is tolerable). As such we can define the P_{red} in the following ways:

- 0.2 bar-g (3.0 psig) – Deformation is tolerable. Deformation may likely occur, but the enclosure is not expected to rupture in a way that creates projectile hazards.
- 0.133 bar-g (2.0 psig) – Deformation is tolerable. Deformation will likely occur, but the enclosure is not expected to rupture in a way that creates projectile hazards. Inclusive of a safety factor multiplier of 2/3 applied for consistency with the intent of NFPA 68.

Additionally, the NFPA 69 analysis performed by Jensen Hughes indicated a detection time of 9 seconds and the total time for complete open vents of 36 seconds, which were assumed for all the FLACS CFD scenarios. However, for the 197 LPM venting rate, the anticipated detection is quicker than 9 seconds, which would lead to different gas accumulation and overpressure conditions that are lower than those observed at 9 seconds and at 36 seconds.

Based on the analysis performed and detailed in this report and the observed results, it is indicative that within the bounds of the assumptions and inputs to the analysis, the JF 2 DC LINK enclosure is expected to withstand the overpressure that may be generated due to the limited accumulation of vent gases from a thermal runaway event, ignition of those gases and subsequent deflagration during the initial moments before the activation of the ventilation system.

8 LIMITATIONS

At the request of LG, FRA performed a flammable gas dispersion and deflagration analysis for JF2 DC LINK BESS manufactured by LG. The DC LINK is a fully integrated BESS consisting of battery modules, power electronics, control systems, a battery management system, a thermal management system, fire detection system, and explosion control systems all pre-assembled within a single, non-occupiable cabinet. It is meant for outdoor installations, mounted to the ground, for commercial, industrial, and utility applications. This analysis was performed using the CFD tool FLACS to determine the impact of a deflagration occurring in the JF2 DC LINK enclosure. The main objective of the analysis was to determine the overpressure levels on the enclosure walls from an internal explosion, based on the criteria in NFPA 68. The simulation results provide guidance to the potential overpressures the enclosure may be exposed to during an internal deflagration event. The scope of services performed during this analysis may not adequately address the needs of other users of this report, and any re-use of this report or its conclusions presented herein are at the sole risk of the user. The opinions and comments formulated during this assessment are based on observations, information, and data available at the time of the analysis provided to FRA by LG. Any engineering analysis that utilizes modeling and calculations, such as the one presented in this report, has inherent limitations. While the methodology and assumptions used are based on best practices and available data, there are inherent assumptions made in any analysis and there may be additional uncertainties and unknown factors that can affect the accuracy of the results. Additionally, the analysis is limited by the quality and quantity of the data available at the time of the study. Therefore, the results of this analysis should be interpreted with these limitations in mind and should not be considered as absolute or definitive. No guarantee or warranty as to future performance is expressed or implied.

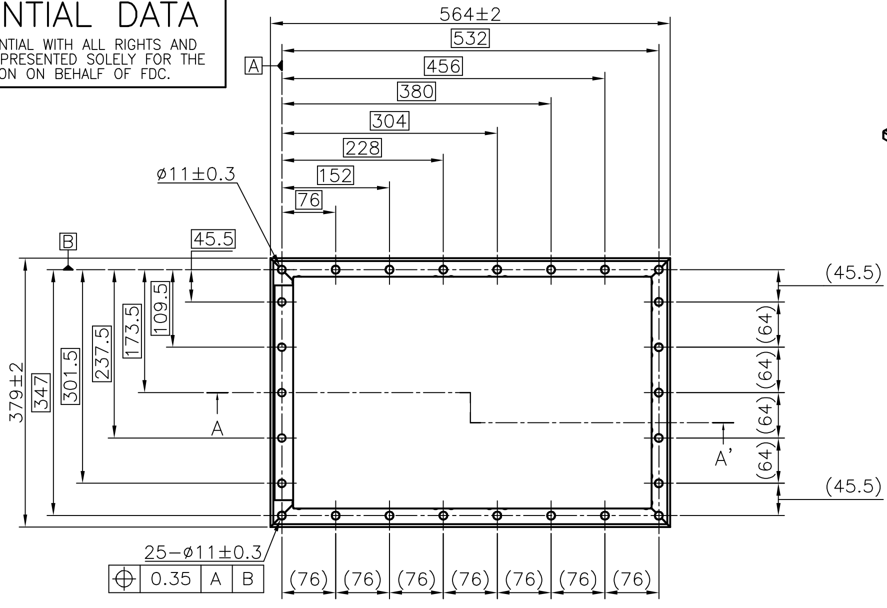
8.1 Disclaimer

This report and its contents are provided for informational purposes only and are based on the specific conditions, data, and product specifications available at the time of its preparation. The recommendations, designs, and conclusions presented herein are applicable solely to the specific product, site, or application described in this report.

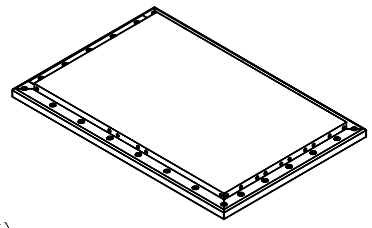
The results presented in this report do not constitute a guarantee or warranty of performance in the field. All designs, calculations, and recommendations should be verified through appropriate field testing and site-specific evaluations. The accuracy and applicability of this report's findings may be subject to changes in conditions, technology, and standards that are beyond the scope of this analysis.

It is the responsibility of the owner, contractor, or designated party to conduct comprehensive testing and obtain all necessary approvals to confirm the validity of the design in the field. The authors, engineers, and firms involved in the creation of this report assume no liability for performance, errors, omissions, or failures that may arise during construction or operation, and no warranty of fitness for a particular purpose is implied.

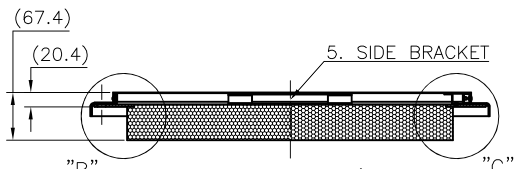
APPENDIX 3-B: DEFLAGRATION PANEL SPECIFICATIONS



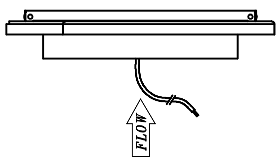
TOP VIEW



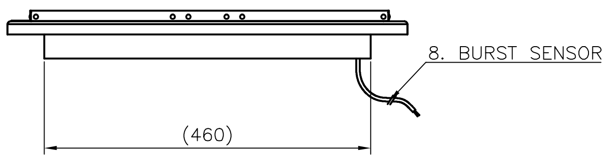
ISOMETRIC VIEW



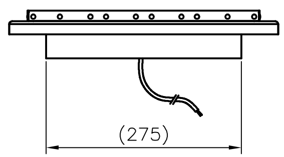
SECTION A-A'



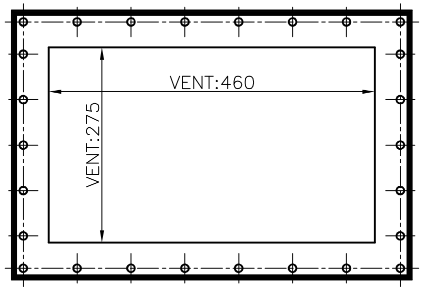
LEFT VIEW



FRONT VIEW



RIGHT VIEW



BOTTOM VIEW

NO	DESCRIPTION	MATERIAL TABLE	REMARK
1	WEATHER COVER	AL5052	
2	IP FLANGE	STS304 (SUS304)	
3	EXPLOSION PANEL	STS304 (SUS304)	
4	FRONT BRACKET	STS304 (SUS304)	
5	SIDE BRACKET	STS304 (SUS304)	
6	GASKET	SILICONE FOAM	
7	INSULATION	NB FORM	
8	BURST SENSOR	MFR SPEC (2P)	

SPECIFICATION

SERVICE CONNECTION	SPECIAL
SET PRESSURE	0.1 barg ± 25 %
BURST PRESSURE	
MINIMUM NET FLOW AREA	0.126 m^2
FLUID	AIR / GAS
BACK PRESSURE CONDITON	0.05 barg
SUPPLY Q'TY	1 EA

NOTE

IF THE EVA-W 275X460 IS DAMAGED OR DEFORMED, THE EVA-W 275X460 MAY BE RUPTURED AT A PRESSURE DIFFERENT FROM THE SET PRESSURE.
(EVA-W 275X460이 파손되거나 변형이 되면 설정 압력과 다른 압력에서 EVA-W 275X460이 파열될 수 있습니다.)

REV.	DATE(YYMMDD)	DESCRIPTION	DWG.	CHK'D	APP'D
2	25.05.23	REVISED FOR CONCEPT	J.S.PARK		J.S.PARK
1	25.04.21	REVISED FOR CONCEPT	J.S.PARK		J.S.PARK
0	25.04.15	ISSUED FOR CONCEPT	J.S.PARK		J.S.PARK

TITLE ***ESS DEFLAGRATION VENT TYPE***

MODEL ***EVA-W 275X460***
SPECIAL DWG.

SCALE N.S | DWG NO. EVA-W 275X460-S | SHEET NO.1 OF 1

FDC FDC Co., Ltd.