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APPENDIX 12-C: CATL ENERC+ LARGE SCALE BURN TEST

TEST REPORT

CATL EnerC+ Large Scale Burn Test

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This report presents the results of analysis conducted by DNV on behalf of Customer.

Prepared by:	Verified by:	Approved by:
Mark Kellenberger Senior Engineer Energy Storage Technology and Safety	Stephen Jones Senior Principal Consultant Energy Storage Advisory	Michael Kleinberg Head of Department Energy Storage Advisory

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A	25 November 2024	Draft	Preliminary report	M. Kellenberger	S. Jones	
B	13 January 2025	Final	Heat flux, BMS data updates	M. Kellenberger	S. Jones	M. Kleinberg

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List of abbreviations

The following table lists some of the abbreviations used in this Report.

Acronym	Abbreviation
BESS	Battery Energy Storage System
BMS	Battery Management System
BMU	Battery Management Unit
cfm	cubic feet per minute
C_2H_2	Acetylene
C_2H_4	Ethylene
C_2H_6	Ethane
C_3H_6	Propylene
C_3H_8	Propane
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
DC	Direct Current
EPA	Environmental Protection Agency
FID	Flame Ionization Detection
GC	Gas Chromatography
H_2	Hydrogen
H_2S	Hydrogen Sulfide
HC	Hydrocarbon
HCl	Hydrogen Chloride
HCN	Hydrogen Cyanide
HF	Hydrogen Fluoride
IC	Ion Chromatography
IR	Infrared
kWh	Kilo Watt-hour
LFL	Lower Flammability Limit
LFP	Lithium Iron Phosphate (LiFePO4)
mph	mile per hour
MS	Mass Spectrometry
MW	Mega Watt
MWh	Mega Watt-hour
N_2	Nitrogen
NOAA	National Oceanic and Atmospheric Administration
O_2	Oxygen
PCS	Power Conversion System
SOC	State of Charge
TC	Thermocouple
TR	Thermal Runaway

EXECUTIVE SUMMARY

DNV developed the test plan and witnessed the large scale burn test of the CATL EnerC+ 306 battery energy storage system on 21 August 2024 in Sanford, North Carolina. The test setup consisted of four CATL EnerC+ battery enclosures that were fully populated with battery modules. All battery racks were charged to 100% SOC, except for two racks furthest away from the initiating unit which were charged to 23% SOC. One module was not present during the test, as it was utilized for a module pre-test. The BMS of all units were active and captured cell voltages and temperatures during the test and the systems were filled with coolant typical of normally operating system. Auxiliary power was provided for cooling, power communications, fire detection, and explosion mitigation systems, however the cooling system was not actively running during the test. Target units were cooled to typical operating temperatures prior to the initiation of the test. The explosion mitigation system was active and operated as it would in the field.

The units were spaced at their minimum recommended spacing, which was selected to mimic the proposed spacing for the Customer BESS project for which Customer is providing engineering, procurement and construction services. As part of project development, Customer requires that a single complete BESS enclosure needs to be fully involved in a fire and left to burn itself out without the use of any suppression. For the duration of the test including post-burn cool down, no cells within the complete target units can exceed 75% of the thermal runaway temperature (181 °C) and no other components of the target units shall catch fire.

The four test units were instrumented with 94 thermocouples to record the temperature progression throughout the test, including 20 in the initiating module. Thermocouples were placed both internally and externally on all units. BMS data was also captured to monitor the internal module and cell temperatures, as well as other system data. High-speed piezoelectric pressure transducers were mounted inside the battery compartment to measure the pressures generated in a deflagration event. Gas sampling was conducted throughout the test, initially within the initiating unit, then from outside the initiating unit. Heat flux gauges were placed at the nearest faces of target units, as well as locations representing equipment to be used at the project site. A weather station monitored the environmental conditions throughout the test. At the time of test commencement, the temperature, humidity and wind speed were 76 °F, 51% RH, and 2 m/s, respectively. The test was recorded on video from seven conventional video cameras, including two internal to the initiating unit, as well as two infrared cameras.

The test was initiated using electrical resistance heaters placed under the outer cells in the initiating module, which was chosen to be in the middle of the initiating unit. A module pre-test was conducted to establish the suitability of the heating method to generate a cell failure and full module fire involvement.

For test initiation, the heaters were set to a rate of 5 °C/min until the heater temperature reached 200 °C. Following that, the heaters were turned down to a rate of 1 °C/min to allow time for the heat to sink into the module cold plate and cell casings. After approximately 2 hours of heating, the first cell thermal runaways occurred in the initiating module when the sounds of cell venting, and a small deflagration occurred where the emergency ventilation damper was briefly pushed open. The first smoke seen externally also occurred around this time. Approximately 45 seconds after the first sounds of cell venting, the emergency gas ventilation system was automatically activated. After 14 minutes of forced ventilation, venting appeared to cease and smoke passively emitted from exhaust and eventually the emergency ventilation intake as well. The following hours saw generally lower smoke emission, until approximately 6.25 hours into the test where there was a significant increase in smoke, before once again dropping to a lower amount. A significant explosion then occurred 6.5 hours into the test in the auxiliary power panel, which knocked the doors off the end of the initiating unit. The battery compartment doors remained closed following the explosion and no significant fire was noted. The initiating unit continued to release various amounts of smoke for the next 3 hours, when at approximately 9.5 hours into the test, a lit road flare was thrown into the low-laying gas cloud surrounding the initiation unit. As intended, the flare ignited the gas/smoke to ensure full worst case burn of the initiating unit and caused the initiating unit to catch on fire and burn completely. At times, a significant jet flame was observed shooting out of the emergency gas ventilation air intake and impinging on the doors of the unit facing the initiating unit. The fire continued to burn for several hours, eventually reducing in intensity. The fire burned at a generally reducing intensity until 16.5 hours into the test where it was no longer visible from the exterior of the initiating unit.

During the test, no target units were observed to catch on fire and no unit-to-unit fire of thermal runaway propagation was observed. Post test examination confirmed that all battery modules in the initiating unit burned completely, and no significant damage was seen in the interior of the target units. Thermocouple data indicated that temperatures of greater than 1400 °C were seen in the initiating module. Internal temperatures inside the initiating unit reached 600 °C during the initial stages of thermal runaway, and were recorded to reach approximately 1350 °C after the fire was initiated. External thermocouples on the initiating unit indicated temperatures of 1350 °C and temperatures on the exterior of the closest target unit (behind the initiating unit) reached 1100 °C, but the maximum internal temperature for this target unit reached 80 °C. BMS data provided by CATL for this unit was incomplete, however, it is likely that the internal module temperature was lower than the maximum internal unit temperature as measured by the thermocouples. Therefore, there is a high likelihood that the true maximum internal BMS module temperature that would have been seen if the BMS data was available for a longer duration would be less than the 80 °C maximum temperature measured by the thermocouples in Unit B. This is well below the Customer requirement of 181 °C.

The target unit facing the initiating unit saw the highest external and internal temperatures of approximately 500 °C, as this unit had the jet flame from the initiating unit impinging on its doors. Examination of the BMS data indicated that the maximum cell temperature in this unit reached 56 °C, again well below the Customer requirement of 181 °C. The final target unit saw external temperatures of approximately 800 °C on the end nearest to the initiating unit, but BMS data showed the maximum internal module temperature reached during the test was 23 °C. This temperature was essentially the ambient temperature, and no measurable temperature rise was seen in the modules in unit D.

Minimal heat flux was measured prior to the ignition of the initiating unit. A large spike in heat flux corresponded to the ignition of the gas cloud outside and the subsequent fire within the initiating unit. As previously discussed, a significant flame jet impinged on the target unit facing the initiating unit, which lead to a maximum heat flux reading of approximately 22 kW/m^2, while the heat flux seen at the project breaker panel distance from the end of unit A (89 inches) reached a maximum of 2.2 kW/m^2.

The test was successful in creating a large fire event by triggering one module into thermal runaway using electrical heaters that resulted in propagation and complete burn-up of all racks in the initiating unit. No thermal runaway propagation or visually apparent damage to internals of adjacent units was observed. Temperature data indicated that while high external and internal temperatures were seen in some target units, at no time did cell temperatures exceed 75% of the thermal runaway temperature (181 °C) and no other components of the target units caught fire, apart from paint and door seals.

1 INTRODUCTION AND BACKGROUND

CATL Customer. (“CATL Customer” or the “Customer”) engaged DNV for technical services in support of bespoke fire testing of CATL EnerC+ battery energy storage system (BESS) units. The actual testing was conducted at SAFE Laboratories and Engineering Corporation (“SAFE Labs”) in Sanford, North Carolina.

DNV understands that Customer is providing engineering, procurement and construction services for the Customer energy storage facility near Arlington, Arizona. As part of project development, this project Final Customer requires the testing of the types of BESS to be deployed at the facility. Test requirements set out by Customer indicated that the fire test was to force a single complete BESS enclosure into a fully involved fire and left to burn itself out without the use of any suppression. Target units were to be placed at distances in accordance with proposed project site layout spacing. For the duration of the test including post-burn cool down, no cells within the complete target units can exceed 75% of the thermal runaway temperature and no other components of the target units shall catch fire.

The objective of this test is to create a real-world simulation of a large-scale thermal event inside one unit, to verify whether there is a tendency or risk of propagation to adjacent units. The importance of this test is to ensure in the worst of circumstances, that a thermal event is contained to a single unit, which validates the safety measures designed into the Unit to keep personnel safe. This test procedure outlines the setup, procedure, and acceptance criteria for this test, with the intent to create a test event that mirrors an above worst-case scenario, more severe than the cases required to be tested via UL 9540A.

The test plan was designed to evaluate an extreme battery failure event, such as when multiple cells enter thermal runaway (TR) at the same time with propagation throughout the module, rack, and eventually leading to involvement of the entire battery unit. The intention of the test was to show that the BESS systems and design provide sufficient safety to prevent a large fire event in one unit from propagating to neighboring units.

1.1 UL 9540A testing

This extreme burn test goes well beyond the current testing requirements set out in UL 9540A, in which only one cell is typically triggered into thermal runaway, often with benign consequences. CATL had conducted UL 9540A tests on the cell (CATL 306 Ah CBDD0) [1], module [2], and unit [3] where it was found that thermal runaway initiated on one cell was limited to propagation to neighboring cells (between 2 and 3) with no further propagation throughout the module or unit. The plastic module covers were noted to have expended due to gas release from the failed cells, as shown in Figure 1-1, but no large fire was reported during UL 9540A testing.

UL 9540A test reports were reviewed, and it was noted that the average cell venting and thermal runaway temperature, as measured in the cell-level tests, were 154 °C and 241 °C, respectively. These temperatures are important when evaluating what temperatures are critical at neighboring cells and modules that could lead to thermal runaway.

Figure 1-1: Example of UL 9540A Module Level Test [2]

1.2 Testing goals

The goal of the large-scale burn test is to simulate an extreme battery failure event (expected to be more extreme than the system would experience during operations) and evaluate the severity of the outcome. As an extreme scenario, it is assumed that not just one cell is triggered into thermal runaway (TR) by film heaters (as is done in the UL 9540A testing), but that a large set of cells within a module is triggered into thermal runaway simultaneously.

Goals:

The test is designed to evaluate the following:

a. Will the temperatures at the battery modules in neighboring units be high enough to trigger thermal runaway?

b. Will module-to-module (within a vertical stack of modules) and rack-to-rack (within a unit) propagation occur in the initiating unit with this extreme trigger event?

c. How fast will module-to-module propagation occur and to how many modules?

d. What temperatures will be observed inside the initiating unit?

e. Will there be an explosion and/or fire and will the fire extend outside the unit, if so, how far?

f. How high will the temperature and heat flux be in egress pathways at different distances?

g. What are the constituents of the smoke that is released internally and externally of the enclosure?

Note that the test is not intended to evaluate whether applying water to neighboring units or the target unit itself will slow or stop the fire from spreading to neighboring units, but rather the robustness of the units themselves to control propagation.

2 SYSTEM SPECIFICATIONS

The CATL EnerC+ 306 system that was tested is shown in Figure 2-1 and Figure 2-2. Each unit contains 5 racks with 8 CATL liquid cooled modules, each containing 104 cells, and arranged for a total energy capacity of 4073 kWh per unit. The interior of a module, showing the cell layout can be seen in Figure 2-3. The modules are wired in strings of 8 modules and connected to string controllers in the bottom slot of each rack. The enclosures contain a thermal management section, battery section, and electrical connection/communication section. The units are intended to be used in a 2-hour system. System specifications are shown in Table 2-1.

Figure 2-1 CATL EnerC+ components

Figure 2-2: Interior design of CATL EnerC+ [4]

Figure 2-3: CATL Module containing 104 cells [2]

Table 2-1: CATL EnerC+ BESS Specifications [1] [2] [3] [4]

Standard 2 h Operation	Unit	String/Racks	Module	Cell
Model Name	**C02306P05L01**	**C02306P05L01-R**	**M02306P05L01**	**CBDD0**
Energy (kWh)	4073.47	814.69	101.84	0.979
Capacity (Ah)	612	612	612	306
Voltage min (Vdc)	1040	1040	130	2.5
Voltage nom. (Vdc)	1331.2	1331.2	166.4	3.2
Voltage max (Vdc)	1500	1500	189.8	3.65
Configuration	5P-1S 5 Racks in parallel	1P-8S 8 Modules in series	2P-52S	
Dry Weight	36000 kg	7200 kg	653 kg	5.5 kg
Size Width	6058 mm	936 mm	830 mm	175 mm
Size Height	2896 mm	2698 mm	250 mm	207 mm
Size Depth	2438 mm	2252 mm	2235 mm	72 mm

The BESS has an exhaust ventilation system intended to meet the NFPA 69 standard. Figure 2-4 shows the inlet and outlet of the emergency ventilation system on the enclosure exterior. Louvers at the inlet and outlet, as well as a fan incorporated into the exhaust port, are electrically powered and operated by the BESS controls. No deflagration panels are described in the system specifications.

Figure 2-4 Exhaust ventilation inlet and outlet [4]

The minimum recommended BESS installation distances within a facility layout are depicted in Figure 2-5 and summarized in Table 2-2.

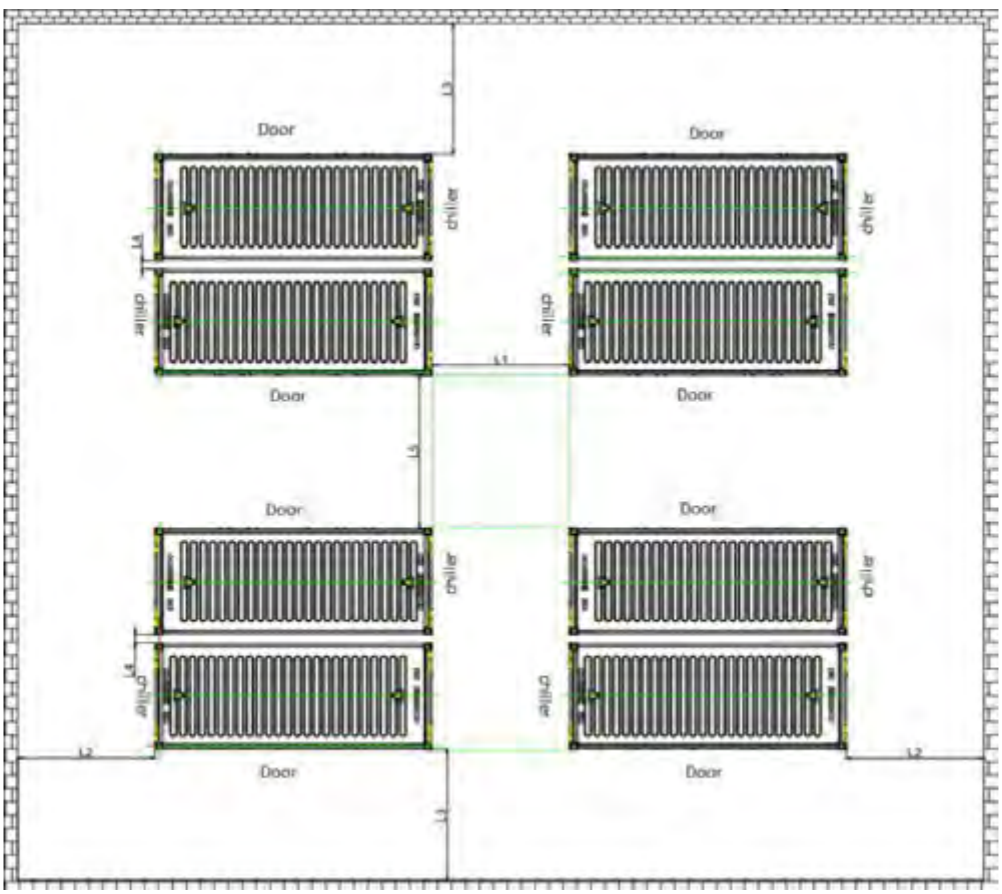


Figure 2-5 Specified installing clearances (see Table 2-2)

Table 2-2 EnerC+ minimum specified installation clearances

Figure call-out	Description	meters	feet	inches
L1	One BESS end to another BESS end	3	9.84 (9’10”)	118
L2	BESS end to site obstruction	3	9.84 (9’10”)	118
L3	BESS door to site obstruction	3 (3.5 recommended)	9.84 (9’10”)	118
L4	BESS back to BESS back	0.2	0.66 (7 7/8”)	7 7/8
L5	BESS door to BESS door	3 (3.5 recommended)	9.84 (9’10”)	118

2.1 Component nomenclature

Each cell, module, rack, and unit component are identified by a numbering scheme, as shown in Figure 2-6 and Figure 2-7 below.

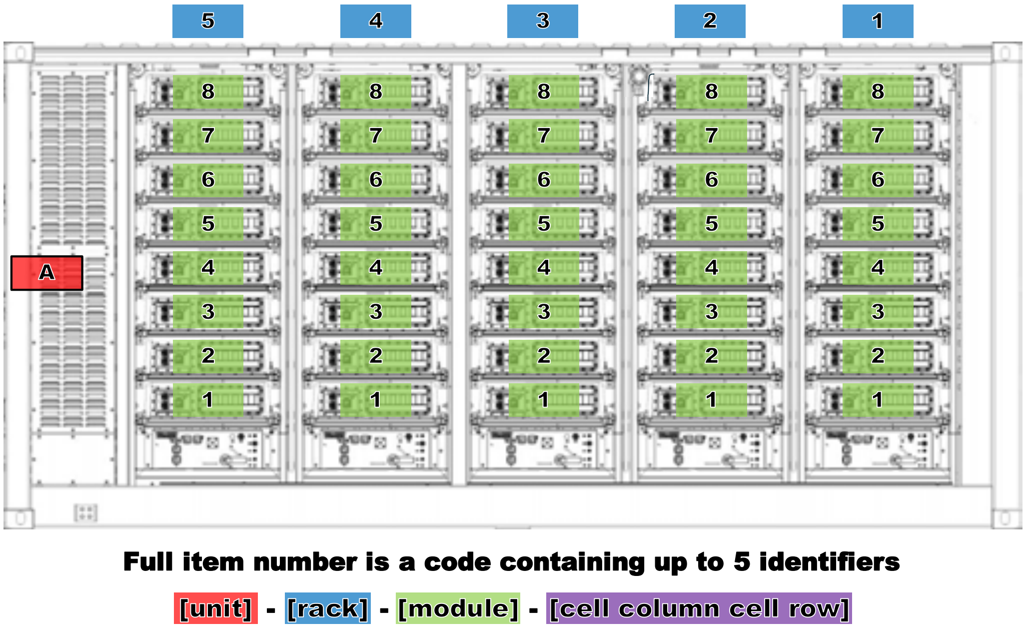


Figure 2-6: CATL EnerC+ module numbering

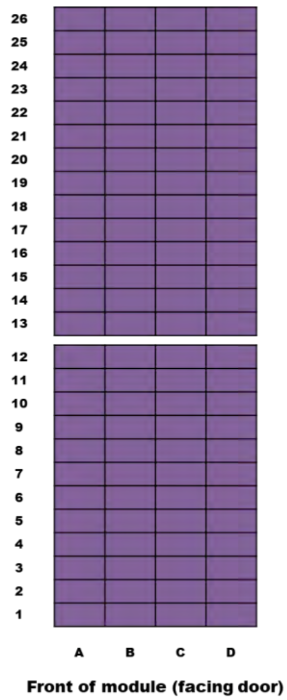


Figure 2-7 Module layout

3 MODULE PRE-TEST

In order to confirm the suitability and effectiveness of the main test initiation method, a module pre-test was carried out on 18 August 2024. The module to be pre-tested was harvested from one of the non-initiating units, from a rack located farthest from the initiating unit. The pre-tested module was charged to 100% SOC prior to the per-test.

Based on prior test experience, the use of electrical resistance heaters was chosen as the primary initiation method. The electric heater method most closely simulates an extreme electrical battery failure event, one in which most cells in one module are internally failing and going into thermal runaway, triggered at the same time. If a complete module can be triggered this way into TR, it will release the entire stored electro-chemical energy contained in it over a short time period (about 15 minutes). This can be considered one of the most extreme internal battery failure events, almost certainly resulting in module-to-module propagation within the rack and most likely resulting in a large fire or explosion event of the entire BESS.

Due to the module design, four 600 W strip heaters with dimensions of 24 inches by 1.5 inches were chosen, with two placed along each of the long sides of the module, as shown in Figure 3-1. Using the existing module cell starting, the heaters were shimmed to ensure contact with the cells. Small portions of the module cover had to be removed to facilitate the connection of the power source to the heaters. Prior to the execution of the test, tape was placed over the holes in the module cover.

The heaters were placed along the A and D cell columns in the module, across cell rows 6 to 20 (see Figure 2-7). This placed a total of 28 cells in direct contact with the heaters. A heater ramp rate of 5 °C/min was chosen for the module pre-test. The heaters were first turned on until they reached 100 °C, at which the temperature was held constant for a soak period of 15 minutes to ensure input heat energy was conducted throughout the module. After the soak period the heaters were once again turned on at 5 °C/min until 125 °C was reached and another 15-minute soak was performed. This heat and soak cycle continued every 25 °C until thermal runaway occurred in the module. This was ultimately adjusted for the main test to reduce the heating time required. Four thermocouples were utilized in the module pre-test to monitor the heater temperatures as part of the PID control loop.

Figure 3-1 Module heater location

Figure 3-2 Module pre-test heater and control thermocouple wiring

The module pre-test resulted in the initiation of a fire, which engulfed and eventually consumed the entire module, as shown in Figure 3-3 and Figure 3-4. Based on the fire generated, the test initiation method was confirmed to be viable for the main test.

Figure 3-3 Module pre-test video snapshots

Figure 3-4 Module condition after pre-test

Table 3-1 Module pre-test major event timeline

Time	Event	Notes
16:20:00	Heater power on	Test start
20:23:17	Cell venting	White smoke coming from module
20:24:10	Ignition of vent gas	Flames from left side of module
20:24:12	Secondary ignition	Flames from both sides of module

4 TEST SETUP

The test was set-up outdoors at the SAFE Labs test facility burn pad, which can accommodate the four test units (one initiating unit and three target units). The test area also includes an elevated 12” by 12” fume hood over the test area. Figure 4-1 shows the overall layout.

Unit spacing was selected to mirror the proposed spacing for the Customer project. DNV notes that this door-to-door spacing (unit A to unit C) aligns with the L4 recommended spacing given by CATL in the EnerC+ installation manual (see Table 2-2).

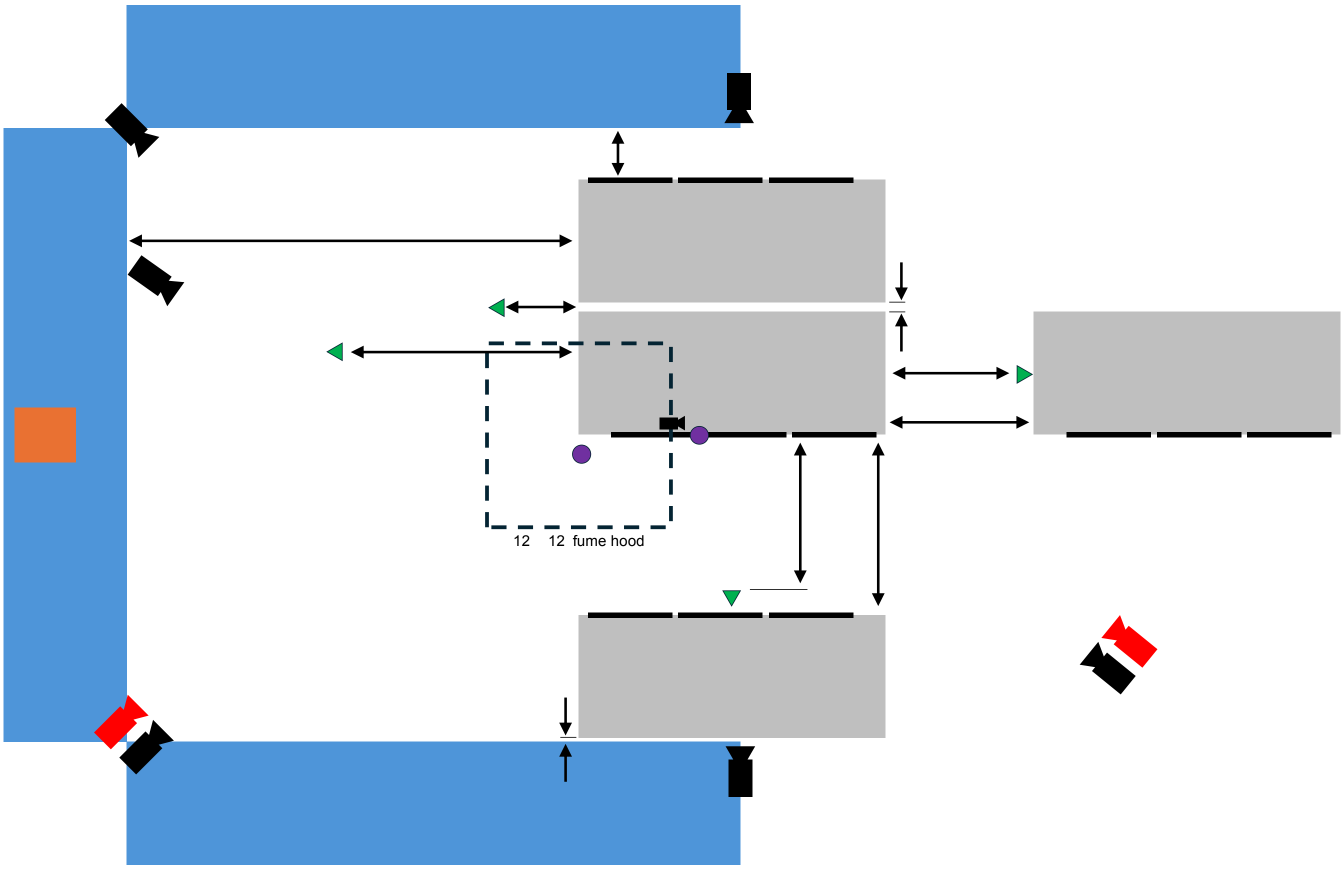


Figure 4-1 Test layout

Additional thermocouples were installed in various locations to independently monitor and record cell and other temperatures. Heat flux gauges were also placed throughout the test setup (see Section 5.5). Additionally, continuous gas monitoring was implemented to collect samples from both inside initiating unit A and in the fume hood exhaust sitting above unit A. Video cameras were placed at seven locations around the test area to both the initiating and target units. Two infrared cameras were also utilized to monitor initiating unit A.

4.1 Unit operation

For the test the following unit operating conditions were utilized:

- Prior to the test, all racks were charged to 100% SOC, except for racks D-4 and D-5 which were charged to 23% SOC. DNV notes that module D-1-1 was not present during the test, as it was utilized for the module pre-test

- The BMS of all target units were active including routine measurement and recording of cell voltages and temperatures during the test
- The system was filled was coolant typical of normal operating conditions
- Auxiliary power was provided to cooling, power communications, fire detection, and explosion mitigation systems
- Cooling system was not actively running during the test, however target units were cooled to typical operating temperatures prior to the initiation of the test
- The explosion mitigation system was active and operated as it would in the field

4.2 Initiating module

The initiation module was in the sixth position from the top of the unit, in the middle rack. This module has global identifier A-3-3 (see Figure 2-6). The reason for choosing a low position is that the most probable direction of module-to-module propagation is upwards, because the hot vent gases and heat and flames generated from the initially triggered thermal runaway will go upwards and affect the modules above it the most, thus representing the most severe probable case. To also evaluate the potential for module-to-module propagation downwards, the initiation module should be located not at the very bottom, but a few modules up from the bottom. The sixth location from the top seems ideal, because then a downward propagation not only from the triggered initiation module to the one below, but also from a second, not heated module, to the very bottom module could be observed (see Figure 4-2).

Figure 4-2 Initiating module A-3-3 location within Unit A

4.3 Instrumentation

A series of thermocouples, gas sampling ports, and heat flux gauges were added to the initiating and target units to monitor the progress and severity of the fire. Thermocouple data was captured at an internal of 3 seconds throughout the test.

4.3.1 Thermocouples (TCs)

A total of 94 thermocouples were utilized during the test. A mixture of 20-gage and 24-gage thermocouple were utilized, with heavier ones being used in areas that were expected to see high heat.

Table 4-1 Summary of thermocouples

Location	Count
Initiating module (control)	1
Initiating module (monitoring)	19
Initiating unit A interior	17
Initiating unit A exterior	9
Target unit B interior	8
Target unit B exterior	13
Target unit C interior	8
Target unit C exterior	8
Target unit D interior	7
Target unit D exterior	4
Total	94

4.3.1.1 Initiating module

20 thermocouples were installed in the initiating module to be used for temperature measurement with one being utilized to control the heater temperature. Thermocouples are represented as blue markers in Figure 4-3. Marker that are off the edge of the cell indicate a thermocouple on the side of the cell. Note that thermocouples A8, A15, C8, and C15 were placed under the heaters on the side of the battery cells. Thermocouple A8 was utilized for heater control, so no time-series data was recorded by the data acquisition system.

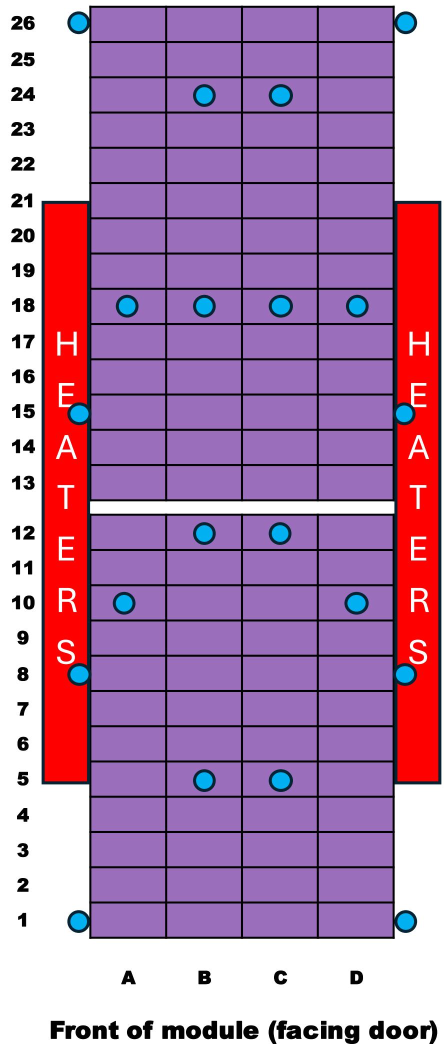


Figure 4-3 Placement of heaters and thermocouples on initiating module A-3-3. Thermocouples are represented as blue markers. Marker that are off the edge of the cell indicate a thermocouple on the side of the cell.

4.3.1.2 Unit A

In addition to the 16 thermocouples utilized in the initiating module, an additional 26 thermocouples were placed on unit A, with 17 being on the interior and 9 being on the exterior. A diagram of thermocouple placement on the exterior of unit A is shown in Figure 4-4.

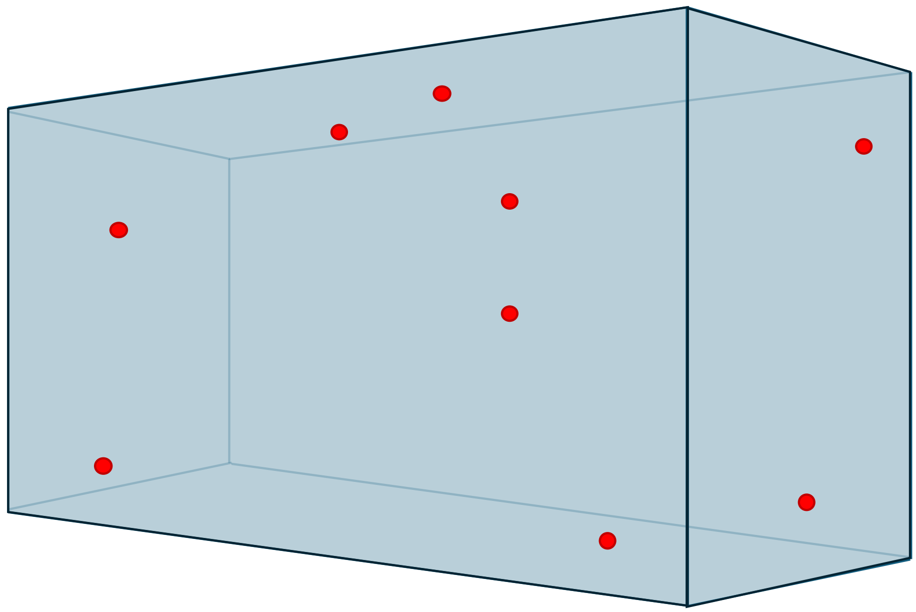


Figure 4-4 Unit A external thermocouple locations

In addition to the thermocouples placed inside the initiation module, additional temperature measurements were captured throughout the interior of unit A, as shown in Figure 4-5.

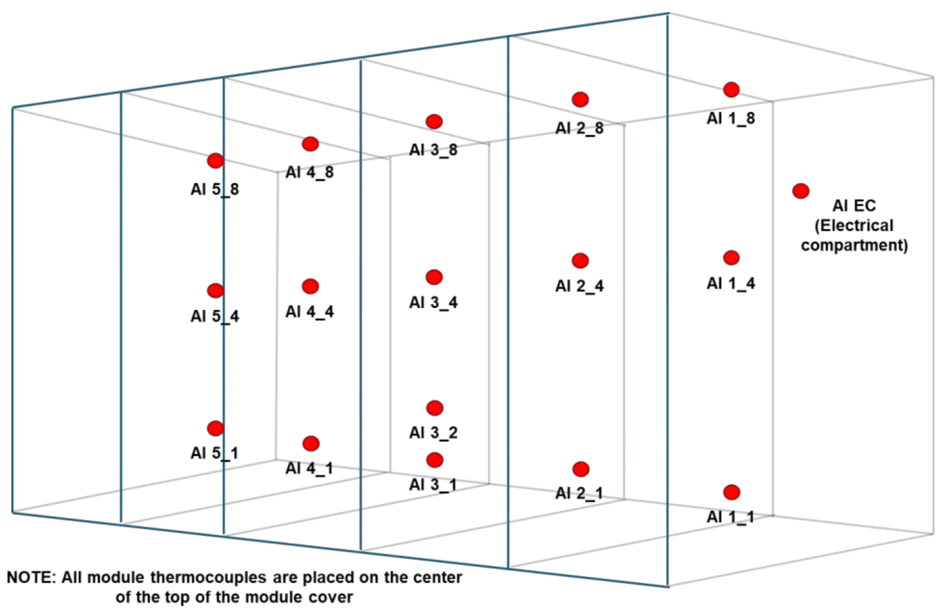


Figure 4-5 Unit A internal thermocouples. Initiating module thermocouples not shown.

4.3.1.3 Unit B

For unit B, 13 exterior thermocouples were used, including 6 on the rear exterior to examine the effects of heat transfer from the back of initiating unit A. A diagram of the exterior thermocouples on unit B is shown in Figure 4-6. A diagram of the 8 interior unit B thermocouples is shown in Figure 4-7.

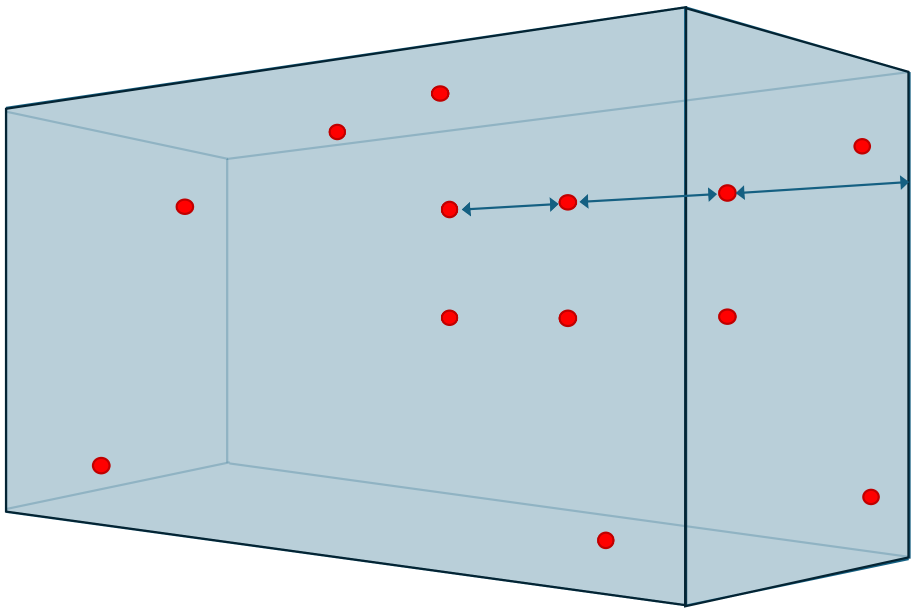


Figure 4-6 Unit B external thermocouple locations

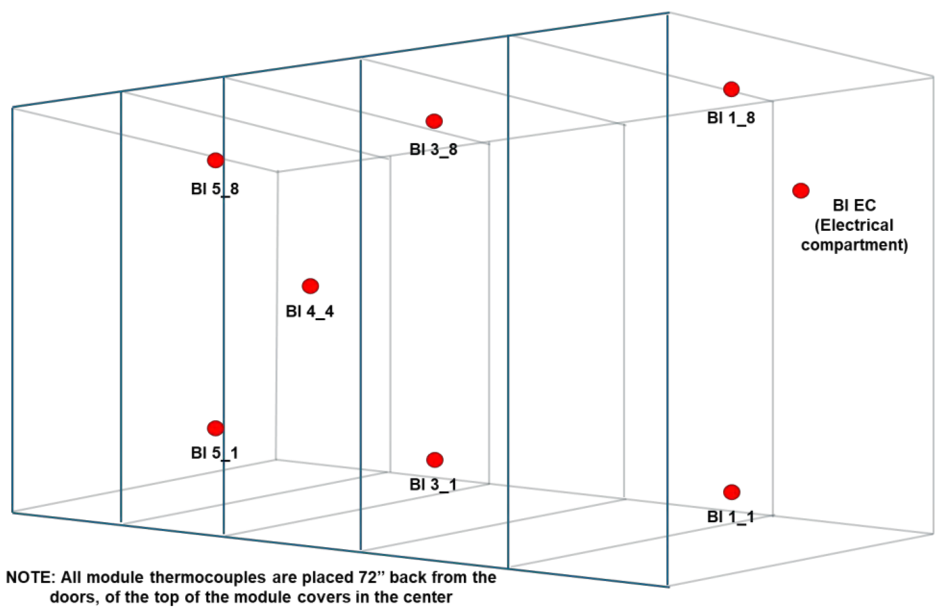


Figure 4-7 Unit B internal thermocouple locations

4.3.1.4 Unit C

For unit C, 8 exterior and 8 interior thermocouples were used. A diagram of the exterior thermocouples on unit C is shown in Figure 4-8. Locations of the internal thermocouples are shown in Figure 4-9.

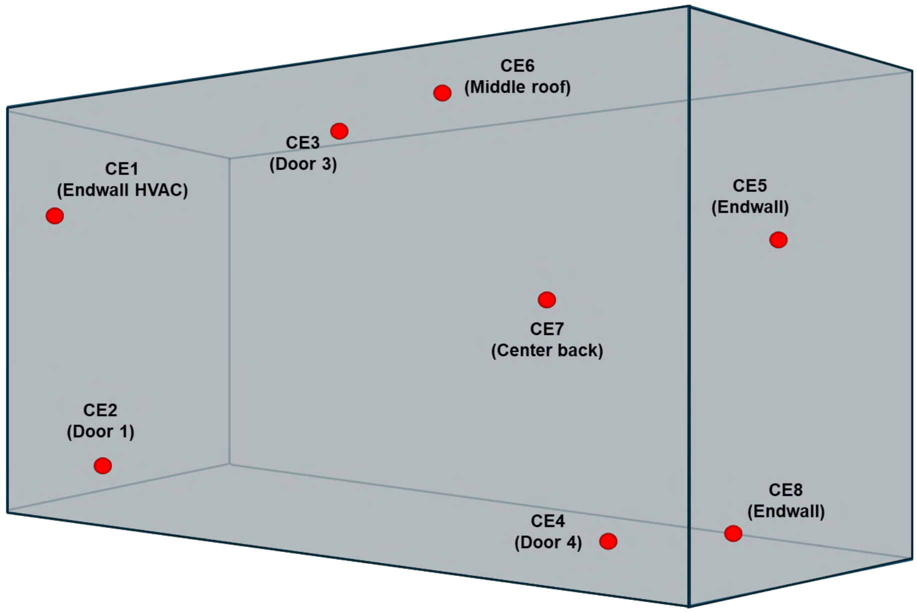


Figure 4-8 Unit C exterior thermocouples

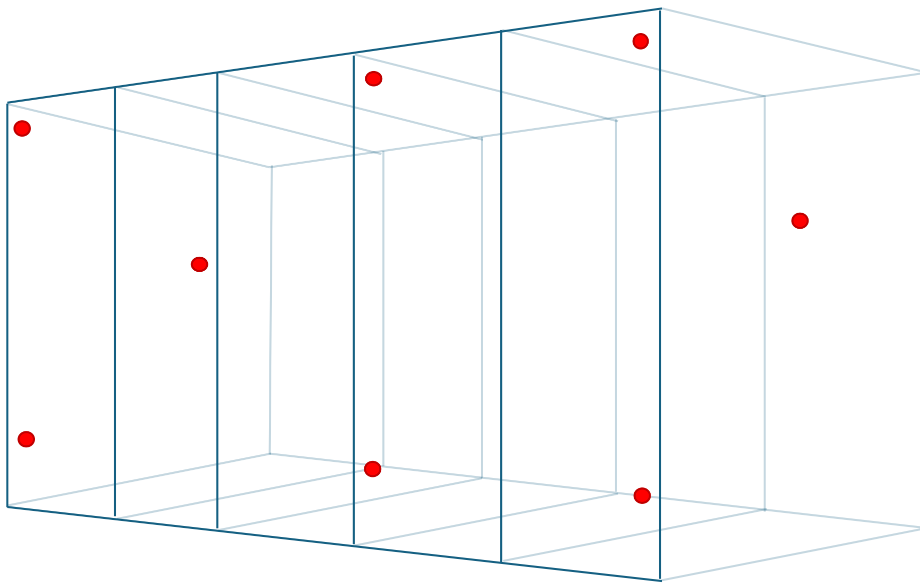


Figure 4-9 Unit C interior thermocouples

4.3.1.5 Unit D

For unit D, 7 exterior and 4 interior thermocouples were used. A diagram of the exterior thermocouples on unit C is shown in Figure 4-10. Location of the internal thermocouples are shown in Figure 4-9.

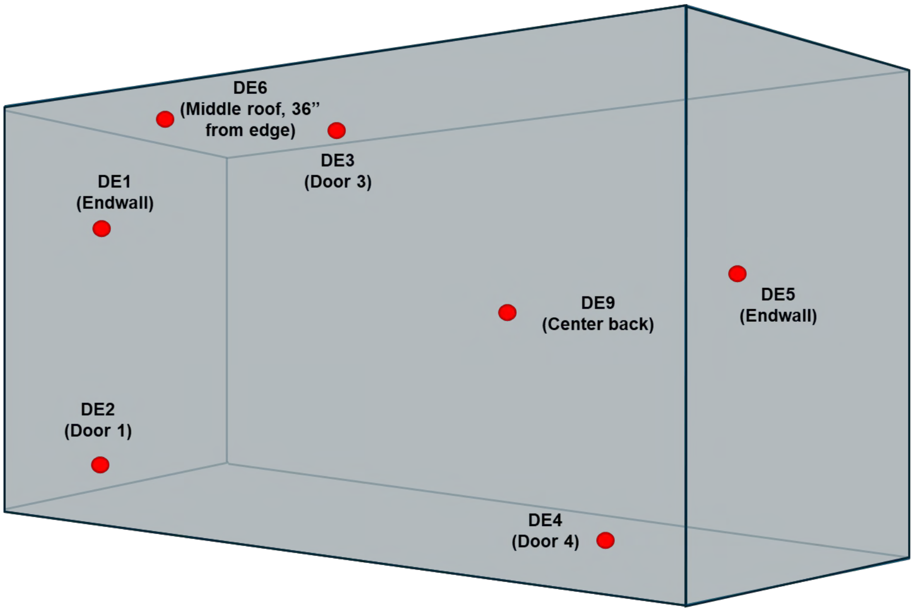


Figure 4-10 Unit D exterior thermocouples

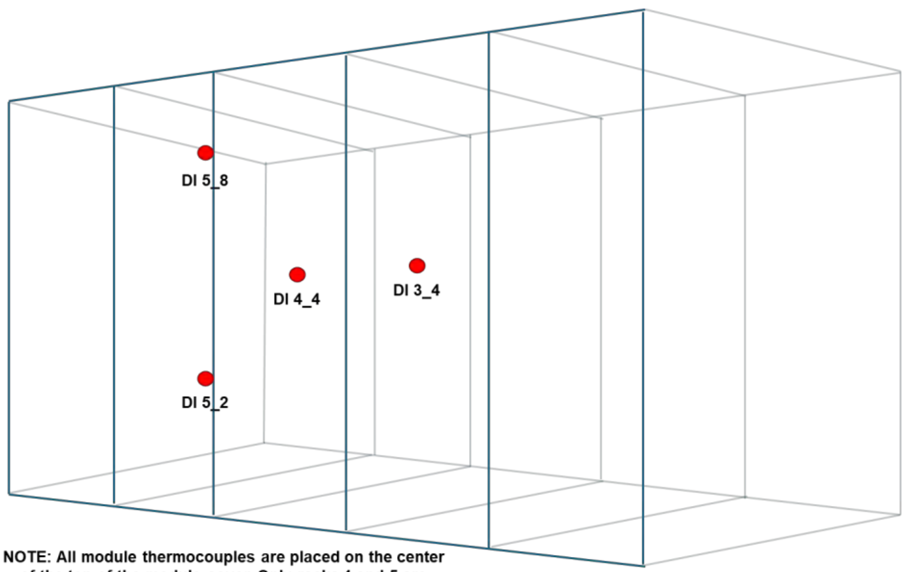


Figure 4-11 Unit D interior thermocouples

4.3.2 Gas sampling

Gases will be continuously sampled and analyzed with a Fourier-Transform Infrared Spectrometer (FTIR). At the start of the test, the system will pull gas from a sample tube placed inside the initiating unit A, in front of the initiating rack. As the test progresses, valves will be turned to switch the FTIR to be fed from a 12' by 12' hood located above initiating unit A. Not all gases will be captured by the hood, and the constituents sampled will depend on where gases flow out of the unit. No discrete gas samples were captured.

The location of the “A Inside” sampling point is shown in Figure 4-12, and the location of the “Hood” arrangement is shown in Figure 4-13. Not all gases coming from the unit were captured by the hood, and the constituents sampled will depend on where gases flow out of the unit and the extent they are captured by the hood.

Gas constituents sampled are shown in Table 4-2.

Figure 4-12: “ ”

Figure 4-13: “ ”

Table 4-2 Gas sampling constituents

1,3 butadiene (80) 191C	Acetylene (1000) 191C
CH4 (250) 191C	CO (500) 191C (1of2)
CO% (1) 191C (2of2)	CO2 (7500) 191C
COS (100) 150C	Oil as octane (200) 191C
Diethyl carbonate (500) 191C	Dimethyl carbonate (1000) 191c
Ethane (500) 191C	Ethylene (100,3000) 191C
Ethylene oxide (100) 150C	Ethylmethyl carbonate (500) 191C
Formaldehyde (70) 191C	H2O% (3) 191C
H2SO4 (50) 150C	HBr (100) 180C
HCl ppm (100) 191C	HCN (100) 191C
HF (400) 191C	Isobutylene (500) 191C
MeOH (1000) 191C	N2O (100,200,300) 191C
NH3 (300) 191C	NO (350,3000) 191C
NO2 (150) 191C	POF3 191C
Propane (1000) 191C	Propylene (200,1000) 191C
SF6 (10) 191C	Total Hydrocarbon
H2	O2

4.3.3 Heat-flux gauges

Heat flux gauges are located as shown in the general layout of Figure 4-1.

- High-quality water-cooled heat flux gauges (Schmidt-Boelter) in key positions:
    - in aisles at 4 ft height and at 10 ft height (front of unit C and end of unit D)
    - at end of initiating unit A, at distances of 89” and 200” at 4 ft and 10 ft height (representing distance to PCS and breaker panel equipment at the project site)

4.3.4 Pressure transducers

To be able to monitor the overpressures generated during a deflagration event, three high-speed piezoelectric pressure transducers were mounted in steel wells in the middle of doors 1, 2, and 4. The mounting wells were fully welded to the unit doors and allowed the pressure transducers to sit flush with the door interior surface, as shown in Figure 4-14 and Figure 4-15.

During the test, there was no explosion in the battery compartment, so no pressure traces recorded from these pressure transducers are included in this report.

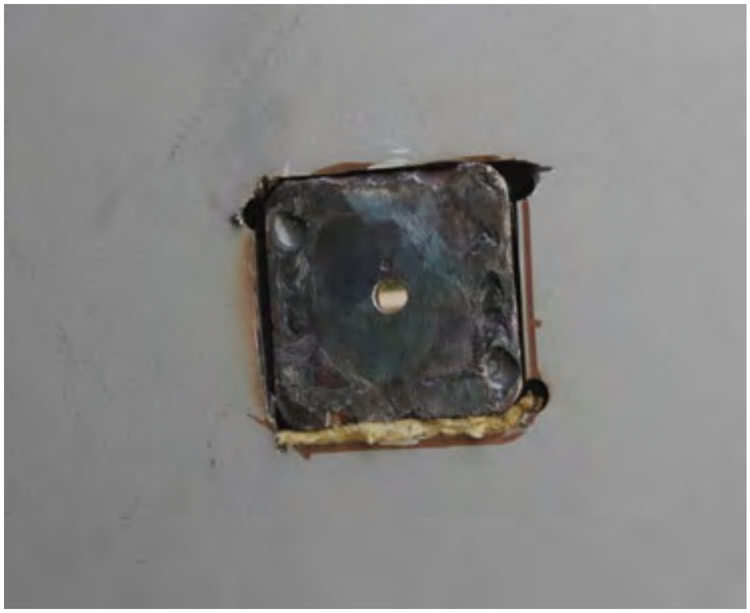


Figure 4-14 Pressure transducer well interior

Figure 4-15 Pressure transducer well exterior

4.3.5 Environmental conditions during test

During test execution, a weather station at the test area was continuously monitoring the temperature, wind speed, wind direction, and precipitation. At the time of test commencement, the temperature, humidity and wind speed were 76 °F, 51% RH, and 2 m/s, respectively. The weather conditions, as measured at the weather station in the test area are shown in Figure 4-16. No precipitation was observed during the test.

Per UL 9540A the following testing guideline, at the start of test, the following conditions were satisfied.

- Maximum wind speed below 12 mph = 5.4 m/s
- Temperature range within 10 °C to 40 °C (50 °F to 104 °F)
- Humidity < 90% RH
- Sufficient light to observe the testing
- No precipitation during the testing

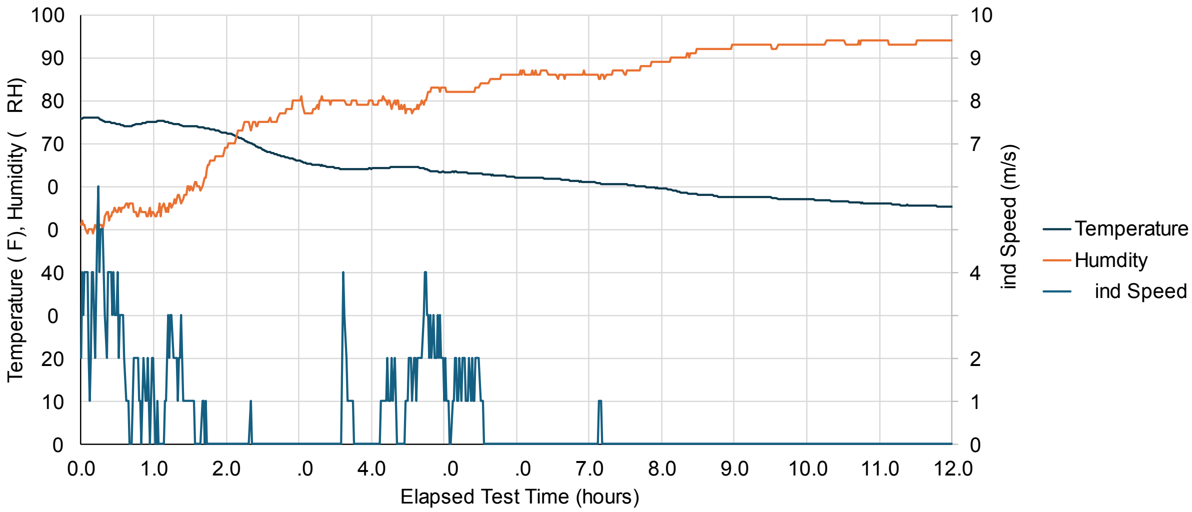


Figure 4-16 Weather conditions during large-scale burn test

4.3.6 CATL BMS Data

Representatives from CATL attended the test site and were able to connect to the CAN Bus system to capture temperature and voltage data directly from the BMS. Data was captured in a proprietary format and processed by CATL and shared with DNV in a standard spreadsheet format.

Data provided from the BMS included a variety of data types, including internal module thermistor data, which was used, in part, to determine if the test was successful in meeting the Customer test criteria.

4.4 Test set-up documentation

Details and images of the test setup prior to the execution of the test are shown below.

Test Site at SAFE Labs in Sanfor, North Carolina	
Test set-up with all four units in place.	

Set-up showing units A and B	
Test set-up looking at initiation unit A, with unit B behind, and unit C across the aisle. Fire blankets are placed on the ground to protect test instrument cabling.	

Unit A exterior showing connected thermocouples and pressure transducers	
Spacing and thermocouples between A and B	

Thermocouple wiring for initiating module A-3-3 and rack A-3.	

5 TEST EXECUTION

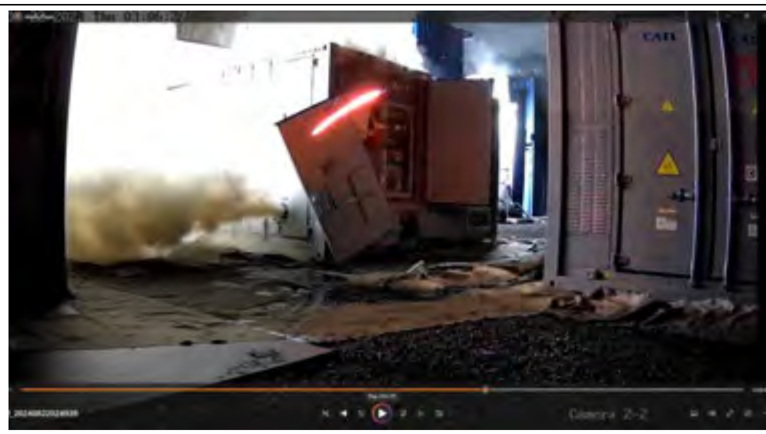
5.1 Test timeline with pictures

Local Time	Elapsed Time (hh:mm)	Event	Picture/Description
21 Aug 2024 at 17:35	00:00	Heaters turned on to start test	
19:35:23	2:00:23	Sound of cell venting; small deflagration 9 seconds later; subsequent venting noises and smoke	
19:35:32	2:00:32	Sound of small deflagration; vent door blows open briefly	

19:35:40	2:00:40	First smoke seen; fire alarm strobe and audible	
19:35:55	2:00:55	EV vents open and forced air on	
19:47	2:12	Active venting continues, smoke builds	

19:49:35	2:14:35	Fan-forced venting appears to cease; smoke passively emits from exhaust and eventually EV intake also	
20:00	2:25	Hours of generally lower smoke emission	
21:42:38	4:07:38	Drone visit	

23:50:55	6:15:55	Significant increase in smoke, then less again later	
12:04:28	6:29:28	Explosion in the auxiliary power panel	
12:04:29	6:29:29	Doors sway open & close after explosion	

12:04:40	6:29:40	Door falls off hinges	
…		Various amounts of smoke emit from unit for hours	
3:06:27	9:31:27	Lit road flare thrown at unit ignites smoke to ensure full worst case burn of initiating unit	

3:06:28	9:31:28	Fire ensues	
3:12	9:37	Fire continues to burn for several hours	
…		Fire continues, eventually reducing in intensity	

6:45	13:10	Fire continues for hours with less intensity	
10:00	16:25	Fire mostly out	

5.2 Post test pictures (10 August 2024)

View of test site	
View of unit A exterior	

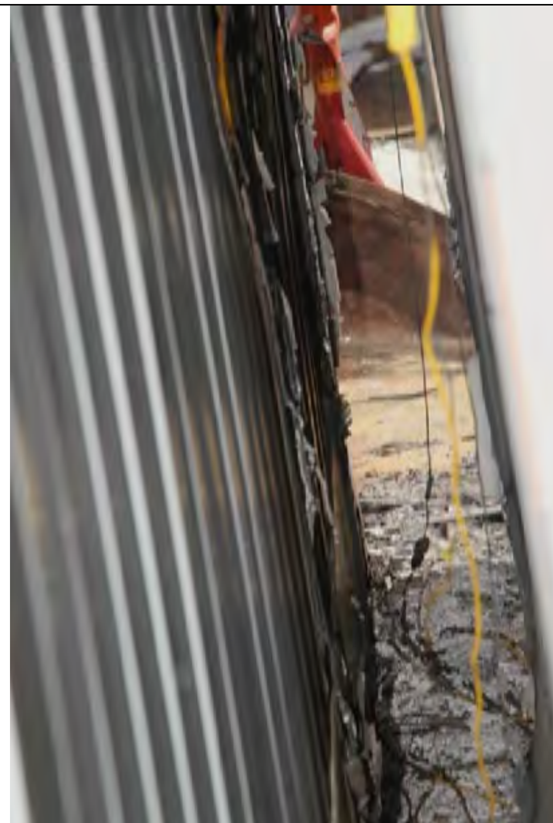
View of unit A top	
View of unit B exterior	

View of unit B back	
View of unit C exterior	

View of unit C top	
View of unit D exterior	

Unit A HVAC end	
Unit A electrical cabinet end	

Unit A electrical cabinet left door	
Unit A auxiliary power distribution cabinet door	

Back of unit A	
Unit A emergency ventilation output	

Unit A initiating rack	
Unit A interior	
Unit B interior	

Unit B interior	
Unit C interior	
Unit C interior	

Unit D interior	
Unit D emergency ventilation door facing initiating unit A	

5.3 Initiating unit

5.3.1 Initiating module temperature progression

Figure 5-1 shows the three thermocouples (TC) utilized to measure the heater temperature. Note that TC LH1 was utilized for heater PID control, so it was not available for data acquisition. For test initiation, the heaters were set to a rate of 5 °C/min until the heater temperature reached 200 °C. Following that, the heaters were turned down to a rate of 1 °C/min to allow time for the heat to sink into the module cold plate, and cell casings. After approximately 2 hours of heating, the first cell thermal runaways occurred in initiation module A-3-3.

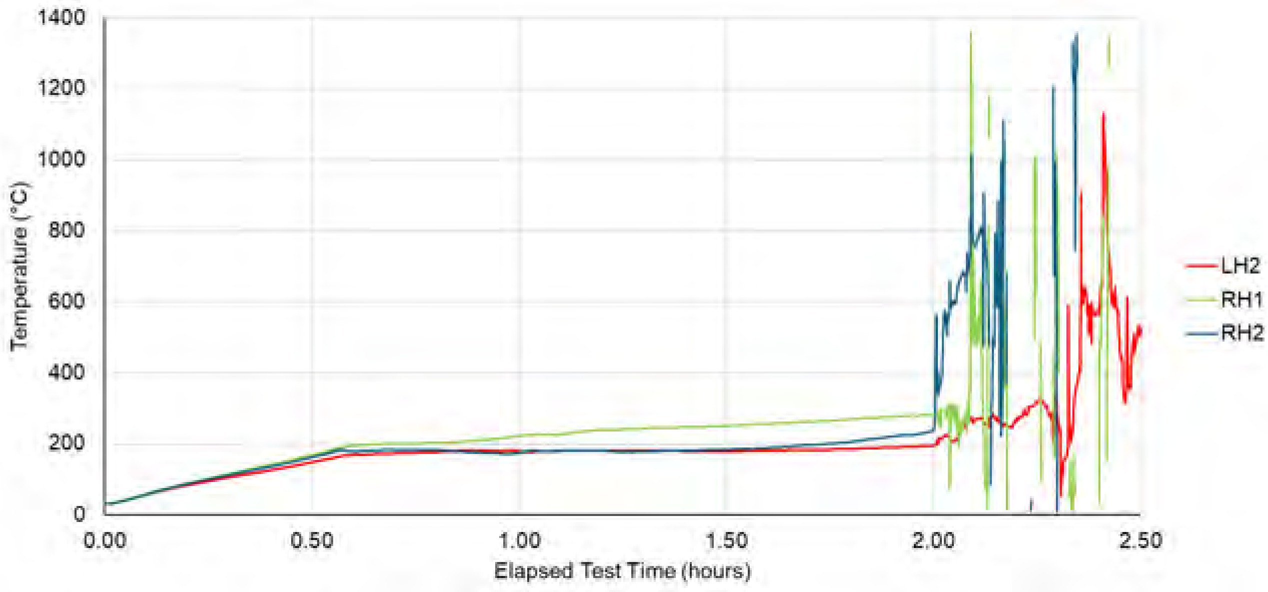


Figure 5-1 Heater ramp date and temperature progression to thermal runaway

Figure 5-2 shows the measured thermocouple temperatures in the initiation module. The first cells to enter thermal runaway are those that are in contact with the heaters, namely cells A10, A18, C10, and C18.

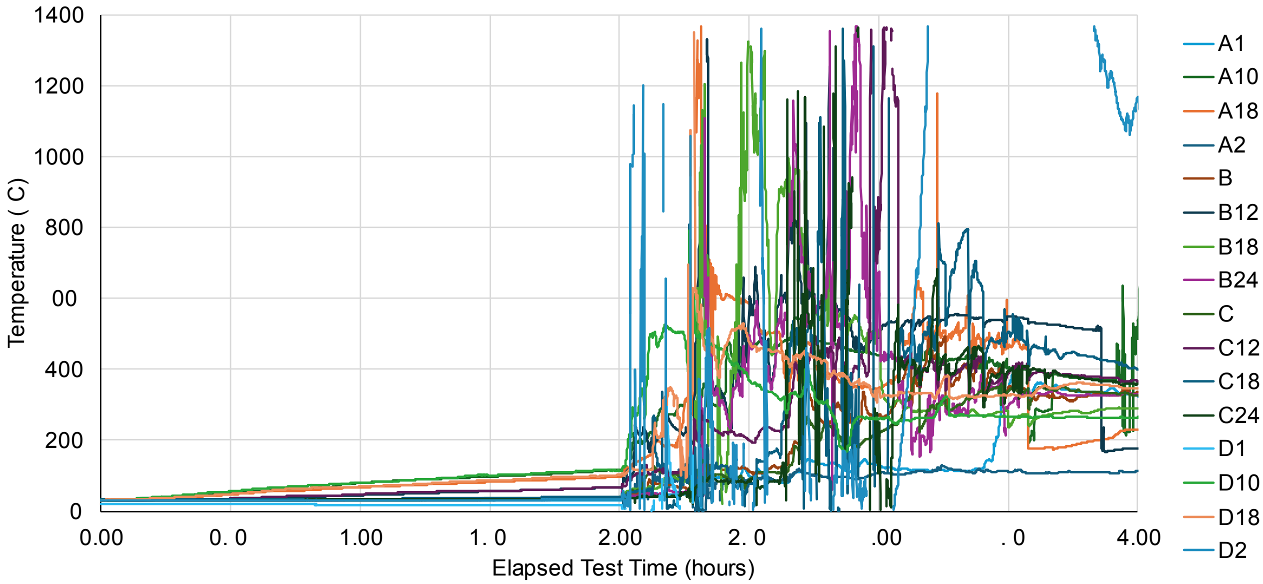


Figure 5-2 Temperature history of the cells in the initiating module

Overall, it took about 120 minutes until the first cells showed self-heating beyond the heater temperature, indicating the start of thermal runaway (cell D8). This is corroborated by the internal cameras picking up cell venting and a small deflagration at this time. Shortly following this, additional cells in cells in row D, i.e. D10 and D18, were reaching temperatures in excess of 300 °C. This was then followed by cells the other side of the module (A10 and A18) exceeding 300 °C. Cell B12 was next to exhibit TR, likely due to the aluminum heat sinks that make up the module structure at the center of the pack transferring heat from the exterior heaters to the center of the module where cell B12 is located. After approximately 1.5 hours after the first thermal runaway was detected, all working thermocouples within the initiating module were reading in excess of 300 °C, indicating that the entire module had undergone TR by this time.

Based on the temperature data, it appears as if the signal wiring for some of the TCs was damaged when the cell in the outside columns of the initiating module went into thermal runaway as the cables were routed along those sides of the modules.

5.3.2 Unit A – internal temperature progression

As was shown in the prior section, module A-3-3 went into thermal runaway after being triggered with heaters. This section looks at the TR progression from module to module in the unit. The module thermocouples were mounted on top of the module covers, but temperature data was also collected from the BMS directly at the cells. The TC layout for the interior of unit A can be seen in Figure 4-5.

TCs were positioned on top of modules 1, 4, and 8 in all racks, plus additional TCs were added on modules A-3-1 and A-3-4 which were directly below and above the initiating module, respectively. Shown in Figure 5-3 is the temperature history with unit A as measured by these TCs.

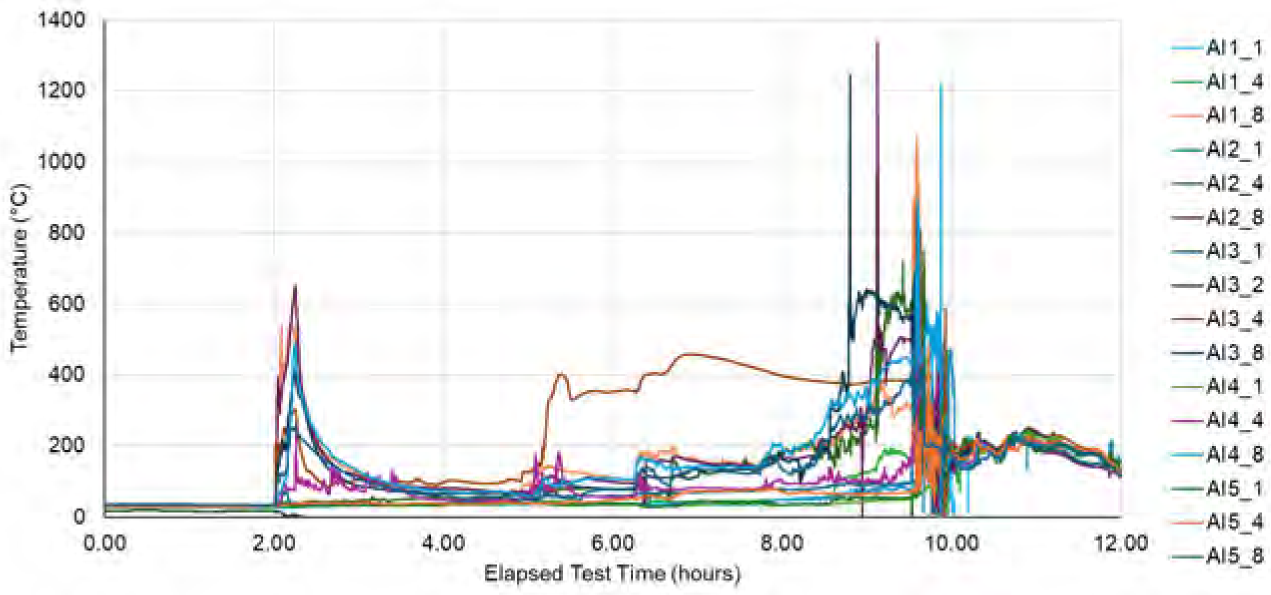


Figure 5-3 Temperature history of modules in the unit A (AI_EC data removed)

As can be seen in Figure 5-3, internal temperatures in unit A remined stable at around 30 °C until 120 minutes following power being applied to the heaters, as discussed in previous sections. At this time, the first cell venting and thermal runaway events took place, and visible flames could be seen on the interior camera. This resulted in an initial spike of temperature for all modules in rack position 8 (at the top of the unit) due to the rising heat. A rise in temperature was also seen in module A-3-4, which was directly above the venting and flaming initiating module A-3-3. The internal unit temperatures then dropped over the next hour until when about 5 hours into the test, there was a rapid increase in the temperature measures at module A-3-4 once again and remains elevated at about 400 °C until the road flare was used to ignite the external gas cloud approximately 9.5 hours into the test. This resulted in all the internal TCs exceeding 400 °C, indicating a full burn of the initiating unit A. A smaller temperature excursion can also be seen at 6.5 hours, which corresponds to the time of the electrical cabinet explosion. This explosion damaged TC AI_EC, so it has been removed from Figure 5-3.

5.3.3 Unit A – external temperature progression

To examine the amount of heat from the internal fire in the initiating unit that was making it to the outside of the unit, TCs were placed in critical areas on the exterior, as shown in Figure 4-4. Temperature histories shown in Figure 5-4 indicate that external temperatures remained below 75 °C until 9.5 hours into the test were here the road flare was used to ignite the external gas cloud. This resulted in a large spike in the external temperature and subsequent burning of the unit. It is noted that the data from AE5 has been removed from Figure 5-4, as this TC was damaged when the electrical cabinet door exploded.

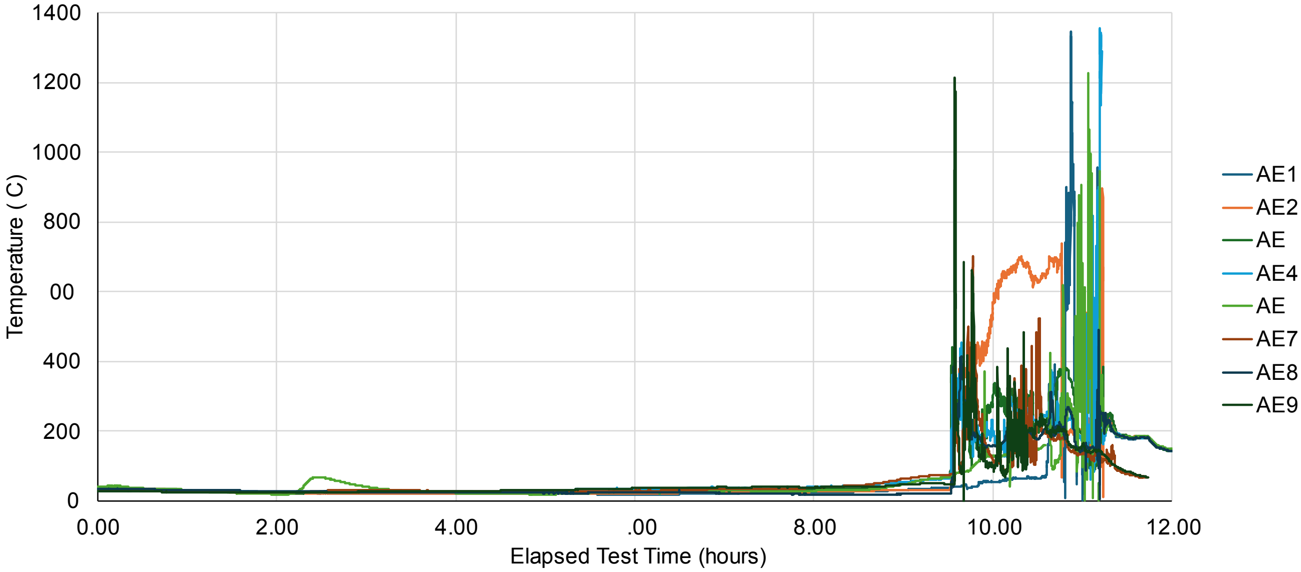


Figure 5-4 Temperature history of exterior of unit A (AE5 data removed)

5.4 Target units

In order to meet the criteria set out by Customer, for the duration of the test including post-burn cool down, no cells within the complete target units can exceed 75% of the thermal runaway temperature and no other components of the target units shall catch fire. In the case of the CATL CBDD0 cell utilized in the EnerC+ 306, the cell thermal runaway temperature was reported to be 241 °C [1], making the 75% threshold criteria temperature 181 °C.

5.4.1 Unit B – temperature progression

Unit B was the unit behind initiating unit A with a back-to-back separation distance of 8 inches, so this was expected to have a significant heat exposure from a fire in unit A. Examination of Figure 5-5 reveals that very little temperature rise was seen until ignition of the gas cloud with the lit road flare. Ignition of the gas cloud led to temperatures greater than 500 °C at the exterior surface. TC BE1 was damaged in the electrical cabinet explosion and was subsequently removed from Figure 5-5 for clarity.

The internal temperatures reached within unit B, according to the internal TCs, are shown in Figure 5-6. No temperature rise was seen internally before the fire was ignited and once the fire was burning the maximum measured internal temperature was less than 80 °C. Note that the thermocouples in unit B were place appro imately 72” from the front of the module, along the back wall, in close proximity to unit A.

Images provided following the test did not show any evidence of damage to the front of the modules, however access to the rear of the module was not possible. With rear of the modules being closest to initiating unit A, this would be expected to have the greatest potential for damage within unit B.

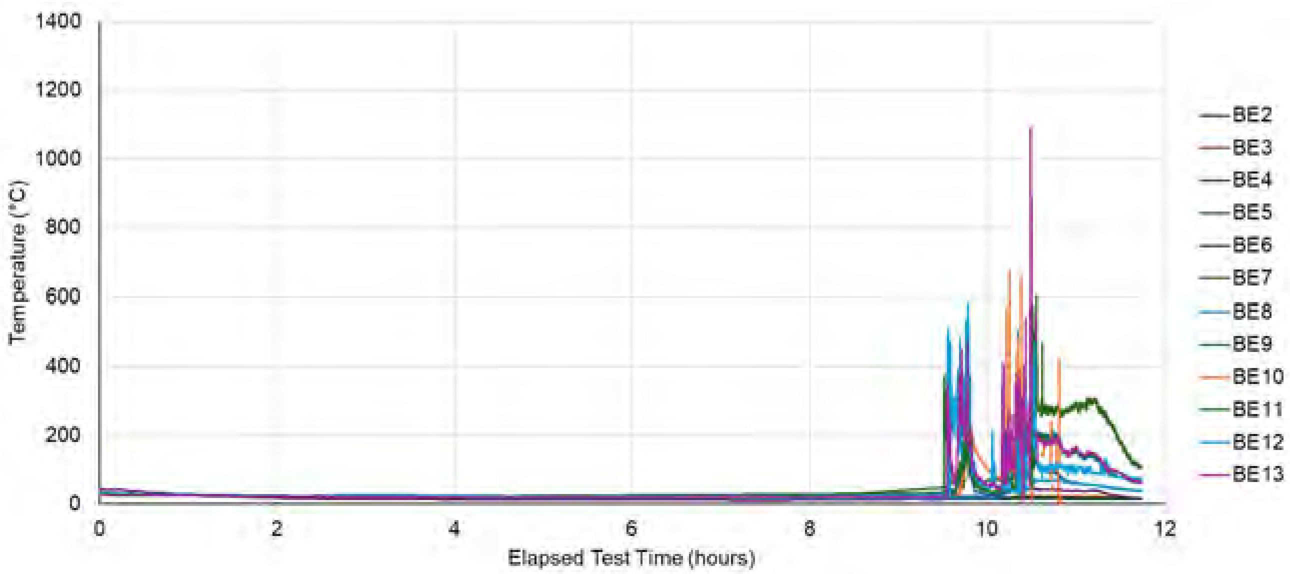


Figure 5-5 Temperature history of exterior of unit B (BE1 data removed)

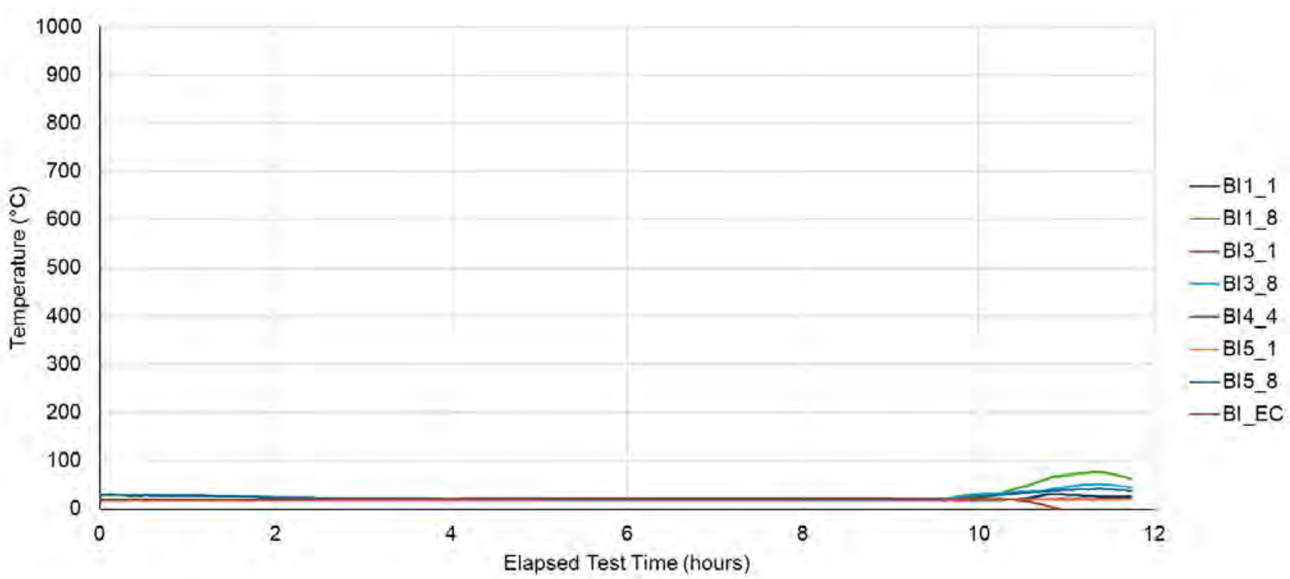


Figure 5-6 Temperature history of interior of unit B

5.4.1.1 BMS data

BMS data from each of the three target enclosures were captured during the test at 1 second intervals. Among other parameters, the BMS captured cell temperatures based on thermistors internal to the modules. Temperature data captured from the BMS indicated that the maximum cell temperature seen during testing within Unit B was 23 °C, as shown in Figure 5-7. This is well below the Customer requirement of 181 °C (75% of the thermal runaway temperature). However, BMS data provided by CATL for Unit B contained only 173 minutes of data, so this temperature likely does not represent the maximum temperature seen inside container B, as Unit A ignition occurred after approximately 571 minutes. For perspective, the data provided for Unit C ran for 912 minutes and data provided for Unit D ran for 909 minutes.

Despite the BMS temperature data for Unit B being incomplete, it is likely that the internal module temperature was lower than the maximum internal Unit temperature as measured by the thermocouples. Therefore, there is a high likelihood that the true maximum internal BMS module temperature that would have been seen if the BMS data was available for a longer duration would be less than the 80 °C maximum temperature measured by the test thermocouples in Unit B, as described in Section 5.4.1.

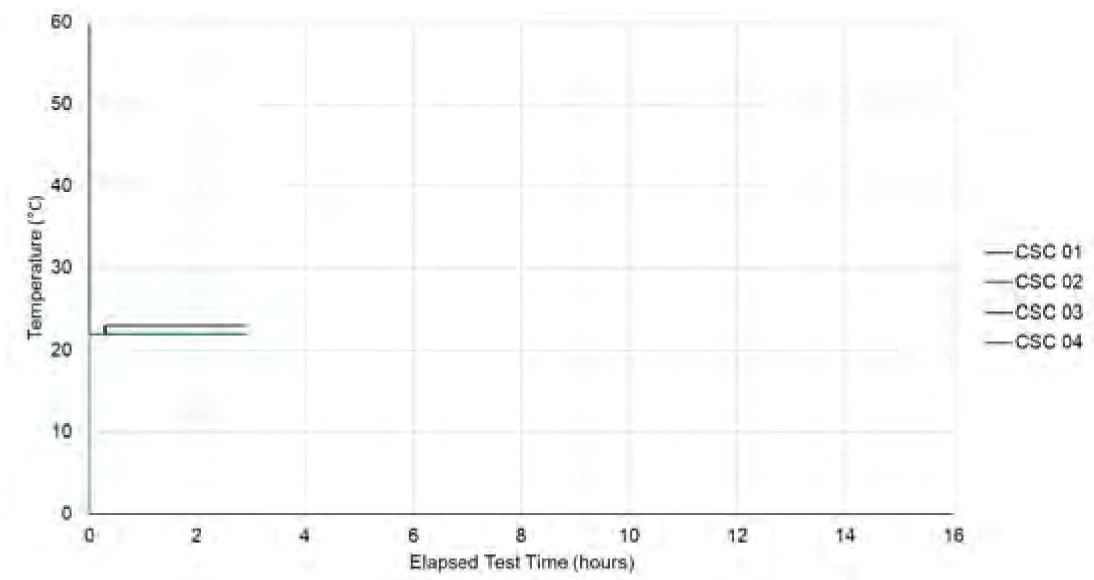


Figure 5-7 Maximum BMS-measured module temperature in unit B

5.4.2 Unit C – temperature progression

External and internal TC temperature time histories are shown in Figure 5-8 and Figure 5-9, respectively. Externally, with the significant source of heat being in front of unit C, temperatures reached over 500 °C in the immediate aftermath of the gas cloud ignition at the top of the doors in the middle of the unit. Internal temperatures of approximately 500 °C existed for a short period of time at the top of rack 5, which was across the aisle from the ventilation intake on unit A. With significant gas generation and smoke production pushing out of unit A, this intake acted to direct a flame jet towards unit C that, at times, impinged directly on the door, as shown in the video image in Figure 5-10.

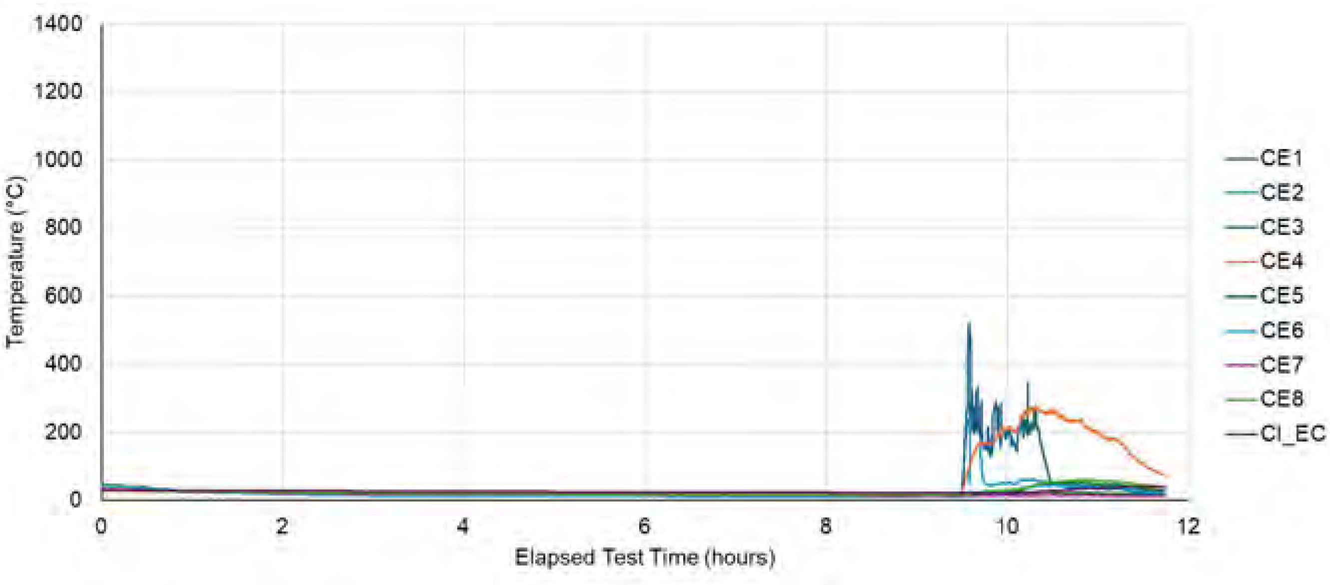


Figure 5-8 Temperature history of exterior of unit C

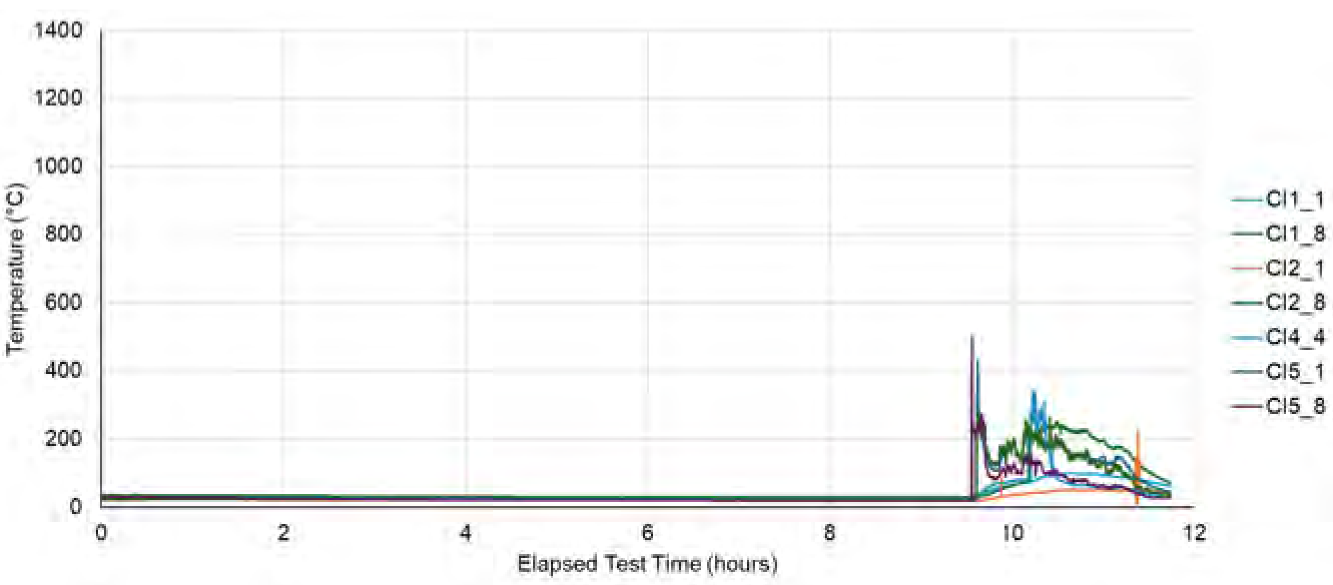


Figure 5-9 Temperature history of interior of unit C

Figure 5-10 Impingement of flame jet on doors of unit C

5.4.2.1 BMS data

While the thermocouple data showed high internal unit temperatures, actual module temperatures did not see such extreme heat. BMS temperature data collected for unit C indicated the maximum internal module temperature reached during the test was 56 °C. This is less than the Customer requirement of 181 °C (75% of the thermal runaway temperature). This temperature was reached after 748 minutes, which is significantly after the maximum internal Unit C temperature was reached. A plot of the maximum BMS-measured module temperature is shown in Figure 5-11.

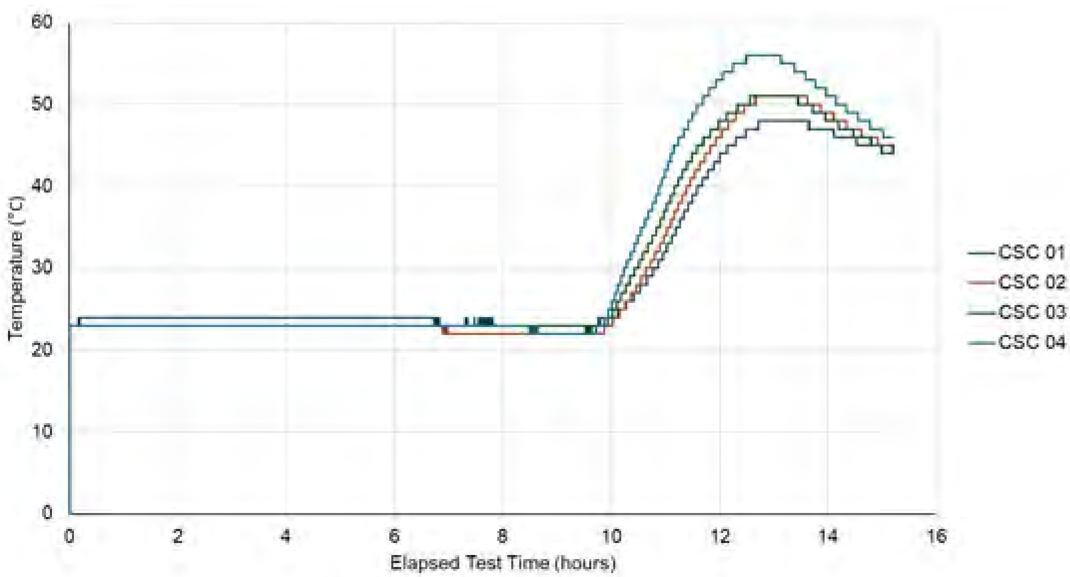


Figure 5-11 Maximum BMS-measured module temperature in unit C

![DNV logo]

5.4.3 Unit D – temperature progression

External temperatures reached a maximum of 140 °C, while internal temperatures in unit D were not measured to exceed 30 °C, as shown in Figure 5-8 and Figure 5-9. Note that TC DE1 on the end wall facing unit A appeared to stop functioning properly after 10.25 hours, slightly after unit A was ignited.

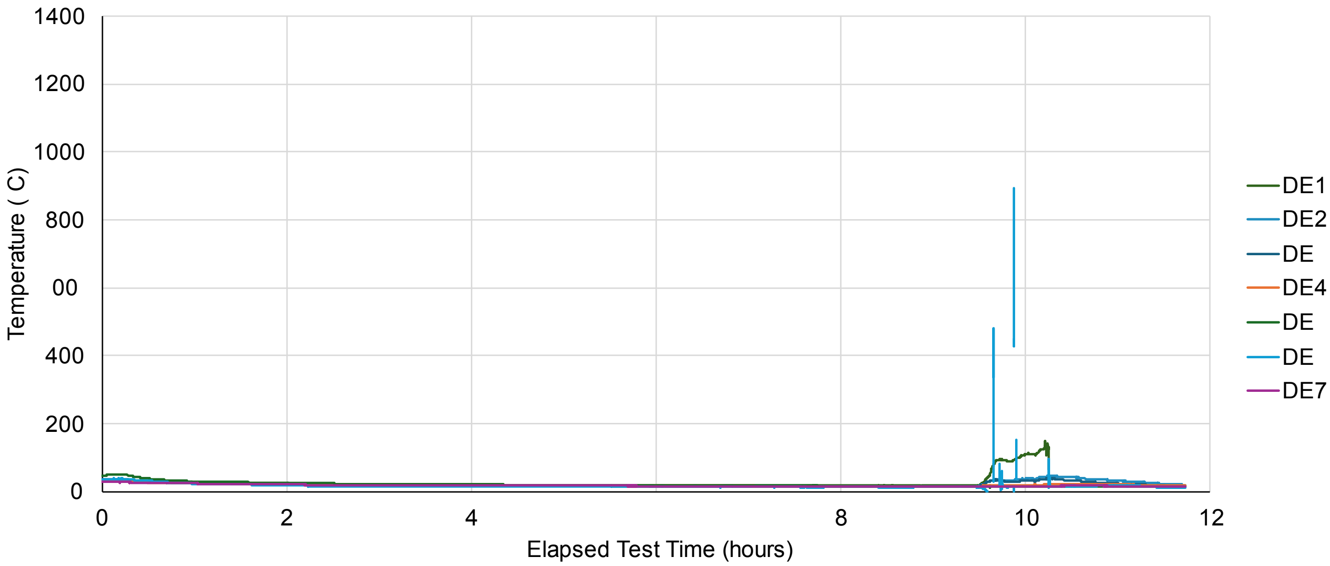


Figure 5-12 Temperature history of exterior of unit D (DE1 data truncated at 10.25 hours)

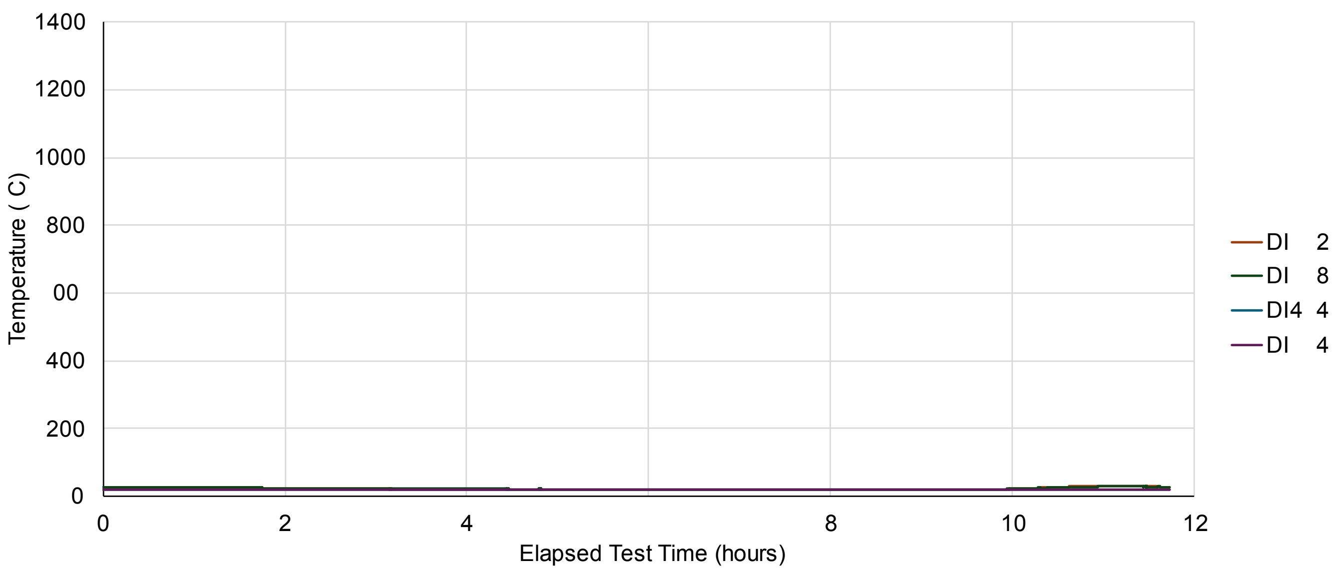


Figure 5-13 Temperature history of interior of unit D

5.4.3.1 BMS data

BMS temperature data collected for unit D indicated the maximum internal module temperature reached during the test was 23 °C. This is less than the Customer requirement of 181 °C (75% of the thermal runaway temperature). This temperature was essentially the ambient temperature, and no measurable temperature rise was seen in the modules in unit D. A plot of the maximum BMS-measured module temperature is shown in Figure 5-14.

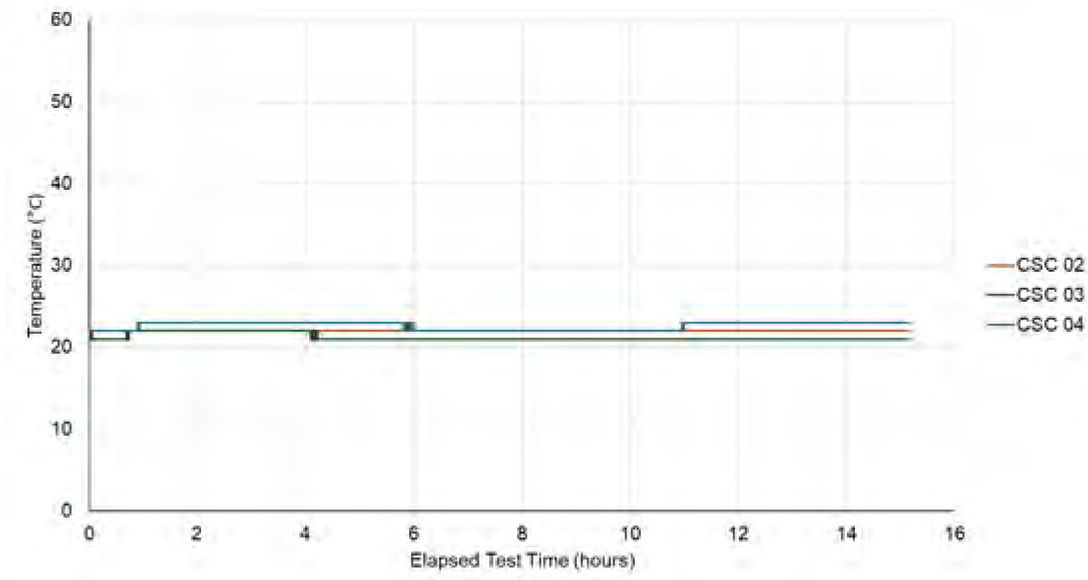


Figure 5-14 Maximum BMS-measured module temperature in unit D

5.5 Heat flux measurements

A total of 8 water-cooled Schmidt-Boelter heat flux-sensors were installed at locations and with sensitivities as shown in Figure 4-1. The green triangle symbols indicate sensor locations. Each sensor location has a heat flux gauge at 4 ft and 10 ft height. The direction of the wide part of the triangle symbol represents the direction the gauges are facing during the test.

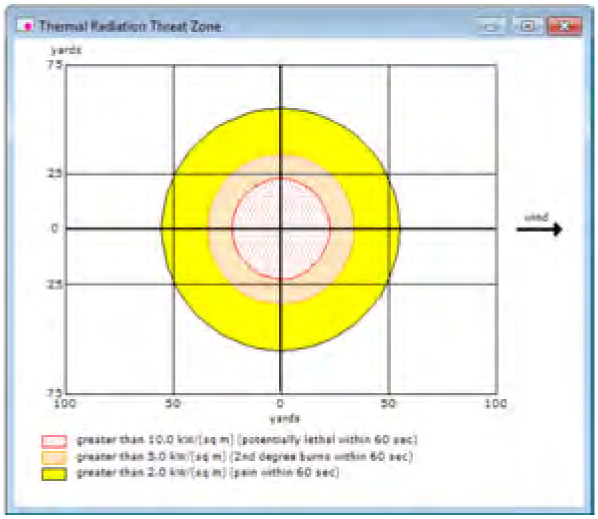


Figure 5-15: EPA/NOAA Thermal Radiation Threat Zones

Heat Flux is typically used to evaluate the safety of personnel to escape a fire. Depending on clothing, different levels of heat flux are acceptable. The U.S. Environmental Protection Agency (EPA) and National Oceanic and Atmospheric Administration (NOAA) have developed an Air Hazard Program that sets the heat flux danger levels as shown in Figure 5-15. UL 9540A defines the limit for allowed heat flux in the center of an egress pathway measured at mid-height as a maximum of 1.3 kW/m^2.

During the testing, minimal heat flux was measured prior to the ignition of unit A, as shown in Figure 5-16. A spike can be seen in the heat flux at the location of the project breaker panel (10 ft) that corresponds to the first activation of the emergency gas ventilation system, which exhausted hot vent gas in that direction. At 9.5 hours a large spike in heat flux corresponds to the ignition of the gas cloud outside unit A and the subsequent fire within unit A. As previously discussed, a significant flame jet impinged on unit C, which lead to a maximum heat flux reading of approximately 22 kW/m^2. The heat flux seen at the front of unit C was the most significant, while the heat flux seen at the project breaker panel distance from the end of unit A (89 inches) reached a maximum of 2.2 kW/m^2.

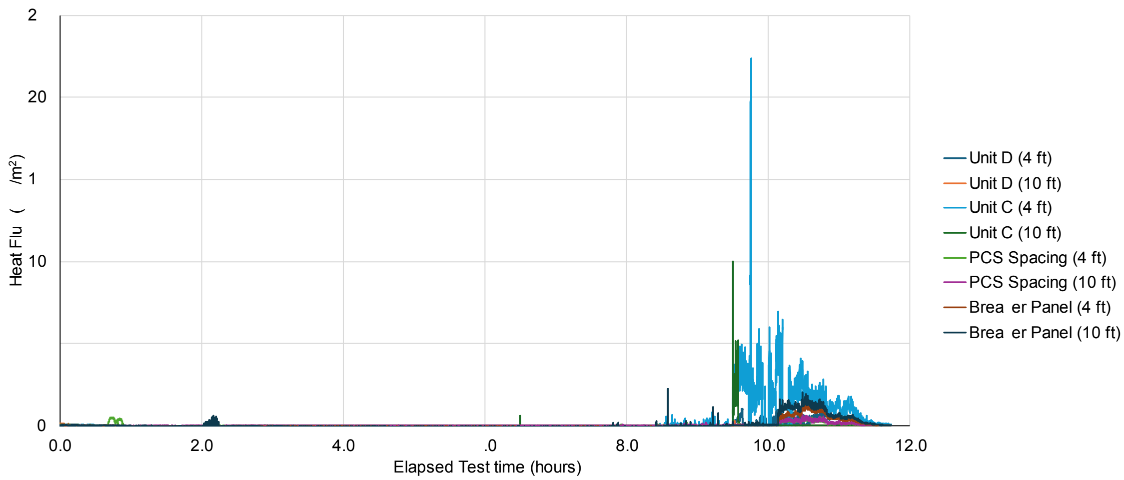


Figure 5-16 Heat flux measurements during test

6 GAS ANALYSIS RESULTS

A continuous gas sampling system was used during the test. Early in the test, the sampling system drew from a sample tube placed to draw gas from within the initiation unit (A Inside). During the test, at approximately 19:53 (7:53 pm) local time (about 2 hours and 18 minutes after test start), a valve was manually moved so the sampling system draw gas from the approximately 12 foot by 12 foot square hood located generally above units A and B (Hood). It is noted that test results just after the switchover are not indicative of actual conditions of either A Inside or Hood due to the source transition.

Continuous scans of gases using a Fourier-Transform Infrared Spectrometer (FTIR) were conducted from before the start of the test to about noon the next day (about 19 hours of data). FTIR results were calculated and checked for goodness of fit for 20 constituents. Over approximately the same time period, measurements of hydrogen (H_2) were conducted using gas chromatography -- thermal conductivity. Measurements of Oxygen (O_2) and total hydrocarbons (THC) were also conducted. Time series plots of selected data are provided in Figure 6-1 to Figure 6-5.

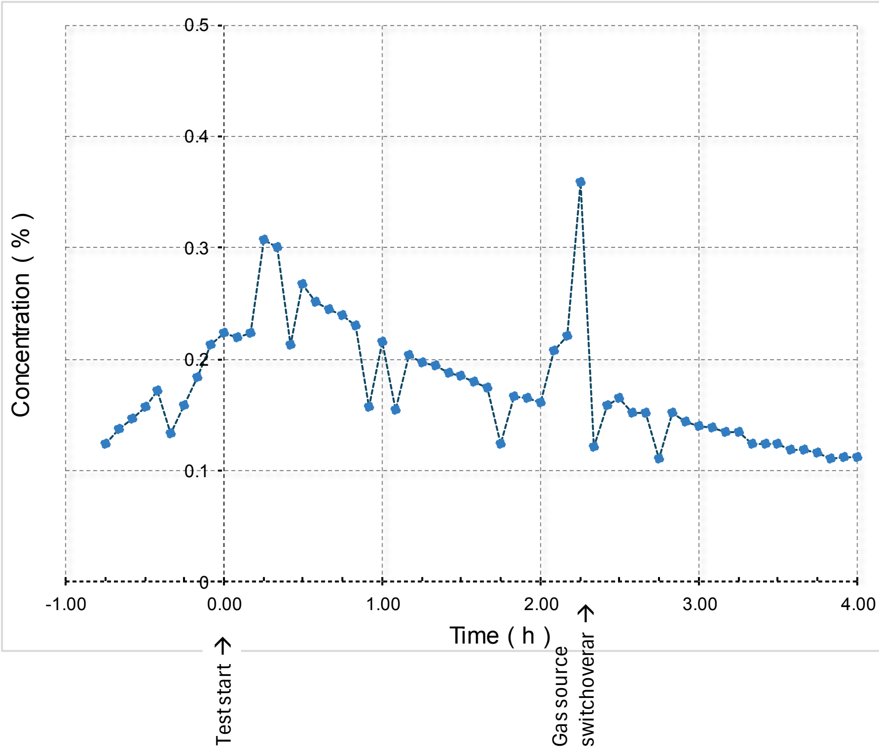


Figure 6-1: Time history of hydrogen (H_2) concentration

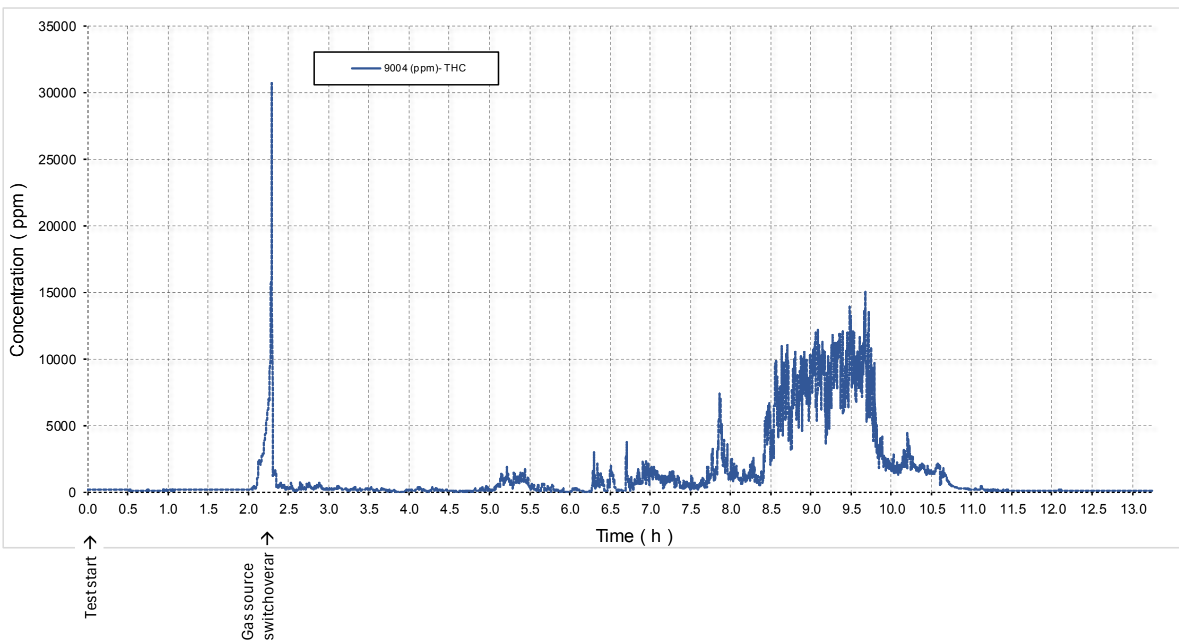


Figure 6-2: Time history of total hydrocarbon (THC) concentration

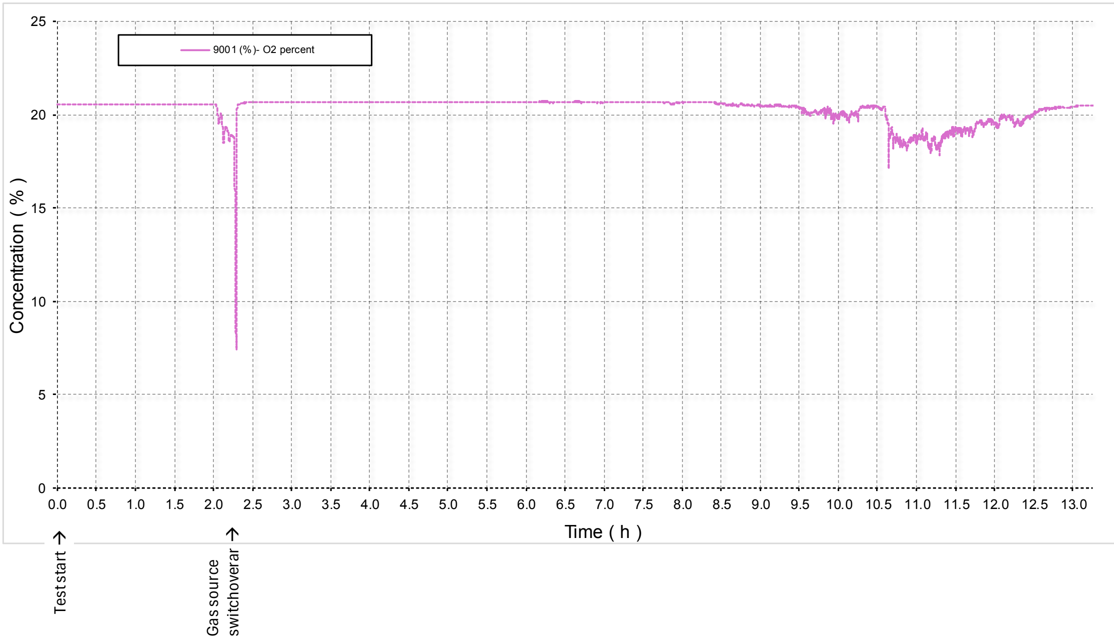


Figure 6-3: Time history of oxygen (O_2) concentration

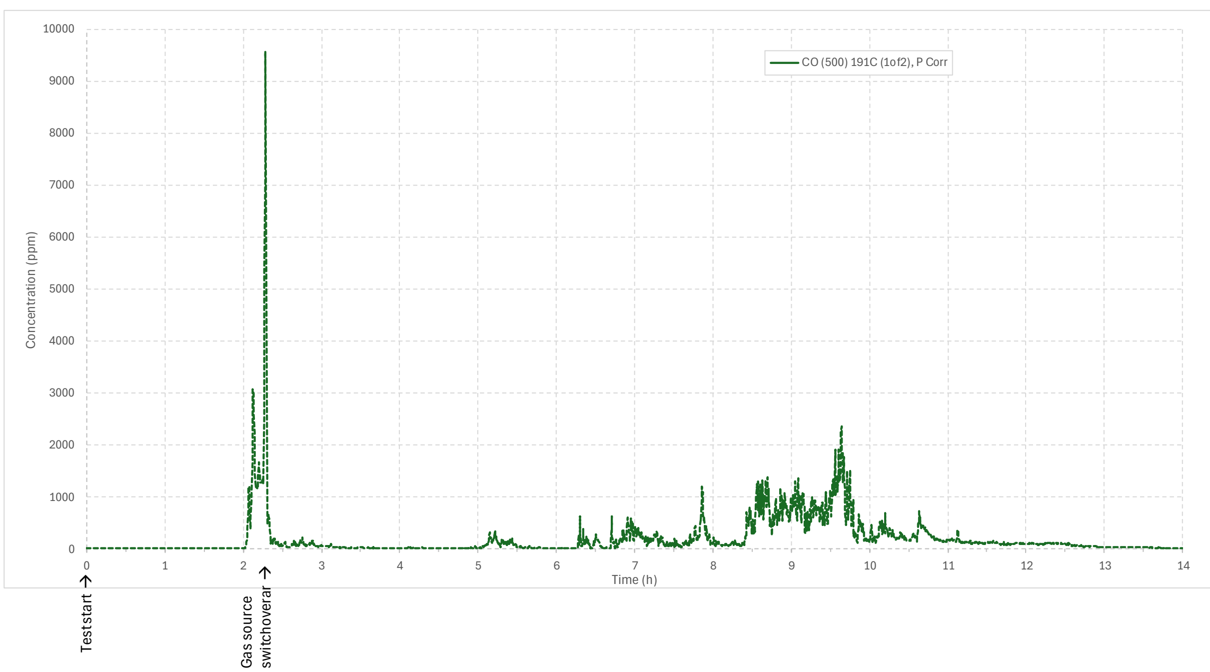


Figure 6-4: Time history of carbon monoxide (CO) concentration

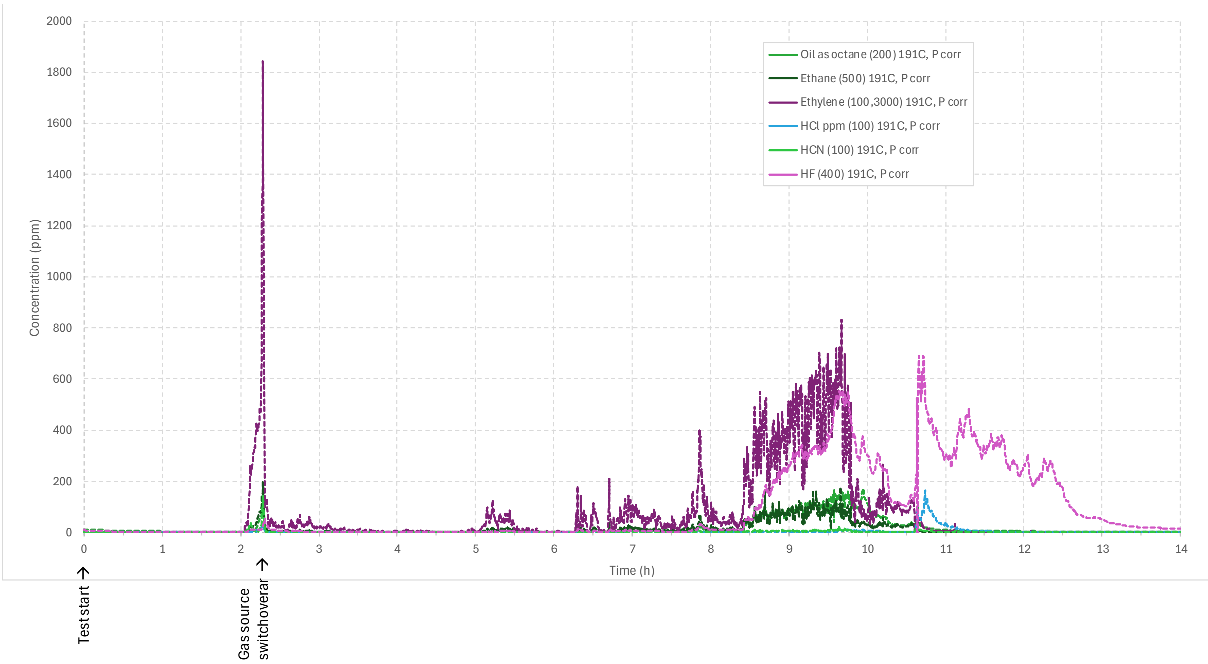


Figure 6-5: Time history of other constituent concentrations

7 CONCLUSIONS

DNV developed the test plan and witnessed the large-scale burn test of the CATL EnerC+ 306 battery energy storage system on 21 August 2024 in Sanford, North Carolina. The test setup consisted of four CATL EnerC+ battery enclosures that were fully populated with battery modules. The test was successful in creating a large fire event by triggering one module into thermal runaway using electrical heaters that resulted in propagation and complete burn-up of all racks in the initiating unit. No thermal runaway propagation to adjacent units was observed. Temperature data indicated that while high external temperatures were seen at the target units, internal temperature increases in target units were moderated by the enclosure envelope and insulation. At no time did target unit cell temperatures exceed 75% of the thermal runaway temperature (181 °C) and no other components of the target units caught fire, apart from paint and door seals. DNV believes this meets the Customer testing requirements.

DNV

8 REFERENCES

[1] UL Solutions, CELL TEST REPORT UL 9540A, 2023.
[2] UL Solutions, MODULE TEST REPORT UL 9540A, 2023.
[3] UL Solutions, UNIT TEST REPORT UL 9540A, 2023.
[4] CATL, EnerC+ 306 Container Product Specification, 2023.

About DNV

DNV is a global quality assurance and risk management company. Driven by our purpose of safeguarding life, property, and the environment, we enable our customers to advance the safety and sustainability of their business. We provide classification, technical assurance, software, and independent expert advisory services to the maritime, oil & gas, power, and renewables industries. We also provide certification, supply chain and data management services to customers across a wide range of industries. Operating in more than 100 countries, our experts are dedicated to helping customers make the world safer, smarter, and greener.

APPENDIX 12-D: PLUME ANALYSIS

NextEra Corby BESS

Plume Analysis for Outside Ground Mounted Battery Energy Storage Systems: CATL EnerC+ Solano County, California

Report | Rev0 | May 16, 2025

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Date	Revision	Reason for Issue	Developed By	Checked By	Approved by
May 16, 2025	0	Initial	DB	MHR	GM

EXECUTIVE SUMMARY

Fire and Risk Alliance, LLC (FRA) performed a plume analysis to evaluate the plume dynamics from the release of battery vent gas due to a propagating thermal runaway event in the Contemporary Amperex Technology Co., Limited (CATL) EnerC+ Lithium-Ion Battery Energy Storage System (BESS) intended for installation at the Corby BESS facility located at 6865 Byrnes Road in unincorporated Solano County, California. The analysis objective was to evaluate the plume dynamics from modeled battery vent gas release scenarios due to a propagating thermal runaway event. This plume analysis was performed using the Process Hazard Analysis Software Tools (PHAST) consequence modeling program to model pre-combustion battery vent gas dispersion and all associated consequences based upon the gas composition and release dynamics described in the UL 9540A cell/module/unit level tests.

This report considers consequence extents for potential pre-combustion battery vent gas release scenarios up to the full enclosure level. Scenarios for pre-combustion releases included the four-cell UL 9540A module level test-based release, and additional hypothetical release scenarios including a full-volume module level release, a full-volume release from a rack of eight modules, and a full-volume release from an entire BESS enclosure of five racks (40-modules).

Analysis of results for all pre-combustion battery vent gas release scenarios show that there are no significant hazards that extend measurably beyond the nearest occupied property boundary for both the flammable and toxic portions of the dispersed cloud**.**

The distance from the nearest BESS to property boundaries was measured at approximately 148 ft (45.11 m) from the eastern property boundary bordering Byrnes Rd, 870 ft (265.17 m) from the northern property boundary bordering Kilkenny Rd, and 164 ft (50 m) from the western property boundary bordering the farmland property. The south property boundary is not visible in the site layout. The maximum extent of impact from the ½ lower flammability limit (LFL) flammable vapor cloud (3.62%) was 24.41 ft (7.4 m) for the UL 9540A based propagation duration release from a full BESS enclosure. Flash fires were a modeled consequence for all pre-combustion scenarios. The flash fire envelope did not extend beyond the proposed property boundaries for any scenarios.

For non-flaming pre-combustion releases where all battery vent gas is released via thermal runaway conditions alone, the component with the largest immediately dangerous to life or health (IDLH) footprint and required potential exposure duration (30-minutes) is carbon monoxide (CO). The largest CO IDLH extent with a duration greater than 30-minutes was 63.32 ft (19.30 m) for Scenario 4.1, below the offset distance to the proposed property boundary from the closest BESS. As such, it is recommended that by incorporating a 1.5x safety factor, the minimum approach distance (MAD) for non-flaming release conditions be a minimum of 95 ft (28.95 m).

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.

Limitations:

At the request of ORR Protection Systems, Inc., FRA performed a plume analysis for the CATL EnerC+ BESS. The EnerC+ is a fully integrated BESS consisting of battery modules, power electronics, control systems, a battery management system, a thermal management system, and an explosion control system all pre-assembled within a single, non-occupiable container. It is meant for outdoor installations, mounted to the ground, for commercial, industrial, and utility applications. This assessment evaluated the plume dynamics from the release of battery vent gas due to a propagating thermal runaway event from the EnerC+ for the Corby BESS Site. The modeled battery vent gas release scenarios could be caused by a non-fire propagating thermal runaway event affecting specified numbers of cells and modules. This analysis is based on one EnerC+ container that contains five racks, each with eight modules consisting of 104 cells per module.

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 and information available at the time of the analysis from the UL 9540A test reports provided to FRA by ORR Protection Systems, Inc. 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.

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1.0 INTRODUCTION

Fire and Risk Alliance, LLC (FRA) performed a plume analysis to evaluate the plume dynamics from the release of battery vent gas due to a propagating thermal runaway event in the Contemporary Amperex Technology Co., Limited (CATL) EnerC+ Lithium-Ion Battery Energy Storage System (BESS) intended for installation at the Corby BESS facility located at 6865 Byrnes Road in unincorporated Solano County, California. The EnerC+ BESS is a pre-assembled, non-walk-in (NWI) style lithium-ion BESS container utilizing CATL cells and modules.

The Corby BESS facility uses EnerC+ containers with an energy capacity of 4,073 kWh. The proposed facility will contain 384 EnerC+ enclosures with space allocated for future augmentation of 160 additional enclosures, as shown in Figure 1. Other equipment on site will include auxiliary transformers, auxiliary distribution switchboards, inverters, and power conversion system skids. The BESS yard will be surrounded by a perimeter fence with two points of ingress and egress on Byrnes Road. Fire apparatus access roads are provided throughout the BESS yard with a width of 24 feet. A site substation is located to the north of the BESS yard, surrounded by a separate perimeter fence with a single point of ingress and egress on Byrnes Road. The substation includes three transformers and a site control enclosure. A sound barrier is located on the north end of the site just south of Kilkenny Road. The Corby BESS facility will have an approximate capacity of 300 megawatts (MW) / 1200 megawatt hours (MWh).

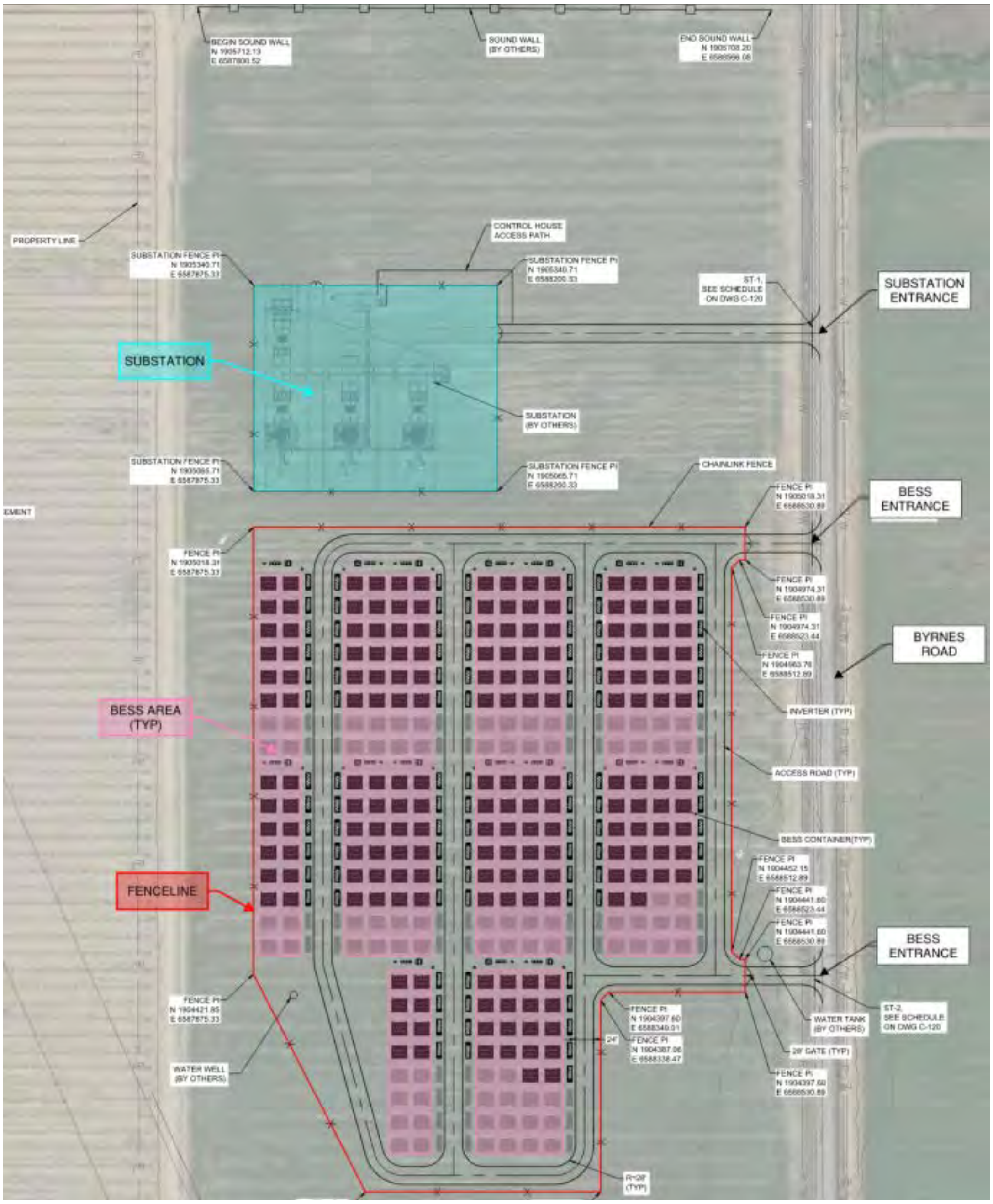


Figure 1. Corby BESS Site Layout

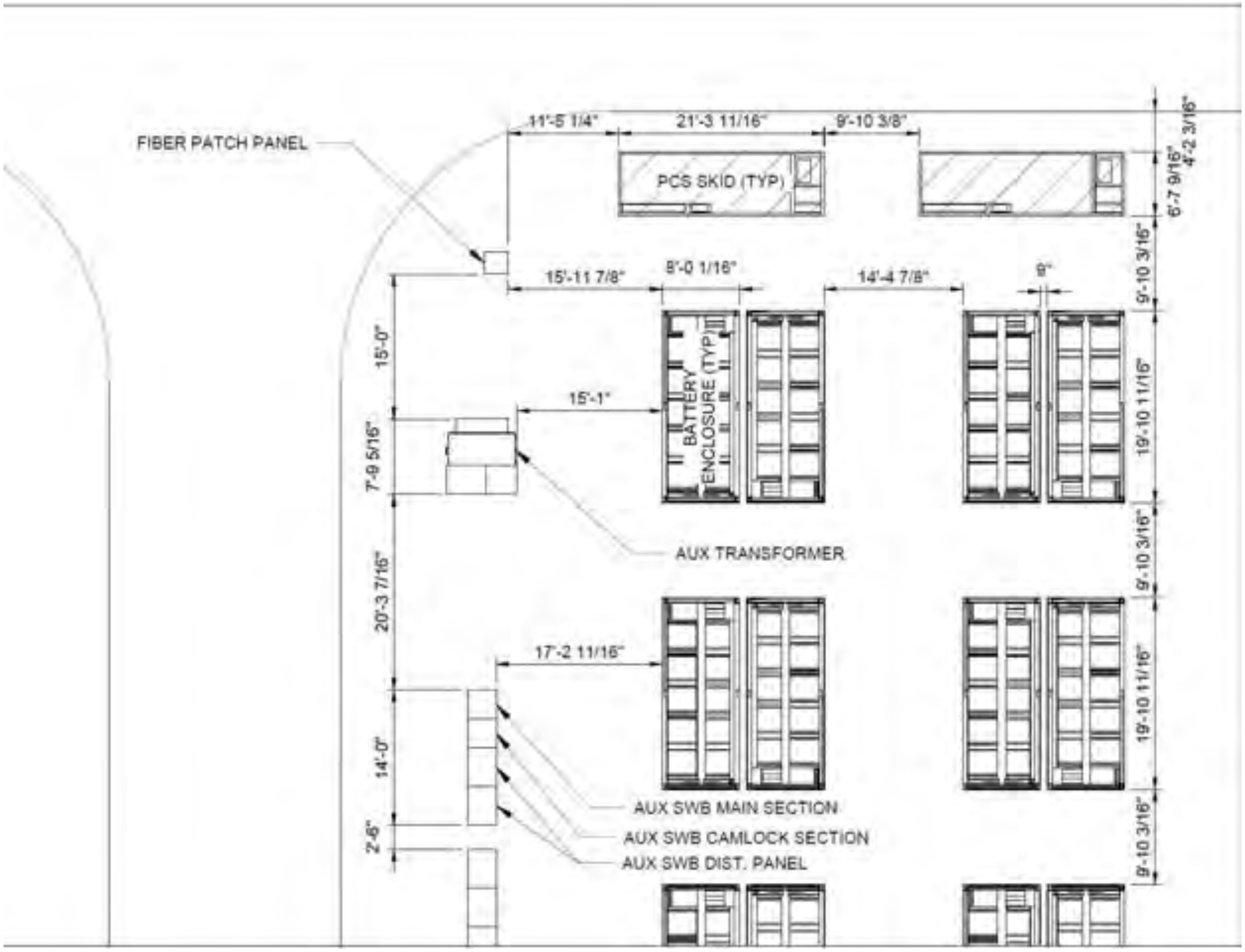


Figure 2. Corby BESS Site Typical BESS Equipment Spacing

2.0 CATL EnerC+ OVERVIEW

2.1 Cell

The BESS cell is the smallest anatomy of the battery assembly. The cell is UL 1973 listed with a nominal capacity of 306 Ah, a nominal voltage of 3.2 Vdc, and is composed of lithium iron phosphate (LFP) chemistry. UL(Changzhou) Quality Technical Service Co., LTD, performed standardized cell level UL9540A testing and a UL9540A report[1] was provided. The gas composition produced during the UL 9540A cell level test is shown in Table 1. The cell vent gas flammability properties are shown in Table 2.

Figure 3. BESS Cell

Table 1. UL 9540A Cell Test Gas Composition

Gas Name	Chemical Structure	% Measured
Carbon Monoxide	CO	14.595
Carbon Dioxide	CO2	26.925
Hydrogen	H2	43.066
Methane	CH4	7.051
Acetylene	C2H2	0.119
Ethylene	C2H4	3.289
Ethane	C2H6	1.060
Propylene	C3H6	0.686
Propane	C3H8	0.260
Ethyl Methyl Carbonate	C4H8O3	0.101
Benzene	C6H6	1.304
Toluene	C7H8	0.012

[1] UL 9540A Cell Level Test Report # 4790838636.3, UL(Changzhou) Quality Technical Service Co., LTD, Dated 2023.08.24

Gas Name	Chemical Structure	% Measured
1-Heptene	C7H14	0.025
Styrene	C8H8	0.013
Iso-butane	C4 (Total)	0.865
Pentane	C5 (Total)	0.399
Hexane	C6(Total)	0.148
Total	-	100

Table 2. Cell Test Vent Gas Flammability Properties

Vent Gas Information and Flammability Properties	
Average cell surface temperature at gas venting	154°C
Average cell surface temperature at thermal runaway	241°C
LFL, % volume in air at the ambient temperature	8.595%
LFL, % volume in air at the venting temperature	7.24%

2.2 Module

The BESS module is the second smallest level of the BESS anatomy. The module is constructed with a metal base with a non-metallic plastic cover. The model, with a 52S2P configuration, has a nominal capacity of 612 Ah, a nominal voltage of 166.4 V, and is composed of 104 cells. UL(Changzhou) Quality Technical Service Co., LTD, performed standardized module level UL9540A testing and a UL9540A report[2] was provided.

Figure 4. BESS Module

This module is manufactured for use in the EnerC+ and is intended to be part of the unit-level assembly. The module assembly supports safe operation through its material insulation and internal cooling. Passive safety features include material reliability and manufactured assembly process. The module itself does not have any active emergency functions for disconnection from the charging source or discharging stored potential energy. The module also consists of a Cell

[2] UL 9540A Module Level Test Report # 4790931782, UL(Changzhou) Quality Technical Service Co., LTD, Dated 2023.09.13

Sensor Circuit (CSC) that functions as a part of the system BMS. Known hazards of the module during normal operation consist of either electrical, thermal, or mechanical failures which could result in gas release, flaming electrical fluid, electrical shorting, thermal heating, and/or thermal runaway.

2.3 Unit

The unit (or rack) is the third level of BESS anatomy. Each unit holds eight modules and includes a sub-control box that includes a Slave Battery Management Unit (SBMU), as shown in Figure 5. The EnerC+ unit is model C02306P05L01-R that utilizes an 8S1P module configuration. It has a nominal capacity of 612 Ah, a nominal voltage of 1331.2 V, a nominal energy capacity of 814.69 kWh and has overall dimensions of 8.85 ft (2698 mm) × 3.07 ft (936 mm) × 7.39 ft (2252.5 mm). The unit is manufactured for use in the EnerC+ and is intended to be part of the container-level assembly. UL performed UL 9540A unit level testing and issued a report[3].

Figure 5. BESS Unit: Photo (Left) and Rendering (Right)

2.4 Container

The container is the final and largest level of the BESS. The EnerC+ container is a rigid metal (steel) enclosure designed to house the batteries, associated controllers, and appurtenances. The container supports the safe operation of the BESS through its exterior rigid housing structure that helps to protect the batteries from mechanical damage and weather conditions. It is 8 ft wide, 9.5 ft tall, and 20 ft long and is intended for outdoor installations, with an IP-55 rating, ground-

[3] Project # 4790931774, UL (Changzhou) Quality Technical Service Co., LTD Dated 2023.10.27

mounted. The EnerC+ contains a battery compartment, an electrical controls compartment, and a TMS compartment, as shown in Figure 6.

Figure 6. BESS Container

3.0 PHAST CONSEQUENCE MODELING

The PHAST Unified Dispersion Model (UDM) was used to calculate the downwind dispersion distances, concentration profiles, and widths of flammable and toxic releases for pre-combustion battery vent gas. Dispersion models require the use of an averaging time to calculate the maximum concentration and plume width over the entire duration of the release and subsequent time until the cloud concentration falls below threshold values for flammable and toxic levels. The PHAST calculated averaging time for flammable dispersion models is 18.75 seconds and 30 minutes for immediately dangerous to life or health (IDLH) concentrations.

For all of the pre-combustion venting scenarios, the XX.1 Sub-Scenarios represent model scenarios using a calculated release duration based on the cell-to-cell thermal runaway propagation rate observed in the UL 9540A test data, then scaled up to the number of cells within a module/rack/container. This scaled release duration was then utilized as the duration for all subsequent module/rack/container level releases, a conservative approach that assumes a common fault/failure leading to thermal runaway in all modules at the enclosure scale.

For all of the pre-combustion venting scenarios, the XX.2 Sub-Scenarios represent the theoretical upper-bounding release condition (hereby referenced as TURC), this is achieved by condensing the entire released vent gas volume into a 10-minute duration release for all module/string/container level scenarios. These upper-bounding theoretical worst-case release sub-scenarios are specifically included in this analysis for use only as a comparison for understanding the hypothetical peak potential impacts from a condensed release and are not representative of the consequences to be expected from a propagating non-flaming thermal runaway event, nor utilized for evaluating facility siting.

All individual gas components of the battery vent gas mixture defined in the UL 9540A cell level testing were included in the consequence analysis. Modeling accounted for all toxic components with established IDLH values within the battery vent gas mixture and were individually tracked in dispersion calculations such that the centerline concentration for each component was documented over the duration of the release. The default PHAST averaging time for IDLH calculations is 30-minutes, as it is the minimum exposure duration needed to meet the IDLH exposure requirements. PHAST calculates downwind concentration extents and cloud widths for each tracked toxic component within the battery vent gas mixture which, depending on gas composition, may include some or all of the following: Carbon Monoxide (CO); Carbon Dioxide (CO2); Toluene; Benzene; Xylene; Hydrogen Fluoride (HF); Hydron Bromide (HBr); Hydrogen Chloride (HCl); and other trace components.

With the exception of CO and CO2, model inputs for all other toxic components within the battery vent gas mixture fell below the PHAST required minimum component concentration (i.e. below individual IDLH concentrations) for dispersion calculations to be performed. Trace toxic components all fell below concentrations measurable beyond the immediate release location. Accordingly, CO and CO2 were evaluated for IDLH extents. Upon initial review of intermediate modeling results, it became clear that the extent of the CO2 IDLH cloud (40,000 parts per millions (PPM)) did not extend measurably beyond the release location. As such, the vapor cloud was modeled as a mixture according to the component concentrations listed in the UL 9540A reports for pre-combustion and associated gas properties, and CO was tracked as an individual component of the release mixture to determine the maximum extent of IDLH concentrations (1,200 ppm CO) within the cloud.

3.1 Pre-Combustion Venting Scenarios

Battery vent gas release scenarios were modeled in PHAST to determine the maximum extent of the flammable cloud (3.62% ½ LFL, 7.24% LFL from UL 9540A reports) and of the CO IDLH (1,200 ppm) component of the pre-combustion cloud. All release timing and mass flow rates for PHAST modeling were based on the conservative values obtained from UL 9540A cell/module test data, with a cell-based mass flow rate for total vent gas (TVG) of 0.00197 kg/s.

The following four scenarios and associated sub-scenarios were modeled in PHAST:

- Scenario 1: UL 9540A Based Scenario (four-cells venting under thermal runaway)
  - 1.1: Propagation rate of four cells per 20.4 minutes from UL 9540A module test for all cells (40 l/min)
  - 1.2: 10-minute release duration (TURC)
  - 1.3: Instantaneous release
- Scenario 2: Single Module Release (104-cells)
  - 2.1: Propagation simultaneously through each cell at a rate of four cells per 20.4 minutes from the UL 9540A module test for all cells (280.63 l/min for 75.6 min)
  - 2.2: 10-minute release duration (TURC)
- Scenario 3: 1-Rack Release (8-modules (832-cells))
  - 3.1: Propagation simultaneously through each module at a rate of four cells per 20.4 minutes from the UL 9540A module test for all cells (2,245.08 l/min for 75.6)
  - 3.2: 10-minute release duration (TURC)
- Scenario 4: 1-Container Release (5-racks (40-modules (4,160-cells))
  - 4.1: Propagation simultaneously through each module at a rate of four cells per 20.4 minutes from the UL 9540A module test for all cells (11,229.36 l/min for 75.6min)
  - 4.2: 10-minute release duration (TURC)

For all the above listed scenarios, the flammable cloud was modeled as a mixture according to the component concentrations listed in the UL 9540A reports and gas properties, and CO was tracked as a component of the release to determine the maximum extent of IDLH concentrations (1,200 ppm CO).

3.2 PHAST Model Parameters

Atmospheric stability and wind speed impact the consequence analysis results by increasing or reducing the turbidity of the air flow, in turn maximizing or minimizing the dispersion of the vapor cloud. Pasquill stability classes are given in Table 3. Stability Class F was used as it is the most conservative approach and maximizes the extent and concentration of the vapor cloud. Wind speed data was obtained for the site based on long-term weather data, as shown in Table 4.

Table 3. Pasquill Stability Classes

Stability Class	Definition	Stability Class	Definition
A	Very Unstable	D	Neutral
B	Unstable	E	Slightly Stable

C	Slightly Unstable	F	Stable

Table 4. Wind Speeds Utilized

Wind Speed (mph)	Pasquill Stability
3 (avg min)	F
6.5 (avg)	F
14 (avg max)	F

The site based average daily minimum, daily average, and daily maximum wind speeds (3 mph, 6.5 mph, 14 mph) were used in a sensitivity analysis to determine what produced the furthest extent of the cloud (flammable and CO IDLH). As shown below in Figure 7 and Figure 8, the 3 mph wind speed produced the farthest extents for the flammable cloud and CO IDLH and was used as the baseline for all PHAST modeling scenarios.

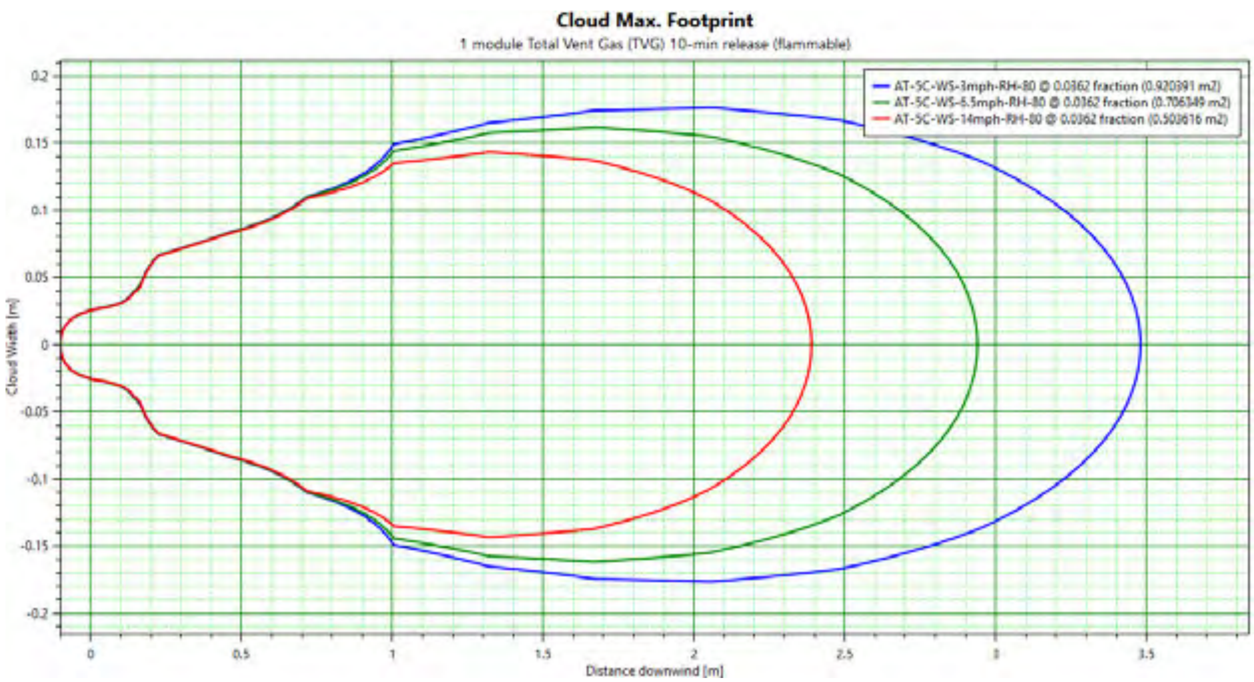


Figure 7. Wind Speed Comparison for TVG ½ LFL Extent (Blue = 3 mph)

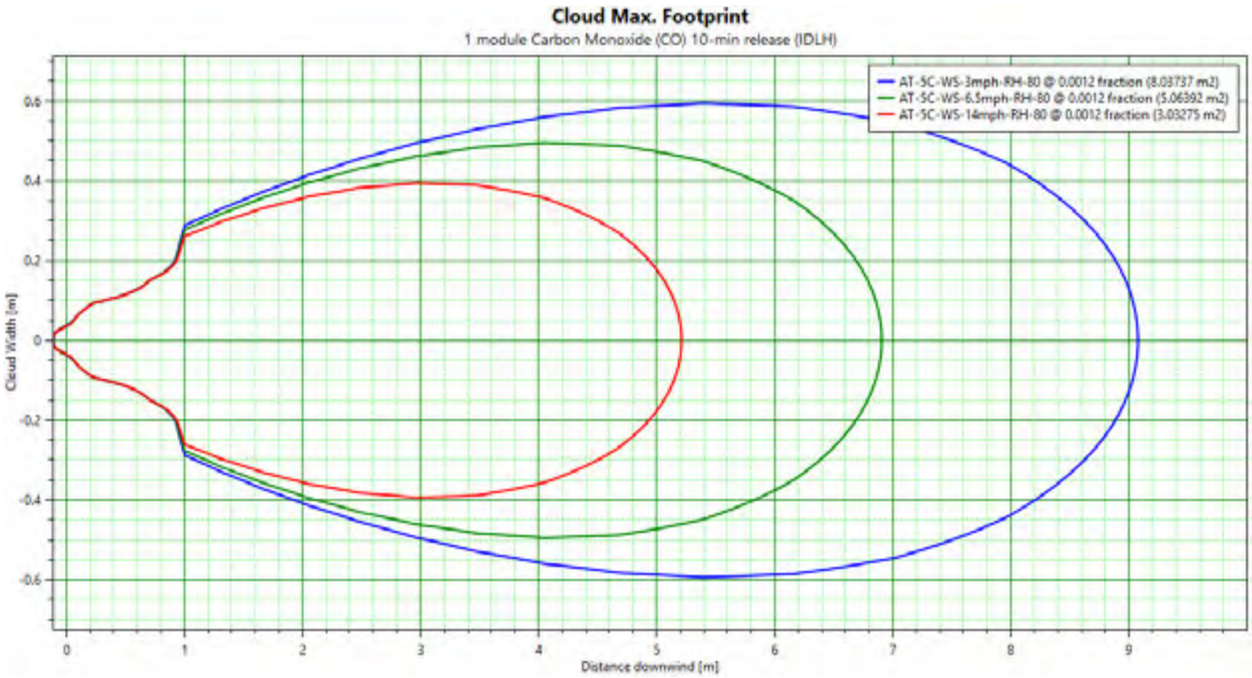


Figure 8. Wind Speed Comparison for CO IDLH Extent (Blue = 3 mph)

Table 5. Representative Weather Conditions

Component	Corby BESS Facility
Average Minimum Wind Speed (mph)	3
Pasquill Stability Class	F
Ambient Temperature (°F) / (°C)	41 / 5
Relative Humidity (%)	80

All other PHAST modeling parameters for release conditions were taken directly from the UL 9540A reports and from the conservative calculations of the battery vent gas release rate, release duration, and propagation rate for individual cells.

4.0 PHAST RESULTS

Results of the PHAST consequence analysis for the four battery gas venting scenarios and associated sub-scenarios identified above in Section 3 are presented below.

Table 6. Results Summary of Flammable and Toxic Extents for Release Scenarios (m)

Scenario	Sub-Scenario	Flash-Fire Radius	100% LFL	50% LFL	IDLH
1 (UL 9540A Four-Cell)	1.1 (20.4- min)	1.02	0.31	0.59	1.70
	1.2 (10-min TURC)	1.20	0.43	1.07	2.27
	1.3 (Instantaneous*)	1.60	1.18	1.47	2.75
2 (Single-Module)	2.1 (75.6- min)	1.70	1.04	1.52	3.84
	2.2 (10-min TURC)	4.10	1.95	3.48	9.10
3 (1-Rack of Eight Modules)	3.1 (75.6- min)	4.20	2.00	3.58	9.30
	3.2 (10-min TURC)	10.50	5.18	9.00	23.50
4 (1-Container of Five Racks)	4.1 (75.6- min)	8.80	4.24	7.44	19.30
	4.2 (10-min TURC)	22.00	11.00	19.00	48.80

**Instantaneous release was modeled for four-cell volume only. Module, rack, and container level releases exceed the interior free-air volume space of the BESS*

Table 7. Results Summary of Explosion Overpressures

Scenario	Sub-Scenario	Deflagration (m)		
		0.02068 bar	0.1379 bar	0.2068 bar
3 (1-Rack of Eight Modules)	3.2 (10-min TURC)	22.00	13.00	12.50
4 (1-Container of Five Racks)	4.2 (10-min TURC)	46.00	27.00	25.00

Table 8. Results Summary of Fireball

Scenario	Sub-Scenario	Fireball (m)	
		4.7 kW/m^2	12.5 kW/m^2
1 (UL 9540A Four-Cell)	1.3 (Instantaneous)	8.00	5.00

4.1 Scenario 1 (Four-Cell Release): PHAST Modeling Results

4.1.1 Sub-Scenario 1.1

Figure 9. Map of horizontal extent of vapor cloud for LFL (7.24%) and ½ LFL (3.62%)

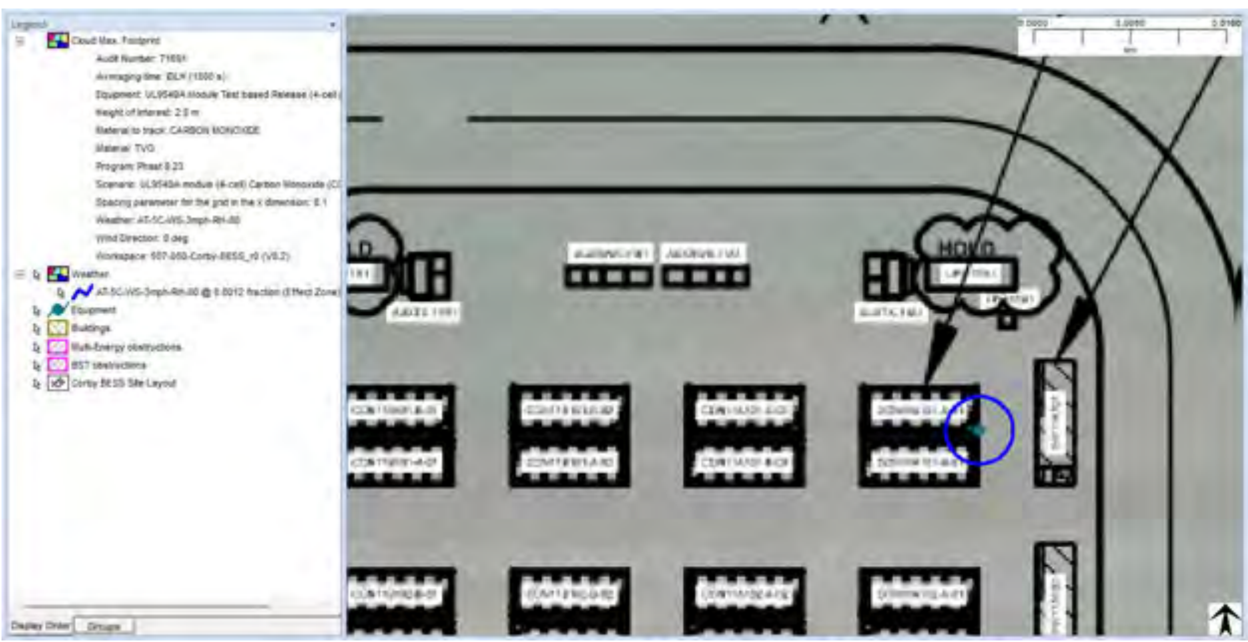


Figure 10. Map of horizontal extent of vapor cloud for CO IDLH (1200 ppm)

4.1.2 Sub-Scenario 1.2

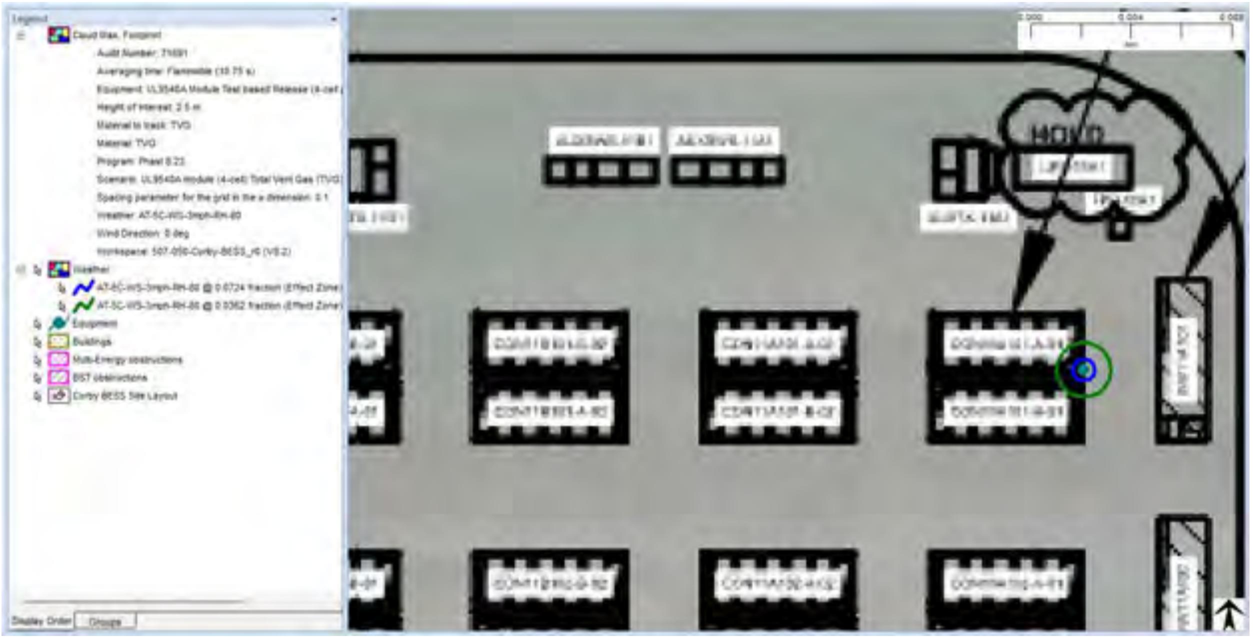


Figure 11. Map of horizontal extent of vapor cloud for LFL (7.24%) and ½ LFL (3.62%)

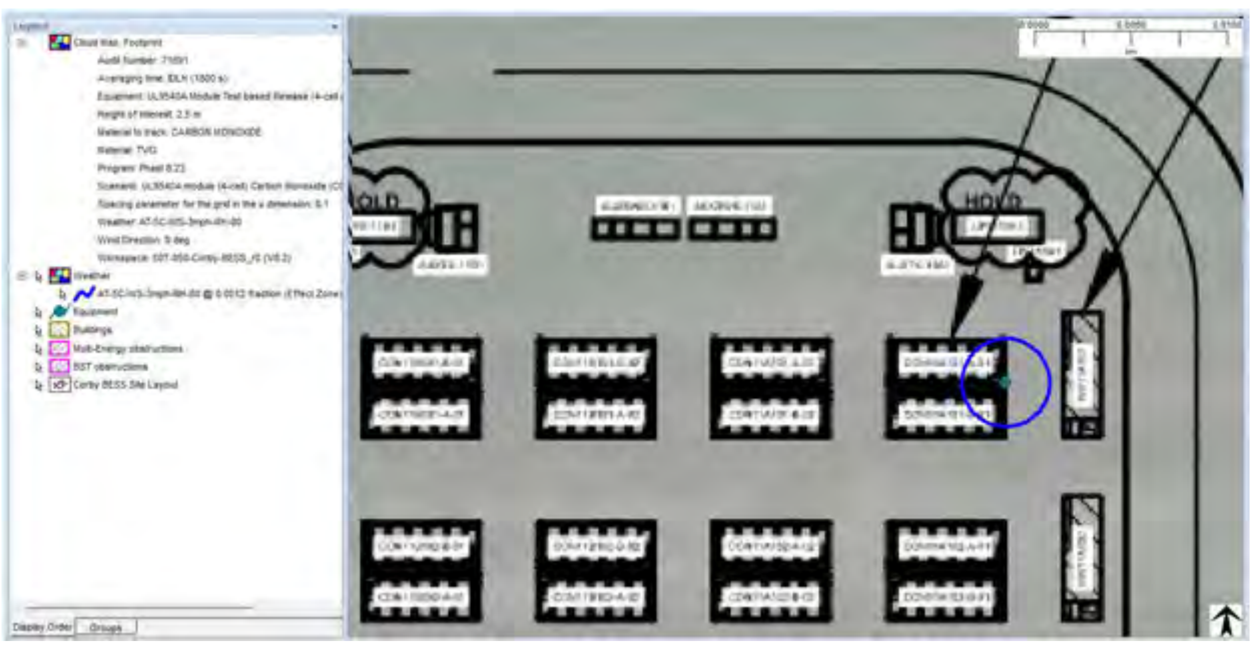


Figure 12. Map of horizontal extent of vapor cloud for CO IDLH (1200 ppm)

4.1.3 Sub-Scenario 1.3

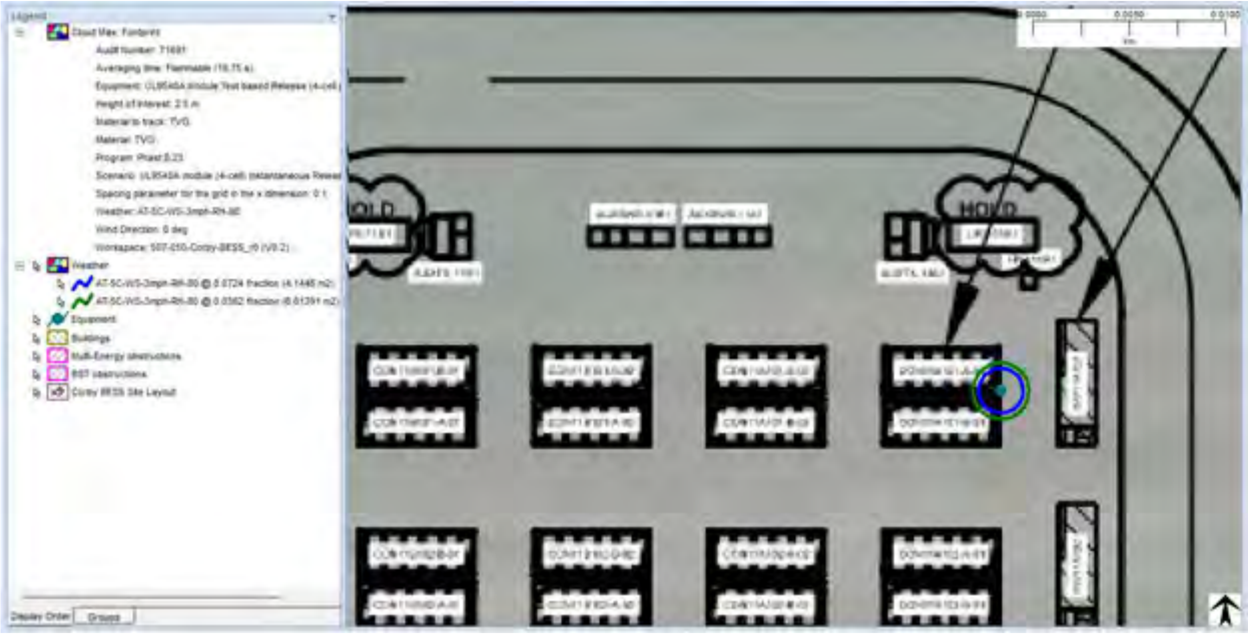


Figure 13. Map of horizontal extent of vapor cloud for LFL (7.24%) and ½ LFL (3.62%)

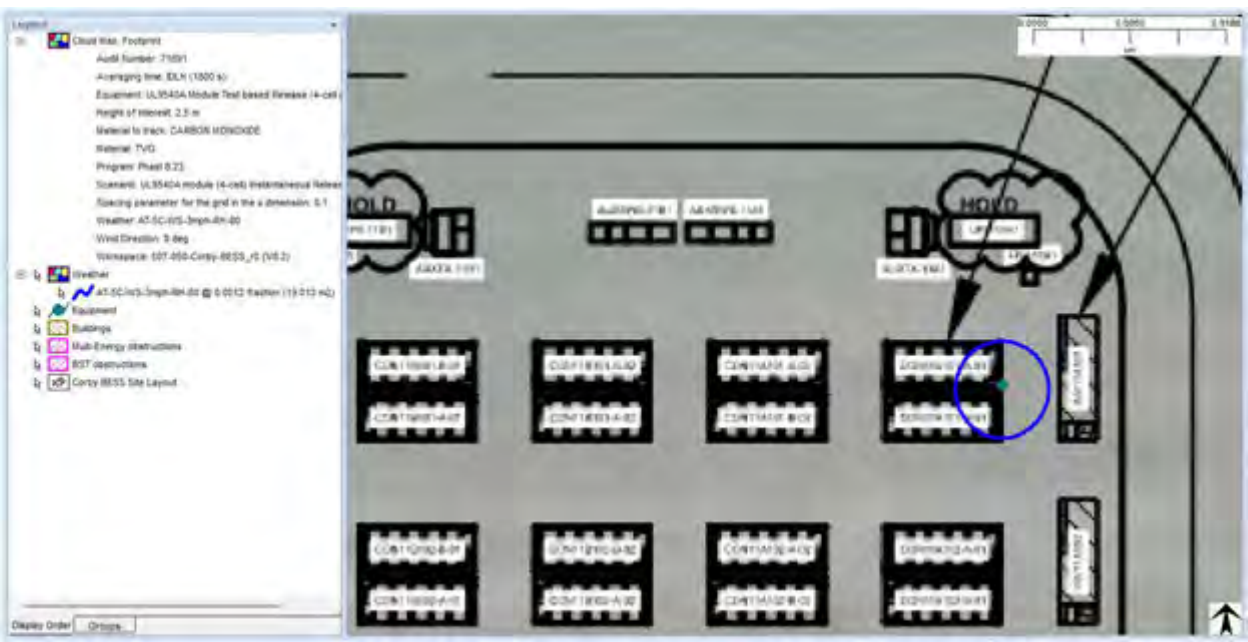


Figure 14. Map of horizontal extent of vapor cloud for CO IDLH (1200 ppm)

4.2 Scenario 2 (1-Module Release): PHAST Modeling Results

4.2.1 Sub-Scenario 2.1

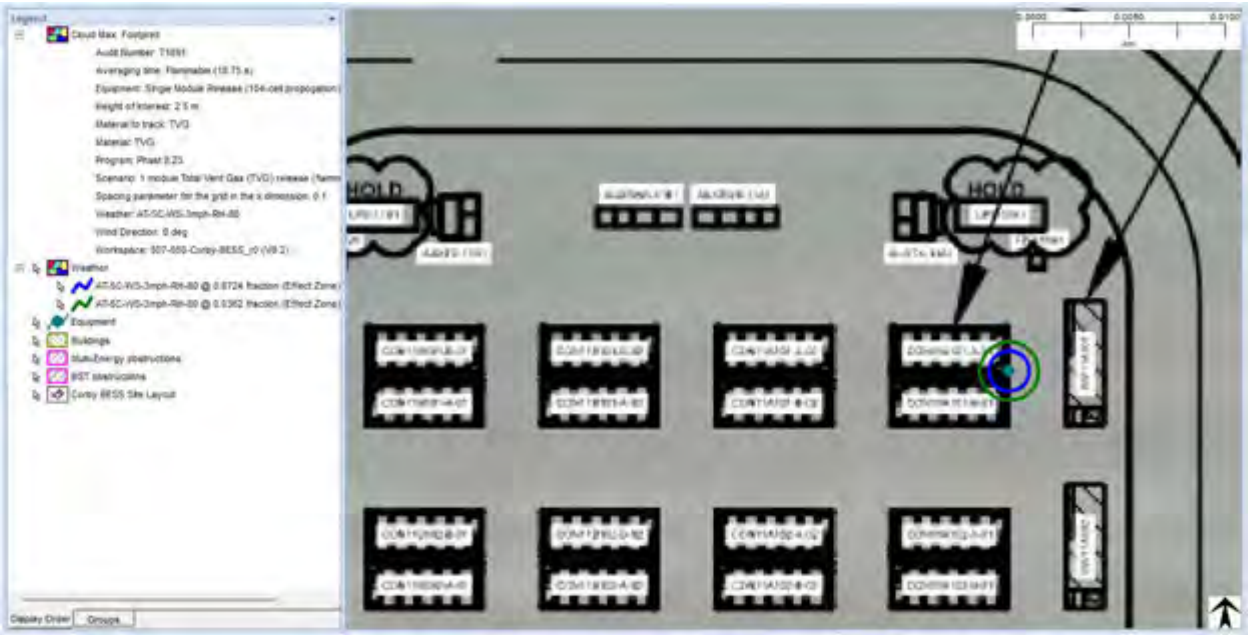


Figure 15. Map of horizontal extent of vapor cloud for LFL (7.24%) and ½ LFL (3.62%)

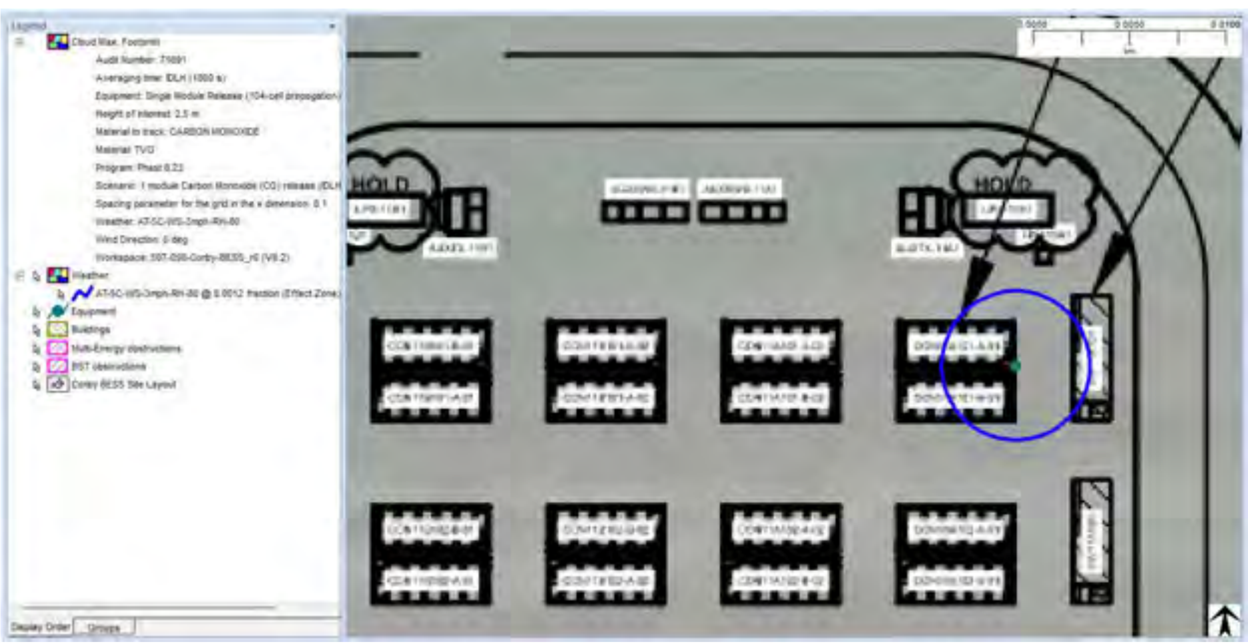


Figure 16. Map of horizontal extent of vapor cloud for CO IDLH (1200 ppm)

4.2.2 Sub-Scenario 2.2

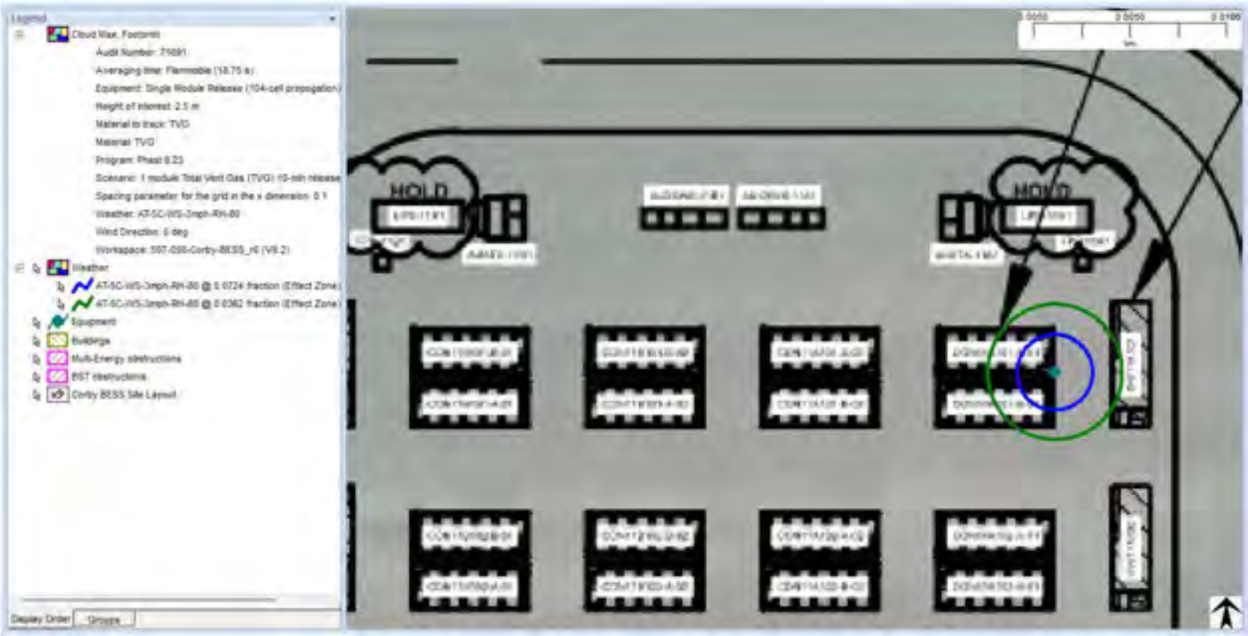


Figure 17. Map of horizontal extent of vapor cloud for LFL (7.24%) and ½ LFL (3.62%)

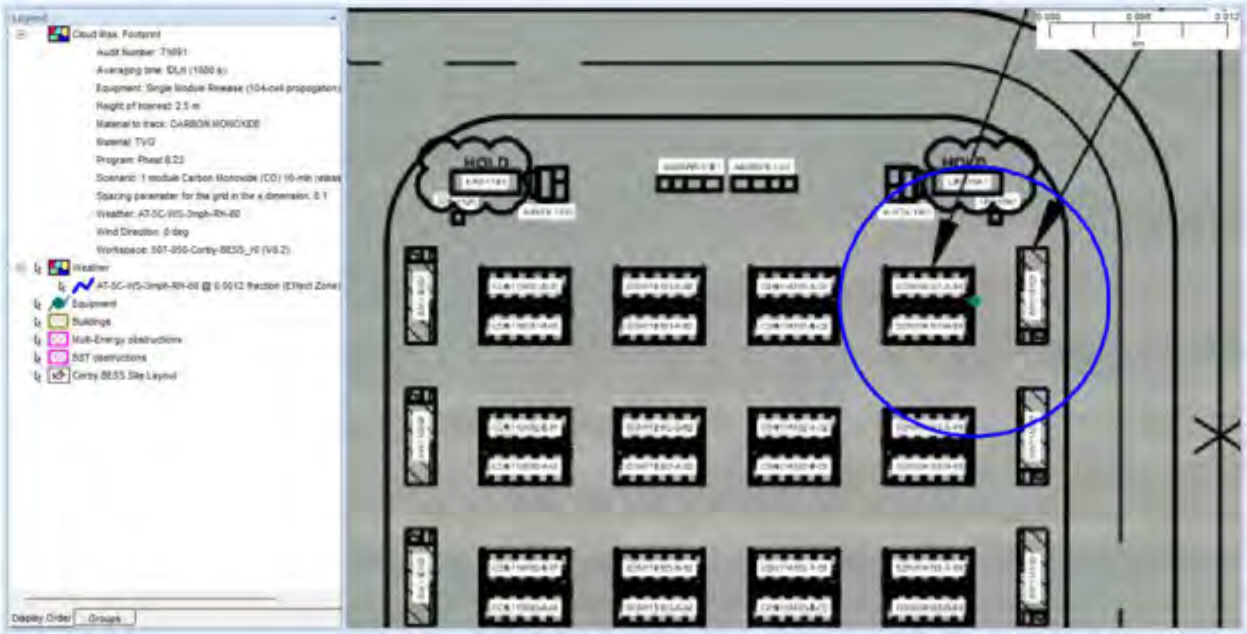


Figure 18. Map of horizontal extent of vapor cloud for CO IDLH (1200 ppm)

4.3 Scenario 3 (1-Rack Release): PHAST Modeling Results

4.3.1 Sub-Scenario 3.1

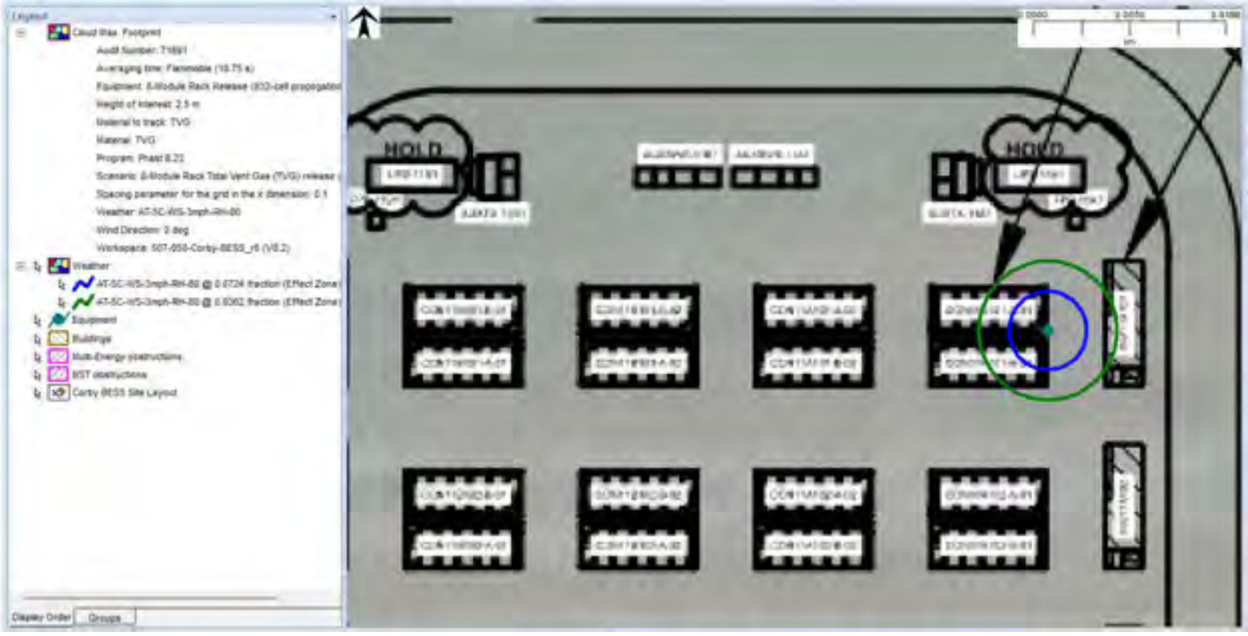


Figure 19. Map of horizontal extent of vapor cloud for LFL (7.24%) and ½ LFL (3.62%)

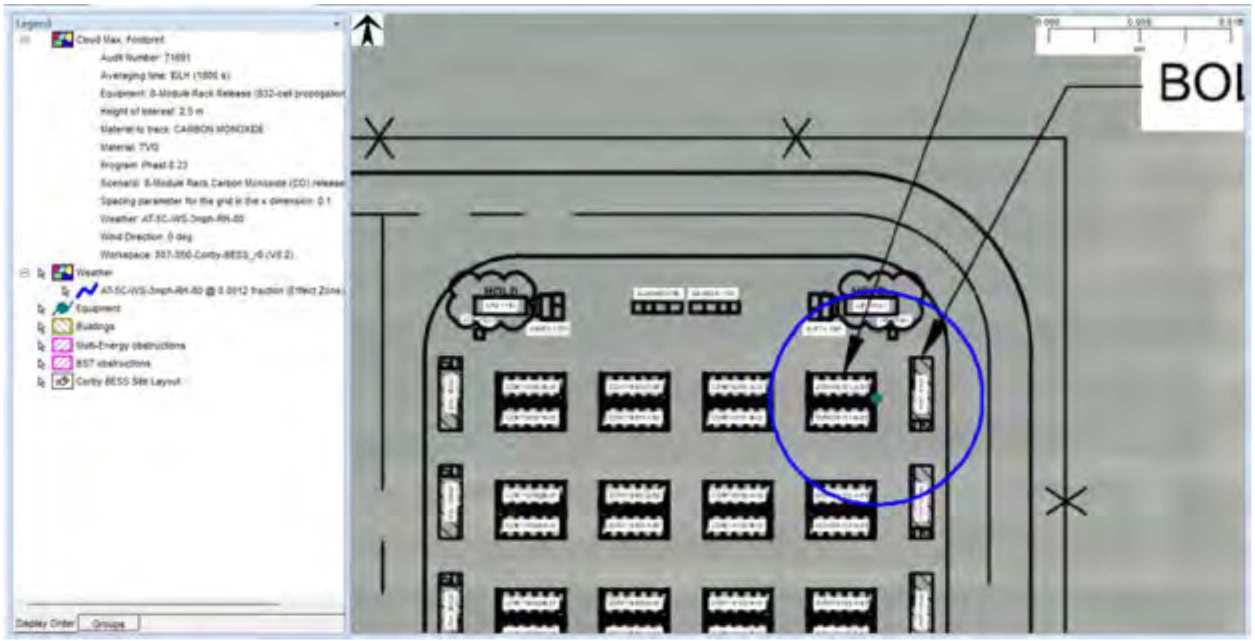


Figure 20. Map of horizontal extent of vapor cloud for CO IDLH (1200 ppm)

4.3.2 Sub-Scenario 3.2

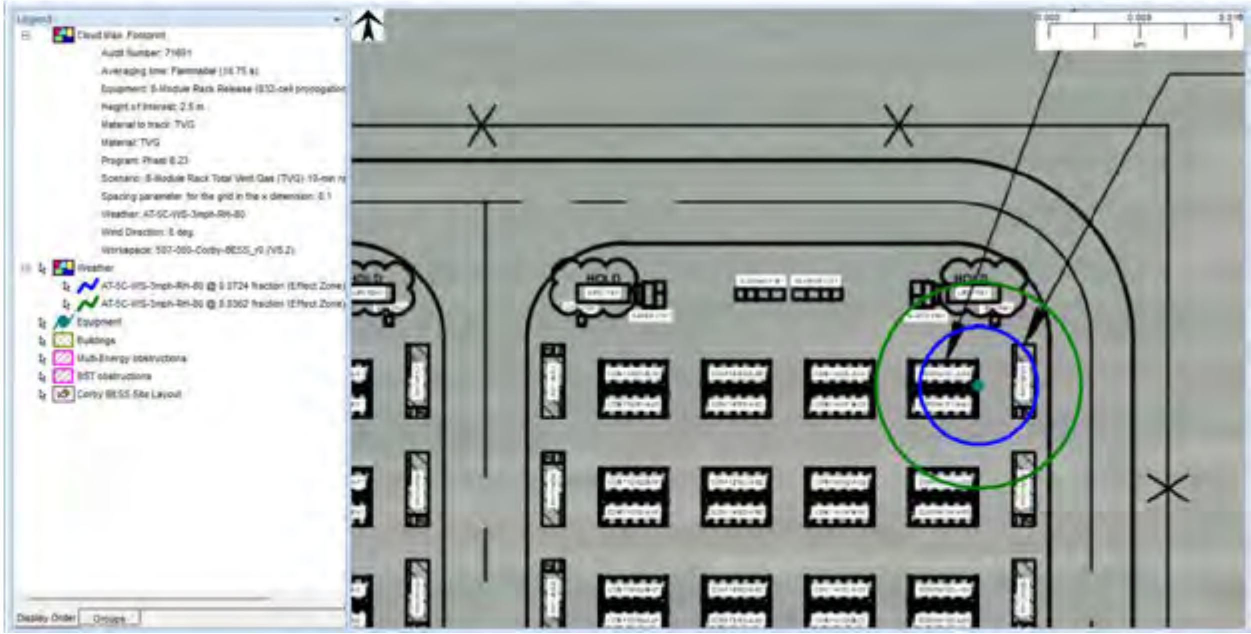


Figure 21. Map of horizontal extent of vapor cloud for LFL (7.24%) and ½ LFL (3.62%)

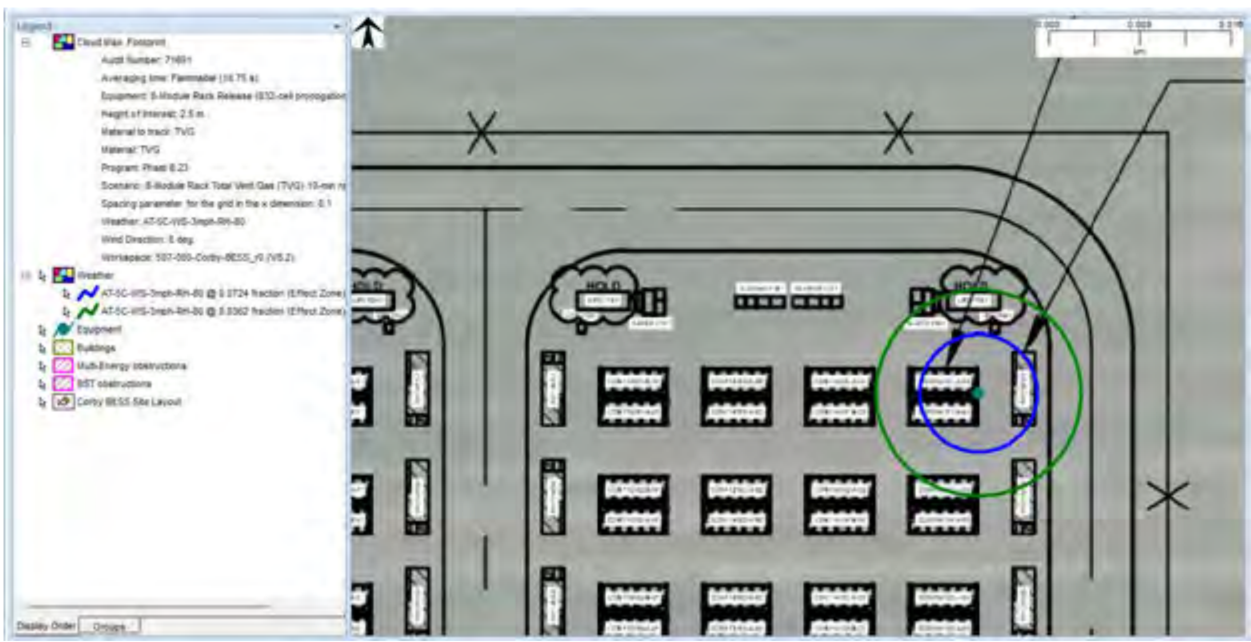


Figure 22. Map of horizontal extent of vapor cloud for CO IDLH (1200 ppm)

4.4 Scenario 4 (1-Container Release): PHAST Modeling Results

4.4.1 Sub-Scenario 4.1

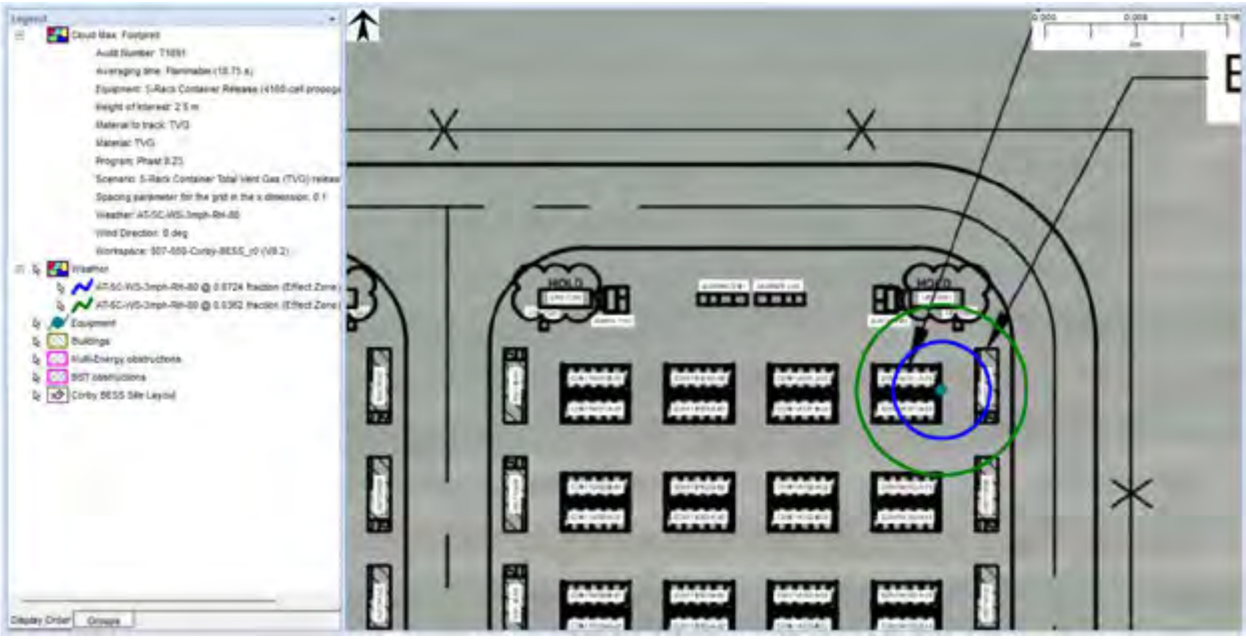


Figure 23. Map of horizontal extent of vapor cloud for LFL (7.24%) and ½ LFL (3.62%)

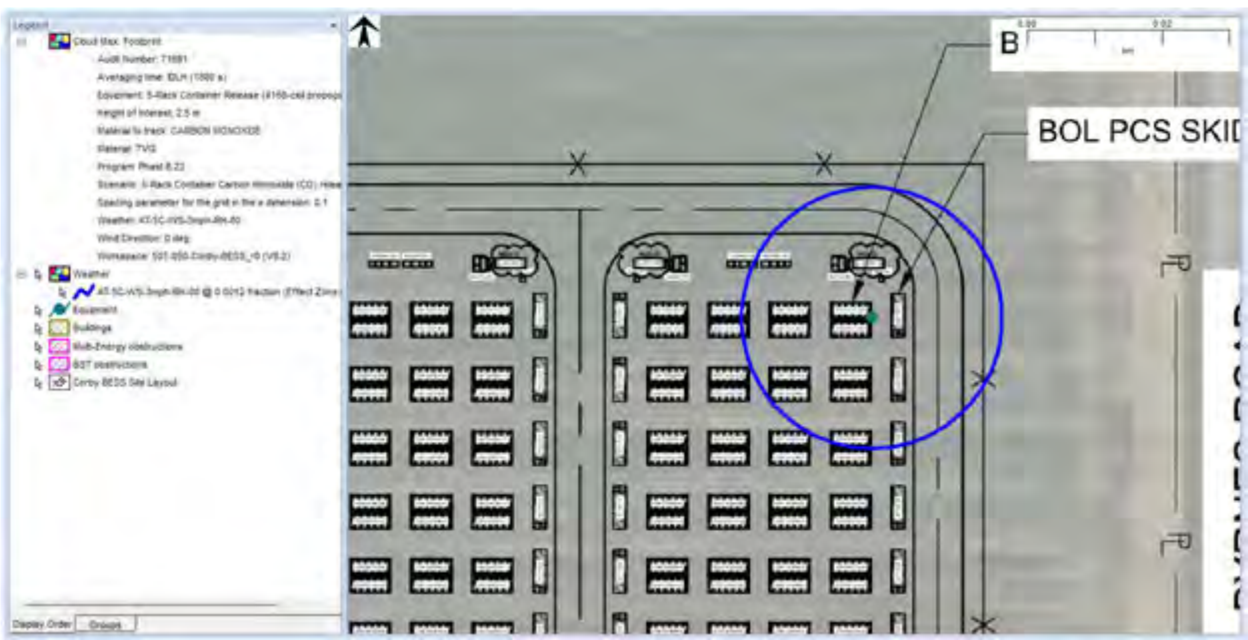


Figure 24. Map of horizontal extent of vapor cloud for CO IDLH (1200 ppm)

4.4.2 Sub-Scenario 4.2

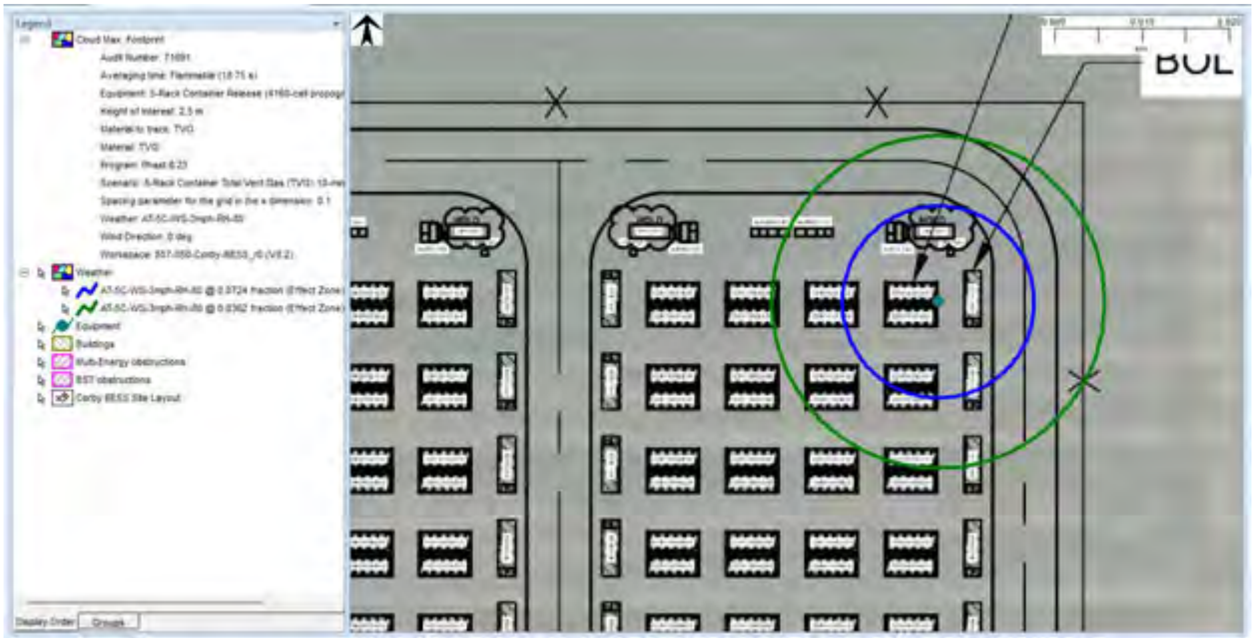


Figure 25. Map of horizontal extent of vapor cloud for LFL (7.24%) and ½ LFL (3.62%)

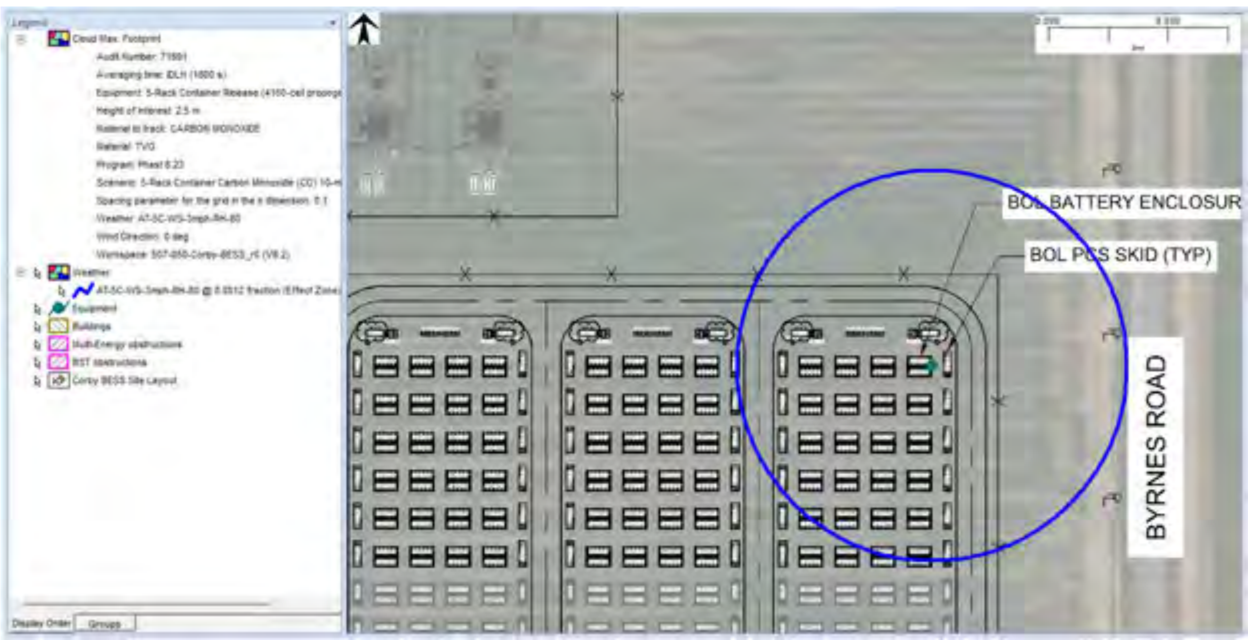


Figure 26. Map of horizontal extent of vapor cloud for CO IDLH (1200 ppm)

4.5 Scenarios 1-4: Flash-Fire Results

A flash fire occurs when the battery vent gas released is diffused in air such that all flammable fuel shall be consumed nearly instantaneously once ignited. In a flash fire the flame front accelerates rapidly from the ignition point to the limit of the flammable cloud, after which it immediately goes out. Thus, the duration of heat flux values equal to those sufficient to ignite flammable clothing or cause second-degree burns to exposed skin does not occur for more than 1-3 seconds (NFPA defines the upper limit of a flash fire to be 3 seconds) in any single location within the flash fire envelope.

4.5.1 Scenario 1 (Four-Cell Release): Sub-Scenarios 1.1, 1.2, & 1.3

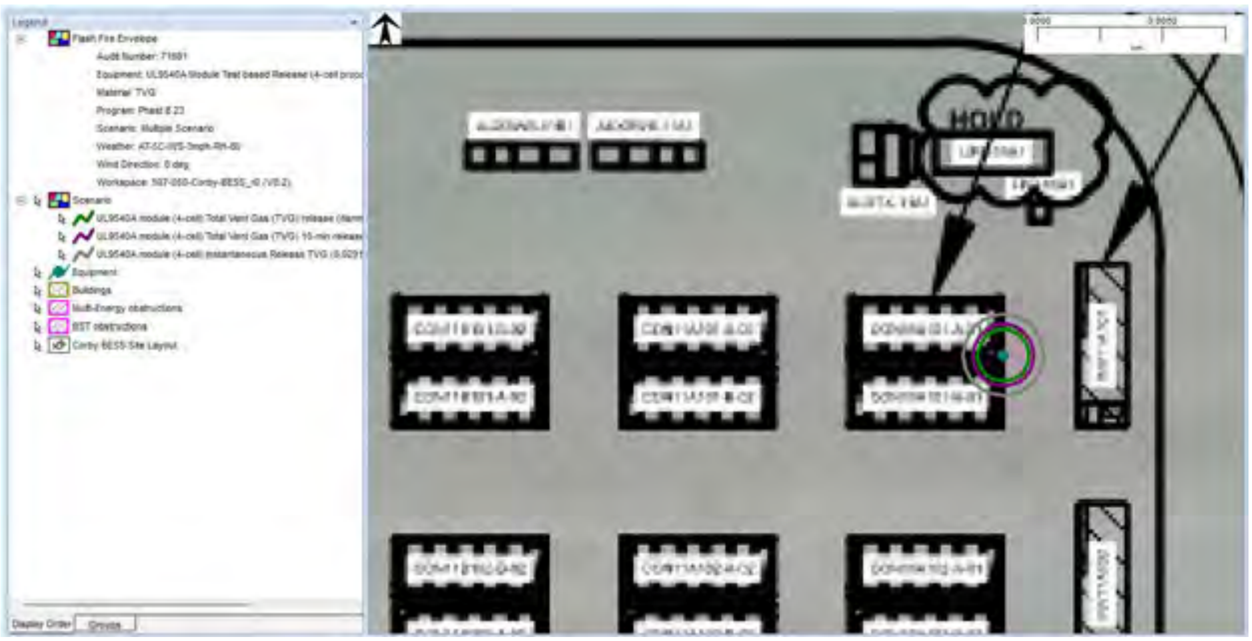


Figure 27. Maximum Extent of Flash Fire Envelope (Duration < 3 sec)

4.5.2 Scenario 2 (1-Module Release): Sub-Scenarios 2.1 & 2.2

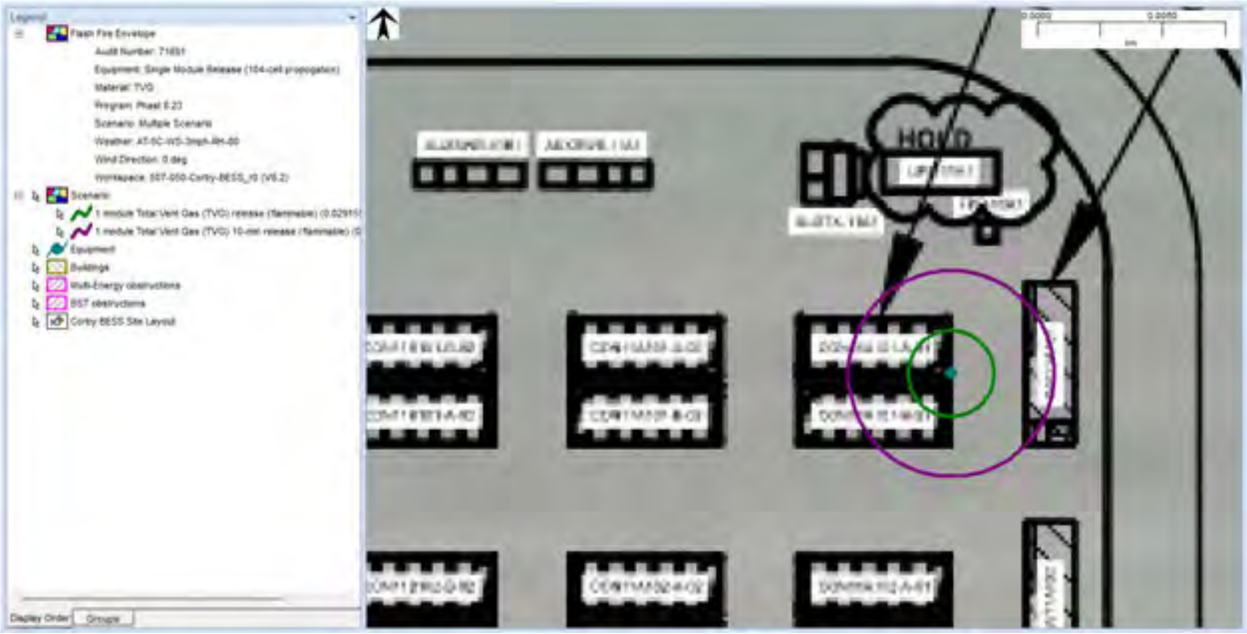


Figure 28. Maximum Extent of Flash Fire Envelope (Duration < 3 sec)

4.5.3 Scenario 3 (1-Rack Release): Sub-Scenarios 3.1 & 3.2

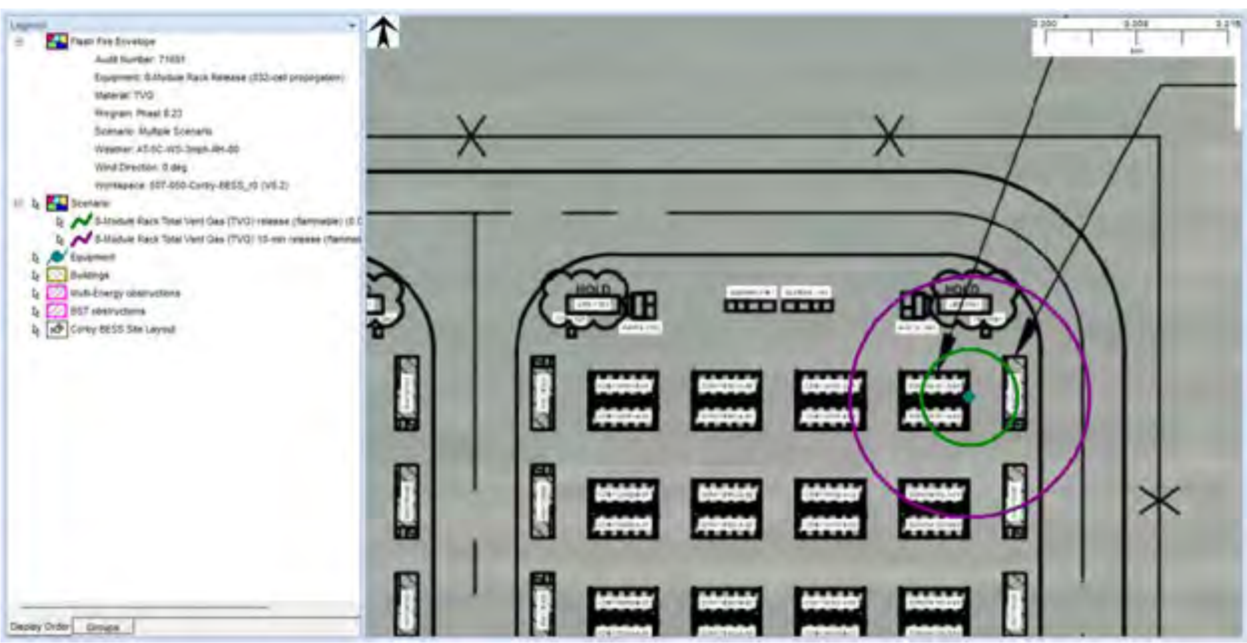


Figure 29. Maximum Extent of Flash Fire Envelope (Duration < 3 sec)

4.5.4 Scenario 4 (1-Container Release): Sub-Scenarios 4.1 & 4.2

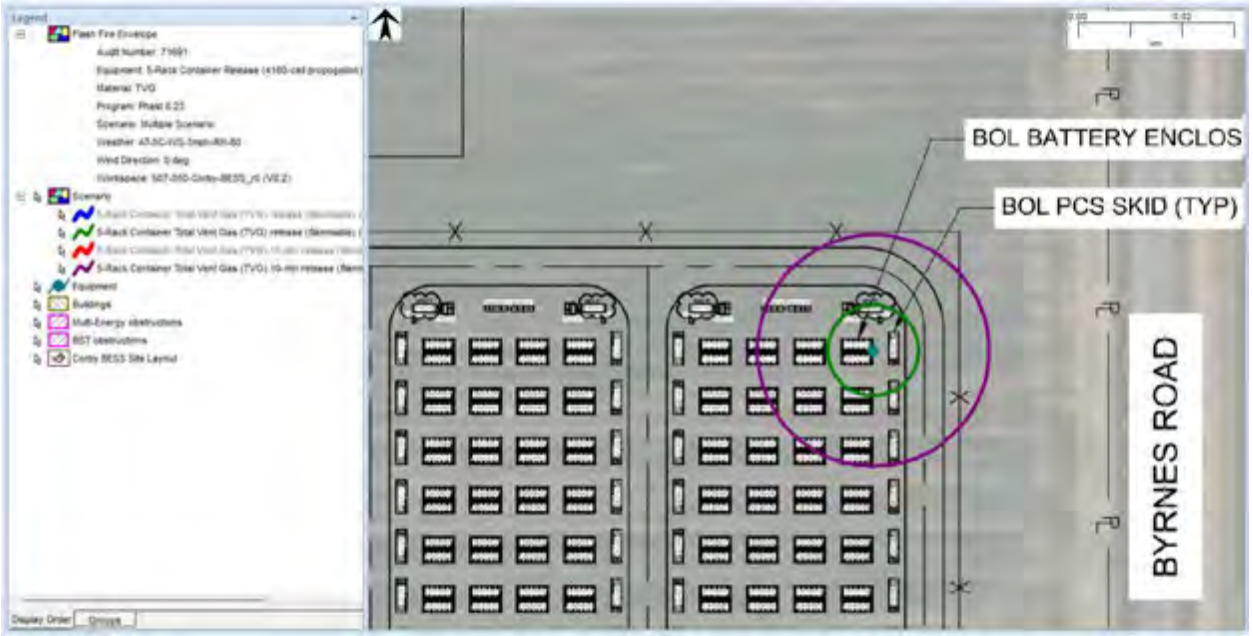


Figure 30. Maximum Extent of Flash Fire Envelope (Duration < 3 sec)

4.6 Explosion and Fireball Results

Only the theoretical upper-bounding venting TURC scenarios, Scenario 3.2 (1-rack, 10-minute duration venting release) and Scenario 4.2 (1-container, 10-minute duration venting release), resulted in the formation of explosion overpressures from ignition, highlighting that there is no risk from a vapor cloud explosion. It must be noted that these scenarios, i.e., those of a full volume release of all battery vent gas from all 4,160 cells in the container within 10-minutes, has no mechanism of occurrence documented in the BESS literature, in documented failure modes, contained in BESS failure modes and effect analysis (FMEAs), or anecdotally. These scenarios are included in this analysis only as a comparison for understanding the hypothetical peak potential impacts from a condensed release and are not representative of the consequences to be expected from a propagating non-flaming thermal runaway event nor utilized for evaluating facility siting.

As these scenarios are not representative of real-world venting cases, *the associated impacts are taken only for establishing the hypothetical peak consequence limits*.

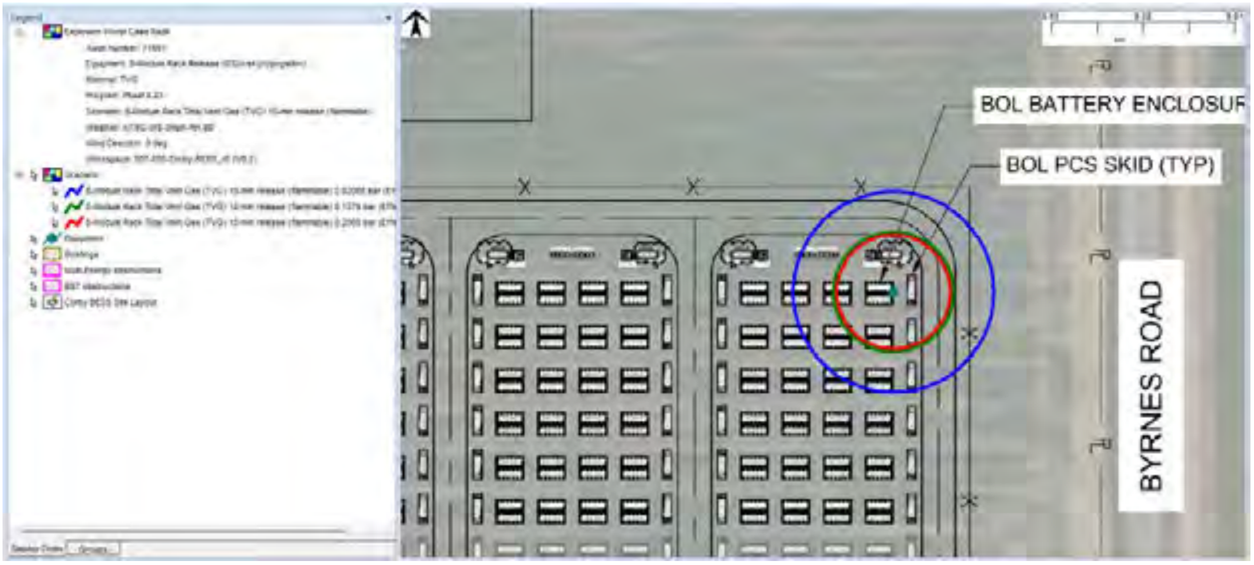


Figure 31. Scenario 3.2 Explosion Worst Case Radii (red = .2068 bar [3 psi]; green = .1379 bar [2 psi]; blue = .02068 bar [.3 psi])

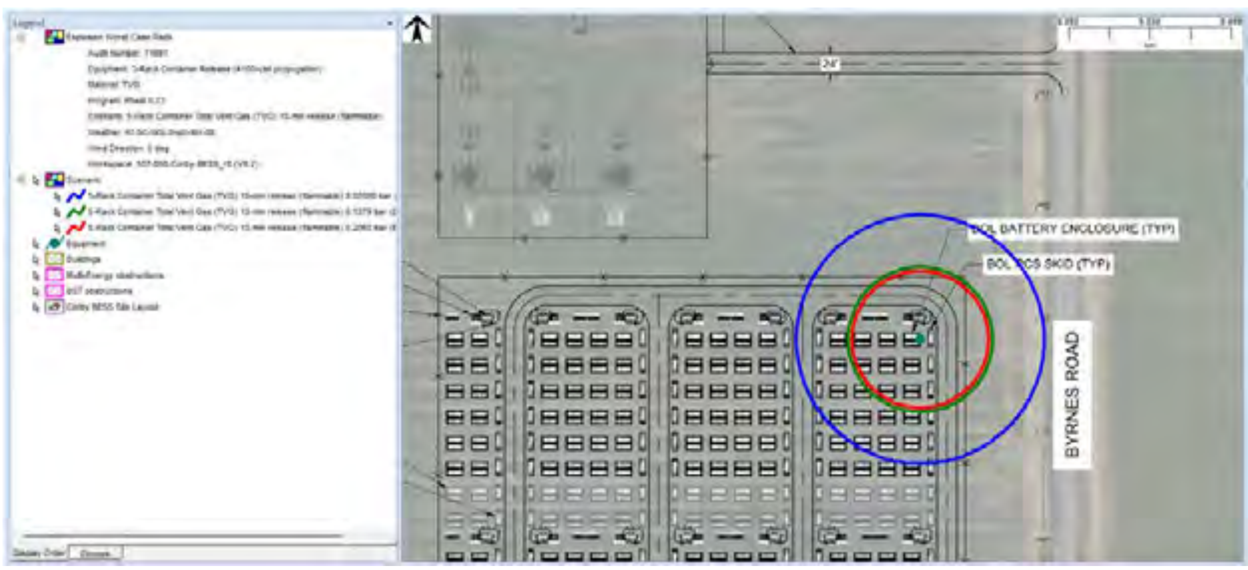


Figure 32. Scenario 4.2 Explosion Worst Case Radii (red = .2068 bar [3 psi]; green = .1379 bar [2 psi]; blue = .02068 bar [.3 psi])

No other modeled battery vent gas release scenario led to the consequence of an explosion. Only Scenario 1.3 (four-cell instantaneous release) resulted in a potential fireball occurring (requires late ignition). However, it must be noted that the duration of the fireball was less than 1-second as shown in Figure 33.

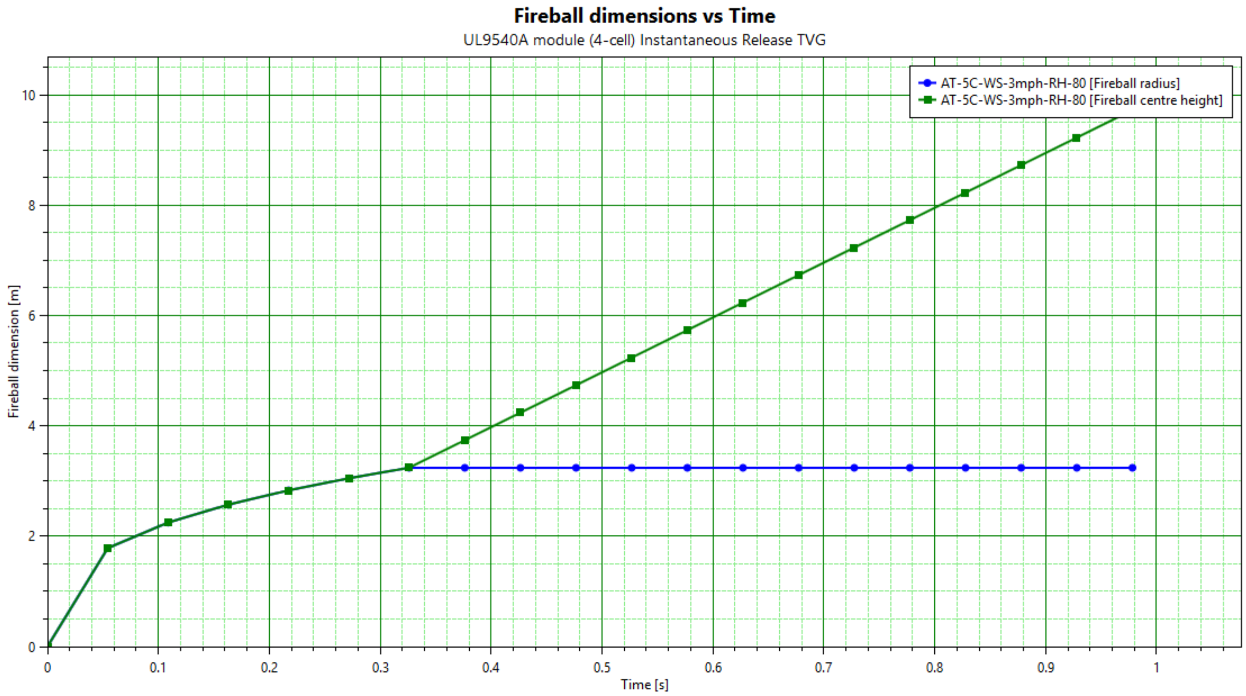


Figure 33. Fireball Duration and Extent for Scenario 1.3

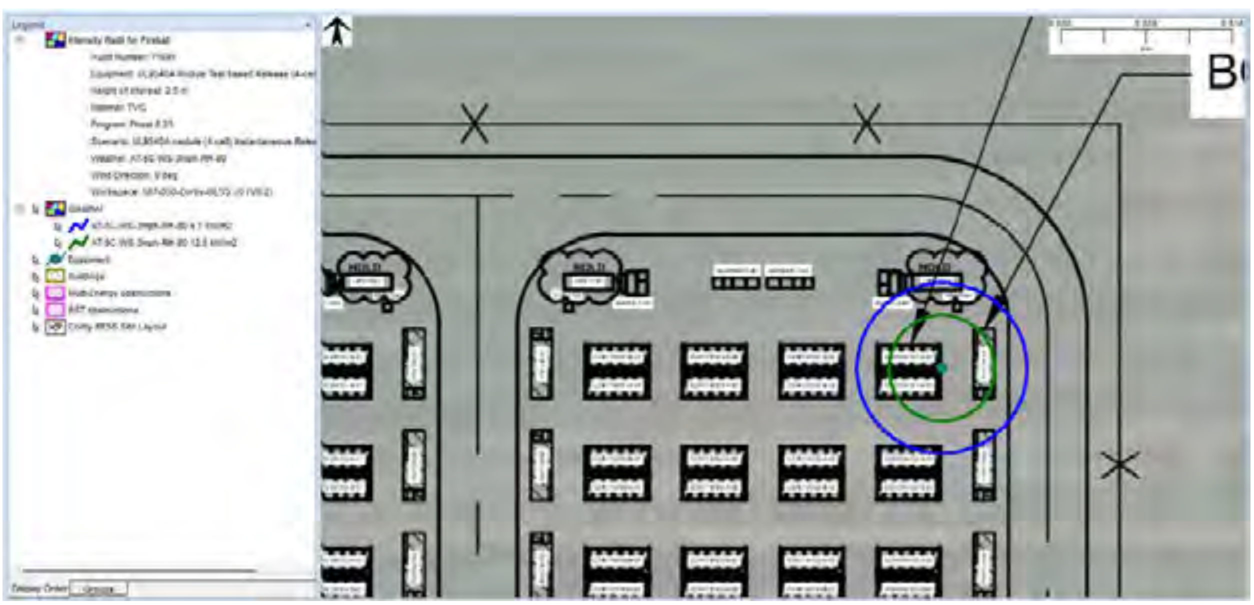


Figure 34. Fireball Heat Flux Extent (green = 12.5 kW/m^2; blue = 4.7 kW/m^2)

No other modeled battery vent gas release scenario led to the consequence of an explosion or fireball occurring based on the calculated release rates and release volumes, therefore there was no explosion or fireball risk identified from a release of battery gas to the atmosphere.

5.0 CONCLUSIONS

It must be noted that though Scenario 4 (5-rack 40-module full container release) was included in this analysis for understanding the worst-case bounding scenarios of a pre-combustion release from all cells within all modules of all racks per container, it is not a feasible release scenario as the UL 9540A reports show no direct thermal runaway propagation between modules. Additionally, there are no single failures identified in the FMEA, documented in the available BESS failure literature, or reported in anecdotal incident case reports that show or support a mechanism of failure that would cause thermal runaway to occur in 104-cells within a single module simultaneously, let alone within all 4,160-cells for the 40-module CATL EnerC+ container. As such, there is no existing test data or established failure mechanism in the UL 9540A reports that document all 104 cells within a module or 4,160-cells within a container initiating thermal runaway from a single failure. Rather, thermal runaway propagation from cell-to-cell and module-to-module would remain a direct component of battery vent gas release timing, release conditions, and associated consequences for all potential single failures initiating thermal runaway and battery gas venting in the CATL EnerC+ BESS.

Additionally, all TURC releases (10-minute duration release scenarios) are included in the analysis only as a comparison tool to frame the UL 9540A test data-based analysis results against the theoretical upper-bounding venting condition, achieved by assuming thermal runaway and venting are initiated simultaneously for the all cells within an entire BESS over a 10-minute duration for all module/rack/container level scenarios. These upper-bounding theoretical worst-case release sub-scenarios were only included to provide an understanding of the hypothetical peak impact associated with a condensed release and are not representative of the consequences to be expected from any propagating non-flaming thermal runaway event.

5.1 Total Vent Gas LFL Extent

In conclusion, modeling results for all UL9540A based scenarios and sub-scenarios showed no significant impacts from flammable battery vent gas dispersion, with all releases staying within the site property boundaries (45.11 m [148 ft] offset from nearest BESS).

The maximum extent of impact, from the ½ LFL flammable vapor cloud (3.62%) was 24.41 ft (7.4 m) from the BESS, for a upper-bounding release from all 40-modules of the container (Scenario 4.2) where all of the battery vent gas is released to atmosphere within 10-minutes and 62.3 ft (19 m) for the UL 9540A based propagation duration release, as shown in the figures below in comparison to the other release scenarios.

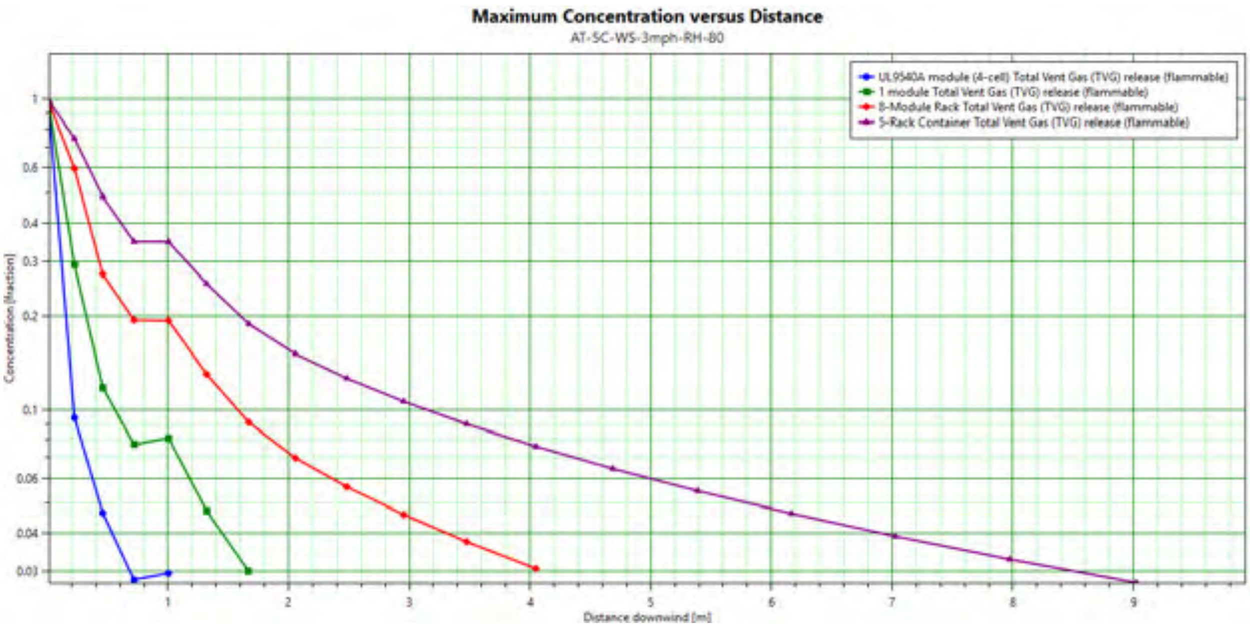


Figure 35. Concentration vs Distance for Sub-Scenarios 1.1, 2.1, 3.1, 4.1 (UL9450A cell-to-cell release duration)

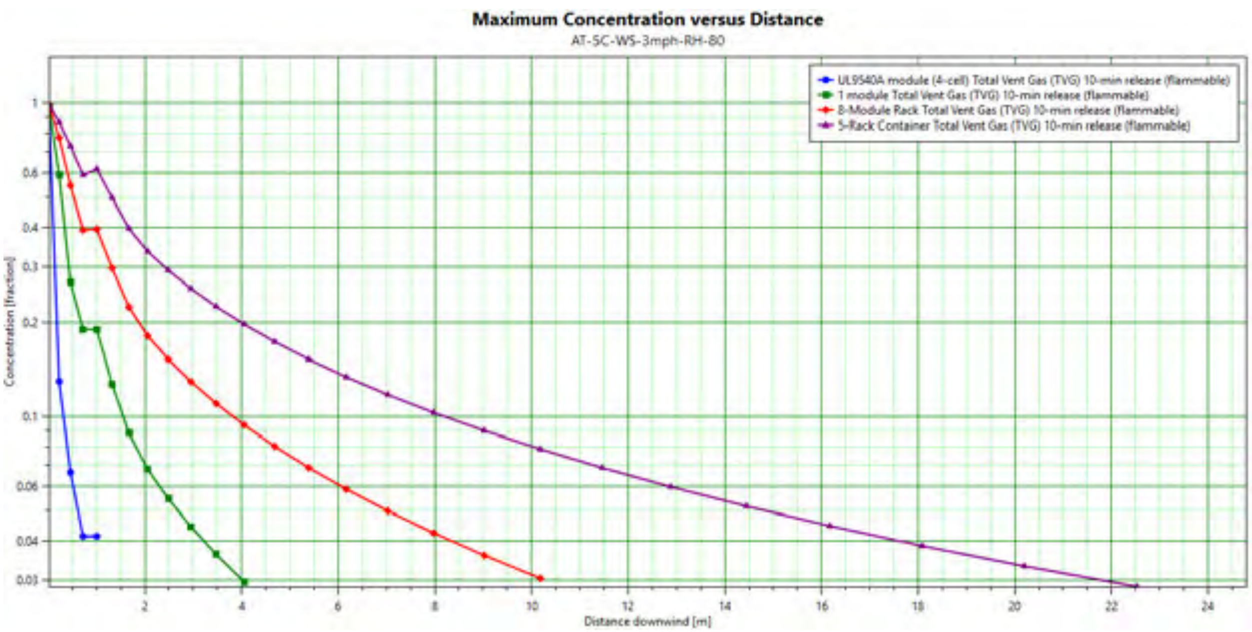


Figure 36. Concentration vs Distance for Sub-Scenarios 1.2, 2.2, 3.2, 4.2 (10-minute release duration)

5.2 Flash Fires

Flash fires were a modeled consequence for all venting scenarios. The flash fire envelope did not extend beyond the proposed property boundaries (148 ft [45.11 m] offset from nearest BESS) for any of the UL 9540A based scenarios. Even within any affected area onsite, the duration of heat flux values equivalent to those sufficient to ignite flammable clothing or cause second-degree burns to exposed skin does not occur for more than 1-3 seconds (NFPA defines the upper limit of a flash fire to be 3 seconds) in any single location within the flash fire envelope.

As such, there would be no significant risk to persons or property offsite from the described venting scenarios.

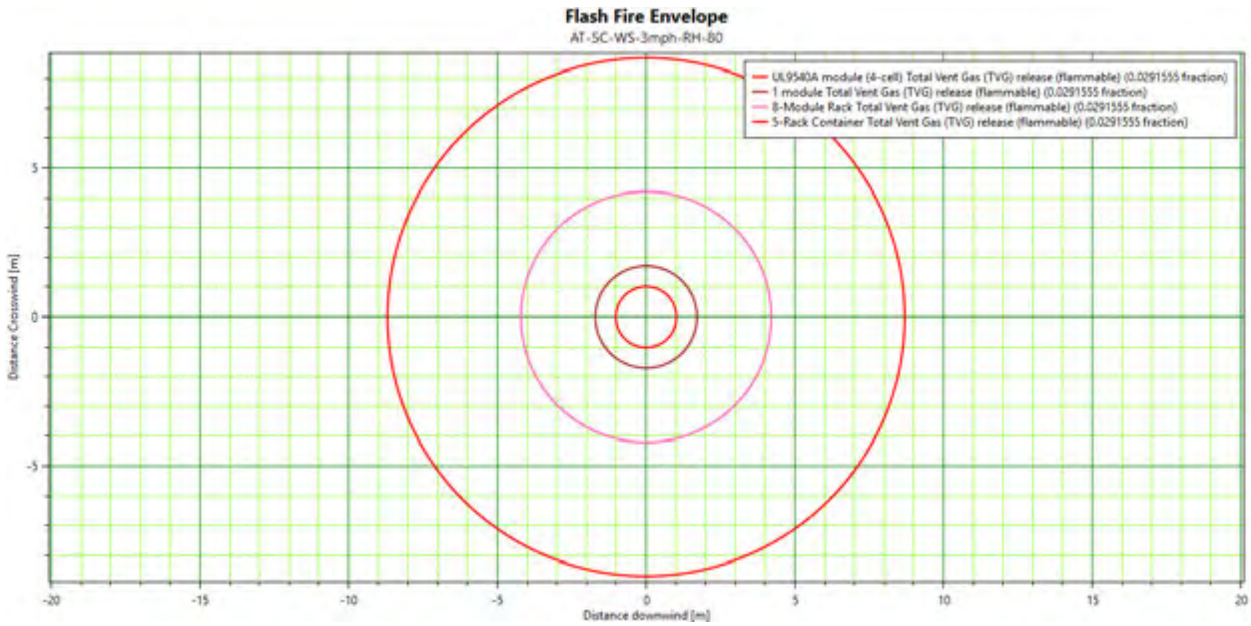


Figure 37. Flash Fire Envelope for Sub-Scenarios 1.1, 2.1, 3.1, 4.1 (UL9450A cell-to-cell propagation release duration)

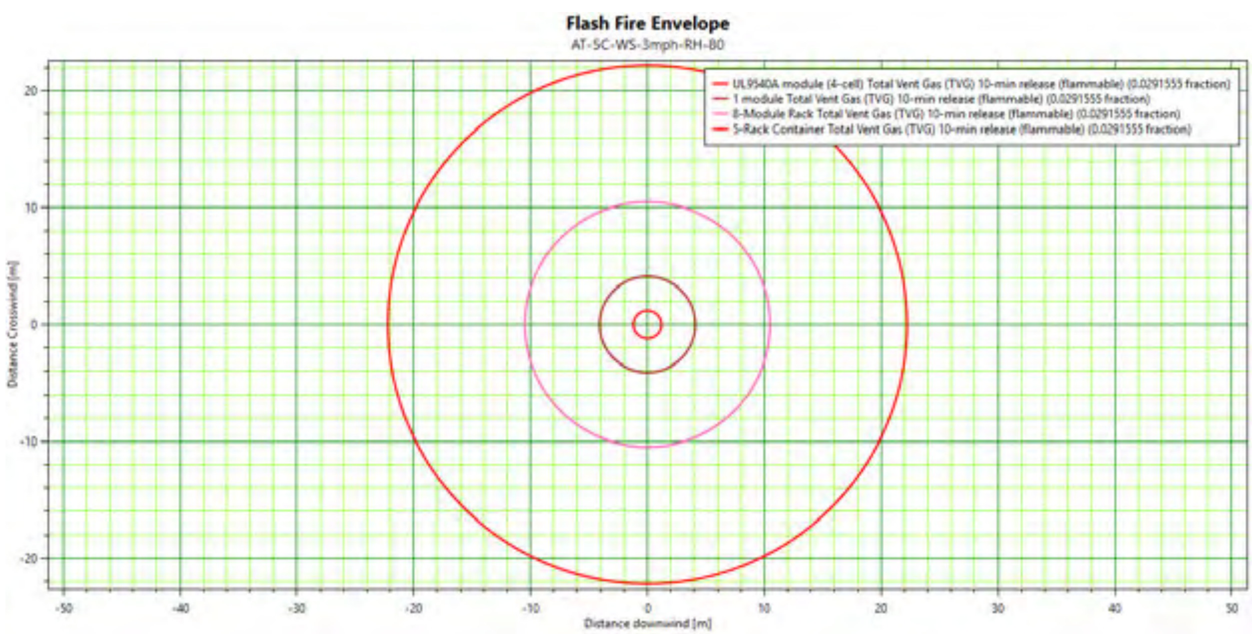


Figure 38. Flash Fire Envelope for Sub-Scenarios 1.2, 2.2, 3.2, 4.2 (10-minute release duration)

5.3 Carbon Monoxide IDLH Extent

Modeling results for the carbon monoxide (CO) component of battery vent gas for IDLH (1200 ppm) concentrations showed that the maximum extent of 160.10 ft (48.80 m) for the CO IDLH contour was from the TURC Scenario 4.2 (40-module full container release for 10-minute duration). However, risk from CO exposure is a factor of both concentration and exposure time, with a minimum required exposure time of 30-minutes at the IDLH concentration of 1200 ppm, therefore even this TURC scenario posed no health risk offsite. The largest CO IDLH extent with a duration greater 30-minutes was 63.32 ft (19.30 m) for Scenario 4.1, below the nearest distance to the property boundary.

Therefore, there would be no significant risk offsite from CO exposure from any modeled scenario.

See the below quote from the CDC CO IDLH publication as reference.

> *"It has been stated that a 1-hour exposure to 1,000 to 1,200 ppm would cause unpleasant but no dangerous symptoms, but that 1,500 to 2,000 ppm might be a dangerous concentration after 1 hour [Henderson et al. 1921a, 1921b].* ***In general, a carboxyhemoglobin (COHb) level of 10-20% will only cause slight headaches [NIOSH 1972]*** *and a COHb of 11-13% will have no effect on hand and foot reaction time, hand steadiness, or coordination [Stewart and Peterson 1970]. At a COHb of 35%, manual dexterity is impaired [Stewart 1975]. At 40% COHb, mental confusion, added to increasing incoordination, precludes driving an automobile [Stewart 1975].* ***A 30-minute exposure to 1,200 ppm will produce aCOHb of 10-13% [NIOSH 1972]****.*

5.4 Recommended Minimum Approach Distance (Based on Toxic Exposure)

The MAD for emergency response personnel based solely on potential toxic exposure shall be governed by the component with the largest IDLH footprint.

For non-flaming pre-combustion releases where all battery vent gas is released via venting during thermal runaway conditions alone, the component with the largest IDLH footprint and required potential exposure duration (30-minutes) is CO. The extent of the CO IDLH cloud was 63.32 ft (19.30 m) for the full container 75.6-minute duration release. As such, it is recommended that by incorporating a 1.5x safety factor, the MAD for non-flaming release conditions be a minimum of 95 ft (28.95 m).

6.0 APPENDIX A: SUPPORTING GRAPHICAL OUTPUT

APPENDIX A: GRAPHICAL RESULTS (PHAST ANALYSIS)

1.0 SCENARIO 1: 4-CELL UL9540A THERMAL RUNAWAY (FROM UL 9540A TEST DATA)

1.1.1 TVG Flammable Vapor Cloud Extent (20.4 min Release)

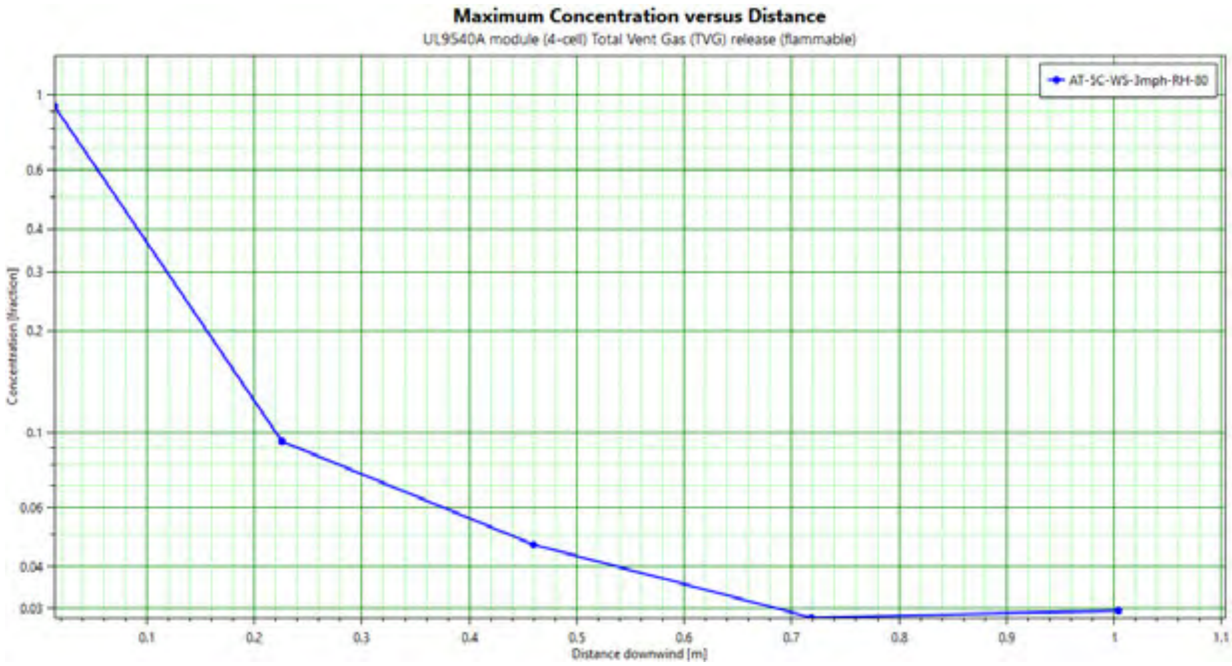


Figure 1 Maximum concentration vs distance for flammable vapor cloud

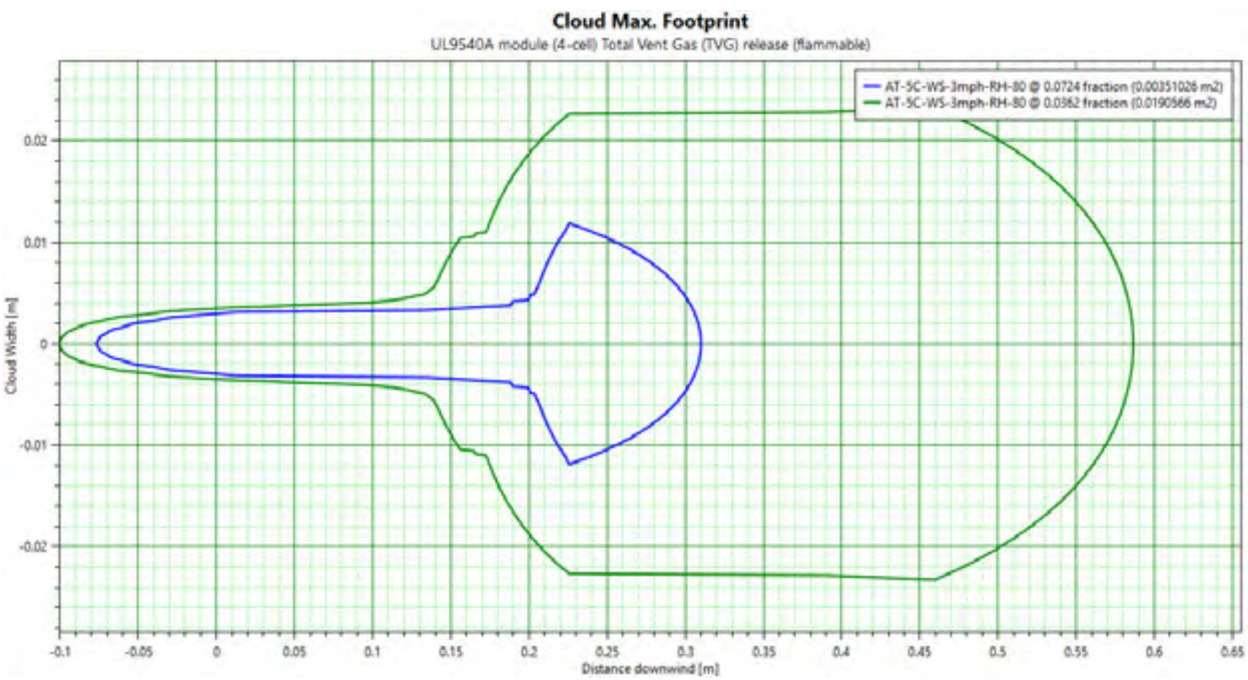


Figure 2 Maximum horizontal extent of vapor cloud for LFL (7.24%) and ½ LFL (3.62%)

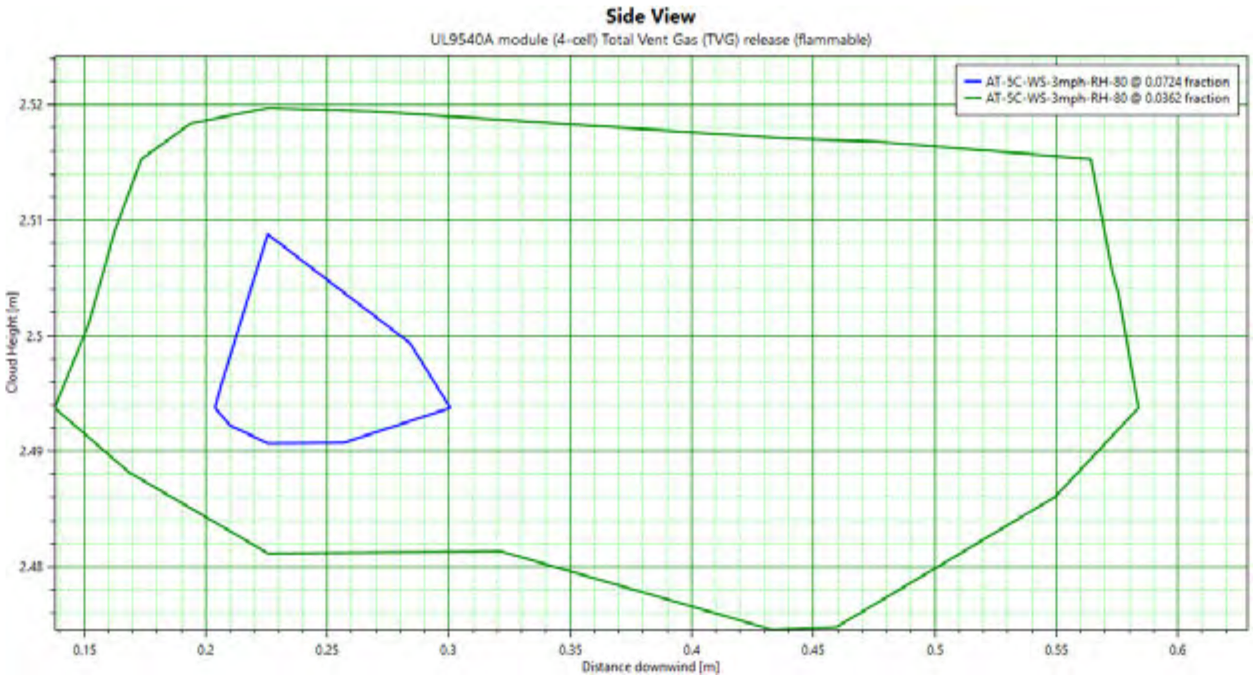


Figure 3 Maximum vertical extent of vapor cloud for LFL (7.24%) and ½ LFL (3.62%)

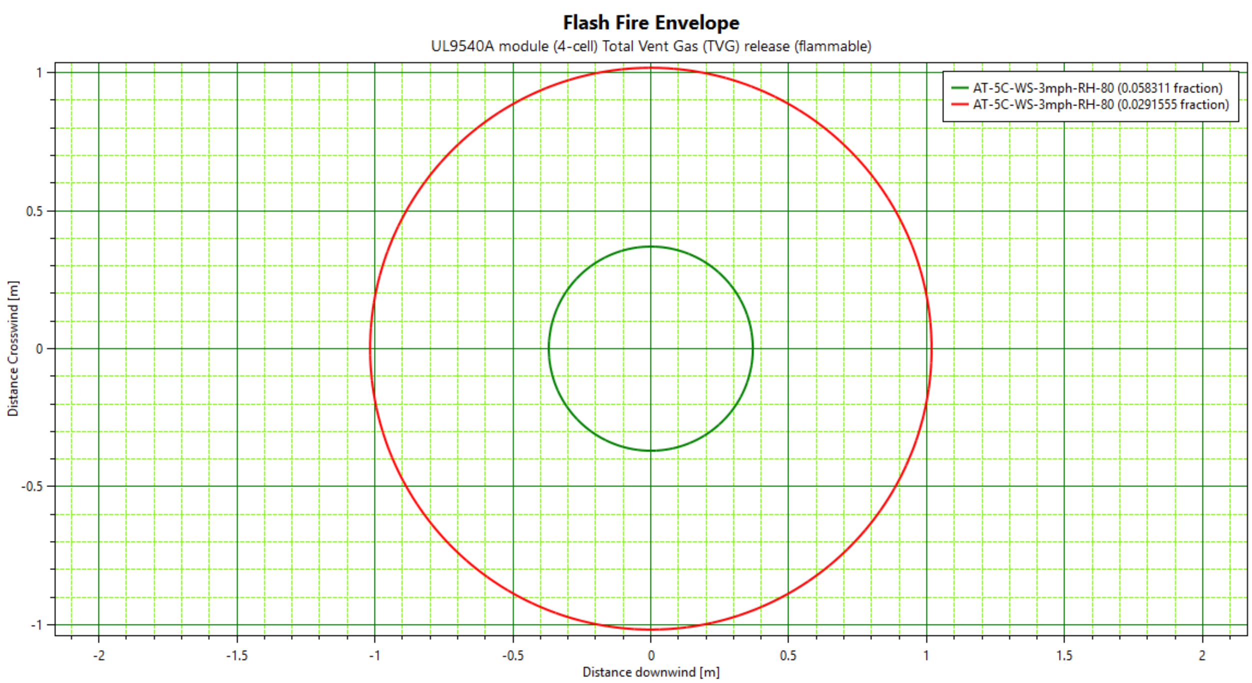


Figure 4 Flash Fire Envelope for LFL (7.24%) and ½ LFL (3.62%)

1.1.2 CO IDLH (1200 ppm) Component Extent (20.4 min Release)

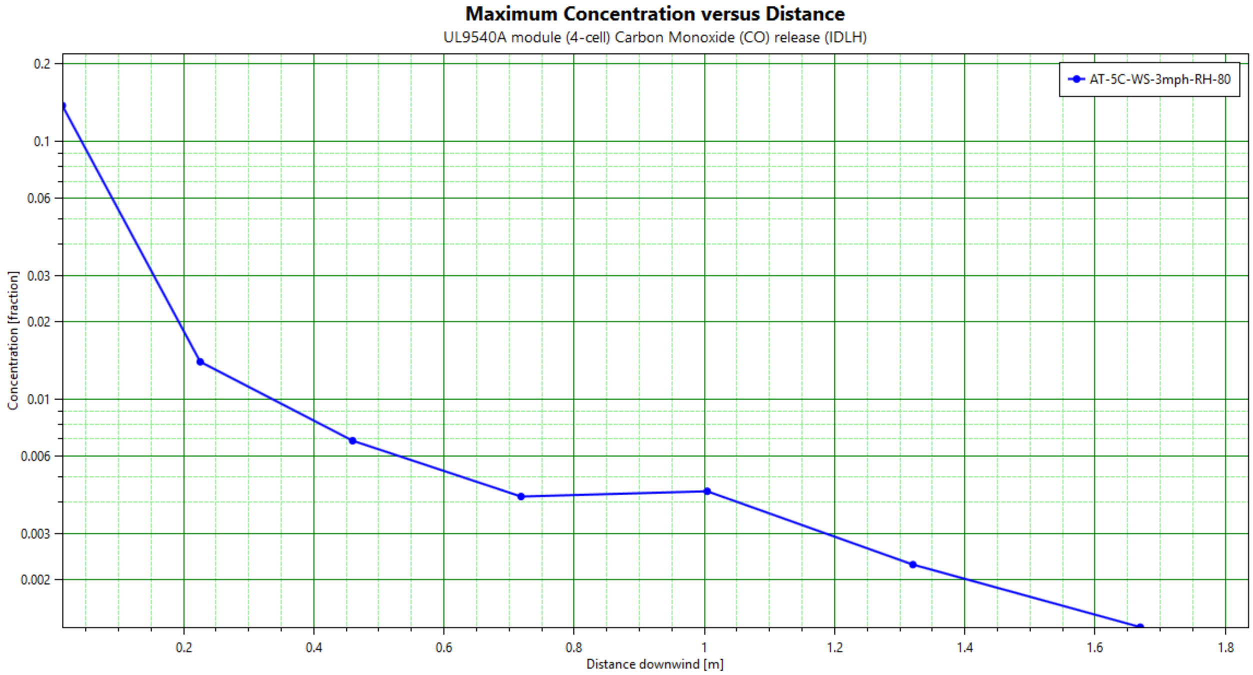


Figure 5 Maximum Concentration vs distance for CO gas component

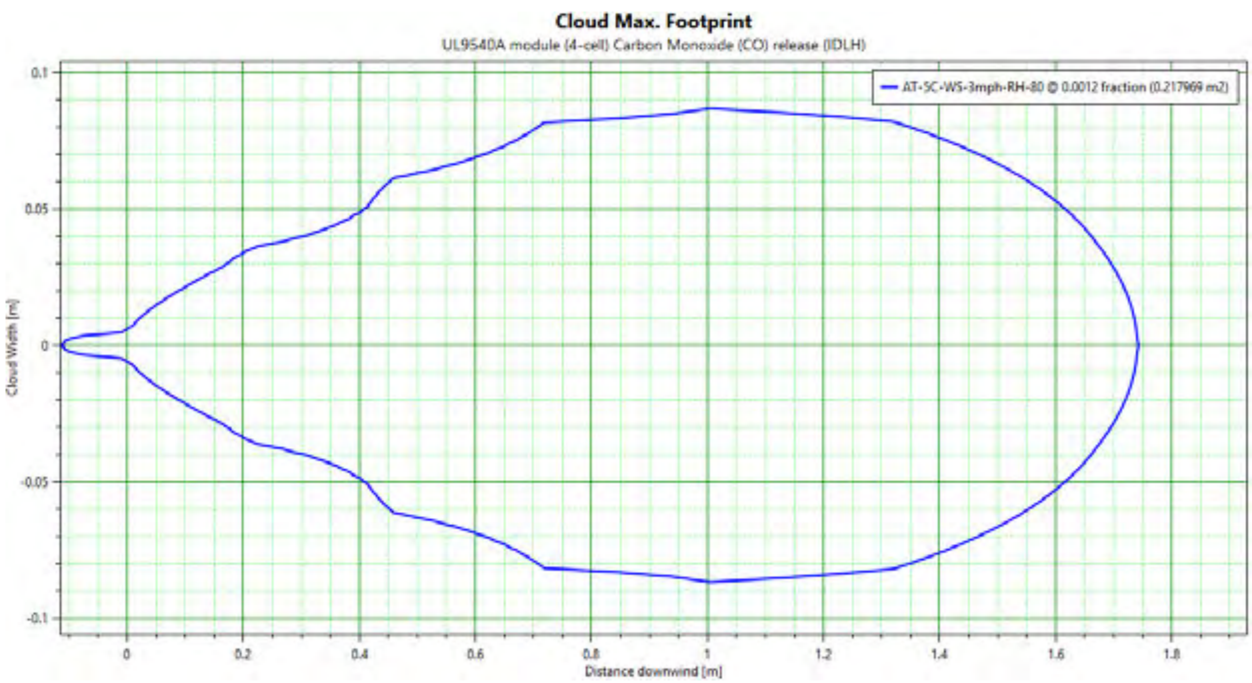


Figure 6 Maximum horizontal extent of vapor cloud for CO IDLH (1200 ppm)

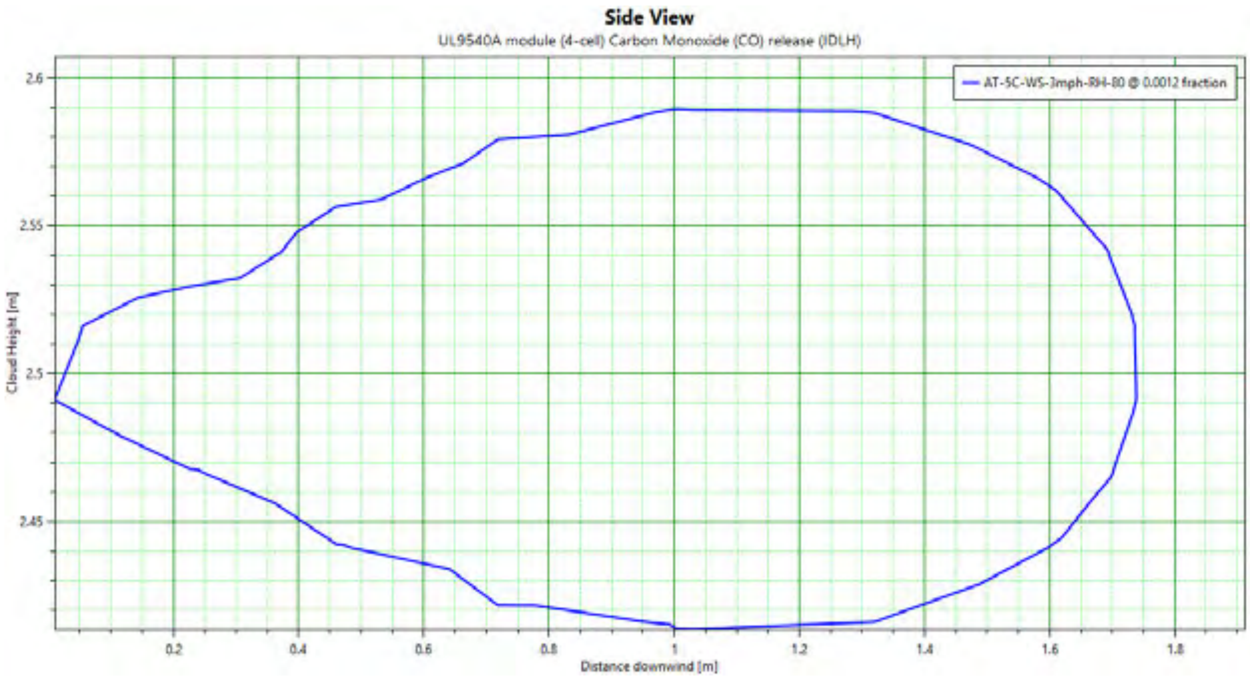


Figure 7 Maximum vertical extent of vapor cloud for CO IDLH (1200 ppm)

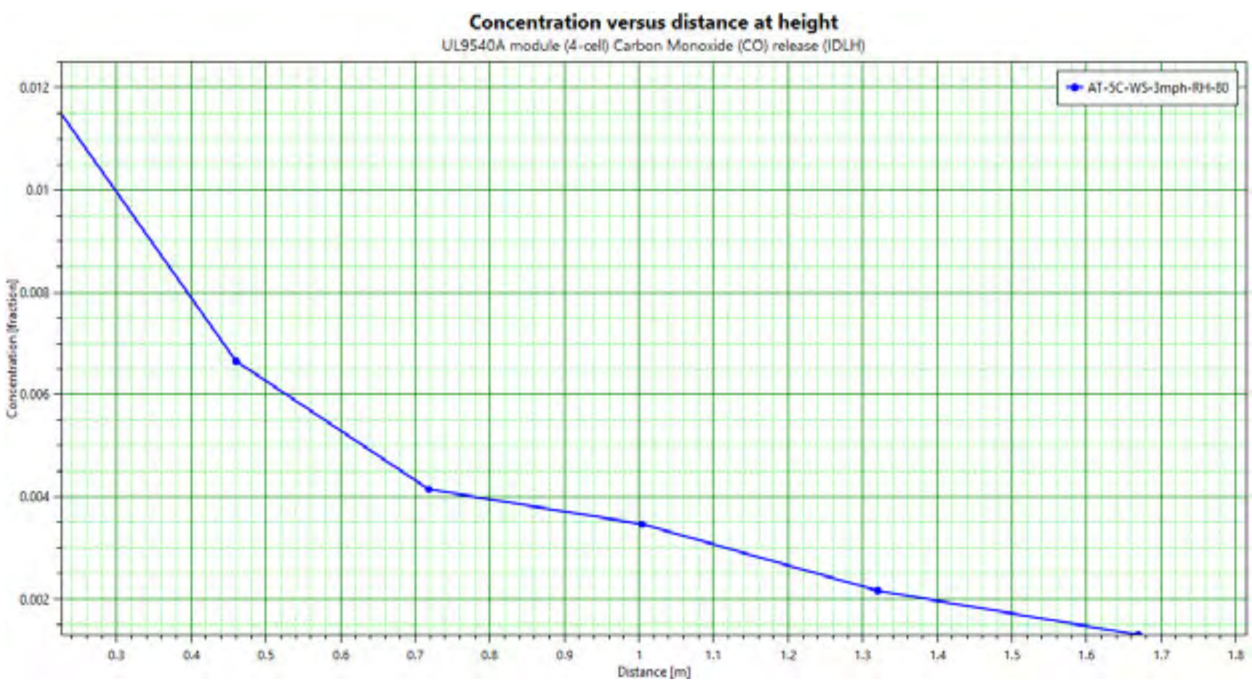


Figure 8 Concentration vs distance for CO IDLH (1200 ppm)

1.1.3 TVG Flammable Vapor Cloud Extent (10 min Release)

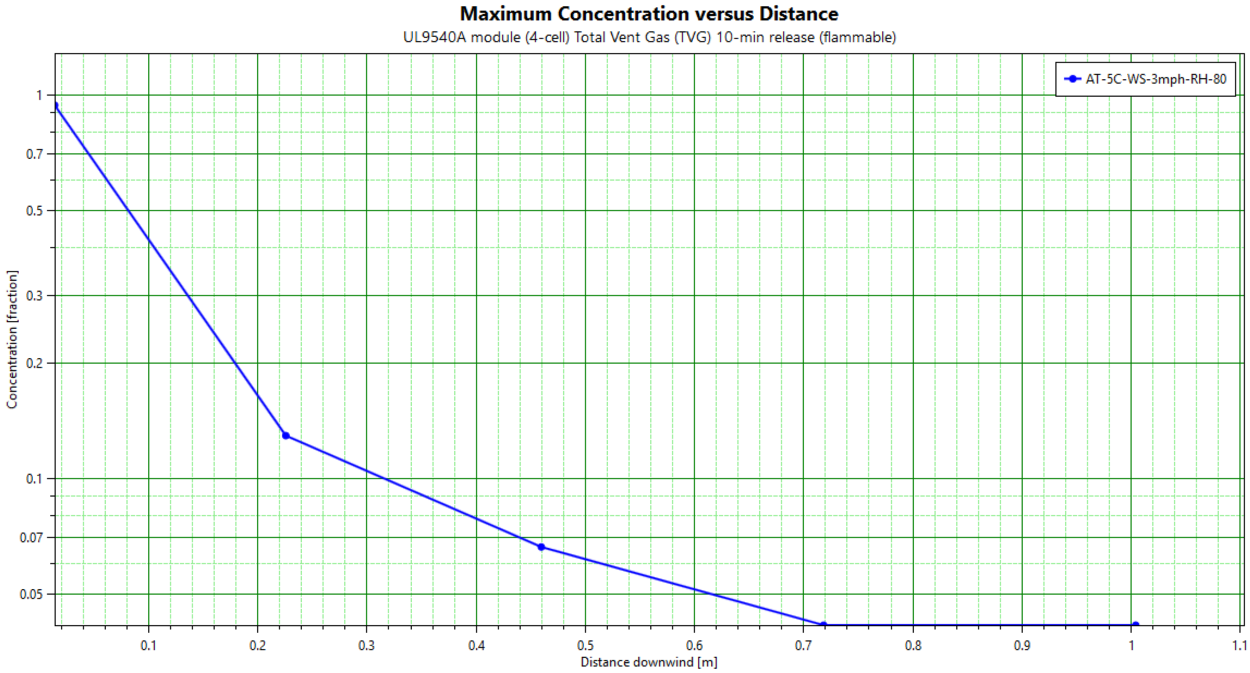


Figure 9 Maximum concentration vs distance for flammable vapor cloud

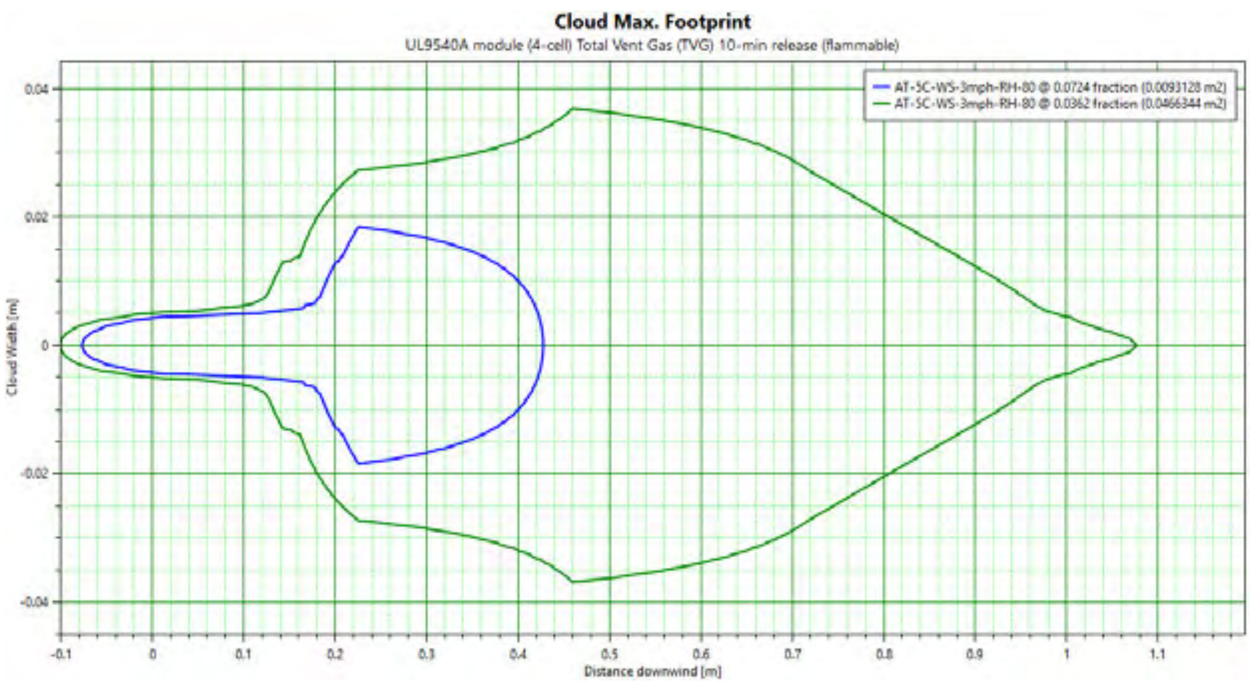


Figure 10 Maximum horizontal extent of vapor cloud for LFL (7.24%) and ½ LFL (3.62%)

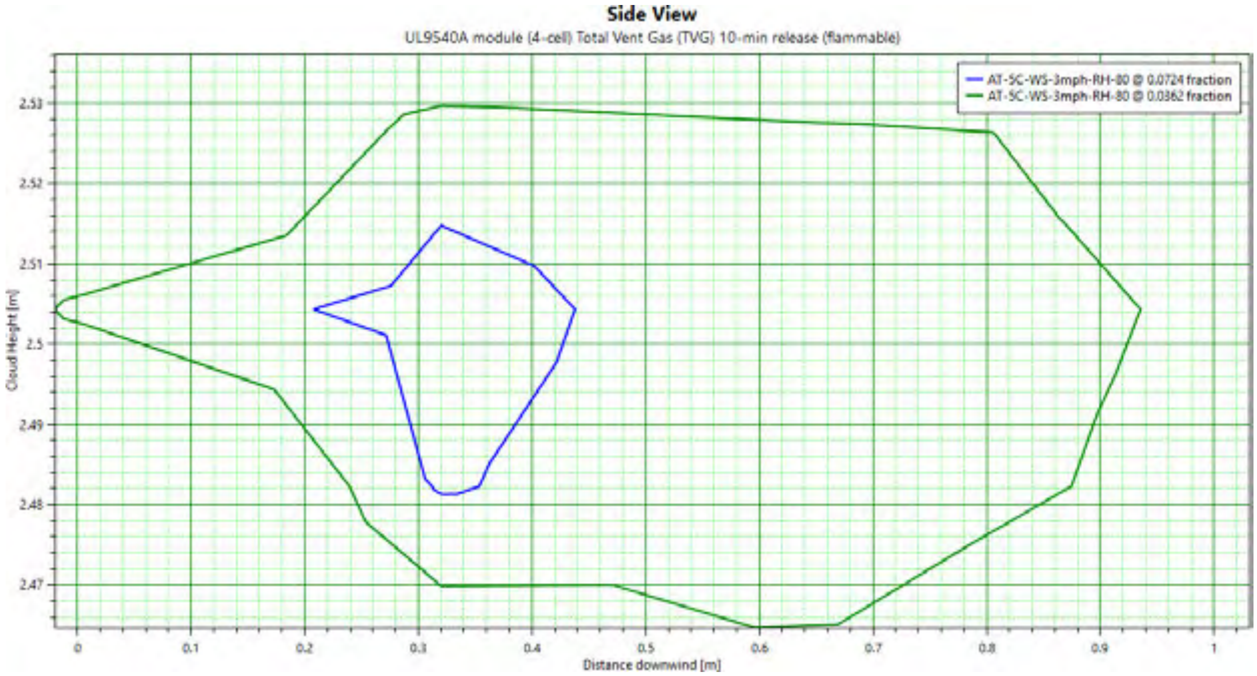


Figure 11 Maximum vertical extent of vapor cloud for LFL (7.24%) and ½ LFL (3.62%)

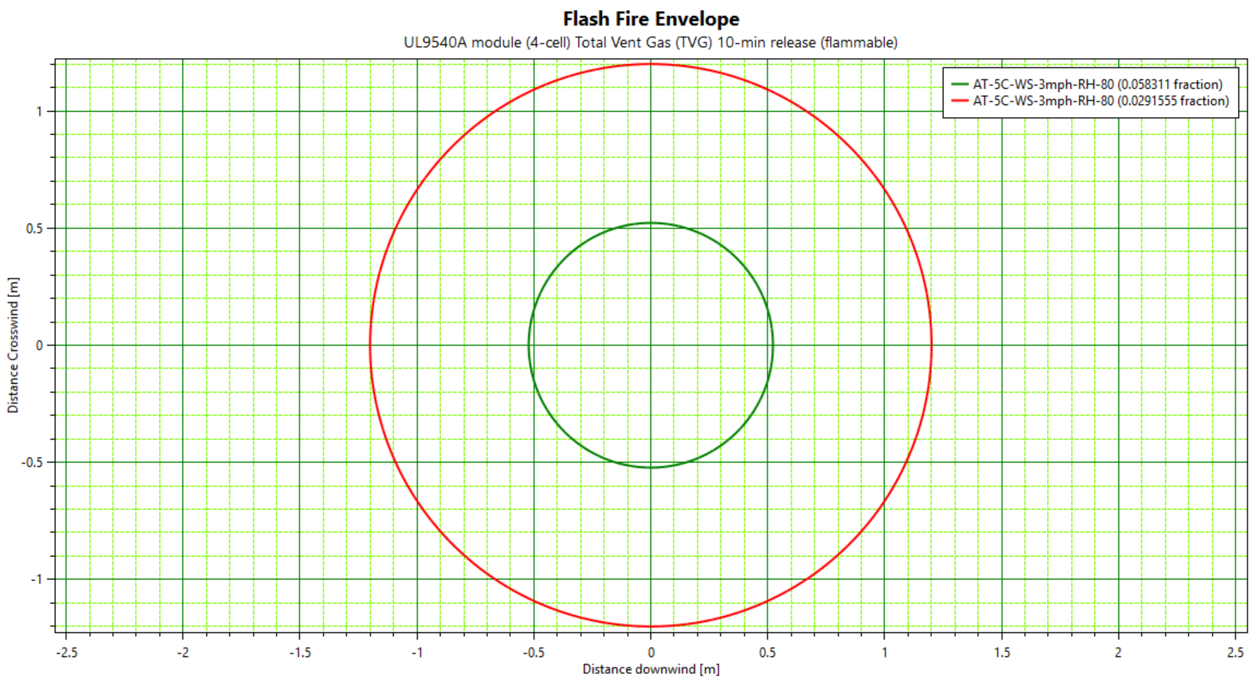


Figure 12 Flash Fire Envelope for LFL (7.24%) and ½ LFL (3.62%)

1.1.4 CO IDLH (1200 ppm) Component Extent (10 min Release)

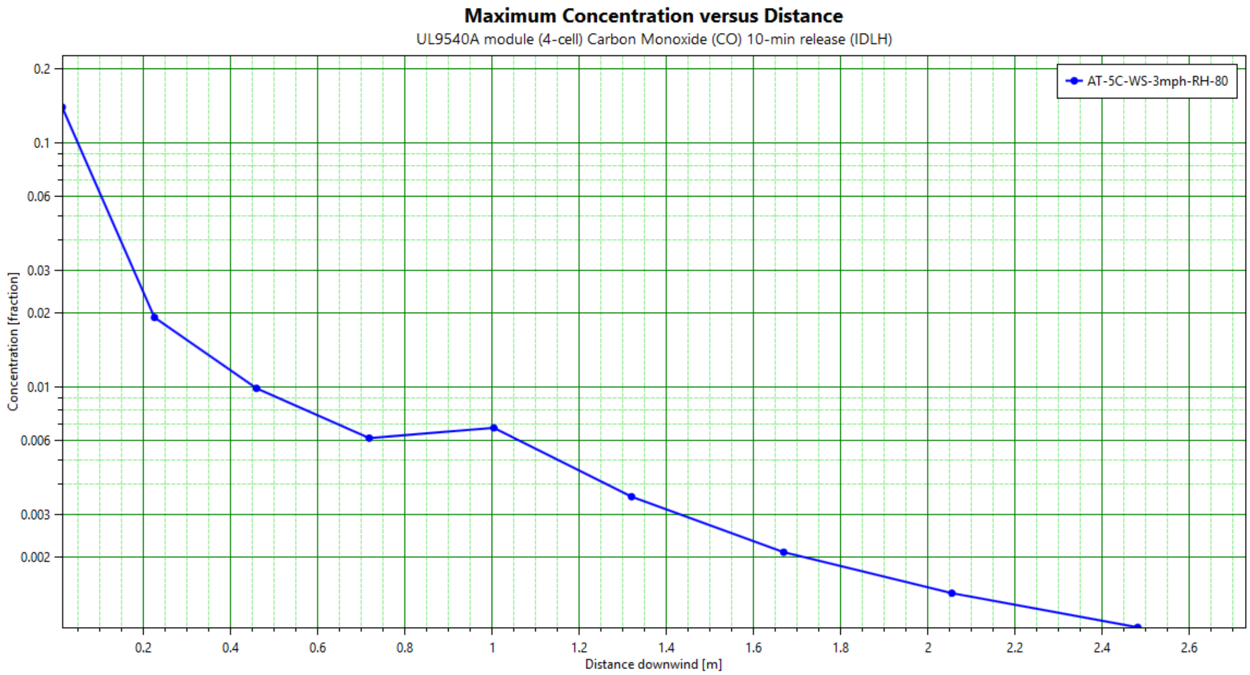


Figure 13 Maximum Concentration vs distance for CO gas component

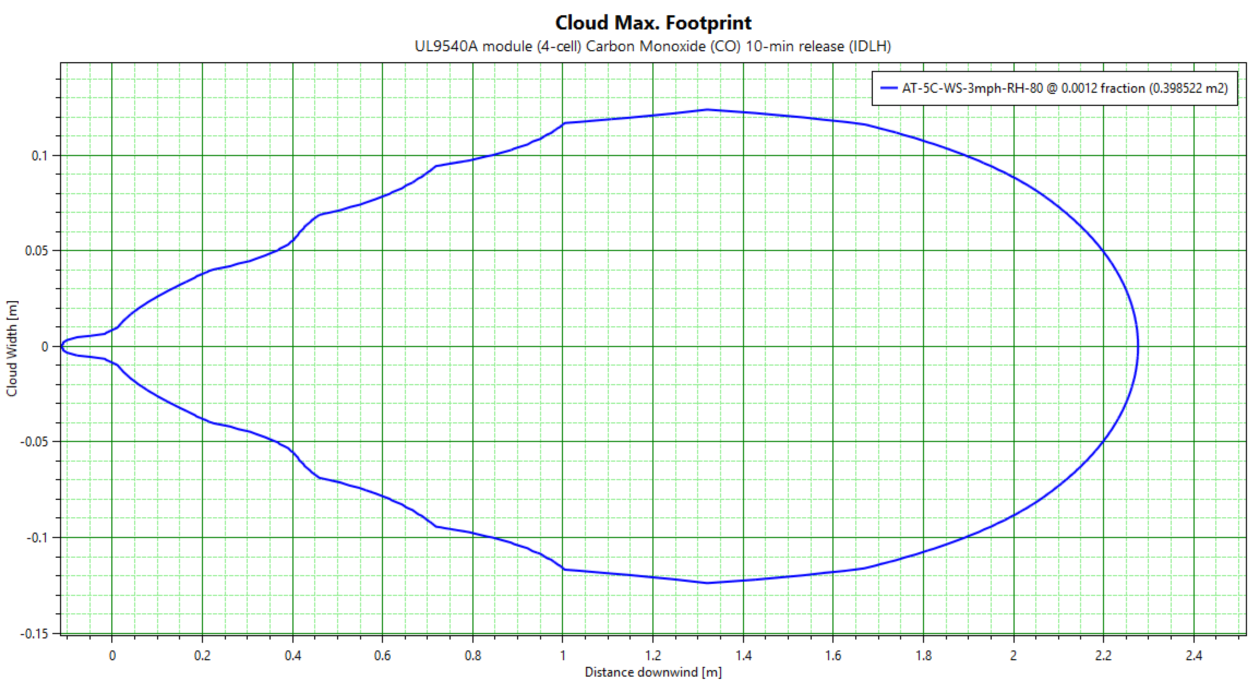


Figure 14 Maximum horizontal extent of vapor cloud for CO IDLH (1200 ppm)

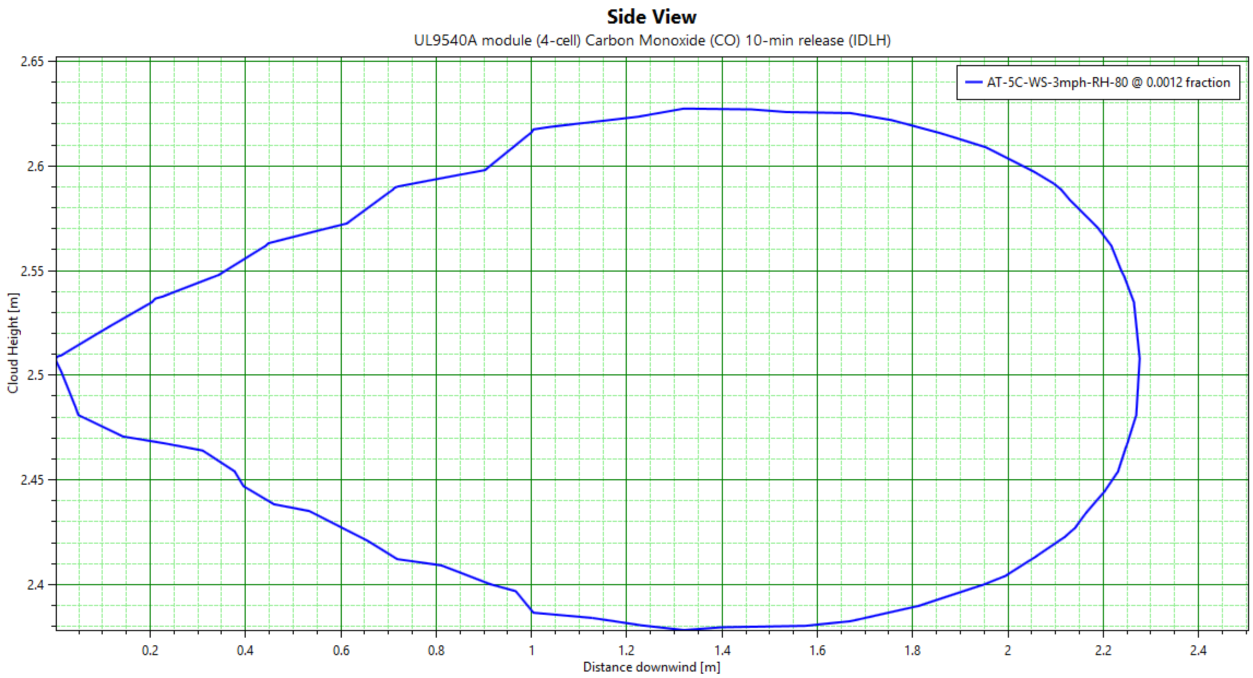


Figure 15 Maximum vertical extent of vapor cloud for CO IDLH (1200 ppm)

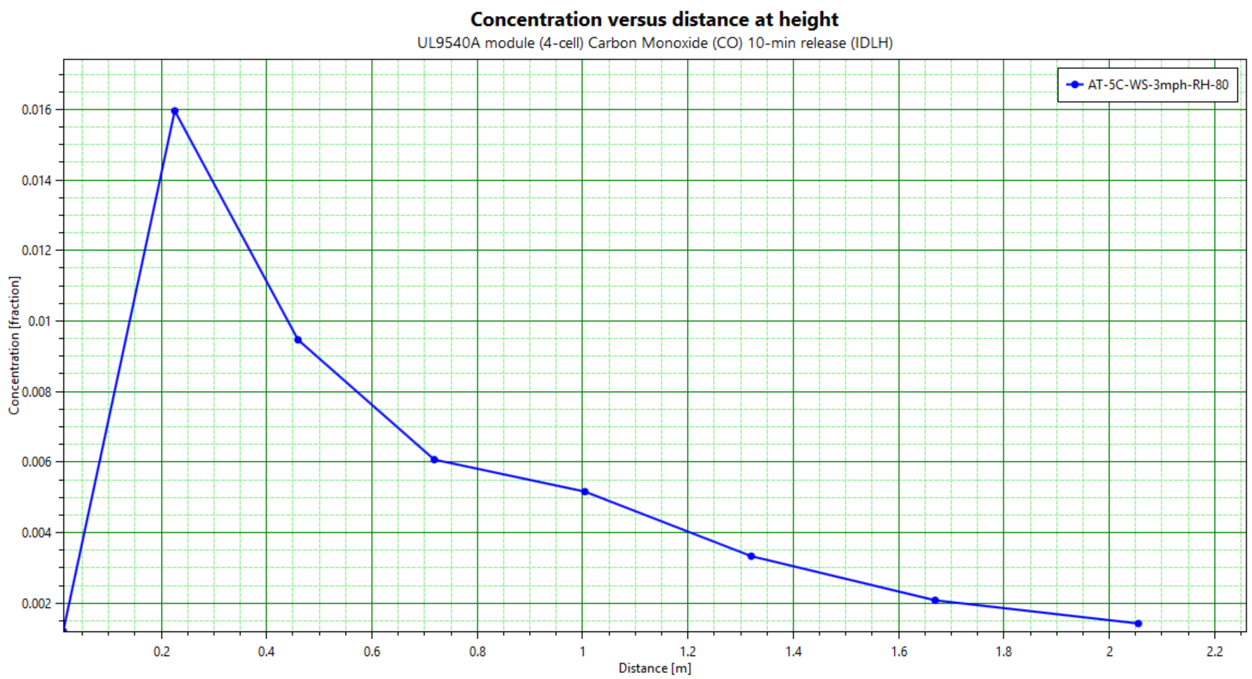


Figure 16 Concentration vs distance for CO IDLH (1200 ppm)

1.1.5 TVG Flammable Vapor Cloud Extent (Instantaneous Release)

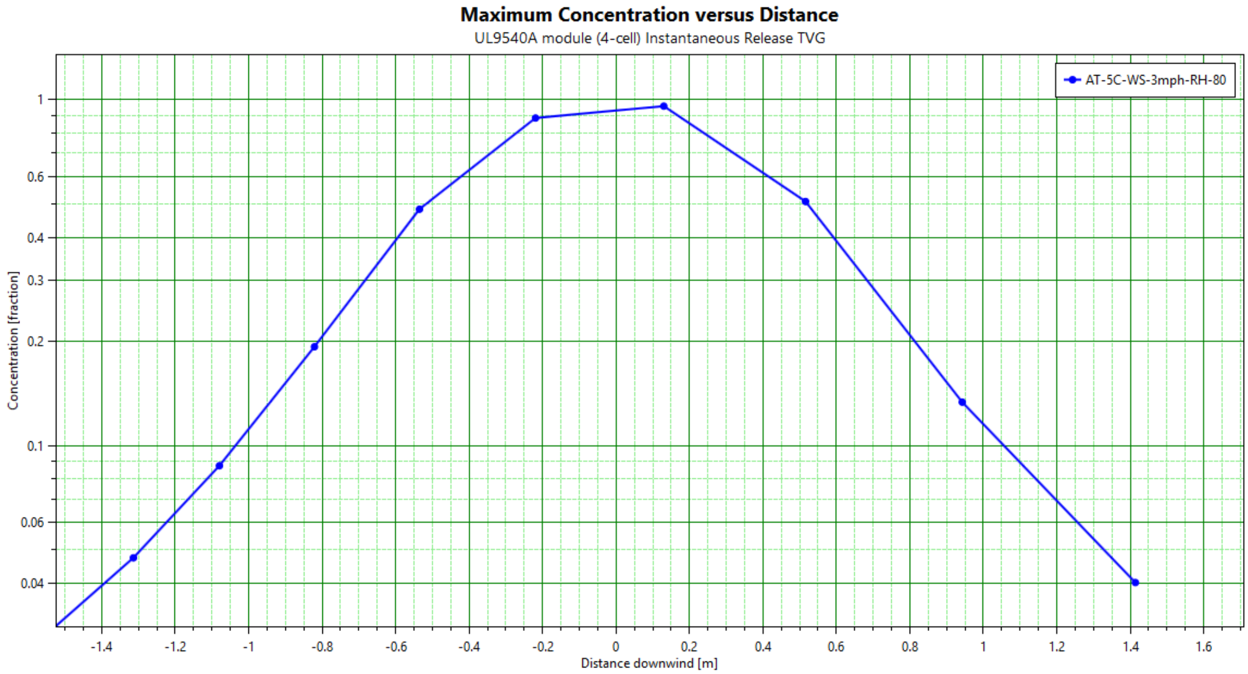


Figure 17 Maximum concentration vs distance for flammable vapor cloud

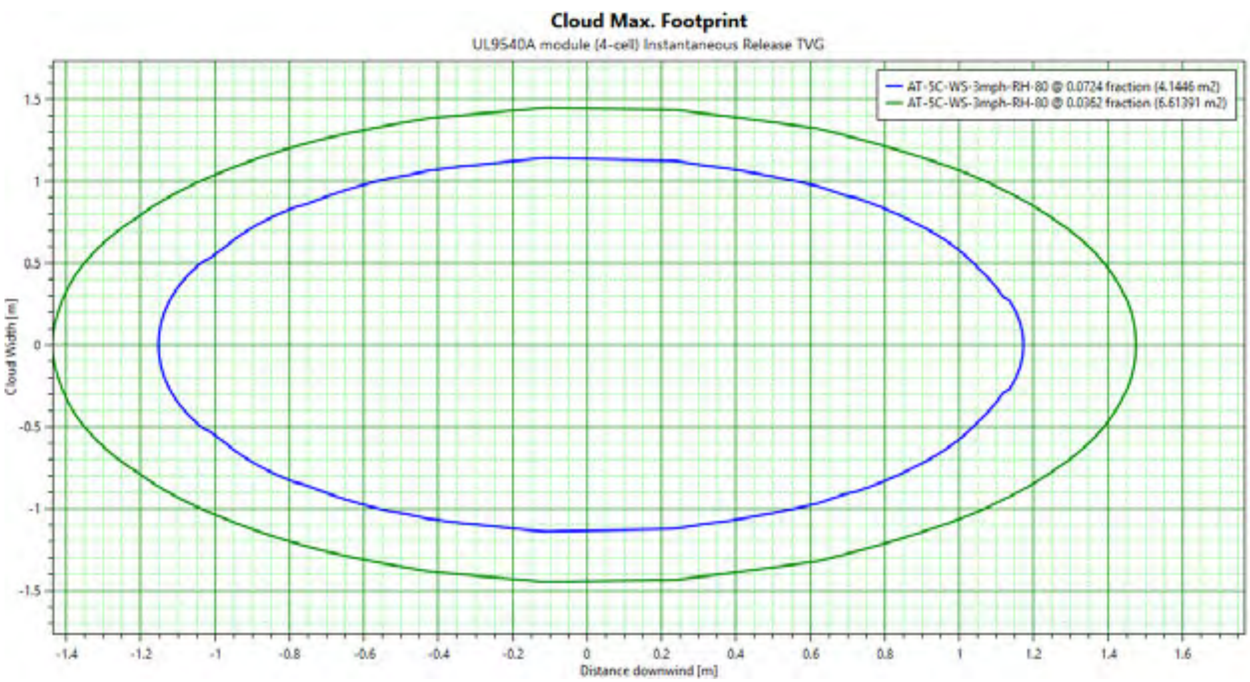


Figure 18 Maximum horizontal extent of vapor cloud for LFL (7.24%) and ½ LFL (3.62%)

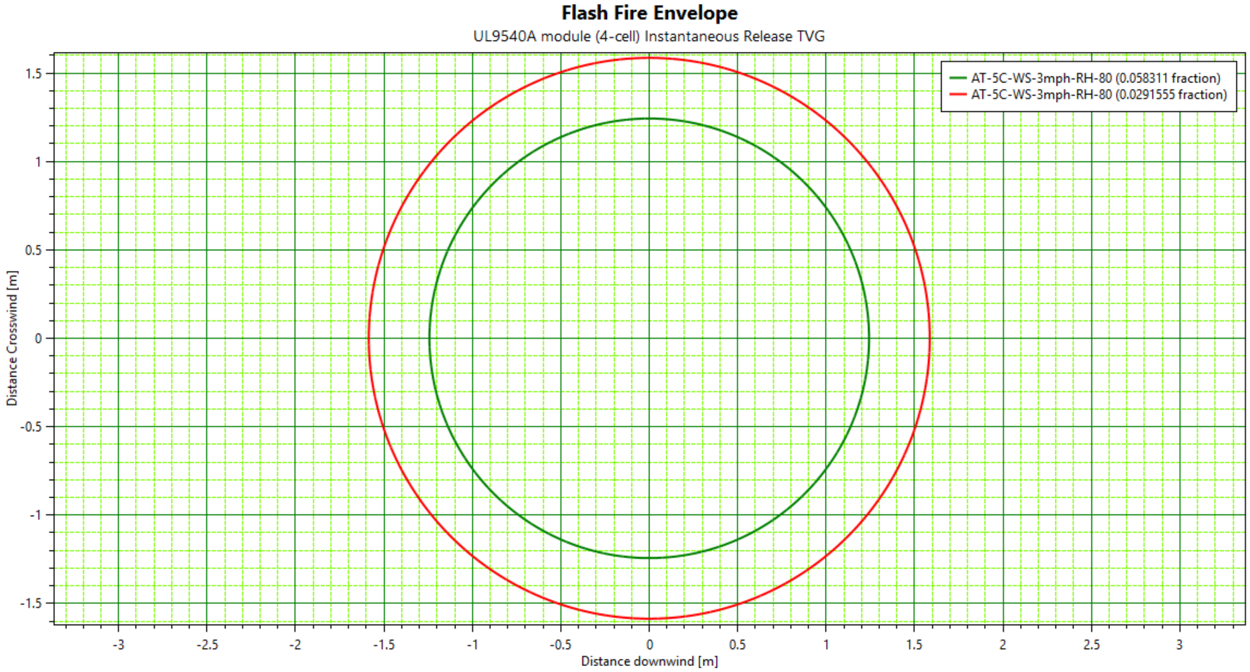


Figure 19 Flash Fire Envelope for LFL (7.24%) and ½ LFL (3.62%)

1.1.6 CO IDLH (1200 ppm) Component Extent (Instantaneous Release)

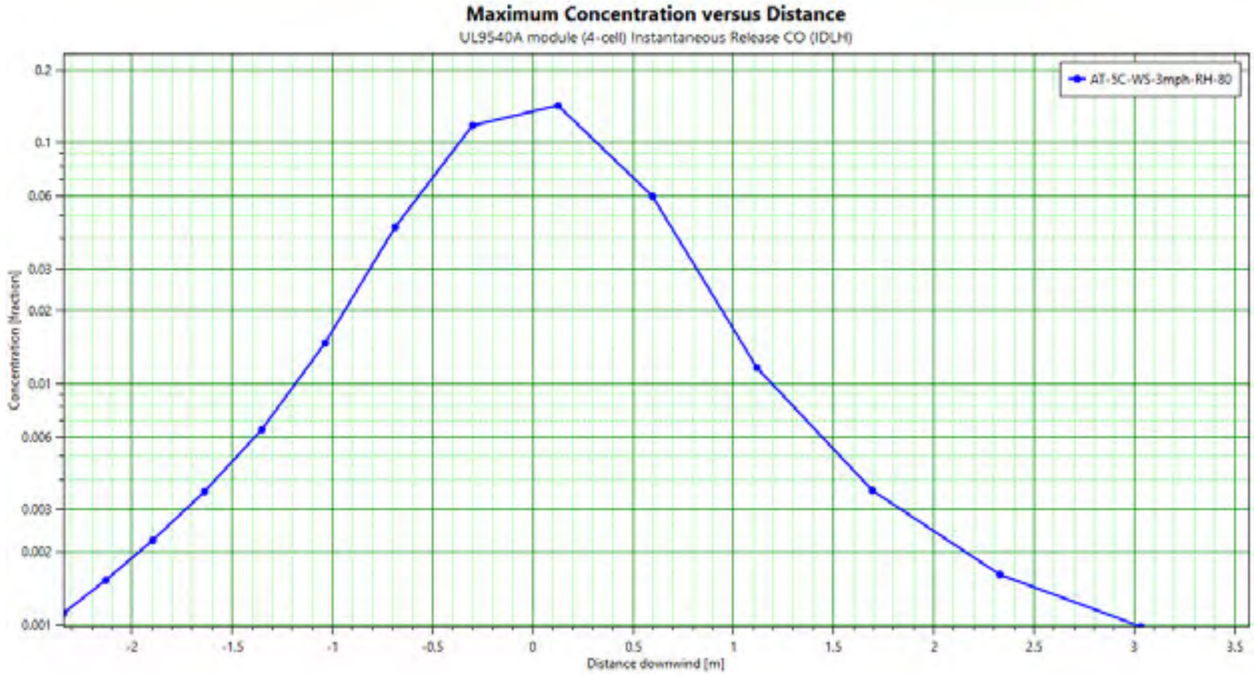


Figure 20 Maximum Concentration vs distance for CO gas component

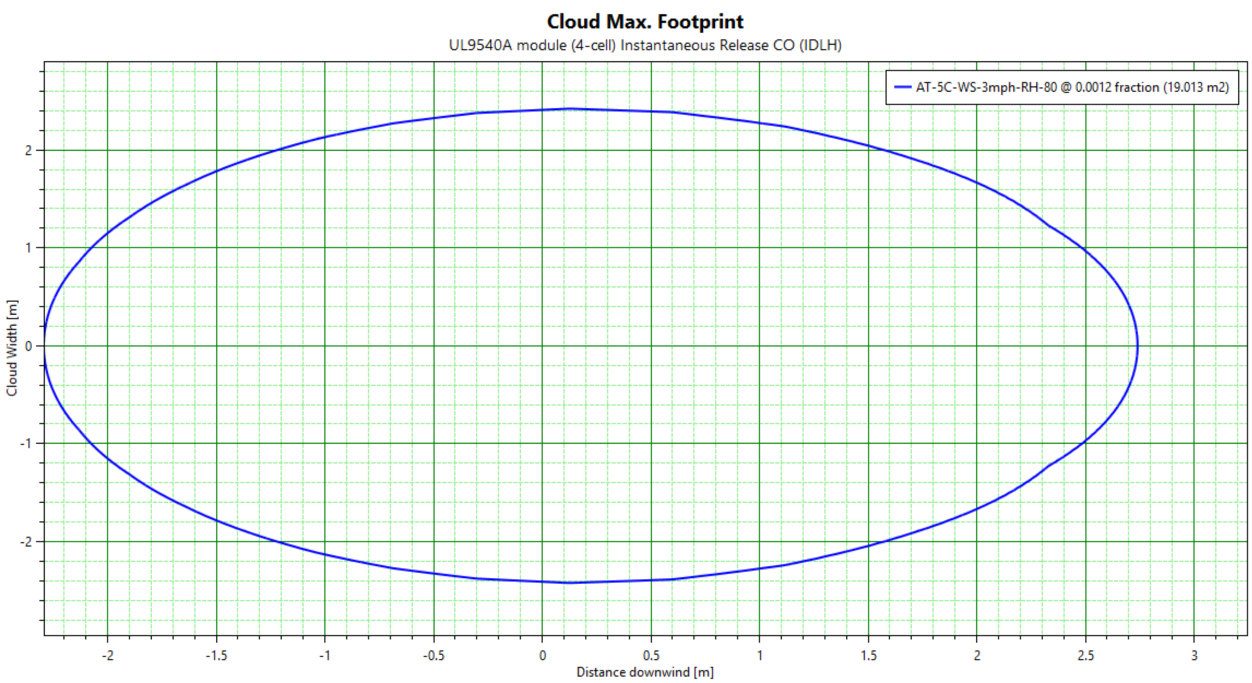


Figure 21 Maximum horizontal extent of vapor cloud for CO IDLH (1200 ppm)

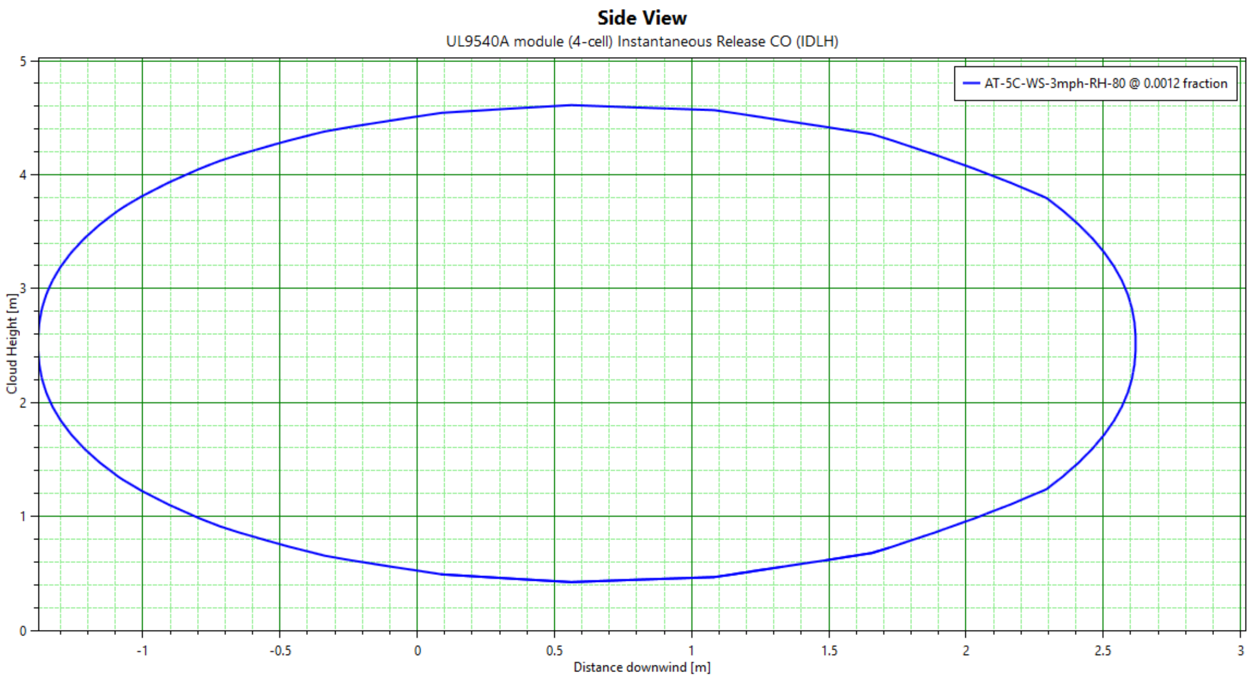


Figure 22 Maximum vertical extent of vapor cloud for CO IDLH (1200 ppm)

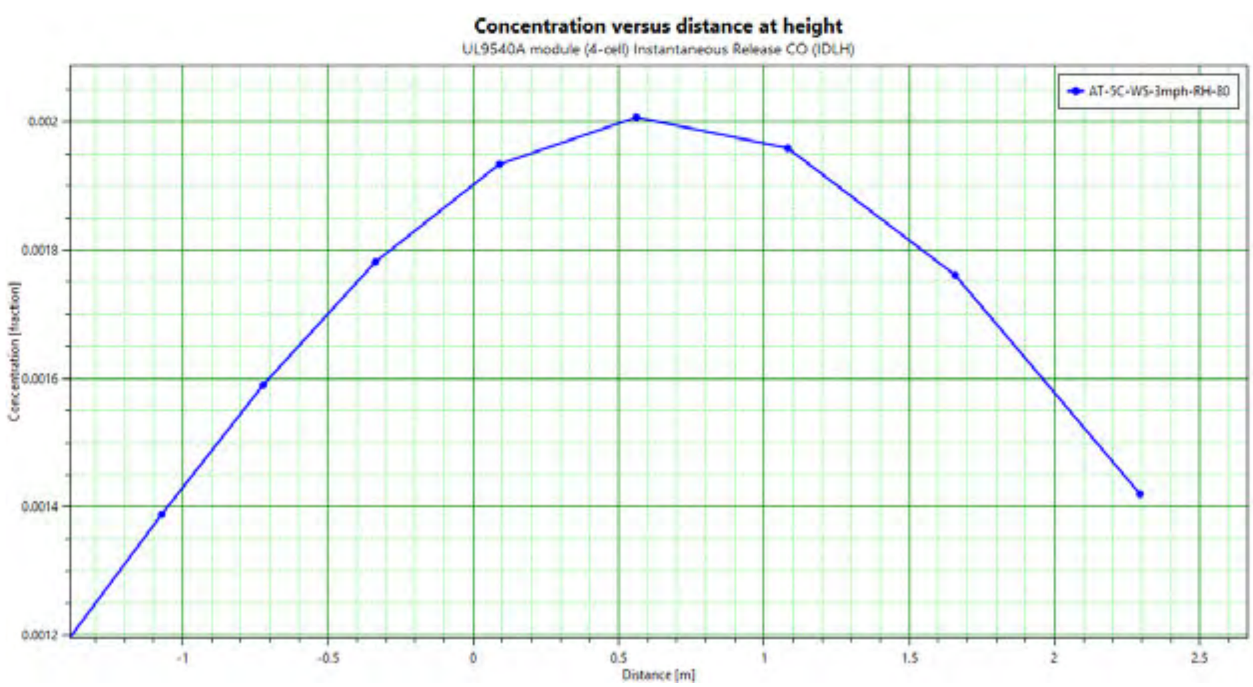


Figure 23 Concentration vs distance for CO IDLH (1200 ppm)

1.2 Scenario 2: 1-Module Release

1.2.1 TVG Flammable Vapor Cloud Extent (75.6 min Release)

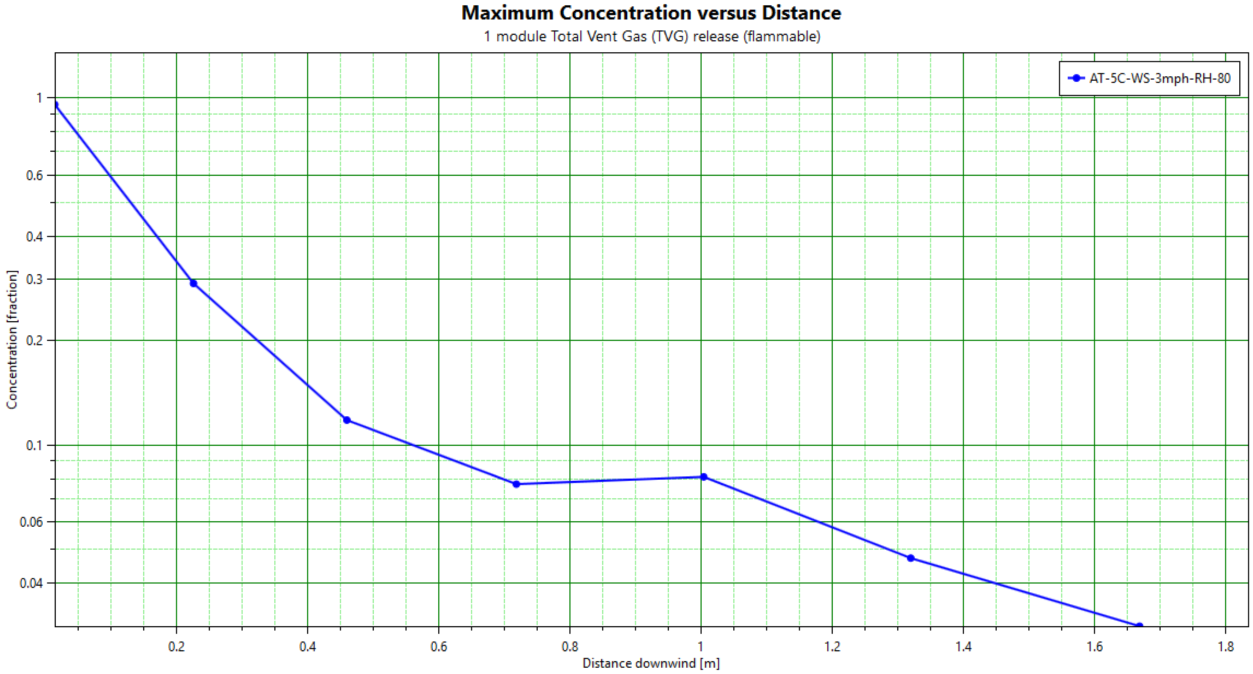


Figure 24 Maximum concentration vs distance for flammable vapor cloud

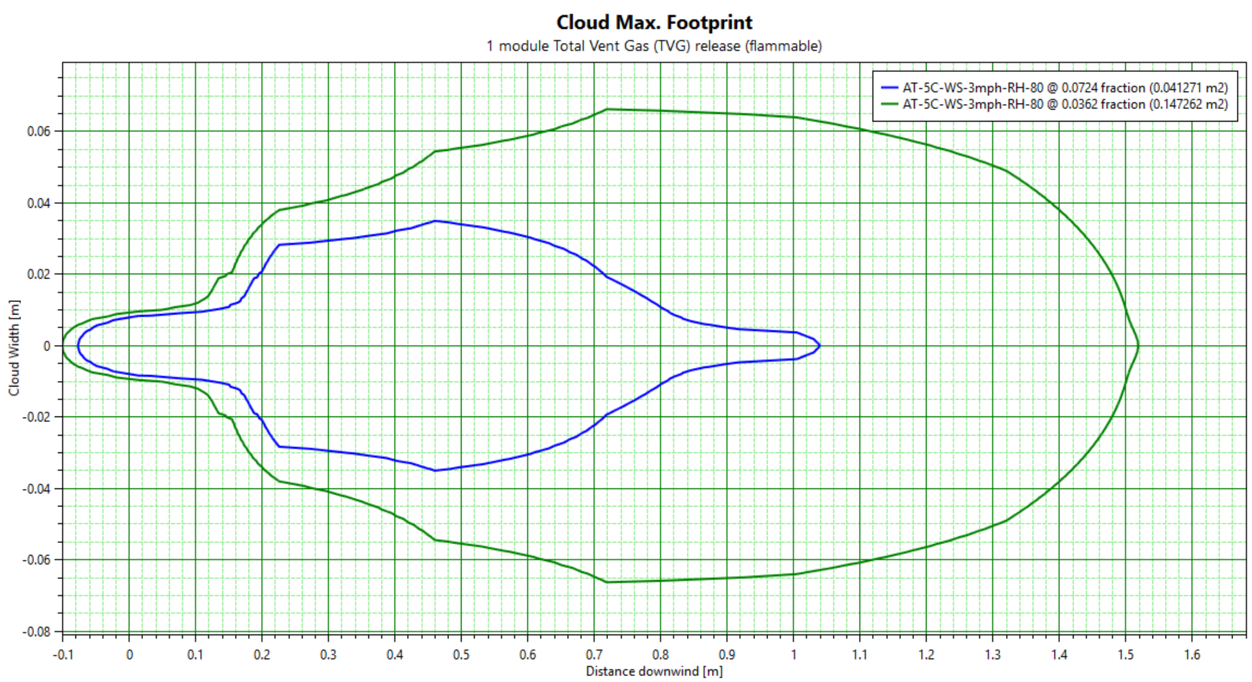


Figure 25 Maximum horizontal extent of vapor cloud for LFL (7.24%) and ½ LFL (3.62%)

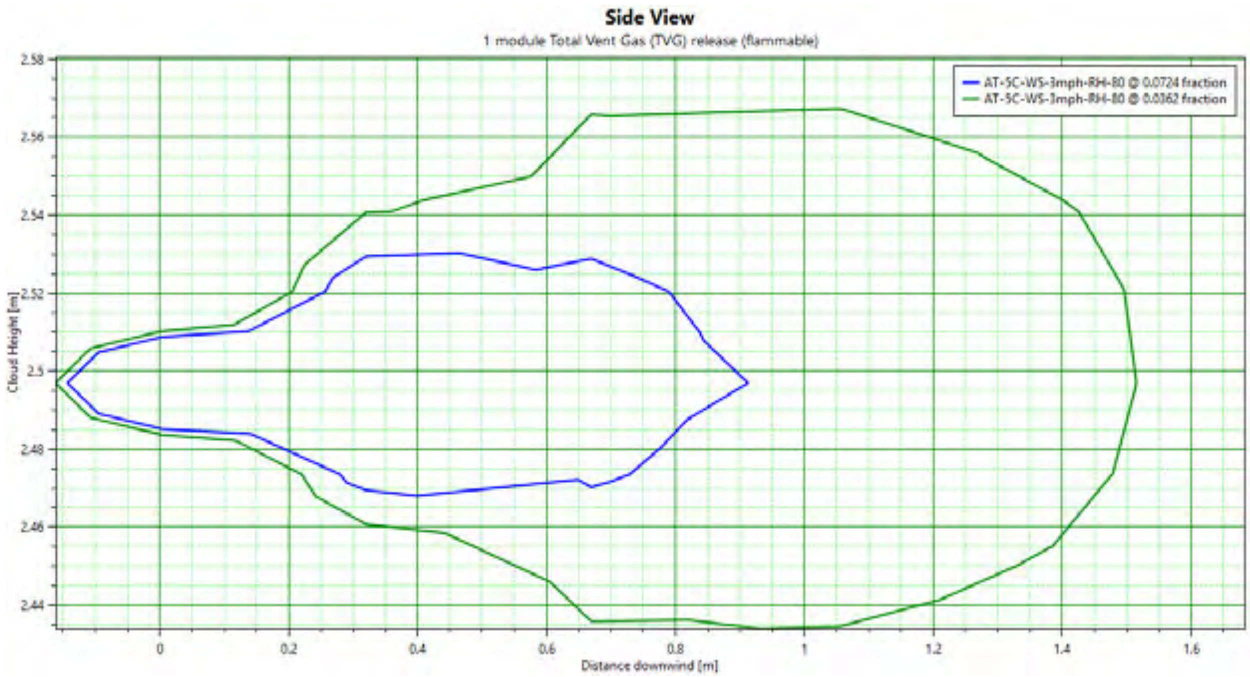


Figure 26 Maximum vertical extent of vapor cloud for LFL (7.24%) and ½ LFL (3.62%)

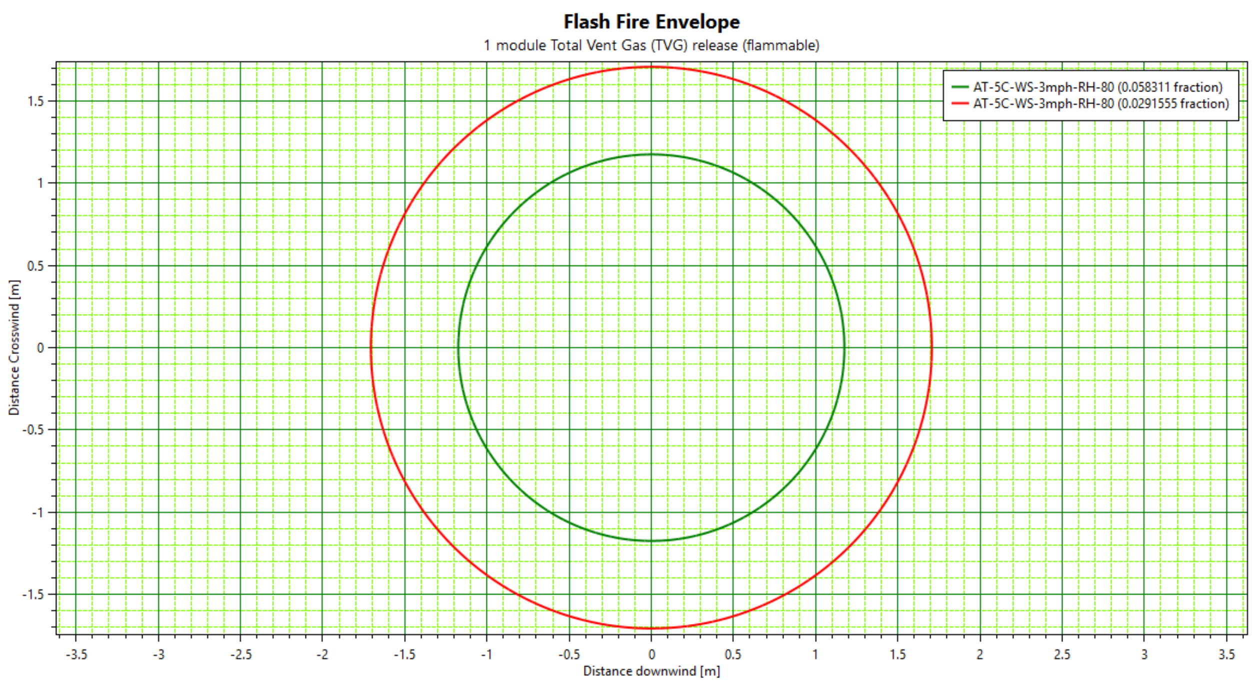


Figure 27 Flash Fire Envelope for LFL (7.24%) and ½ LFL (3.62%)

1.2.2 CO IDLH (1200 ppm) Component Extent (75.6 min Release)

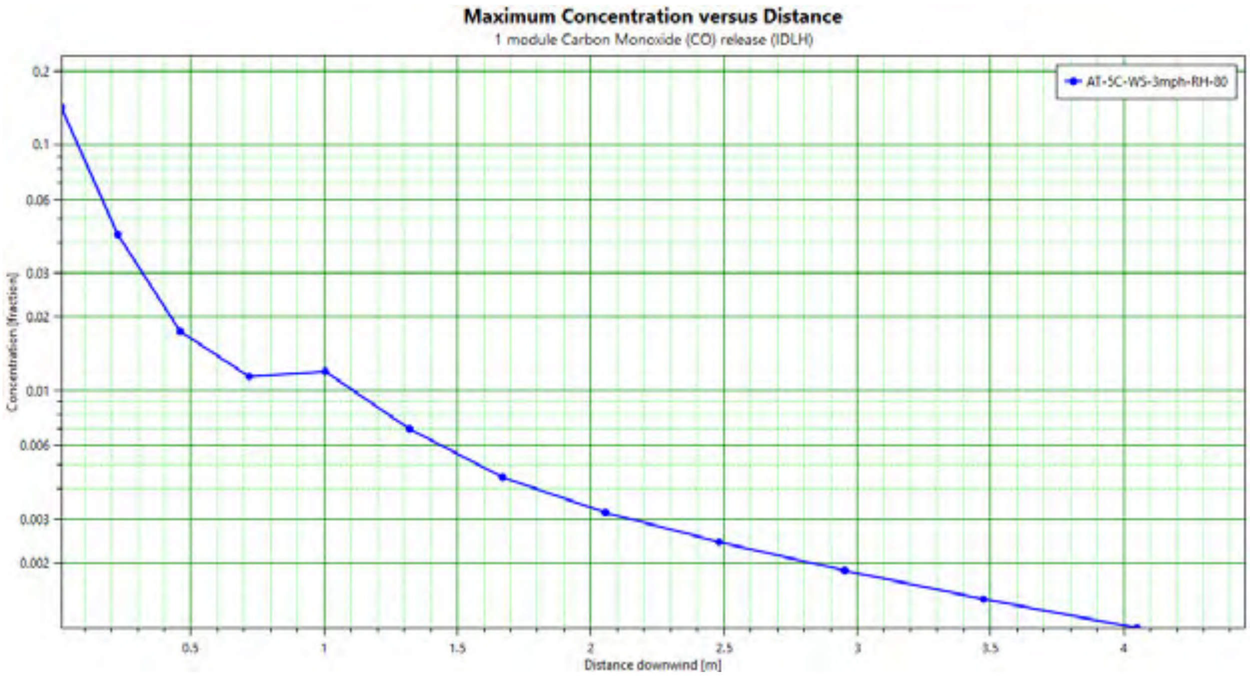


Figure 28 Maximum Concentration vs distance for CO gas component

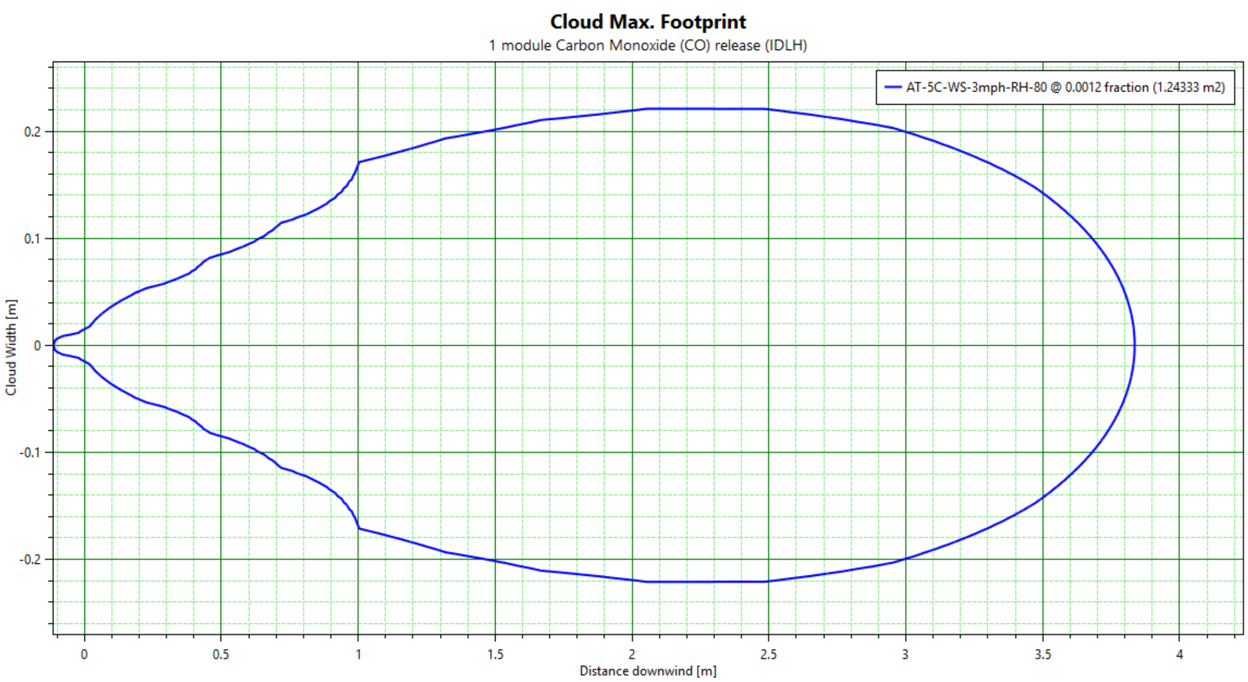


Figure 29 Maximum horizontal extent of vapor cloud for CO IDLH (1200 ppm)

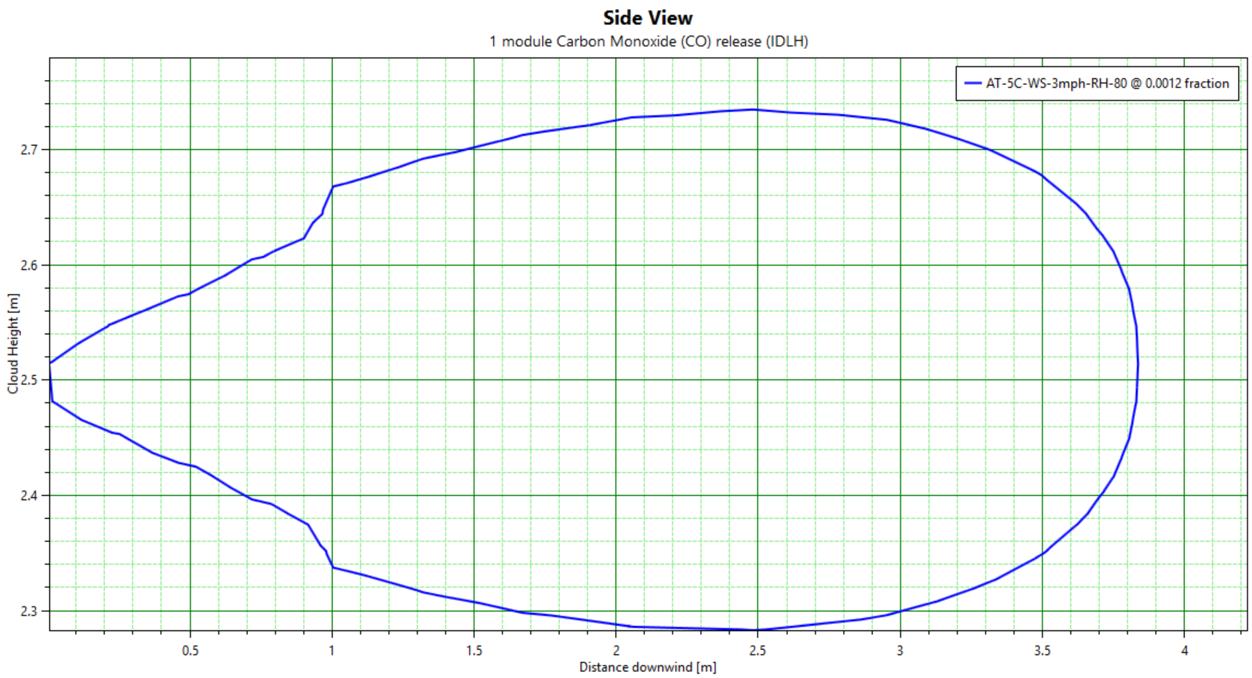


Figure 30 Maximum vertical extent of vapor cloud for CO IDLH (1200 ppm)

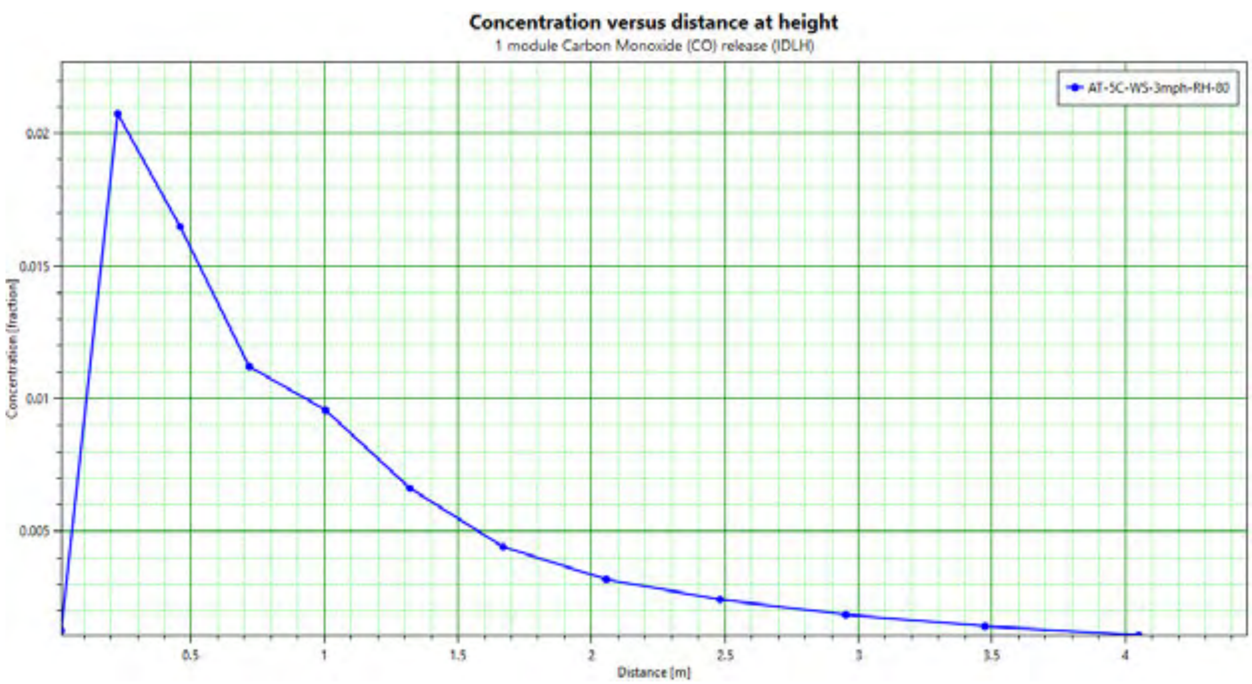


Figure 31 Concentration vs distance for CO IDLH (1200 ppm)

1.2.3 TVG Flammable Vapor Cloud Extent (10 min Release)

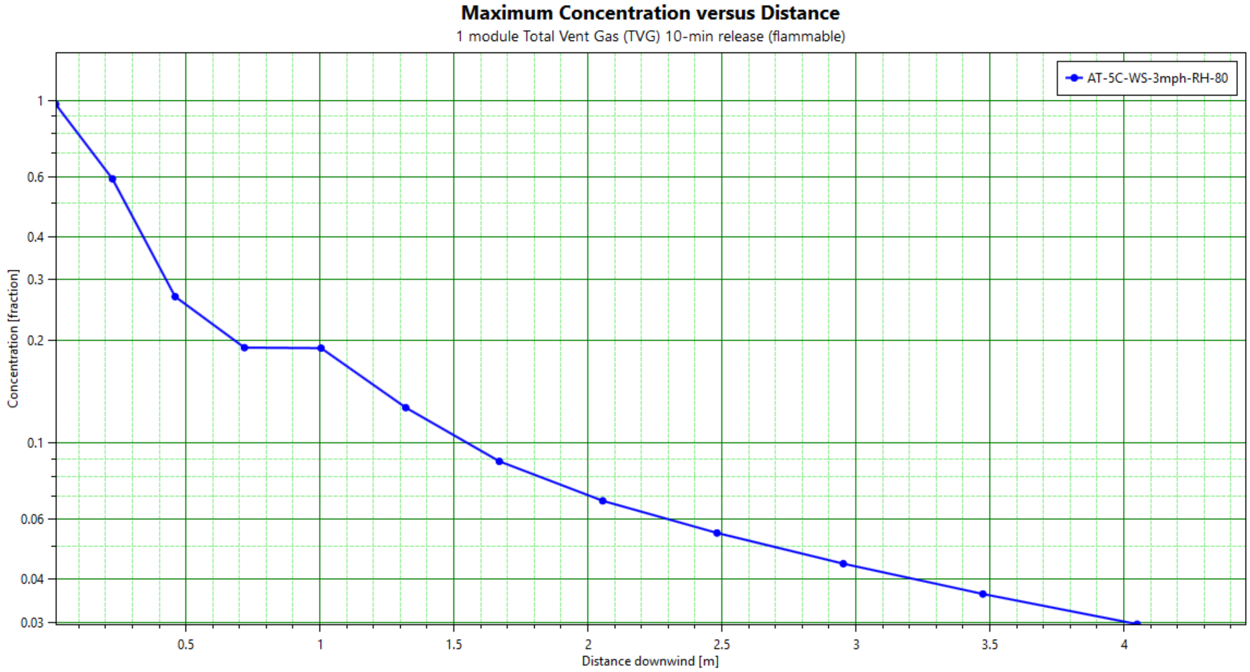


Figure 32 Maximum concentration vs distance for flammable vapor cloud

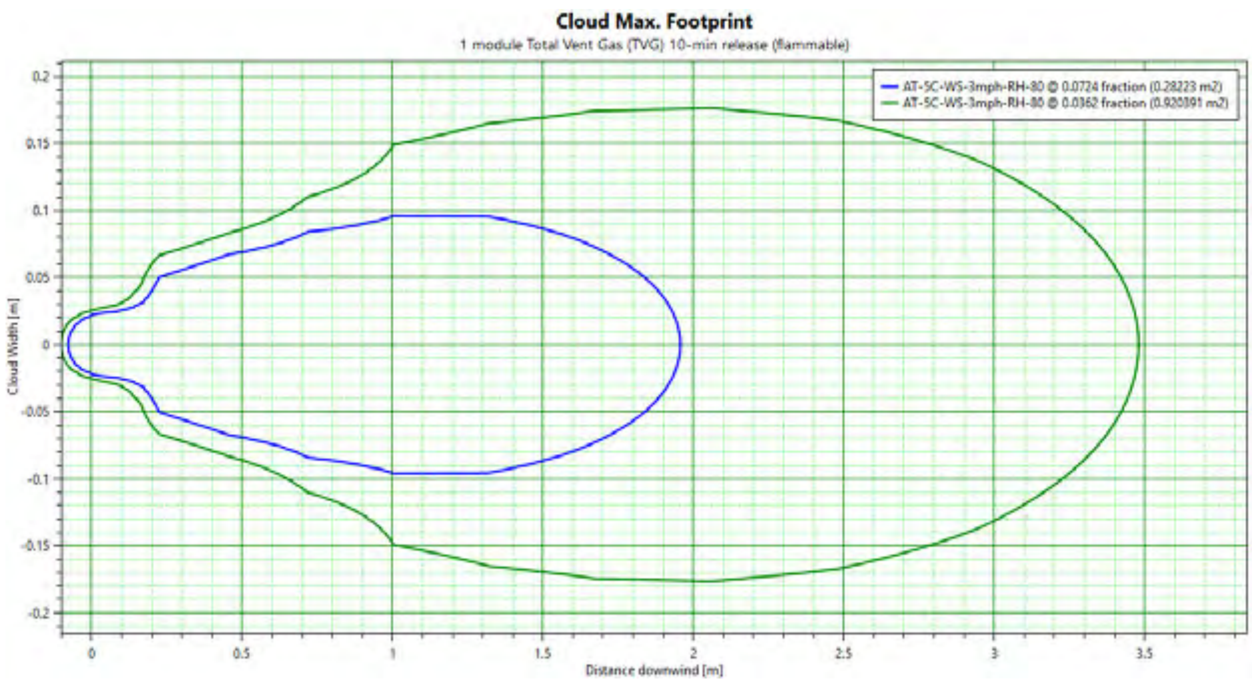


Figure 33 Maximum horizontal extent of vapor cloud for LFL (7.24%) and ½ LFL (3.62%)

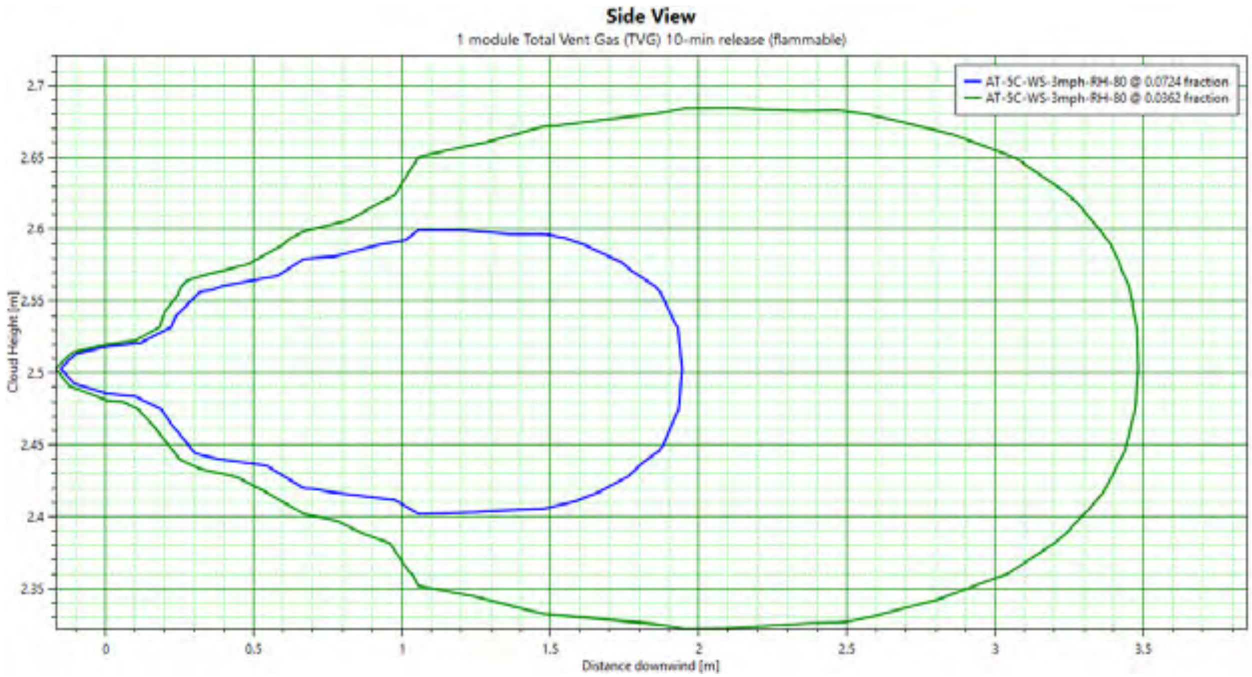


Figure 34 Maximum vertical extent of vapor cloud for LFL (7.24%) and ½ LFL (3.62%)

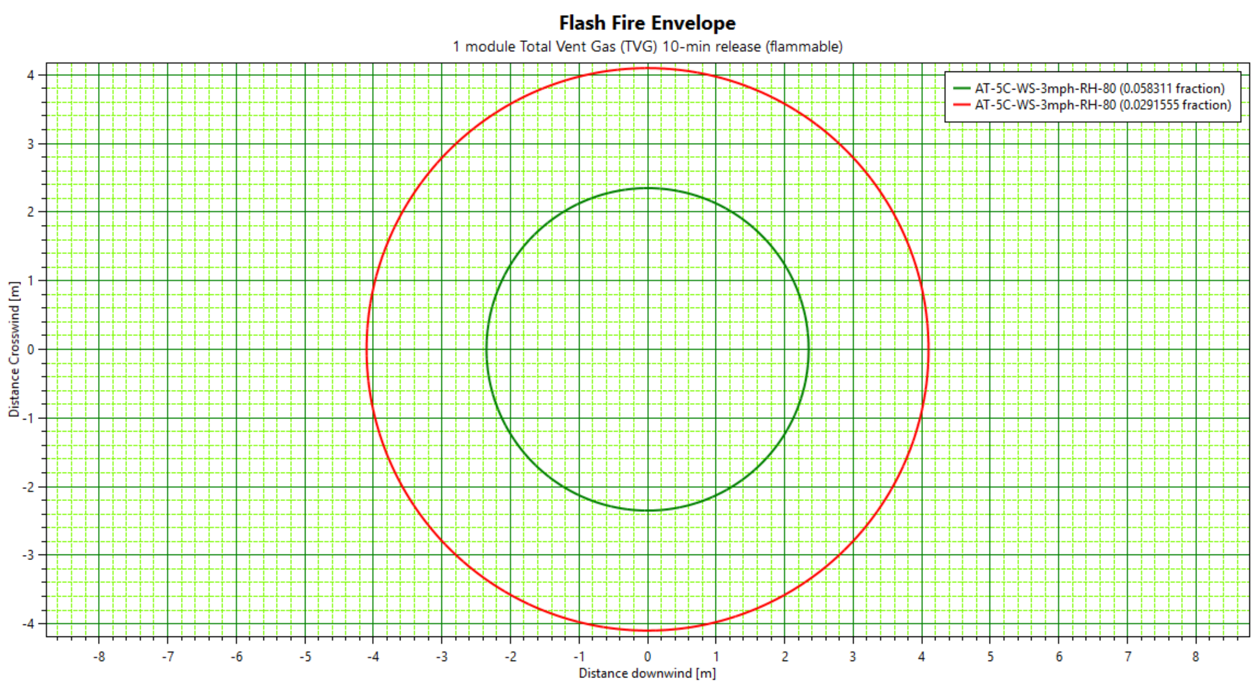


Figure 35 Flash Fire Envelope for LFL (7.24%) and ½ LFL (3.62%)

1.2.4 CO IDLH (1200 ppm) Component Extent (10 min Release)

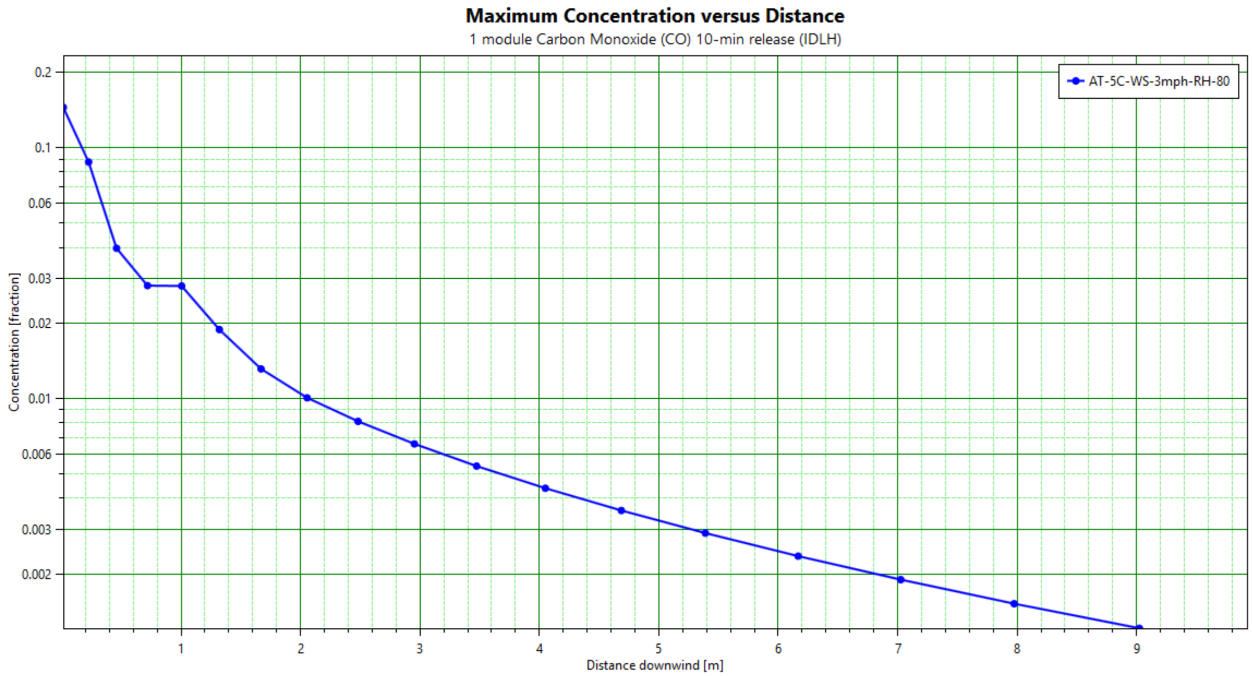


Figure 36 Maximum Concentration vs distance for CO gas component

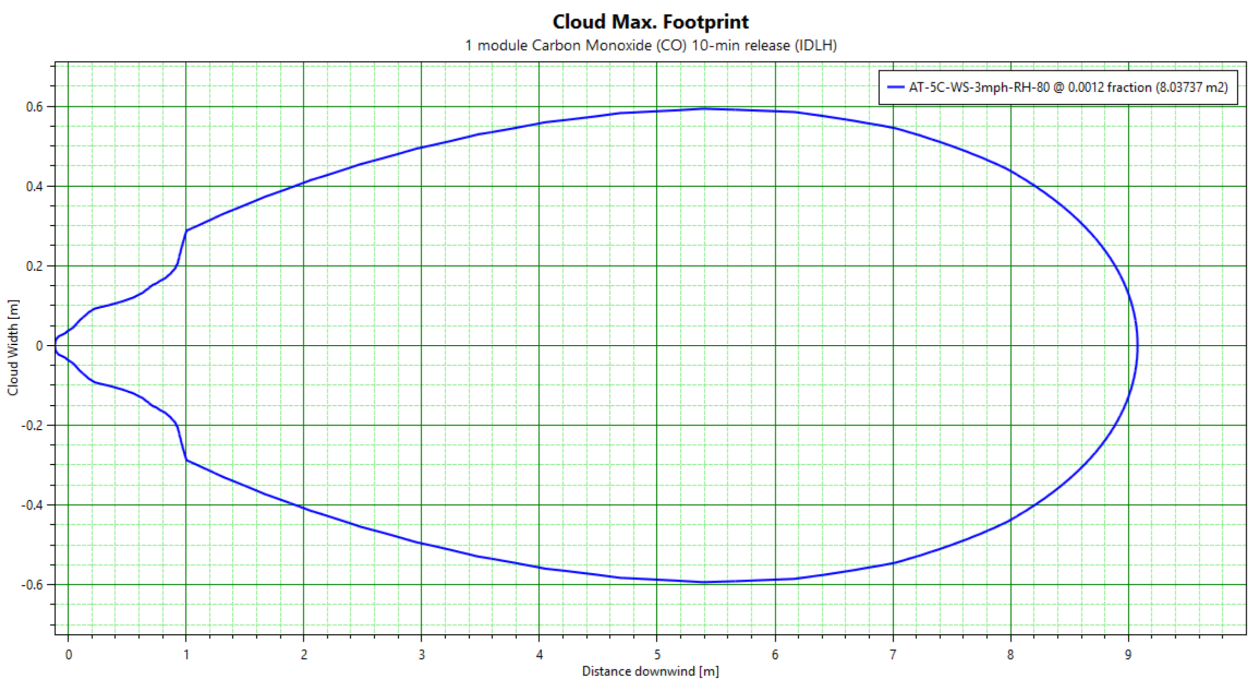


Figure 37 Maximum horizontal extent of vapor cloud for CO IDLH (1200 ppm)

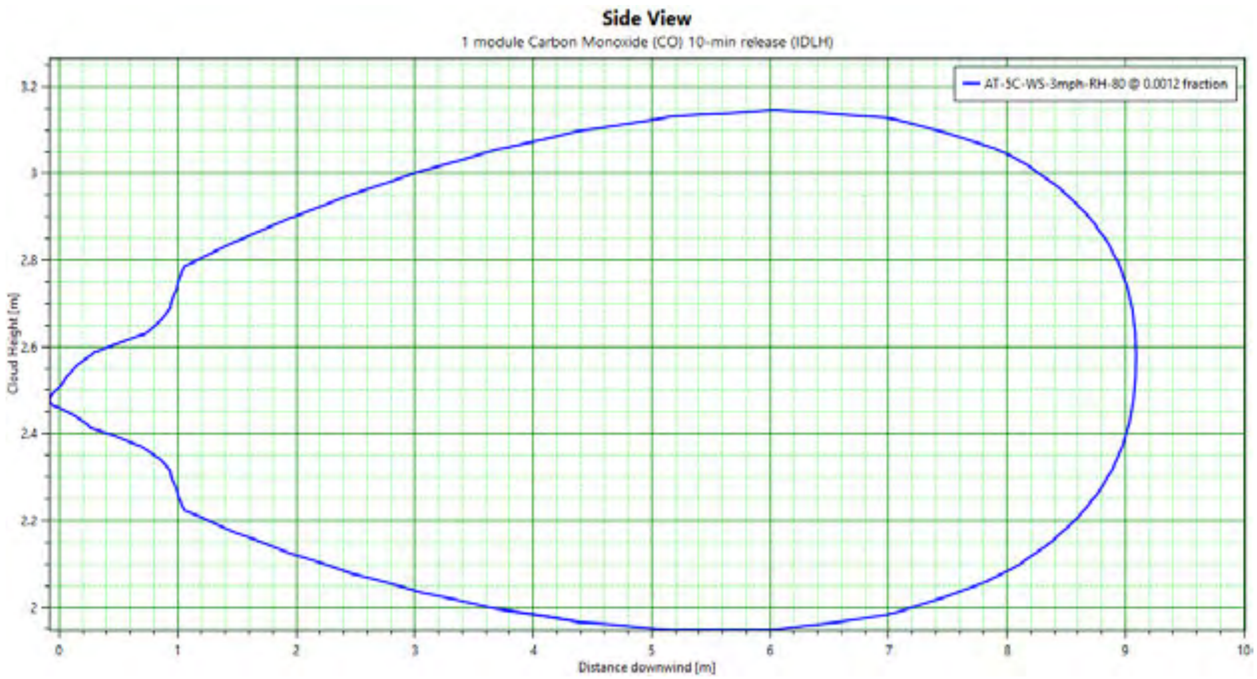


Figure 38 Maximum vertical extent of vapor cloud for CO IDLH (1200 ppm)

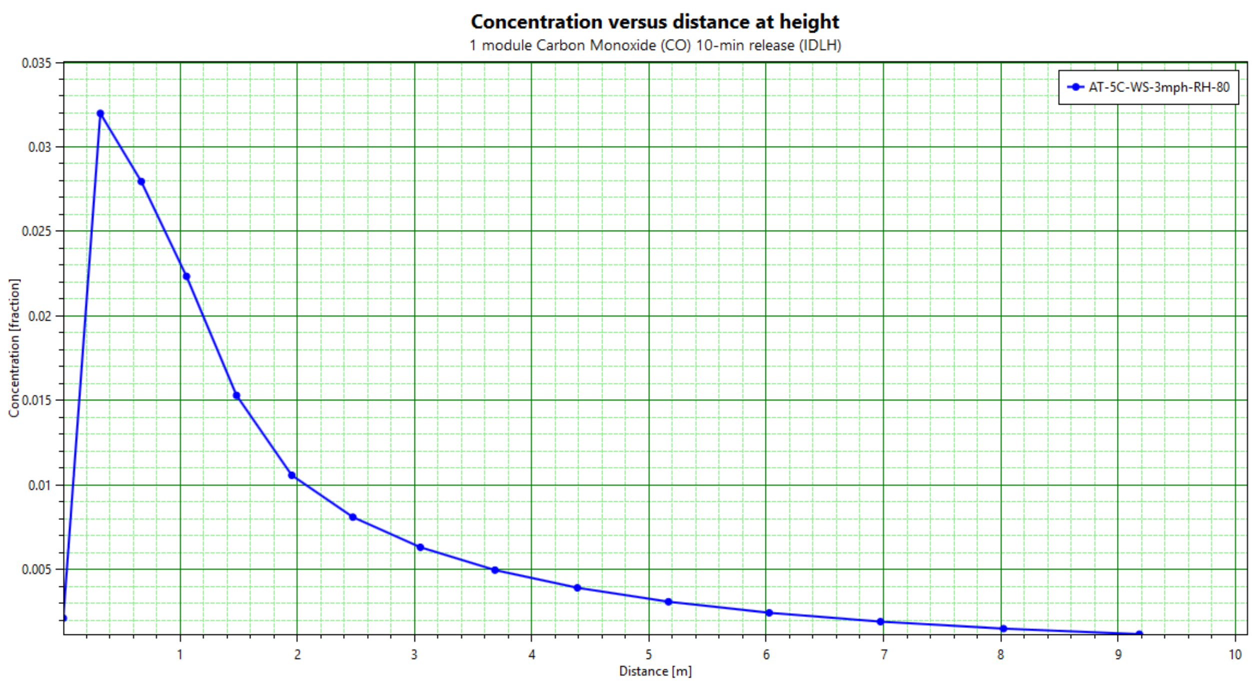


Figure 39 Concentration vs distance for CO IDLH (1200 ppm)

1.3 Scenario 3: 1-Rack Release

1.3.1 TVG Flammable Vapor Cloud Extent (75.6 min Release)

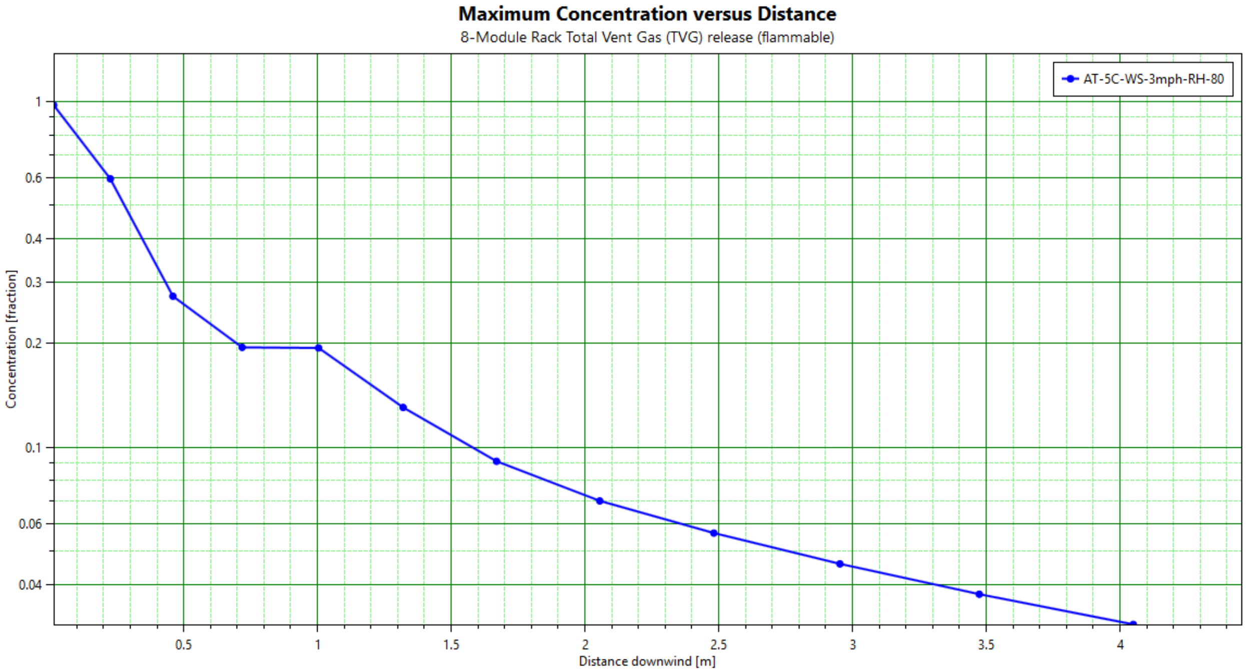


Figure 40 Maximum concentration vs distance for flammable vapor cloud

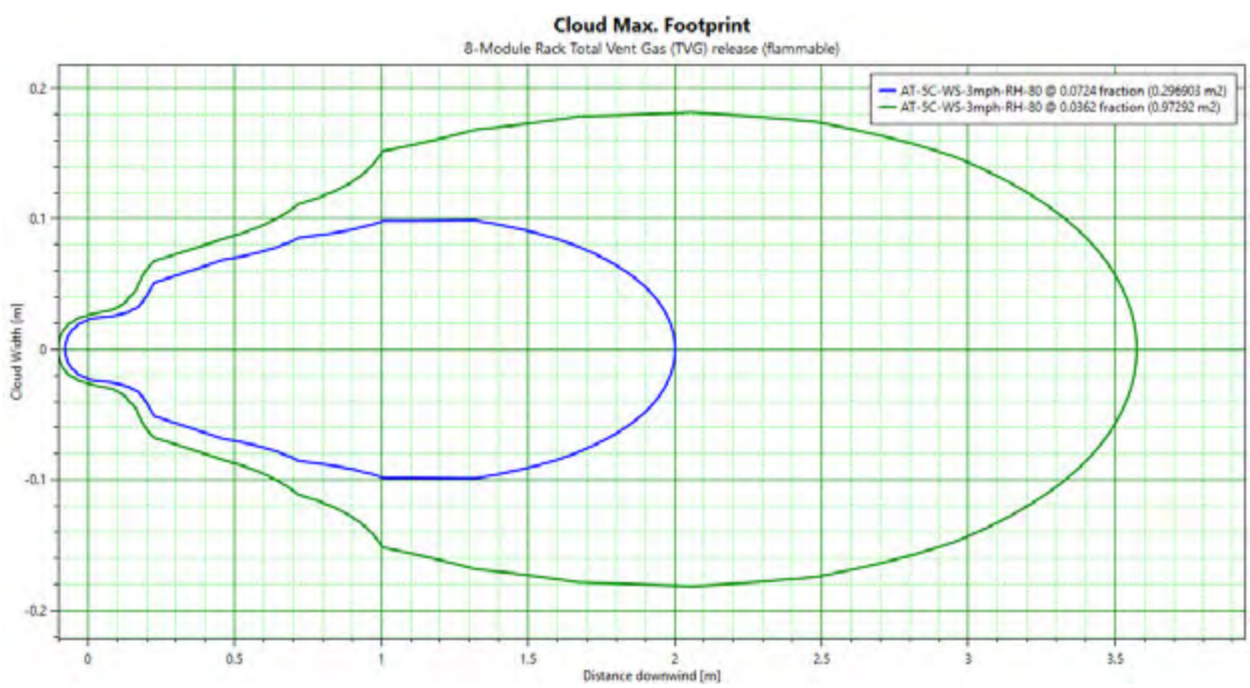


Figure 41 Maximum horizontal extent of vapor cloud for LFL (7.24%) and ½ LFL (3.62%)

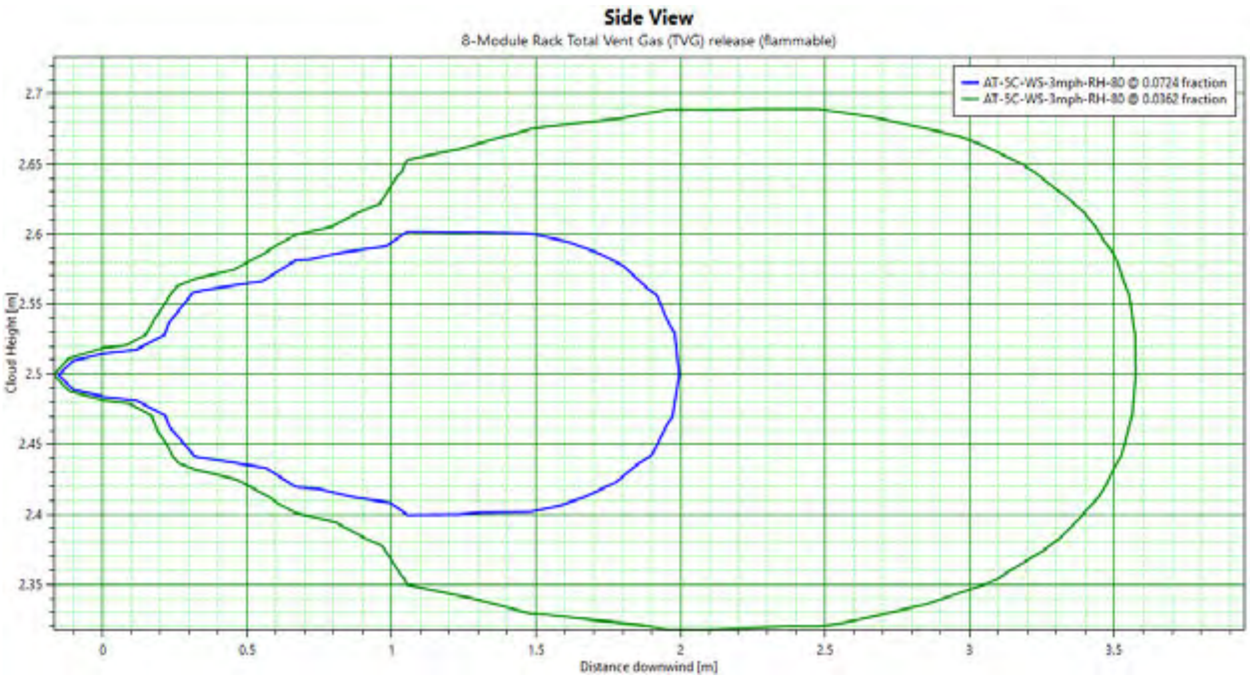


Figure 42 Maximum vertical extent of vapor cloud for LFL (7.24%) and ½ LFL (3.62%)

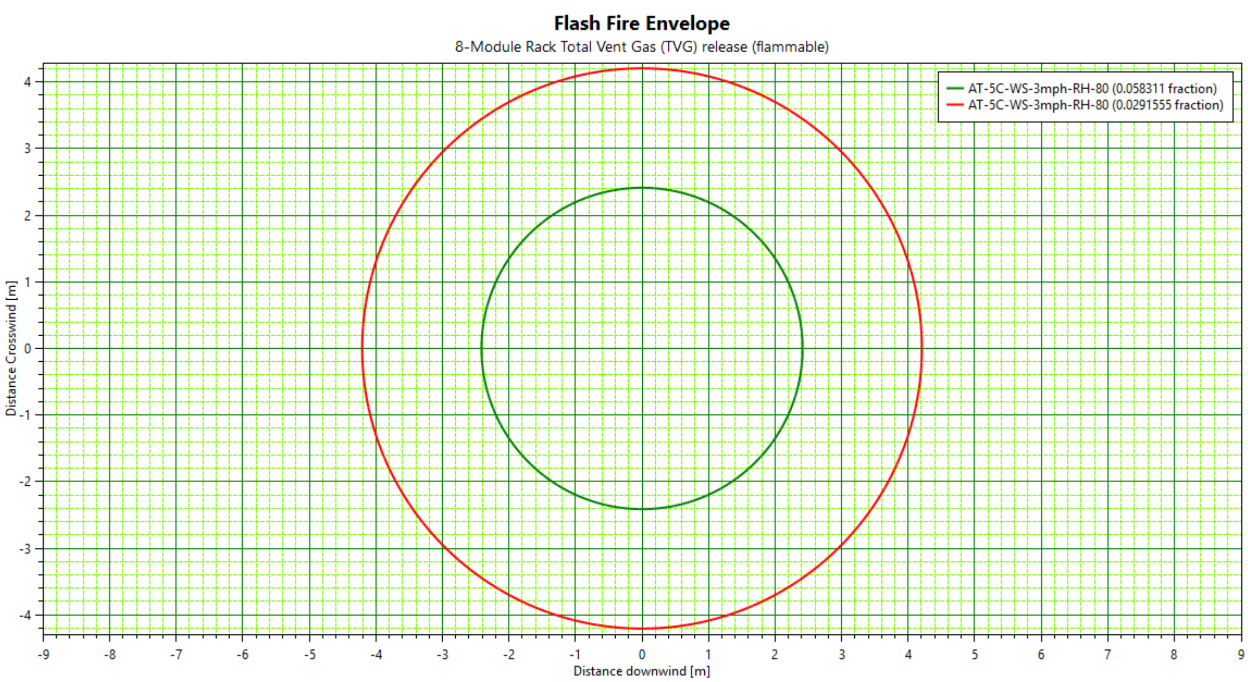


Figure 43 Flash Fire Envelope for LFL (7.24%) and ½ LFL (3.62%)

1.3.2 CO IDLH (1200 ppm) Component Extent (75.6 min Release)

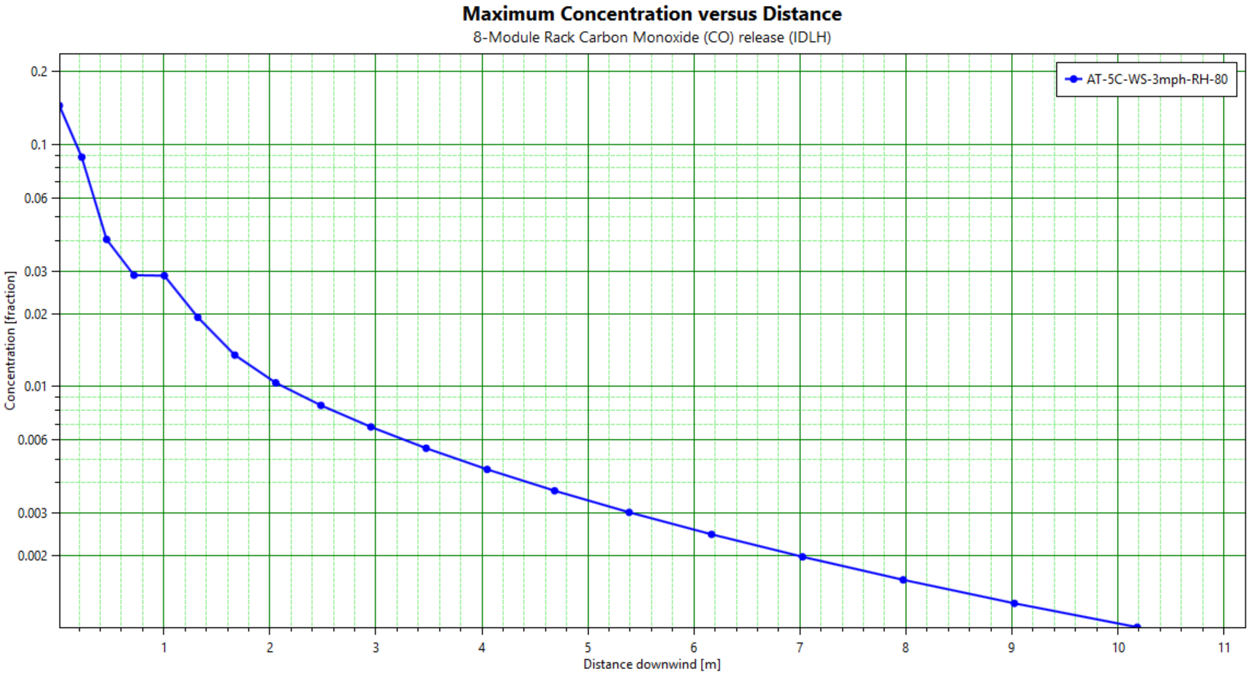


Figure 44 Maximum Concentration vs distance for CO gas component

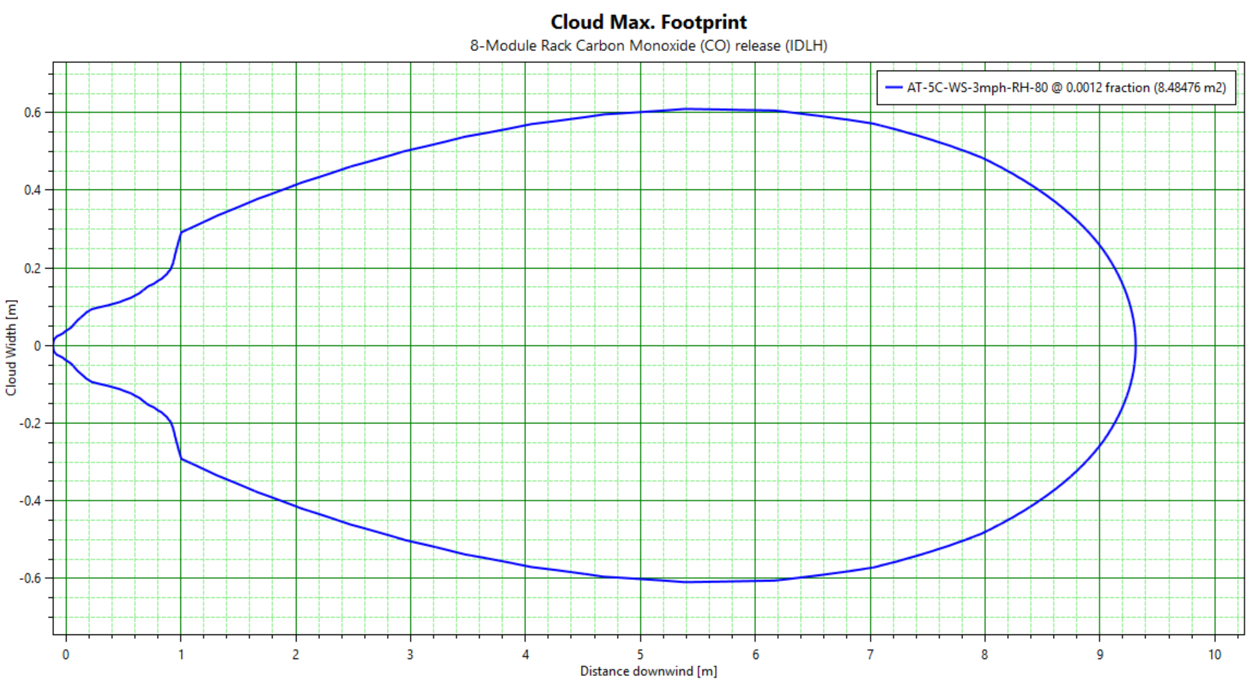


Figure 45 Maximum horizontal extent of vapor cloud for CO IDLH (1200 ppm)

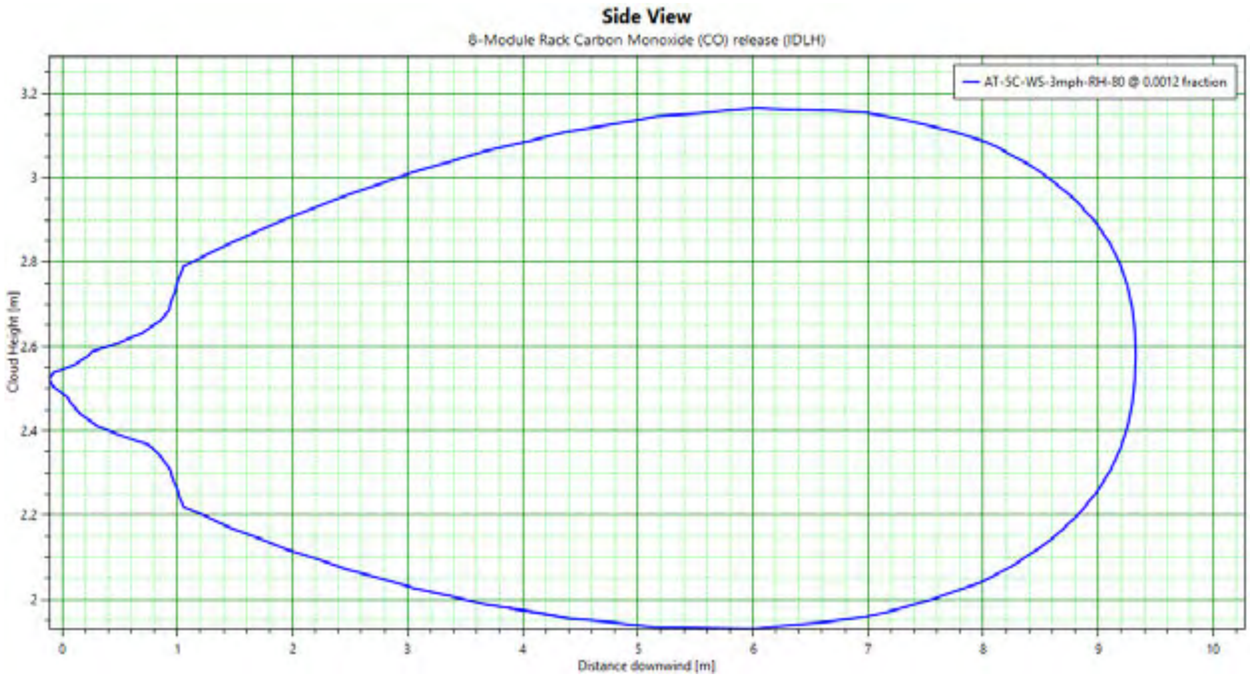


Figure 46 Maximum vertical extent of vapor cloud for CO IDLH (1200 ppm)

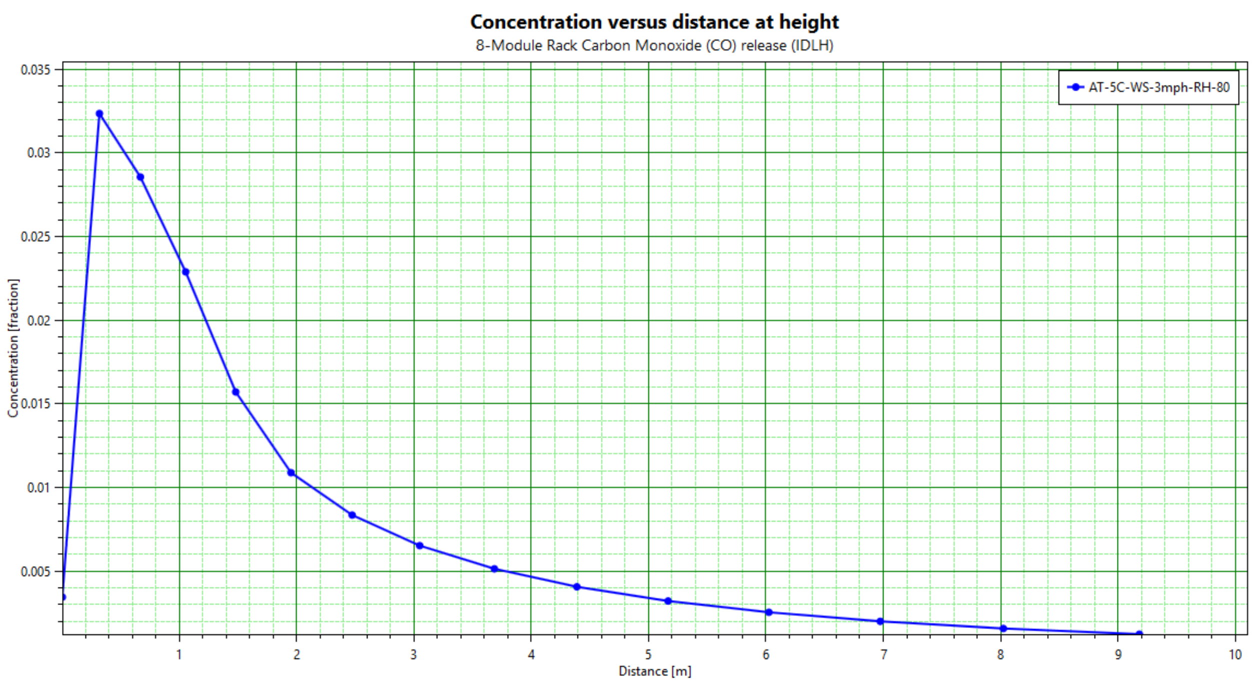


Figure 47 Concentration vs distance for CO IDLH (1200 ppm)

1.3.3 TVG Flammable Vapor Cloud Extent (10 min Release)

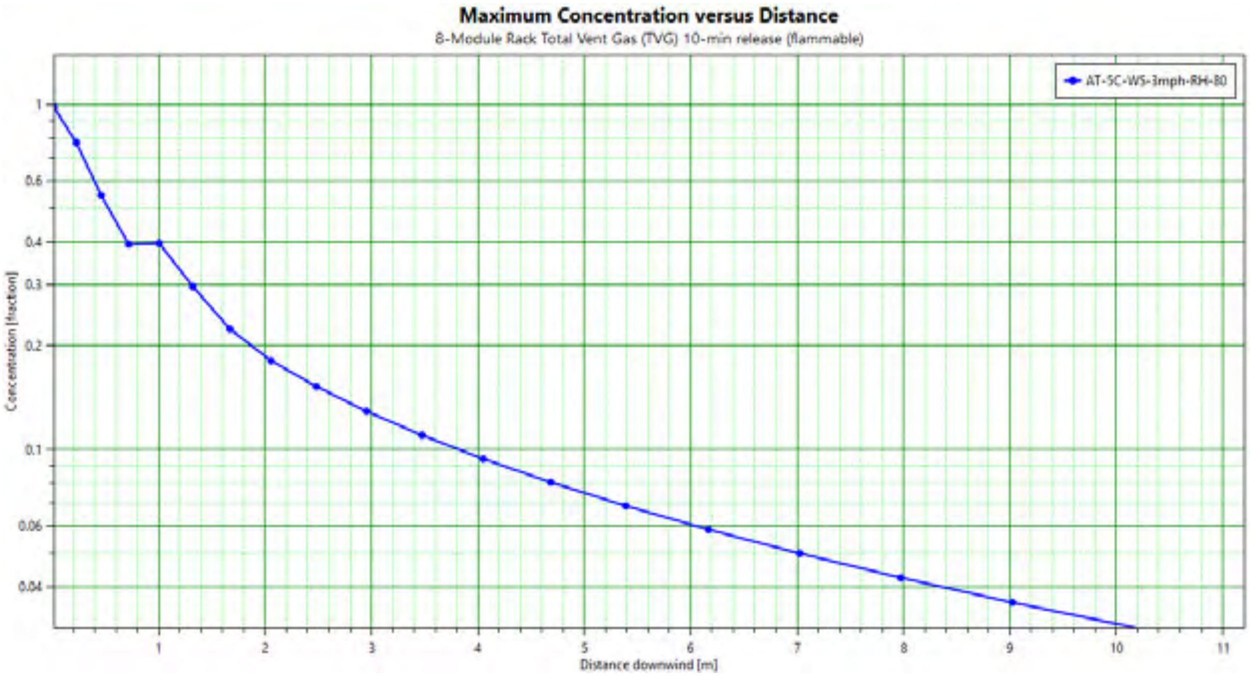


Figure 48 Maximum concentration vs distance for flammable vapor cloud

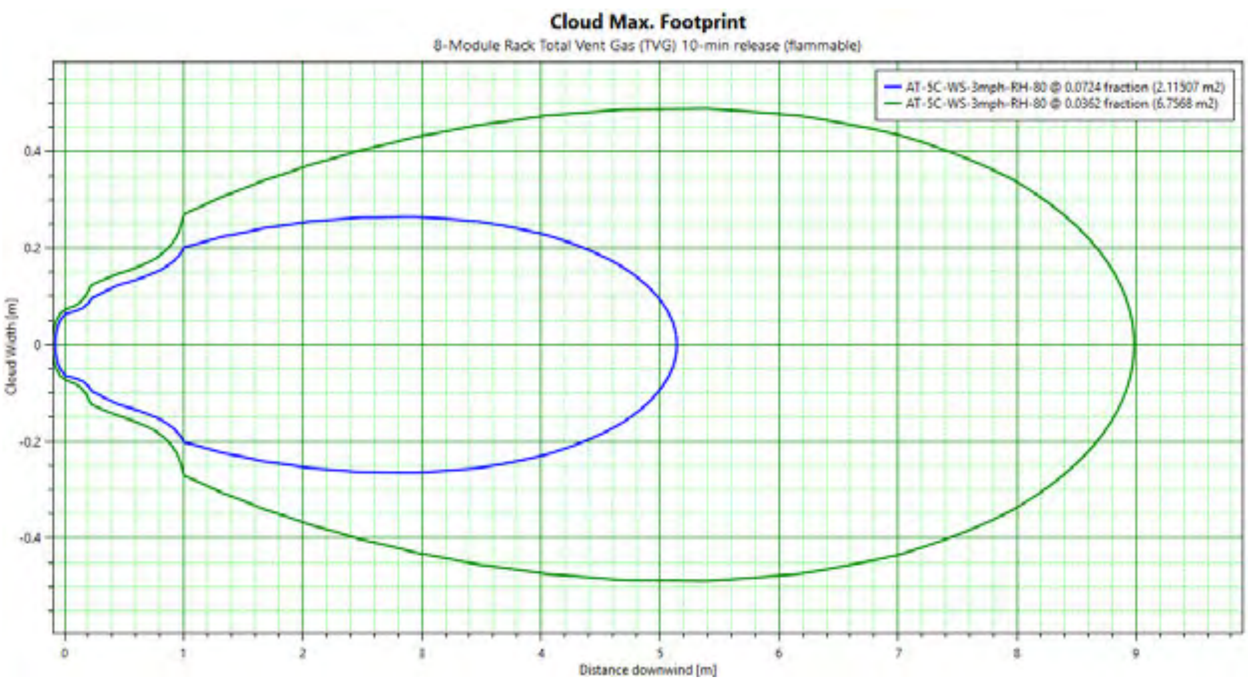


Figure 49 Maximum horizontal extent of vapor cloud for LFL (7.24%) and ½ LFL (3.62%)

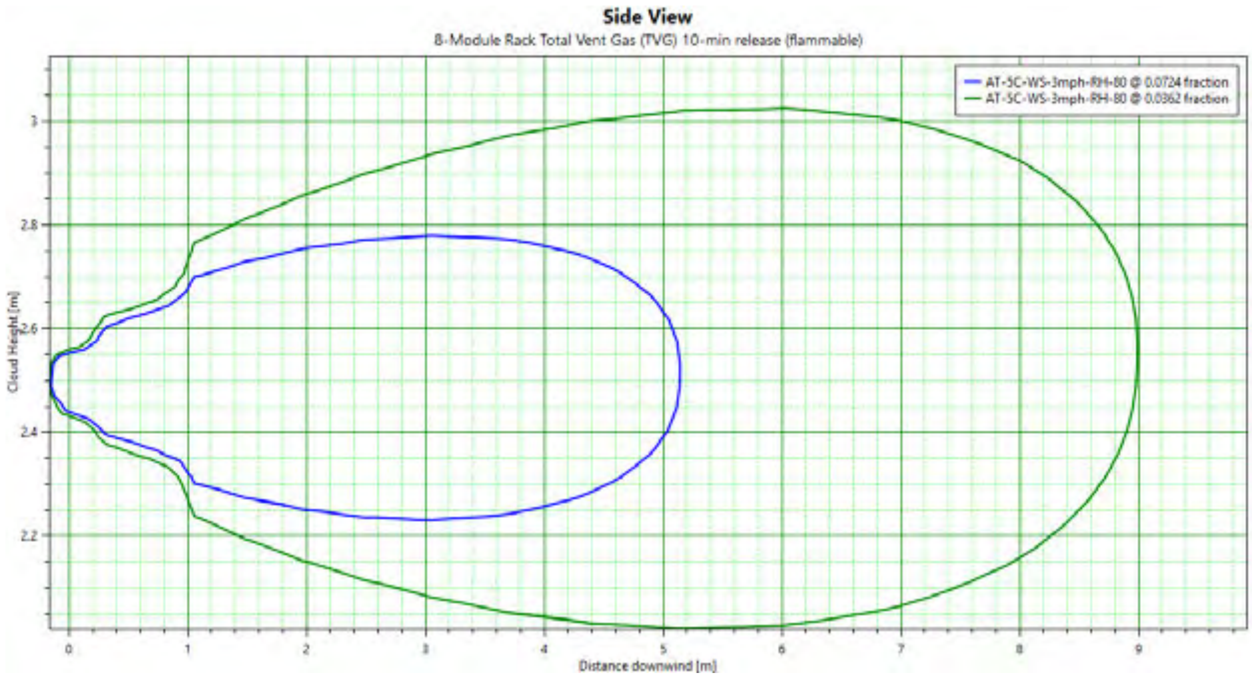


Figure 50 Maximum vertical extent of vapor cloud for LFL (7.24%) and ½ LFL (3.62%)

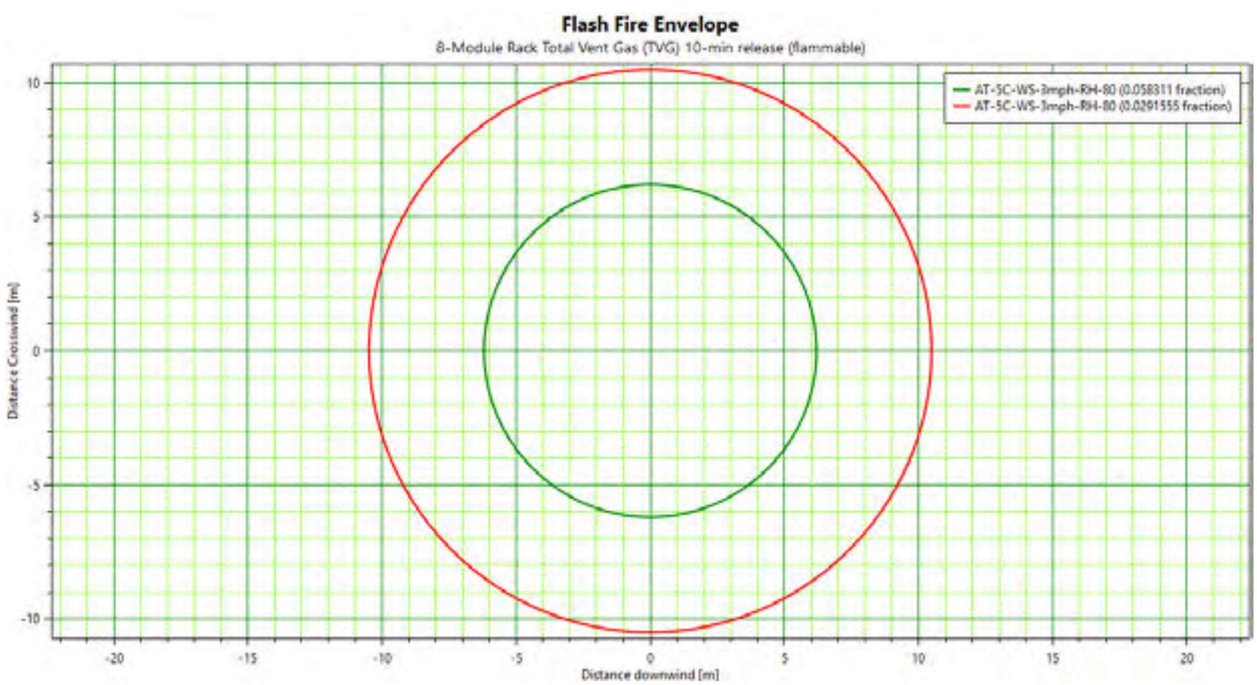


Figure 51 Flash Fire Envelope for LFL (7.24%) and ½ LFL (3.62%)

1.3.4 CO IDLH (1200 ppm) Component Extent (10 min Release)

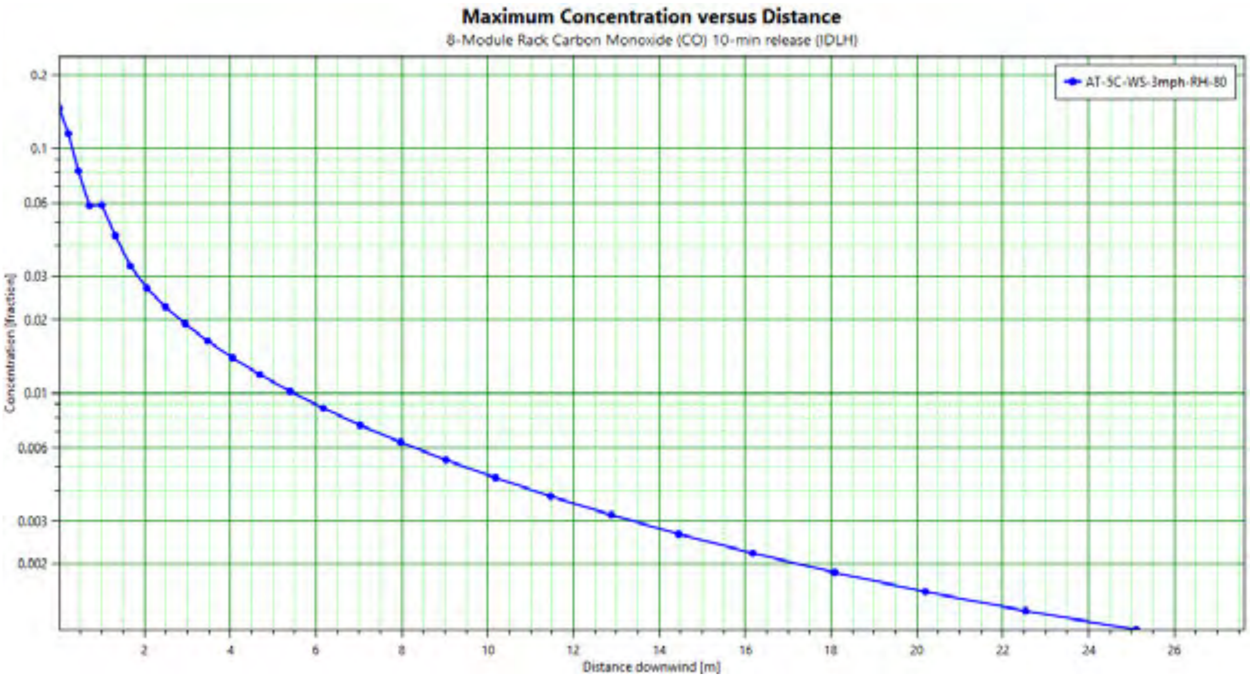


Figure 52 Maximum Concentration vs distance for CO gas component

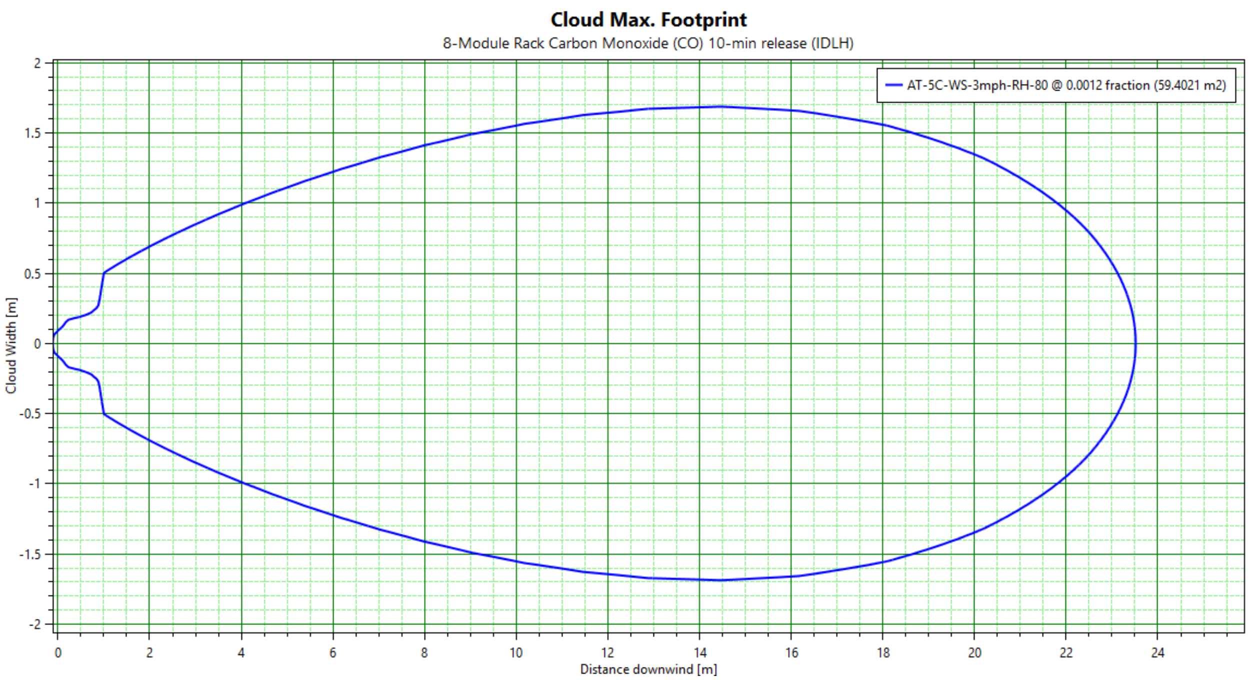


Figure 53 Maximum horizontal extent of vapor cloud for CO IDLH (1200 ppm)

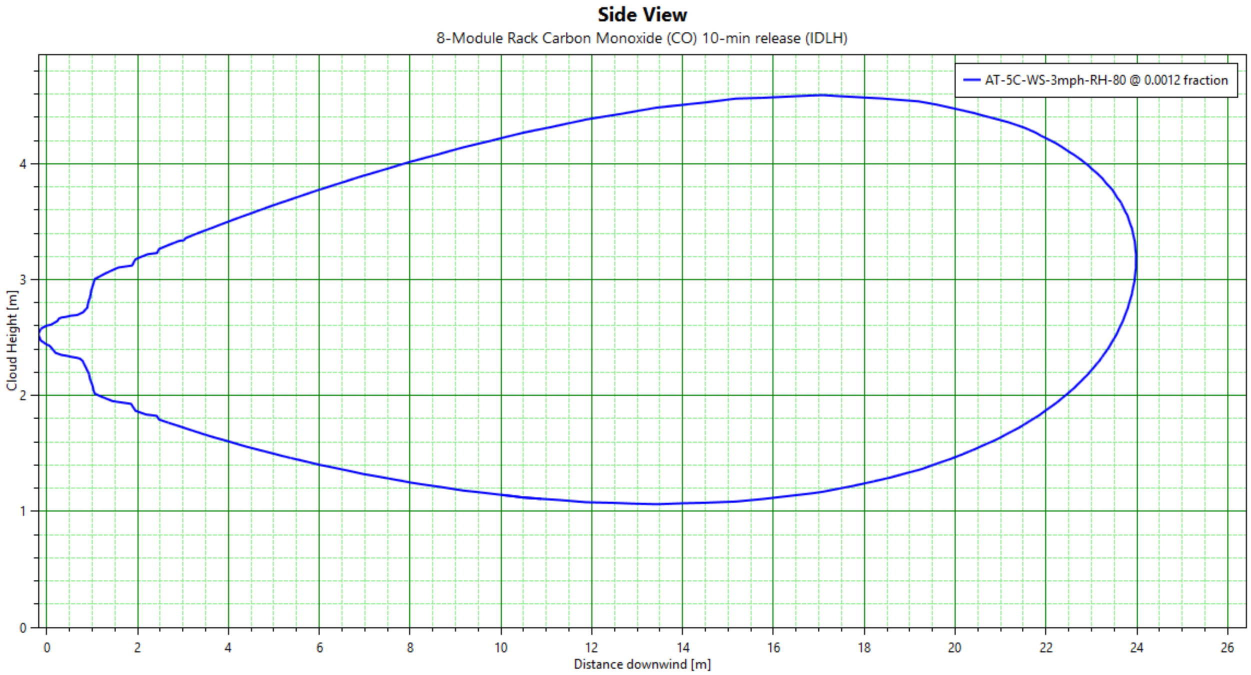


Figure 54 Maximum vertical extent of vapor cloud for CO IDLH (1200 ppm)

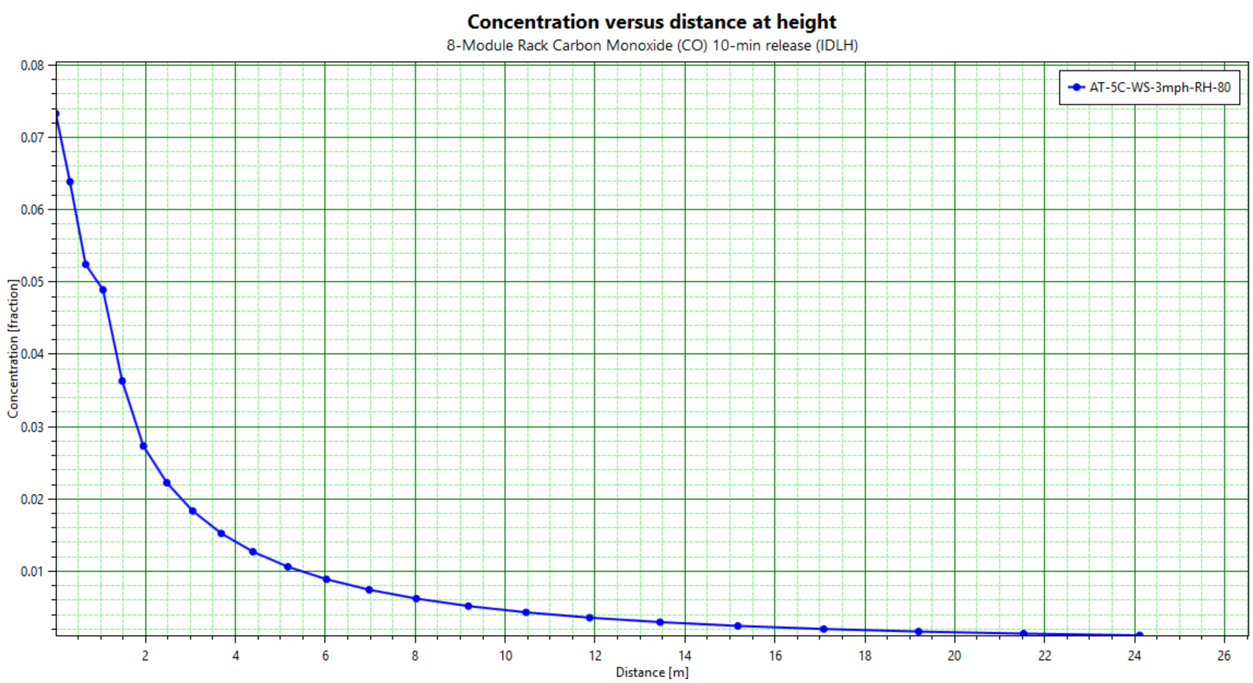


Figure 55 Concentration vs distance for CO IDLH (1200 ppm)

1.4 Scenario 4: 1-Container Release

1.4.1 TVG Flammable Vapor Cloud Extent (75.6 min Release)

Figure 56 Maximum concentration vs distance for flammable vapor cloud

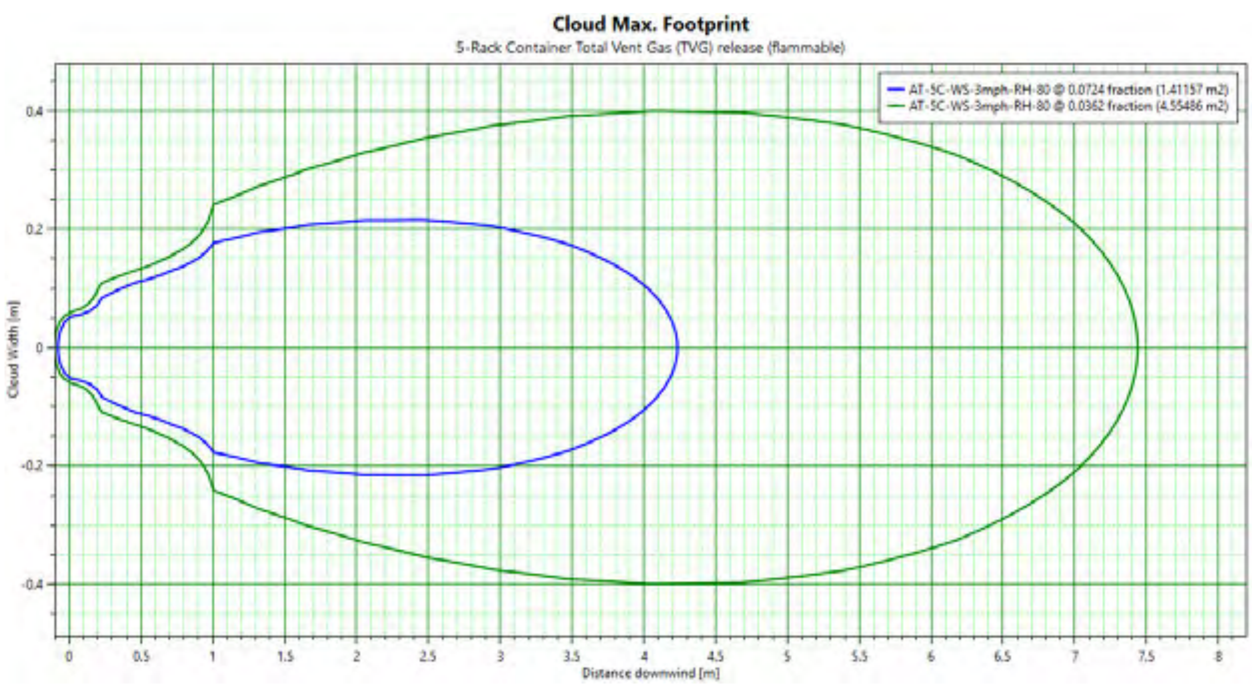


Figure 57 Maximum horizontal extent of vapor cloud for LFL (7.24%) and ½ LFL (3.62%)

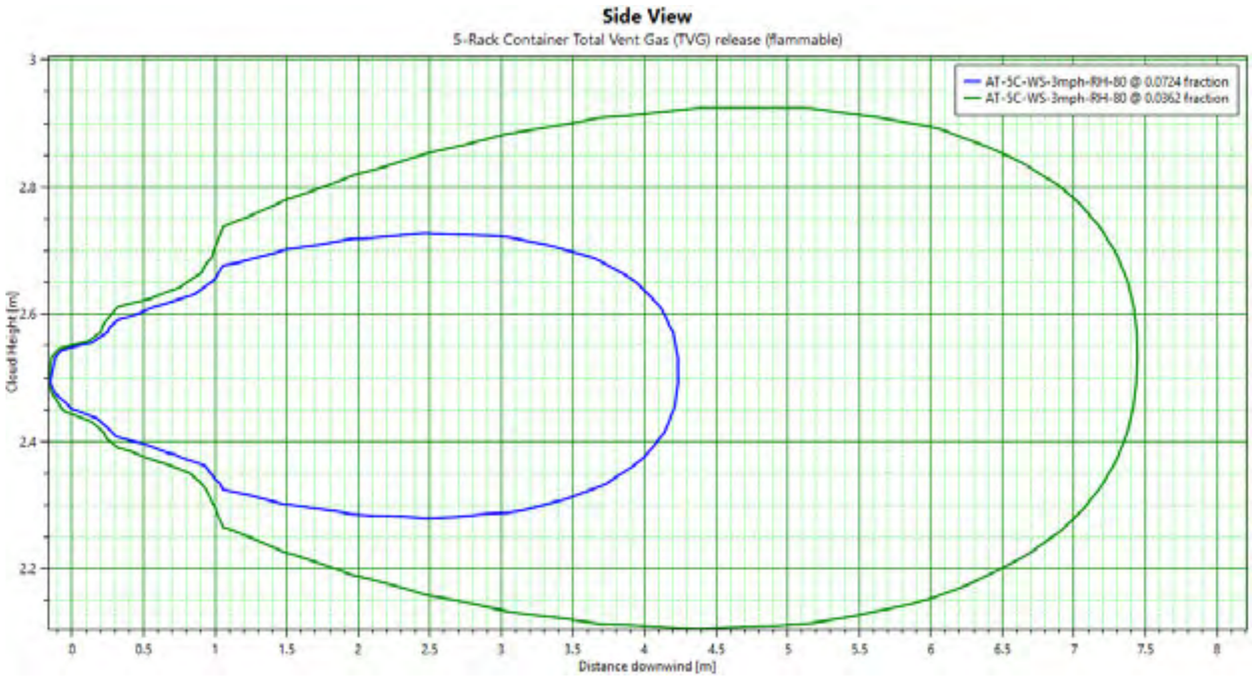


Figure 58 Maximum vertical extent of vapor cloud for LFL (7.24%) and ½ LFL (3.62%)

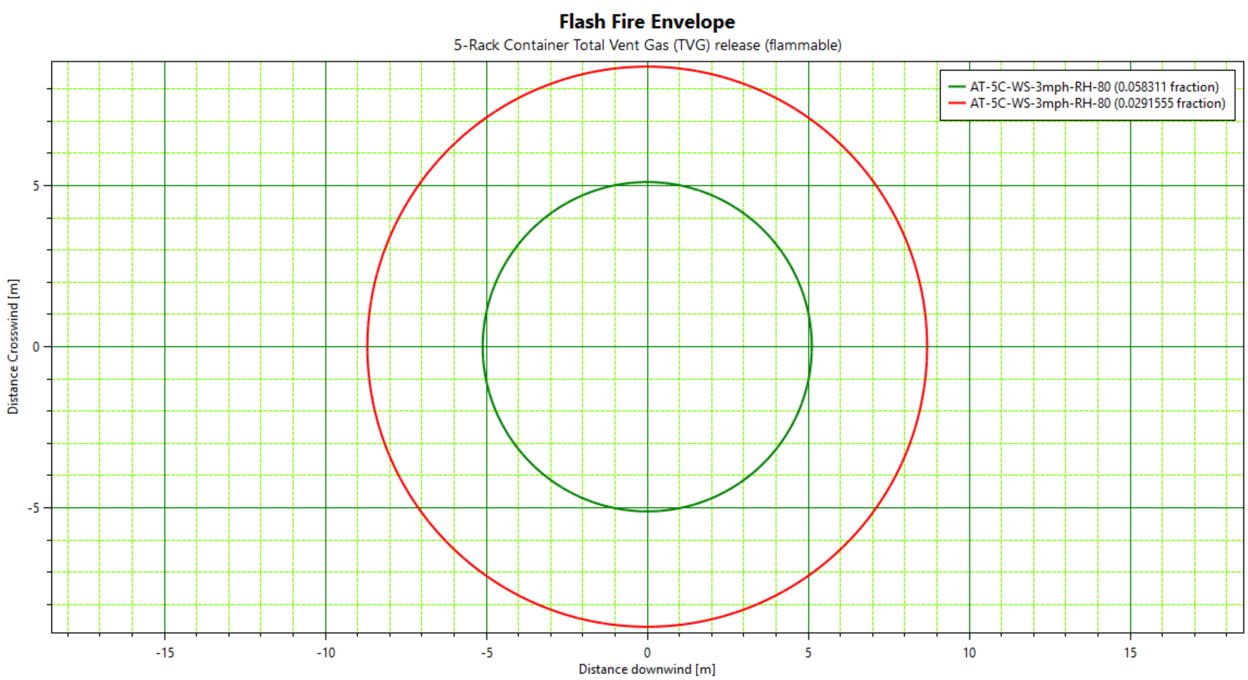


Figure 59 Flash Fire Envelope for LFL (7.24%) and ½ LFL (3.62%)

1.4.2 CO IDLH (1200 ppm) Component Extent (75.6 min Release)

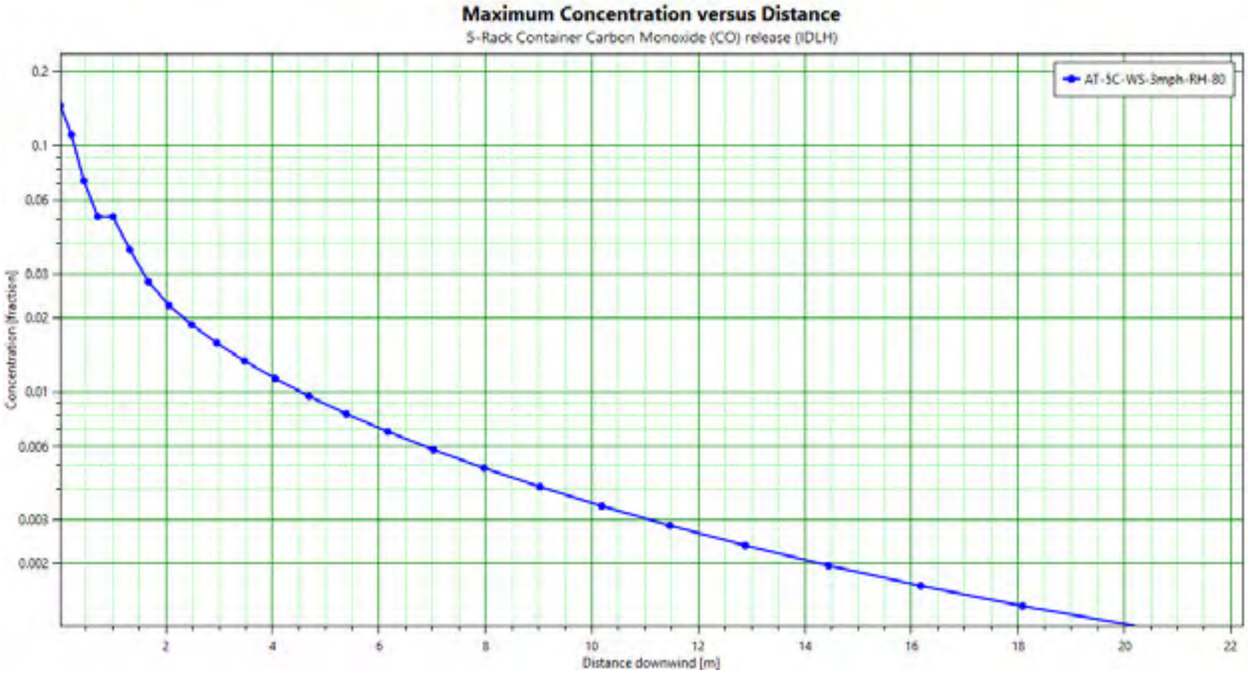


Figure 60 Maximum Concentration vs distance for CO gas component

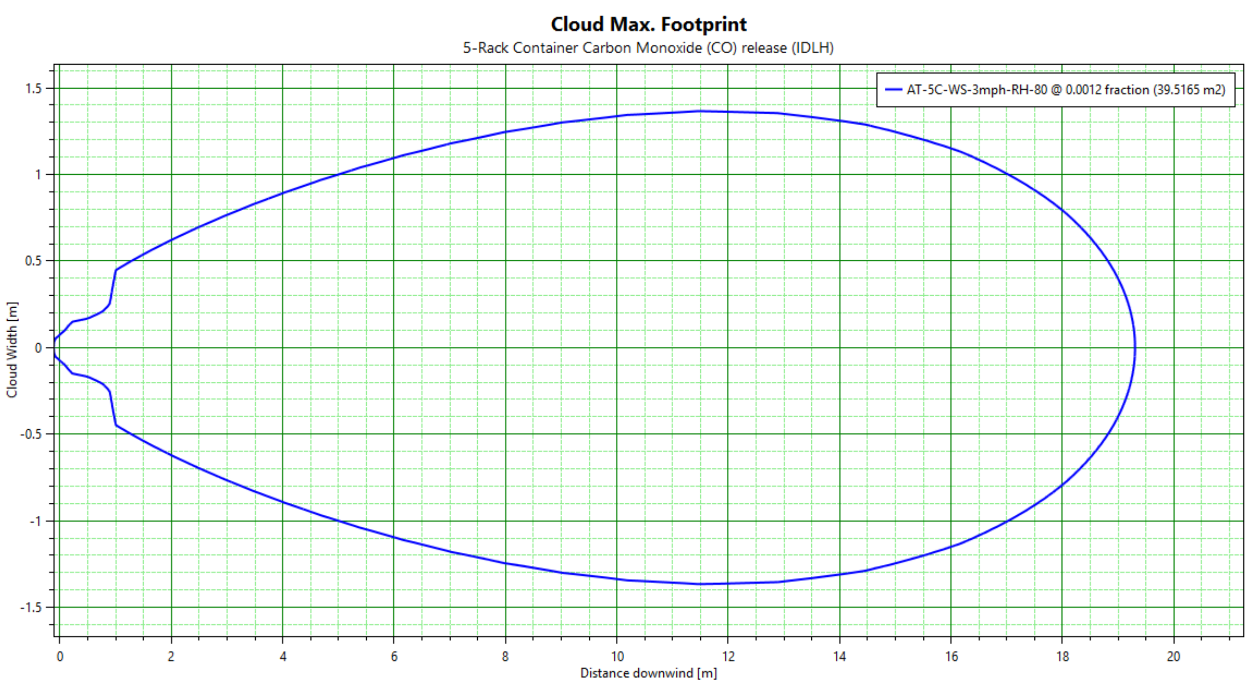


Figure 61 Maximum horizontal extent of vapor cloud for CO IDLH (1200 ppm)

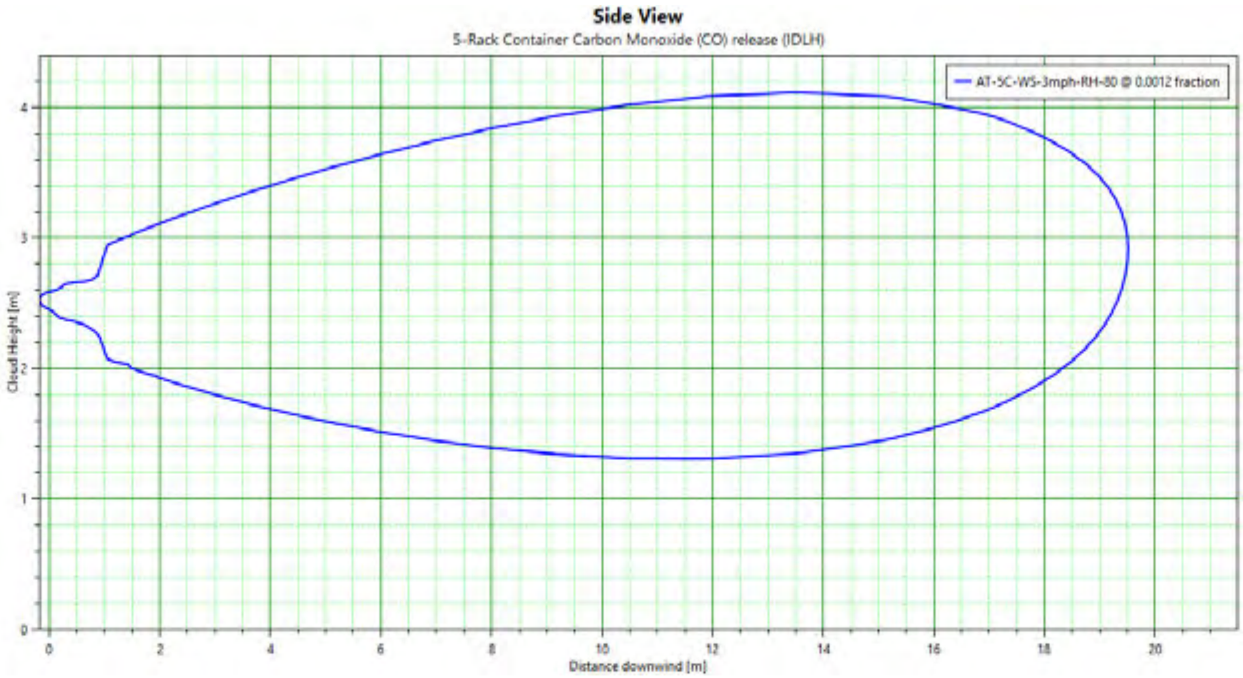


Figure 62 Maximum vertical extent of vapor cloud for CO IDLH (1200 ppm)

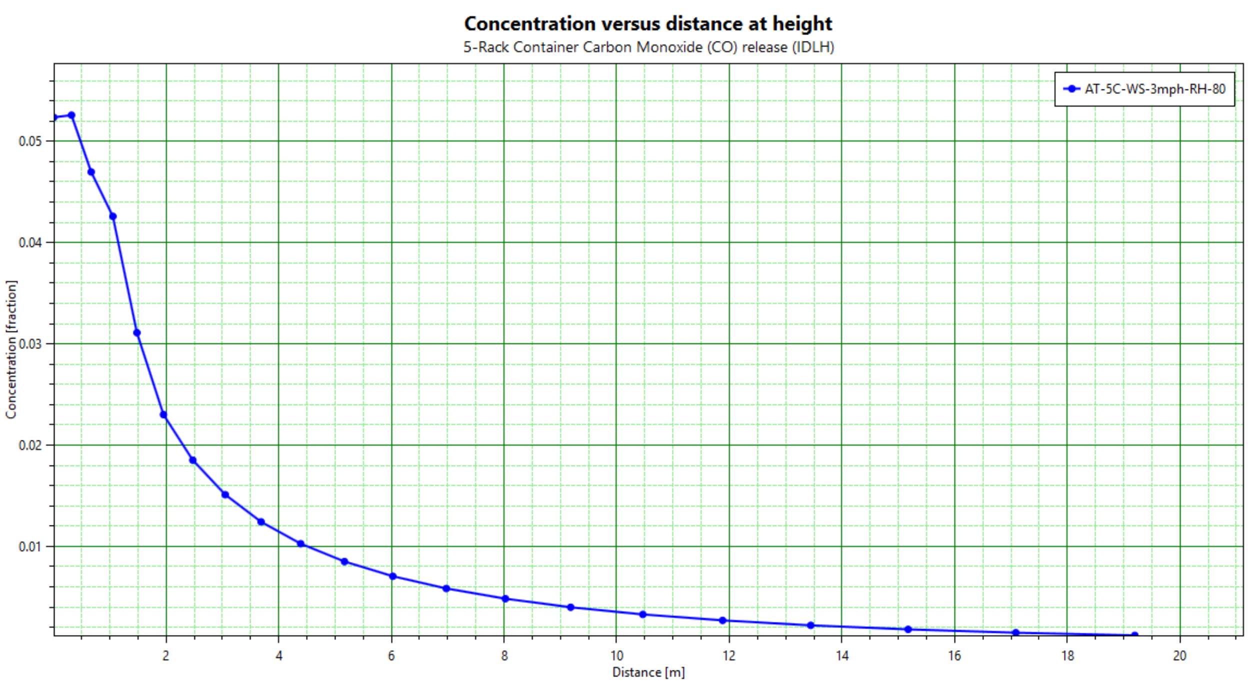


Figure 63 Concentration vs distance for CO IDLH (1200 ppm)

1.4.3 TVG Flammable Vapor Cloud Extent (10 min Release)

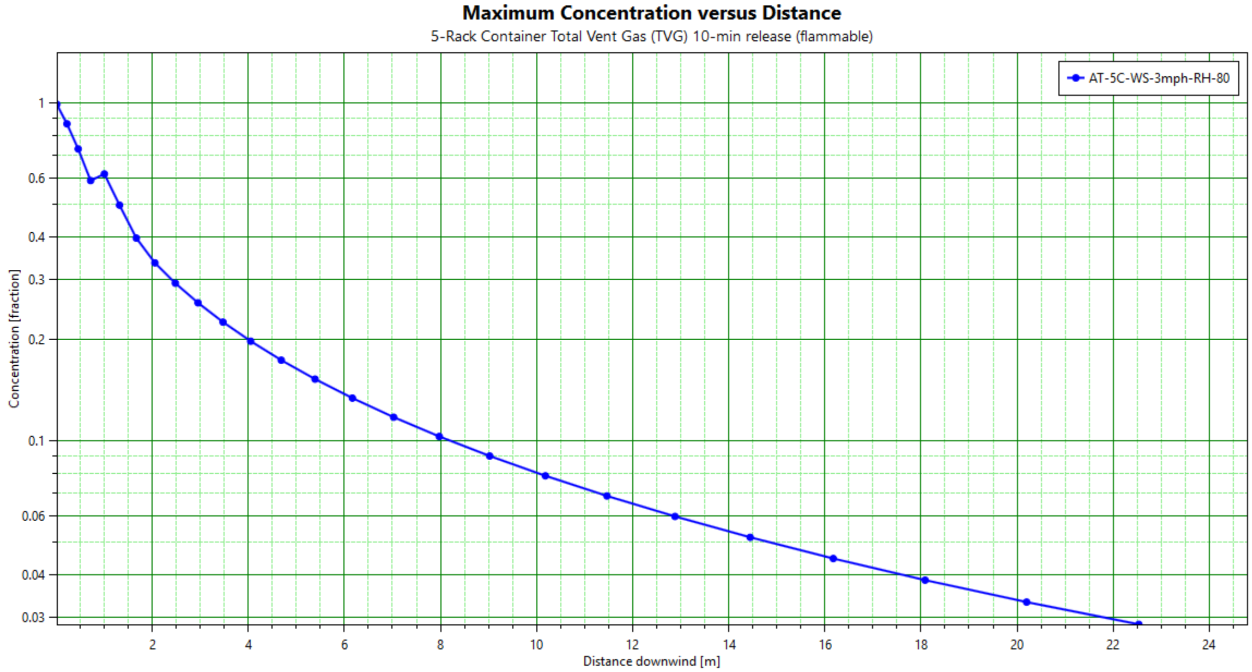


Figure 64 Maximum concentration vs distance for flammable vapor cloud

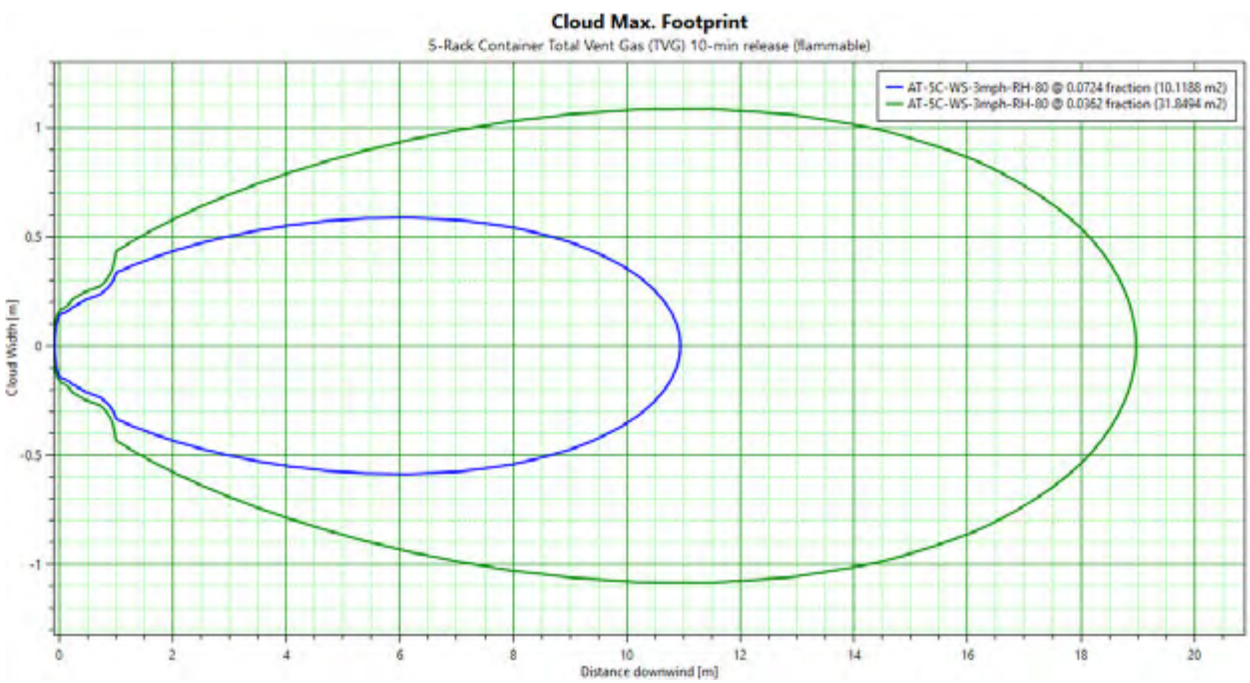


Figure 65 Maximum horizontal extent of vapor cloud for LFL (7.24%) and ½ LFL (3.62%)

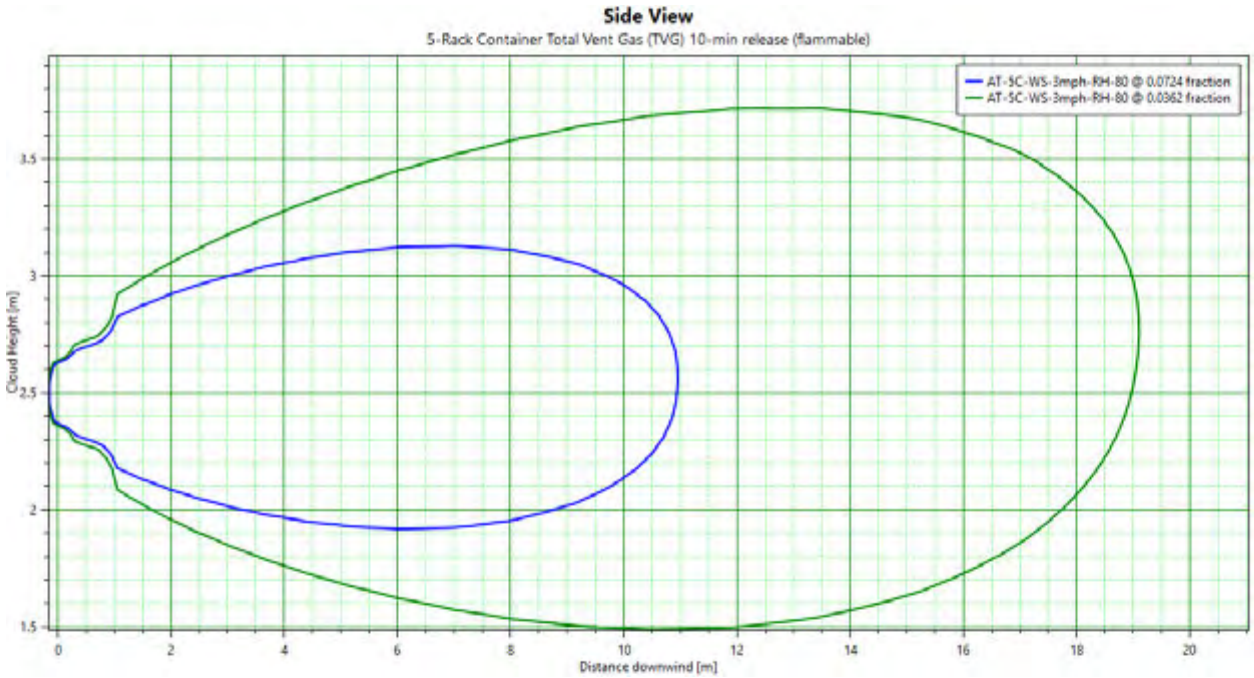


Figure 66 Maximum vertical extent of vapor cloud for LFL (7.24%) and ½ LFL (3.62%)

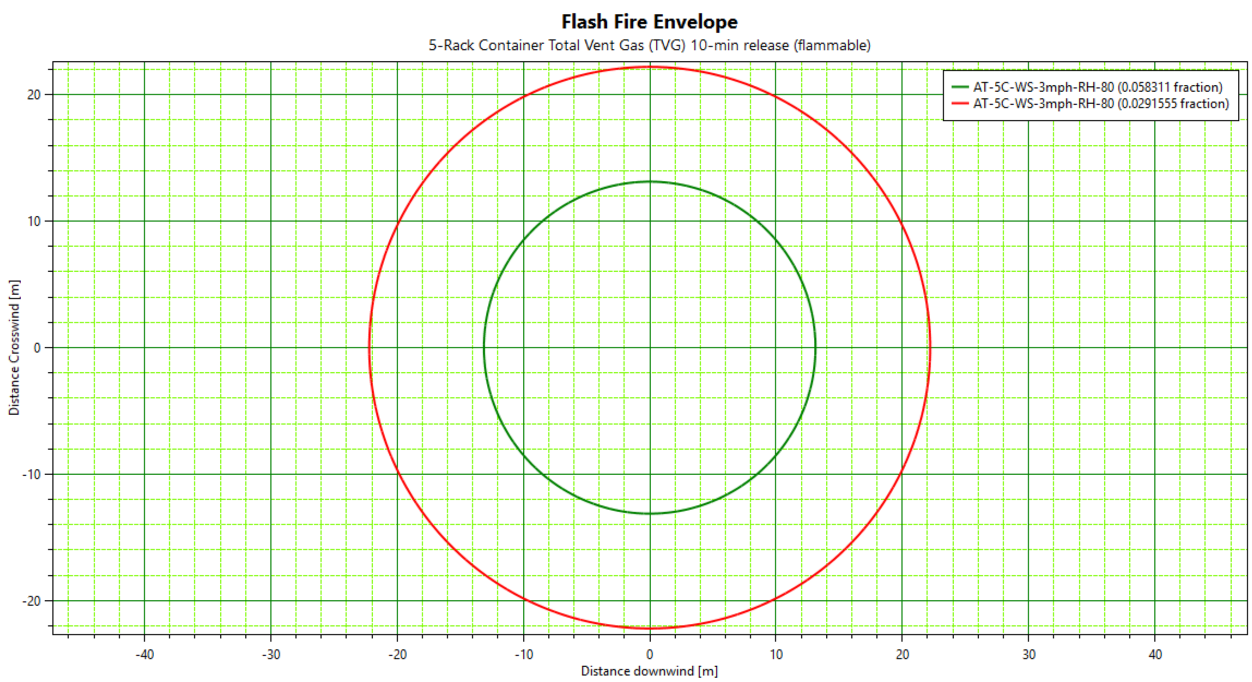


Figure 67 Flash Fire Envelope for LFL (7.24%) and ½ LFL (3.62%)

1.4.4 CO IDLH (1200 ppm) Component Extent (10 min Release)

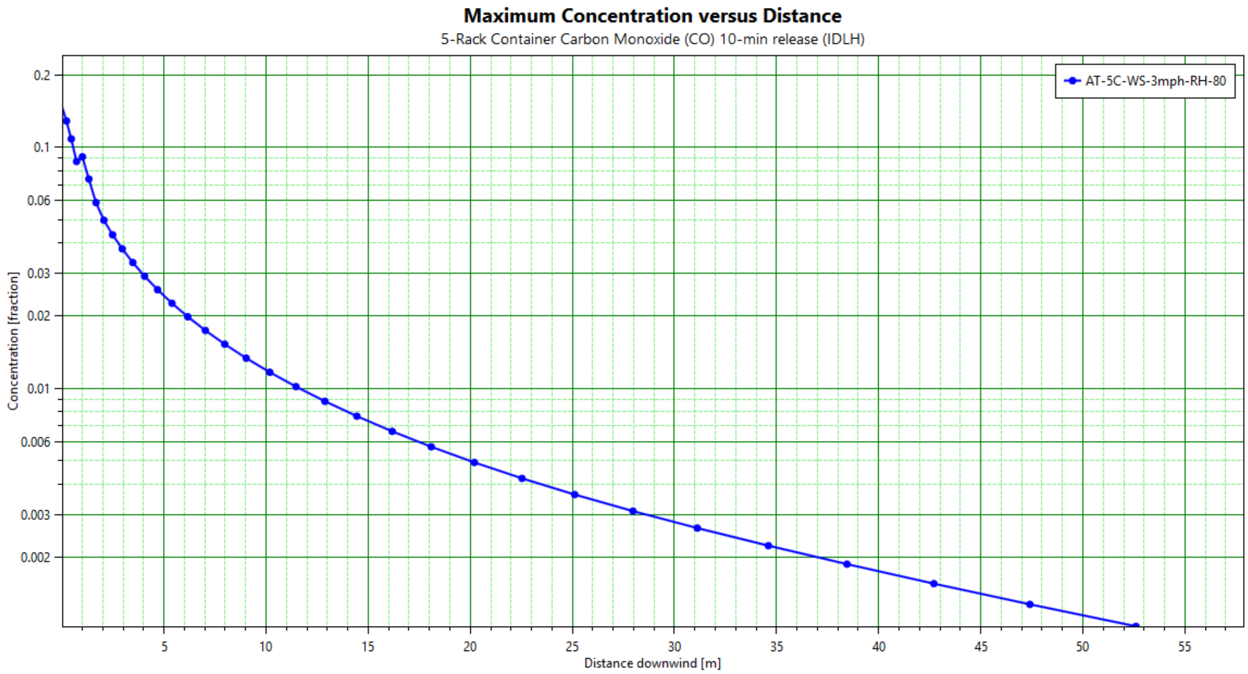


Figure 68 Maximum Concentration vs distance for CO gas component

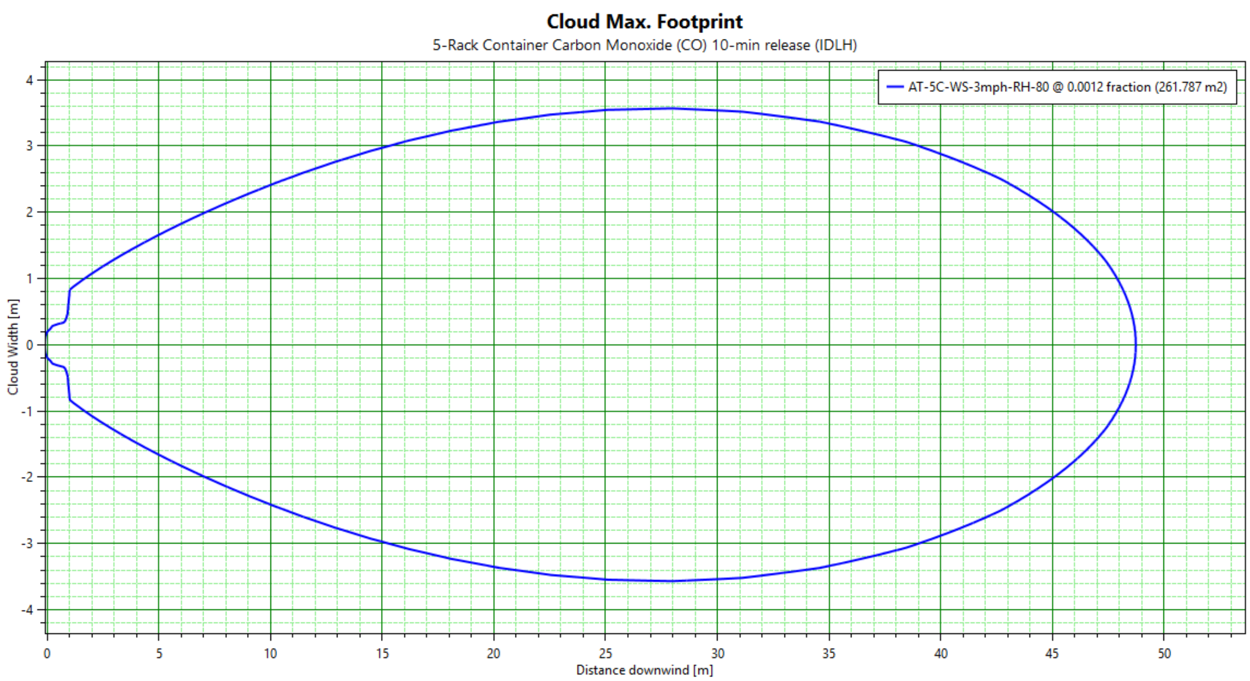


Figure 69 Maximum horizontal extent of vapor cloud for CO IDLH (1200 ppm)

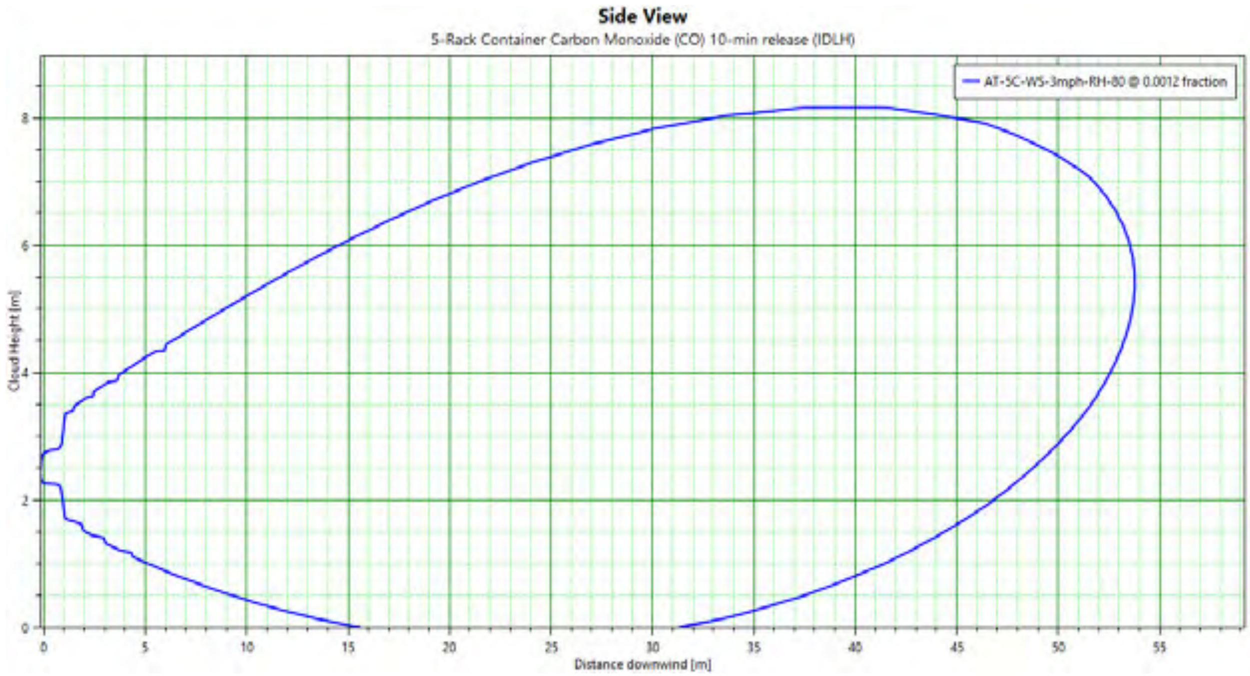


Figure 70 Maximum vertical extent of vapor cloud for CO IDLH (1200 ppm)

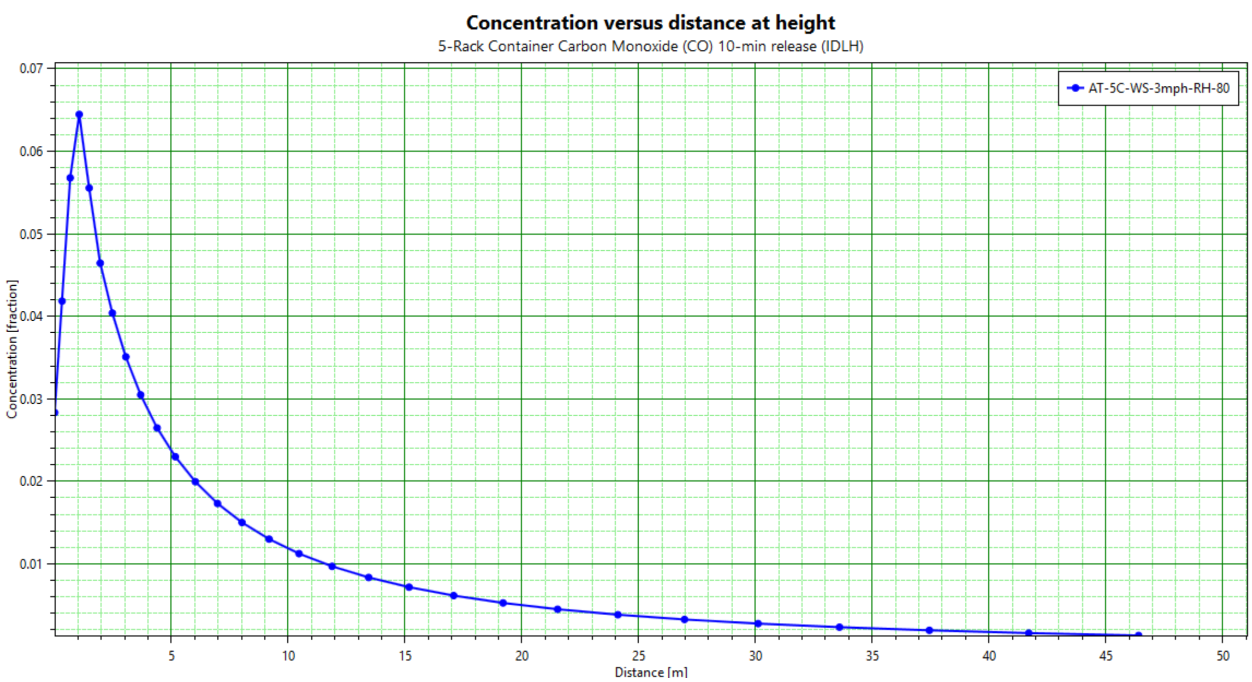


Figure 71 Concentration vs distance for CO IDLH (1200 ppm)

1.5 Summary Results for Vent Gas LFL Extent

1.5.1 Scenario 1: UL9540A Thermal Runaway (4-Cells)

Figure 72 Maximum concentration vs distance for flammable vapor cloud for all sub-scenarios

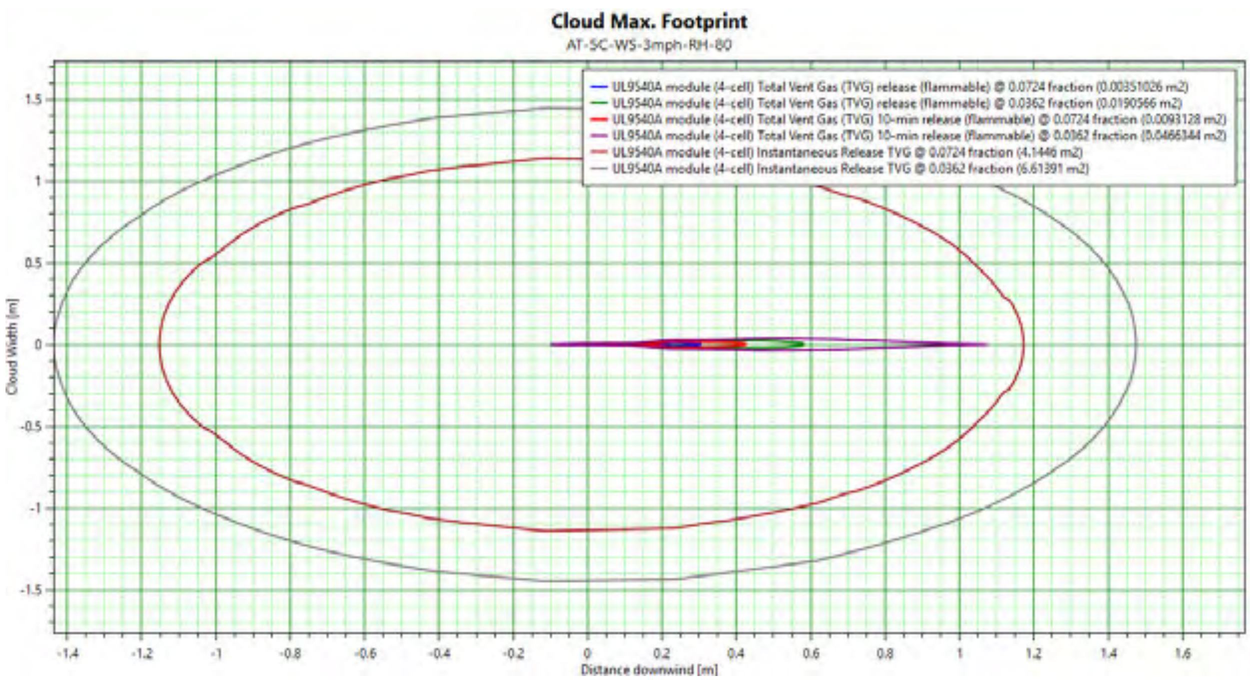


Figure 73 Maximum horizontal extent of vapor cloud for LFL (7.24%) and ½ LFL (3.62%) for all sub-scenarios

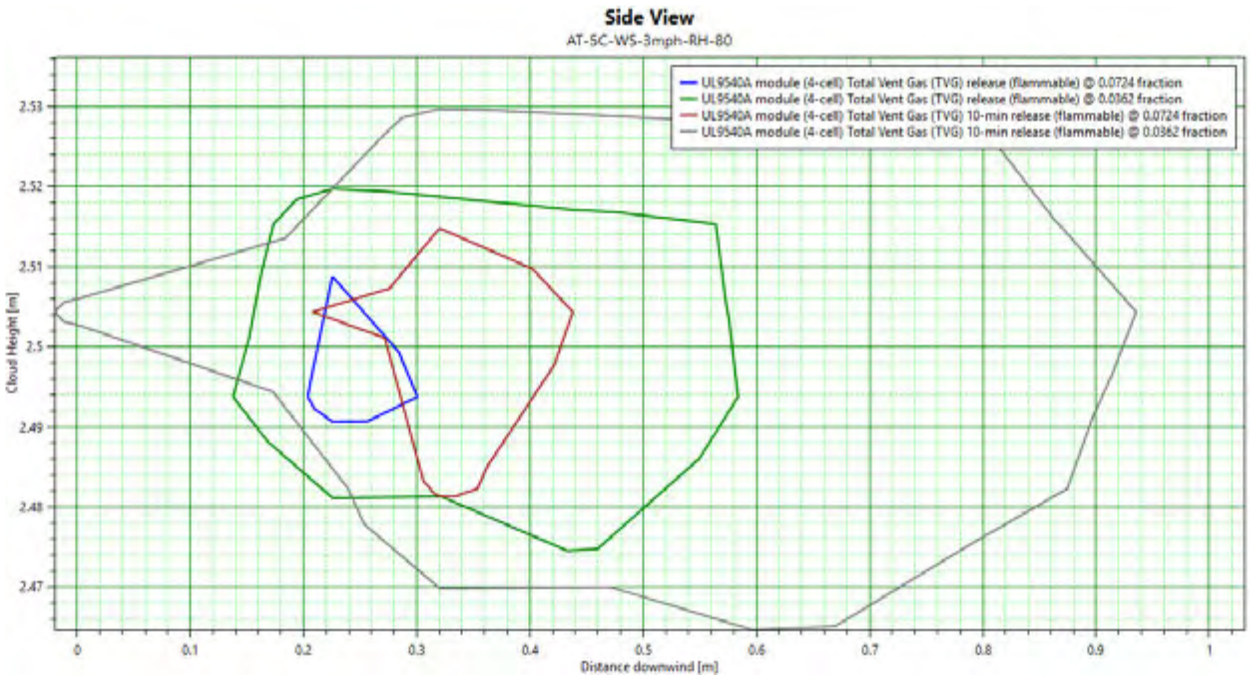


Figure 74 Maximum vertical extent of vapor cloud for LFL (7.24%) and ½ LFL (3.62%) for all sub-scenarios

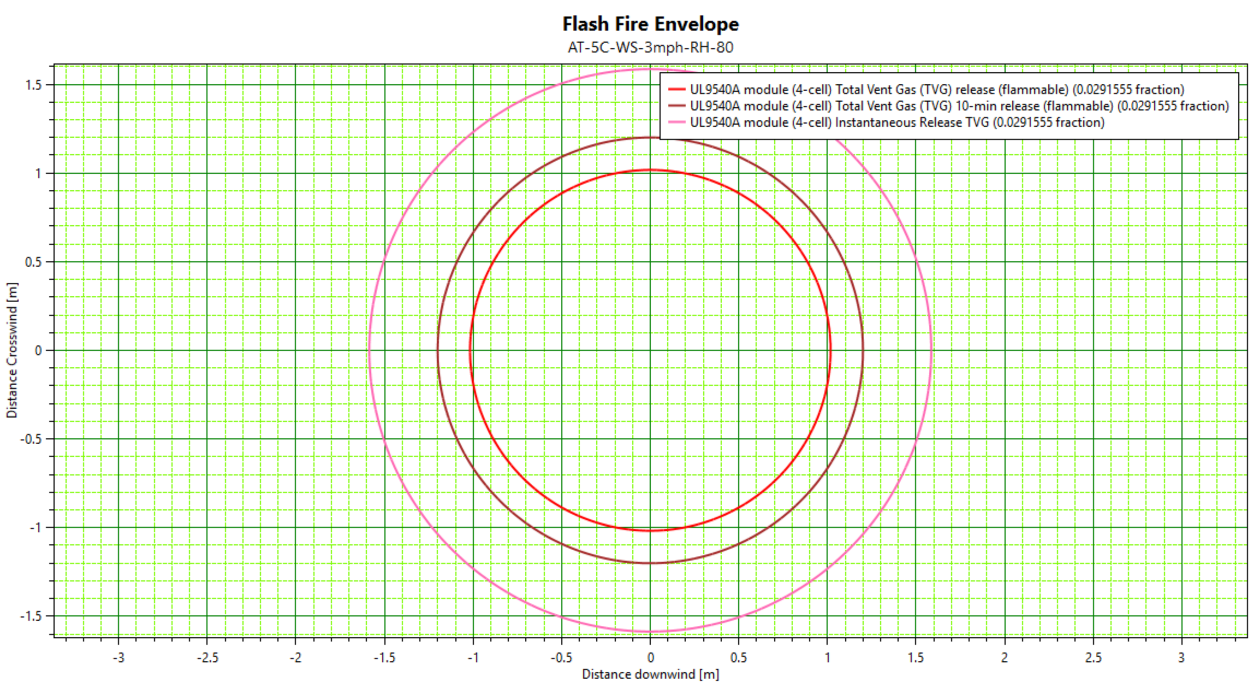


Figure 75 Flash Fire Envelope for ½ LFL (3.62%) for all sub-scenarios

1.5.2 Scenario 2: 1-Module Release

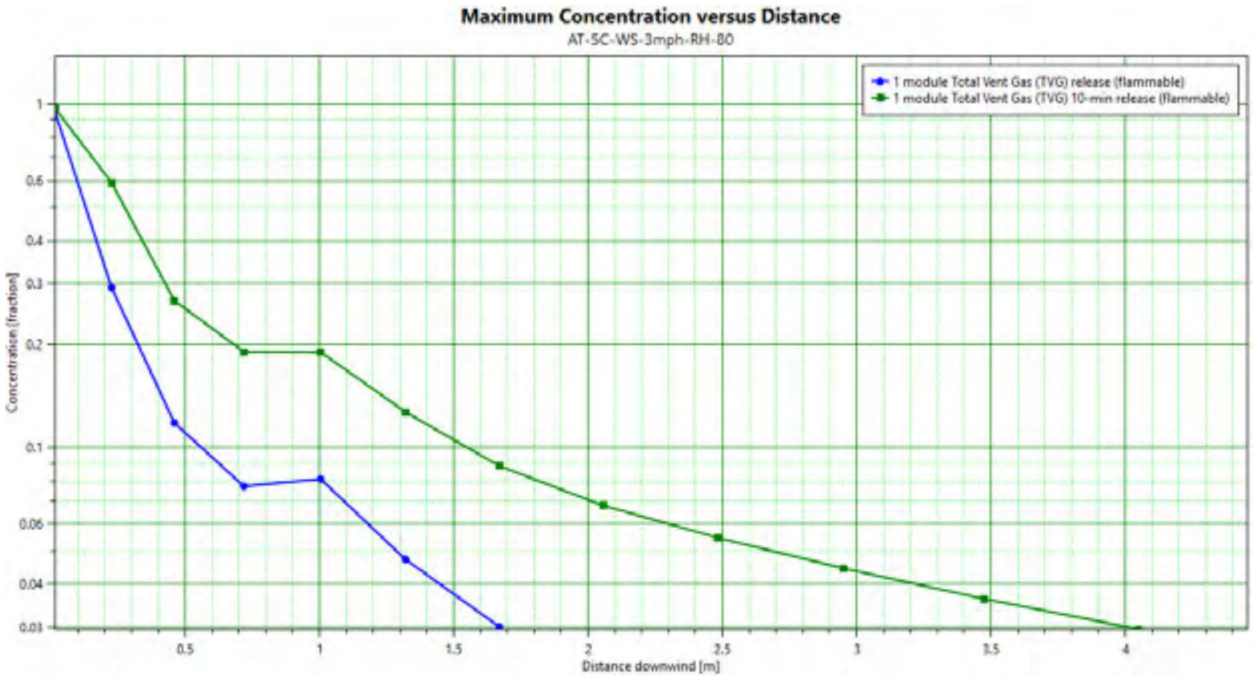


Figure 76 Maximum concentration vs distance for flammable vapor cloud for all sub-scenarios

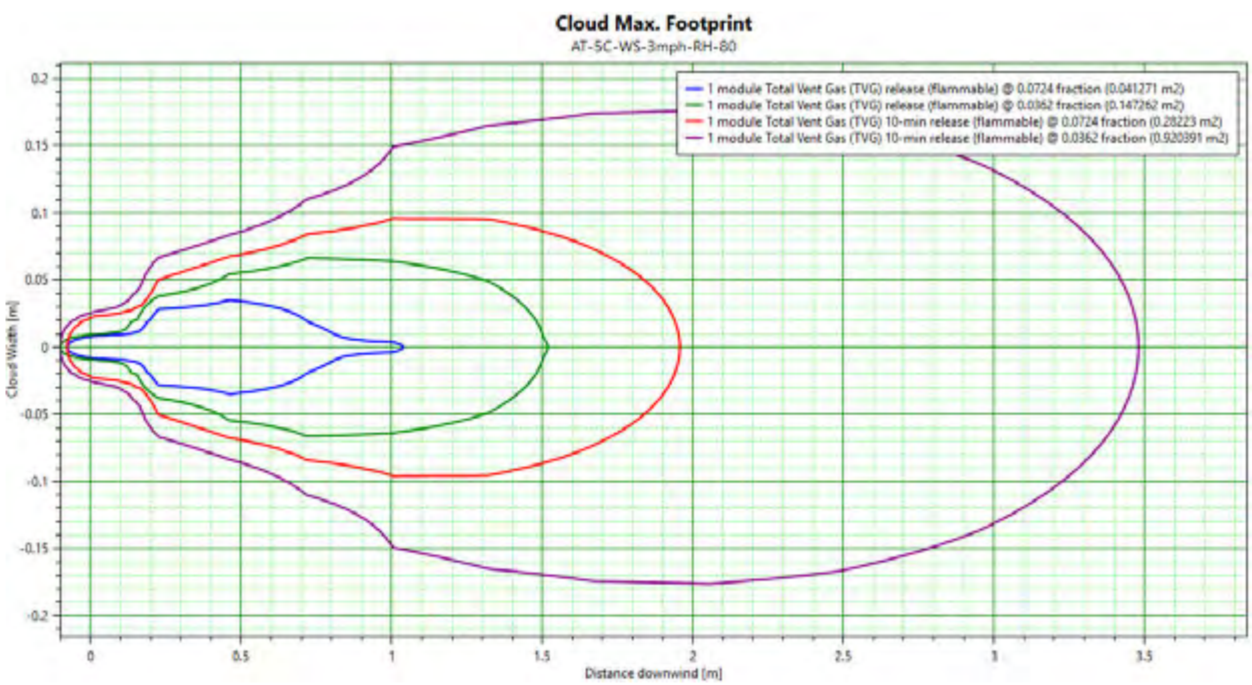


Figure 77 Maximum horizontal extent of vapor cloud for LFL (7.24%) and ½ LFL (3.62%) for all sub-scenarios

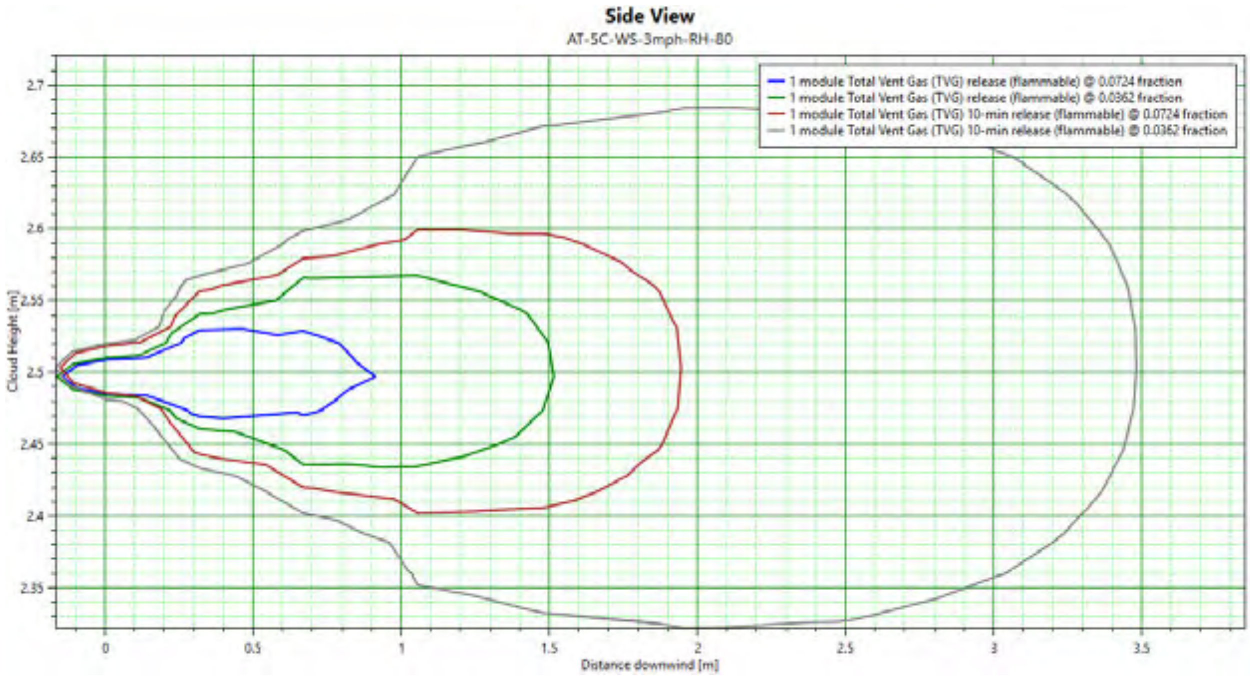


Figure 78 Maximum vertical extent of vapor cloud for LFL (7.24%) and ½ LFL (3.62%) for all sub-scenarios

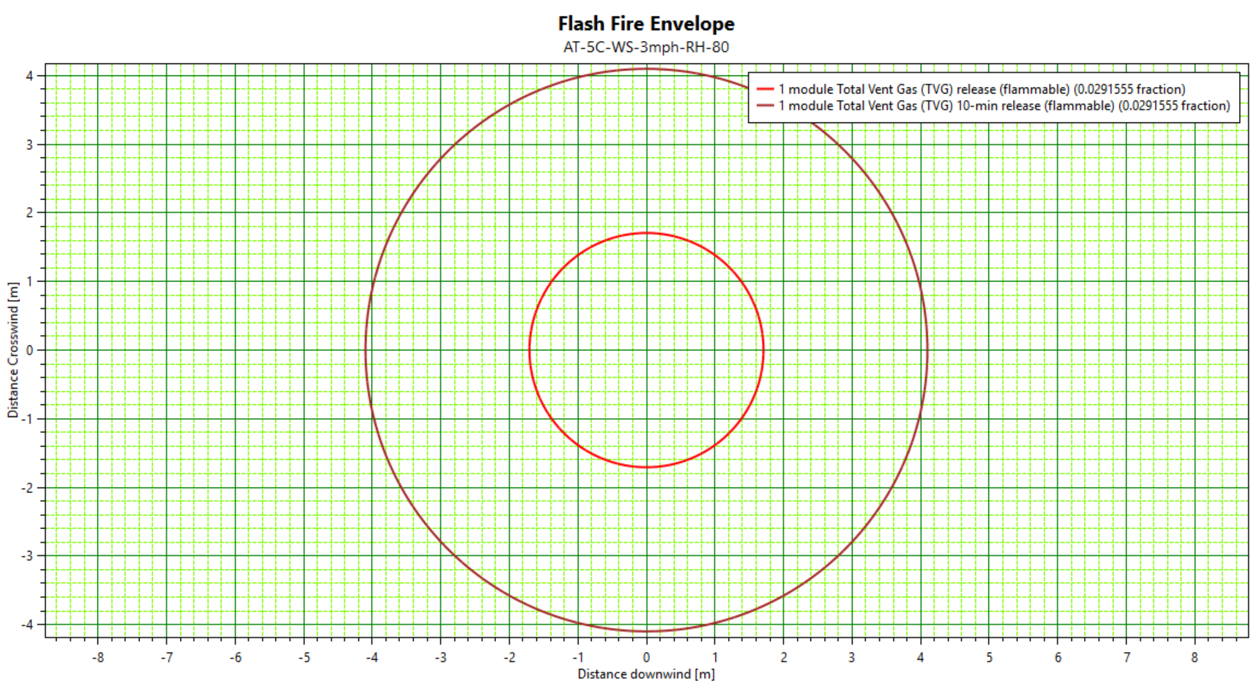


Figure 79 Flash Fire Envelope for ½ LFL (3.62%) for all sub-scenarios

1.5.3 Scenario 3: 1-Rack Release

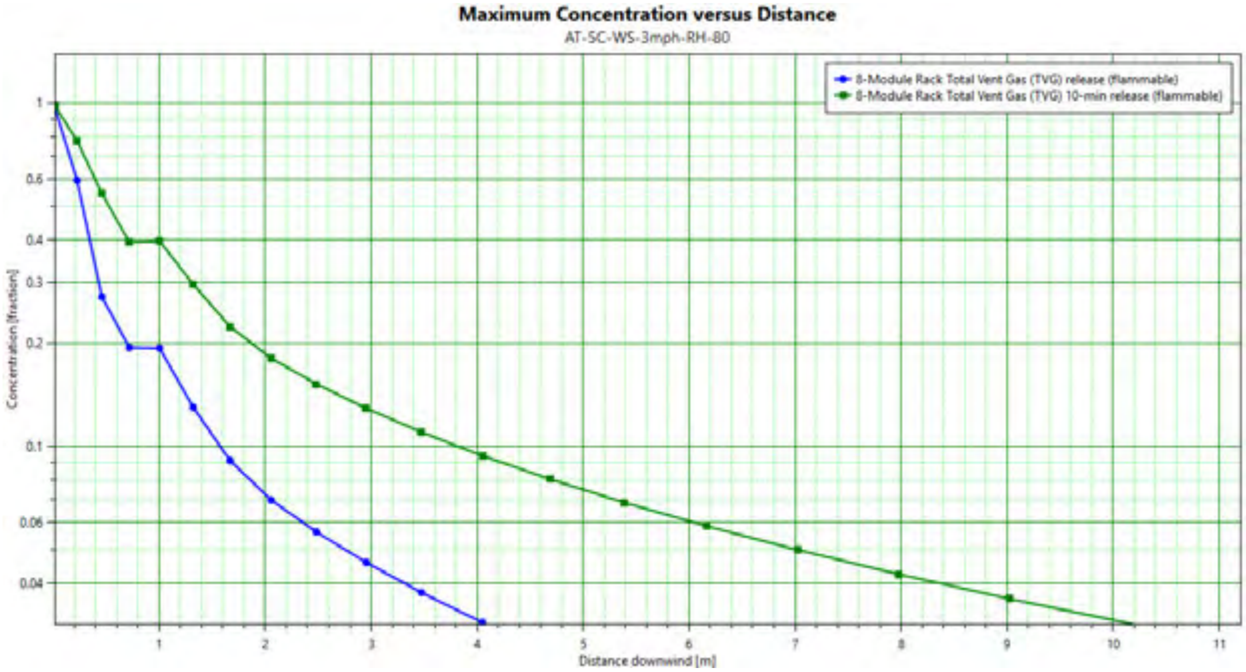


Figure 80 Maximum concentration vs distance for flammable vapor cloud for all sub-scenarios

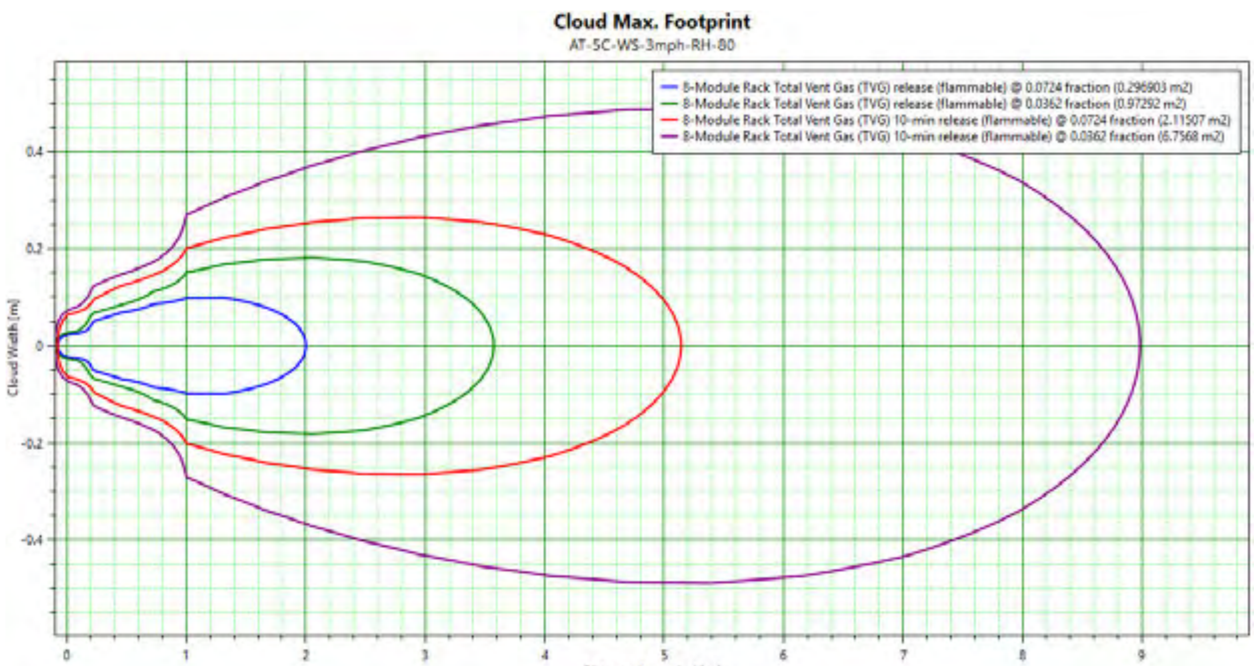


Figure 81 Maximum horizontal extent of vapor cloud for LFL (7.24%) and ½ LFL (3.62%) for all sub-scenarios

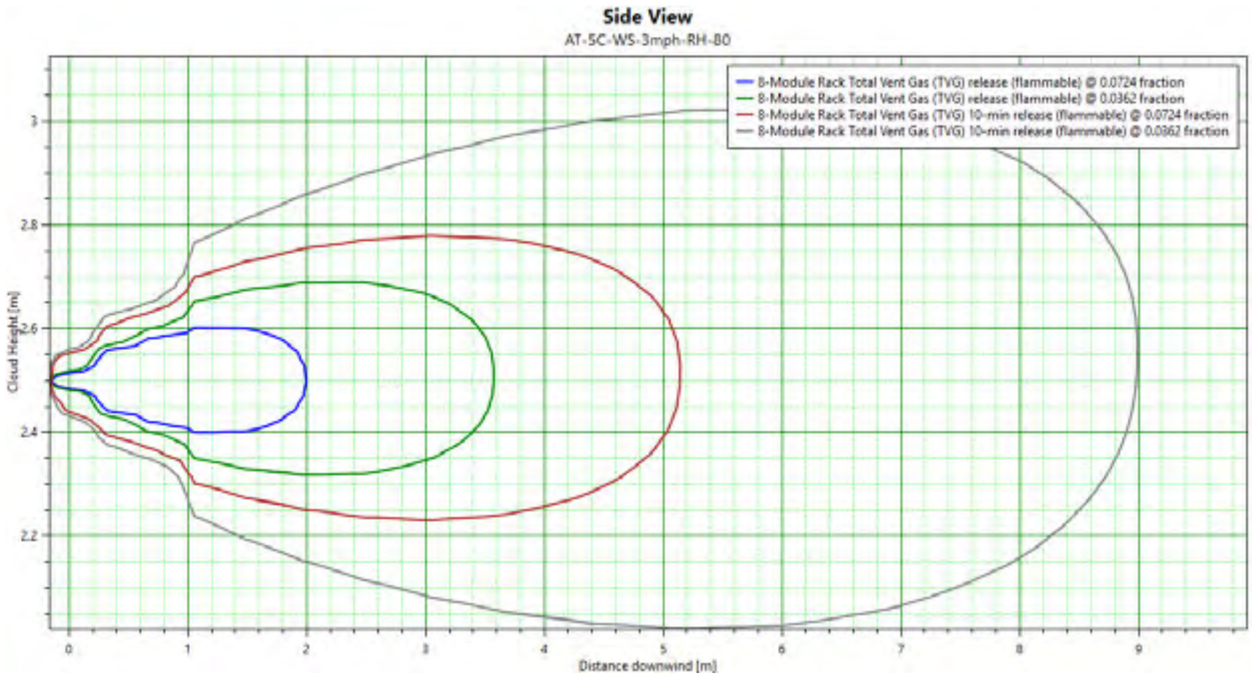


Figure 82 Maximum vertical extent of vapor cloud for LFL (7.24%) and ½ LFL (3.62%) for all sub-scenarios

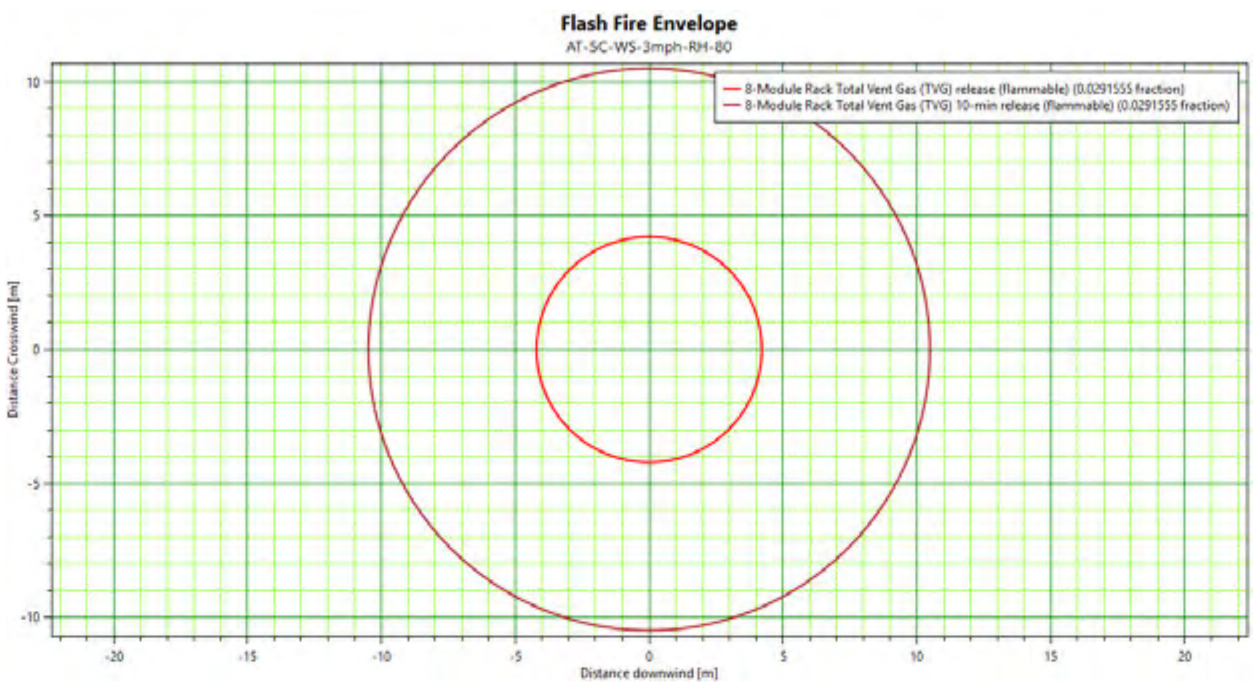


Figure 83 Flash Fire Envelope for ½ LFL (3.62%) for all sub-scenarios

1.5.4 Scenario 4: 1-Container Release

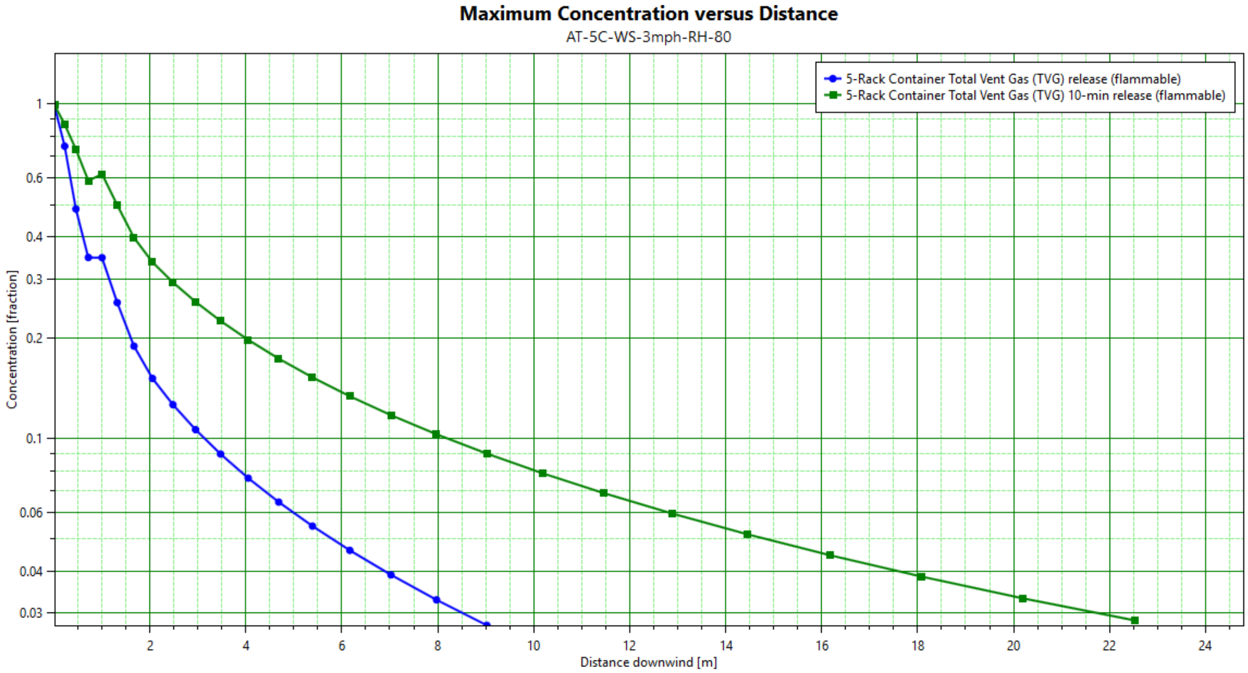


Figure 84 Maximum concentration vs distance for flammable vapor cloud for all sub-scenarios

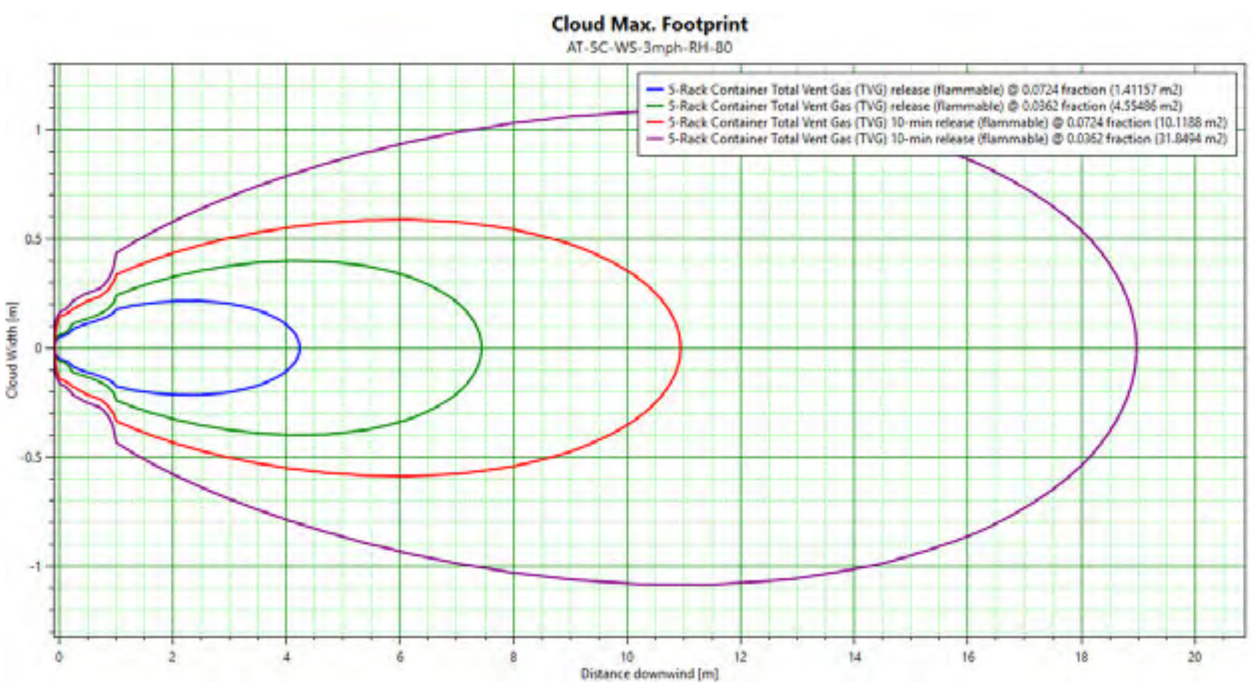


Figure 85 Maximum horizontal extent of vapor cloud for LFL (7.24%) and ½ LFL (3.62%) for all sub-scenarios

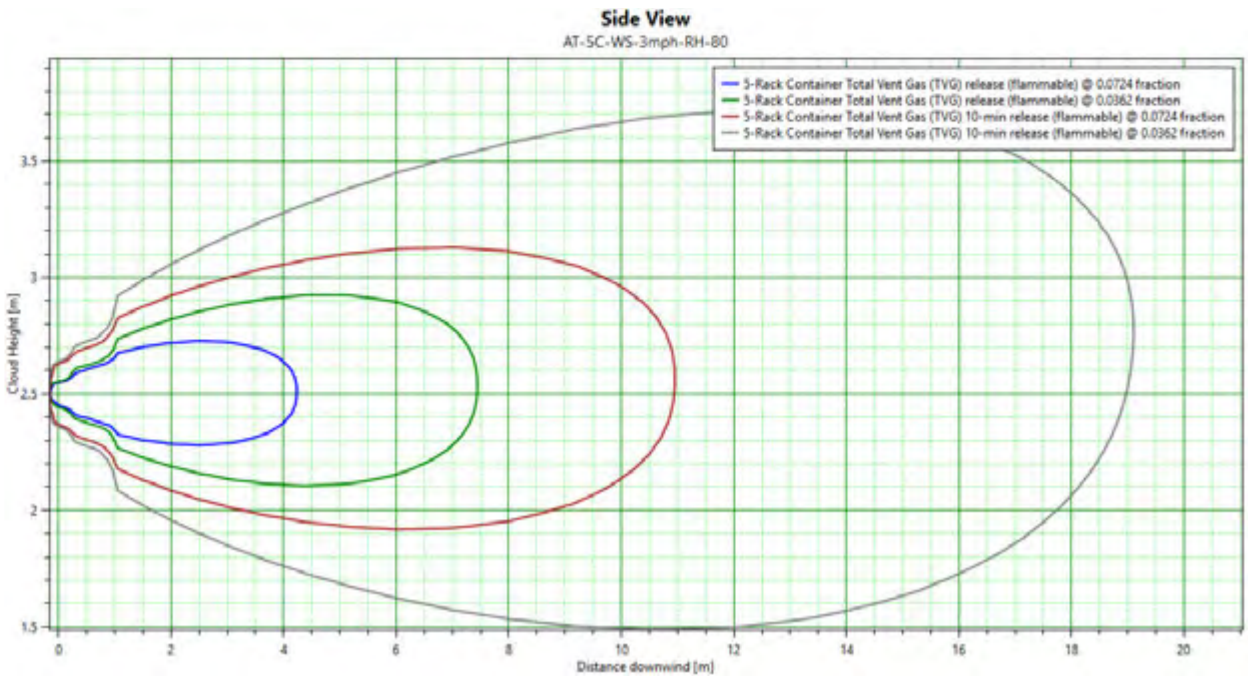


Figure 86 Maximum vertical extent of vapor cloud for LFL (7.24%) and ½ LFL (3.62%) for all sub-scenarios

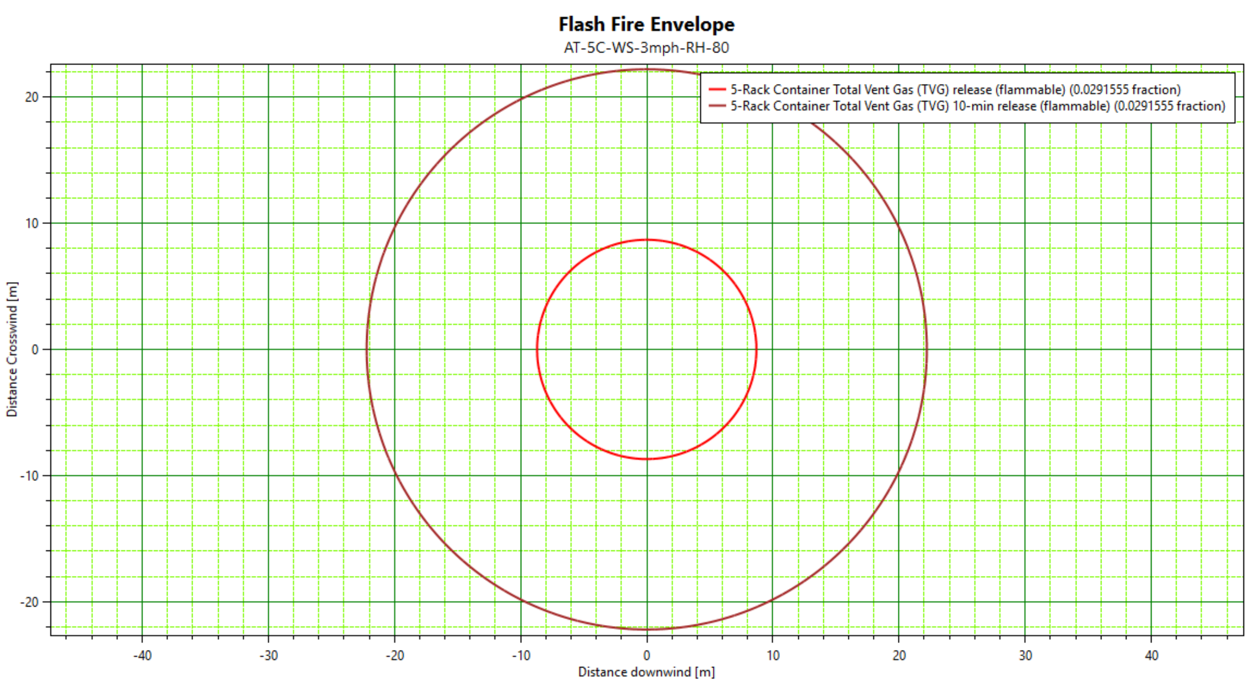


Figure 87 Flash Fire Envelope for ½ LFL (3.625%) for all sub-scenarios

1.6 Summary Results for Vent Gas CO IDLH (1200ppm) Extent

1.6.1 Scenario 1: UL9540A Thermal Runaway (4-Cells)

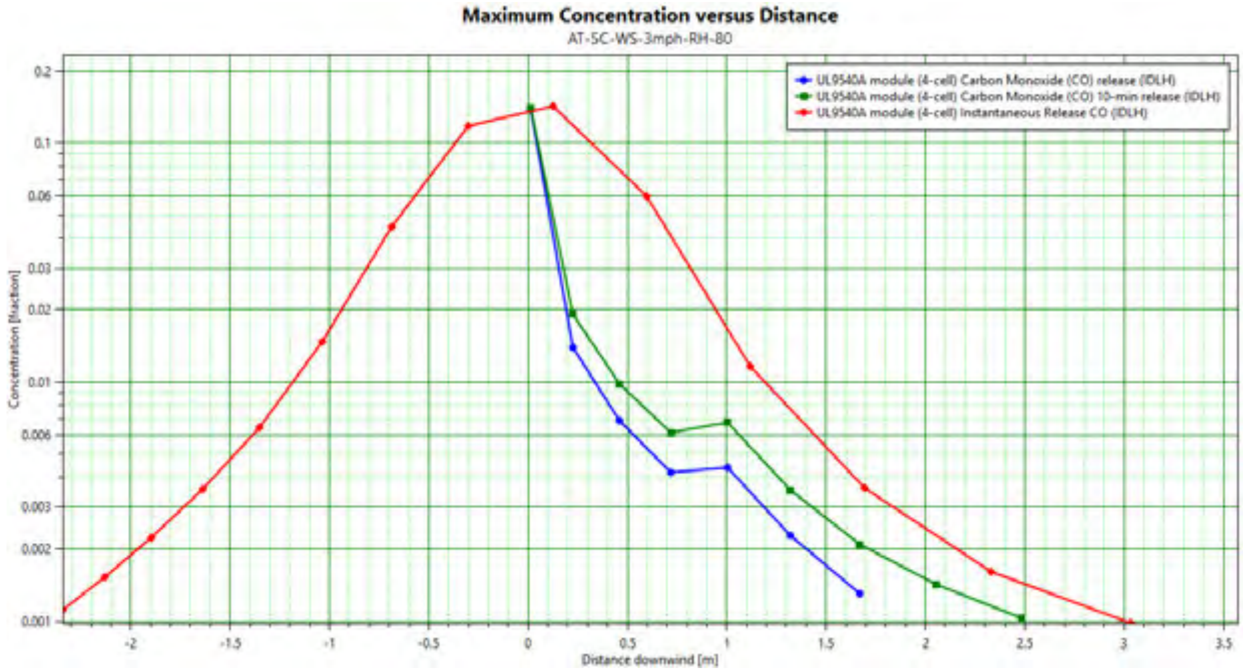


Figure 88 Maximum concentration vs distance at height (2.5 m) for CO IDLH (1200ppm) for all sub-scenarios

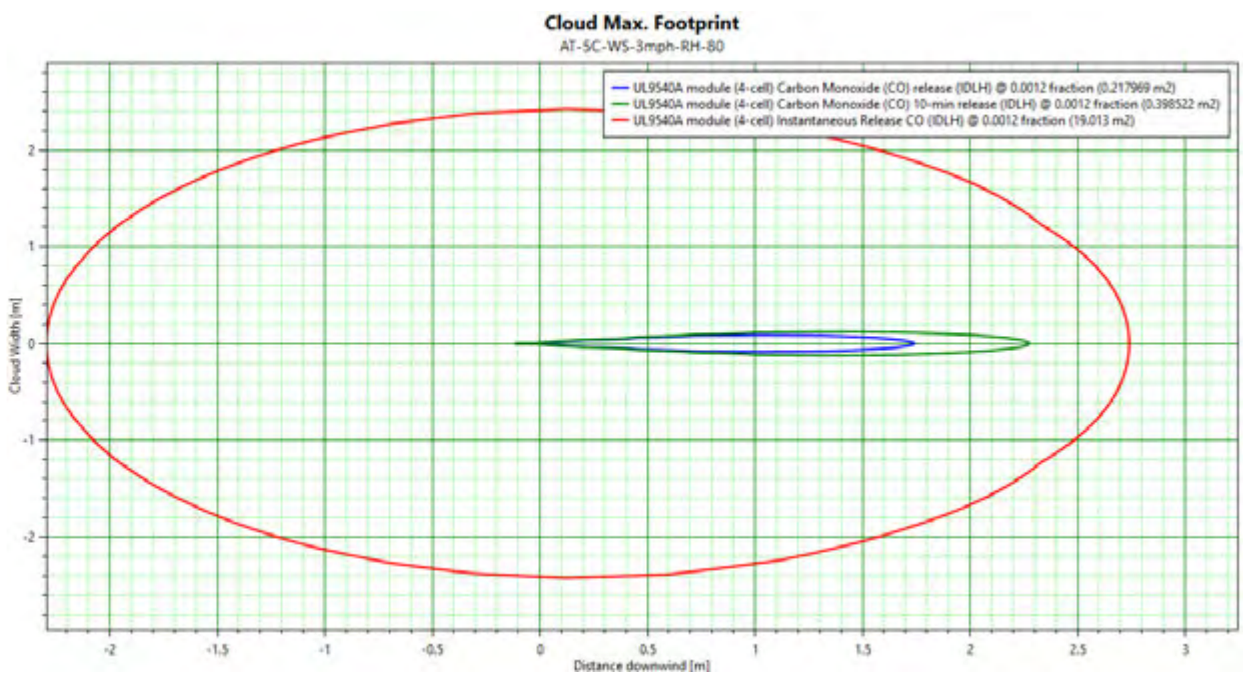


Figure 89 Maximum horizontal extent of vapor cloud for CO IDLH (1200 ppm) for all sub-scenarios

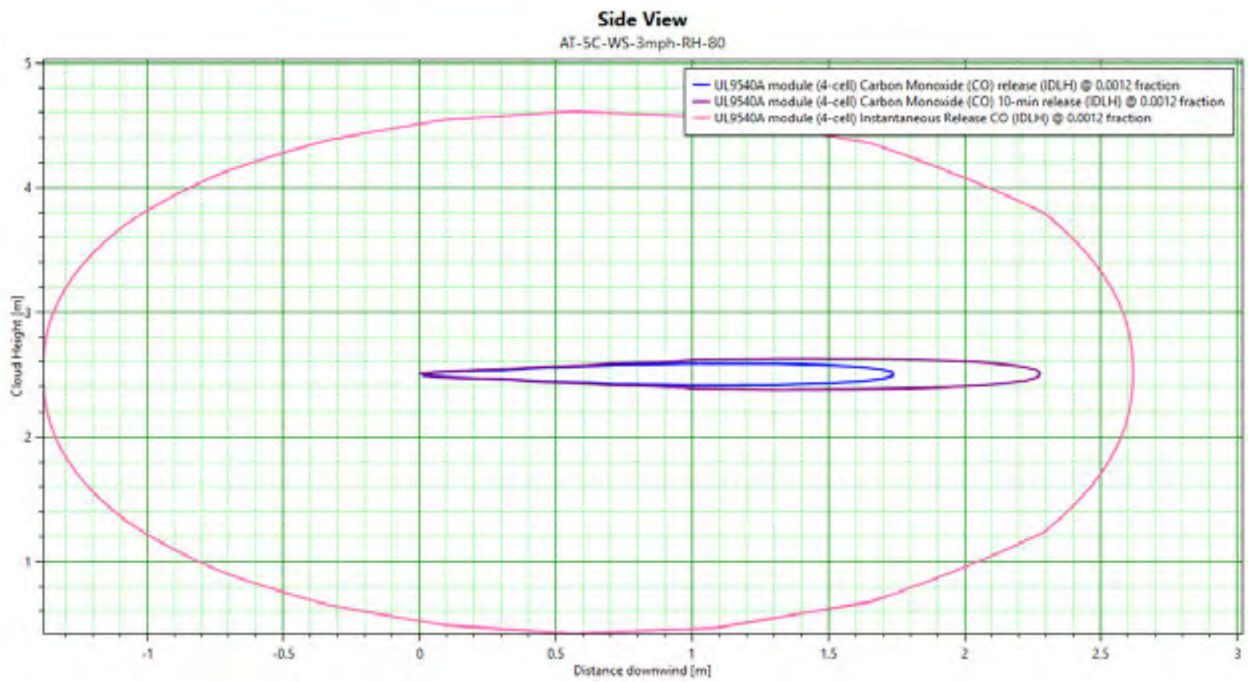


Figure 90 Maximum vertical extent of vapor cloud for CO IDLH (1200 ppm) for all sub-scenarios

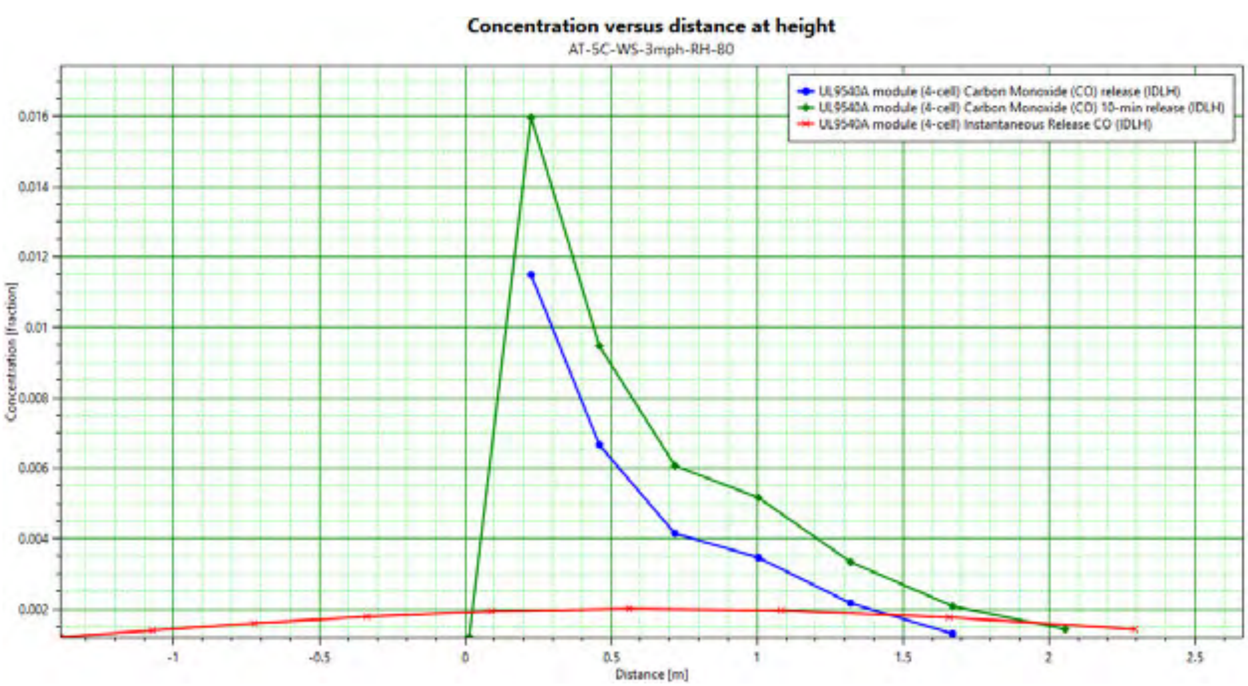


Figure 91 Concentration vs. distance for CO IDLH (1200 ppm) for all sub-scenarios

1.6.2 Scenario 2: 1-Module Release

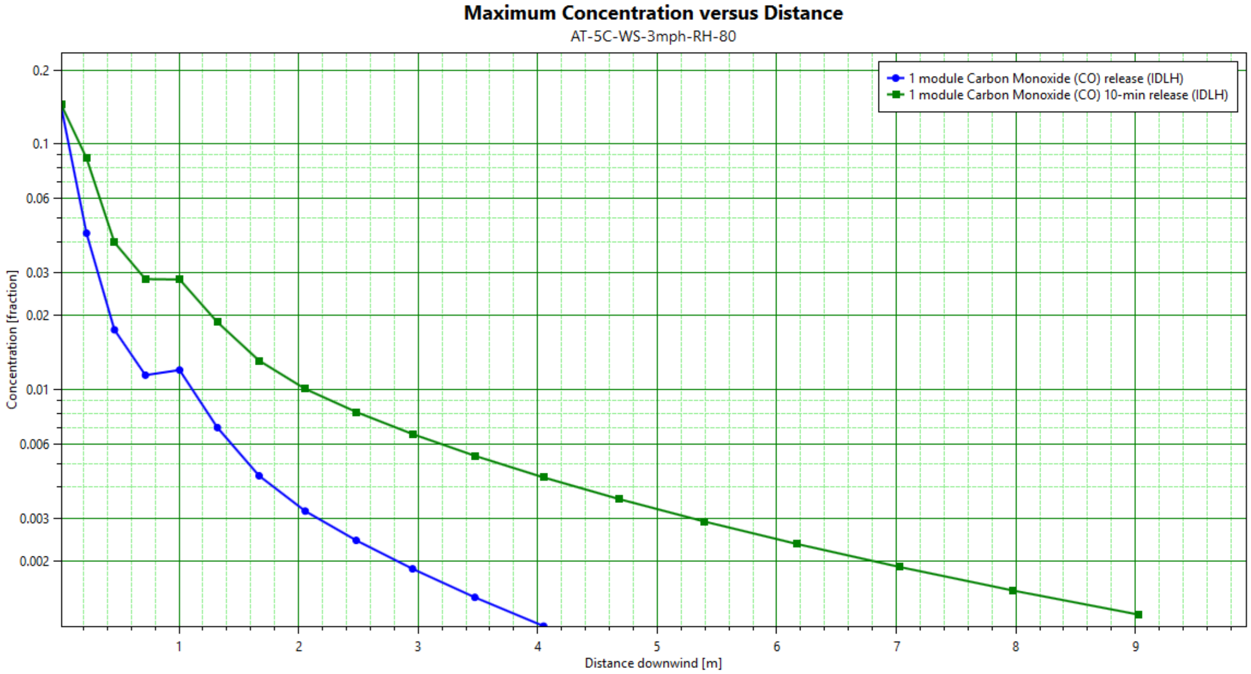


Figure 92 Maximum concentration vs distance at height (2.5 m) for CO IDLH (1200ppm) for all sub-scenarios

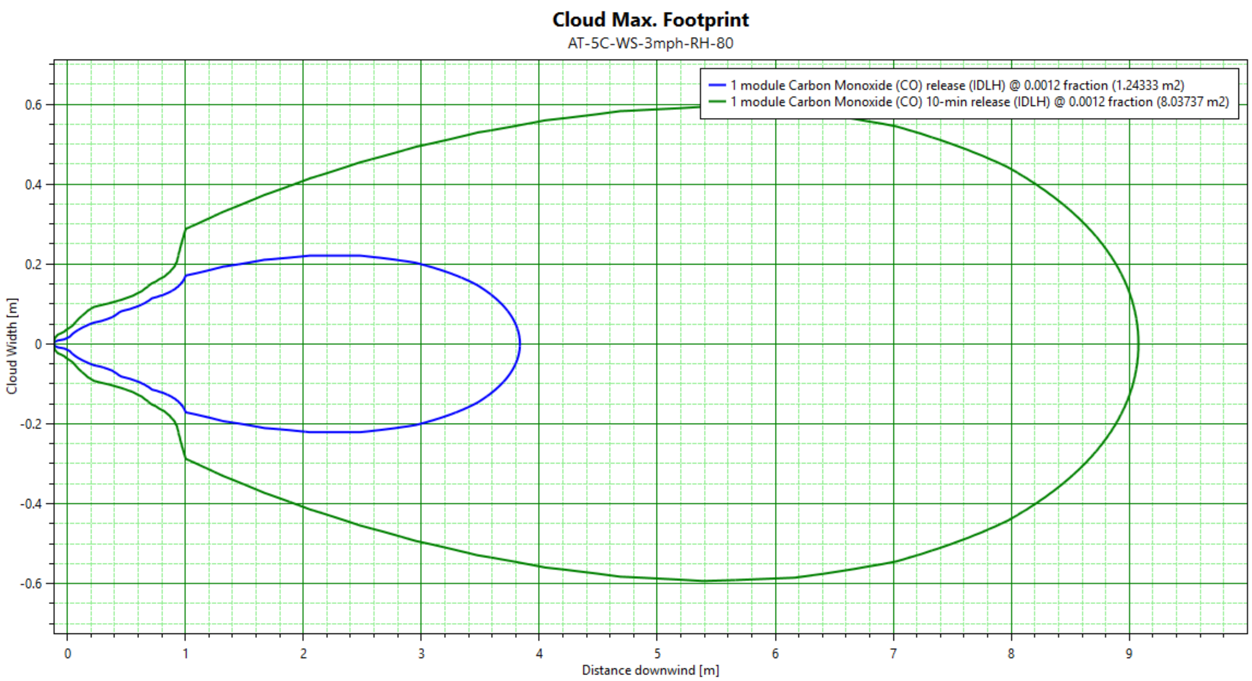


Figure 93 Maximum horizontal extent of vapor cloud for CO IDLH (1200 ppm) for all sub-scenarios

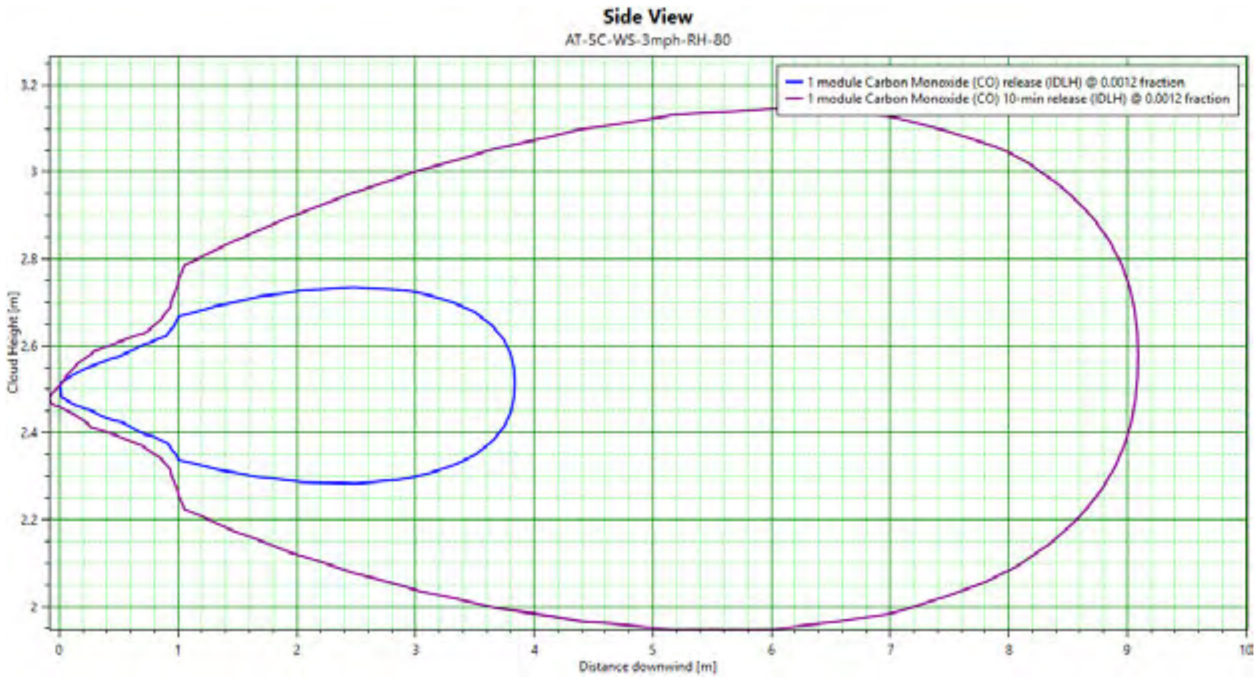


Figure 94 Maximum vertical extent of vapor cloud for CO IDLH (1200 ppm) for all sub-scenarios

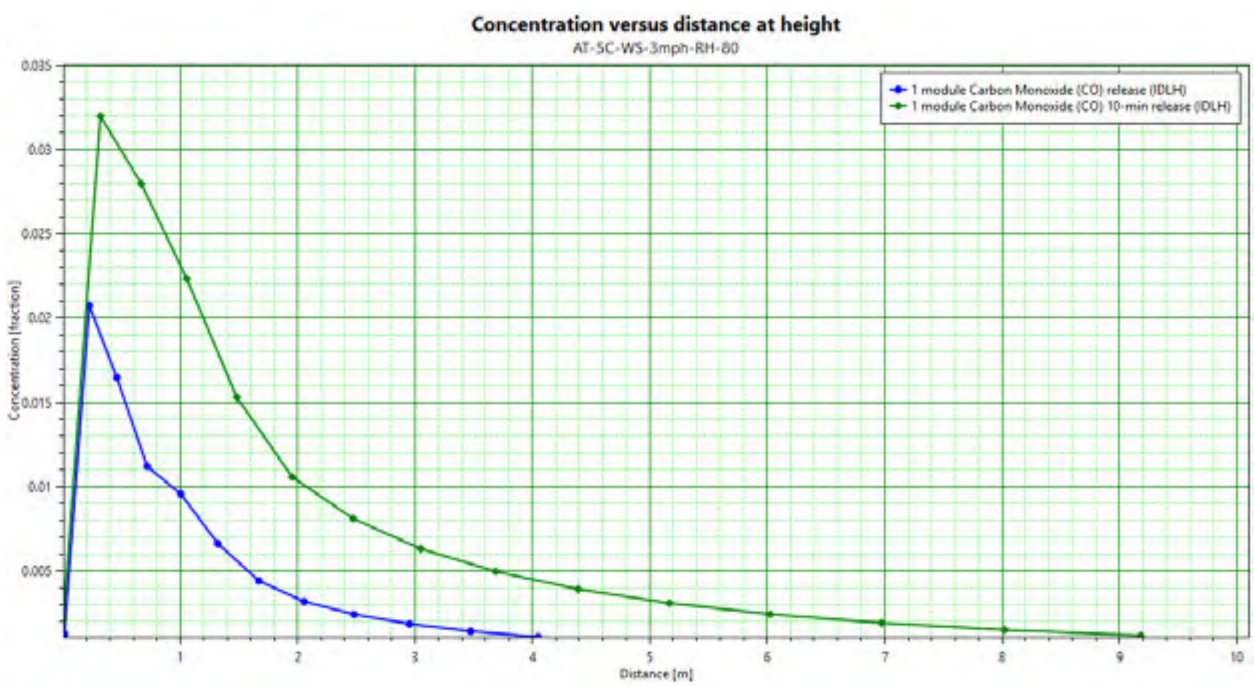


Figure 95 Concentration vs. distance for CO IDLH (1200 ppm) for all sub-scenarios

1.6.3 Scenario 3: 1-Rack Release

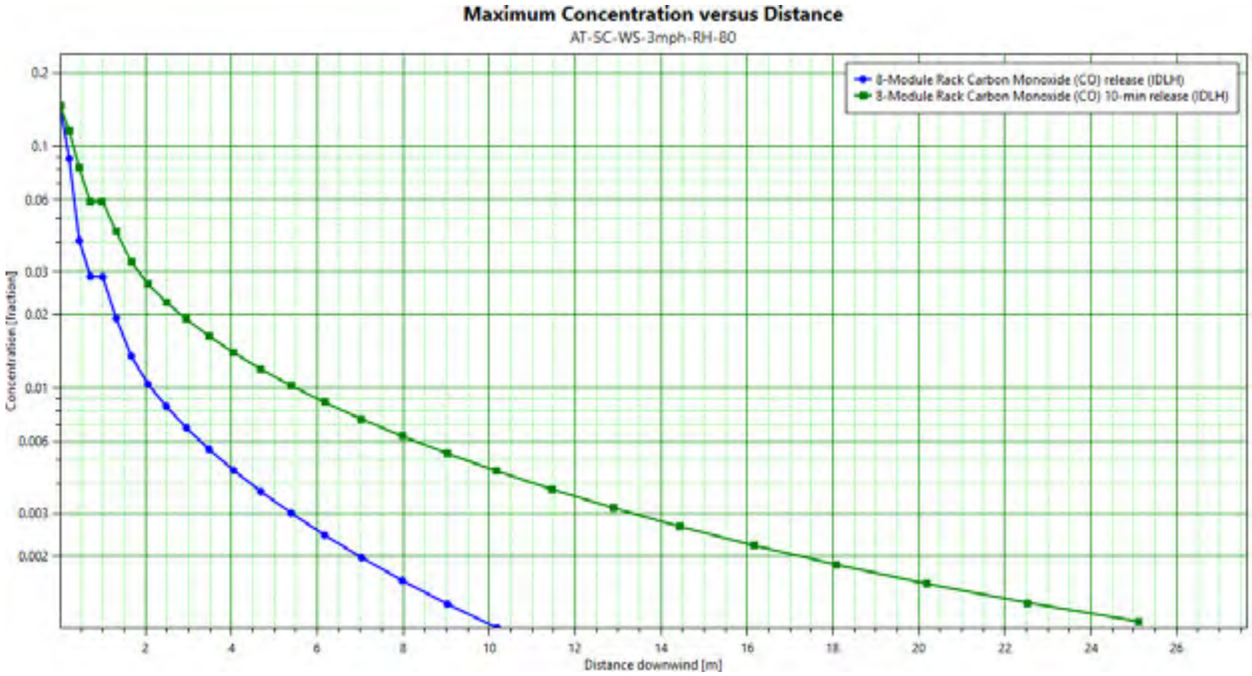


Figure 96 Maximum concentration vs distance at height (2.5 m) for CO IDLH (1200ppm) for all sub-scenarios

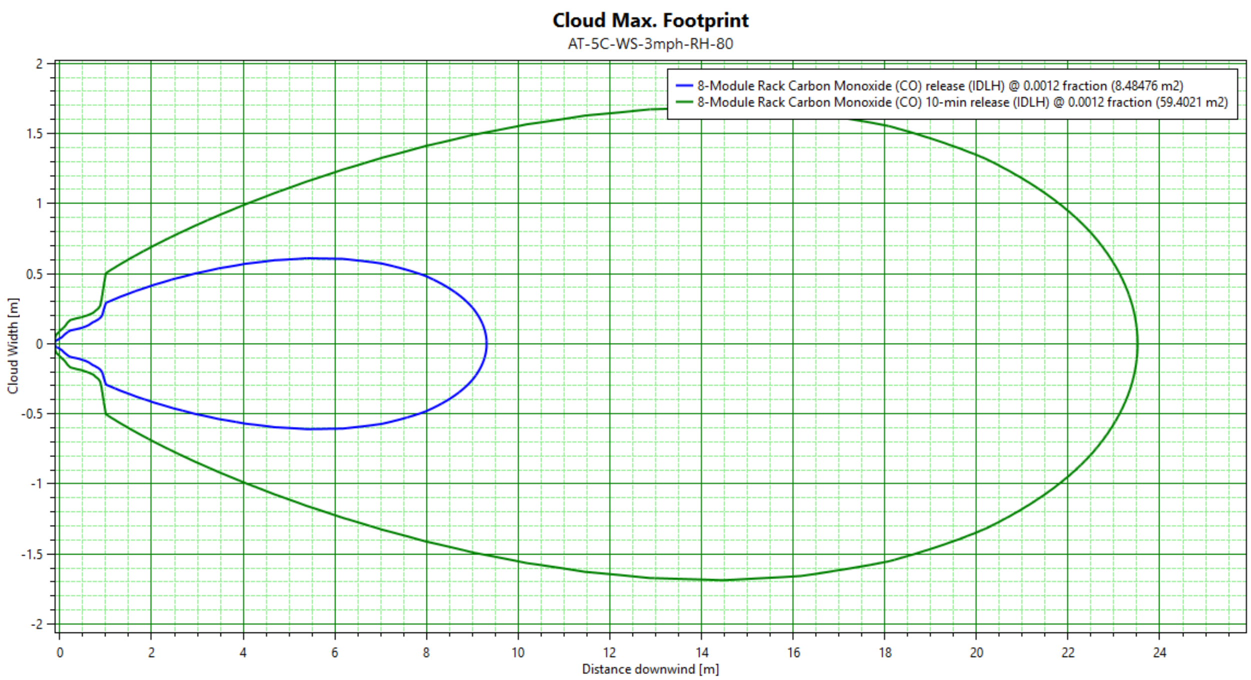


Figure 97 Maximum horizontal extent of vapor cloud for CO IDLH (1200 ppm) for all sub-scenarios

Figure 98 Maximum vertical extent of vapor cloud for CO IDLH (1200 ppm) for all sub-scenarios

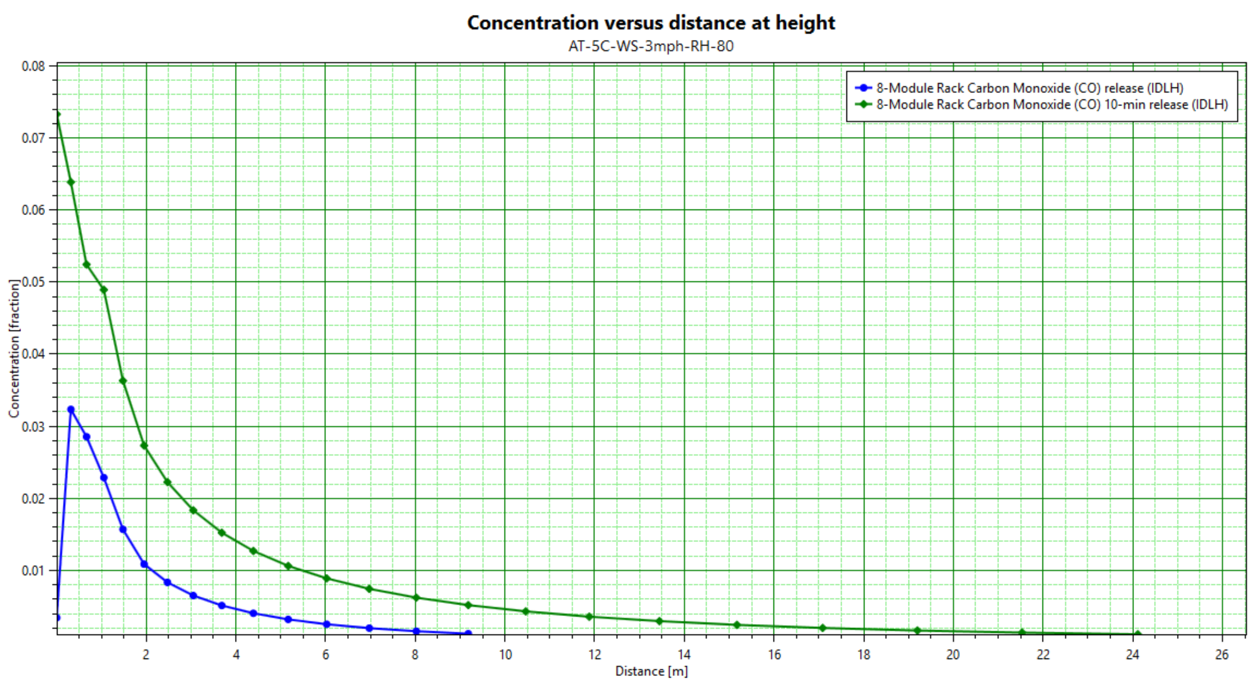


Figure 99 Concentration vs. distance for CO IDLH (1200 ppm) for all sub-scenarios

1.6.4 Scenario 4: 1-Container Release

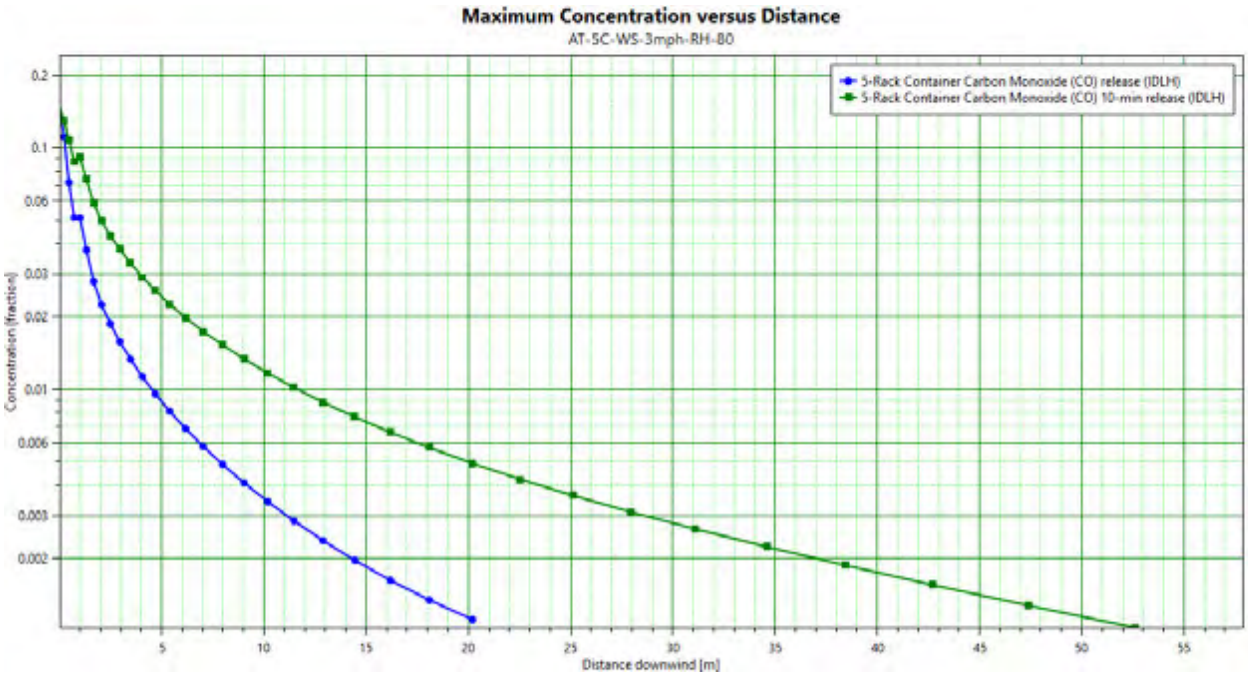


Figure 100 Maximum concentration vs distance at height (2.5 m) for CO IDLH (1200ppm) for all sub-scenarios

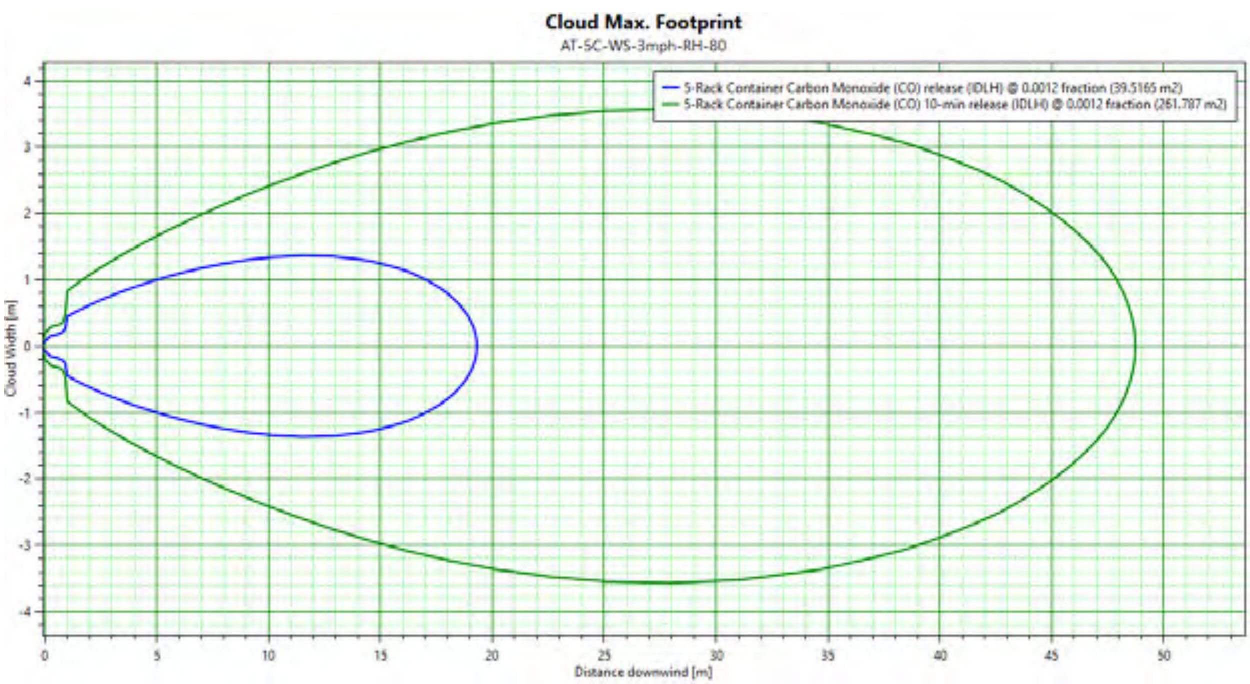


Figure 101 Maximum horizontal extent of vapor cloud for CO IDLH (1200 ppm) for all sub-scenarios

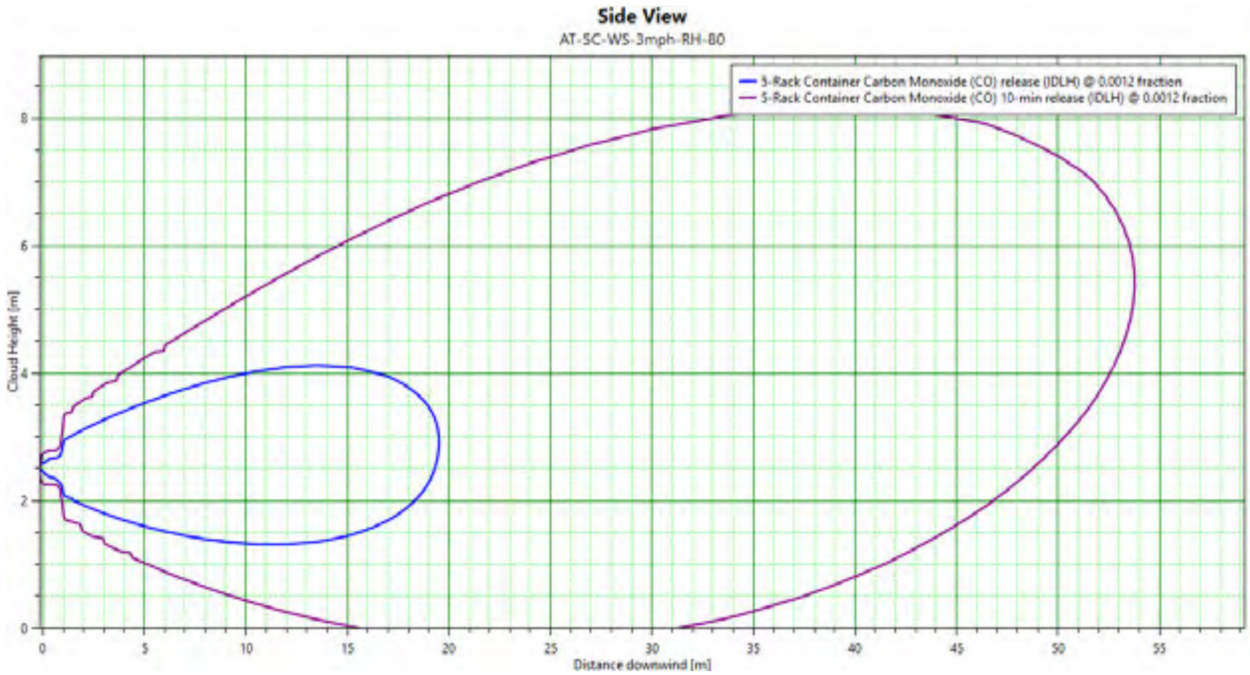


Figure 102 Maximum vertical extent of vapor cloud for CO IDLH (1200 ppm) for all sub-scenarios

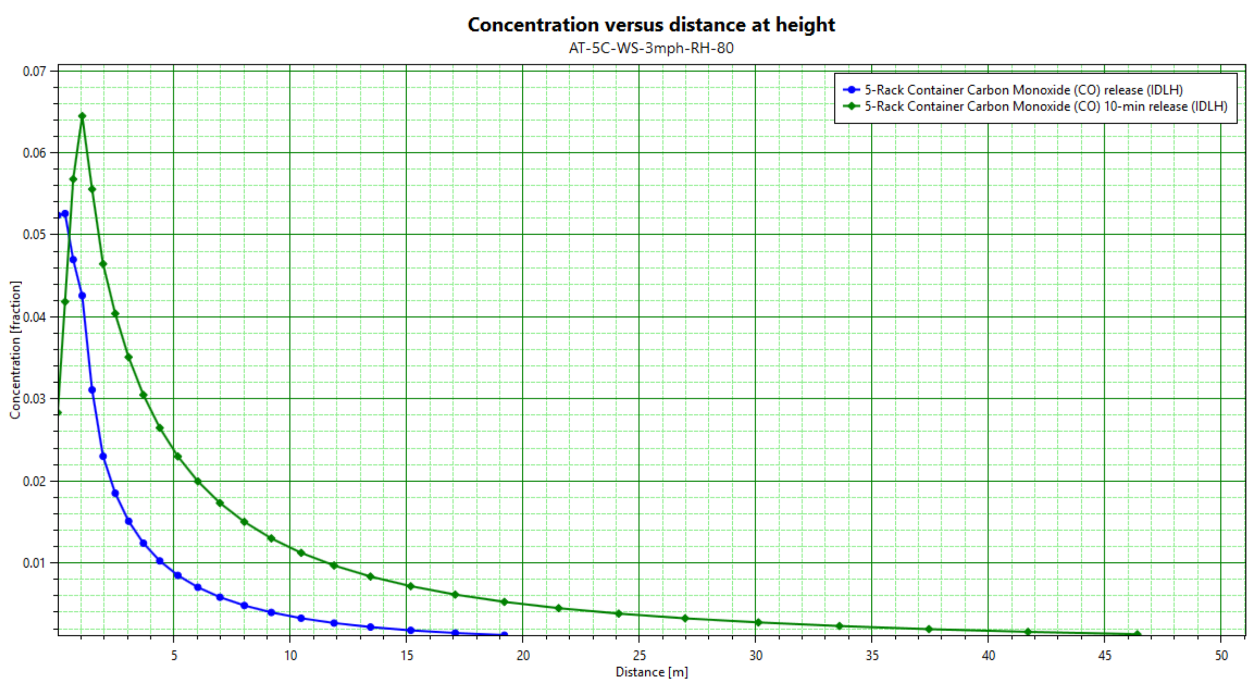


Figure 103 Concentration vs. distance for CO IDLH (1200 ppm) for all sub-scenarios

7.0 APPENDIX B: CONSEQUENCE SUMMARY REPORT

DNV·GL

Consequence Summary Report

Workspace: 507-050-Corby-BESS_r0 (V8.2)

Study: Study

Summary Basis

These tables will only report global values set in the parameters. Values that are modified in the study tree will not be reported.

The report is context sensitive, and filters up to the study level. You willl need to generate multiple summary reports if you have multiple studies in your workspace.

Discharge Results (after atmospheric expansion)

Path	Scenario	Weather	Peak Flowrate [kg/s]	Temperature [degC]	Liquid mass fraction in material [fraction]	Droplet diameter [um]	Expanded diameter [m]	Velocity [m/s]	End time of release [s]
Study\Corby BESS\UL 9540A Module Test based Release (4-cell propogation)	UL9540A module (4-cell) Total Vent Gas (TVG) release (flammable)	AT-5C-WS-3mph-RH-80	0.00114014	-22.7483	0	0	0.0019159	388.31	1224
		AT-5C-WS-6.5mp	0.00114014	-22.7483	0	0	0.0019159	388.31	1224

		h-RH-80							
		AT-5C-WS-14mph-RH-80	0.00114014	-22.7483	0	0	0.0019159	388.31	1224
	UL9540A module (4-cell) Carbon Monoxide (CO) release (IDLH)	AT-5C-WS-3mph-RH-80	0.00114014	-22.7483	0	0	0.0019159	388.31	1224
		AT-5C-WS-6.5mph-RH-80	0.00114014	-22.7483	0	0	0.0019159	388.31	1224
		AT-5C-WS-14mph-RH-80	0.00114014	-22.7483	0	0	0.0019159	388.31	1224
	UL9540A module (4-cell) Total Vent Gas (TVG) 10-min release (flammable)	AT-5C-WS-3mph-RH-80	0.00232588	-22.7483	0	0	0.00273645	388.31	600
		AT-5C-WS-	0.00232588	-22.7483	0	0	0.00273645	388.31	600

		6.5mph-RH-80							
		AT-5C-WS-14mph-RH-80	0.00232588	-22.7483	0	0	0.00273645	388.31	600
	UL9540A module (4-cell) Carbon Monoxide (CO) 10-min release (IDLH)	AT-5C-WS-3mph-RH-80	0.00232588	-22.7483	0	0	0.00273645	388.31	600
		AT-5C-WS-6.5mph-RH-80	0.00232588	-22.7483	0	0	0.00273645	388.31	600
		AT-5C-WS-14mph-RH-80	0.00232588	-22.7483	0	0	0.00273645	388.31	600
	UL9540A module (4-cell) Instantaneous Release TVG	AT-5C-WS-3mph-RH-80		-22.7534	0	0		77.6659	
		AT-5C-WS-6.5mp		-22.7534	0	0		77.6659	

		h-RH-80							
		AT-5C-WS-14mph-RH-80		-22.7534	0	0		77.6659	
	UL9540A module (4-cell) Instantaneous Release CO (IDLH)	AT-5C-WS-3mph-RH-80		-22.7534	0	0		77.6659	
		AT-5C-WS-6.5mph-RH-80		-22.7534	0	0		77.6659	
		AT-5C-WS-14mph-RH-80		-22.7534	0	0		77.6659	
Study\Corby BESS\Single Module Release (104-cell propogation)	1 module Total Vent Gas (TVG) release (flammable)	AT-5C-WS-3mph-RH-80	0.00799905	-22.7483	0	0	0.00507473	388.31	4536
		AT-5C-WS-6.5mp	0.00799905	-22.7483	0	0	0.00507473	388.31	4536

		h-RH-80							
		AT-5C-WS-14mph-RH-80	0.00799905	-22.7483	0	0	0.00507473	388.31	4536
	1 module Carbon Monoxide (CO) release (IDLH)	AT-5C-WS-3mph-RH-80	0.00799905	-22.7483	0	0	0.00507473	388.31	4536
		AT-5C-WS-6.5mph-RH-80	0.00799905	-22.7483	0	0	0.00507473	388.31	4536
		AT-5C-WS-14mph-RH-80	0.00799905	-22.7483	0	0	0.00507473	388.31	4536
	1 module Total Vent Gas (TVG) 10-min release (flammable)	AT-5C-WS-3mph-RH-80	0.0604728	-22.7483	0	0	0.0139532	388.31	600
		AT-5C-WS-6.5mph-RH-80	0.0604728	-22.7483	0	0	0.0139532	388.31	600
		AT-5C-	0.0604	-22.7483	0	0	0.0139	388.3	600

		WS-14mph-RH-80	728				532	1	
	1 module Carbon Monoxide (CO) 10-min release (IDLH)	AT-5C-WS-3mph-RH-80	0.0604728	-22.7483	0	0	0.0139532	388.31	600
		AT-5C-WS-6.5mph-RH-80	0.0604728	-22.7483	0	0	0.0139532	388.31	600
		AT-5C-WS-14mph-RH-80	0.0604728	-22.7483	0	0	0.0139532	388.31	600
Study\Corby BESS\8-Module Rack Release (832-cell propogation)	8-Module Rack Total Vent Gas (TVG) release (flammable)	AT-5C-WS-3mph-RH-80	0.0639924	-22.7483	0	0	0.0143535	388.31	4536
		AT-5C-WS-6.5mph-RH-80	0.0639924	-22.7483	0	0	0.0143535	388.31	4536
		AT-5C-WS-	0.0639924	-22.7483	0	0	0.0143535	388.31	4536

		14mph-RH-80							
	8-Module Rack Carbon Monoxide (CO) release (IDLH)	AT-5C-WS-3mph-RH-80	0.0639924	-22.7483	0	0	0.0143535	388.31	4536
		AT-5C-WS-6.5mph-RH-80	0.0639924	-22.7483	0	0	0.0143535	388.31	4536
		AT-5C-WS-14mph-RH-80	0.0639924	-22.7483	0	0	0.0143535	388.31	4536
	8-Module Rack Total Vent Gas (TVG) 10-min release (flammable)	AT-5C-WS-3mph-RH-80	0.483783	-22.7483	0	0	0.0394656	388.31	600
		AT-5C-WS-6.5mph-RH-80	0.483783	-22.7483	0	0	0.0394656	388.31	600
		AT-5C-WS-14mp	0.483783	-22.7483	0	0	0.0394656	388.31	600

		h-RH-80							
	8-Module Rack Carbon Monoxide (CO) 10-min release (IDLH)	AT-5C-WS-3mph-RH-80	0.483783	-22.7483	0	0	0.0394656	388.31	600
		AT-5C-WS-6.5mph-RH-80	0.483783	-22.7483	0	0	0.0394656	388.31	600
		AT-5C-WS-14mph-RH-80	0.483783	-22.7483	0	0	0.0394656	388.31	600
Study\Corby BESS\5-Rack Container Release (4160-cell propogation)	5-Rack Container Total Vent Gas (TVG) release (flammable)	AT-5C-WS-3mph-RH-80	0.319962	-22.7483	0	0	0.0320954	388.31	4536
		AT-5C-WS-6.5mph-RH-80	0.319962	-22.7483	0	0	0.0320954	388.31	4536
		AT-5C-WS-	0.319962	-22.7483	0	0	0.0320954	388.31	4536

		14mph-RH-80							
	5-Rack Container Carbon Monoxide (CO) release (IDLH)	AT-5C-WS-3mph-RH-80	0.319962	-22.7483	0	0	0.0320954	388.31	4536
		AT-5C-WS-6.5mph-RH-80	0.319962	-22.7483	0	0	0.0320954	388.31	4536
		AT-5C-WS-14mph-RH-80	0.319962	-22.7483	0	0	0.0320954	388.31	4536
	5-Rack Container Total Vent Gas (TVG) 10-min release (flammable)	AT-5C-WS-3mph-RH-80	2.41891	-22.7483	0	0	0.0882478	388.31	600
		AT-5C-WS-6.5mph-RH-80	2.41891	-22.7483	0	0	0.0882478	388.31	600
		AT-5C-WS-14mp	2.41891	-22.7483	0	0	0.0882478	388.31	600

		h-RH-80							
	5-Rack Container Carbon Monoxide (CO) 10-min release (IDLH)	AT-5C-WS-3mph-RH-80	2.41891	-22.7483	0	0	0.0882478	388.31	600
		AT-5C-WS-6.5mph-RH-80	2.41891	-22.7483	0	0	0.0882478	388.31	600
		AT-5C-WS-14mph-RH-80	2.41891	-22.7483	0	0	0.0882478	388.31	600

Dispersion Results

Input dispersion parameters

Core averaging time	18.75	s
Flammable averaging time	18.75	s
Toxic averaging time	**60**	s
Height of interest	**2.5**	m

Distance downwind to defined concentrations

The reported concentration of interest is defined at the scenario

Path	Scenario	Weather	Material	Material to track	Concentration of interest [fraction]	Averaging time selected	Distance downwind to concentration of interest [m]
Study\Corby BESS\UL9540A Module Test based Release (4-cell propogation)	UL9540A module (4-cell) Total Vent Gas (TVG) release (flammable)	AT-5C-WS-3mph-RH-80	**TVG**	TVG	0.0362	Flammable	1.01787
		AT-5C-WS-6.5mph-RH-80	**TVG**	TVG	0.0362	Flammable	0.526512
		AT-5C-WS-14mph-RH-80	**TVG**	TVG	0.0362	Flammable	0.461385
	UL9540A	AT-5C-	**TVG**	**CARBO**	0.0012	IDLH	1.74141

	module (4-cell) Carbon Monoxide (CO) release (IDLH)	WS-3mph-RH-80		**N MONOXIDE**			
		AT-5C-WS-6.5mph-RH-80	**TVG**	**CARBON MONOXIDE**	0.0012	IDLH	1.51646
		AT-5C-WS-14mph-RH-80	**TVG**	**CARBON MONOXIDE**	0.0012	IDLH	1.34711
	UL9540A module (4-cell) Total Vent Gas (TVG) 10-min release (flammable)	AT-5C-WS-3mph-RH-80	**TVG**	TVG	0.0362	Flammable	1.08709
		AT-5C-WS-6.5mph-RH-80	**TVG**	TVG	0.0362	Flammable	1.024
		AT-5C-WS-14mph-RH-80	**TVG**	TVG	0.0362	Flammable	0.628013
	UL9540A module (4-cell) Carbon Monoxide	AT-5C-WS-3mph-RH-80	**TVG**	**CARBON MONOXIDE**	0.0012	IDLH	2.27533

	(CO) 10-min release (IDLH)						
		AT-5C-WS-6.5mph-RH-80	**TVG**	**CARBON MONOXIDE**	0.0012	IDLH	1.86994
		AT-5C-WS-14mph-RH-80	**TVG**	**CARBON MONOXIDE**	0.0012	IDLH	1.58329
	UL9540A module (4-cell) Instantaneous Release TVG	AT-5C-WS-3mph-RH-80	**TVG**	TVG	0.042975	Flammable	1.38149
		AT-5C-WS-6.5mph-RH-80	**TVG**	TVG	0.042975	Flammable	1.39693
		AT-5C-WS-14mph-RH-80	**TVG**	TVG	0.042975	Flammable	1.44293
	UL9540A module (4-cell) Instantaneous Release CO (IDLH)	AT-5C-WS-3mph-RH-80	**TVG**	**CARBON MONOXIDE**	0.0012	IDLH	2.68635
		AT-5C-WS-6.5mph	**TVG**	**CARBON MONOX**	0.0012	IDLH	3.62694

		-RH-80		**IDE**			
		AT-5C-WS-14mph-RH-80	**TVG**	**CARBON MONOXIDE**	0.0012	IDLH	6.70055
Study\Corby BESS\Single Module Release (104-cell propogation)	1 module Total Vent Gas (TVG) release (flammable)	AT-5C-WS-3mph-RH-80	**TVG**	TVG	0.0362	Flammable	1.51133
		AT-5C-WS-6.5mph-RH-80	**TVG**	TVG	0.0362	Flammable	1.38677
		AT-5C-WS-14mph-RH-80	**TVG**	TVG	0.0362	Flammable	1.25605
	1 module Carbon Monoxide (CO) release (IDLH)	AT-5C-WS-3mph-RH-80	**TVG**	**CARBON MONOXIDE**	0.0012	IDLH	3.83786
		AT-5C-WS-6.5mph-RH-80	**TVG**	**CARBON MONOXIDE**	0.0012	IDLH	3.02834
		AT-5C-WS-14mph-RH-80	**TVG**	**CARBON MONOXIDE**	0.0012	IDLH	2.36817
	1 module Total Vent	AT-5C-WS-	**TVG**	TVG	0.0362	Flammable	3.48114

	Gas (TVG) 10-min release (flammable)	3mph-RH-80					
		AT-5C-WS-6.5mph-RH-80	**TVG**	TVG	0.0362	Flammable	2.9401
		AT-5C-WS-14mph-RH-80	**TVG**	TVG	0.0362	Flammable	2.3893
	1 module Carbon Monoxide (CO) 10-min release (IDLH)	AT-5C-WS-3mph-RH-80	**TVG**	**CARBON MONOXIDE**	0.0012	IDLH	9.07907
		AT-5C-WS-6.5mph-RH-80	**TVG**	**CARBON MONOXIDE**	0.0012	IDLH	6.90968
		AT-5C-WS-14mph-RH-80	**TVG**	**CARBON MONOXIDE**	0.0012	IDLH	5.21289
Study\Cor by BESS\8-Module Rack Release (832-cell propogation)	8-Module Rack Total Vent Gas (TVG) release (flammable)	AT-5C-WS-3mph-RH-80	**TVG**	TVG	0.0362	Flammable	3.57423

		AT-5C-WS-6.5mph-RH-80	**TVG**	TVG	0.0362	Flammable	3.01466
		AT-5C-WS-14mph-RH-80	**TVG**	TVG	0.0362	Flammable	2.44681
	8-Module Rack Carbon Monoxide (CO) release (IDLH)	AT-5C-WS-3mph-RH-80	**TVG**	**CARBON MONOXIDE**	0.0012	IDLH	9.31514
		AT-5C-WS-6.5mph-RH-80	**TVG**	**CARBON MONOXIDE**	0.0012	IDLH	7.07073
		AT-5C-WS-14mph-RH-80	**TVG**	**CARBON MONOXIDE**	0.0012	IDLH	5.33688
	8-Module Rack Total Vent Gas (TVG) 10-min release (flammable)	AT-5C-WS-3mph-RH-80	**TVG**	TVG	0.0362	Flammable	8.98632
		AT-5C-WS-6.5mph-RH-80	**TVG**	TVG	0.0362	Flammable	7.36337
		AT-5C-WS-	**TVG**	TVG	0.0362	Flammable	5.72598

		14mph -RH-80					
	8-Module Rack Carbon Monoxide (CO) 10-min release (IDLH)	AT-5C-WS-3mph-RH-80	**TVG**	**CARBON MONOXIDE**	0.0012	IDLH	23.5214
		AT-5C-WS-6.5mph -RH-80	**TVG**	**CARBON MONOXIDE**	0.0012	IDLH	18.5838
		AT-5C-WS-14mph -RH-80	**TVG**	**CARBON MONOXIDE**	0.0012	IDLH	12.4121
Study\Corby BESS\5-Rack Container Release (4160-cell propogation)	5-Rack Container Total Vent Gas (TVG) release (flammable)	AT-5C-WS-3mph-RH-80	**TVG**	TVG	0.0362	Flammable	7.44164
		AT-5C-WS-6.5mph -RH-80	**TVG**	TVG	0.0362	Flammable	6.11924
		AT-5C-WS-14mph -RH-80	**TVG**	TVG	0.0362	Flammable	4.80671
	5-Rack Container	AT-5C-WS-	**TVG**	**CARBON**	0.0012	IDLH	19.3059

	Carbon Monoxide (CO) release (IDLH)	3mph-RH-80		**MONOXIDE**			
		AT-5C-WS-6.5mph-RH-80	**TVG**	**CARBON MONOXIDE**	0.0012	IDLH	14.6923
		AT-5C-WS-14mph-RH-80	**TVG**	**CARBON MONOXIDE**	0.0012	IDLH	10.207
	5-Rack Container Total Vent Gas (TVG) 10-min release (flammable)	AT-5C-WS-3mph-RH-80	**TVG**	TVG	0.0362	Flammable	18.9799
		AT-5C-WS-6.5mph-RH-80	**TVG**	TVG	0.0362	Flammable	15.6449
		AT-5C-WS-14mph-RH-80	**TVG**	TVG	0.0362	Flammable	11.8258
	5-Rack Container Carbon Monoxide (CO) 10-min release (IDLH)	AT-5C-WS-3mph-RH-80	**TVG**	**CARBON MONOXIDE**	0.0012	IDLH	48.7865

		AT-5C-WS-6.5mph-RH-80	**TVG**	**CARBON MONOXIDE**	0.0012	IDLH	48.8526
		AT-5C-WS-14mph-RH-80	**TVG**	**CARBON MONOXIDE**	0.0012	IDLH	41.8163

Path	**Scenario**	**Weather**	**Distance to UFL [m]**	**Distance to LFL [m]**	**Distance to LFL fraction [m]**
Study\Corby BESS\UL9540A Module Test based Release (4-cell propogation)	UL9540A module (4-cell) Total Vent Gas (TVG) release (flammable)	AT-5C-WS-3mph-RH-80	0.0778136	0.369712	1.01732
		AT-5C-WS-6.5mph-RH-80	0.0789639	0.348696	0.624651
		AT-5C-WS-14mph-RH-80	0.0815535	0.317747	0.537097
	UL9540A module (4-cell) Carbon Monoxide (CO) release (IDLH)	AT-5C-WS-3mph-RH-80	0.0778136	0.369712	1.01732
		AT-5C-WS-6.5mph-RH-80	0.0789639	0.348696	0.624651
		AT-5C-WS-14mph-RH-80	0.0815535	0.317747	0.537097

	UL9540A module (4-cell) Total Vent Gas (TVG) 10-min release (flammable)	AT-5C-WS-3mph-RH-80	0.0931627	0.522173	1.2003
		AT-5C-WS-6.5mph-RH-80	0.094123	0.487447	1.11996
		AT-5C-WS-14mph-RH-80	0.0962628	0.438108	1.03941
	UL9540A module (4-cell) Carbon Monoxide (CO) 10-min release (IDLH)	AT-5C-WS-3mph-RH-80	0.0931627	0.522173	1.2003
		AT-5C-WS-6.5mph-RH-80	0.094123	0.487447	1.11996
		AT-5C-WS-14mph-RH-80	0.0962628	0.438108	1.03941
	UL9540A module (4-cell) Instantaneous Release TVG	AT-5C-WS-3mph-RH-80	0.4498	1.24279	1.58575
		AT-5C-WS-6.5mph-RH-80	0.449803	1.24991	1.62051
		AT-5C-WS-14mph-RH-80	0.449807	1.27209	1.7472
	UL9540A module (4-cell) Instantaneous	AT-5C-WS-3mph-RH-80	0.4498	1.24279	1.58575

	Release CO (IDLH)				
		AT-5C-WS-6.5mph-RH-80	0.449803	1.24991	1.62051
		AT-5C-WS-14mph-RH-80	0.449807	1.27209	1.7472
Study\Corby BESS\Single Module Release (104-cell propogation)	1 module Total Vent Gas (TVG) release (flammable)	AT-5C-WS-3mph-RH-80	0.128295	1.17461	1.70666
		AT-5C-WS-6.5mph-RH-80	0.128874	1.10822	1.53356
		AT-5C-WS-14mph-RH-80	0.130188	1.02644	1.3678
	1 module Carbon Monoxide (CO) release (IDLH)	AT-5C-WS-3mph-RH-80	0.128295	1.17461	1.70666
		AT-5C-WS-6.5mph-RH-80	0.128874	1.10822	1.53356
		AT-5C-WS-14mph-RH-80	0.130188	1.02644	1.3678
	1 module Total Vent Gas (TVG) 10-min release (flammable)	AT-5C-WS-3mph-RH-80	0.221878	2.3494	4.09792
		AT-5C-WS-6.5mph-RH-80	0.221384	2.07571	3.40065

		AT-5C-WS-14mph-RH-80	0.220523	1.78777	2.72315
	1 module Carbon Monoxide (CO) 10-min release (IDLH)	AT-5C-WS-3mph-RH-80	0.221878	2.3494	4.09792
		AT-5C-WS-6.5mph-RH-80	0.221384	2.07571	3.40065
		AT-5C-WS-14mph-RH-80	0.220523	1.78777	2.72315
Study\Corby BESS\8-Module Rack Release (832-cell propogation)	8-Module Rack Total Vent Gas (TVG) release (flammable)	AT-5C-WS-3mph-RH-80	0.225415	2.4129	4.20586
		AT-5C-WS-6.5mph-RH-80	0.224878	2.12515	3.48539
		AT-5C-WS-14mph-RH-80	0.223929	1.8242	2.78879
	8-Module Rack Carbon Monoxide (CO) release (IDLH)	AT-5C-WS-3mph-RH-80	0.225415	2.4129	4.20586
		AT-5C-WS-6.5mph-RH-80	0.224878	2.12515	3.48539
		AT-5C-WS-14mph-RH-80	0.223929	1.8242	2.78879
	8-Module Rack	AT-5C-WS-	0.407864	6.19659	10.4834

	Total Vent Gas (TVG) 10-min release (flammable)	3mph-RH-80			
		AT-5C-WS-6.5mph-RH-80	0.404941	5.27813	8.4602
		AT-5C-WS-14mph-RH-80	0.399121	4.25874	6.47878
	8-Module Rack Carbon Monoxide (CO) 10-min release (IDLH)	AT-5C-WS-3mph-RH-80	0.407864	6.19659	10.4834
		AT-5C-WS-6.5mph-RH-80	0.404941	5.27813	8.4602
		AT-5C-WS-14mph-RH-80	0.399121	4.25874	6.47878
Study\Corby BESS\5-Rack Container Release (4160-cell propogation)	5-Rack Container Total Vent Gas (TVG) release (flammable)	AT-5C-WS-3mph-RH-80	0.359402	5.11109	8.69384
		AT-5C-WS-6.5mph-RH-80	0.357148	4.37788	7.03125
		AT-5C-WS-14mph-RH-80	0.352587	3.56344	5.44262
	5-Rack Container Carbon Monoxide (CO) release (IDLH)	AT-5C-WS-3mph-RH-80	0.359402	5.11109	8.69384

		AT-5C-WS-6.5mph-RH-80	0.357148	4.37788	7.03125
		AT-5C-WS-14mph-RH-80	0.352587	3.56344	5.44262
	5-Rack Container Total Vent Gas (TVG) 10-min release (flammable)	AT-5C-WS-3mph-RH-80	1.00106	13.1265	22.2064
		AT-5C-WS-6.5mph-RH-80	0.752329	11.0303	18.3545
		AT-5C-WS-14mph-RH-80	0.811947	8.64986	13.6722
	5-Rack Container Carbon Monoxide (CO) 10-min release (IDLH)	AT-5C-WS-3mph-RH-80	1.00106	13.1265	22.2064
		AT-5C-WS-6.5mph-RH-80	0.752329	11.0303	18.3545
		AT-5C-WS-14mph-RH-80	0.811947	8.64986	13.6722

Outdoor Toxic Results

Distance downwind to defined concentrations

The reported concentrations are defined in the respective material properties

Path	Scenario	Weather	Distance downwind to ERPG1 (3600 s) [m]	Distance downwind to ERPG2 (3600 s) [m]	Distance downwind to ERPG3 (3600 s) [m]	Distance downwind to STEL (900 s) [m]	Distance downwind to IDLH (1800 s) [m]
Study\Corby BESS\UL9540A Module Test based Release (4-cell propogation)	UL9540A module (4-cell) Total Vent Gas (TVG) release (flammable)	AT-5C-WS-3mph-RH-80	n/a	n/a	n/a	n/a	n/a
		AT-5C-WS-6.5mph-RH-80	n/a	n/a	n/a	n/a	n/a
		AT-5C-WS-14mph-RH-80	n/a	n/a	n/a	n/a	n/a
	UL9540A module (4-cell) Carbon Monoxide (CO) release (IDLH)	AT-5C-WS-3mph-RH-80	n/a	n/a	n/a	n/a	n/a
		AT-5C-	n/a	n/a	n/a	n/a	n/a

		WS-6.5mph-RH-80					
		AT-5C-WS-14mph-RH-80	n/a	n/a	n/a	n/a	n/a
	UL9540A module (4-cell) Total Vent Gas (TVG) 10-min release (flammable)	AT-5C-WS-3mph-RH-80	n/a	n/a	n/a	n/a	n/a
		AT-5C-WS-6.5mph-RH-80	n/a	n/a	n/a	n/a	n/a
		AT-5C-WS-14mph-RH-80	n/a	n/a	n/a	n/a	n/a
	UL9540A module (4-cell) Carbon Monoxide (CO) 10-min release (IDLH)	AT-5C-WS-3mph-RH-80	n/a	n/a	n/a	n/a	n/a
		AT-5C-WS-6.5mph-RH-80	n/a	n/a	n/a	n/a	n/a

		AT-5C-WS-14mph-RH-80	n/a	n/a	n/a	n/a	n/a
	UL9540A module (4-cell) Instantaneous Release TVG	AT-5C-WS-3mph-RH-80	n/a	n/a	n/a	n/a	n/a
		AT-5C-WS-6.5mph-RH-80	n/a	n/a	n/a	n/a	n/a
		AT-5C-WS-14mph-RH-80	n/a	n/a	n/a	n/a	n/a
	UL9540A module (4-cell) Instantaneous Release CO (IDLH)	AT-5C-WS-3mph-RH-80	n/a	n/a	n/a	n/a	n/a
		AT-5C-WS-6.5mph-RH-80	n/a	n/a	n/a	n/a	n/a
		AT-5C-WS-14mph-RH-80	n/a	n/a	n/a	n/a	n/a
Study\Corby BESS\Singl	1 module Total Vent Gas (TVG)	AT-5C-WS-3mph-	n/a	n/a	n/a	n/a	n/a

e Module Release (104-cell propogation)	release (flammable)	RH-80					
		AT-5C-WS-6.5mph-RH-80	n/a	n/a	n/a	n/a	n/a
		AT-5C-WS-14mph-RH-80	n/a	n/a	n/a	n/a	n/a
	1 module Carbon Monoxide (CO) release (IDLH)	AT-5C-WS-3mph-RH-80	n/a	n/a	n/a	n/a	n/a
		AT-5C-WS-6.5mph-RH-80	n/a	n/a	n/a	n/a	n/a
		AT-5C-WS-14mph-RH-80	n/a	n/a	n/a	n/a	n/a
	1 module Total Vent Gas (TVG) 10-min release (flammable)	AT-5C-WS-3mph-RH-80	n/a	n/a	n/a	n/a	n/a
		AT-5C-WS-6.5mph	n/a	n/a	n/a	n/a	n/a

		-RH-80					
		AT-5C-WS-14mph-RH-80	n/a	n/a	n/a	n/a	n/a
	1 module Carbon Monoxide (CO) 10-min release (IDLH)	AT-5C-WS-3mph-RH-80	n/a	n/a	n/a	n/a	n/a
		AT-5C-WS-6.5mph-RH-80	n/a	n/a	n/a	n/a	n/a
		AT-5C-WS-14mph-RH-80	n/a	n/a	n/a	n/a	n/a
Study\Corby BESS\8-Module Rack Release (832-cell propogation)	8-Module Rack Total Vent Gas (TVG) release (flammable)	AT-5C-WS-3mph-RH-80	n/a	n/a	n/a	n/a	n/a
		AT-5C-WS-6.5mph-RH-80	n/a	n/a	n/a	n/a	n/a
		AT-5C-WS-14mph-RH-80	n/a	n/a	n/a	n/a	n/a
	8-Module	AT-5C-	n/a	n/a	n/a	n/a	n/a

	Rack Carbon Monoxide (CO) release (IDLH)	WS-3mph-RH-80					
		AT-5C-WS-6.5mph-RH-80	n/a	n/a	n/a	n/a	n/a
		AT-5C-WS-14mph-RH-80	n/a	n/a	n/a	n/a	n/a
	8-Module Rack Total Vent Gas (TVG) 10-min release (flammable)	AT-5C-WS-3mph-RH-80	n/a	n/a	n/a	n/a	n/a
		AT-5C-WS-6.5mph-RH-80	n/a	n/a	n/a	n/a	n/a
		AT-5C-WS-14mph-RH-80	n/a	n/a	n/a	n/a	n/a
	8-Module Rack Carbon Monoxide (CO) 10-min release	AT-5C-WS-3mph-RH-80	n/a	n/a	n/a	n/a	n/a

	(IDLH)						
		AT-5C-WS-6.5mph-RH-80	n/a	n/a	n/a	n/a	n/a
		AT-5C-WS-14mph-RH-80	n/a	n/a	n/a	n/a	n/a
Study\Corby BESS\5-Rack Container Release (4160-cell propogation)	5-Rack Container Total Vent Gas (TVG) release (flammable)	AT-5C-WS-3mph-RH-80	n/a	n/a	n/a	n/a	n/a
		AT-5C-WS-6.5mph-RH-80	n/a	n/a	n/a	n/a	n/a
		AT-5C-WS-14mph-RH-80	n/a	n/a	n/a	n/a	n/a
	5-Rack Container Carbon Monoxide (CO) release (IDLH)	AT-5C-WS-3mph-RH-80	n/a	n/a	n/a	n/a	n/a
		AT-5C-WS-6.5mph-RH-80	n/a	n/a	n/a	n/a	n/a
		AT-5C-	n/a	n/a	n/a	n/a	n/a

		WS-14mph-RH-80					
	5-Rack Container Total Vent Gas (TVG) 10-min release (flammable)	AT-5C-WS-3mph-RH-80	n/a	n/a	n/a	n/a	n/a
		AT-5C-WS-6.5mph-RH-80	n/a	n/a	n/a	n/a	n/a
		AT-5C-WS-14mph-RH-80	n/a	n/a	n/a	n/a	n/a
	5-Rack Container Carbon Monoxide (CO) 10-min release (IDLH)	AT-5C-WS-3mph-RH-80	n/a	n/a	n/a	n/a	n/a
		AT-5C-WS-6.5mph-RH-80	n/a	n/a	n/a	n/a	n/a
		AT-5C-WS-14mph-RH-80	n/a	n/a	n/a	n/a	n/a

Distance downwind to defined dangerous doses

The reported dangerous doses are defined in the respective material properties

Exposure duration at defined dangerous doses

The reported dangerous doses are defined in the respective material properties

Jet Fire Results

Distance downwind to defined radiation levels

The reported radiations are defined in the parameters

Path	Scenario	Weather	Flame length [m]	Distance downwind to intensity level 1 (4.7 kW/m2) [m]	Distance downwind to intensity level 2 (12.5 kW/m2) [m]	Distance downwind to intensity level 3 (37.5 kW/m2) [m]
Study\Corby BESS\UL9540A Module Test based Release (4-cell propogation)	UL9540A module (4-cell) Total Vent Gas (TVG) release (flammable)	AT-5C-WS-3mph-RH-80	0.613837	n/a	n/a	n/a
		AT-5C-WS-6.5mph-RH-80	0.613802	n/a	n/a	n/a
		AT-5C-WS-14mph-RH-80	0.613735	n/a	n/a	n/a
	UL9540A module (4-cell) Carbon Monoxide (CO) release (IDLH)	AT-5C-WS-3mph-RH-80	0.613837	n/a	n/a	n/a
		AT-5C-	0.61380	n/a	n/a	n/a

		WS-6.5mph-RH-80	2			
		AT-5C-WS-14mph-RH-80	0.613735	n/a	n/a	n/a
	UL9540A module (4-cell) Total Vent Gas (TVG) 10-min release (flammable)	AT-5C-WS-3mph-RH-80	0.844449	n/a	n/a	n/a
		AT-5C-WS-6.5mph-RH-80	0.844359	n/a	n/a	n/a
		AT-5C-WS-14mph-RH-80	0.84419	n/a	n/a	n/a
	UL9540A module (4-cell) Carbon Monoxide (CO) 10-min release (IDLH)	AT-5C-WS-3mph-RH-80	0.844449	n/a	n/a	n/a
		AT-5C-WS-6.5mph-RH-80	0.844359	n/a	n/a	n/a
		AT-5C-WS-	0.84419	n/a	n/a	n/a

		14mph-RH-80				
Study\Corby BESS\Single Module Release (104-cell propogation)	1 module Total Vent Gas (TVG) release (flammable)	AT-5C-WS-3mph-RH-80	1.45919	n/a	n/a	n/a
		AT-5C-WS-6.5mph-RH-80	1.45879	n/a	n/a	n/a
		AT-5C-WS-14mph-RH-80	1.45804	n/a	n/a	n/a
	1 module Carbon Monoxide (CO) release (IDLH)	AT-5C-WS-3mph-RH-80	1.45919	n/a	n/a	n/a
		AT-5C-WS-6.5mph-RH-80	1.45879	n/a	n/a	n/a
		AT-5C-WS-14mph-RH-80	1.45804	n/a	n/a	n/a
	1 module Total Vent Gas (TVG) 10-min release (flammable)	AT-5C-WS-3mph-RH-80	3.52868	1.85212	n/a	n/a

		AT-5C-WS-6.5mph-RH-80	3.52503	1.84676	n/a	n/a
		AT-5C-WS-14mph-RH-80	3.51848	1.82919	n/a	n/a
	1 module Carbon Monoxide (CO) 10-min release (IDLH)	AT-5C-WS-3mph-RH-80	3.52868	1.85212	n/a	n/a
		AT-5C-WS-6.5mph-RH-80	3.52503	1.84676	n/a	n/a
		AT-5C-WS-14mph-RH-80	3.51848	1.82919	n/a	n/a
Study\Corby BESS\8-Module Rack Release (832-cell propogation)	8-Module Rack Total Vent Gas (TVG) release (flammable)	AT-5C-WS-3mph-RH-80	3.61622	1.28965	1.28965	n/a
		AT-5C-WS-6.5mph-RH-80	3.61235	1.88222	1.30726	n/a
		AT-5C-WS-14mph-RH-80	3.60543	1.86523	n/a	n/a

	8-Module Rack Carbon Monoxide (CO) release (IDLH)	AT-5C-WS-3mph-RH-80	3.61622	1.28965	1.28965	n/a
		AT-5C-WS-6.5mph-RH-80	3.61235	1.88222	1.30726	n/a
		AT-5C-WS-14mph-RH-80	3.60543	1.86523	n/a	n/a
	8-Module Rack Total Vent Gas (TVG) 10-min release (flammable)	AT-5C-WS-3mph-RH-80	8.88237	4.28454	3.58671	n/a
		AT-5C-WS-6.5mph-RH-80	9.13946	4.40703	3.77943	n/a
		AT-5C-WS-14mph-RH-80	9.7032	4.64632	4.16954	n/a
	8-Module Rack Carbon Monoxide (CO) 10-min release (IDLH)	AT-5C-WS-3mph-RH-80	8.88237	4.28454	3.58671	n/a

		AT-5C-WS-6.5mph-RH-80	9.13946	4.40703	3.77943	n/a
		AT-5C-WS-14mph-RH-80	9.7032	4.64632	4.16954	n/a
Study\Corby BESS\5-Rack Container Release (4160-cell propogation)	5-Rack Container Total Vent Gas (TVG) release (flammable)	AT-5C-WS-3mph-RH-80	7.40305	3.57272	1.77207	n/a
		AT-5C-WS-6.5mph-RH-80	7.57984	3.66099	3.08709	n/a
		AT-5C-WS-14mph-RH-80	7.96681	3.82979	3.42707	n/a
	5-Rack Container Carbon Monoxide (CO) release (IDLH)	AT-5C-WS-3mph-RH-80	7.40305	3.57272	1.77207	n/a
		AT-5C-WS-6.5mph-RH-80	7.57984	3.66099	3.08709	n/a
		AT-5C-WS-14mph-	7.96681	3.82979	3.42707	n/a

		RH-80				
	5-Rack Container Total Vent Gas (TVG) 10-min release (flammable)	AT-5C-WS-3mph-RH-80	17.9076	9.26367	7.04116	2.66545
		AT-5C-WS-6.5mph-RH-80	18.6474	9.57235	7.46065	3.10581
		AT-5C-WS-14mph-RH-80	20.2965	10.2177	8.58553	4.79747
	5-Rack Container Carbon Monoxide (CO) 10-min release (IDLH)	AT-5C-WS-3mph-RH-80	17.9076	9.26367	7.04116	2.66545
		AT-5C-WS-6.5mph-RH-80	18.6474	9.57235	7.46065	3.10581
		AT-5C-WS-14mph-RH-80	20.2965	10.2177	8.58553	4.79747

Fireball Results

Distance downwind to defined radiation levels

The reported radiations are defined in the parameters

Path	Scenario	Weather	Fireball diameter [m]	Distance downwind to intensity level 1 (4.7 kW/m2) [m]	Distance downwind to intensity level 2 (12.5 kW/m2) [m]	Distance downwind to intensity level 3 (37.5 kW/m2) [m]
Study\Corby BESS\UL9540A Module Test based Release (4-cell propogation)	UL9540A module (4-cell) Instantaneous Release TVG	AT-5C-WS-3mph-RH-80	6.48148	7.92352	4.92989	n/a
		AT-5C-WS-6.5mph-RH-80	6.48148	7.92352	4.92989	n/a
		AT-5C-WS-14mph-RH-80	6.48148	7.92352	4.92989	n/a
	UL9540A module (4-cell) Instantaneous Release CO (IDLH)	AT-5C-WS-3mph-RH-80	6.48148	7.92352	4.92989	n/a
		AT-5C-WS-6.5mph-RH-80	6.48148	7.92352	4.92989	n/a

		AT-5C-WS-14mph-RH-80	6.48148	7.92352	4.92989	n/a

Flash Fire Results

Distance downwind to defined concentrations

The reported LFL and LFL fraction are defined in the respective material property

Path	Scenario	Weather	Distance downwind to LFL [m]	Distance downwind to LFL Fraction [m]
Study\Corby BESS\UL9540A Module Test based Release (4-cell propogation)	UL9540A module (4-cell) Total Vent Gas (TVG) release (flammable)	AT-5C-WS-3mph-RH-80	0.369712	1.01732
		AT-5C-WS-6.5mph-RH-80	0.348696	0.624651
		AT-5C-WS-14mph-RH-80	0.317747	0.537097
	UL9540A module (4-cell) Carbon Monoxide (CO) release (IDLH)	AT-5C-WS-3mph-RH-80	0.369712	1.01732
		AT-5C-WS-6.5mph-RH-80	0.348696	0.624651
		AT-5C-WS-14mph-RH-80	0.317747	0.537097
	UL9540A module (4-cell) Total Vent Gas (TVG) 10-min release (flammable)	AT-5C-WS-3mph-RH-80	0.522173	1.2003
		AT-5C-WS-6.5mph-RH-	0.487447	1.11996

		80		
		AT-5C-WS-14mph-RH-80	0.438108	1.03941
	UL9540A module (4-cell) Carbon Monoxide (CO) 10-min release (IDLH)	AT-5C-WS-3mph-RH-80	0.522173	1.2003
		AT-5C-WS-6.5mph-RH-80	0.487447	1.11996
		AT-5C-WS-14mph-RH-80	0.438108	1.03941
	UL9540A module (4-cell) Instantaneous Release TVG	AT-5C-WS-3mph-RH-80	1.24279	1.58575
		AT-5C-WS-6.5mph-RH-80	1.24991	1.62051
		AT-5C-WS-14mph-RH-80	1.27209	1.7472
	UL9540A module (4-cell) Instantaneous Release CO (IDLH)	AT-5C-WS-3mph-RH-80	1.24279	1.58575
		AT-5C-WS-6.5mph-RH-80	1.24991	1.62051
		AT-5C-WS-14mph-RH-80	1.27209	1.7472

Study\Corby BESS\Single Module Release (104-cell propogation)	1 module Total Vent Gas (TVG) release (flammable)	AT-5C-WS-3mph-RH-80	1.17461	1.70666
		AT-5C-WS-6.5mph-RH-80	1.10822	1.53356
		AT-5C-WS-14mph-RH-80	1.02644	1.3678
	1 module Carbon Monoxide (CO) release (IDLH)	AT-5C-WS-3mph-RH-80	1.17461	1.70666
		AT-5C-WS-6.5mph-RH-80	1.10822	1.53356
		AT-5C-WS-14mph-RH-80	1.02644	1.3678
	1 module Total Vent Gas (TVG) 10-min release (flammable)	AT-5C-WS-3mph-RH-80	2.3494	4.09792
		AT-5C-WS-6.5mph-RH-80	2.07571	3.40065
		AT-5C-WS-14mph-RH-80	1.78777	2.72315
	1 module Carbon Monoxide (CO) 10-min release (IDLH)	AT-5C-WS-3mph-RH-80	2.3494	4.09792
		AT-5C-WS-6.5mph-RH-	2.07571	3.40065

		80		
		AT-5C-WS-14mph-RH-80	1.78777	2.72315
Study\Corby BESS\8-Module Rack Release (832-cell propogation)	8-Module Rack Total Vent Gas (TVG) release (flammable)	AT-5C-WS-3mph-RH-80	2.4129	4.20586
		AT-5C-WS-6.5mph-RH-80	2.12515	3.48539
		AT-5C-WS-14mph-RH-80	1.8242	2.78879
	8-Module Rack Carbon Monoxide (CO) release (IDLH)	AT-5C-WS-3mph-RH-80	2.4129	4.20586
		AT-5C-WS-6.5mph-RH-80	2.12515	3.48539
		AT-5C-WS-14mph-RH-80	1.8242	2.78879
	8-Module Rack Total Vent Gas (TVG) 10-min release (flammable)	AT-5C-WS-3mph-RH-80	6.19659	10.4834
		AT-5C-WS-6.5mph-RH-80	5.27813	8.4602
		AT-5C-WS-14mph-RH-80	4.25874	6.47878

	8-Module Rack Carbon Monoxide (CO) 10-min release (IDLH)	AT-5C-WS-3mph-RH-80	6.19659	10.4834
		AT-5C-WS-6.5mph-RH-80	5.27813	8.4602
		AT-5C-WS-14mph-RH-80	4.25874	6.47878
Study\Corby BESS\5-Rack Container Release (4160-cell propogation)	5-Rack Container Total Vent Gas (TVG) release (flammable)	AT-5C-WS-3mph-RH-80	5.11109	8.69384
		AT-5C-WS-6.5mph-RH-80	4.37788	7.03125
		AT-5C-WS-14mph-RH-80	3.56344	5.44262
	5-Rack Container Carbon Monoxide (CO) release (IDLH)	AT-5C-WS-3mph-RH-80	5.11109	8.69384
		AT-5C-WS-6.5mph-RH-80	4.37788	7.03125
		AT-5C-WS-14mph-RH-80	3.56344	5.44262
	5-Rack Container Total Vent Gas (TVG) 10-min release (flammable)	AT-5C-WS-3mph-RH-80	13.1265	22.2064

		AT-5C-WS-6.5mph-RH-80	11.0303	18.3545
		AT-5C-WS-14mph-RH-80	8.64986	13.6722
	5-Rack Container Carbon Monoxide (CO) 10-min release (IDLH)	AT-5C-WS-3mph-RH-80	13.1265	22.2064
		AT-5C-WS-6.5mph-RH-80	11.0303	18.3545
		AT-5C-WS-14mph-RH-80	8.64986	13.6722

Maximum distance to LFL fraction at any height

Path	Scenario	Weather	Max flash fire distance [m]	Height of the max flash fire distance [m]	Time [s]
Study\Corby BESS\UL9540A Module Test based Release (4-cell propogation)	UL9540A module (4-cell) Total Vent Gas (TVG) release (flammable)	AT-5C-WS-3mph-RH-80	0.697869	2.50958	1.50157
		AT-5C-WS-6.5mph-RH-80	0.623999	2.49031	1.50156
		AT-5C-WS-14mph-RH-80	0.539575	2.49431	1.50156

	UL9540A module (4-cell) Carbon Monoxide (CO) release (IDLH)	AT-5C-WS-3mph-RH-80	0.697869	2.50958	1.50157
		AT-5C-WS-6.5mph-RH-80	0.623999	2.49031	1.50156
		AT-5C-WS-14mph-RH-80	0.539575	2.49431	1.50156
	UL9540A module (4-cell) Total Vent Gas (TVG) 10-min release (flammable)	AT-5C-WS-3mph-RH-80	1.14685	2.49627	591.523
		AT-5C-WS-6.5mph-RH-80	1.11695	2.49975	591.515
		AT-5C-WS-14mph-RH-80	0.744366	2.50513	591.514
	UL9540A module (4-cell) Carbon Monoxide (CO) 10-min release (IDLH)	AT-5C-WS-3mph-RH-80	1.14685	2.49627	591.523
		AT-5C-WS-6.5mph-RH-80	1.11695	2.49975	591.515
		AT-5C-WS-14mph-RH-80	0.744366	2.50513	591.514
	UL9540A module (4-cell)	AT-5C-WS-3mph-RH-	1.55483	2.5399	0.04

	Instantaneous Release TVG	80			
		AT-5C-WS-6.5mph-RH-80	1.57757	2.53992	0.04
		AT-5C-WS-14mph-RH-80	1.71264	2.53995	0.11
	UL9540A module (4-cell) Instantaneous Release CO (IDLH)	AT-5C-WS-3mph-RH-80	1.55483	2.5399	0.04
		AT-5C-WS-6.5mph-RH-80	1.57757	2.53992	0.04
		AT-5C-WS-14mph-RH-80	1.71264	2.53995	0.11
Study\Corby BESS\Single Module Release (104-cell propogation)	1 module Total Vent Gas (TVG) release (flammable)	AT-5C-WS-3mph-RH-80	1.72227	2.5071	4471.31
		AT-5C-WS-6.5mph-RH-80	1.52398	2.48886	248.477
		AT-5C-WS-14mph-RH-80	1.37916	2.49797	2268.03
	1 module Carbon Monoxide (CO) release (IDLH)	AT-5C-WS-3mph-RH-80	1.72227	2.5071	4471.31
		AT-5C-WS-6.5mph-	1.52398	2.48886	248.477

		RH-80			
		AT-5C-WS-14mph-RH-80	1.37916	2.49797	2268.03
	1 module Total Vent Gas (TVG) 10-min release (flammable)	AT-5C-WS-3mph-RH-80	4.09804	2.50473	591.715
		AT-5C-WS-6.5mph-RH-80	3.40035	2.51421	300.086
		AT-5C-WS-14mph-RH-80	2.72451	2.50281	132.219
	1 module Carbon Monoxide (CO) 10-min release (IDLH)	AT-5C-WS-3mph-RH-80	4.09804	2.50473	591.715
		AT-5C-WS-6.5mph-RH-80	3.40035	2.51421	300.086
		AT-5C-WS-14mph-RH-80	2.72451	2.50281	132.219
Study\Corby BESS\8-Module Rack Release (832-cell propogation)	8-Module Rack Total Vent Gas (TVG) release (flammable)	AT-5C-WS-3mph-RH-80	4.20623	2.50035	4471.49
		AT-5C-WS-6.5mph-RH-80	3.48521	2.51	751.391
		AT-5C-WS-14mph-RH-80	2.78976	2.49881	248.478

	8-Module Rack Carbon Monoxide (CO) release (IDLH)	AT-5C-WS-3mph-RH-80	4.20623	2.50035	4471.49
		AT-5C-WS-6.5mph-RH-80	3.48521	2.51	751.391
		AT-5C-WS-14mph-RH-80	2.78976	2.49881	248.478
	8-Module Rack Total Vent Gas (TVG) 10-min release (flammable)	AT-5C-WS-3mph-RH-80	10.4993	2.59083	592.11
		AT-5C-WS-6.5mph-RH-80	8.45951	2.53878	300.232
		AT-5C-WS-14mph-RH-80	6.47665	2.51384	300.125
	8-Module Rack Carbon Monoxide (CO) 10-min release (IDLH)	AT-5C-WS-3mph-RH-80	10.4993	2.59083	592.11
		AT-5C-WS-6.5mph-RH-80	8.45951	2.53878	300.232
		AT-5C-WS-14mph-RH-80	6.47665	2.51384	300.125
Study\Corby BESS\5-Rack Container Release (4160-cell propogation)	5-Rack Container Total Vent Gas (TVG) release (flammable)	AT-5C-WS-3mph-RH-80	8.69821	2.53738	4471.78

		AT-5C-WS-6.5mph-RH-80	7.0289	2.5404	751.423
		AT-5C-WS-14mph-RH-80	5.4404	2.52082	248.485
	5-Rack Container Carbon Monoxide (CO) release (IDLH)	AT-5C-WS-3mph-RH-80	8.69821	2.53738	4471.78
		AT-5C-WS-6.5mph-RH-80	7.0289	2.5404	751.423
		AT-5C-WS-14mph-RH-80	5.4404	2.52082	248.485
	5-Rack Container Total Vent Gas (TVG) 10-min release (flammable)	AT-5C-WS-3mph-RH-80	22.459	2.94135	592.934
		AT-5C-WS-6.5mph-RH-80	18.4223	2.75603	300.539
		AT-5C-WS-14mph-RH-80	13.6767	2.58008	428.965
	5-Rack Container Carbon Monoxide (CO) 10-min release (IDLH)	AT-5C-WS-3mph-RH-80	22.459	2.94135	592.934
		AT-5C-WS-6.5mph-RH-80	18.4223	2.75603	300.539

		AT-5C-WS-14mph-RH-80	13.6767	2.58008	428.965

Explosion Results

Explosion scenarios for worst-case maximum downwind distance to defined overpressures.

These results are produced during the consequence run and depend on the precise setting of the scenario. These results may be quite different to the explosion results calculated during the risk or effects modelling as these will depend on the obstructed regions defined on the map.

The reported overpressures are defined in the explosion parameters

Path	Scenario	Weather	Overpressure level [bar]	Maximum distance [m]	Diameter [m]
Study\Corby BESS\8-Module Rack Release (832-cell propogation)	8-Module Rack Total Vent Gas (TVG) 10-min release (flammable)	AT-5C-WS-3mph-RH-80	0.02068 0.1379 0.2068	21.8178 13.0599 12.3677	23.6356 6.11983 4.73539
	8-Module Rack Carbon Monoxide (CO) 10-min release (IDLH)		0.02068 0.1379 0.2068	21.8178 13.0599 12.3677	23.6356 6.11983 4.73539
Study\Corby BESS\5-Rack Container Release (4160-cell propogation)	5-Rack Container Total Vent Gas (TVG) 10-min release (flammable)		0.02068 0.1379 0.2068	45.732 26.6627 25.1554	51.4641 13.3253 10.3108
		AT-5C-WS-6.5mph-RH-80	0.02068 0.1379 0.2068	33.5837 16.1064 14.725	47.1674 12.2128 9.44999
		AT-5C-WS-14mph-	0.02068 0.1379	30.7629 15.376	41.5258 10.7521

		RH-80	0.2068	14.1598	8.3197
	5-Rack Container Carbon Monoxide (CO) 10-min release (IDLH)	AT-5C-WS-3mph-RH-80	0.02068 0.1379 0.2068	45.732 26.6627 25.1554	51.4641 13.3253 10.3108
		AT-5C-WS-6.5mph-RH-80	0.02068 0.1379 0.2068	33.5837 16.1064 14.725	47.1674 12.2128 9.44999
		AT-5C-WS-14mph-RH-80	0.02068 0.1379 0.2068	30.7629 15.376 14.1598	41.5258 10.7521 8.3197

Supplementary data for worst-case explosion scenarios

Path	Scenario	Weather	Overpressure level [bar]	Explosion flammable mass [kg]	Ignition time [s]	Ignition source [m]	Cloud centre [m]	Explosion centre [m]
Study\Corby BESS\8-Module Rack Release (832-cell propogation)	8-Module Rack Total Vent Gas (TVG) 10-min release (flammable)	AT-5C-WS-3mph-RH-80	0.02068 0.1379 0.2068	0.134773 0.134773 0.134773	7.48233 7.48233 7.48233	10 10 10	3.33396 3.33396 3.33396	10 10 10
	8-Module Rack Carbon Monoxide (CO)		0.02068 0.1379 0.2068	0.134773 0.134773 0.134773	7.48233 7.48233 7.4823	10 10 10	3.33396 3.33396 3.333	10 10 10

	10-min release (IDLH)				3		96	
Study\Corby BESS\5-Rack Container Release (4160-cell propogation)	5-Rack Container Total Vent Gas (TVG) 10-min release (flammable)		0.02068 0.1379 0.2068	1.39129 1.39129 1.39129	7.7993 7.7993 7.7993	20 20 20	7.01833 7.01833 7.01833	20 20 20
		AT-5C-WS-6.5mph-RH-80	0.02068 0.1379 0.2068	1.0711 1.0711 1.0711	1.26043 1.26043 1.26043	10 10 10	5.87134 5.87134 5.87134	10 10 10
		AT-5C-WS-14mph-RH-80	0.02068 0.1379 0.2068	0.730901 0.730901 0.730901	1.26015 1.26015 1.26015	10 10 10	4.59473 4.59473 4.59473	10 10 10
	5-Rack Container Carbon Monoxide (CO) 10-min release (IDLH)	AT-5C-WS-3mph-RH-80	0.02068 0.1379 0.2068	1.39129 1.39129 1.39129	7.7993 7.7993 7.7993	20 20 20	7.01833 7.01833 7.01833	20 20 20
		AT-5C-WS-6.5mph-RH-80	0.02068 0.1379 0.2068	1.0711 1.0711 1.0711	1.26043 1.26043	10 10 10	5.87134 5.87134	10 10 10

					1.2604 3		5.871 34	
		AT-5C- WS- 14mph- RH-80	0.02068 0.1379 0.2068	0.730901 0.730901 0.730901	1.2601 5 1.2601 5 1.2601 5	10 10 10	4.594 73 4.594 73 4.594 73	10 10 10

APPENDIX 12-E: BESS SITE PLAN AND ELEVATION DRAWINGS

REV	DATE	BY	CKD	DESCRIPTION
A	12/21/23	DCR	ERA	ISSUED FOR 30% REVIEW
B	05/03/24	DCR	JTD	ISSUED FOR 60% REVIEW
C	02/14/25	DCR	ERA	ISSUED FOR 60% REVIEW

PRELIMINARY - NOT FOR CONSTRUCTION

BURNS McDONNELL

BURNS & McDONNELL WESTERN ENTERPRISES, INC.
140 S STATE COLLEGE BLVD., SUITE 100
BREA, CA 92821

date	detailed
05/03/2024	J. DOLL
designed	checked
D. ROSENBLUM	J.T. DOWELL

CORBY ENERGY STORAGE, LLC
700 UNIVERSE BLVD.
JUNO BEACH, FL 33408

CORBY BESS PROJECT
6865 BYRNES ROAD
VACAVILLE, CALIFORNIA 95687

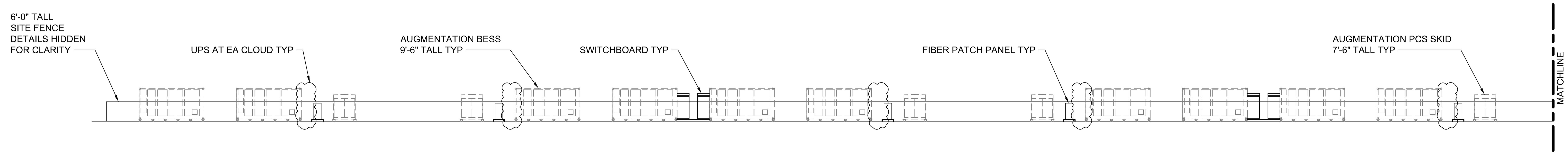
CORBY BESS
SITE PLAN

project	contract
163851	8410

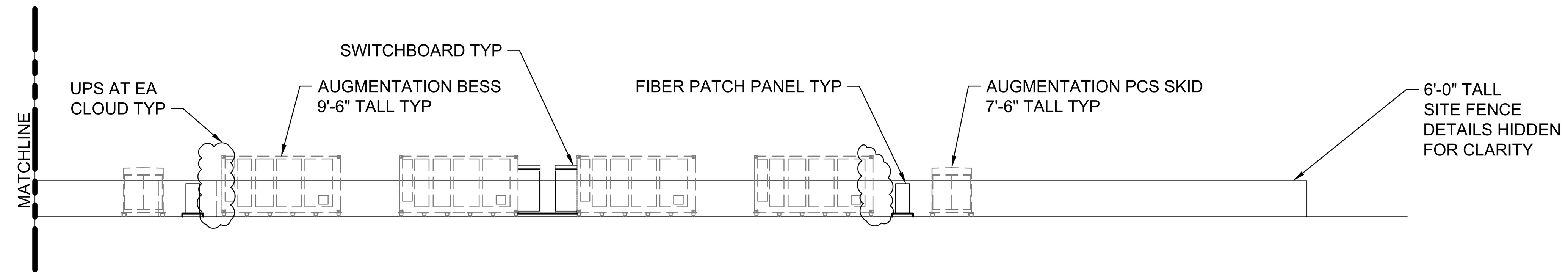
drawing **BCR-C-003** – rev. **C**

sheets

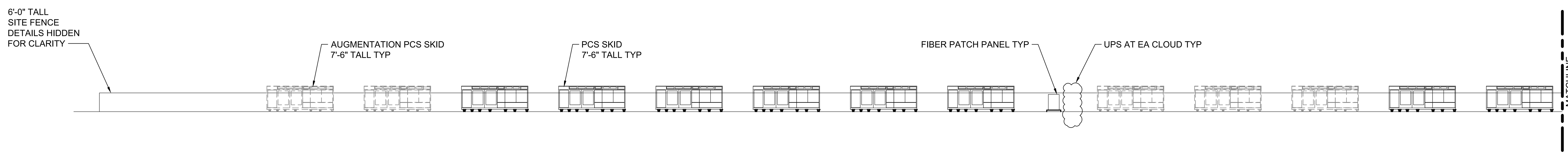
file 163851BCR-C-003.dwg



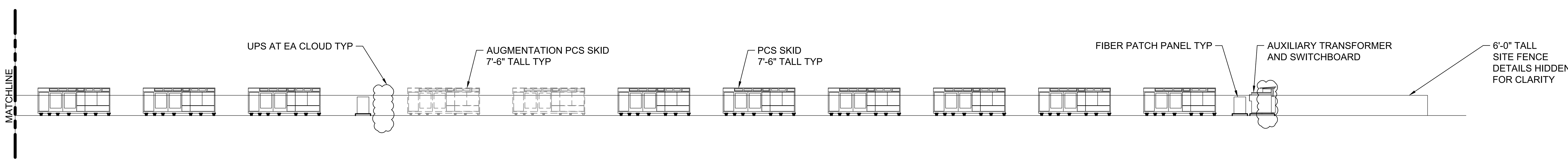
ELEVATION A
VIEW LOOKING NORTH
0 8' 16' 32'
SCALE IN FEET



ELEVATION A
VIEW LOOKING NORTH
0 8' 16' 32'
SCALE IN FEET



ELEVATION B
VIEW LOOKING WEST
0 8' 16' 32'
SCALE IN FEET



ELEVATION B
VIEW LOOKING WEST
0 8' 16' 32'
SCALE IN FEET

REV	DATE	BY	CKD	DESCRIPTION
A	05/03/24	MRP	JJM	ISSUED FOR 60% REVIEW

PRELIMINARY - NOT FOR CONSTRUCTION

BURNS McDONNELL
BURNS & McDONNELL WESTERN ENTERPRISES, INC.
140 S STATE COLLEGE BLVD., SUITE 100
BREA, CA 92821
714-256-1595

date	detailed
04/26/24	C. BRYAN
designed	checked
M. PACHECO	J. MASSA

CORBY ENERGY STORAGE, LLC
700 UNIVERSE BLVD.
JUNO BEACH, FL 33408

CORBY BESS PROJECT
6865 BYRNES ROAD
VACAVILLE, CALIFORNIA 95687

CORBY BESS
ELEVATION VIEWS
LOOKING NORTH & WEST

project	contract
163851	-

drawing **BCR-EXS-101** rev. **A**

sheet of sheets

file BCR-EXS-101.dwg

REV	DATE	BY	CKD	DESCRIPTION
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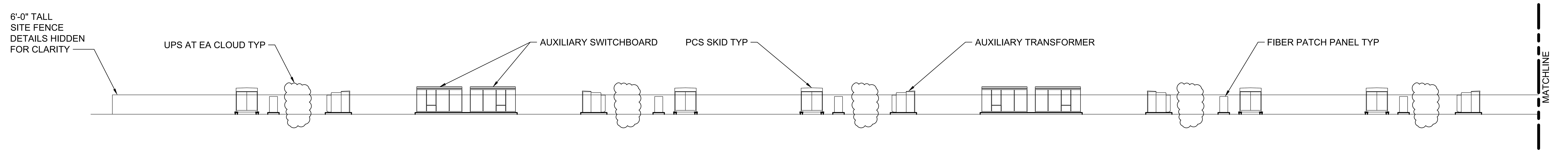
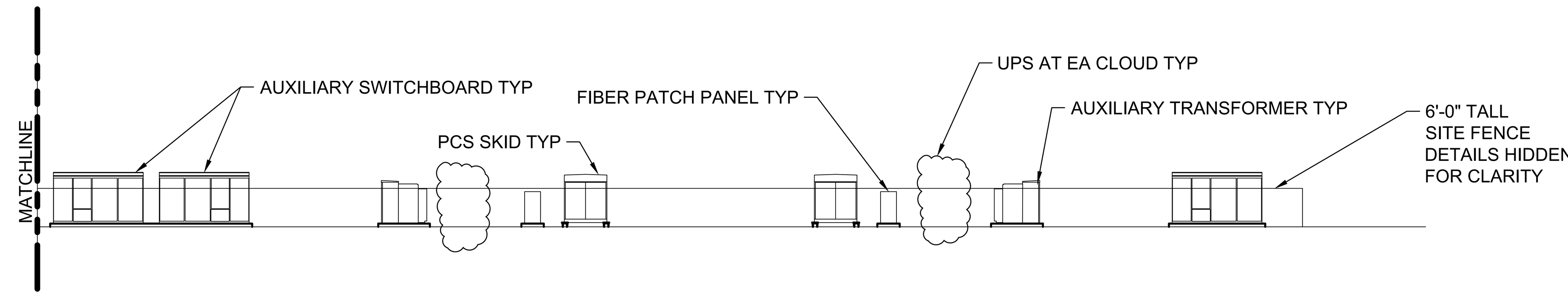
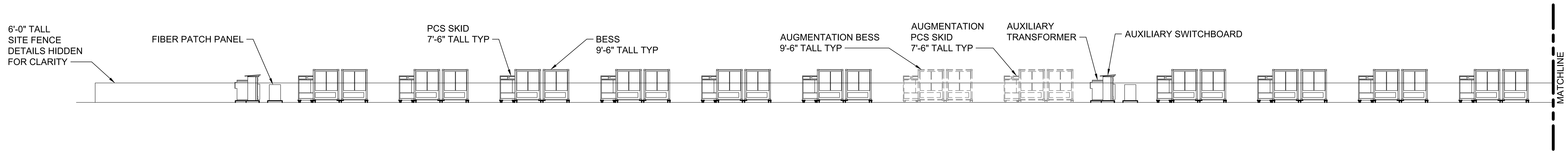


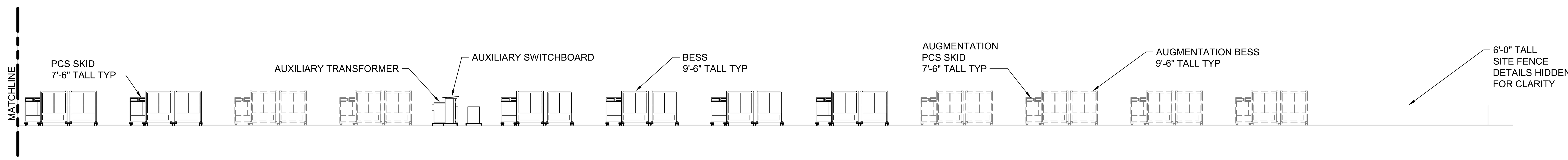
ELEVATION C
VIEW LOOKING SOUTH
0 8' 16' 32'
SCALE IN FEET



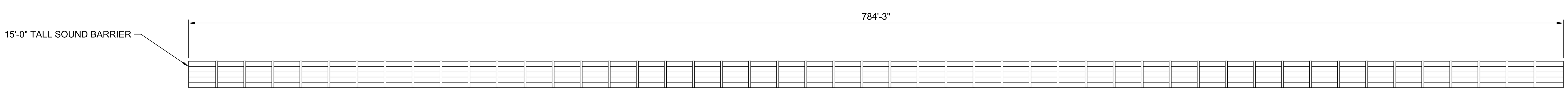
ELEVATION C
VIEW LOOKING SOUTH
0 8' 16' 32'
SCALE IN FEET



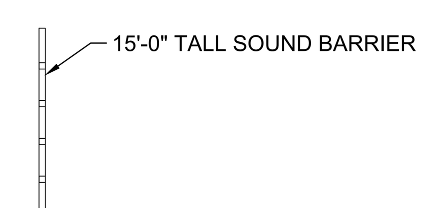
ELEVATION D
VIEW LOOKING EAST
0 8' 16' 32'
SCALE IN FEET



ELEVATION D
VIEW LOOKING EAST
0 8' 16' 32'
SCALE IN FEET



ELEVATION E
VIEW LOOKING SOUTH
0 30' 60'
SCALE IN FEET



ELEVATION F
VIEW LOOKING EAST
0 10' 20'
SCALE IN FEET

PRELIMINARY - NOT FOR CONSTRUCTION

BURNS McDONNELL

BURNS & McDONNELL WESTERN ENTERPRISES, INC.
140 S STATE COLLEGE BLVD., SUITE 100
BREA, CA 92821
714-256-1595

date	detailed
04/26/24	C. BRYAN
designed	checked
M. PACHECO	J. MASSA

CORBY ENERGY STORAGE, LLC
700 UNIVERSE BLVD.
JUNO BEACH, FL 33408

CORBY BESS PROJECT
6865 BYRNES ROAD
VACAVILLE, CALIFORNIA 95687

CORBY BESS
ELEVATION VIEWS
LOOKING SOUTH & EAST

project	contract
163851	-

drawing **BCR-EXS-102** rev. **A**

sheet of sheets

file BCR-EXS-102.dwg

APPENDIX 12-F: UL 9540A TEST RESULTS AND UL 9549 CERTIFICATE OF COMPLIANCE

CELL TEST REPORT
UL 9540A
Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems (AACD)

Project Number...............................:	**4790838636.3**
Date of issue ....:	**2023.08.24**
Total number of pages...................:	**35**
UL Report Office ....:	**UL(Changzhou) Quality Technical Service Co., LTD**
Applicant's name...........................:	**Contemporary Amperex Technology Co., Limited**
Address ....:	No 2 Xingang Road Zhangwan Town Jiaocheng District NingdeFujian 352100 China
Test specification:	4th Edition, Section 7, November 12, 2019
Standard ....:	UL 9540A, Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems
Test procedure ....:	7.1, 7.2, 7.3.1, 7.4, 7.6.1, 7.7
Non-standard test method ....:	N/A

General disclaimer:

The test results presented in this report relate only to the sample tested in the test configuration noted on the list of the attachments.

UL LLC did not select the sample(s), determine whether the sample(s) was representative of production samples, witness the production of the test sample(s), nor were we provided with information relative to the formulation or identification of component materials used in the test sample(s).

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Cell level information	
Model No ....:	CBDD0
Ratings (Vdc, Ah) ....:	3.2V, 306Ah
Chemistry of test item………………:	Lithium Iron Phosphate
Original Equipment Manufacturer (OEM):	Contemporary Amperex Technology Co., Limited
Branding Manufacturer (if not OEM):	N/A
Was the cell certified? ………………………….:	Yes
Standard test item certified to …………..:	UL 1973
Organization that certified test item …….:	MH62898
Average cell surface temperature at gas venting, °C:	154
Average surface temperature at thermal runaway, °C:	241
Gas Volume-:	204L
Lower flammability limit (LFL), % volume in air at the ambient temperature	8.595
Lower flammability limit (LFL), % volume in air at the venting temperature	7.24
Burning velocity (S_u) cm/s:	54.20
Maximum pressure (P_{max}) psig:	102.74

Cell Gas composition

Gas		**Measured %**
Carbon Monoxide	CO	14.596
Carbon Dioxide	CO_2	26.925
Hydrogen	H_2	43.066
Methane	CH_4	7.051
Acetylene	C_2H_2	0.119
Ethylene	C_2H_4	3.289
Ethane	C_2H_6	1.060
Propylene	C_3H_6	0.686
Propane	C_3H_8	0.260
-	C4 (Total)	0.865
-	C5 (Total)	0.399
-	C6 (Total)	0.148
1-Heptene	C7H14	0.025
Styrene	C8H8	0.013
Benzene	C_6H_6	0.082
Toluene	C_7H_8	0.012
Dimethyl Carbonate	$C_3H_6O_3$	1.304
Ethyl Methyl Carbonate	$C_4H_8O_3$	0.101
Total	-	100

Cell failure test method performed (summary of method and test clause):

☒ External heating using thin film with 4°C to 7°C thermal ramp.
☐ Nail Penetration
☐ Overcharge
☐ External short circuit (***X*** Ω *external resistance*)
☐ Flow Battery with 2 active electrolyte methods
☐ Flow Battery with 1 active electrolyte methods
☐ Others

Description of method used to fail cells if other than external thin film heater with thermal ramp, :N/A

Summary of testing:

Performance Criteria in accordance with Clause 7.7 and Figure 1.1:

[ ] Thermal runaway was not induced in the cell; and

[ ] The cell vent gas did not present a flammability hazard when mixed with any volume of air, as determined in accordance with ASTM E918 at both ambient and vent temperatures.

Necessity for a module level test

[X] The performance criteria of the cell level test as indicated in 7.7 of UL 9540A 4th edition has not been met, therefore a module level testing in accordance with UL 9540A will need to be conducted on a complete module employing this cell.

[ ] The performance criteria of the module level tests as indicated in 7.7 of UL 9540A 4th edition has been met, therefore a module level testing in accordance with UL 9540A need not be conducted.

Testing Laboratory information

Testing Laboratory and testing location(s):

Testing Laboratory:	UL(Changzhou) Quality Technical Service Co., LTD	
Testing location/ address .... :	21 Longmen Rd, National High-Tech Industrial Development District, Wujin, Changzhou, Jiangsu, China	
Tested by (name, signature)........................ :	Huang Fei /Vic Zhang	
Witnessed by (for 3rd Party Lab Test Location) (name, signature) .... :	N/A	N/A
Project Handler (name, signature).............. :	Arui Zhou	Arui Zhou
Reviewer (name, signature) …………….:	Benjamin Liu	Benjamin Liu

Gas Analysis Testing Laboratory :

Testing location/ address .... :	UL SOLUTIONS 333 Pfingsten Rd. Northbrook, Il 60062 USA
Project Handler (name, signature).............. :	Ian A. Erickson

Reviewer (name, signature) …………….:	Sean. Mitchell
List of Attachments (including a total number of pages in each attachment):	
Attachment A: Cell Conditioning (Charge/discharge) Profiles - (*Pages **17** through **19***) **Attachment B:** Cell Instrumentation Photos - (*Pages **20** through **20***) **Attachment C**: Cell Temperature Profiles during testing - (*Pages **21** through **23***) **Attachment D**: Cell Testing Photos - (*Pages **24** through **33***) **Attachment E**: Cell vent gas test chamber photo and profile of chamber gas analysis (O_2 and Pressure) – (*Pages **34** through **34***) **Attachment F**: Cell Gas Analysis Report - (*Pages **35** through **35***)	

Photo of cell/Stack

Figure 0-1

Figure 0-2

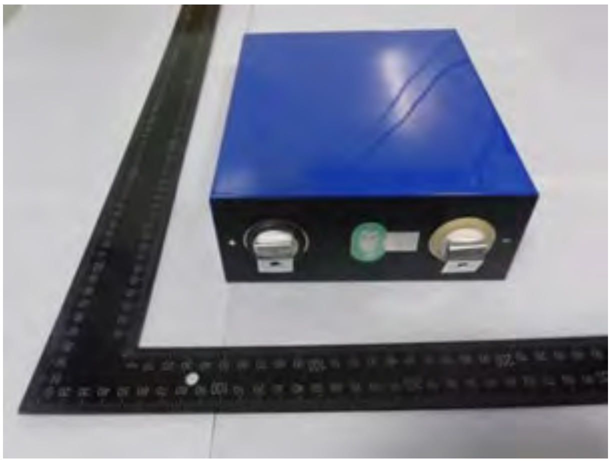


Figure 0-3

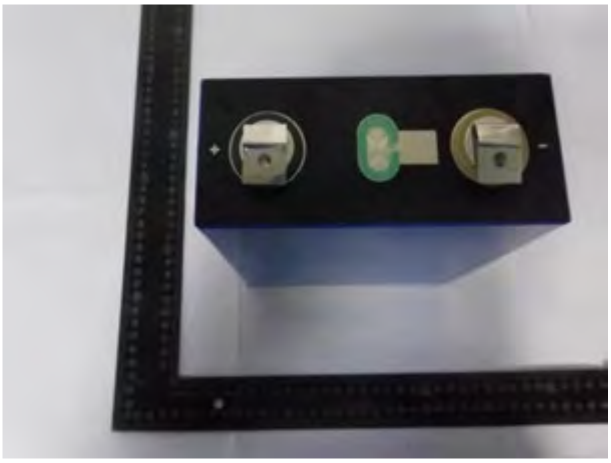


Figure 0-4

Test Item Charge/Discharge Specifications:	
• **Charge current, A:**	153
• **Charge Power, w**	489.6
• **Standard full charge voltage, Vdc:**	3.65
• **Charge temperature range, °C:**	0~60
• **End of charge voltage, V:**	3.65
• **Discharge current, A:**	153
• **Discharge Power, w**	489.6
• **End of discharge voltage, Vdc:**	2.5
• **Discharge temperature range, °C:**	-20~60

Test item particulars:	
Possible test case verdicts:	
- test case does not apply to the test object...........:	N/A
- test object does meet the requirement ....:	P (Pass)
- test object does not meet the requirement...........:	F (Fail)
- test object was completed per the requirement...:	C(Complete)
- test object was completed with modification……:	M(Modification)
Testing...:	CBDD0
Date of receipt of test item ....:	2023-04-28
Date (s) of performance of tests ....:	2023-05-10~2023-05-13
General remarks:	
"(See Enclosure #)" refers to additional information appended to the report. "(See appended table)" refers to a table appended to the report. **Throughout this report a point is used as the decimal separator.**	
Manufacturer’s Declaration of samples submitted for test:	
The applicant for this report includes samples from more than one factory location and a declaration from the Manufacturer stating that the sample(s) submitted for evaluation is (are) representative of the products from each factory has been provided ....:	☒ **Yes** ☐ **Not applicable**
Name and address of factory (ies) .... :	Factory_1: Guangdong Ruiqing Contemporary Amperex Technology Limited Factory_1 address: No.1 Shidai Street,High-tech Industrial Development Zone, Zhaoqing City，Guangdong Province Factory_2: Jiangxi Yichun Contemporary Amperex Technology Limited Factory_2 address: No. 1, Chunfeng Road, Yichun Economic and Technological Development Zone, Jiangxi Province Factory_3: Fuding Contemporary Amperex Technology Limited Factory_3 address: No. 1, Shidai Road, Xueqiao village, Qianqi Town, Fuding City, Ningde City, Fujian Province

General product information and other remarks:

The tested cell is a Lithium-ion battery cell, Model CBDD0. Each cell has a capacity of 306 Ah and nominal voltage 3.2 Vdc.

The overall dimensions of cell are 71.6±0.8mm(Width) by 174.7±0.8mm(Length) by 207.3±0.8mm(Height).

The weight of cell is 5500g±300g.

The test samples were produced in Factory 1.

The test samples are figure 0-1 and figure 0-2.

The customer has changed the design of the top cover of the cell, figures 0-1 and 0-2 are the original design of the cell, 0-3 and 0-4 are the new designs.

According to customer analysis, the above differences do not affect the test results. The new design is for reference only, and the samples after the design change have not been tested.

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict

5.0	**CONSTRUCTION**		**Verdict**
5.1. 5.4	**Cell/Stack Construction**		—
5.1.1, 5.4.1	Generic Chemistry:	Lithium iron phosphate	—
	Electrolyte Chemistry:	LiPF6 with additives	—
	Flow Battery Electrolyte No. 1 Chemistry:	Not flow battery	—
	Max volume of system electrolyte No. 1, L:	Not flow battery	—
	Flow Battery Electrolyte No. 2 Chemistry:	Not flow battery	—
	Max volume of system electrolyte No. 2, L:	Not flow battery	—
	Separator Melt Temperature, °C:	Not used during test	—
	Format: Cylindrical /Prismatic /Pouch Flow Battery Stack	Prismatic	—
	Overall Dimensions, mm	174.7±0.8mm (Length) by 71.6±0.8mm (width) by 207.3±0.8mm (height)	—
	Cell Weight, g	5500±300	—
5.1.2	Cell Certification:	Yes	—
	Standard Used for Cell Certification:	UL 1973	—
	Organization that Certified Cell:	MH62898	—
5.1.1, 5.4.1	Cell/Stack Ratings: • Nominal Voltage, Vdc •Nominal Capacity, Ah	3.2 306	— —
5.4.1	Flow Battery: No. of Cells per Stack:	Not flow battery	—
	Flow battery system manufacturer:	Not flow battery	—
	Flow battery system model:	Not flow battery	—
	Flow battery system ratings, Vdc, Ah:	Not flow battery	—
5.4.2	Flow battery system certified to UL 1973:	Not flow battery	—
	Organization that certified flow battery system:	Not flow battery	—
6.0	**PERFORMANCE**		**Verdict**
6.1	**General**		C
7.2	**Samples**		C

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict

7.2.1	Samples conditioned through charge discharge cycling a minimum of 2 cycles.	See Attachment A for profiles See Table 1 for specifications See also Table 2	C
7.2.2	100% SOC and stabilize from 1h to 8 h before testing		
7.2.3	Pouch Cells constrained per end use during testing.		N/A
7.3	**Determination of thermal runaway methodology**		C
7.3.1	**General**		C
7.3.1.1	Ambient indoor laboratory conditions: 25 ±5°C (77 ±9°F) ≤50 ±25% RH at the initiation of the test.	See Attachment C See Table 3	C
7.3.1.2	Heat the cell to thermal runaway by externally applied flexible film heaters	See Attachment B	C
	Heater Dimension	Two heaters 152.4mm by 203.2 mm in size for each sample. Each side of the cells was instrumented with the heater	
	A surface heating rate of 4° C (7.2° F) to 7° C (12.6° F) per minute was applied to the cell.	See Attachment C, D See Table 4	C
	Maximum surface end point temperature, °C	Not used, the cells are heated until the thermal runaway achieved According to the Certification Requirement Decision: Test Method for Evaluating Thermal Runaway Fire Propagation in Battery. Holding temperature was not utilized during the test and the cell was continuously heated until thermal runaway occurred	
	The following method(s) was employed to cause thermal runaway: ☐ Mechanical (e.g. nail penetration); ☐ Electrical stress in the form of overcharging, ☐ Electrical stress in the form of over discharging ☐ Electrical stress in the form of external short-circuiting ☐ Use of alternate heating sources (e.g. oven). ☐ Other (explain)	Only external heating in the form of using flexible thin film heaters to cause thermal runaway	N/A
7.3.1.3	Detail of test method when using another cell abuse method to initiate thermal runaway	See Attachment E	N/A

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict

7.3.1.4	Monobloc batteries such as a lead acid battery		N/A
7.3.1.5	Estimated surface temperature at which internal short circuiting within the cell will occur that could lead to a thermal runaway condition.	Not used, the cells are heated until the thermal runaway achieved According to the Certification Requirement Decision: Test Method for Evaluating Thermal Runaway Fire Propagation in Battery. Holding temperature was not utilized during the test and the cell was continuously heated until thermal runaway occurred	N/A
7.3.1.6	The cell was heated until thermal runaway has occurred.	Refer to Attachment C	C
	Another external heating method was used to cause cell thermal runaway		N/A
7.3.1.7	The cell's exterior surface temperature was measured	See Attachment B	C
7.3.1.8	The temperature at which the cell case vents due to internal pressure rise was documented.	See Table 4 See Attachment C, D	C
7.3.1.9	The temperature at the onset of thermal runaway was documented.	See Table 4 See Attachment C, D	C
	If cell venting occurs first, the cell was heated continuously until thermal runaway occurs.	See Attachment C	C
7.3.1.10	When using methods other than the heater method, the stresses were applied to the cell until thermal runaway occurs.		N/A
7.3.1.11	3 additional samples were tested using the same method and exhibited thermal runaway	See Table 3, 4 and 5 See Attachment C, D	C
7.4	**Cell vent gas composition test**		C
7.4.1	Cell vent gas was generated and captured by forcing a cell into thermal runaway with the methodology developed in 7.3, inside a pressure vessel	Size of pressure vessel used: 100L Refer to Attachment E	C
	The test was initiated with an initial condition of atmospheric pressure and less than 1% oxygen by volume.	Refer to Attachment E Atmospheric pressure (psig):0.13	C

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict

		Oxygen concentration measured (% volume):0.06 Inert gas used: Nitrogen	
7.4.2	Cell vent gas composition was determined using Gas Chromatography (GC)	Refer to Table 8 Refer to Attachment F	C
	Hydrogen gas was measured	Refer to Table 8	C
	The initial atmospheric conditions prior to testing were noted.	Refer to Table 3 Refer to attachment C and F	C
7.4.3	The lower flammability limit of the cell vent gas was determined on samples of the synthetically replicated gas mixture in accordance with ASTM E918, testing at both ambient and cell vent temperatures.	Refer to Table 9 and 10	C
7.4.4	The gas burning velocity of the synthetically replicated cell vent gas was determined in accordance with the Method of Test for Burning Velocity Measurement of Flammable Gases Annex in ISO 817.	Refer to Table 9 and 10	C
7.4.5	P_{max} of the synthetically replicated cell vent gas was determined in accordance with EN 15967.	Refer to Table 9 and 10	C
7.6	**Cell Level Test Report Information**		C
7.6.1	Minimum information provided in the report for items a) through m)		C
7.6.2	Minimum information of items a) through k) was provided in the report for flow battery		N/A
7.7	**Performance – cell level test**		C
7.7.1	a) Thermal runaway cannot be induced in the cell; and	Thermal runaway can be induced in the cell with external heater during the test	F
	b) The cell vent gas does not present a flammability hazard when mixed with any volume of air, at both ambient and vent temperatures.	As a result of gas analysis, the gas generated from the cell were identified flammable	F

Table 1 – Specified conditioning parameters			
Charging:		Discharging	
Power (CP), W	489.6	Power (CP), W	489.6
Standard full charge voltage, Vdc	3.65	Voltage at start of discharge, Vdc	3.65
End of charge voltage, Vdc	3.65	End of discharge voltage, Vdc	2.5
Charging Test Ambient, °C	0~60	Discharging Test Ambient, °C	-20~60
Refer to Attachment A for charge/discharge profiles for each cell.			

Table 2 – Charge completion and cell test initiation times		
Cell Test Number	**Charge Completion Date and Time**	**Cell test Date and Time**
1	2023-05-10 08:24	2023-05-10 11:14
2	2023-05-10 08:26	2023-05-10 15:28
3	2023-05-11 10:18	2023-05-11 15:26
4	2023-05-12 11:41	2023-05-12 14:59
5	2023-05-13 11:11	2023-05-13 17:49

Table 3 - Test Initiation Details					
	Cell Test 1	**Cell Test 2**	**Cell Test 3**	**Cell Test 4**	**Cell Test 5**
Test Date	2023-05-10	2023-05-10	2023-05-11	2023-05-12	2023-05-13
Test Start Time	11:14	15:28	15:26	14:59	17:49
Initial Lab Temperature	21.6°C	21.6°C	21.6°C	21.6°C	23.6°C
Initial Relative Humidity	68.5%RH	68.5%RH	68.5%RH	68.5%RH	68.1%RH

Table 4 - Thermal Runaway Results					
	Cell Test 1	**Cell Test 2**	**Cell Test 3**	**Cell Test 4**	**Cell Test 5**
OCV at start of test, Vdc	3.384	3.374	3.405	3.400	3.379
Average Heating Rate, °C/min	4.5	4.5	4.5	4.5	4.5
Venting Time after the test start (hh:mm:ss)	0:34:55	0:36:44	0:35:46	0:36:00	0:36:24
Venting Temperature, °C	153	153	159	152	166
Thermal Runaway Time after the test start (hh:mm:ss)	0:55:32	0:57:42	0:56:49	0:56:41	0:56:10
Thermal Runaway Temperature, °C	240	243	244	238	247
Refer to Attachment C for surface temperature profiles during testing					

Table 5 – Average Vent and Thermal Runaway Temperatures	
Average of Cell Vent Temperatures, °C	154
Average of Cell Thermal Runaway Temperatures, °C	241
#Averages of cell tests other than the gas analysis test	

Table 6 – Parameters Flow Battery
N/A

Table 7 – Results of Flammability Testing of Flow Battery Electrolyte
N/A

Table 8 – Results of Gas Analysis (Excluding O_2 and N_2)			
Gas		Measured %	Component LFL[1]
Carbon Monoxide	CO	14.596	10.9
Carbon Dioxide	CO_2	26.925	N/A
Hydrogen	H_2	43.066	4.0
Methane	CH_4	7.051	4.4
Acetylene	C_2H_2	0.119	2.3
Ethylene	C_2H_4	3.289	2.4
Ethane	C_2H_6	1.060	2.4
Propylene	C_3H_6	0.686	1.8
Propane	C_3H_8	0.260	1.7
-	C4 (Total)	0.865	N/A
-	C5 (Total)	0.399	N/A
-	C6 (Total)	0.148	N/A
1-Heptene	C7H14	0.025	N/A
Styrene	C8H8	0.013	1.1
Benzene	C_6H_6	0.082	1.2
Toluene	C_7H_8	0.012	1.0
Dimethyl Carbonate	$C_3H_6O_3$	1.304	N/A
Ethyl Methyl Carbonate	$C_4H_8O_3$	0.101	N/A
Total	-	100	-

[1] Extracted LFL values from ISO 10156-2017

Table 9 – Gas composition excluding the constituents with boiling points higher than 60°C[2]			
Gas		**Measured %**	**Component LFL**
Carbon Monoxide	CO	14.846	10.9
Carbon Dioxide	CO2	27.386	N/A
Hydrogen	H2	43.804	4.0
Methane	CH4	7.172	4.4
Acetylene	C2H2	0.121	2.3
Ethylene	C2H4	3.345	2.4
Ethane	C2H6	1.078	2.4
Propylene	C3H6	0.697	1.8
Propane	C3H8	0.264	1.7
Propadiene	C3H4	0.000	1.9
-	C4 (Total)	0.880	N/A
-	C5 (Total)	0.405	N/A
Total	-	100	-

[2] The constituents with a higher boiling point were excluded for the flammability characteristic analysis as these components will turn into a liquid state at room temperature and will not release from the gas bottle as a homogenous mixture.

Table 10 – Properties of Vent Gas Analysis	
Lower Flammability limit at Ambient Temperature, 25°C (% vol in air)	8.595
Lower Flammability limit at Vent Temperature, [154 °C] (% vol in air)	7.24
Burning Velocity Measurement, S_u cm/sec	54.20
Maximum Pressure P_{max}, psig	102.74

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict

	TABLE: Critical components information				
Object / part No.	**Manufacturer/ trademark**	**Type / model**	**Technical data**	**Standard**	**Mark(s) of conformity**
Cell Model	Contemporary Amperex Technology Co.,Limited	CBDD0	Nominal voltage：3.2V Rated capacity：306Ah	UL 1973	MH62898
Separator	Contemporary Amperex Technology Co.,Limited	SBM	Material: PE Size: LxWxT;(27937-33532mm) * (176-214mm) * (0.008-0.018mm) Separator melting temperature: 140±5°C	—	—
Electrolyte	Contemporary Amperex Technology Co.,Limited	ESN	Composition: $LiPF_6$, DMC, EMC, EC, PC, DEC;	—	—
Case	Contemporary Amperex Technology Co.,Limited	PPA	Material: Al 3003 Minimum thickness: 0.6-0.7mm	—	—
Insulators/ location in cell	Contemporary Amperex Technology Co.,Limited	PTA PAP	Up-Plate Material: PP Down-Plate Material: PP	—	—
Vent	Contemporary Amperex Technology Co.,Limited	PTA	Length: (25.3-30.3)mm, Width: (13.7-16.7)mm Material: MFX2 Valve opening pressure:(0.4-1.2)MPa	—	—

Attachment A: Cell Conditioning (Charge/discharge) Profiles - (*Pages **17** through **19***)

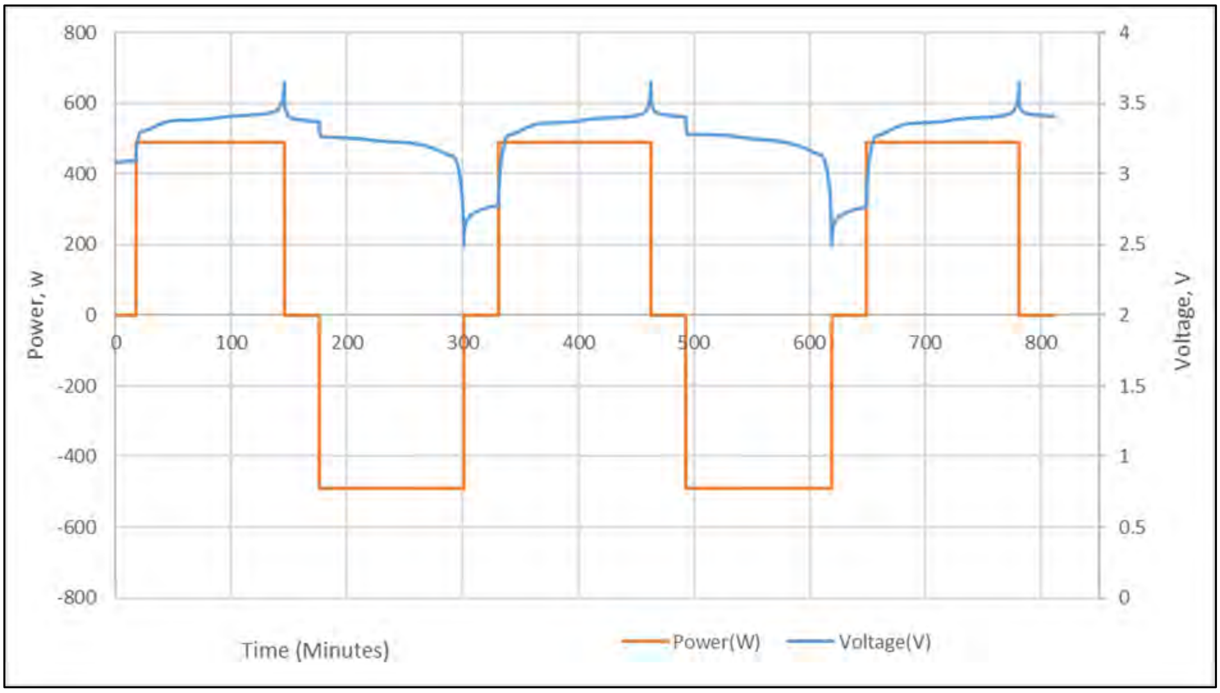


Figure 1: Cell 1 Conditioning (Charge/discharge) Profiles

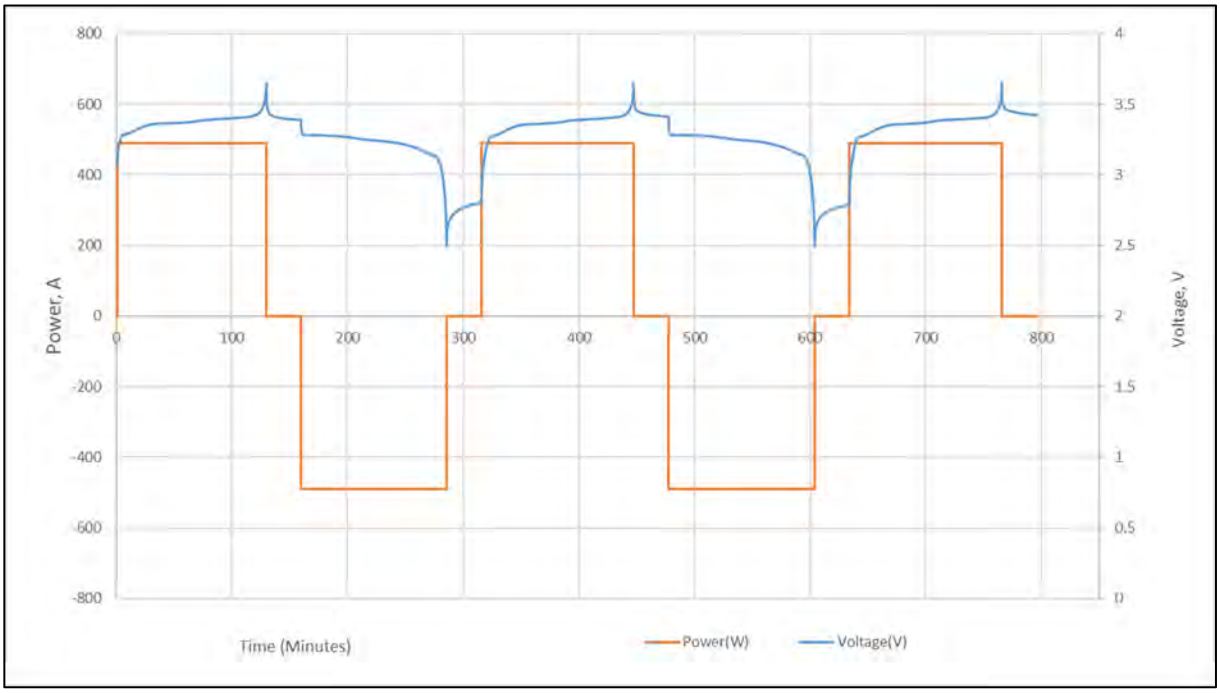


Figure 2: Cell 2 Conditioning (Charge/discharge) Profiles

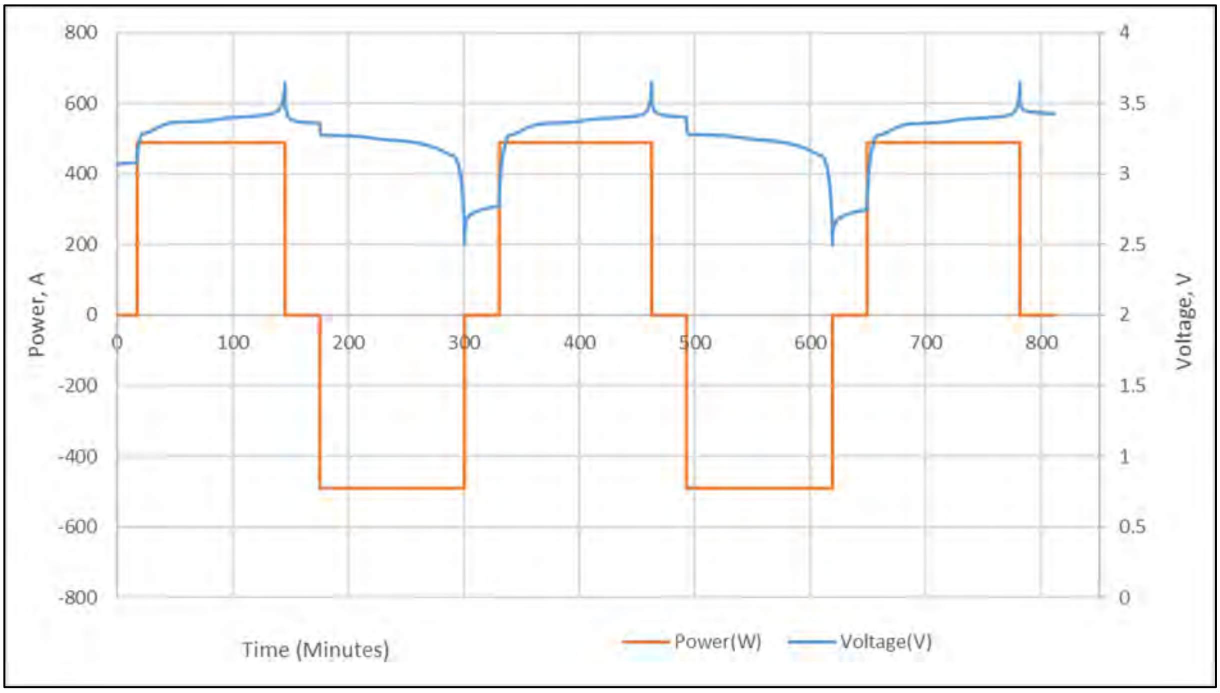


Figure 3: Cell 3 Conditioning (Charge/discharge) Profiles

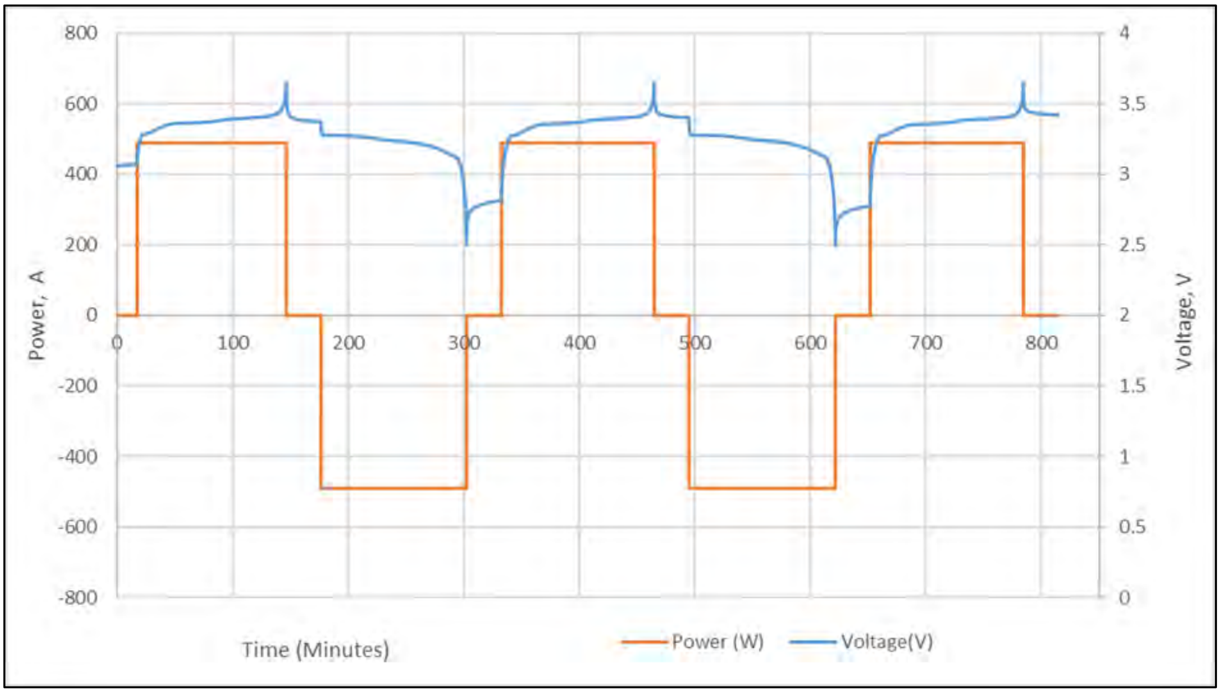


Figure 4: Cell 4 Conditioning (Charge/discharge) Profiles

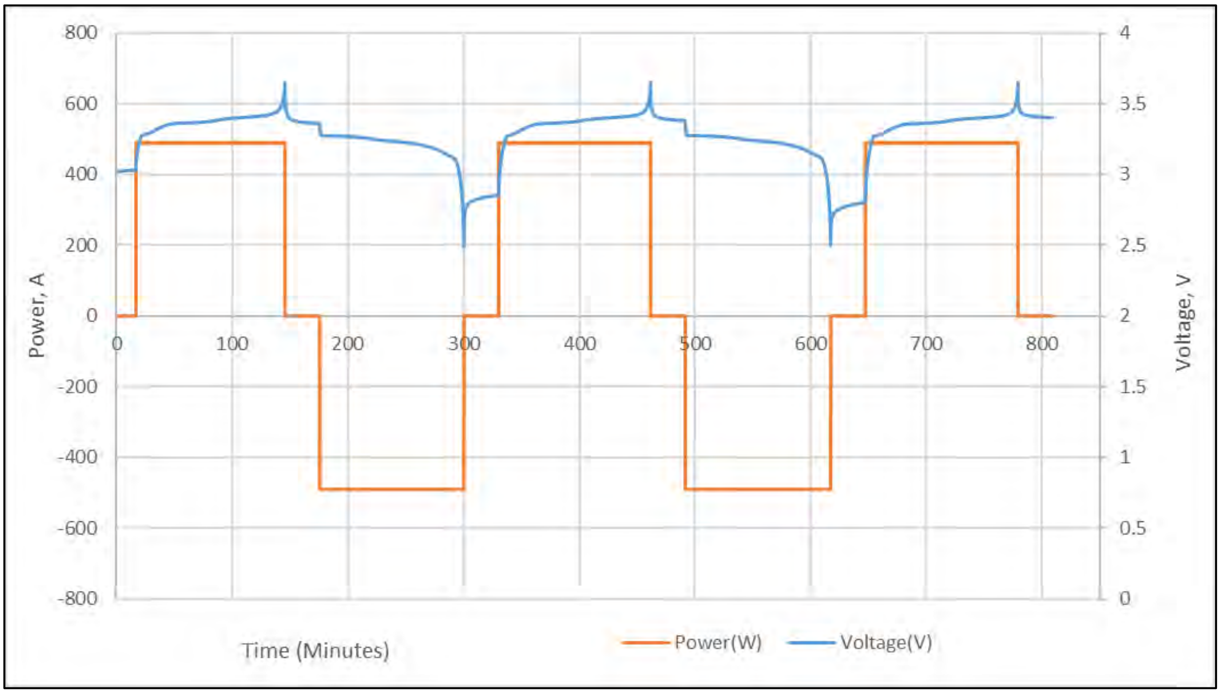
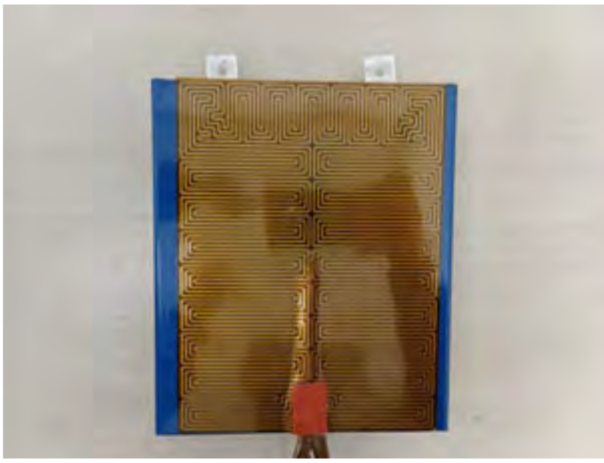
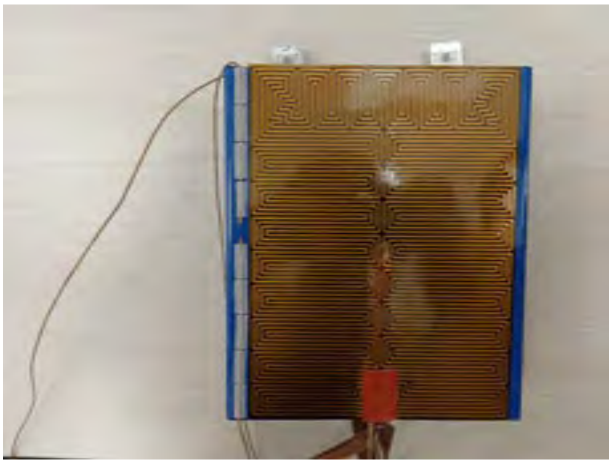


Figure 5: Cell 5 Conditioning (Charge/discharge) Profiles

Attachment B: Cell Instrumentation Photos - (*Pages **20** through **20***)





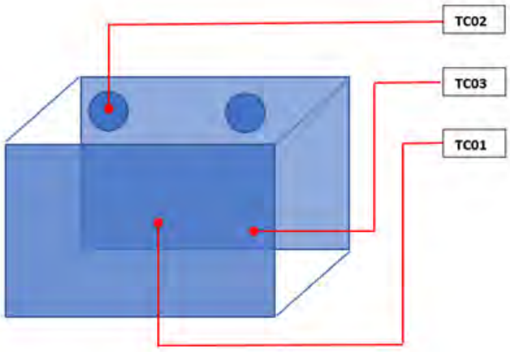


Figure 6: Sample Instrumentation Prior to Test
Note: heaters were placed on two sides of the cell after thermocouples were instrumented.
Note: TC01 between cell body and heater; TC02 on the cell positive; TC03 on the cell body not covered by heater; TC04 Ambient temperature; V1 cell voltage.

Attachment C: Cell Temperature Profiles during testing - (*Pages **21** through **23***)

Note: TC01 between cell body and heater; TC02 on the cell positive; TC03 on the cell body not covered by heater; TC04 Ambient temperature; V1 cell voltage.
TC01 was used to control the temperature at 4 to 7°C/min and TC03 temperatures were reported herein for the surface temperature at the onset of vent and thermal runaway.

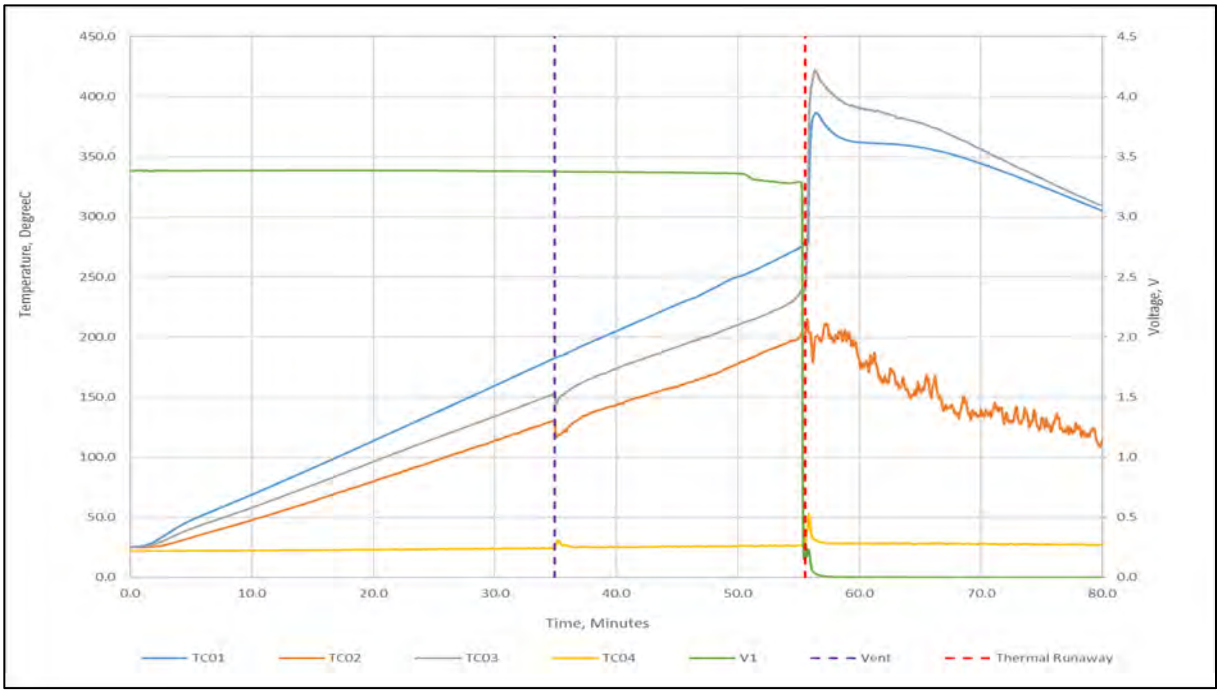


Figure 7: Cell 1 – External Heating 4.5°C per minute

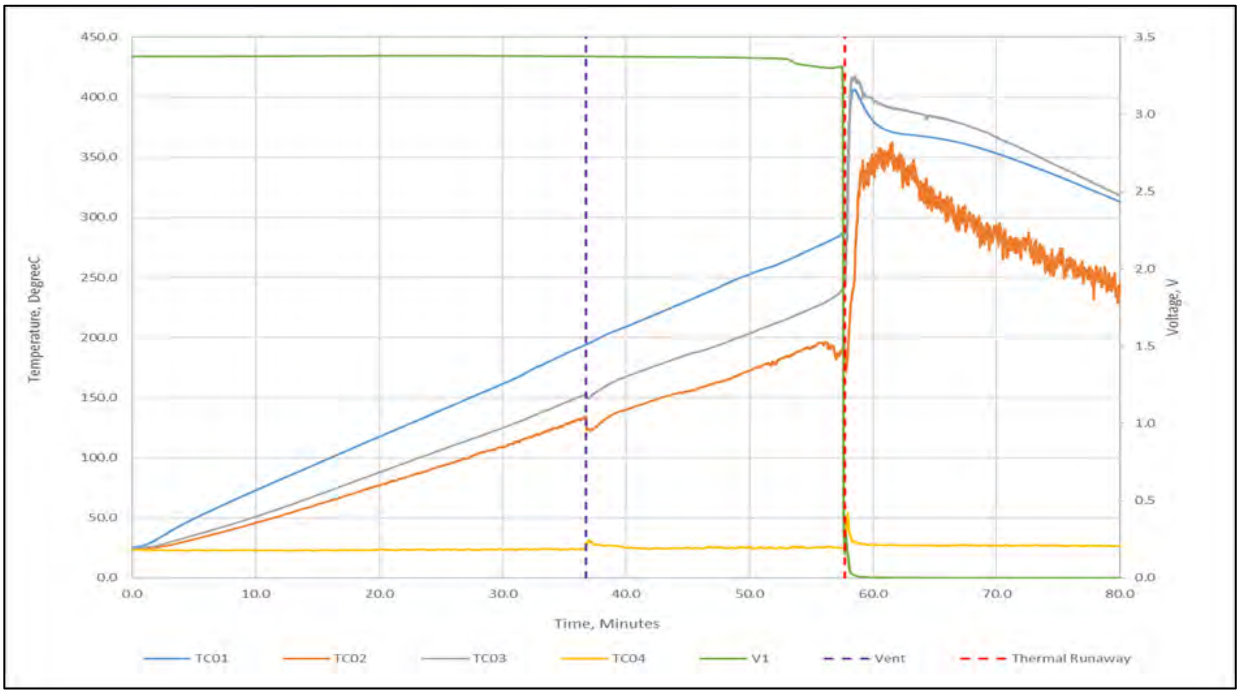


Figure 8: Cell 2 – External Heating 4.5°C per minute

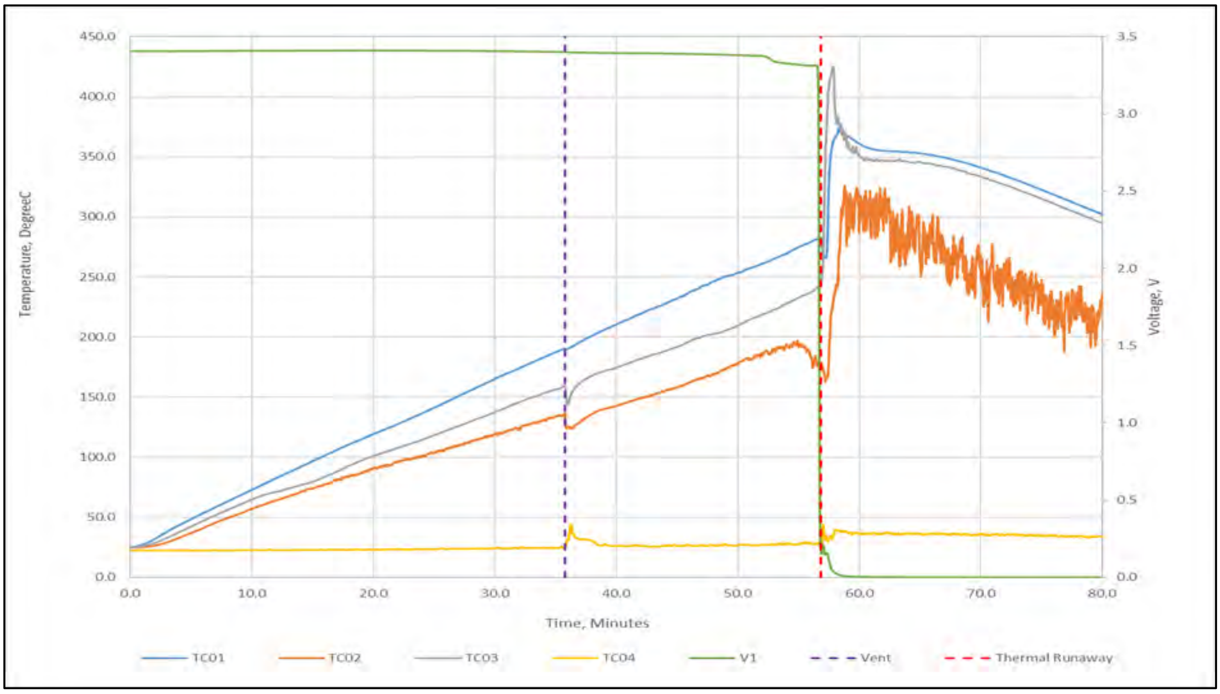


Figure 9: Cell 3 – External Heating 4.5°C per minute

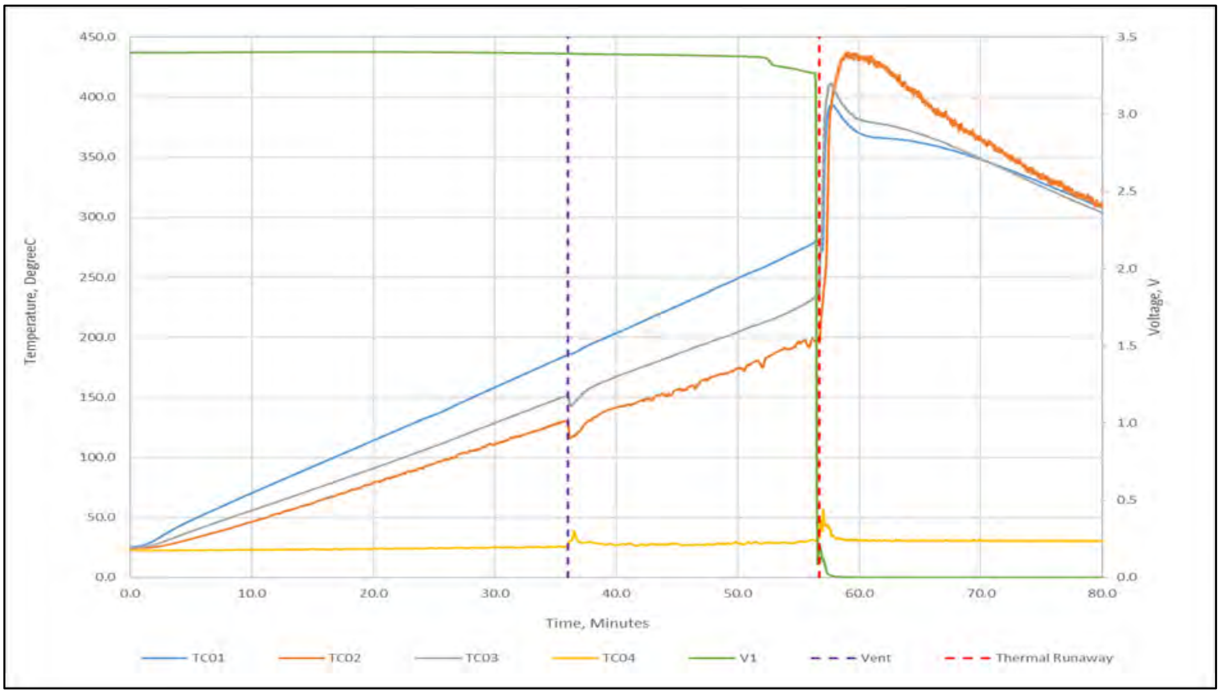


Figure 10: Cell 4 – External Heating 4.5°C per minute

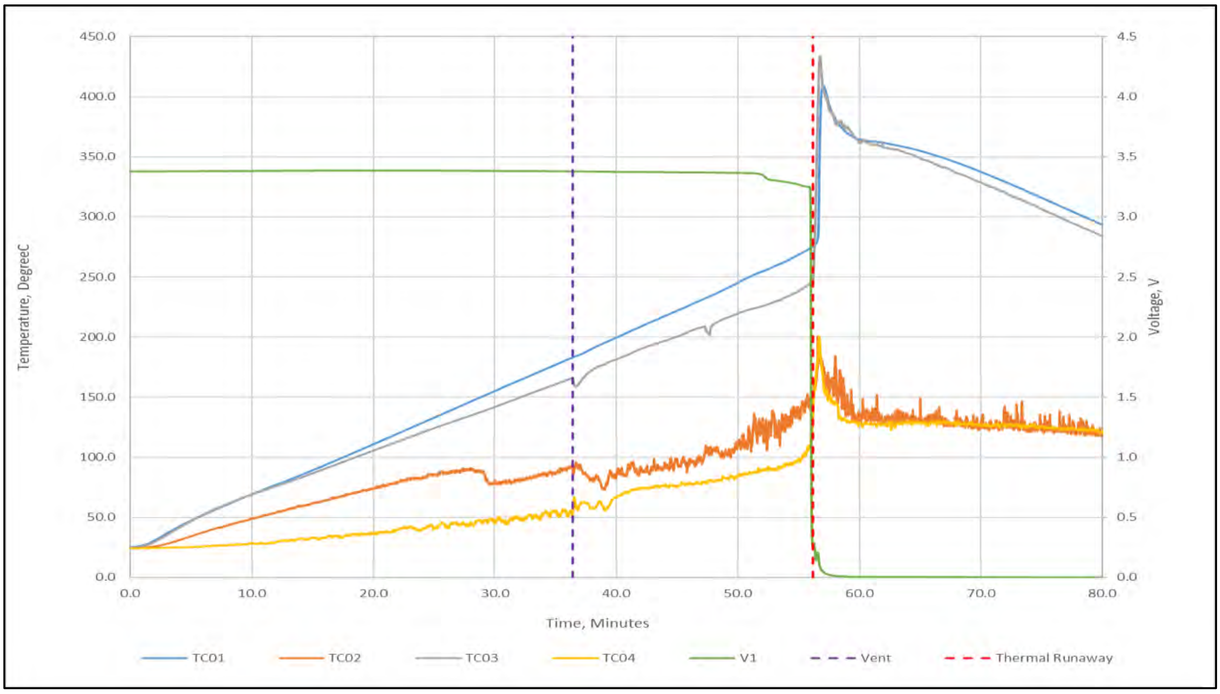


Figure 11: Cell 5 – External Heating 4.5°C per minute

Attachment D: Cell Testing Photos - (*Pages **24** through **33***)

Cell Sample 1 – below figure shows highlights of cell testing. Cell venting and thermal runaway were observed, however no evidence of fire. Figure on next page shows photos of cell after testing.

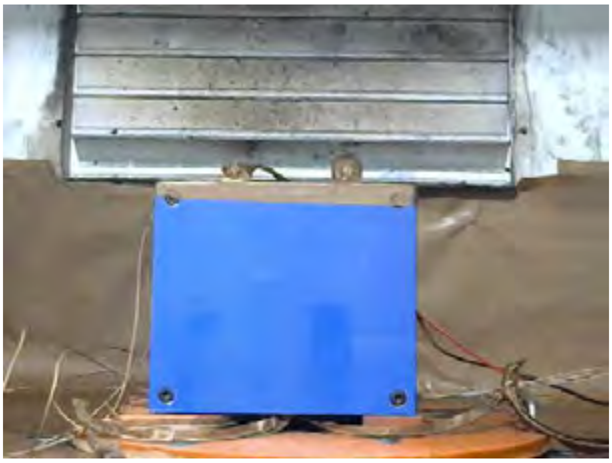
<table>
<tr><td></td><td></td></tr>
<tr><td>(a) Test Start
[00:00]</td><td>(b) Cell Venting
[34:55]</td></tr>
<tr><td></td><td></td></tr>
<tr><td>(c) Thermal runaway behavior
[55:32]</td><td></td></tr>
<tr><td colspan="2">Figure 12: Highlights of Cell 1 Testing</td></tr>
</table>

Figure 13: Sample 1 Post Test Photos

Cell Sample 2 – below figure shows highlights of cell testing. Cell venting and thermal runaway were observed, however no evidence of fire. Figure on next page shows photos of cell after testing.

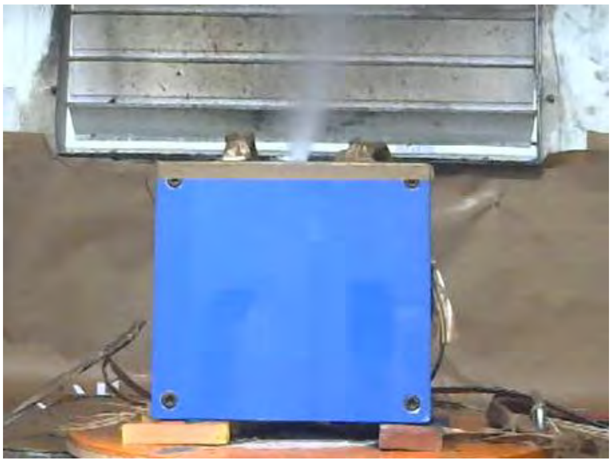
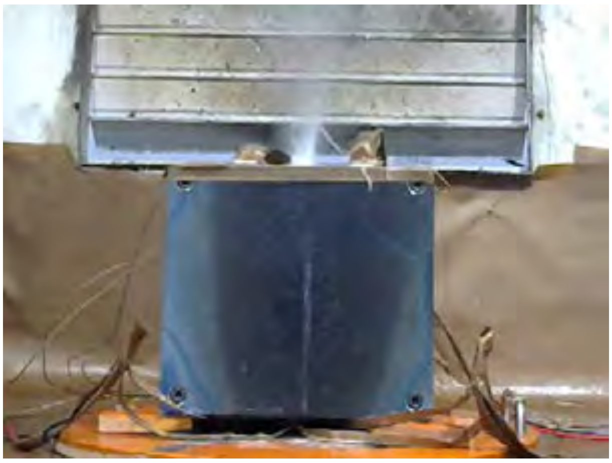
	
(a) Test Start [00:00]	(b) Cell Venting [36:44]
	
(c) Thermal runaway behavior [57:42]	

Figure 14: Highlights of Cell 2 Testing

Figure 15: Sample 2 Post Test Photos

Cell Sample 3 – below figure shows highlights of cell testing. Cell venting and thermal runaway were observed, however no evidence of fire. Figure on next page shows photos of cell after testing.

<table>
<tr><td></td><td></td></tr>
<tr><td>(a) Test Start
[00:00]</td><td>(b) Cell Venting
[35:46]</td></tr>
<tr><td></td><td></td></tr>
<tr><td>(c) Thermal runaway behavior
[56:49]</td><td></td></tr>
<tr><td colspan="2">Figure 16: Highlights of Cell 3 Testing</td></tr>
</table>

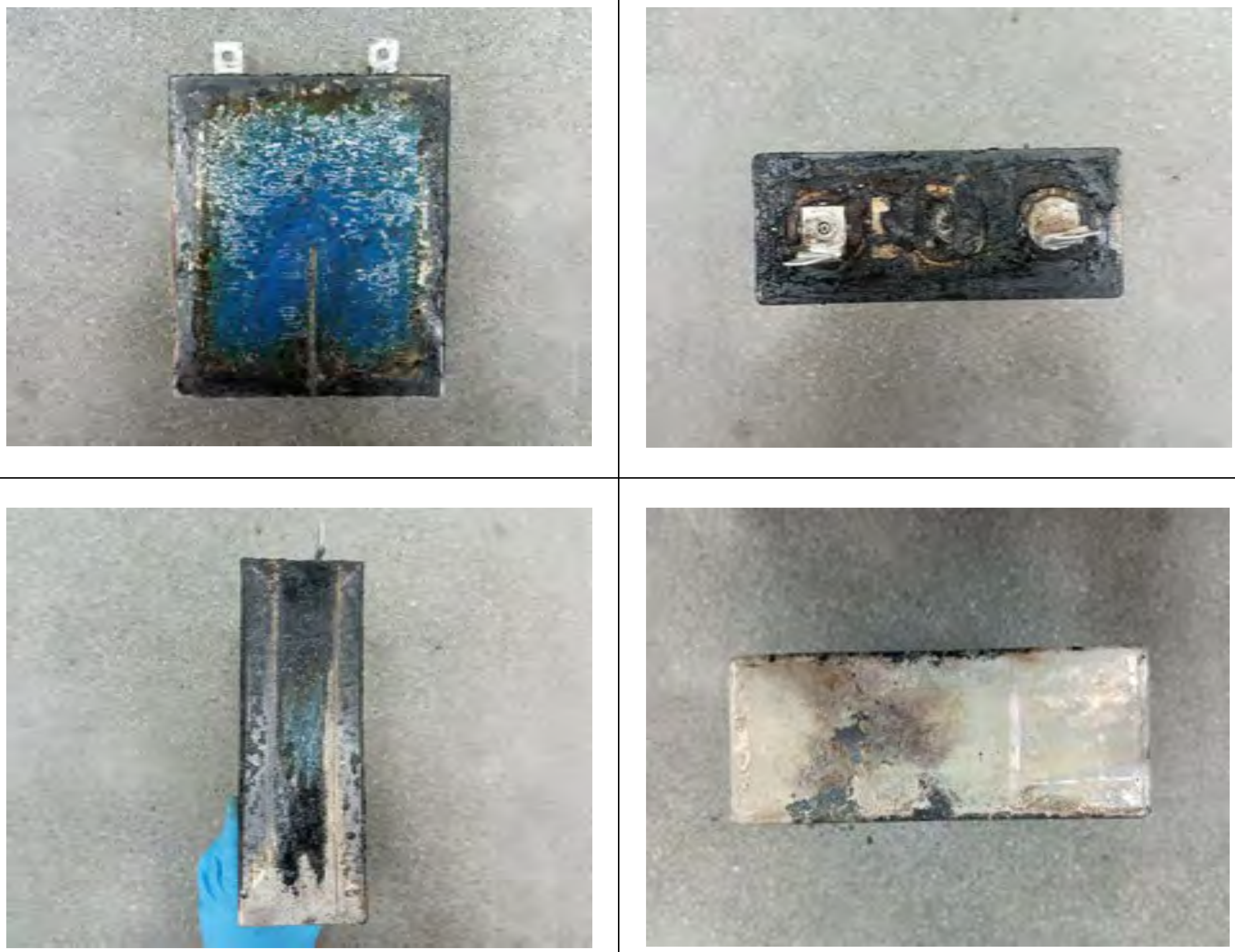


Figure 17: Sample 3 Post Test Photos

Cell Sample 4 – below figure shows highlights of cell testing. Cell venting and thermal runaway were observed, however no evidence of fire. Figure on next page shows photos of cell after testing.

	
(a) Test Start [00:00]	(b) Cell Venting [36:00]
	
(c) Thermal runaway behavior [56:41]	
Figure 18: Highlights of Cell 4 Testing	

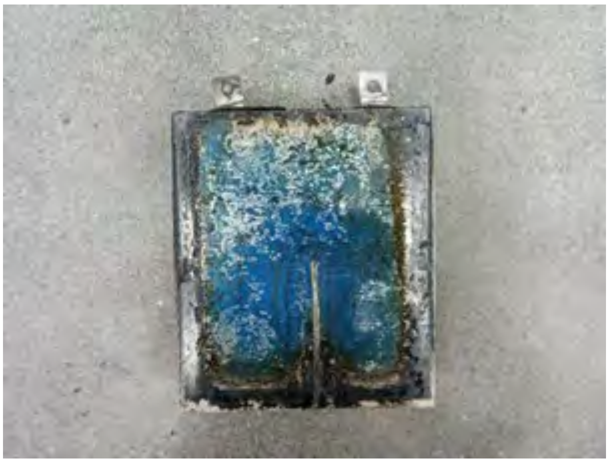



Figure 19 Sample 4 Post Test Photos

Cell Sample 5 – below figure shows highlights of cell testing. Cell venting and thermal runaway were observed, however no evidence of fire. Figure on next page shows photos of cell after testing.

	
(a) Test Start [00:00]	(b) Cell Venting [36:24]
	
(c) Thermal runaway behavior [56:10]	
Figure 20: Highlights of Cell 5 Testing	

Figure 21: Sample 5 Post Test Photos

Attachment E: Cell vent gas test chamber photo and profile of chamber gas analysis (O2 and Pressure) - (Pages ***34*** through ***34***)

The gas composition test was conducted with the battery inserted into the battery gas composition test chamber and the chamber was sealed. The battery gas composition test chamber is a 100 L pressure vessel and is shown in figure below.

Prior to initiating thermal runaway, the chamber's atmosphere was purged until a condition of less than 1% oxygen by volume (actual 0.06%, with initial pressure 0.13psig).

Figure 22: Sample 5 instrumented and inside gas test chamber

$\phi_{O2,\ chamber}$=	0.06	%

Pinitial,chamber=	0.13	psig

Figure 23: Profile of gas test chamber (O2 and Pressure)

Attachment F: Cell Gas Analysis Report - (Pages ***35*** through ***35***)

Table Re-normalized Gas Quantification, excluding N_2 and O_2, and unknown compounds.			
Item	**Measure**	**Chemical formula**	**Conc.(%)**
1	Carbon Monoxide	CO	14.596
2	Carbon Dioxide	CO_2	26.925
3	Hydrogen	H_2	43.066
4	Methane	CH_4	7.051
5	Ethylene	C_2H_4	3.289
6	Acetylene	C_2H_2	0.119
7	Ethane	C_2H_6	1.060
8	Propane	$CH_3CH_2CH_3$	0.260
9	Propylene	C_3H_6	0.686
10	Propadiene (Allene)	C_3H_4	0.000
11	Isobutane	$CH_3CH(CH_3)CH_3$	0.006
12	Butane	C_4H_{10}	0.121
13	Isobutylene	C_4H_8	0.322
14	1-Butene	C_4H_8	0.161
15	trans-2-Butene	C_4H_8	0.101
16	cis-2-Butene	C_4H_8	0.154
17	Pentane	C_5H_{12}	0.227
18	trans-2-Pentene	C_5H_{10}	0.067
19	cis-2-Pentene	C_5H_{10}	0.068
20	1,4-Pentadiene	C_5H_8	0.036
21	Hexane	C_6H_{14}	0.022
22	1-Hexene	C_6H_{12}	0.125
23	Benzene	C_6H_6	0.082
24	1-Heptene	C_7H_{14}	0.025
25	Toluene	C_7H_8	0.012
26	Styrene	C_8H_8	0.013
27	Dimethyl Carbonate	$C_3H_6O_3$	1.304
28	Ethyl Methyl Carbonate	$C_4H_8O_3$	0.101
29	Diethyl Carbonate	$C_5H_{10}O_3$	0.000
	Total	**Measurement result**	**100.000**

MODULE TEST REPORT
UL 9540A
Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems (AACD)

Project Number. ....:	**4790931782**
Date of issue..................................:	**2023-09-13**
Total number of pages ....:	**27**
UL Report Office ....:	**UL(Changzhou) Quality Technical Service Co., LTD**
Applicant's name ....:	**Contemporary Amperex Technology Co., Limited**
Address..:	**Contemporary Amperex Technology Co., Limited** **No.2 Xin'gang Road, Zhangwan Town, Jiaocheng District, Ningde, Fujian, China**
Test specification:	4th Edition, Section 8, November 12, 2019
Standard..:	UL 9540A, Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems
Test procedure ....:	8.1 – 8.4
Non-standard test method ....:	N/A

General disclaimer:

The test results presented in this report relate only to the sample tested in the test configuration noted on the list of the attachments.

UL LLC did not select the sample(s), determine whether the sample(s) was representative of production samples, witness the production of the test sample(s), nor were we provided with information relative to the formulation or identification of component materials used in the test sample(s).

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UL LLC, its employees, and its agents shall not be responsible to anyone for the use or non-use of the information contained in this Report, and shall not incur any obligation or liability for damages, including consequential damages, arising out of or in connection with the use of, or inability to use, the information contained in this Report.

Cell level information	
Cells in Module:	
●**Manufacturer Name**	**Contemporary Amperex Technology Co., Limited**
●**Part Number**	**CBDD0**
●**Chemistry**	**Lithium Iron Phosphate**
●**Format**	**Prismatic**
Ratings (Vdc, Ah) :	**3.2V, 306Ah**
Was the cell certified? :	**Yes**
Standard the cell was certified to:	**UL 1973**
Organization that certified the cell:	**MH62898**
Average cell surface temperature at gas venting, °C:	**154**
Average cell surface temperature at thermal runaway, °C:	**241**
Gas Volume:	**204L**
Lower flammability limit (LFL), % volume in air at the ambient temperature:	**8.595**
Lower flammability limit (LFL), % volume in air at the venting temperature:	**7.24**
Burning velocity (S_u) cm/s:	**54.20**
Maximum pressure (P_{max}) psig:	**102.74**

Cell Gas Composition:

Gas		Measured %
Carbon Monoxide	CO	14.596
Carbon Dioxide	CO_2	26.925
Hydrogen	H_2	43.066
Methane	CH_4	7.051
Acetylene	C_2H_2	0.119
Ethylene	C_2H_4	3.289
Ethane	C_2H_6	1.060
Propylene	C_3H_6	0.686
Propane	C_3H_8	0.260
-	C4 (Total)	0.865
-	C5 (Total)	0.399
-	C6 (Total)	0.148
1-Heptene	C7H14	0.025
Styrene	C8H8	0.013
Benzene	C_6H_6	0.082
Toluene	C_7H_8	0.012
Dimethyl Carbonate	$C_3H_6O_3$	1.304
Ethyl Methyl Carbonate	$C_4H_8O_3$	0.101
Total	**-**	**100**

Module level Information	
Model No:	M02306P05L01
Ratings (Vdc, Ah) :	166.4V, 612Ah
Module cell configuration (xS/yP) ……:	52S2P
Module dimensions (W x D x H (mm)) :	830mm*2235mm * 250mm
Module weight (kgs) :	653±5kg
Module enclosure material:	Bottom enclosure -Material: Al6063.T6 -Thickness: ≥2mm -Size: L*W*H(mm) (2235±3.5)*(830±3)*(31±3) Top Plastic enclosure: -Material: PP -Thickness: ≥2.5mm -Size: L*W*H（mm）2203.1*830*218.5 -Fire rating: V-0 -Maximum ambient temperature: 90±2°C
Was the module certified? :	N/A
Standard the module was certified to:	N/A
Organization that certified test item:	N/A

Cell failure test method performed for the module level (summary of method and test clause):

- ☒ External heating using thin film with 4°C to 7°C thermal ramp.
- ☐ Nail Penetration
- ☐ Overcharge
- ☐ External short circuit (***X*** Ω *external resistance*)
- ☐ Others

Description of method used to fail cells if other than external thin film heater with thermal ramp, :N/A

Description of components employed within the module that serve to supress propagation (fire protection features).
N/A

Number of initiating cells failed to achieve propagation.	1
Thermal Runaway Propagation:	Initiating cell went into thermal runaway and propagated to three adjacent cells.
Maximum Smoke Release Rate (m^2/s)	0.52
Total Smoke Released: (m^2)	1.41
Total smoke released duration	0:47:08 to 2:00:00

Peak Chemical Heat Release Rate: (kW):	No flaming occurred
External Flaming:	No external flaming occurred
Location(s) of Flame Venting:	No flaming occurred
Flying Debris:	No flying debris occurred
Re-ignitions:	No further re-ignitions were observed during post test observation

Summary of Module level test Gas Analysis Data:

Gas Analysis:

☒ **Flame ionization detection**

☐ **Fourier-Transform infrared Spectrometer**

☒ **Hydrogen Sensor (palladium-nickel, thin-film solid state sensor)**

☒ **White light source with photo detector (smoke release rate)**

- **Gas Composition & Volume for Each Compound (Pre-flaming and After flame):**

Gas Compound	Gas Type	Pre-Flaming (L)	Flaming (L)	Minimum detectable flow rate (LPM)
Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	260.29	No flaming	0.50
Carbon Dioxide	Carbon Containing	217.03	No flaming	1.82
Carbon Monoxide	Carbon Containing	77.57	No flaming	0.61
Hydrogen	Hydrogen	263.37	No flaming	14.29

Summary of Module testing:

Performance Criteria in accordance with Clause 8.4 and Figure 1.1:

[X] The effects of thermal runaway was contained by the module design;

[ ] Cell vent gas (based upon the cell level test) was non-flammable

Necessity of a unit level test

[X] The performance criteria of the module level test as indicated in 8.4 and as shown in Figure 1.1 of UL 9540A 4th edition has not been met, therefore unit level testing in accordance with UL 9540A will need to be conducted on a complete unit employing this module.

[ ] The performance criteria of the module level test as indicated in 8.4 and as shown in Figure 1.1 of UL 9540A 4th edition has been met, therefore unit level testing in accordance with UL 9540A need not be conducted.

Testing Laboratory information

Testing Laboratory and testing location(s):

Testing Laboratory:	Beijing Building Materials Testing Academy
Testing location/ address ....:	Block 1, B15 Yaxin Road, Doudian Town, Fangshan district, Beijing 102402, CN PSN: 3369533

Tested by (name, signature) ....:	Zhang Qi, Huang Fei	
Witnessed by (for 3rd Party Lab Test Location) (name, signature) ....:	N/A	N/A
Project Handler (name, signature)..............:	Arui Zhou	Arui Zhou
Reviewer (name, signature) …………….:	Benjamin Liu	Benjamin Liu

List of Attachments (including a total number of pages in each attachment):
Attachment A: Module Conditioning (Charge/discharge) Profiles - (*Pages **19** through **19***) **Attachment B:** Module Construction Photos - (Pages ***20*** through ***20***) **Attachment C:** Module Instrumentation Photos - (*Pages **21** through **21***) **Attachment D**: Module and Initiating Cell(s) Temperature Profiles During Testing - (*Pages **22** through **22***) **Attachment E**: Module Testing Photos - (*Pages **23** through **24***) **Attachment F**: Module Gas Flow Rate and Heat Release Profiles - (*Pages **25** through **27***)

Photo(s) of module:

Test Item Charge/Discharge Specifications:	M02306P05L01
• Charge Power, kW:	50.91, then 5.091
• Standard Full charge Voltage, Vdc:	Any cell reaches of 3.65V or total voltage reach 189.8V
• Charge temperature range, °C:	0~60
• End of charge voltage, Vdc:	Any cell reaches of 3.65V or total voltage reach 189.8V
• Discharge Power, kW:	50.91
• End of discharge voltage, Vdc:	Any cell reaches of 2.5V or total voltage reach 130V
• Discharge temperature range, °C:	-20~60
• Storage temperature, °C:	-30~60

Test item particulars.. :	
Possible test case verdicts:	
- test case does not apply to the test object...........:	N/A
- test object does meet the requirement..................:	P (Pass)
- test object does not meet the requirement...........:	F (Fail)
- test object was completed per the requirement...:	C(Complete)
- test object was completed with modification……:	M(Modification)
Testing...:	
Date of receipt of test item ....:	2023.08.15
Date (s) of performance of tests ....:	2023.08.18
General remarks:	
"(See Enclosure #)" refers to additional information appended to the report. "(See appended table)" refers to a table appended to the report. **Throughout this report a point is used as the decimal separator.**	
Manufacturer's Declaration of samples submitted for test:	
The applicant for this report includes samples from more than one factory location and a declaration from the Manufacturer stating that the sample(s) submitted for evaluation is (are) representative of the products from each factory has been provided..........................:	☒ **Yes** ☐ **Not applicable**

Name and address of factory (ies) ....:	Factory1: Contemporary Amperex Technology Co., Limited Factory address1: No.2 Xin'gang Road, Zhangwan Town, Jiaocheng District, Ningde, Fujian, China Factory 2: Guangdong Ruiqing Contemporary Amperex Technology Limited Factory address 2: No.1 Contemporary Avenue, Sihui City, Zhaoqing City, Guangdong Province, People's Republic of China Factory 3: Yichun Contemporary Amperex Technology Limited Factory address 3: No.1 chunfeng Road ,Economic and Technological Development Zone ,Yichun City, Jiangxi Province, People's Republic of China Factory 4: Jiaocheng Contemporary Amperex Technology Limited Factory address 4: No. 1, outer ring road, Feiluan Town, Jiaocheng District, Ningde City, Fujian Province China

General product information and other remarks:

Battery Module Model M02306P05L01 employs cell Models CBDD0 manufactured by Contemporary Amperex Technology Co., Limited, rated 166.4V, 612Ah.

5.0	CONSTRUCTION		Verdict
5.2	**Module Construction**		—
5.2.1, 5.2.3	Construction information	See Test Item Description at the beginning of this report	—
	General layout of module contents	See Attachment B	—
5.2.2	Module certified to UL 1973	**No**	
	Organization that certified module:	**N/A**	—
6.0	**PERFORMANCE**		**Verdict**
6.1	**General**		
8.1	**Samples**		
8.1.1	Samples conditioned through charge discharge cycling a minimum of 2 cycles.	See Attachment A for profiles See Table 1 for specifications See also Table 2 The module voltage was checked before the test, and the voltage did not drop further compared to 1h to 8h after cycles, which was judged acceptable.	M
8.1.2	100% SOC and stabilize from 1h to 8 h before testing		
8.1.3	Electronic controls such as BMS not relied upon during testing.		C
8.2	**Test Method**		-
8.2.1	Ambient indoor laboratory conditions: 25 ±5°C (77 ±9°F) ≤50 ±25% RH at the initiation of the test.	See Table 3 The ambient humidity at the beginning of the test was 79%. The engineering judgment is that it is acceptable.	M
8.2.2	Test conducted under a smoke collection hood appropriately sized for the module	See Attachment C for figures showing location within the module of the cell(s) forced into thermal runaway	C
8.2.3	The weight of the module was recorded before and after testing, (kg)	See Table 11	C
8,2,4	A sufficient number of cells were forced into thermal runaway to create a condition of cell to cell propagation within the module.	See Attachment C See Tables 4 and 5 One cell was forced into thermal runaway selected by client.	C
	The location of the cell(s) forced into thermal runaway were selected to present the greatest thermal exposure to adjacent cells	See Attachment C for figures showing location within the module of the cell(s) forced into thermal runaway	C

8.2.5	The method used to initiating thermal runaway in the cell(s) were in accordance with 7.2	See Summary of Cell Testing at the beginning of this report.	C
8.2.6	The occurrence of thermal runaway was verified	See Test Results from Cell Level Test from the beginning of this report. See Attachments D	C
8.2.7	The module was placed on top of a non-combustible horizontal surface with the module orientation representative of its intended final installation.	See Attachment E	C
8.2.8	The chemical heat release rate of the module was measured with oxygen consumption calorimetry	See Table 10 See Attachment F	C
8.2.9	The chemical heat relate rate was measured for the duration of the test	See Attachment E	C
8.2.10	The chemical heat release rate was measured using the following equipment: ● Paramagnetic oxygen analyser ● Non-dispersive infrared carbon dioxide and carbon monoxide analyser ● Velocity probe ● Type K thermocouple	See Table 10 See Attachment F	C
	The instrumentation was located in the exhaust duct of the heat release rate calorimeter at a location that minimizes the influences of bends or exhaust devices.	See Attachment F	C
8.2.11	The chemical heat release rate at each of the flows was calculated in accordance with 8.2.11.	See Attachment F	C
8.2.12	The hydrocarbon content of the vent gas was measured using flame ionization detection.	See Attachment F	C
	Hydrogen gas shall be measured with a palladium-nickel thin-film solid state sensor.	See Table 9	C
8.2.13	The hydrocarbon content of the vent gas may also be measured using a Fourier-Transform Infrared Spectrometer with a minimum resolution of 1 cm-1 and a path length of at least 2 m (6.6 ft), or equivalent gas analyzer.	FTIR analysis was not used in accordance with the Certification Requirement Decision: Corrections to gas measurement methods to make FTIR as an option for measuring hydrocarbon contents of gas emissions and to include Hydrogen measurements during the Unit Level Test. FTIR was considered redundant to the other gas measurement methods used.	C

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict

	Vent gas velocity and temperature measurements respectively were obtained in the exhaust duct of the heat release rate calorimeter using equipment specified in 8.2.10.		C
8.2.14	The light transmission in the exhaust duct of the heat release rate calorimeter was measured using a white light source and photo detector for the duration of the test.		C
8.2.15	Smoke release rate was calculated as outlined in 8.2.15	See Table 10 See Attachment F	C
8.3	**Module level test report**		
	a. Module manufacturer and model number; b. Number of cells in module; c. Module configuration;	See Test Item Description in beginning of this report.	C
	d. Module construction features;	See Attachment C See Critical Components Table	C
	e. Module voltage corresponding to the tested SOC;	See Table 3	C
	f. Thermal runaway initiation method used;	See Attachment C	C
	g. Heat release rate versus time data;	See Table 10 See Attachment F	C
	h. Flammable gas generation and composition data;	See Attachment F See Tables 8 and 9	C
	i. Peak smoke release rate and total smoke release data.	See Table 10	C
	j. Observation(s) of flying debris or explosive discharge of gases;	See Table 12	C
	k. Observation(s) of sparks, electrical arcs, or other electrical events;	See Table 12	C
	l. Identification/location of cells(s) that exhibited thermal runaway within the module;	See Tables 4 and 5	C
	m. Locations and visual estimations of flame extension and duration from the module;	See Attachments E and F See Table 7	C
	n. Module weight loss;	See Table 11	C
	o. Video of the test.		C
8.4	**Performance – Module level**		
8.4.1	The following performance conditions are met during the module level test: a) Thermal runaway is contained by module design;	Thermal runaway was contained by module design.	P

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict
	b) Cell vent gas is nonflammable as determined by the cell level test	Cell gas report show the cell gases are flammable. See Cell Gas Composition Table.	F

Table 1 – Specified conditioning parameters			
Charging:		**Discharging:**	
Power (CP), kW	50.91,then 5.091	Power (CP), kW	50.91
Standard full Charge Voltage, Vdc	Any cell reaches of 3.65V or total voltage reach 189.8V	End of discharge voltage, Vdc	Any cell reaches of 2.5V or total voltage reach 130V
Cutoff Voltage, Vdc	Any cell reaches of 3.65V or total voltage reach 189.8V	Cutoff Voltage, Vdc	Any cell reaches of 2.5V or total voltage reach 130V
Charging Test Ambient, °C	0~60	Discharging Test Ambient, °C	-20~60
Refer to Attachment A for charge/discharge profiles for the module.			

Table 2 – Charge completion and module test initiation times	
Charge Completion Date and Time	**Module Test Date and Time**
2023-8-14 19:01 PM	2023-8-18 09:33 AM

Table 3 - Test Initiation Details	
	Module No.:
Test Date	2023-08-18
Test Start Time	09:33 AM
Initial Lab Temperature	28.0°C
Initial Relative Humidity	79%
Module OCV at Start of Test, Vdc	173.2V

Table 4 – Approximate time of thermal runaway propagation through module	
Time to thermal runaway	**Location**
0:48:53	Cell 20-2
0:50:41	Cell 20-1
0:54:54	Cell 21-1
1:07:12	Cell 21-2

Table 5 – Test overview timeline		
Time (HH:MM:SS)	**Event**	**Description**
00:00:00	Test Start	The test was started and the heater was turned on to heat the initiating cell (Cell 20-2) at a ratio of 4 ~ 7 °C/min.
00:47:08	Venting of initiating Cell	Initiating cell (Cell 20-2) vented at around 173.5 °C measured through TC 2-1 by an indication of sudden dip in cell’s temperature curve. See Figure (b)
00:48:53	Thermal runaway of initiating cell	Initiating cell (Cell 20-2) was at around 183.2 °C measured through T2-1. The temperature of cell 20-2 began to increase inan uncontrollable manner, With the release of smoke. See Figure (c)
00:50:41	Thermal runaway of initiating cell	Thermal runaway propagated to nearby cell (cell 20-1). More gas released and accompanied by electrolyte and molten material outflow. See Figure (e)

00:54:54	Thermal runaway of initiating cell	Thermal runaway propagated to nearby cell (cell 21-1). More gas released. See Figure (f)
01:07:12	Thermal runaway of initiating cell	Thermal runaway propagated to nearby cell (cell 21-2). More gas released. See Figure (g)
02:00:00	Test Termination	Data acquisition was stopped. The module was left in the test overnight and with video monitored.

Table 6 – Gases measured and measurement methods used in unit level testing			
Measurement Method	**Gases Measured**	**Chemical Formula**	**Gas Type**
Flame Ionization Detection (FID)	Total Hydrocarbons	-	Hydrocarbons
Solid-state Hydrogen Sensor	Hydrogen	H_2	--
Non-dispersive infrared spectroscopy (NDIR)	Carbon Dioxide	CO_2	Carbon Containing
	Carbon Monoxide	CO	Carbon Containing
# - This table was modified to reflect the gases measured during testing.			

Table 7 - Gas generation periods	
Time	**Condition**
0:47:08 to 02:00:00	No flaming
External Flaming of Gas	
Condition	**Duration (hh:mm:ss)**
External Flaming of Vent Gases:	N/A

Table 8– Summary of battery gas volumes for deflagration hazard calculations				
Gas Component	Gas Type	During Pre-flaming (L)	During Flaming (L)	Minimum detectable flow rate (LPM)
See Table 9				

Table 9– Summary of battery gas volumes for deflagration hazard calculations				
Gas Component	Gas Type	During Pre-flaming (L)	During Flaming (L)	Minimum detectable flow rate (LPM)
Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	260.29	No flaming	0.50
Carbon Dioxide	Carbon Containing	217.03	No flaming	1.82
Carbon Monoxide	Carbon Containing	77.57	No flaming	0.61
Hydrogen	Hydrogen	263.37	No flaming	14.29

Table 10 – Smoke and heat release rate			
Heat Release Rate (HRR)		**Smoke Release Rate (SRR)**	
Peak Chemical HRR (kW)	0(No flaming)	Maximum SRR (m^2/s)	0.52
		Total Smoke Released (m^2)	1.41

Table 11 – Module Weight During Test, kg	
Before Test:	655.5kg
After Test:	653.5kg
Weight Loss:	2kg

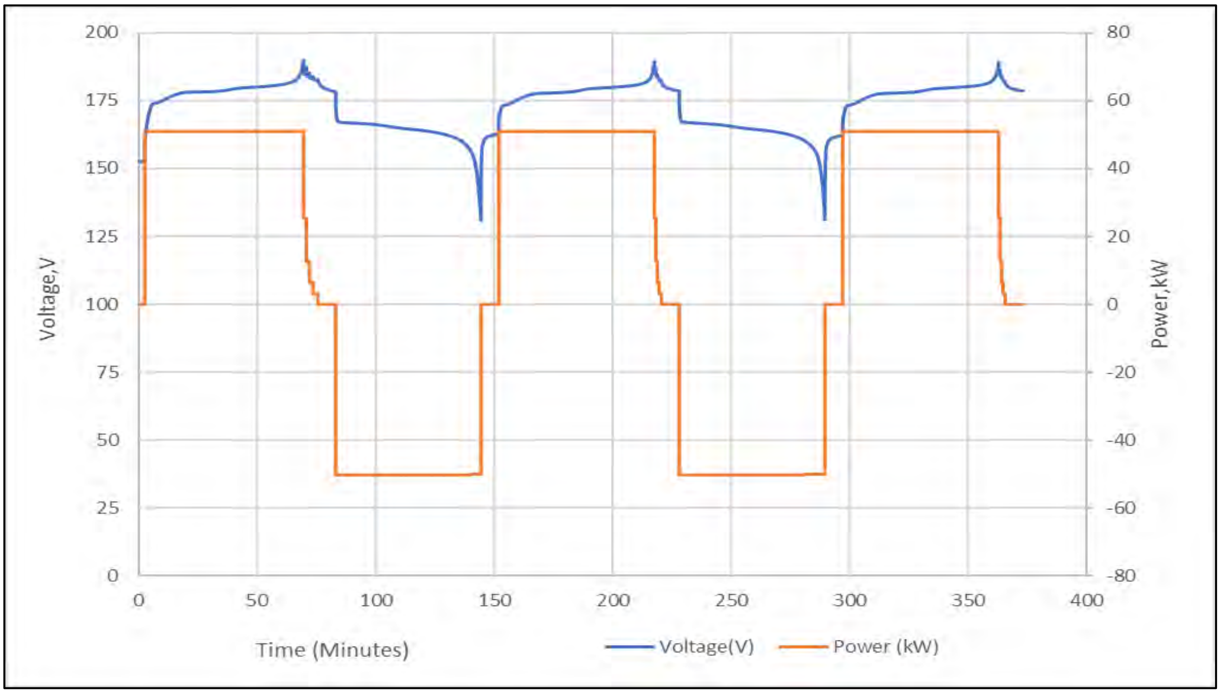
Table 12 – Other Observations during module test		
	Observed, Yes/No	Location
Flying debris	No	N/A
Explosive discharge of gas	No	N/A
Sparks or electrical arcs	No	N/A

	TABLE: Critical components information				
Object / Part No.	**Manufacturer/ trademark/ Supplier Code**	**Type / model**	**Technical data**	**Standard**	**Mark(s) of conformity**
Cells	CATL	CBDD0	Nominal voltage：3.2Vdc Rated capacity：306Ah	UL 1973 IEC 62619：2022	UL MH62898 JPTUV-146897
Metal enclosure	CATL	-	Material: Al6063.T6 Thickness: ≥2mm Size: L*W*H(mm) (2235±3.5)*(830±3)*(31±3)	–	–
Plastic enclosure	0000013277	NHPP-FR NHPP-FR-2	Fire rating：V-0 Material: PP RTI: 65°C	UL746	UL E171666
Connector	0000007975	REA4	Voltage：1500VDC Current：350A for TUV, 300A for UL Fire rating：V-0	UL4818 EN 61984	UL E526230 J 50586193
Connecting wire for HV	0000009966	3932	Voltage: 2000V Current-carrying capability: 75°C 350A Maximum ambient temperature:-40°C~+125°C	UL 758 EN 50525 IEC 60227 IEC 60228:2004	E214184 M.2021.206.C63716
Wire for LV	0000009966	3666	Voltage: 600V Wire diameter: (0.5~4mm2) Maximum ambient temperature: -40°C~+105°C	UL 758 EN 50525 IEC 60227 IEC 60228:2004	E214184 0B160705.DNTDS30
Plastic material (Harness isolation plate)	0000015262	PP C6540R-G20HF	Fire rating: V-0 Maximum ambient temperature: 90±2°C	UL94	SHMR220800424401
Plastic material (Output pole base)	0000007541	46GF30	Fire rating: V-0 Maximum ambient temperature: 180°C	UL94	UL E225348
Plastic material (Buffer pad)	0000007929	MPP	Fire rating: V-0 Maximum ambient temperature: 100°C	UL94	UL E509966

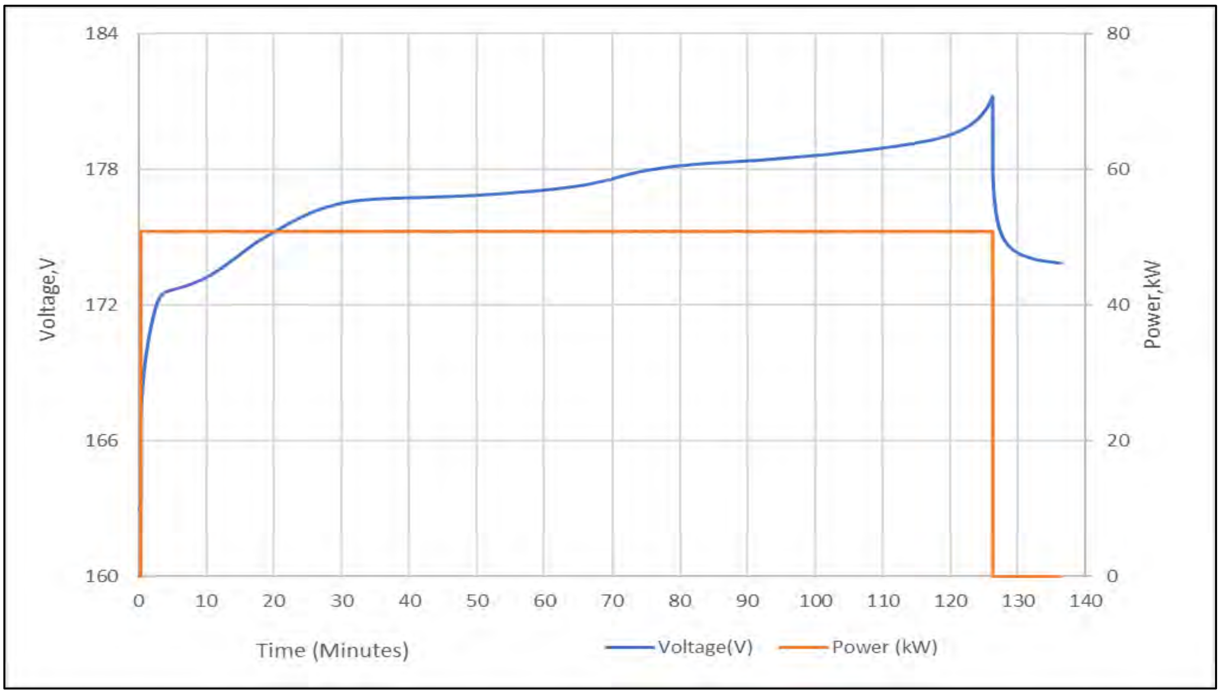
Plastic material (PC Insulating sheet)	0000007929	U42B-1(PC)	Fire rating: VTM-0 Maximum ambient temperature: -40°C ~+85°C	UL94	A2230075498101C
Plastic material (Fuse base)	0000027338	PBT-GF30	Fire rating: V-0 Maximum ambient temperature: 120±2°C	UL94	UL E225348
Plastic material (Wire harness bracket)	0000027338	PBT-GF30	Fire rating: V-0 Maximum ambient temperature: 120±2°C	UL94	UL E225348
Plastic material (Injection-molded slide rail)	0000027338	POM	Fire rating: HB Maximum ambient temperature: 90±2°C	UL94	UL E171666
Plastic material (Fuse Protective Cover)	0000027338	P2G(X)	Fire rating: V-0 Maximum ambient temperature: 120±2°C	UL94	E204321
Plastic material (Gasket)	0000011532	SecA	Fire rating：≥V-0 Maximum ambient temperature: -50~200°C	UL94	UL E529227
Mica paper	0000014138	_	Fire rating: V-0 Maximum ambient temperature: 1000±200°C	GB/T 2408-2008 UL94	MS220712040C-04 E302583

Attachment A: Module Conditioning (Charge/discharge) Profiles - (*Pages **19** through **19***)

Ntoe: 1. BMS power reduction charging strategy is as follows: initially charge at 1P until the battery voltage is 3.65 V, then reduce the charging power to 0.5 P, while the battery voltage is 3.65 V, reduce the charging power to 0.25 P, then charge at 0.125 P and 0.05 P to 3.65 V in turn, and then stand for 10min, and discharge at 1P power until the voltage is 2.5 V, and the discharge ends.
2. Charge to 100% SOC: Charge at constant power 50.91kW until any cell voltage reaches 3.65V then derate until charge with 0.05P till 189.8V or any cell voltage reaches 3.65V



Chargre/Discharge Cycle



Charge to 100% SOC

Attachment B: Module Construction Photos - (Pages ***20*** through ***20***)

Figure 1: Photo of cell – large side

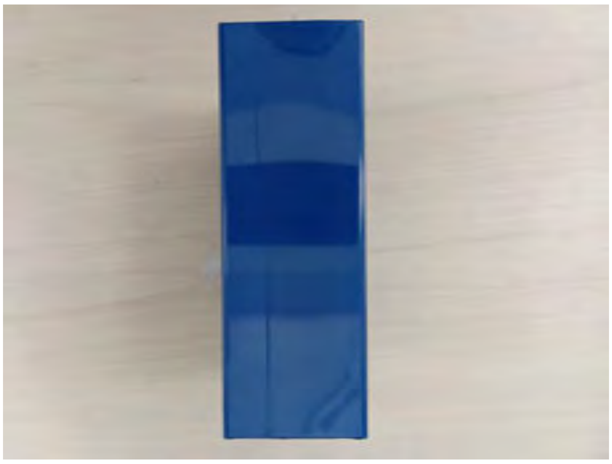


Figure 2: Photo of cell with Heaters

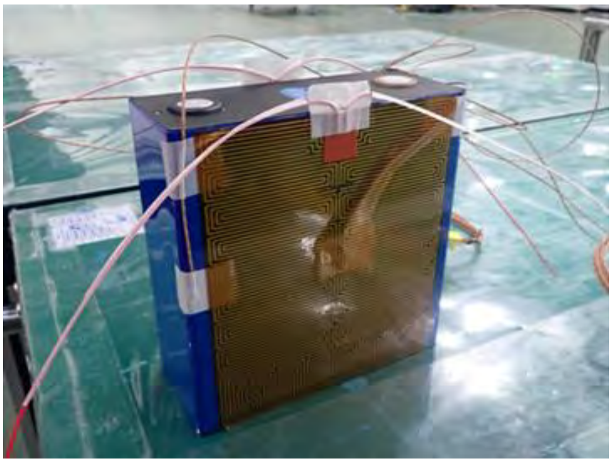


Figure 3: Cell with heater. two pieces of 203.0 mmby 152.4 mm for each sample.

Figure 4: Photo of module

Figure 5: Mica sheet in the module

Figure 6: Photo of module

Attachment C: Module Instrumentation Photos - (*Pages **21** through **21***)

Figure 7: Module on the test platform-side view

Figure 8: Module on the test platform-front view

Note: The thermocouple T1-1 was used to control the supply power to the heater to keep the heating rate at 4 ~ 7 °C/min. T2-1 and T2-3 were used to represent the temperature of initiating cell.
T1-1, on the wide side surface center of cell 20-2, between the cell and heater.
T1-2 on the other wide side surface center of cell 20-2, between the cell and heater.
T2-1, T2-2, on each wide side surface center of cell 20-2, not covered by heater.
V1, V3, V4, V5, V6, V6, V7, V8, V9 was the voltage of cell 19-2, 20-1, 21-1, 22-1, 7-2, 33-2, M6, M7, M8 separately.
T3 to T8 and Ta to Tc were attached on the wide side surface center of cells shown in below illustration.

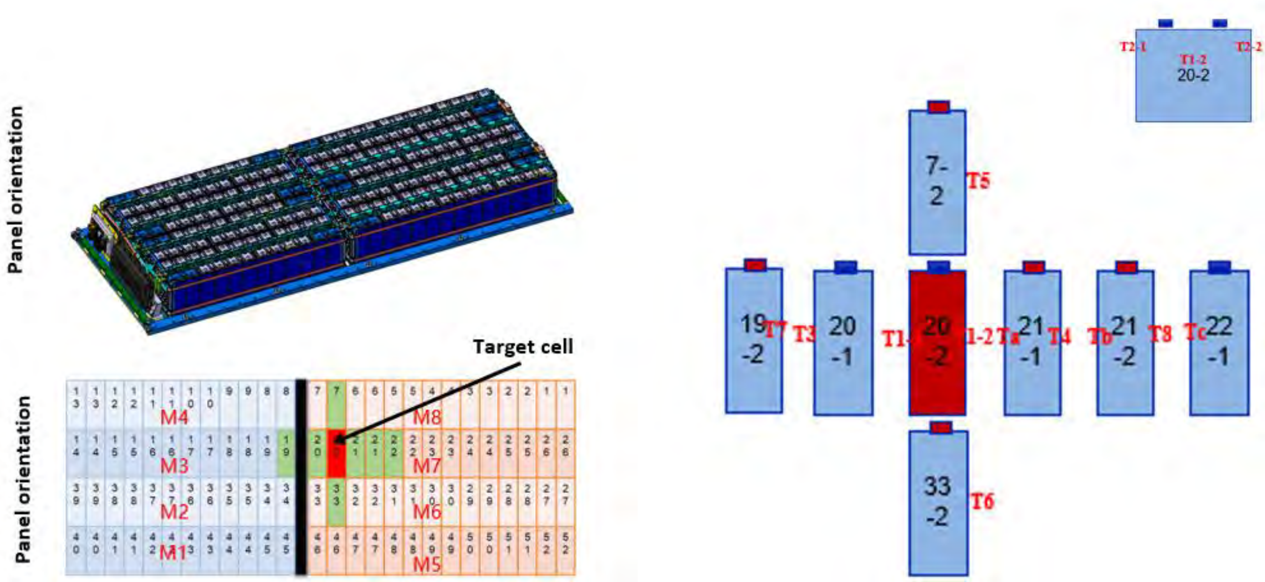


Figure 9: Locations of TCs

Attachment D: Module and Initiating Cell(s) Temperature Profiles During Testing - (*Pages **22** through **22***)

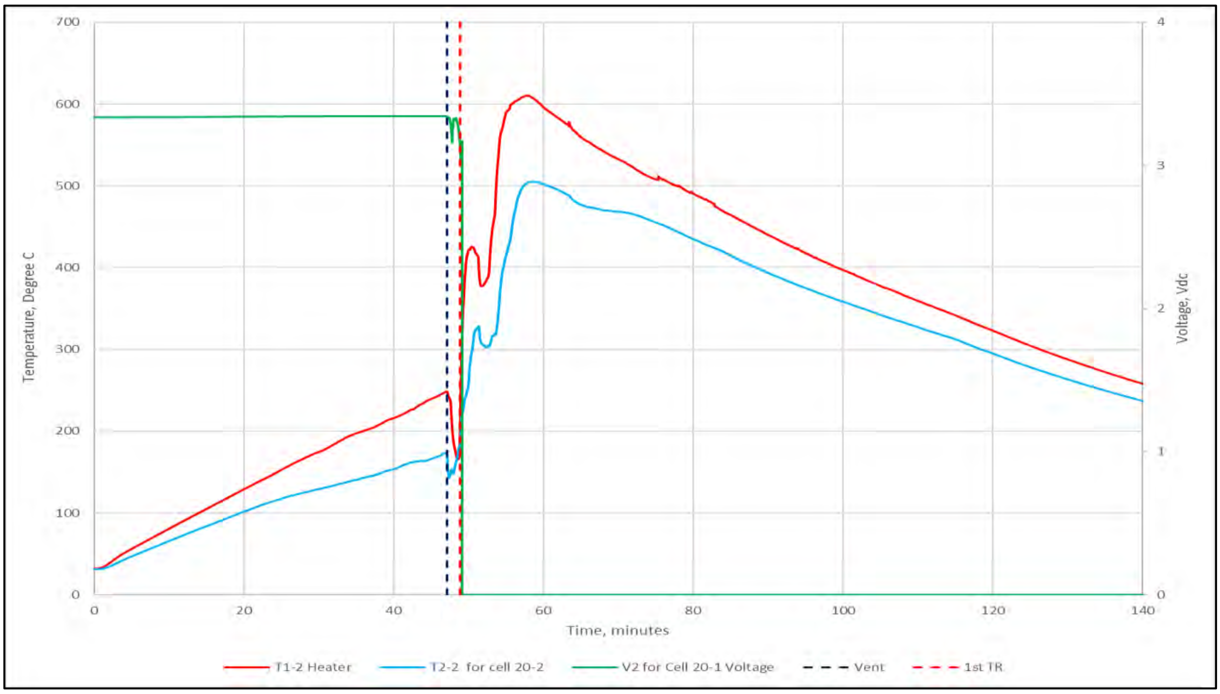


Figure 10: Initiating cell Temperature and voltage Profiles During Testing

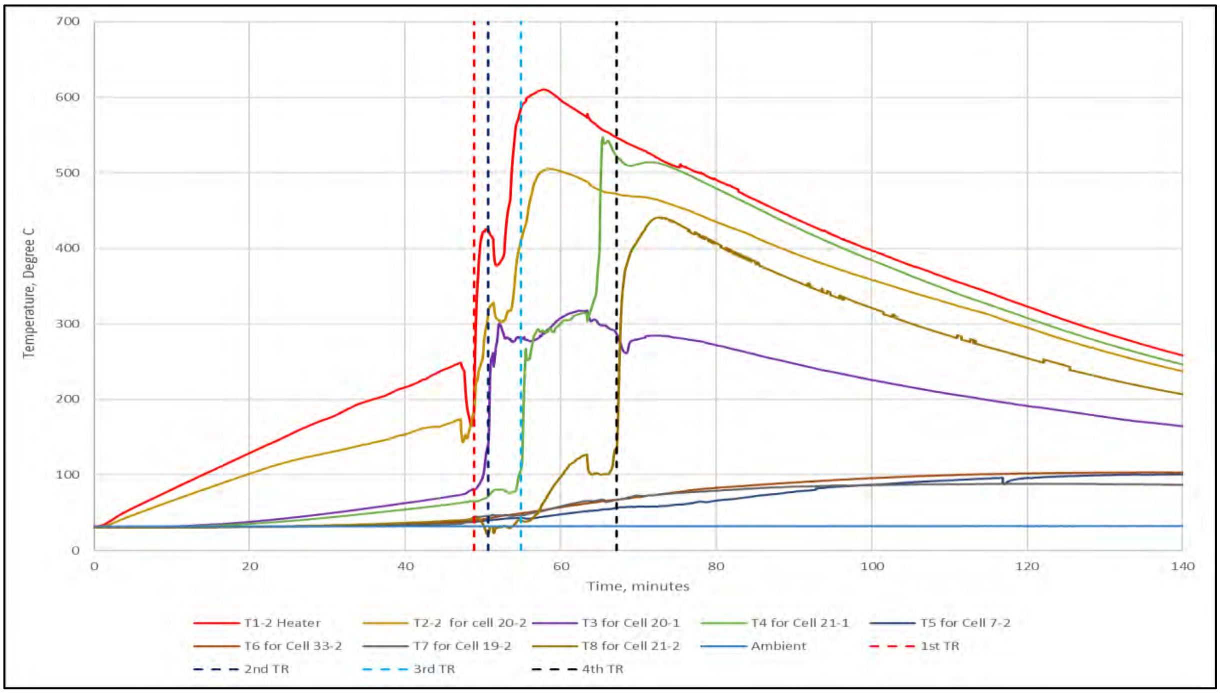


Figure 11: Temperature Profiles Describing Cell to Cell Propagation

Attachment E: Module Testing Photos - (*Pages **23** through **24***)

	
(a) Test Start [00:00:00]	(b) Initiating cell Venting [00:47:08]
	
(c) Smoke released from enclosure [00:48:53]	(d) Thermal runaway of initiating cell [00:50:41]

 (e) Thermal runaway of adjacent cell 21-1 [00:54:54]	 (f) Thermal runaway of adjacent cell 21-2 [01:07:12]
 (g) Test Termination [02:00:00]	

Attachment F: Module Gas Flow Rate and Heat Release Profiles - (*Pages **25** through **27***)

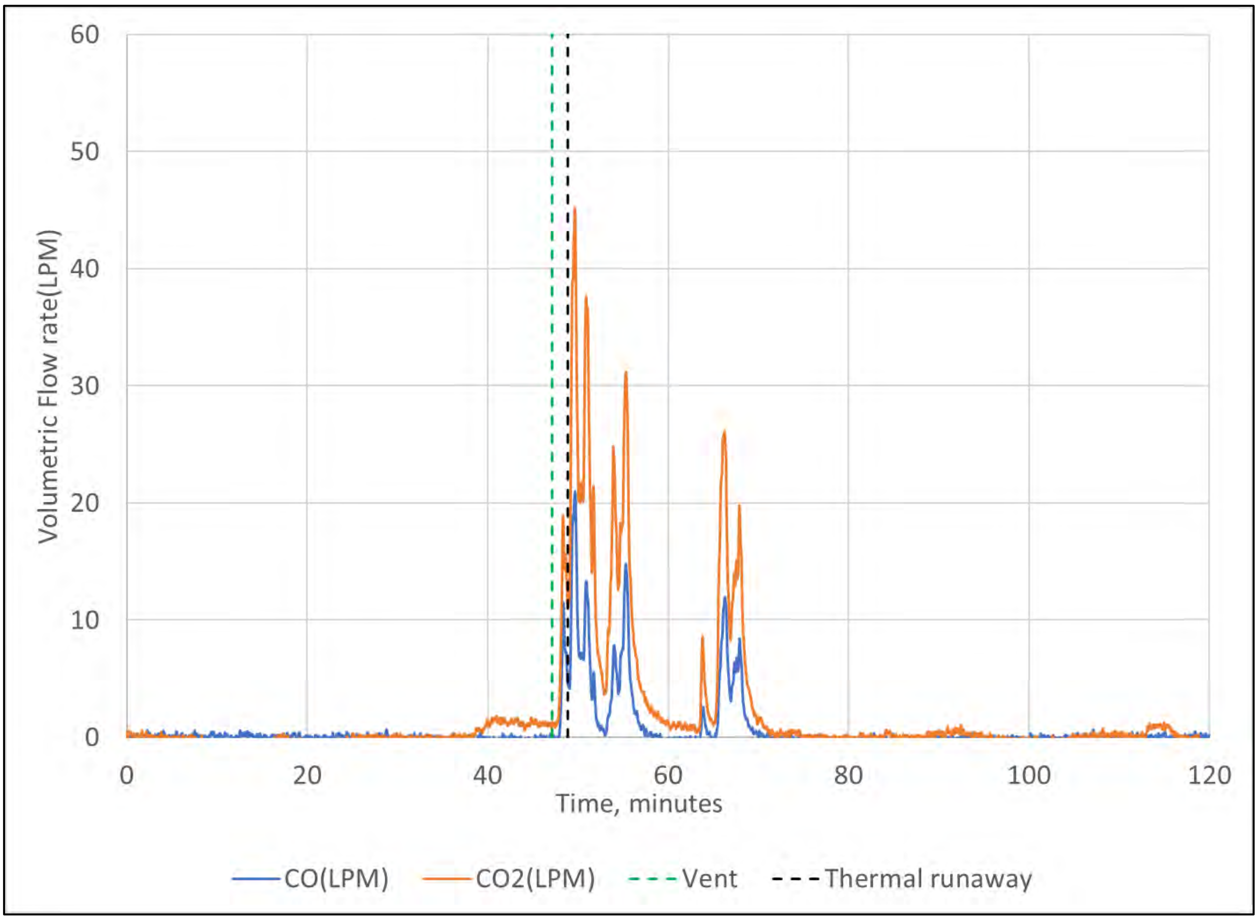


Figure 12: CO, CO2 Volumetric flow rates

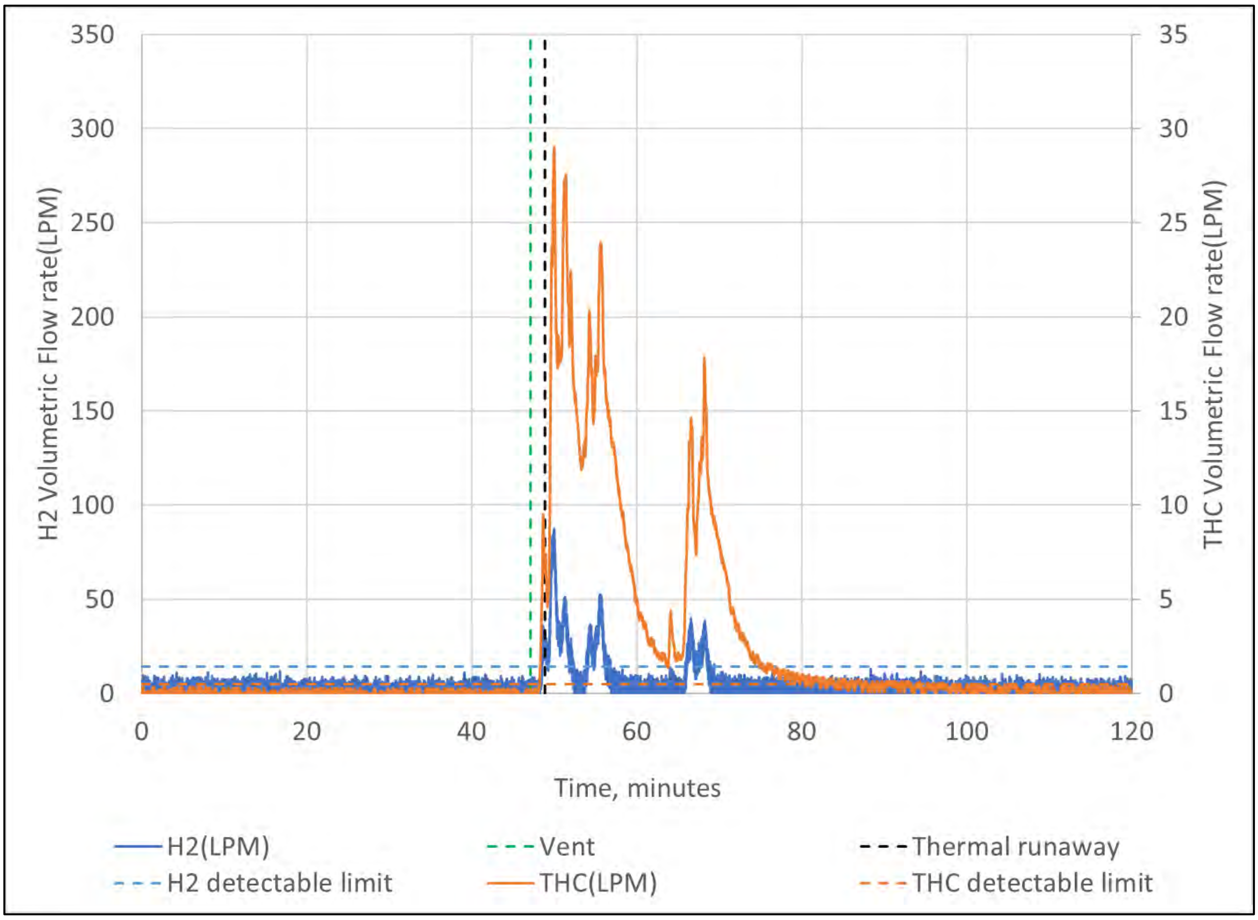


Figure 13: THC, H2 Volumetric flow rates

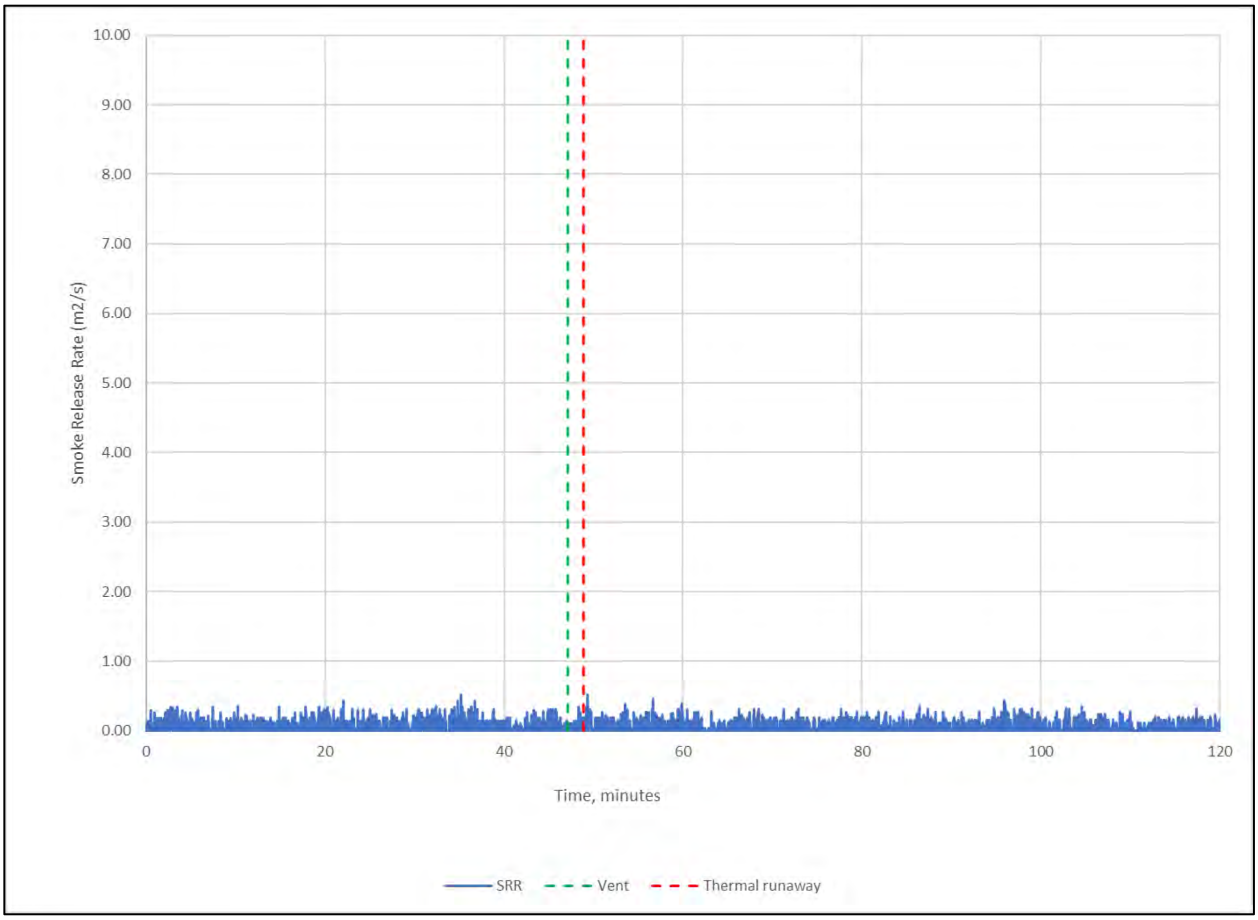


Figure 14: Smoke release rate

UNIT TEST REPORT
UL 9540A
Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems (AACD)

Project Number...............................:	**4790931774**
Date of issue ....:	**2023-10-27**
Total number of pages...................:	**44**
UL Report Office ....:	**UL(Changzhou) Quality Technical Service Co., LTD**
Applicant's name............................:	**Contemporary Amperex Technology Co., Limited**
Address ....:	**No.2 Xin'gang Road, Zhangwan Town, Jiaocheng District, Ningde, Fujian, China**
Test specification:	4th Edition, Section 9, November 12, 2019
Standard ....:	UL 9540A, Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems
Test procedure ....:	9.1 – 9.8
Non-standard test method ....:	UL 9540A, Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems

General disclaimer:

The test results presented in this report relate only to the sample tested in the test configuration noted on the list of the attachments.

UL LLC did not select the sample(s), determine whether the sample(s) was representative of production samples, witness the production of the test sample(s), nor were we provided with information relative to the formulation or identification of component materials used in the test sample(s).

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Cell level information	
Cells in Module:	
●Manufacturer Name	**Contemporary Amperex Technology Co., Limited**
●Part Number	**CBDD0**
●Chemistry	**Lithium Iron Phosphate**
●Format	**Prismatic**
Ratings (Vdc, Ah) :	**3.2V, 306Ah**
Cell certified? :	**Yes**
Standard the cell was certified to:	**UL 1973**
Organization that certified the cell:	**MH62898**
Average cell surface temperature at gas venting, °C:	**154**
Average cell surface temperature at thermal runaway, °C:	**241**
Gas Volume:	**204L**
Lower flammability limit (LFL), % volume in air at the ambient temperature:	**8.595**
Lower flammability limits (LFL), % volume in air at the venting temperature:	**7.24**
Burning velocity (S_u) cm/s:	**54.20**
Maximum pressure (P_{max}) psig:	**102.74**

Cell level Gas Composition:

Gas		Measured %
Carbon Monoxide	CO	14.596
Carbon Dioxide	CO_2	26.925
Hydrogen	H_2	43.066
Methane	CH_4	7.051
Acetylene	C_2H_2	0.119
Ethylene	C_2H_4	3.289
Ethane	C_2H_6	1.060
Propylene	C_3H_6	0.686
Propane	C_3H_8	0.260
-	C4 (Total)	0.865
-	C5 (Total)	0.399
-	C6 (Total)	0.148
1-Heptene	C7H14	0.025
Styrene	C8H8	0.013
Benzene	C_6H_6	0.082
Toluene	C_7H_8	0.012
Dimethyl Carbonate	$C_3H_6O_3$	1.304
Ethyl Methyl Carbonate	$C_4H_8O_3$	0.101
Total	**-**	**100**

Module level Information	
Model No... :	M02306P05L01

Ratings (Vdc, Ah) .... :	166.4V, 612Ah
Module dimensions (X x **Y** x **Z** (mm)**)……………….:**	830mm*2235mm * 250mm
Module cell configuration (xS/**y**P) **…...:**	52S2P
Module weight (kgs)………………………. :	653±5kg
Module enclosure material……………….. :	Bottom enclosure -Material: Al6063.T6 -Thickness: ≥2mm -Size: L*W*H(mm) (2235±3.5)*(830±3)*(31±3) Top Plastic enclosure: -Material: PP -Thickness: ≥2.5mm -Size: L*W*H（mm）2203.1*830*218.5 -Fire rating: V-0 -Maximum ambient temperature: 90±2°C
Was the module certified? …………………………..:	No
Standard the module was certified to …………..:	N/A
Organization that certified test item …….:	N/A
Number of initiating cells failed to achieve propagation.	1
Thermal Runaway Propagation:	Initiating cell went into thermal runaway and propagated to three adjacent cells.
External Flaming:	No external flaming occurred
Location(s) of Flame Venting:	No flaming occurred
Flying Debris:	No flying debris occurred
Re-ignitions:	No further re-ignitions were observed during post test observation
Test Maximum Smoke Release Rate (m^2/s)	0.52
Test Total Smoke Released: (m^2)	1.41
Test Peak Chemical Heat Release Rate: (kW):	No flaming occurred

Module level test Gas Composition & Volume for Each Compound (Pre-flaming and After flame) :

Gas Compound	Gas Type	Pre-Flaming (L)	Flaming (L)	Minimum detectable flow rate(LPM)
Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	260.29	No flaming	0.50
Carbon Monoxide	Carbon Containing	77.57	No flaming	0.61
Carbon Dioxide	Carbon Containing	217.03	No flaming	1.82
Hydrogen	Hydrogen	263.37	No flaming	14.29

Unit level Information	
Model No. :	C02306P05L01-R
Ratings (Vdc, Ah) .... :	1331.2V, 612Ah
BESS dimensions (W x **D** x **H** (mm)**)……………….:**	2698mm(H)*936mm(W)*2252.5mm(D)
BESS module configuration	8S1P
Number of modules in BESS	8
Module cell configuration (xS/yP**) …...:**	52S2P
Number of cells in module.:	104
BESS weight (kgs)………………………. :	7200kg
BESS enclosure material……………….. :	No enclosure provided for BESS unit, racks are directly mounted on the container frames
BESS Intended Installation: **Non Residential:** outdoor ground mounted, indoor floor mounted, outdoor wall mounted, indoor wall mounted, roof top, open garage **Residential:** Outdoor ground mounted, indoor floor mounted, outdoor wall mounted, indoor wall mounted	Non Residential: indoor floor mounted in a container. For a container system BESS including those intended for outdoor installation only, the unit level test shall be in accordance with the indoor floor mounted unit level test using the battery system racks as the test units and with the test installation set up in accordance with the installation layout within the container. According to 9.1.2.1 from the CRD, it should be treated as indoor floor mounted application
Residential Indoor Use: Smallest volume room installations specified.	N/A
Original Equipment Manufacturer (OEM):	Contemporary Amperex Technology Co., Limited
Branding Manufacturer (if not OEM):	N/A
Was the unit certified? ………………………….:	No
Standard the unit was certified to …………..:	N/A
Organization that certified the unit …….:	N/A
Cell failure test method performed (summary of method and test clause): ☒ External heating using thin film with 4°C to 7°C thermal ramp. ☐ Nail Penetration ☐ Overcharge ☐ External short circuit (***X*** Ω *external resistance*) ☐ Others	
Description of method used to fail cells if other than external thin film heater with thermal ramp, :N/A	

Description of components employed within the BESS unit that serve to suppress propagation (fire protection features) N/A	
Deviation from the module level test **N/A**	
Number of initiating cell(s)	1
Thermal Runaway Propagation:	Initiating cell went into thermal runaway and propagated to at least two adjacent cells.
External Flaming from BESS:	No external flaming occurred
Location(s) of Flame Venting:	No flaming occurred
Maximum Target BESS Temperature, °C	30.5
Maximum Wall Surface Temperature[1], °C	28.3
Peak Chemical Heat Release Rate, kW	No flaming occurred
Peak Convective Heat Release Rate, kW	No flaming occurred
Maximum Smoke Heat Release Rate, m^2/s	0.12
Maximum Heat Flux on Target Modules, kW/m^2	0.01
Maximum Heat Flux of Egress Path, kW/m^2	0
Flying Debris:	No flaming occurred
Re-ignitions:	No further re-ignitions were observed during post test observation

Gas Analysis:

☒ Flame ionization detection (FID)

☒ Non-Dispersive Infrared Spectrometer (NDIR)

☐ Fourier-Transform infrared Spectrometer

☒ Hydrogen Sensor (palladium-nickel, thin-film solid state sensor)

☒ White light source with photo detector (smoke release rate)

Summary of Unit level test Gas Analysis Data:

Unit level Gas Composition & Volume for Each Compound (Pre-flaming and After flame):

Gas Compound	Gas Type	Pre-Flaming (L)	Flaming (L)	Minimum detectable flow rate(LPM)
Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	111.98	No flaming	4.13
Carbon Monoxide	Carbon Containing	59.54	No flaming	3.08
Carbon Dioxide	Carbon Containing	138.34	No flaming	3.97
Hydrogen	Hydrogen	3.54	No flaming	104.03

Summary of BESS Unit Test Results

Performance Criteria in accordance with Table 9.1 for Indoor Floor Mounted non-residential unit

[1] Maximum wall surface temperature averaged on 60 seconds.

[X] Flaming outside the initiating BESS unit was not observed;

[X] Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit did not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8;

[X] For BESS units intended for installation in locations with combustible constructions, surface temperature measurements on wall surfaces did not exceed 97°C (175°F) of temperature rise above ambient per 9.2.15;

[X] Explosion hazards were not observed, including deflagration, detonation; and

[X] Heat flux in the center of the accessible means of egress did not exceed 1.3 kW/m^2.

Necessity for an Installation level test

[ ] The performance criteria of the unit level test as indicated in Table 9.1 of UL 9540A 4th edition has not been met, therefore an installation level testing in accordance with UL 9540A will need to be conducted on the representative the installation with this unit installed.

[X] The performance criteria of the unit level tests as indicated in Table 9.1 of UL 9540A 4th edition has been met, therefore an installation level testing in accordance with UL 9540A need not be conducted.

Testing Laboratory Information

Testing Laboratory and testing location(s):

Testing Laboratory:	Beijing Building Materials Testing Academy	
Testing location/ address .... :	Block 1, B15 Yaxin Road, Doudian Town, Fangshan district, Beijing 102402, CN PSN: 3369533	
Tested by (name, signature) .... :	Zhang Qi, Oliver Zhao	
Witnessed by (for 3rd Party Lab Test Location) (name, signature) .... :	N/A	N/A
Project Handler (name, signature).............. :	Arui Zhou	Arui Zhou
Reviewer (name, signature) …………….:	Benjamin Liu	Benjamin Liu

List of Attachments (including a total number of pages in each attachment):
Attachment A: Sample Charging, OCV and SOC Measurement Profiles - (*Pages **27** through **30***)
Attachment B: BESS (including module and any integral fire detection and suppression systems) Construction Photos/Diagrams - (*Pages **31** through **31***)
Attachment C: BESS and Equipment Instrumentation and Test Installation Layout Photos/Diagrams - (*Pages **32** through **35***)
Attachment D: Temperature Profiles and Heat Flux Measurements During Testing (Initiating Cell and Module, Target Modules, Wall Surfaces, etc. - (*Pages **36** through **39***)
Attachment E: BESS Unit Testing and Post Testing Photos - (*Pages **40** through **41***)
Attachment F: BESS Unit Gas Flow Rate and Heat Release and Smoke Release Profiles - (*Pages **42** through **44***)

Photo(s) of BESS unit:

Test Item Charge/Discharge Specifications:	**C02306P05L01-R**
• **Charge Power, kW:**	**50.91 kW, then 5.091 kW for module** **407.34 kW, then 40.734 kW for rack**
• **Standard Full charge voltage, Vdc:**	**Any cell reaches of 3.65V or 189.8V for module** **Any cell reaches of 3.65V or 1500V for rack**
• **Charge temperature range, °C:**	**-25~55**
• **End of charge Power, kW:**	**Any cell reaches of 3.65V or 189.8V for module** **Any cell reaches of 3.65V or 1500V for rack**
• **Discharge Power, kW:**	**50.91 kW for module, 407.34 kW for rack**
• **End of discharge voltage, Vdc:**	**Any cell reaches of 2.5V or 130V for module** **Any cell reaches of 2.5V or 1040V for rack**
• **Discharge temperature range, °C:**	**-25~55**
• **Storage temperature range, °C:**	**-30~60**

Test item particulars ....:	
Possible test case verdicts:	
- test case does not apply to the test object...........:	N/A
- test object does meet the requirement ....:	P (Pass)
- test object does not meet the requirement...........:	F (Fail)
- test object was completed per the requirement...:	C(Complete)
- test object was completed with modification……:	M(Modification)
Testing...:	
Date of receipt of test item ....:	2023.08.27
Date (s) of performance of tests...............................:	2023.09.22

General remarks:

"(See Enclosure #)" refers to additional information appended to the report.
"(See appended table)" refers to a table appended to the report.

Throughout this report a point is used as the decimal separator.

Manufacturer's Declaration of samples submitted for test:

The applicant for this report includes samples from more than one factory location and a declaration from the Manufacturer stating that the sample(s) submitted for evaluation is (are) representative of the products from each factory has been provided ....:	☐ **Yes** ☒ **Not applicable**
Name and address of factory (ies).......................... :	Contemporary Amperex Technology Co., Limited Xin'gang Road, Zhangwan Town, Jiaocheng District, Ningde, Fujian, China

General product information and other remarks:

Battery Unit Model C02306P05L01-R is lithium-ion racks manufacturer by Contemporary Amperex Technology Co., Limited. The rack consists of 8 battery modules Model M02306P05L01 connected in series with a control box. The rack frame is part of the container frame and test was conducted with initiating rack and target racks installed in the container enclosure.

In the test, 3 racks were placed inside the container. Container size: 2698mm(H)*936mm(W)*2252.5mm(D).

Battery Module Model M02306P05L01 employs cell Models CBDD0 manufactured by Contemporary Amperex Technology Co., Limited, rated 166.4V, 612Ah.

5.0	CONSTRUCTION		Verdict
5.3	**Battery energy storage system unit Construction**		—
5.3.1, 5.3.2	Construction information	See Test Item Description at the beginning of this report	—
5.3.2	General layout of BESS unit contents	See Attachment B	—
5.3.3	Details of integral fire suppression system		
5.3.1	BESS certified to UL 9540		
	Organization that certified BESS:		—
6.0	**PERFORMANCE**		**Verdict**
6.1	**General**		C
9.1	**Sample and test configuration**		C
9.1.1	The unit level test conducted with BESS units installed as described in the manufacturer's instructions.	See Attachment C for test installations Installation type: Indoor floor mounted, non-residential use, container type	C
9.1.2	The unit level test required one initiating BESS unit in which an internal fire condition in accordance with the module level test is initiated and target adjacent BESS units representative of an installation.	See Attachment C for test installations	C
	Tests conducted for indoor floor mounted installations are representative of both indoor floor mounted and outdoor ground mounted installations.		N/A
	Tests conducted indoors with fire propagation hazards and separation distances between initiating and target units representative of the installation.		C
	Testing conducted outdoors for outdoor only installations with following in place: a) Wind screens with wind speed of ≤ 12 mph; b) Temperature range is 10°C to 40°C (50°F to 104°F); c) Humidity is < 90% RH; d) Sufficient light to observe the testing; e) There is no precipitation; f) There is control of vegetation and combustibles in the test area; and g) There are protection mechanisms in place to prevent inadvertent access by unauthorized persons in the test area.		N/A

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict

9.1.3	Testing to determine fire characterization was done at the battery system level rather than a complete BESS	One initiating unit sample and two target unit samples were used for test. Power Conversion System was not involved in the test.	C
9.1.4	The initiating BESS contained components representative of a BESS unit in a complete installation.		C
	Combustible components that interconnect the initiating and target BESS units was included.		C
9.1.5	Target BESS units include the outer cabinet (if part of the design), racking, module enclosures, and components that retain cells components.		C
9.1.6	The initiating BESS was at the maximum operating state of charge (MOSOC),	See Table 2 and Attachment A	C
	After charging and prior to testing, the initiating BESS was at rest for a maximum period of 8 hours at room ambient.	See Table 2 All modules were fully charged before test for test setup. All module voltages were checked just before the test, and the voltages did not drop further compared to 1h to 8h after cycles.	M
9.1.7	The BESS unit included an integral fire suppression system.	No include integral fire suppression system.	N/A
9.1.8	Electronics and software controls such as the battery management system (BMS) are not relied upon for this testing.		C
	Included a fire suppression control in accordance with UL 864 that is external to the BESS.		N/A
9.2	**Test method – Indoor floor mounted BESS units**		C
9.2.1	Test room ambient temperature within 10°C (50°F) to 32°C (90°F).	See Table 2 See Attachment F	C
9.2.2	Access door(s) or panels on the initiating BESS unit and adjacent target BESS units were closed, latched and locked duration of the test.	There are no doors or panels for racks, racks are mounted on the container frame.	C
9.2.3	The initiating BESS unit was positioned adjacent to two instrumented wall sections.	Attachment C	C
9.2.4	Instrumented wall sections extend not less than 0.49 m (1.6 ft) horizontally beyond the exterior of target BESS units.	Front wall was 3.6m length, side wall was 7.2m length, rear wall was 6.2m length.	C

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict
9.2.5	Instrumented wall sections were at least 0.61-m (2-ft) taller than the BESS unit height, but not less than 3.66 m (12 ft) in height above the bottom surface of the unit.	Front wall, side wall and rear wall were 3.7m high.	C
9.2.6	The surface of the instrumented wall sections were covered with 16-mm (5/8-in) gypsum wall board and painted flat black.	See Attachment C	C
9.2.7	The initiating BESS unit was centered underneath an appropriately sized smoke collection hood of an oxygen consumption calorimeter.		C
9.2.8	The light transmission in the calorimeter's exhaust duct was measured using a white light source and photo detector. The smoke release rate was calculated.	See Table 11 See Attachment F	C
9.2.9	The chemical and convective heat release rates were measured for the duration of the test.	See Table 11 See Attachment F	C
9.2.10	The heat release rate measurement system was calibrated using an atomized heptane diffusion burner. The calibration was performed using flows of 3.8, 7.6, 11.4 and 15.2 L/min (1, 2, 3 and 4 gpm) of heptane.		C
9.2.11	The chemical heat release rate was measured using the following equipment: ● Paramagnetic oxygen analyser ● Non-dispersive infrared carbon dioxide and carbon monoxide analyser ● Velocity probe ● Type K thermocouple		C
9.2.12	The chemical heat release rate at each of the flows was calculated.		C
9.2.13	The physical spacing between BESS units (both initiating and target) and adjacent walls was representative of the intended installation.	See Attachment C Racks were installed inside container frame. The spacing between the initiating rack and adjacent target racks (left and right of initiating unit) was 0mm. The spacing from the front wall to the container frame was 3000mm, side wall to the container frame was 1100mm and rear wall to the container frame was 200mm	C

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Clause	Requirement + Test	Result - Remark	Verdict
9.2.14	Separation distances were specified by the manufacturer for distance between: a) The BESS units and the instrumented wall sections; and b) Adjacent BESS units.	See Attachment C	C
9.2.15	Wall surface temperature measurements were collected	See Table 6 See Attachment D	C
	The intended installation is composed completely of non-combustible construction		N/A
9.2.16	Wall surface temperatures were measured in vertical array(s) at 152-mm (6-in) intervals for the full height of the instrumented wall sections using No. 24-gauge or smaller, Type-K exposed junction thermocouples.		C
	The thermocouples for measuring the temperature on wall surfaces were horizontally positioned in the wall locations to receive greatest thermal exposure from the initiating BESS unit.		C
9.2.17	Thermocouples were secured to gypsum surfaces and the thermocouple tip was depressed into the gypsum so as to be flush with the gypsum surface at the point of measurement .		C
9.2.18	Heat flux was measured with at least two water-cooled Schmidt-Boelter gauges at the surface of each instrumented wall: a) Both are collinear with the vertical thermocouple array; b) One is positioned to receive the greatest heat from the initiating module; and c) One is positioned to receive the greatest heat flux during potential propagation within the initiating BESS unit.	See Table 7	C
9.2.19	Heat flux was measured with 2 water-cooled Schmidt-Boelter gauges at the surface of each adjacent target BESS units facing initiating BESS unit: a) One is positioned at the elevation estimated to receive the greatest heat flux from the initiating module; and b) One is positioned at the elevation estimated to receive the greatest surface heat flux due to initiating BESS.	See table 7	C
9.2.20	Heat flux was measured with the sensing element of at least one water-cooled Schmidt-Boelter gauge positioned in the center of the accessible means of egress.	See table 7	C

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Clause	Requirement + Test	Result - Remark	Verdict

9.2.21	No. 24-gauge or smaller, Type-K exposed junction thermocouples were installed to measure the temperature of the surface proximate to the cells and between the cells and exposed face of the initiating module.	See Attachment C	C
	Each non-initiating module enclosure within the initiating BESS unit was instrumented with at least one No. 24-gauge or smaller Type-K thermocouple(s) within non-initiating modules.	See Attachment C	C
	Additional thermocouples were placed to account for convoluted geometries.		N/A
9.2.22	For residential use, the DUT was covered with a single layer of cheese cloth ignition indicator. The cheesecloth was untreated cotton cloth running 26 – 28 m2/kg with a count of 28 – 32 threads in either direction within a 6.45 cm^2 (1 in^2) area.	Non-residential use.	N/A
9.2.23	An internal fire condition in accordance with the module level test was created within a single module in the initiating BESS unit: a) The position selected to present the greatest thermal exposure to adjacent modules; and b) The setup was the same as that used to initiate and propagate thermal runaway within the module level test.	See Attachment C	C
9.2.24	The composition, velocity and temperature of the initiating BESS unit vent gases was measured within the calorimeter's exhaust duct. Composition, velocity and temperature instrumentation shall be collocated with heat release rate calorimetry instrumentation.		C
	Hydrogen gas shall be measured with a palladium-nickel thin-film solid state sensor.		
	The hydrocarbon content of the vent gas may also be measured using a Fourier-Transform Infrared Spectrometer with a minimum resolution of 1 cm-1 and a path length of at least 2 m (6.6 ft), or equivalent gas analyzer.	FTIR analysis was not used in accordance with the Certification Requirement Decision: Corrections to gas measurement methods to make FTIR as an option for measuring hydrocarbon contents of gas emissions and to include Hydrogen measurements during the Unit Level Test.	N/A
9.2.25	The hydrocarbon content of the vent gas was measured using flame ionization detection.	See Tables 8, 9, 10 and 11	C

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Clause	Requirement + Test	Result - Remark	Verdict

9.2.26	The test shall be terminated if: a) Temperatures measured inside each module within the initiating BESS unit return to ambient temperature; b) The fire propagates to adjacent units or to adjacent walls; or c) A condition hazardous to test staff or the test facility requires mitigation.	Test temperature recording was terminated until no noticeable phenomenon observed and all measured temperatures of the initiating unit return to ambient temperature.	C
9.2.27	For residential use systems, the gas collection data gathered in 9.2 shall be compared to the smallest room installation specified by the manufacturer to determine if the flammable gas collected exceeds 25% LFL in air.	Non-residential unit.	C
9.7	**Unit level test report**		
9.7.1	Installation type tested:	Indoor floor mounted, non-Residential, container type For a container system BESS including those intended for outdoor installation only, the unit level test shall be in accordance with the indoor floor mounted unit level test using the battery system racks as the test units and with the test installation set up in accordance with the installation layout within the container. According to 9.1.2.1 from the CRD, it should be treated as indoor floor mounted application.	C
9.7.2	Testing is intended to represent more than one installation type.	See Test Item Description in beginning of this report.	C
9.7.3	a. Unit manufacturer name and model number (and whether UL 9540 compliant);		C
	b. Number of modules in the initiating BESS unit		C

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Clause	Requirement + Test	Result - Remark	Verdict

	c. BESS construction features;	See Attachment C See Critical Components Table See Also "Description of components employed within the module that impact propagation (fire protection features)" at the beginning of this report.	C
	d. Fire protection features/ detection/ suppression systems within unit		N/A
	e. Module voltages corresponding to the tested SOC;	See Table 13 See Attachment F	C
	f. Thermal runaway initiation method used;	See Attachment C and F	C
	g. Location of the initiating module within the BESS unit;	See Attachment C	C
	h. Diagram and dimensions of the test setup including mounting location of the initiating and target BESS units, and the locations of walls, ceilings, and soffits;	See Attachment C	C
	i. Observation of any flaming outside the initiating BESS enclosure and the maximum flame extension;	See Table 14 No flame observed outside of the initiating rack.	C
	j. Chemical and convective heat release rate versus time data;	See Table 11 See Attachment F	C
	k. Separation distances from the initiating BESS unit to target walls	See Attachment C	C
	l. Separation distances from the initiating BESS unit to target BESS units	See Attachment C	C
	m. The maximum wall surface and target BESS temperatures achieved during the test and the location of the measuring thermocouple;	Tables 5 and 6	C
	n. The maximum ceiling or soffit surface temperatures achieved during the indoor or outdoor wall mounted test and the location of the measuring thermocouple;		N/A
	o) The maximum incident heat flux on target wall surfaces and target BESS units;	Table 7	C
	p) The maximum incident heat flux on target ceiling or soffit surfaces achieved during the indoor or outdoor wall mounted test;		N/A
	q. Flammable gas generation and composition data;	See Attachment F See Tables 7, 8, 9, and 10	C

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Clause	Requirement + Test	Result - Remark	Verdict

	r. Peak smoke release rate and total smoke release data.	See Table 12 See Attachments F	C
	s. Indication of the activation of integral fire protection systems and if activated the time into the test at which activation occurred;	See Table 13 No fire protection systems	N/A
	t. Observation(s) of flying debris or explosive discharge of gases;	See Table 15	C
	u. Observation of re-ignition(s) from thermal runaway events	See Table 15	C
	v. Observation(s) of sparks, electrical arcs, or other electrical events;	See Table 15	C
	w. Observations of the damage to: 1) The initiating BESS unit; 2) Target BESS units; 3) Adjacent walls, ceilings, or soffits;	See Table 15	C
	x. Video of the test.		C
9.8	**Performance at Unit level testing**		P
9.8.1	Installation level testing in Section 10 was not required if the following performance conditions outlined in Table 9.1 are met during the unit level test.	See Attachment F	P
Non-Residential Installations – Indoor floor mounted:			
	a) Flaming outside the initiating BESS unit is not observed;	No flaming observed	P
	b) Surface temperatures of modules within target BESS units do not exceed the cell venting temperature;	Max surface temperature 30.5°C didn't exceed the cell venting temperature 154°C	P
	c) For BESS units intended for installation in locations with combustible constructions, surface temperature measurements on wall surfaces do not exceed 97°C (175°F) rise above ambient;	Max wall surface temperature 28.3°C didn't exceed 97°C rise above ambient	P
	d) Explosion hazards are not observed, including deflagration, detonation or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases;	No explosion observed	P
	e) Heat flux in the center of the accessible means of egress did not exceed 1.3 kW/m^2.	Measured heat flux 0kW/m2 didn't exceed 1.3 kW/m2	P

Table 1 – Specified Unit charging and discharging parameters			
Charging:		**Discharging:**	
Power (CP), kW	50.91 kW, then 5.091 kW for module 407.34 kW, then 40.734 kW for rack	Power (CP), kW	50.91 kW for module, 407.34 kW for rack
Standard Full Charge Voltage ,Vdc	Any cell reaches of 3.65V or 189.8V for module Any cell reaches of 3.65V or 1500V for rack	End of discharge voltage, Vdc	Any cell reaches of 2.5V or 130V for module Any cell reaches of 2.5V or 1040V for rack
End of Charge Voltage，Vdc	Any cell reaches of 3.65V or 189.8V for module Any cell reaches of 3.65V or 1500V for rack	Discharging Test Ambient, °C	-25~55
Charge temperature range, °C:	-25~55	-	-
Refer to Attachment A for charge/discharge profiles.			

Table 2 - Test Initiation Details	
Test Date	2023-09-22
Test Start Time (HH:MM:SS)	09:49:14
Initial Lab Temperature, °C	24.0°C
Initial Relative Humidity % RH	49% RH
Module OCV at Start of Test, Vdc	173.2V

Table 3 – Approximate time of thermal runaway propagation through module		
Locations (Cell #)	**Event**	**Time**
Cell 20-2	Vent	0:41:08
Cell 20-2	Thermal runaway	0:41:48
Cell 20-1	Thermal runaway	0:44:40
Cell 21-1	Thermal runaway	0:46:03
*	Thermal runaway	1:05:26
*Note: Suspect there is another one cell went into thermal runaway, as there is no more TC in the module, cannot determine the cell location, refer to the temperature curve of Cell 21-1, voltage drop of module, gases generation and video, another cell was suspected to be propagated around 65.5 mintues.		

Table 4 – Test overview timeline		
Time (HH:MM:SS)	**Event**	**Description**
00:00:00	Test Start	The test started and the heater was turned on to heat the initiating cell (Cell 20-2) at a ratio of 4 ~ 7 °C/min.
00:41:08	Venting of initiating Cell	Initiating cell (Cell 20-2) vented at around 168.4 °C measured through TC 2-1 by an indication of sudden dip in cell’s temperature curve. See Figure (b)
00:41:48	Thermal runaway of initiating cell	Initiating cell (Cell 20-2) was at around 145.1 °C measured through T2-1. The temperature of cell 20-2

		began to increase inan uncontrollable manner, With the release of smoke. See Figure (c)
00:44:40	Thermal runaway of adjacent cell	Thermal runaway propagated to nearby cell (cell 20-1). More gas released. See Figure (d)
00:46:03	Thermal runaway of adjacent cell	Thermal runaway propagated to nearby cell (cell 21-1). More gas released. See Figure (e)
01:05:26	Thermal runaway of adjacent cell	Gas released.(Refer to the temperature curve of Cell 21-1, voltage drop of module, gases generation and video, another cell was suspected to be propagated around 65.5 mintues.) See Figure(f)
01:25:00	Test Termination	Data acquisition was stopped. The module was left in the test overnight and with video monitored.

Table 5 - Maximum Temperatures in Target Units			
Cell vent temperature from cell test data, °C			154°C
Target Unit 1		**Target Unit 2**	
Module Location No.	Temperature (°C)	Module Location No.	Temperature (°C)
Module -1	27.2	Module -1	26.9
Module -2	28.8	Module -2	28.1
Module -3	30.5	Module -3	28.7
Module -4	28.5	Module -4	28.0
Module -5	27.5	Module -5	27.7
Module -6	27.3	Module -6	27.2
Module -7	27.3	Module -7	27.0
Module -8	27.8	Module -8	27.5
Note: Temperatures are measured constantly and then averaged every 60-seconds			

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Clause	Requirement + Test	Result - Remark	Verdict

Table 6.1 - Maximum Temperatures on Instrumented Wall- Front Wall					
Ambient Temperature: 24.0°C					
UL 9540A performance criteria, Ambient + 97°C: 121.0°C					
Height, mm	Maximum Temperature (°C)	Height, mm	Maximum Temperature (°C)	Height	Maximum Temperature (°C)
152	26.8	1368	27.2	2584	24.7
304	27.0	1520	27.0	2736	27.2
456	27.1	1672	27.0	2888	27.1
608	25.3	1824	27.2	3040	27.2
760	27.3	1976	27.2	3192	27.4
912	27.3	2128	27.4	3344	27.4
1064	27.0	2280	27.4	3496	27.4
1216	27.0	2432	27.2	3648	27.7
Note: Temperatures are measured constantly and then averaged every 60-seconds					

Table 6.2 - Maximum Temperatures on Instrumented Wall- Side Wall					
Ambient Temperature: 24.0°C					
UL 9540A performance criteria, Ambient + 97°C: 121.0°C					
Height, mm	Maximum Temperature (°C)	Height, mm	Maximum Temperature (°C)	Height	Maximum Temperature (°C)
152	24.9	1368	26.8	2584	26.9
304	25.8	1520	26.9	2736	27.0
456	25.5	1672	26.9	2888	27.3
608	26.1	1824	26.8	3040	27.3
760	26.3	1976	26.7	3192	27.0
912	26.6	2128	26.8	3344	27.1
1064	26.7	2280	26.8	3496	27.0
1216	26.5	2432	27.0	3648	27.0
Note: Temperatures are measured constantly and then averaged every 60-seconds					

Table 6.3 - Maximum Temperatures on Instrumented Wall- Rear Wall					
Ambient Temperature: 24.0°C					
UL 9540A performance criteria, Ambient + 97°C: 121.0°C					
Height, mm	Maximum Temperature (°C)	Height, mm	Maximum Temperature (°C)	Height	Maximum Temperature (°C)
152	26.7	1368	27.6	2584	27.2
304	27.2	1520	27.4	2736	27.5
456	26.8	1672	27.3	2888	27.5
608	26.9	1824	27.6	3040	27.6
760	27.0	1976	27.2	3192	27.6
912	27.1	2128	27.2	3344	27.5
1064	27.2	2280	28.1	3496	28.3
1216	27.1	2432	26.9	3648	27.7
Note: Temperatures are measured constantly and then averaged every 60-seconds					

Table 7 – Heat Flux Measurements			
Summary of maximum heat flux in target units		Summary of maximum heat flux measured on instrumented wall	
Maximum Heat Flux, kW/m^2			
Target Unit 1 Module No.3: 1#	0	Heat Flux Gauge No.	kW/m^2
Target Unit 1 Module No.4: 5#	0	Front wall 1350 mm high, 11#	0
Target Unit 2 Module No.3: 8#	0	Front wall 1600 mm high, 7#	0
Target Unit 2 Module No.4: 9#	0.01	Side wall 1350 mm high, 6#	0
-		Rear wall 1350 mm high, 10 #	0
-		Rear wall 1600 mm high, 4#	0
Egress path measurement- 1: 3 #			0
Egress path measurement- 2: 2#			0

Table 8 – Gases measured and measurement methods used in unit level testing			
Measurement Method	**Gases Measured**	**Chemical Formula**	**Gas Type**
Flame Ionization Detection (FID)	Total Hydrocarbons	-	Hydrocarbons
Solid-state Hydrogen Sensor	Hydrogen	H_2	
Non-dispersive infrared spectroscopy (NDIR)	Carbon Dioxide	CO_2	Carbon Containing
	Carbon Monoxide	CO	Carbon Containing
# - This table was modified to reflect the gases measured during testing.			

Table 9 - Gas generation periods	
Time	**Condition**
From the venting point 0:41:08 to the end of test 2:00:00	Pre-Flaming
Flaming was not observed during the test.	Flaming
External Flaming of Gas	
Condition	**Duration (hh:mm:ss)**
External Flaming of Vent Gases:	Flaming was not observed during the test.

Table 10 – Summary of battery gas volumes for deflagration hazard calculations				
Gas Component	Gas Type	During Pre-flaming (L)	During Flaming (L)	Minimum detectable flow rate(LPM)
Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	111.98	No flaming	4.13
Carbon Dioxide	Carbon Containing	59.54	No flaming	3.08
Carbon Monoxide	Carbon Containing	138.34	No flaming	3.97
Hydrogen	Hydrogen	3.54	No flaming	104.03

Table 11 – Smoke and heat release rate			
Heat Release Rate (HRR)		**Smoke Release Rate (SRR)**	
Peak Chemical HRR (kW)	No flaming observed	Maximum SRR (m^2/s)	0.12
Peak Convective HRR, (kW)	No flaming observed	Total Smoke Released (m^2)	0.23

Table 12 – Integral Fire suppression system Details of Operation
N/A

Table 13 - Module OCV voltage measurement comparison before and after testing			
Module Location In Rack	OCV Prior to Test (V)	OCV Post Test (V)	Difference (V)
1	173.2	173.2	0
2	173.2	173.2	0
3 (Initiating Module)	173.2	166.4	6.8
4	173.6	173.5	0.1
5	173.2	173.2	0
6	172.3	173.2	0.1
7	173.3	173.3	0
8	173.8	173.7	0.1

Table 14 – Other Observations during Unit test			
	Observed, Yes/No	Comments/Location	
Flaming outside of Unit	No	Length of flame:	N/A
Flying debris	No	-	
Explosive discharge of gas	No	-	
Sparks or electrical arcs	No	-	

Table 15 - Post Test Observations	
Thermal runaway behaviour	No further thermal runaway after the test was completed
Re-ignitions	No re-ignition occurred
Explosions	No explosion occurred
Other Observations	N/A

	TABLE: Critical components information				
Object / Part No.	**Manufacturer/ trademark**	**Type / model**	**Technical data**	**Standard**	**Mark(s) of conformity**
Module construction					
Cells	CATL	CBDB0	Nominal voltage：3.2V d.c Rated capacity：306Ah	UL 1973 IEC 62619：2022	UL MH 62898 JPTUV-146897
Module	CATL	-	Nominal voltage：166.4V Rated capacity：612Ah	-	-
Metal enclosure	CATL	-	Material: Al6063.T6 Thickness: ≥2mm Size: L*W*H(mm) (2235±3.5)*(830±3)*(31±3)	—	—
Plastic enclosure	0000013277	NHPP-FR NHPP-FR-2	Fire rating：V-0 Material: PP RTI: 65°C	UL746	UL E171666
Connector	0000007975	REA4	Voltage：1500VDC Current：350A for TUV, 300A for UL Fire rating：V-0	UL4818 EN 61984	UL E526230 J 50586193
Connecting wire for HV	0000009966	3932	Voltage: 2000V Current-carrying capability: 75°C 350A Maximum ambient temperature:-40°C~+125°C	UL 758 EN 50525 IEC 60227 IEC 60228:2004	E214184 M.2021.206.C63716
Wire for LV	0000009966	3666	Voltage: 600V Wire diameter: (0.5~4mm2) Maximum ambient temperature: -40°C~+105°C	UL 758 EN 50525 IEC 60227 IEC 60228:2004	E214184 0B160705.DNTDS30
Plastic material (Harness isolation plate)	0000015262	PP C6540R-G20HF	Fire rating: V-0 Maximum ambient temperature: 90±2°C	UL94	SHMR220800424401
Plastic material (Output pole base)	0000007541	46GF30	Fire rating: V-0 Maximum ambient temperature: 180°C	UL94	UL E225348

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Plastic material (Buffer pad)	0000007929	MPP	Fire rating: V-0 Maximum ambient temperature: 100°C	UL94	UL E509966
Container					
Enclosure	0000014067	-	Material: steel High weather resistance rolled steel Thickness: 1.6mm/12mm Size: 6058*2438*2896(mm)	-	-
Plastic enclosure	0000014067	FR-4 Board	Material: epoxy plate Thickness: (4mm) Size: 516*70*4(mm) Fire rating: V0	ROHS UL 94	STT/22T1032-ROHS 2015-L738
Connector	0000007975	REA4	Voltage: 1500VDC Current: 350A for TUV, 300A for UL Fire rating: V-0	UL4818 EN 61984	UL E526230 J 50586193
Connecting wire for HV	0000009966	3932	Voltage: 2000V Current-carrying capability: 75°C 350A Maximum ambient temperature:-40°C~+125°C	UL 758 EN 50525 IEC 60227 IEC 60228:2004	E214184 M.2021.206.C63716
Main control box					
Enclosure	0000003592	-	Material: steel DC51D+Z&DC01 Thickness: ≥1.5mm Size: 751.5±5*741.4±5*239.3±5 mm	-	-
Wire for LV	0000009966	3666	Voltage: 600V Wire diameter: (0.5~4mm2) Maximum ambient temperature: -40°C~+105°C	UL 758 EN 50525 IEC 60227 IEC 60228:2004	E214184 0B160705.DNTDS30
Connector	0000007975	REA4	Voltage: 1500VDC Current: 350A for TUV, 300A for UL Fire rating: V-0	UL4818 EN 61984	UL E526230 J 50586193

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Clause	Requirement + Test	Result - Remark	Verdict

Connecting wire for HV	0000009966	3932	Voltage: 2000V Current-carrying capability: 75°C 350A Maximum ambient temperature: -40°C~+125°C	UL 758 EN 50525 IEC 60227 IEC 60228:2004	E214184 M.2021.206.C63716
Sealing element	0000011532	LZ302Z(Sec A)	Fire rating: ≥V-0 Maximum ambient temperature: -50~+200°C	UL94	UL E529227

Attachment A: Sample Charging, OCV and SOC Measurement Profiles - (*Pages **27** through**30***)

Note: There were 8 modules in the initiating unit. Due to the voltage limitation of the charging device, the modules in the unit were divided into 8 groups and were then fully charged separately. The charging current of each module is 50.91 kW, then 5.091 kW, and the charging ends when any cell reaches of 3.65V or 1500V for rack.

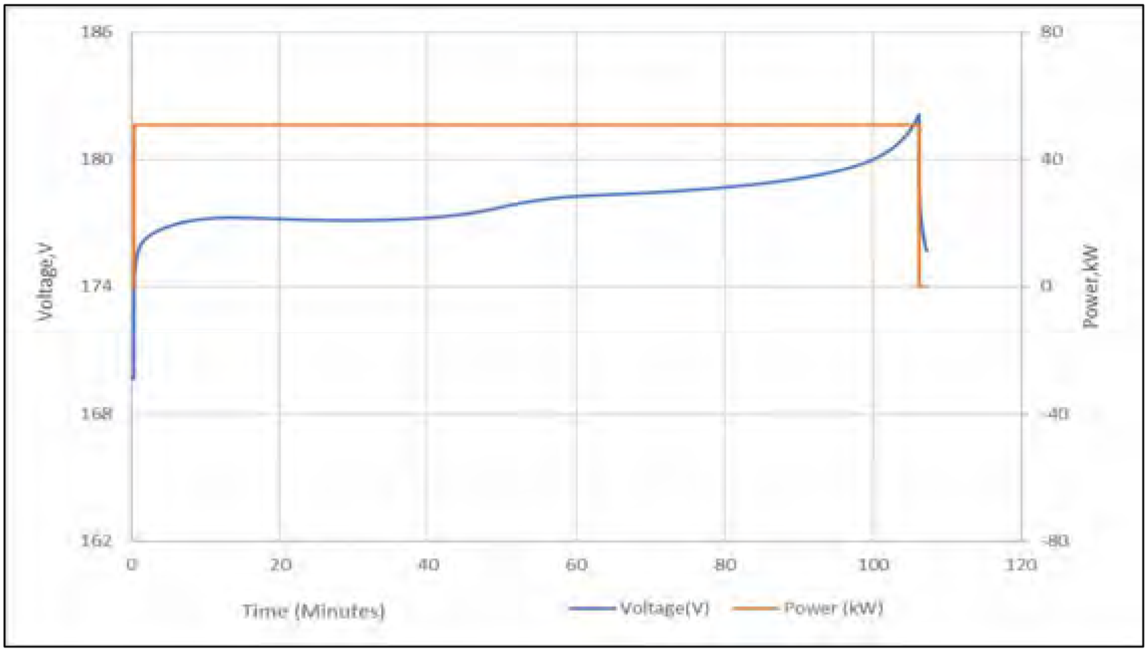


Figure 1: Initiating unit, module 1 charge to 100% SOC

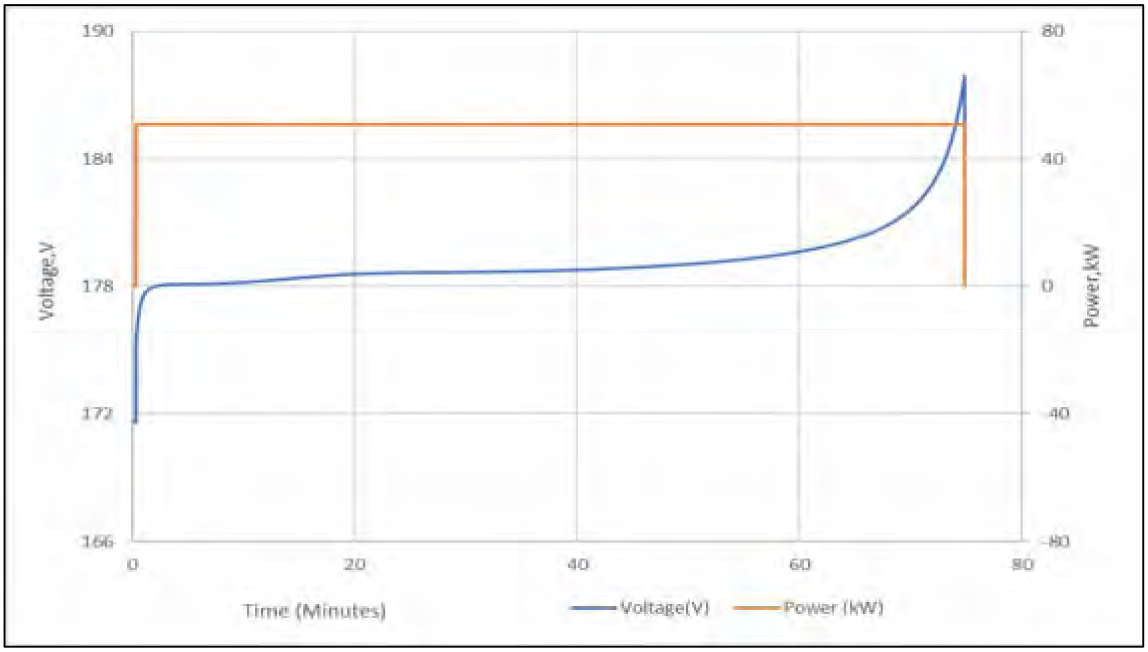


Figure 2: Initiating unit, module 2 charge to 100% SOC

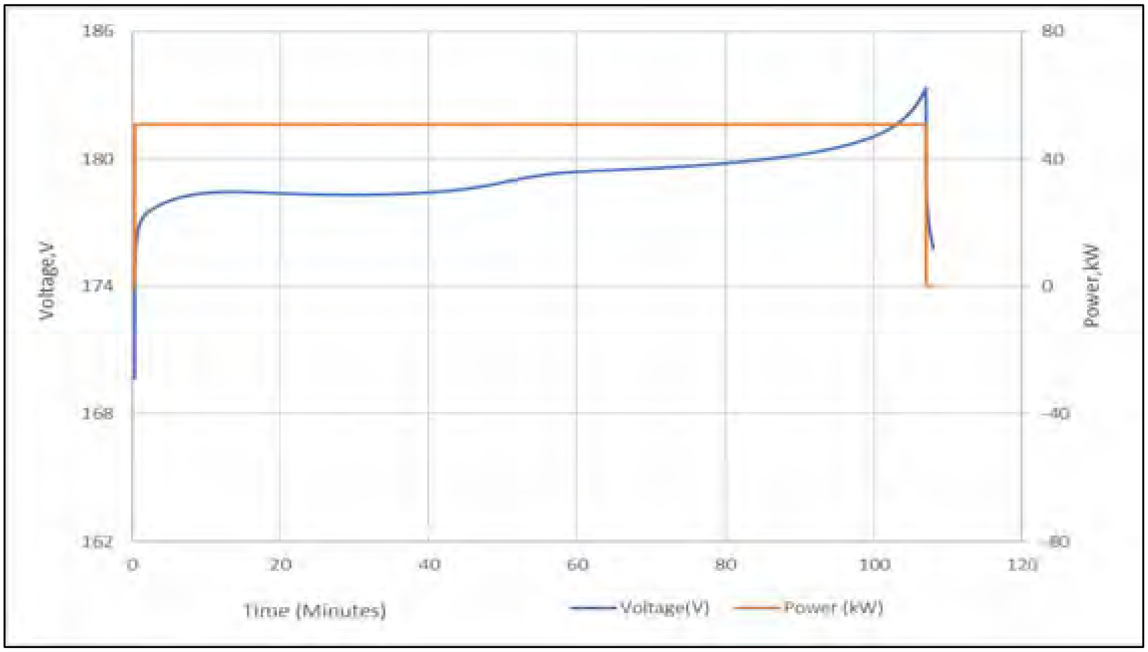


Figure 3: Initiating unit, module 3 charge to 100% SOC

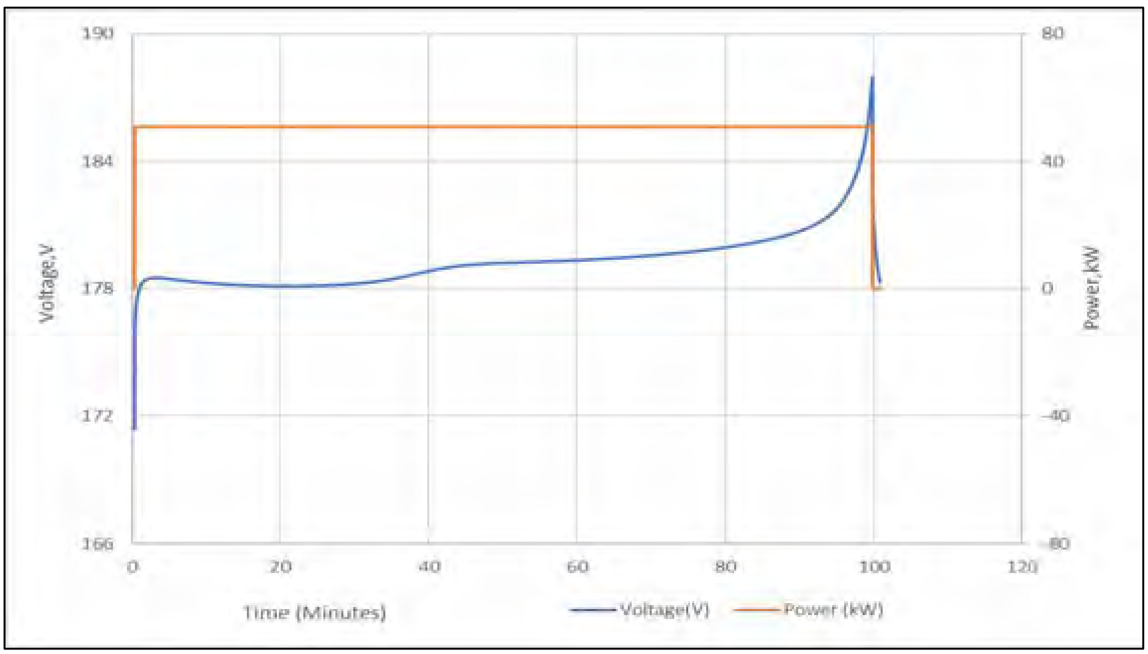


Figure 4: Initiating unit, module 4 charge to 100% SOC

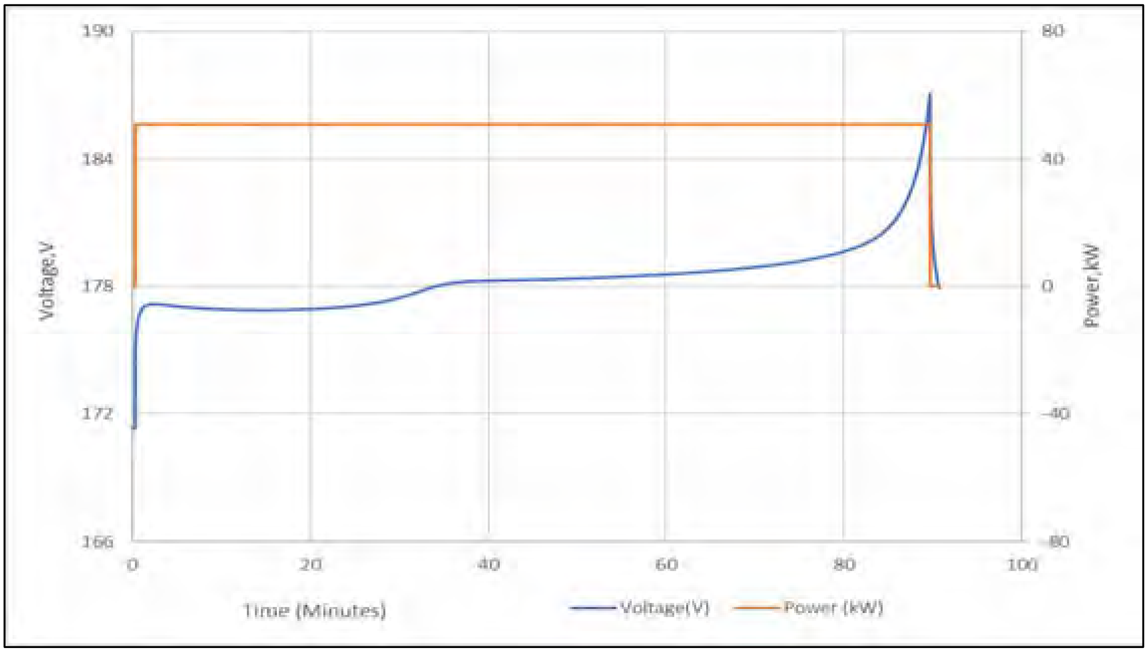


Figure 5: Initiating unit, module 5 charge to 100% SOC

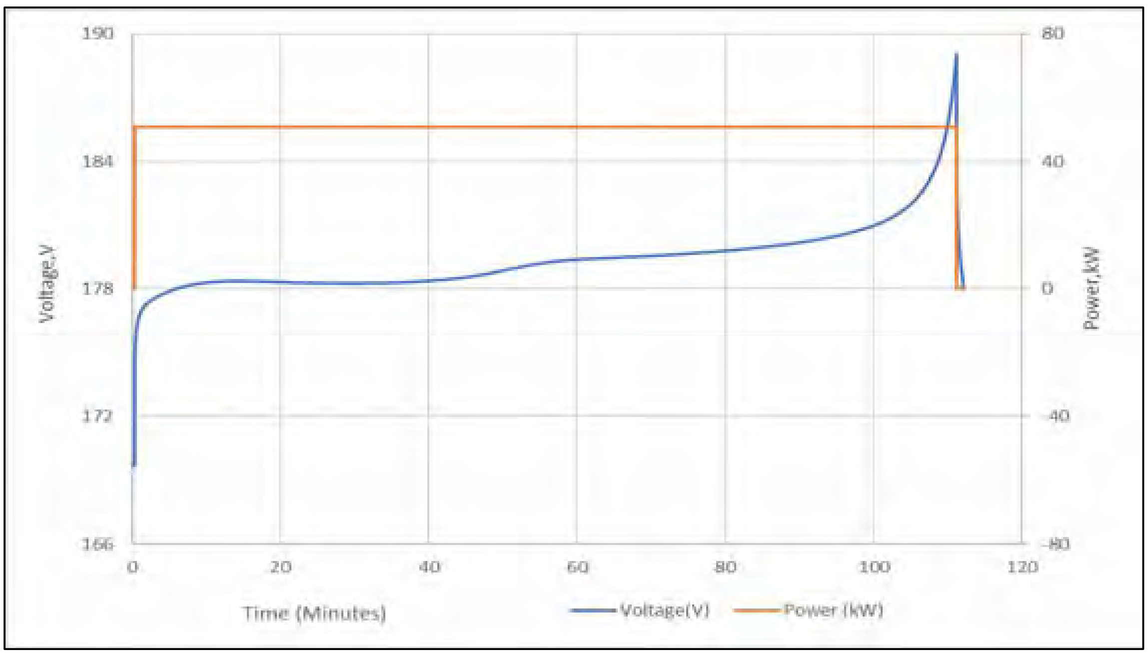


Figure 6: Initiating unit, module 6 charge to 100% SOC

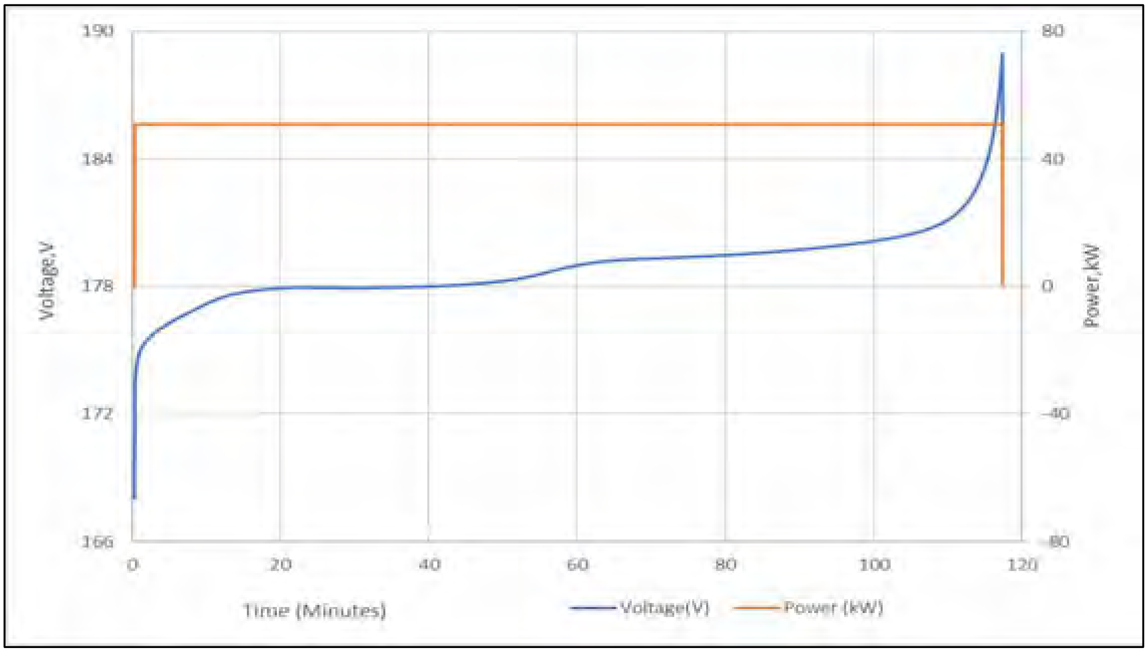


Figure 7: Initiating unit, module 7 charge to 100% SOC

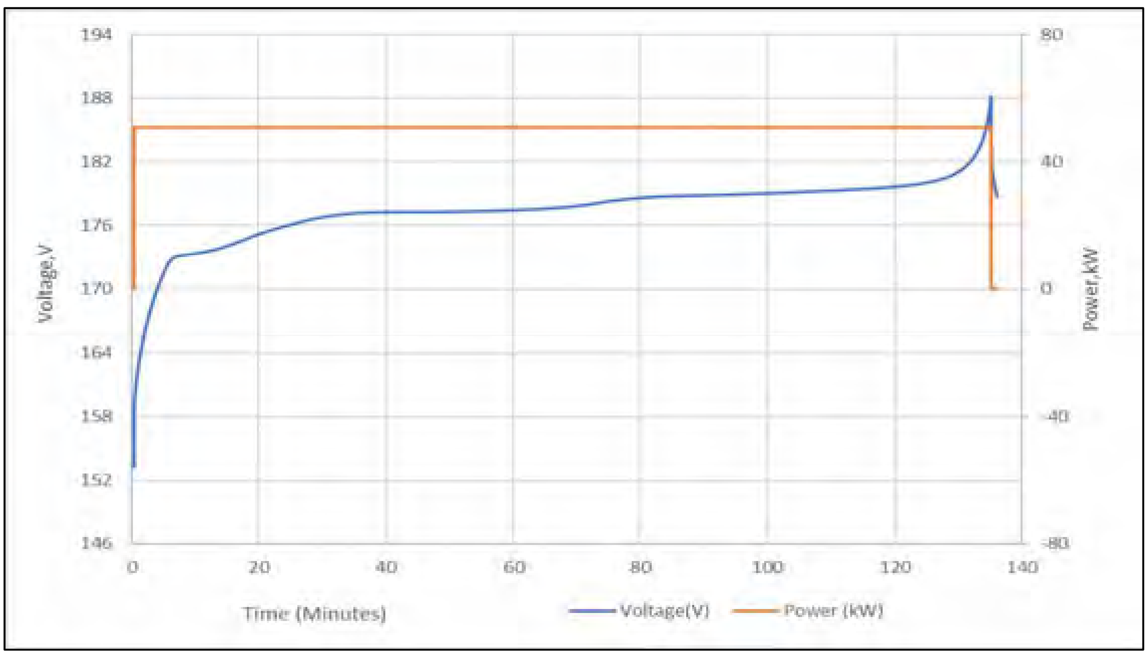


Figure 8: Initiating unit, module 8 charge to 100% SOC

Attachment B: BESS (including module and any integral fire detection and suppression systems) Construction Photos/Diagrams - (*Pages **31** through **31***)

BESS unit and module Construction Photos

Note: there is no fire detection and suppression systems in the Unit BESS.

Attachment C: BESS and Equipment Instrumentation and Test Installation Layout Photos/Diagrams - (*Pages **32** through **35***)

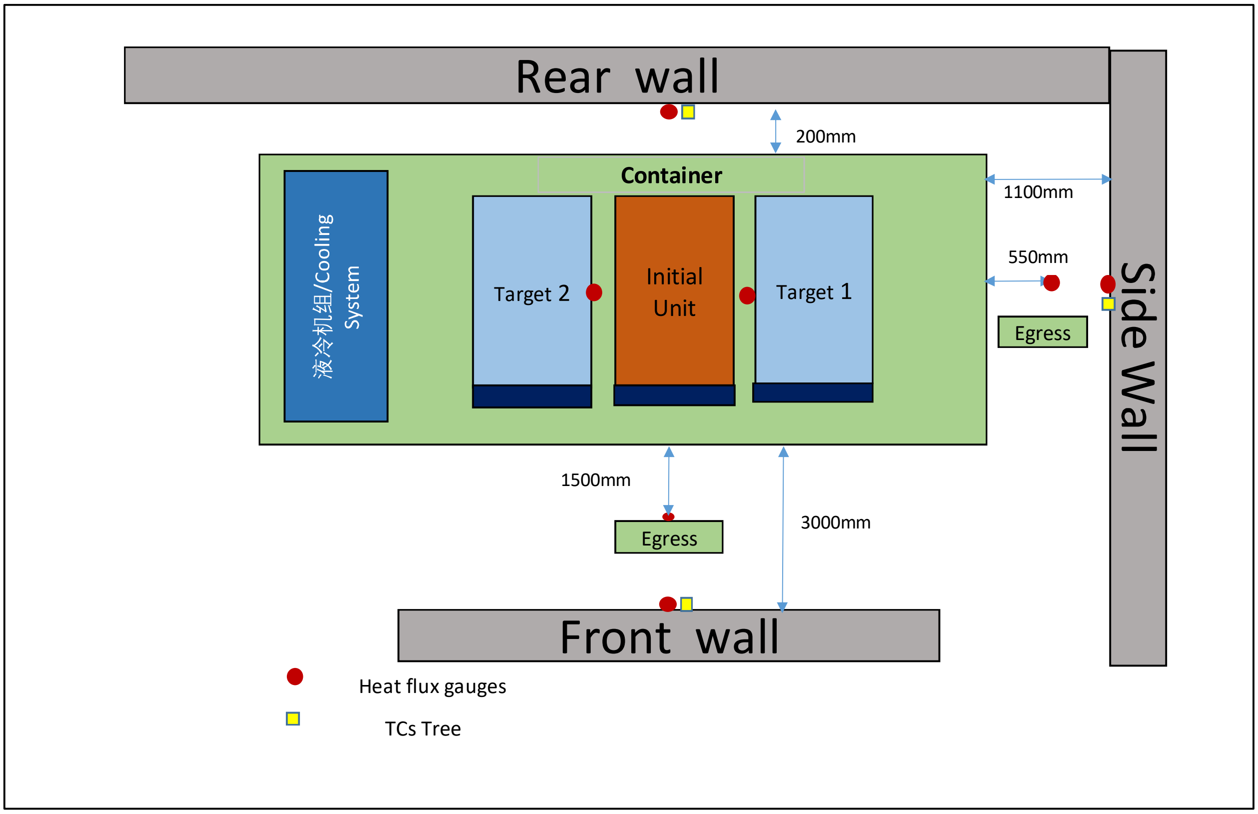
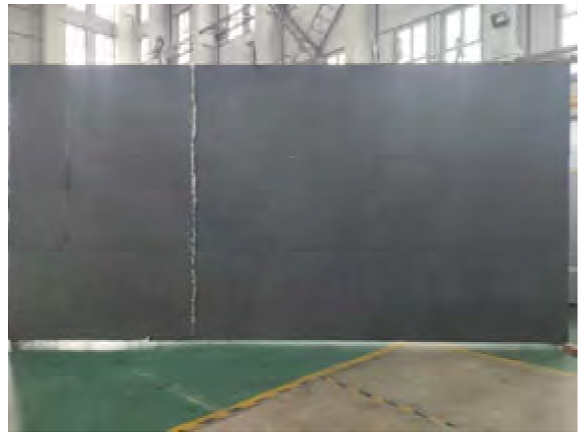


Figure 9: Test area layout

	
Front view - TC Location of front wall. From the bottom to up, TCs were FW-1 to FW-24	Side view - TC Location of side wall. From the bottom to up, TCs were SW-1 to SW-24
	
Rear view - TC Location of side wall. From the bottom to up, TCs were RW-1 to RW-24	

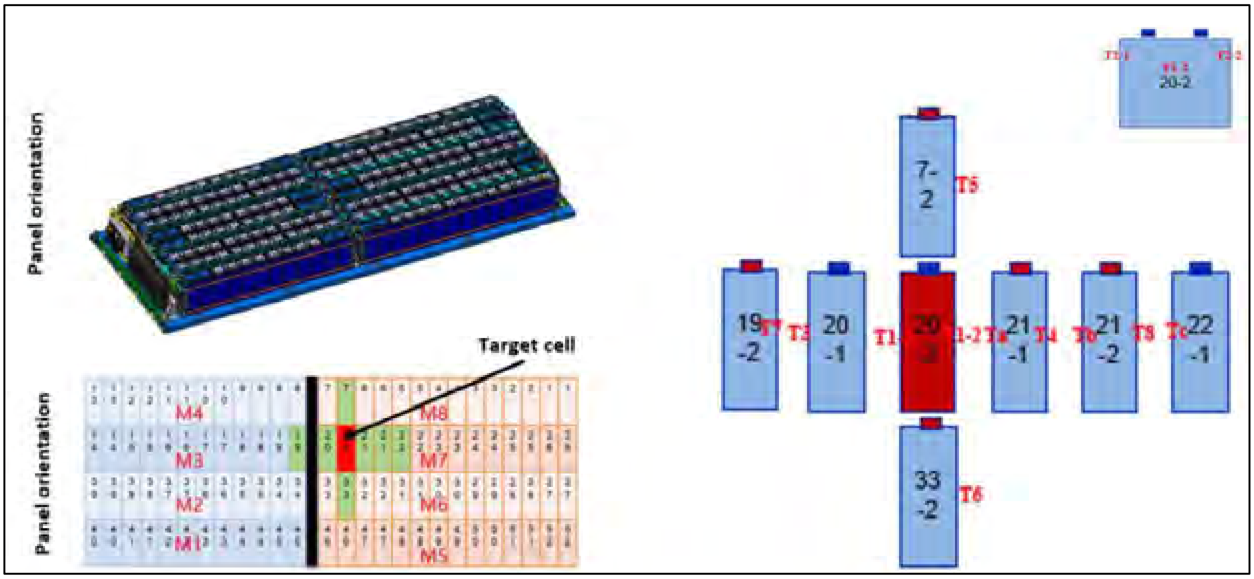


Figure 10: TC Location in the initiating module and above module. TCs were on the cells' large side body

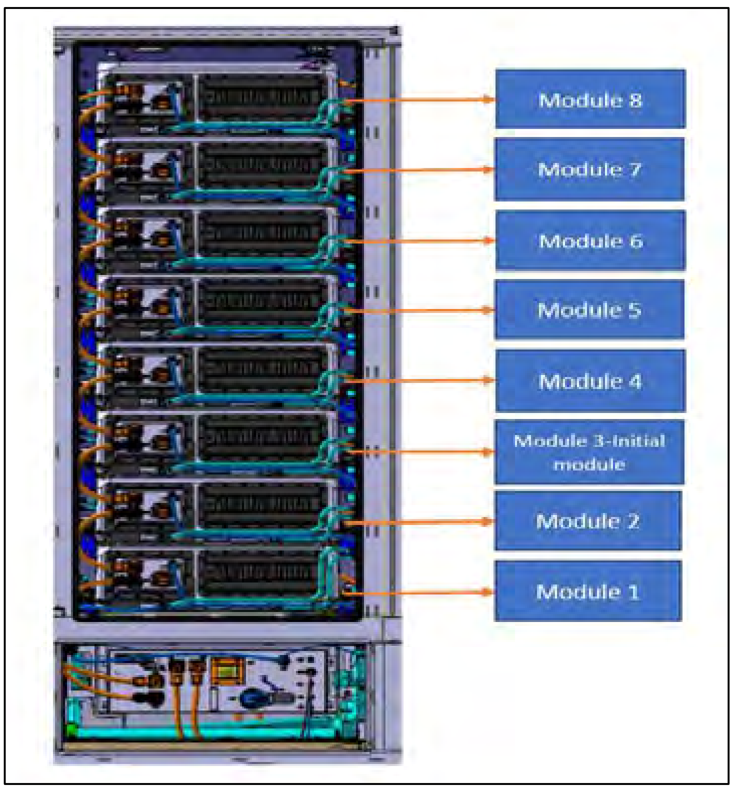


Figure 11: The initiating module 3 location in the initiating unit

Initiating unit	Target unit - 1	Target unit - 2

Figure 12: TC location in the initiating and target units, T16 series for target unit-1, T17 series for target unit-2

(Note: Except T15 affixed to the top frame of the initiating module, other T14 affixed to the middle height of the module frame.)

Attachment D: Temperature Profiles and Heat Flux Measurements During Testing (Initiating Cell and Module, Target Modules, Wall Surfaces, etc. - (*Pages **36** through **39***)

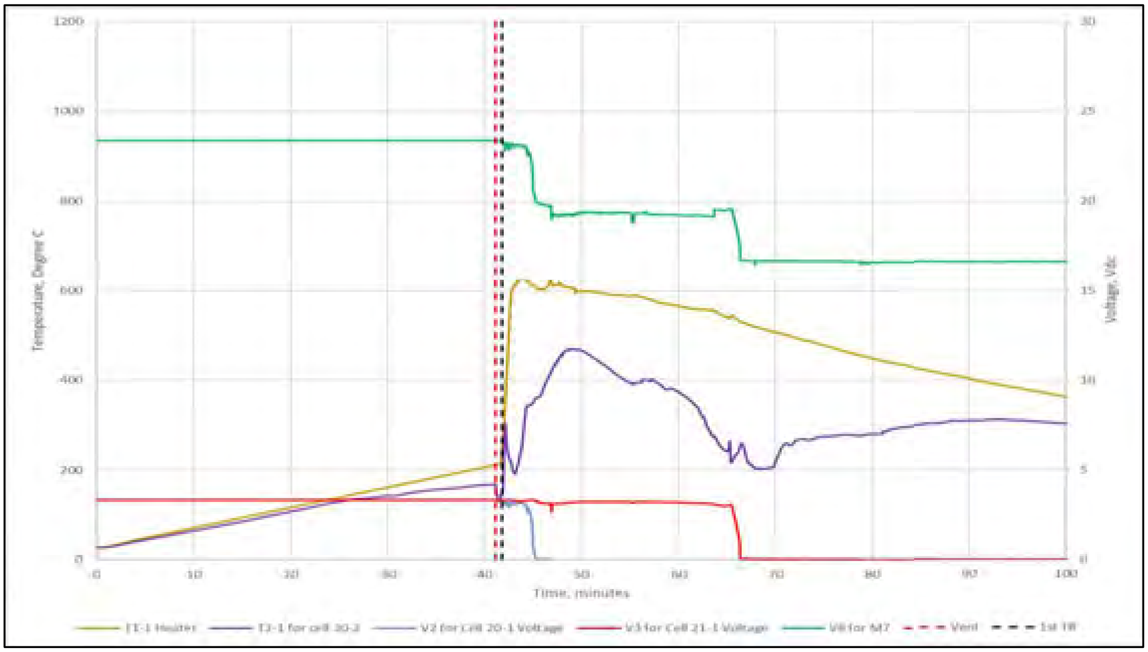


Figure 13: Initiating cells vent, Thermal runaway Initiating cell Temperature and Voltage Profiles During Testing

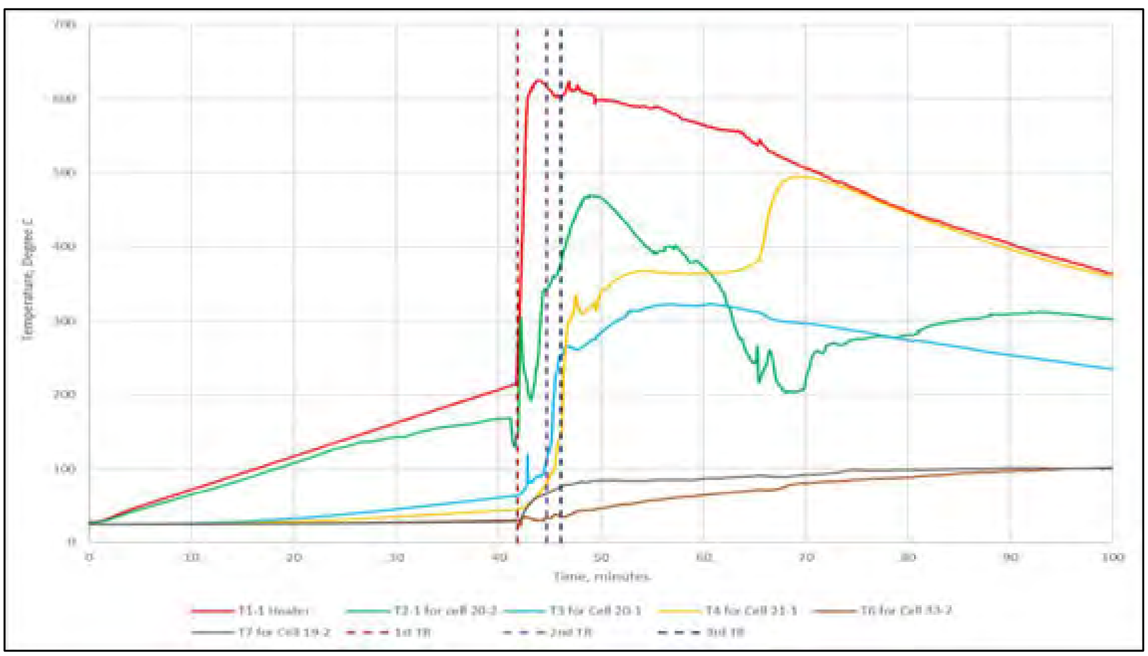


Figure 14: Initiating module temperature

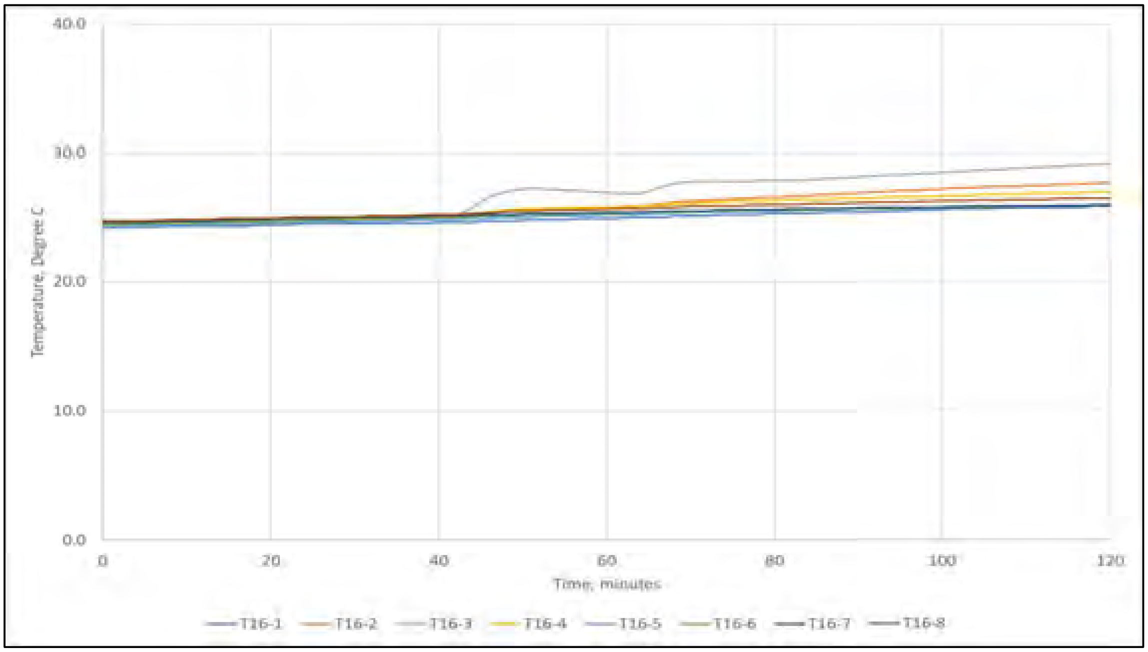


Figure 15: Target unit-1 temperature

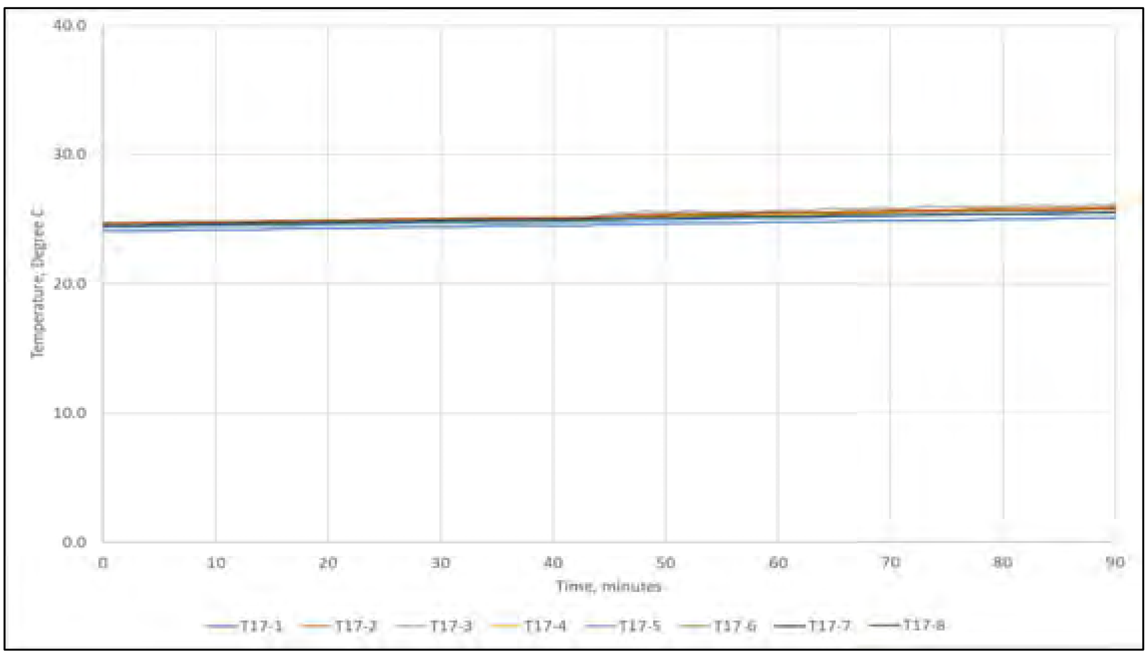


Figure 16: Target unit-2 temperature

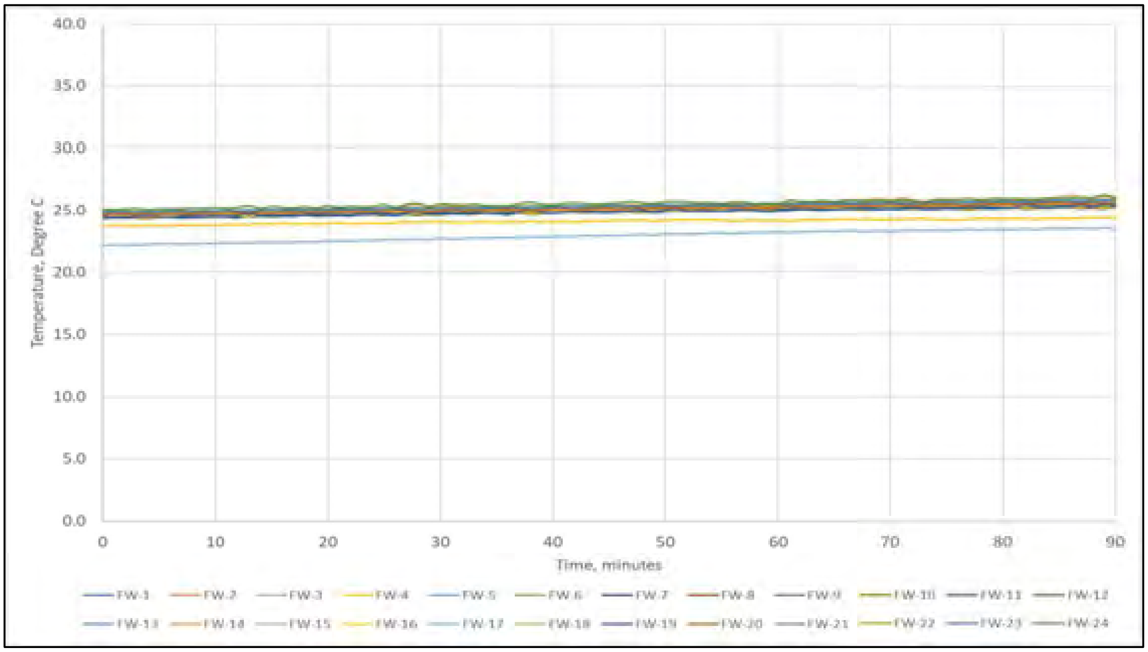


Figure 17: Front wall temperature

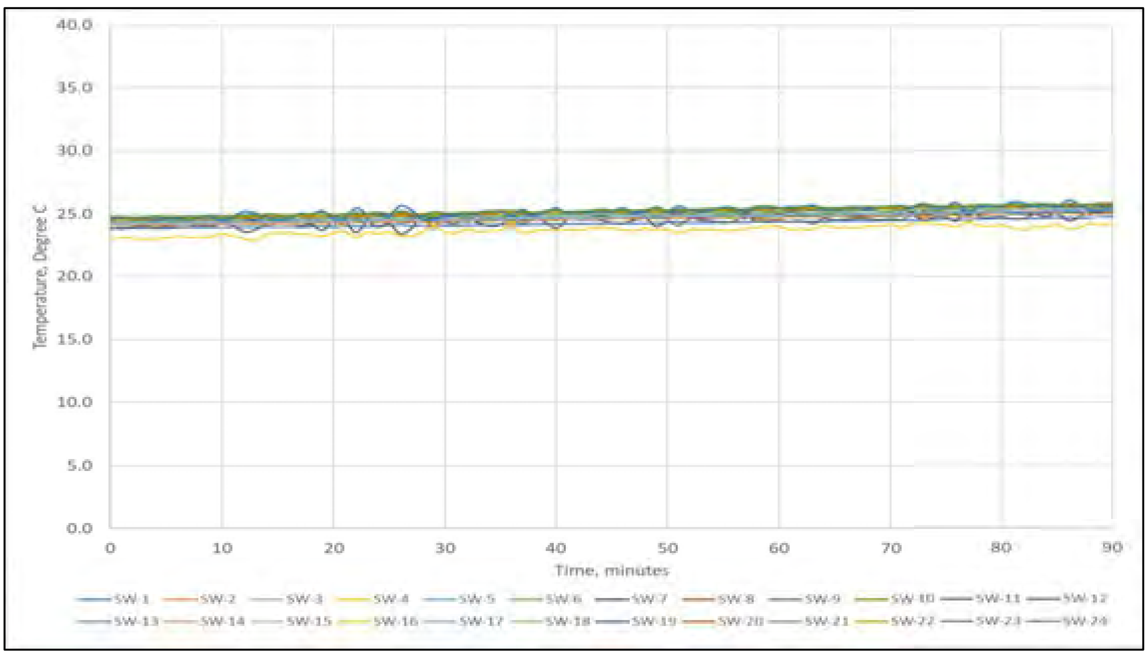


Figure 18: Side wall temperature

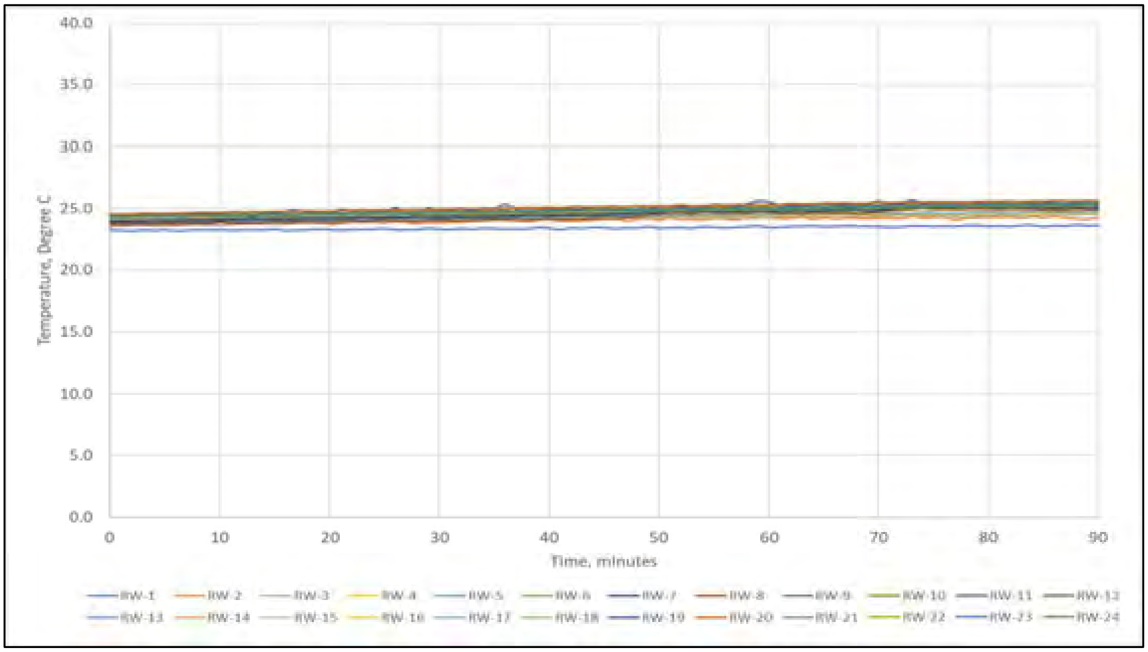


Figure 19: Rear wall temperature

Attachment E: BESS Unit Testing and Post Testing Photos - (*Pages **40** through **41***)

 (a) Start Heating [00:00:00]	 (b) Vent initiating cell 20-2 [00:41:08]
 (c) Initiating cell 20-2 Thermal runaway [00:41:48]	 (d) Cell 20-1 Thermal runaway [00:44:40]
 (e) Cell 21-1 Thermal runaway [00:46:03]	 (f) Thermal runaway of adjacent cell Approximately [01:05:26]

(g) Test Termination
[01:25:00]

Figure 20: BESS Unit Testing Photos

Figure 21: BESS Unit Photos after test

Attachment F: BESS Unit Gas Flow Rate and Heat Release and Smoke Release Profiles - (*Pages **42** through **44***)

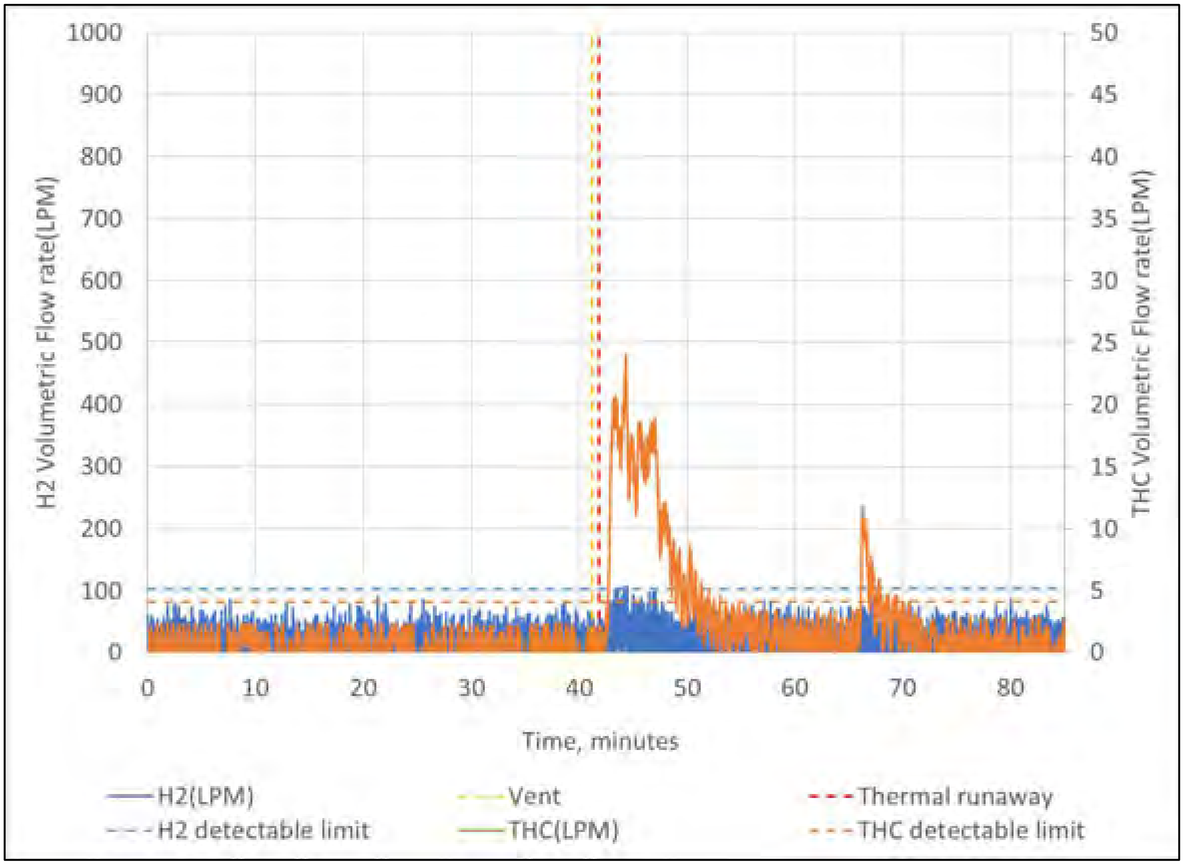


Figure 22: THC, H2 flow rates

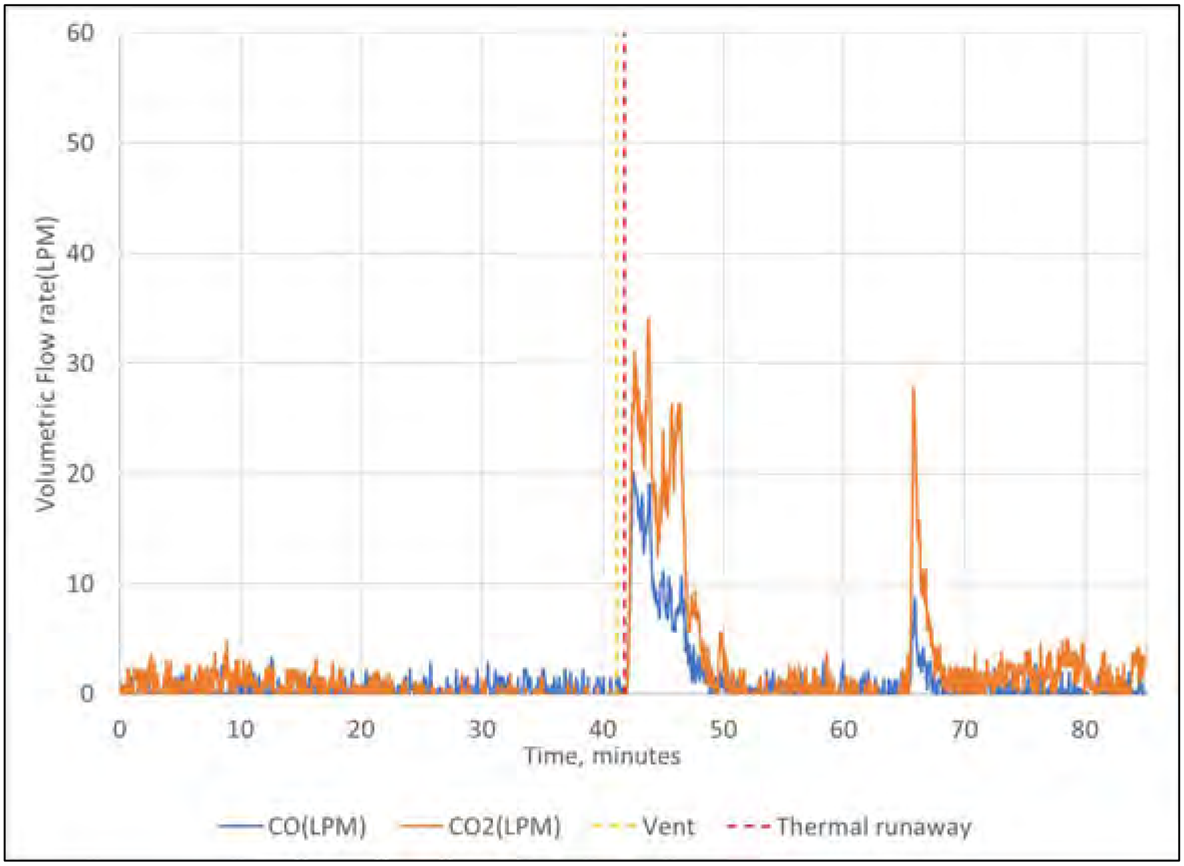


Figure 23: CO, CO2 flow rates

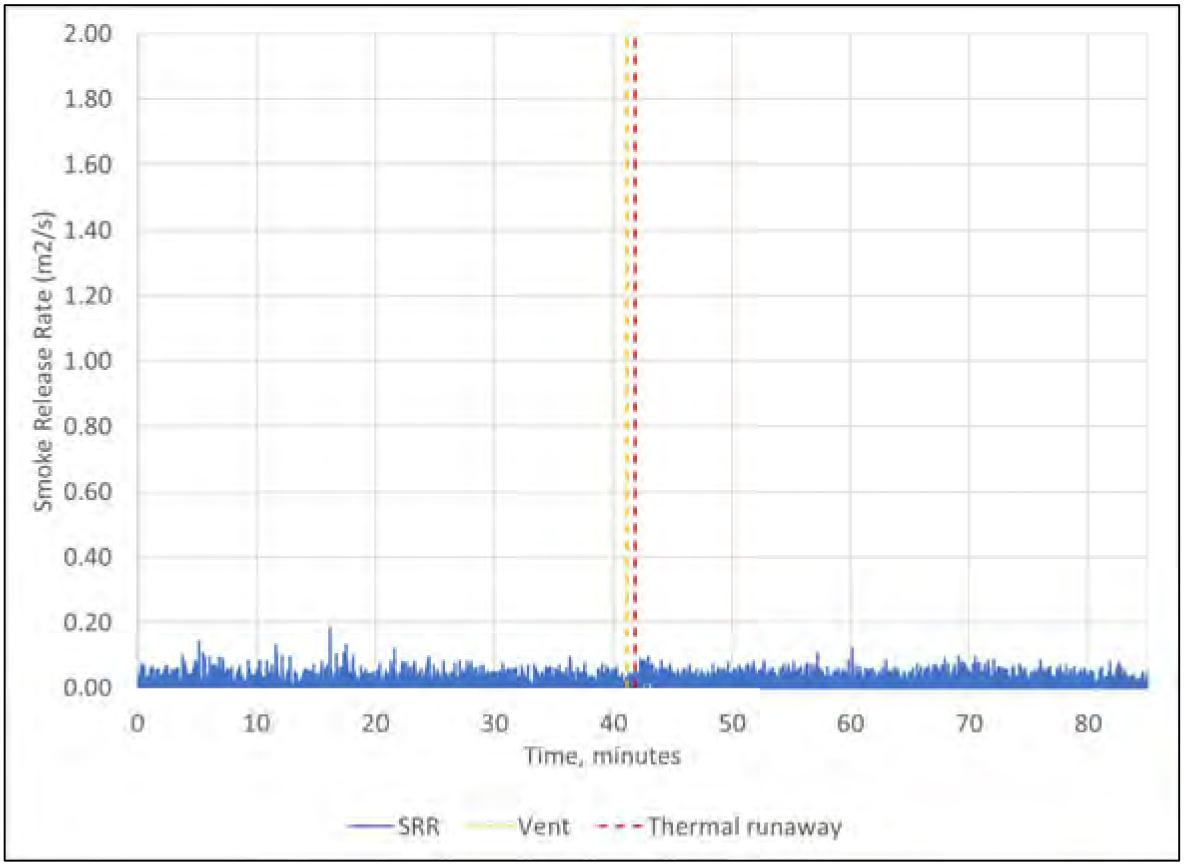


Figure 24: Smoke release rate

Date : 29.08.2024

Contemporary Amperex Technology
Co., Limited
No.2, Xingang Road,
Zhangwan Town, Jiaocheng District
352100 Ningde City Fujian
P.R. China
Attn: Sandy Lv

Re. : CU US + Canada Certificate

Type of Equipment	:	Rechargeable Lithium-ion Battery System
Model Designation	:	See Certificate
Certificate No.	:	CU 72302693 0003
File No.	:	CN23J9GR 003
Engineer/Contact	:	Aoxiao Xie
Standard(s)	:	ANSI/CAN/UL 9540:2023

Dear Ms. Sandy Lv,

Enclosed, please find the TUV Rheinland Certificate of Approval No. CU 72302693 0003 as requested.

The equipment will be held by the manufacturer for reference purposes.

Call the TUV hotline at 1-TUV-Rheinland (1-888-743-4652) to get answers for all your compliance needs.

If we can be of any further assistance to you, please do not hesitate to contact us.

Sincerely yours,
Certification Body

Weichun Li

Enclosure

TÜV Rheinland (China) Ltd.
莱茵检测认证服务（中国）有限公司

Room 301, 3F and Room 1203,12F, Building 4, No.15, Ronghua South Road, Beijing Economic-Technological Development Area Beijing (Yizhuang group in high-end industrial area of Beijing Pilot Free Trade Zone), P.R.China,100176

北京市北京经济技术开发区荣华南路15号院4号楼3层301室、12层1203室(北京自贸试验区高端产业片区亦庄组团)
邮编：100176

Tel: 86 10 8524 2222
Fax: 86 10 8524 2200
e-mail: info@bj.chn.tuv.com
Internet: http://www.chn.tuv.com

Certificate

TÜVRheinland

Certificate no. CU 72302693 03

License Holder:
Contemporary Amperex Technology
Co., Limited
No.2, Xingang Road,
Zhangwan Town, Jiaocheng District
Ningde City
352100 Fujian
P.R. China

Manufacturing Plant:
Contemporary Amperex Technology
Co., Limited
No.2, Xingang Road,
Zhangwan Town, Jiaocheng District
Ningde City
352100 Fujian
P.R. China

Test report no.: USA-AX CN23J9GR 003

Client Reference: Sandy lv

Tested to: ANSI/CAN/UL 9540:2023

Certified Product: Rechargeable Lithium-ion Battery System

License Fee - Units

as pages 0001-0002

Type Designation: C02306P05L01

Remarks : Update test standard
From : ANSI/CAN/UL 9540:2020
To : ANSI/CAN/UL 9540:2023

Appendix: 1, 1-55

Licensed Test mark:

TÜVRheinland C US

Date of Issue (day/mo/yr)
29/08/2024

APPENDIX 12-G: CATL NRC+ SAFETY DATA SHEET

SAFETY DATA SHEET

Issue No.: 2023-A Doc No.: 2023-A-190 Issue Date: 4/14/2023

1. Product & Company Identification

Product description	Container type energy storage system	**CATL model name**	C02P05306L01
Manufacturer	Contemporary Amperex Technology Co. , Limited	**Approximate weight**	36500Kg
Nominal capacity	306Ah	**Nominal voltage**	1081.6-1497.6V
Address	No.2 Xingang Road, Zhangwan Town, Jiaocheng District, Ningde City, Fujian Province, P.R.C., 352100		
Emergency telephone	+86-593-2583668		

2. Hazardous Identification

Lithium ion batteries described in this SDS are hermetically sealed and designed to withstand temperatures and pressures encountered during normal use. Under normal conditions of use, there is no physical danger of ignition, explosion or chemical danger of hazardous materials leakage. The materials contained in this battery may only represent a hazard if the integrity of the battery is compromised or if the battery is mechanically, thermally or electrically abused.

· **Hazard pictograms**

N/A.

· **Hazard statements**

N/A.

· **Precautionary statements**

N/A.

· **Other hazards**

Human health hazard: Electrolyte of the battery may irritate skin and eyes. In the event of a battery rupture, electrolyte fumes/gases can cause serious damage to the eye and cause sensitization and irritation to the respiratory tract.

3. Composition /Information on Ingredients

3.1 Composition of pack

Material or ingredient	%/wt.
Container, steel support and control system（Note: Non-dangerous chemical ）	35-45
Batteries（the composition of the battery reference to the following table 3.2.）	55-65

3.2 Composition of battery

Material or ingredient	CAS No./EC No.	Hazard pictograms & statements	%/wt.
Graphite	CAS# 7782-42-5 EC# 231-955-3	Not established	7-25
Lithium iron Phosphate	CAS# 15365-14-7 EC# 476-700-9	Not established	15-40
Polyvinylidene Fluoride	CAS# 24937-79-9 EC# 607-458-6	Not established	0-5
Acetylene black (Carbon black)	CAS# 1333-86-4 EC# 215-609-9	Not established	0-2
Copper	CAS# 7440-50-8 EC# 231-159-6	Not established	10-12
Aluminum	CAS# 7429-90-5 EC# 231-072-3	Not established	3-5
Carboxymethylcellulose Sodium	CAS# 9004-32-4 EC# 618-378-6	Not established	0-5
Electrolyte			
Lithium Hexafluorophosphate	CAS# 21324-40-3 EC# 244-334-7	Acute Tox. 3, H311 Skin Corr. 1A, H314 Acute Tox. 4, H302 STOT RE 1， H372	0-5
Dimethyl Carbonate	CAS# 616-38-6 EC# 210-478-4	Inflammable， H225	0-15
Ethylene Carbonate	CAS# 96-49-1 EC# 202-510-0	Eye Irrit. 2, H319 Acute Tox. 4,H312	0-15
Diethyl Carbonate	CAS# 105-58-8 EC#203-311-1	Flam. Liq. 3, H226	0-15
Ethyl Methyl Carbonate	CAS# 623-53-0 EC# 613-014-2	Inflammable， H225 Skin Irrit .2, H315	0-15

4. First Aid Measures

Under normal conditions of use, the battery is hermetically sealed.

Ingestion: Drink plenty of water and induce vomiting. Seek medical attention immediately.

Inhalation: Leave area immediately and seek medical attention.

Skin contact: Remove contaminated clothing. Wash the area with soap and plenty of water immediately and for at least 15minutes. Seek medical attention immediately.

Eye contact: Flush with plenty of water for at least 15 minutes (eyelids held open). Seek medical attention immediately.

5. Fire Fighting Measures

5.1 Hazards analysis (electric shock, fire, explosion, environment pollution)

The voltage of the cell or module is less than 50V (safe voltage), there is no hazard of electric shock. The voltage of the pack is much more than 50 V (safe voltage), and there is a hazard of electric shock.

During transportation, the pack may be dropped, crushed, punctured, metal short-circuited, water immersed, etc., which may cause electric shock and fire.

When the electrolyte of the battery leaks, there is a danger of explosion. In addition, improper disposal will also cause environmental pollution.

5.2 Fire fighting measures

Extinguishing media: Plenty of water, carbon dioxide gas, chemical powder, foam fire extinguishing.

Fire fighting procedures: Use a positive pressure self-contained breathing apparatus if batteries are involved in fire. Full protective clothing is necessary. During water application, caution is advised as burning pieces of flammable particles may be ejected from the fire.

Hazardous combustion products: Fire, excessive heat and/or over voltage conditions may produce hazardous decomposition products (i.e. electrolyte fumes and hazardous organic vapors). Vapors may be heavier than air and may travel the ground or be moved by ventilation to an ignition source.

6. Accidental Release Measures

If the internal material of the battery leaks, the relevant emergency measures for leaks are as follows：

Emergency procedures： Rapidly evacuate people from the contaminated area to a safe area and isolate and strictly limit access.Cut off the source of ignition and the source of leakage as far as possible.

Personal protective measures, protective equipment: It is recommended that emergency personnel wear self-contained positive pressure respirators, protective glasses, firefighting suits and do not come into direct contact with the spill.

Environmental protection measures: May be harmful to aquatic life, prevent entry into restricted spaces such as sewers and flood drains.

Electrolyte clean-up method：

Small spill: Absorb spill residue with sand, vermiculite or other inert materials, collect and transport to an open area for burial, evaporation, or burning.

Large spill: Construct an embankment or dig a pit to receive it. Cover with foam to reduce vapour hazard. Transfer to a tanker or special collector with an explosion-proof pump for recycling or transport to a waste disposal site.

7. Handling & Storage

Handling: Do not open or disassemble the batteries. Do not exposure the batteries to fire or store near open flame. Do not mix batteries of varying size or chemicals. Do not connect the positive and negative battery terminals with conductive material or throw into fire. Do not heat or solder the batteries. Do not expose batteries to direct sun light for a prolonged time.

Storage: Batteries should be stored in a well ventilated, cool area with sufficient clearance between batteries and walls. Store the batteries in a cool (below 30℃) area and away from moisture. Keep the batteries away from sources of heat, open flames, food and drink. Do not store the batteries above 55℃ or below -30℃. Storing at elevated temperatures may reduce the life of batteries. Keep batteries away from strong oxidizers and acids. Elevated temperature storage such as 100℃ may result in battery venting flammable liquid and gases.

8. Exposure Control & Personal Protection

No engineering controls are required for normal operation. In case of electrolyte of the battery leakage, increase the ventilation and use self-contained full-face respiratory equipment.

Person protective equipment: Not required during normal use of the battery, in the event of a raptured battery or fire:

Respiratory protection: Self-contained full-face respiratory equipment.

Hand protection: Chemical protective gloves.

Eye protection: Self-contained full-face respiratory equipment.

Skin and body protection: Chemical-protective clothing.

9. Physical & Chemical Properties

State	Solid
Odor	N/A
Vapor pressure	N/A
Vapor density	N/A
Boiling point	N/A
Solubility in water	Insoluble
Specific gravity	N/A
Density	N/A

10. Stability & Reactivity

Stability: Stable under normal conditions.

Reactivity: When a battery is exposed to high temperatures, crushes, deformation, and external short circuit may result in venting harmful gases and volatile organics. In the event of rupture, hydrogen fluoride gas is produced in reaction with water.

11. Toxicological Information

There is no available data for the product itself. The information for the internal cell materials are as follows:

Irritancy: The electrolytes contained in the battery can irritate eyes with any contact. Prolonged contact with skin or mucus membrane may cause irritation.

Sensitization: The nervous system of respiratory organs may be stimulated sensitively.

Carcinogenicity: No information is available at this time.

Reproductive toxicity: No information is available at this time.

Teratogenicity: No information is available at this time.

Mutagenicity: No information is available at this time.

12. Ecological Information

When properly used and disposed, the battery does not present environmental hazard. Do not let internal components enters marine environment. Avoid releasing to water ways, wastewater or ground water.

13. Disposal Considerations

Batteries should be discharged fully prior to disposal. The battery terminals should be capped to prevent a short circuit. Disposal the batteries in accordance with applicable local laws. Lithium-ion batteries may be subjected to federal, state or local regulations.

14. Transport Information

Land transport: International Carriage of Dangerous Goods by Road(ADR 2023), Regulations Concerning the International Carriage of Dangerous Goods by Rail（RID 2021）.

Sea transport: International Maritime Dangerous Goods Code (IMDG CODE 40-20).

Air transport: The International Civil Aviation Organization-Technical Instructions on the Safe Transport of Dangerous Goods by Air (ICAO-TI 2022), International Air Transport Association-Dangerous Goods Regulations (IATA-DGA 64th).

Inland waterway transport: Regulations on the Supervision and Management of the Safety of Dangerous Goods Carried on Board Ships，European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways (ADN).

Model of transport	Land transport (ADR/RID)	Sea transport (IMDG)	Air transport (ICAO/IATA)
UN No.	3536	3536	3536
Proper shipping name	Container type energy storage system	Container type energy storage system	Container type energy storage system
Transport hazard class	9	9	9
Packing group	II		
Packing terms	/	P903	PI 965-967
Label	 		

15. Regulatory Information

15.1 U.S Federal Regulation

Occupational Safety and Health Act（OSHA）： Employers/businesses are required to ensure that lithium batteries, chargers and lithium ion drive related equipment used in the workplace are tested to appropriate test standards (e.g. UL 2054) and certified by a testing body with NRTL (Nationally Recognized Testing Laboratory) status. The certification is issued by a NRTL (Nationally Recognised Testing Laboratory) qualified testing body.

Toxic Substances Control Act（TSCA）: This product is not listed.

Clean Air Act（CAA）: This product is not listed.

Clean Water Act（CCW）: This product is not listed.

15.2 Canada Regulation

Workplace Hazardous Material Information System,（WHMIS）: Not controlled under WHMIS.

Hazardous Product Act（HPA）: This product is not listed.

Canadian Environmental Protection Act（CEPA）: This product is not listed.

15.3 German Regulation

《Verordnung über Anlagen zum Umgang mit wassergefährdenden Stoffen》（AwSV）: Hazard class of electrolyte to water of this product is WGK 1（Slight hazard to water）.

15.4 EU-Regulation

Contains no substances on the REACH candidate list.

Contains no REACH Annex XVII/XIV substances.

15.5 International Regulation

Australia inventory（AICS）： This product is not listed.

China inventory（IECSC）： This product is not listed.

Japan inventory（ENCS）： This product is not listed.

Korea inventory（ISHL）： This product is not listed.

New Zealand Inventory of Chemicals（NZLoC）： This product is not listed.

16. Other Information

The information contained herein is furnished without warranty of any kind. Users should consider this data only as a supplement to other information gathered by them and must make independent determinations of the suitability and completeness of information from all sources to assure proper use and disposal of these materials and the safety and health of employees an oyees and customers.

APPENDIX 12-H: UL 1973 CERTIFICATE FOR THE BATTERY MANAGEMENT SYSTEM

APPENDIX 12-H: UL 1973 CERTIFICATE FOR THE BATTERY MANAGEMENT SYSTEM

Submitted Separately due to File Size

Prüfbericht-Nr.: *Test report no.:*	**CN23QV2N 001**	**Auftrags-Nr.:** *Order no.:*	244501240	Seite 1 von 125 *Page 1 of 125*
Kunden-Referenz-Nr.: *Client reference no.:*	2057436	**Auftragsdatum:** *Order date:*	2023-03-06	

Auftraggeber: *Client:*	**Contemporary Amperex Technology Co., Limited.** No. 2, Xingang Road, Zhangwan Town, Jiaocheng District,Ningde City, 352100 Fujian, P.R. China
Prüfgegenstand: *Test item:*	Rechargeable Lithium-ion Battery System
Bezeichnung / Typ-Nr.: *Identification / Type no.:*	C02306P05L01
Auftrags-Inhalt: *Order content:*	TUV Bauart approval
Prüfgrundlage: *Test specification:*	ANSI/CAN/UL 1973: 2022
Wareneingangsdatum: *Date of sample receipt:*	2023-05-05
Prüfmuster-Nr.: *Test sample no:*	Engineering sample
Prüfzeitraum: *Testing period:*	2023-06-05 to 2023-08-12
Ort der Prüfung: *Place of testing:*	See page 4
Prüflaboratorium: *Testing laboratory:*	TÜV Rheinland (Shanghai) Co., Ltd.
Prüfergebnis*: *Test result*:*	Pass

geprüft von: tested by:	Wilson Zhou	**genehmigt von:** *authorized by:*	Scola Chen
Datum: *Date:* 2023-10-16		**Ausstellungsdatum:** *Issue date:* 2023-10-16	
Stellung / Position:	Project Engineer	**Stellung** / Position:	Reviewer

Sonstiges /
Other: See the following pages for General product information and comment for details.

Zustand des Prüfgegenstandes bei Anlieferung:
Condition of the test item at delivery:
Prüfmuster vollständig und unbeschädigt
Test item complete and undamaged

* Legende:	P(ass) = entspricht o.g. Prüfgrundlage(n)	F(ail) = entspricht nicht o.g. Prüfgrundlage(n)	N/A = nicht anwendbar	N/T = nicht getestet
** Legend:*	*P(ass) = passed a.m. test specification(s)*	*F(ail) = failed a.m. test specification(s)*	*N/A = not applicable*	*N/T = not tested*

Anmerkungen
Remarks

1	Alle eingesetzten Prüfmittel waren zum angegebenen Prüfzeitraum gemäß eines festgelegten Kalibrierungsprogramms unseres Prüfhauses kalibriert. Sie entsprechen den in den Prüfprogrammen hinterlegten Anforderungen. Die Rückverfolgbarkeit der eingesetzten Prüfmittel ist durch die Einhaltung der Regelungen unseres Managementsystems gegeben. Detaillierte Informationen bezüglich Prüfkonditionen, Prüfequipment und Messunsicherheiten sind im Prüflabor vorhanden und können auf Wunsch bereitgestellt werden. *The equipment used during the specified testing period was calibrated according to our test laboratory calibration program. The equipment fulfils the requirements included in the relevant standards. The traceability of the test equipment used is ensured by compliance with the regulations of our management system.* *Detailed information regarding test conditions, equipment and measurement uncertainty is available in the test laboratory and could be provided on request.*
2	Wie vertraglich vereinbart, wurde dieses Dokument nur digital unterzeichnet. Der TÜV Rheinland hat nicht überprüft, welche rechtlichen oder sonstigen diesbezüglichen Anforderungen für dieses Dokument gelten. Diese Überprüfung liegt in der Verantwortung des Benutzers dieses Dokuments. Auf Verlangen des Kunden kann der TÜV Rheinland die Gültigkeit der digitalen Signatur durch ein gesondertes Dokument bestätigen. Diese Anfrage ist an unseren Vertrieb zu richten. Eine Umweltgebühr für einen solchen zusätzlichen Service wird erhoben. Informationen zur Verifizierung der Authentizität unserer Dokumente erhalten Sie über folgenden Link: Einführung in digitale Signaturen *As contractually agreed, this document has been signed digitally only. TUV Rheinland has not verified and unable to verify which legal or other pertaining requirements are applicable for this document. Such verification is within the responsibility of the user of this document. Upon request by its client, TUV Rheinland can confirm the validity of the digital signature by a separate document. Such request shall be addressed to our Sales department. An environmental fee for such additional service will be charged. For information on verifying the authenticity of our documents, please visit the following link: Introduction to Digital Signature*
3	Prüfklausel mit der Note * wurden an qualifizierte Unterauftragnehmer vergeben und sind unter der jeweiligen Prüfklausel des Berichts beschrieben. Abweichungen von Prüfspezifikation(en) oder Kundenanforderungen sind in der jeweiligen Prüfklausel im Bericht aufgeführt. *Test clauses with remark of * are subcontracted to qualified subcontractors and descripted under the respective test clause in the report.* *Deviations of testing specification(s) or customer requirements are listed in specific test clause in the report.*
4	Die Entscheidungsregel für Konformitätserklärungen basierend auf numerischen Messergebnisen in diesem Prüfbericht basiert auf der "Null-Grenzwert-Regel" und der "Einfachen Akzeptanz" gemäß ILAC G8:2019 und IEC Guide 115:2021, es sei denn, in der auf Seite 1 dieses Berichts genannten angewandten Norm ist etwas anderes festgelegt oder vom Kunden gewünscht. Dies bedeutet, dass die Messunsicherheit nicht berücksichtigt wird und daher auch nicht im Prüfbericht angegeben wird. Zu weiteren Informationen bezueglich des Risikos durch diese Entscheidungsregel siehe ILAC G8:2019. *The decision rule for statements of conformity, based on numerical measurement results, in this test report is based on the "Zero Guard Band Rule" and "Simple Acceptance" in accordance with ILAC G8:2019 and IEC Guide 115:2021, unless otherwise specified in the applied standard mentioned on Page 1 of this report or requested by the customer. This means that measurement uncertainty is not taken in account and hence also not declared in the test report. For additional information to the resulting risk based of this decision rule please refer to ILAC G8:2019.*

TEST REPORT

ANSI/CAN/UL 1973

Batteries for Use in Stationary and

Motive Auxiliary Power Applications

Report reference No.......................:	CN23QV2N 001
Date of issue ....:	see cover page
Total number of pages...................:	see cover page
Testing Laboratory.........................:	TÜV Rheinland (Shanghai) Co., Ltd.
Address...:	No. 177, Lane 777, West Guangzhong Road, Jing'an District, Shanghai 200072, P. R. China
Manufacture's name ....:	**Contemporary Amperex Technology Co., Limited.**
Address...:	No. 2, Xingang Road, Zhangwan Town, Jiaocheng District,Ningde City, 352100 Fujian, P.R. China
Test specification:	
Standard..:	ANSI/CAN/UL 1973: 2022
Test procedure ....:	cTUVus mark approval
Non-standard test method…………..:	N/A
Test Report Form No. ....:	UL1973D
Test Report Form(s) Originator ....:	TÜV Rheinland (Shanghai)
Master TRF......................................:	Dated 2022-03
Test item description.....................:	Rechargeable Lithium-ion Battery system
Trade Mark......................................:	CATL
Model/Type reference ....:	C02306P05L01
Ratings ....:	See model list on page 6 for details.

List of Attachments (including a total number of pages in each attachment):

Attachment 1: Photo documentation (13 pages);

Attachment 2: Critical Components List (18 pages)

Summary of testing:

Test items:

	Construction review
cl. 15	Overcharge Test
cl. 16	High Rate Charge
cl. 17	Short Circuit Test
cl. 18	Overload Under Discharge
cl. 19	Overdischarge Protection Test
cl. 20	Temperature and Operating Limits C heck Test
cl. 21	Imbalanced Charging Test
cl. 22	Dielectric Voltage Withstand Test
cl. 23	Continuity Test
cl. 24	Failure of Cooling/Thermal Stability S ystem
cl. 25	Working Voltage Measurements
cl. 26.2	Input
cl. 26.3	Leakage current
cl. 27	Electromagnetic Immunity Tests
cl. 31	Static Force Test
cl. 32	Impact Test
cl. 33	Drop Impact Test
cl. 34	Wall Mount Fixture/Support Structure/ Handle Test
cl. 40	Salt fog test
cl. 42	Single Cell Failure Design Tolerance

The DUT was complied with the requirements of ANSI/CAN/UL 1973:2022.

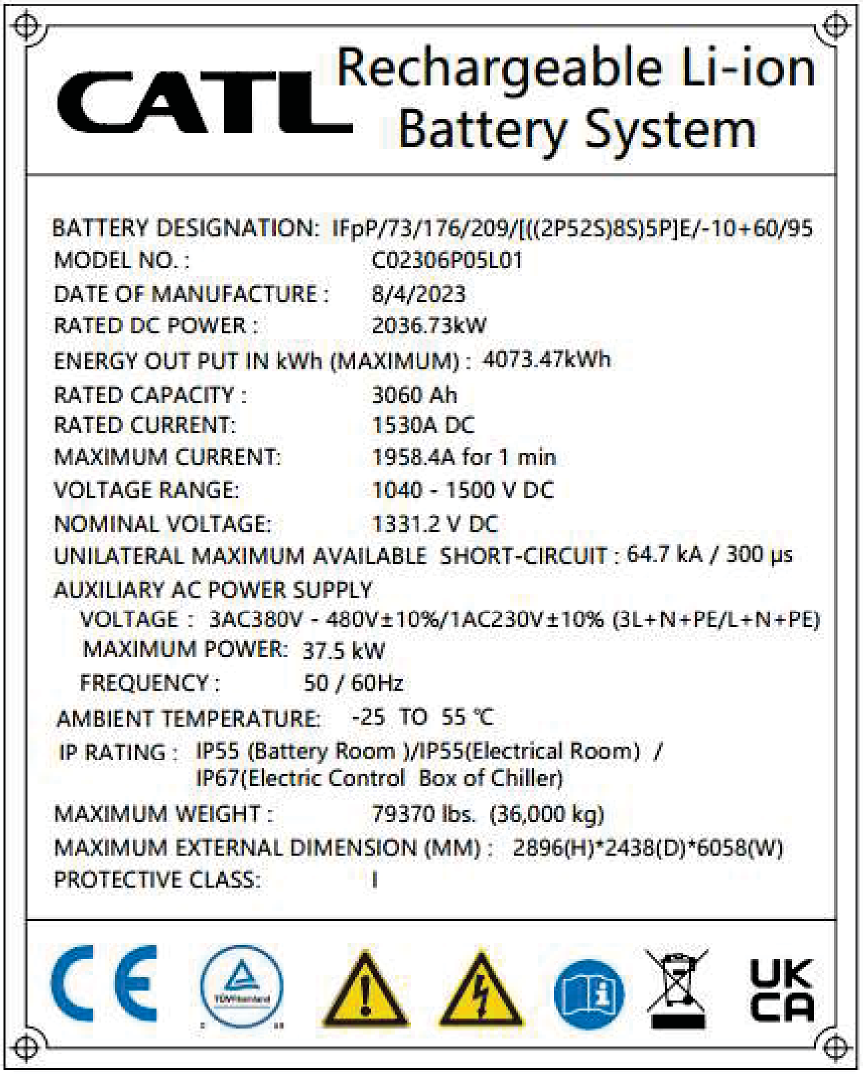
Test Location:

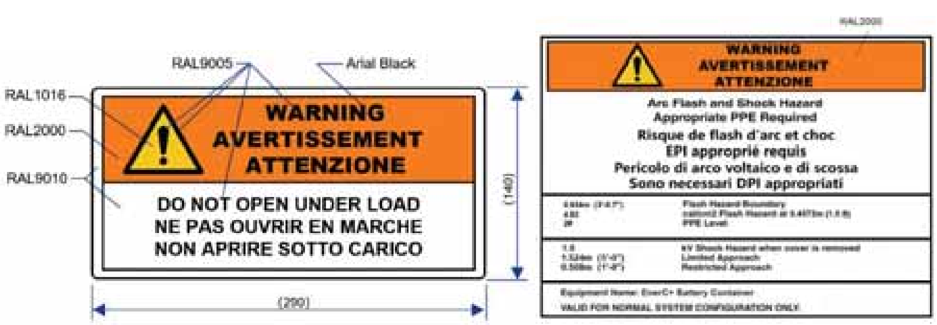
Test location :

Contemporary Amperex Technology Co., Limited.

No. 2, Xingang Road, Zhangwan Town, Jiaocheng District,Ningde City, 352100 Fujian, P.R. China

Copy of marking plate





Test item particulars:	
Information about the product needed to establish a correct test program, such as product mobility, type of power connections and similar.	(Test item particulars are selected by the TRF Originator base on the requirements in the standard)
Equipment application ....:	Stationary
Connection to the mains ....:	Permanent connection, not directly connected to the mains
Mains supply tolerance (%) or absolute mains supply values ....:	N/A
Cell/Battery Type..:	Lithium-ion Cell Used
Battery Voltage Range...:	See model list
Installation/Use environment ....:	outdoors
Overvoltage Category..:	OVC II
Pollution Degree...:	PD3(outside) PD2(inside)
IP protection class ....:	IP55(Battery room); IP55(Electrical room); IP67(Chiller control box)
Altitude during operation (m) ....:	4000
Possible test case verdicts:	
Test case does not apply to the test object ....:	N(/A)
Test object does meet the requirement:	P(ass)
Test object does not meet the requirement ....:	F(ail)
Testing:	
Date of receipt of test item ....:	see cover page
Date(s) of performance of tests ....:	see cover page

General remarks:

This report shall not be reproduced, except in full, without the written approval of the testing laboratory.
The test results presented in this report relate only to the object tested.

"(see remark #)" refers to a remark appended to the report.
"(see appended table)" refers to a table appended to the report.

Throughout this report a ☐ comma / ☒ point is used as the decimal separator.

Factory location:

Contemporary Amperex Technology Co., Limited.

No. 2, Xingang Road, Zhangwan Town, Jiaocheng District,Ningde City, 352100 Fujian, P.R. China

Description of the product:

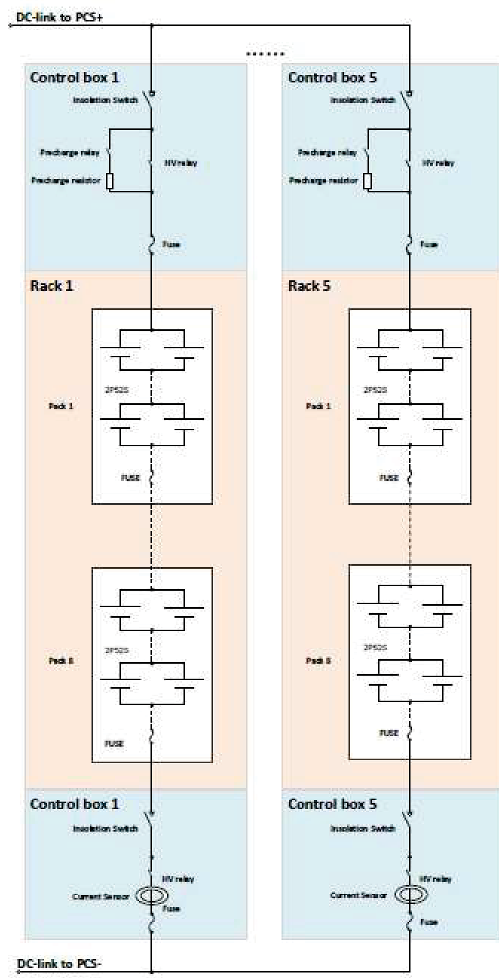
Product Description:

The model C02306P05L01-R Battery rack is the core unit in the energy storage sys-tem and acts as the equipment for storing electrical energy. It can be applied to many applications includ-ing renewable energy integration, frequency regulation, and voltage regulation.Battery rack includes battery , battery management system（BMS）, thermal management system (TMS),auxiliary distribution system, and fire suppression system (FSS).

The battery rack contains 8 battery modules. Each battery module is composed of 52 lithium iron cells (306Ah/3.2V) in series connection.The control box is for providing the auxiliary power for whole BMS control system and TMS liquid cooling system, and the battery system is composed of 416 battery cells. For safety protection, an internal high speed DC fuse is included.

The BMS functional safety was evaluated according to UL 60730-1 Annex H and UL 60730-1 Annex H by TÜV Rheinland.

Block diagram as below:



Item	Specifications			
Product name	Rechargeable Li ion Cell	Rechargeable Li ion Battery Module	Rechargeable Li ion Battery Rack	Rechargeable Li ion Battery System
Type/model	CBDD0	M02306P05L01	C02306P05L01-R	C02306P05L01
Nominal voltage	3.2V	166.4V	1331.2V	1331.2V
Rated capacity	306Ah	612Ah	612Ah	3060Ah
Voltage range	2.5-3.65	130~189.8V	1040~1500V	1040~1500V
Upper limit charging voltage	3.95V	-	-	-
Recommended charging current by manufacturer	153A	306A	306A	1530A
Recommended charging power by manufacturer	489.6W(max 195.84A)	50.91kW	407.34kW	2036.73kW
Maximum continuous charging current	153A	306A	306A	1530A
Recommended discharging current by manufacturer	153A	306A	306A	1530A
Recommended discharging power by manufacturer	489.6W(max 195.84A)	50.91kW	407.34kW	2036.73kW
Maximum continuous discharging current	195.9A	306A	306A	1530A
Standard temperature range for charging	0°C to 60°C	-	-	-
Standard temperature range for discharging	-20°C to 60°C	-	-	-
Operating ambient temperature range	-	-	-25°C to 55°C	-25°C to 55°C
Storage temperature range	-30°C to 60°C	-	-30°C to 60°C	-30°C to 60°C
Standard charging method by manufacturer	153A CC to 3.65V , CV to 15.3A	Charge at constant power 50.91kW until any cell voltage reaches 3.65V then derate until charge with 0.05P till 189.8V or	Charge at constant power 407.34kW until any cell voltage reaches 3.65V then derate until charge with	Charge at constant power 2036.73kW until any cell voltage reaches 3.65V then derate until charge with

		any cell voltage reaches 3.65V	0.05P till 1500V or any cell voltage reaches 3.65V	0.05P till 1500V or any cell voltage reaches 3.65V
Charging method for internal short-circuit test	153A CC to 3.65V , CV to 15.3A	-	-	-
Standard discharging method by manufacturer	153A DC to 2.5V	Discharge at constant power 50.91kW until 130V or any cell voltage reaches 2.5V	Discharge at constant power 407.34kW until 1040V or any cell voltage reaches 2.5V	Discharge at constant power 2036.73kW until 1040V or any cell voltage reaches 2.5V
Lower limit discharging voltage	2V	-	-	-
Over voltage protection value	-	-	max. cell voltage reaches 3.81V	max. cell voltage reaches 3.81V
Under voltage protection value	-	-	min. cell voltage reaches 2.32V	min. cell voltage reaches 2.32V
Overcurrent protection value	-	-	Max(I*135% , 10A)	Max(I*135% , 10A)
Over temperature protection value	-	-	57℃	57℃
Dimension	Width*Depth*Height: 174.7±0.8mm*71.6±0.8mm*207.3±0.8 mm	Width*Depth*Height: 830mm*2235mm * 250mm	Width*Length*Height: 2252.5mm*936mm *2698mm	Width*Length*Height: 2,438mm*6,058mm *2,896mm
Weight	5500±300g	Approx.653±5kg	Approx.7200kg	Approx.36000kg
Configuration	-	2P52S	(2P52S)8S	((2P52S)8S)5P
Max.short circuit current declared by manufacturer	-	-	-12.94kA	-64.7kA
Duration at max.short circuit current declared by manufacturer	-	-	-300 μs	-300 μs

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict

INTRODUCTION			
1	**Scope**		**P**
2	**Components**		**P**
2.1	A component of a product covered by this standard shall comply with the requirements for that component. See Annex A for a list of standards covering components generally used in the products covered by this standard. A component shall comply with the CSA, UL, and/or ULC standards as appropriate for the country where the product is to be used.	See appended table Critical components.	P
3	**Units of Measurement**		**—**
4	**Undated References**		**—**
5	**Normative References**		**—**
6	**Glossary**		**—**
CONSTRUCTION			
7	**General**		**P**
7.1	Non-metallic materials		P
7.1.1	Polymeric materials employed for enclosures shall comply with the requirements as outlined in the Enclosure Requirements table, Table 4.1, Path III, of UL 746C except as modified by this standard. *Exception No. 1: Polymeric materials utilized for light electric rail (LER) enclosures for motive and VAP applications shall have a minimum flammability of V-1 or better, in accordance with UL 94 if intended for building into an enclosure or compartment within the train.* *Exception No. 2: LER enclosure parts for motive and VAP applications may alternatively be evaluated to the 20 mm end-product flame tests in accordance with UL 746C.*	Metal enclosure	N/A

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
7.1.2	The factors taken into consideration when an enclosure is being judged are as follows. For a nonmetallic enclosure, all of these factors shall be considered with respect to thermal aging. Dimensional stability of a polymeric enclosure is addressed by compliance to the mold stress relief distortion test. a) Resistance to impact; b) Crush resistance; c) Abnormal operations; d) Severe conditions; and e) Mold-stress relief distortion.	Metal enclosure	N/A
7.1.3	The polymeric materials employed as enclosures and insulation shall be suitable for the anticipated temperatures encountered in the intended application. Pack enclosures shall have a Relative Thermal Index (RTI) with impact suitable for temperatures encountered in the application but no less than 80 °C (176 °F), as determined in accordance with UL 746B.		N/A
7.1.4	The pack enclosure materials intended to be exposed to sunlight in the end use application shall comply with the UV Resistance and the Water Exposure and Immersion tests in accordance with UL 746C.		N/A
7.1.5	Polymeric materials used as direct support for live parts other than those circuits determined nonhazardous (i.e. limited power circuits) shall comply with the insulation requirements of UL 746C. *Exception: Polymeric materials used as direct support for live parts that meet the requirements for “Safeguards Against Fire Under Normal Operating Conditions and Abnormal Operating Conditions,” Clause 6.3, of UL 62368-1/CSA C22.2 No. 62368-1, or the requirements for “Safeguards Against Fire Under Single Fault Conditions,” Clause 6.4, of UL 62368-1/CSA C22.2 No. 62368-1 are considered acceptable. Where specified in the reference document that components must meet the relevant IEC component standards, those components shall meet the applicable CSA or UL Standards.*		P
7.1.6	Polymeric tanks, piping and housings containing only electrolyte and sensors in flow batteries shall have a flammability rating of HB or better in accordance with UL 94.	No Such components.	N/A

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
7.1.7	Printed wiring boards shall have a flammability rating of V-0 or V-1 in accordance with UL 94. *Exception: This requirement does not apply to printed wiring boards connected only in low-voltage, limitedenergy circuits (LVLE) where the deterioration or breakage of the bond between a conductor and the base material does not result in a risk of fire or electric shock.*		P
7.1.8	Gaskets and Seals relied upon for safety shall be determined suitable for the temperatures they are exposed to and other conditions of use. Compliance is determined by the applicable tests of UL 157.		P
7.2	Metallic parts resistance to corrosion		P
7.2.1	Metal pack enclosures shall be corrosion resistant. A suitable plating or coating process can achieve corrosion resistance. Additional guidance on methods to achieve corrosion protection can be found in UL 50E/C22.2 No. 94.2.	Corrosion resistant metal enclosure used.	P
7.2.2	Conductive parts in contact at terminals and connections shall not be subject to corrosion due to electrochemical action. Combinations above the line in Table D.1 of Annex D shall be avoided unless there is an evaluation that demonstrates that the potential for corrosion is negligible for the particular connection materials and design. See Annex D.		P
7.3	Enclosures		P
7.3.1	The enclosure of a battery system shall have the strength and rigidity required to resist the possible physical abuses that it will be exposed to during its intended use, in order to reduce the risk of fire or injury to persons. Compliance is determined by the tests of this standard.	Compliance checked by the tests. Also see clause 31, 32 and 33.	P
7.3.2	A tool providing the mechanical advantage of a pliers, screwdriver, hacksaw, or similar tool, shall be the minimum mechanical capability required to open the enclosure.	Not opened without a tool.	P

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
7.3.3	Openings in the enclosure shall be designed to prevent inadvertent access to hazardous parts. Compliance is determined by the Tests for Protection Against Access to Hazardous Parts Indicated by the First Characteristic Numeral, Clause 12 of IEC 60529 or CAN/CSA-C22.2 No. 60529, for a minimum IP rating of IP2X or IPXXB, and C22.1, the Enclosure Selection Table for Nonhazardous Locations, Table 65. (Evaluation per IEC 60529 or CAN/CSA-C22.2 No. 60529, Clause 12, consists of the use of the IEC articulate probe applied with a force of 10 N ±10 %). *Exception: For battery systems intended for location in restricted access locations only per 6.51, hazardous parts may be contacted with the articulate probe, but shall be located or guarded to prevent unintended contact by service or other trained personnel. Such equipment shall be provided with installation instructions in accordance with 45.3 and marked in accordance with 44.14.*	Battery room: IP55; Electrical room: IP55 Chiller control box: IP67	P
7.3.4	Openings in the enclosure shall be constructed to prevent accumulation of flammable gases that could lead to a hazardous condition from concentrations of hydrogen gas due to electrolysis of aqueous electrolytes for applicable battery technologies, such as vented or valve regulated lead acid and nickel batteries and applicable electrochemical capacitor technologies, greater than 25 % of the LFL of hydrogen (equivalent to 1 % concentration in a volume of air). Ventilation openings shall have a minimum opening area of: $A = 0.005NC_5(cm^2)$ Where: A = Total cross sectional area of ventilation holes required (cm^2) N = Number of cells in battery C_5 = Capacity of battery at the 5-h rate (Ah) *Exception: The area of ventilation openings can be reduced if it can be demonstrated that there is sufficient ventilation within the battery to prevent hydrogen accumulations above 25 % of the LFL of hydrogen.*	Lithium ion battery technology used, where no hazards condition from concentrations of hydrogen gas occurs.	N/A

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
7.3.5	Packs intended for installation where they may be exposed to moisture either through rain, splashing water or immersion shall be evaluated for their intended resistance to ingress of moisture in accordance with IEC 60529 or CAN/CSA-C22.2 No. 60529, or as outlined in NFPA 70, Article 110, or Section 2 of C22.1 for enclosure type designation and UL 50E/C22.2 No. 94.2, or NEMA 250. See also Section 39.	Battery room: IP55； Electrical room: IP55 Chiller control box: IP67	P
7.4	Wiring and terminals		P
7.4.1	General		P
7.4.1.1	Wiring shall be insulated and acceptable for the purpose, when considered with respect to temperature, voltage, and the conditions of service to which the wiring is likely to be subjected within the equipment.	For more detail of compliance of tests of this standard, see clause 20.	P
7.4.1.2	A wiring splice or connection shall be mechanically secure and shall provide electrical contact without strain on connections and terminals. Wiring shall be secured and routed away from sharp edges or parts exceeding insulation. Openings in compartments through which insulated wiring is routed shall be smooth and well-rounded or provided with protective insulating bushings or grommet to prevent abrasion. Wiring connections between various parts of a battery module/pack and accessories shall be routed and secured to prevent the potential for short circuit conditions to occur.	Wiring splice or connection checked	P
7.4.1.3	An uninsulated live part, including a terminal, shall be secured to its supporting surface by a method other than friction between surfaces so that it will be prevented from turning, shifting in position, or creating short circuit.	Terminal block designed to prevent hazardous construction.	P
7.4.1.4	An external battery terminal shall be designed to prevent inadvertent shorting. An external terminal shall be designed to prevent inadvertent misalignment or disconnection when installed in its end use application.	Terminal block designed to prevent hazardous construction.	P
7.4.1.5	External non-detachable cords and leads that are accessible in the end use installation shall be provided with strain relief that prevents strain to internal conductors under pull and push-back conditions. Compliance is determined by the tests of 26.4 and 26.5.	No such parts.	N/A
7.4.1.6	Plugs and receptacles shall be rated for the intended voltage, current, temperature, and if applicable, for disconnect under load conditions.	No such parts.	N/A

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
7.4.1.7	Battery system cables shall be rated for their anticipated service including voltage, current, temperature and environment. External cords for hazardous voltage circuits shall be jacketed to prevent wear to internal conductors and rated and provided with insulation suitable for the intended applications.	Checked and found eligible for their anticipated service.	P
7.4.1.8	In multiway plugs and sockets, and wherever shorting could otherwise occur, means shall be provided to prevent contact between parts in SELV circuits or parts at hazardous voltage due to loosening of a terminal or breaking of a wire at a termination. Compliance is checked by inspection, by measurement and, where necessary, by the following test. A force of 10 N (2.25 lbf) is applied to the conductor near its termination point. The conductor shall not break away or pivot on its terminal to the extent that spacings are reduced below the values specified in 7.5.	No such parts.	N/A
7.4.1.9	Wiring compartments and wiring terminals provided for connection of the battery system to external circuits shall be constructed as outlined below: a) A field wiring compartment in which supply connections are to be made shall be located so that the connections will be accessible for inspection after the unit is installed as intended. b) A knockout in a sheet-metal enclosure shall be secured and shall be removable without undue deformation of the enclosure. The knockout shall be surrounded by a flat surface to accommodate seating of a conduit bushing or locknut of the appropriate size. c) An outlet box, terminal box, wiring compartment, in which field connections are made shall be free from any sharp edges including screw threads, a burr, a fin or moving part of the like that may abrade the insulation on conductor or otherwise damage wiring. d) A field wiring terminal or lead shall be rated for the connection of a conductor or conductors having a minimum ampacity rating of 125% of the rating of the unit. e) The distance between the end of the connection point of a field installed wire and the wall of the enclosure toward which the wire is to be directed, shall be in accordance with Table 312.6 (A) or (B) of NFPA 70.		P
7.4.2	Beads and ceramic insulators		N/A

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
7.4.2.1	Beads and similar ceramic insulators on conductors shall: a) Be so fixed or supported that they cannot change their position in such a way that a hazard would be created; and b) Not rest on sharp edges or sharp corners.	No such parts.	N/A
7.4.2.2	If beads are located inside flexible metal conduits, they shall be contained within an insulating sleeve, unless the conduit is mounted or secured in such a way that movement in normal use would not create a hazard. Compliance is checked by inspection and, where necessary, by the following test. A force of 10 N (2.25 lbf) is applied to the insulators or to the conduit. The resulting movement, if any, shall not create a hazard in the meaning of this standard.		N/A
7.5	Spacings and separation of circuits		P
7.5.1	General		P
7.5.1.1	Electrical circuits within the pack at opposite polarity shall be provided with reliable physical spacing to prevent inadvertent short circuits (i.e. electrical spacings on printed wiring boards, physical securing of un-insulated leads and parts, etc.). Insulation suitable for the anticipated temperatures and maximum voltages shall be used where spacings cannot be controlled by reliable physical separation.		P

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
7.5.1.2	Electrical spacings in circuits shall be based upon the grade of insulation required as outlined in the Insulation Materials and Requirements, Clause 5.4 of UL 62368-1/CSA C22.2 No. 62368-1, and shall comply with Clearances, Clause 5.4.2, and Creepage Distances, Clause 5.4.3, of UL 62368-1/CSA C22.2 No. 62368-1. For the appropriate pollution degree of the intended environment see 7.5.2 and 7.5.3. *Exception No. 1: As an alternative to these spacing requirements, the spacing requirements in UL 840, may be used. For determination of clearances, a dc source such as a battery does not have an overvoltage category as outlined in the section for Components of UL 840 unless charged through an ac mains connected rectifier, then the overvoltage category should be the same as that required for the rectifier unless the rectifier uses galvanic isolation. If galvanic isolation is employed, then the overvoltage category can be reduced to the next lower overvoltage category. The anticipated pollution degree is determined by the design and application of the battery system or subassembly under evaluation.* *Exception No. 2: As an alternative to the clearance values outlined in UL 62368-1/ CSA C22.2 No. 62368-1 the alternative method for determining minimum clearances in the Annex for Alternative Method for Determining Clearances for Insulation in Circuits Connected to an AC Mains not Exceeding 420 V peak (300 V RMS), Annex X, of UL 62368-1/CSA C22.2 No. 62368-1 may be applied.* *Exception No. 3: As an alternative to these spacing requirements, the spacing requirements of Table 7.1 may be applied instead. When using this table, maximum working voltages of circuits can be determined through the test of Section 23. See the note in Table 7.1 regarding adjustment for spacings where double or reinforced insulation is required.* *Exception No. 4: As an alternative, clearances and creepage distances per IEC 60664-1 can be applied instead.*	The electrical spacings for clearance and creepage, comply with UL 840	P
7.5.1.3	Conductors of circuits operating at different potentials shall be reliably separated from each other unless they are each provided with insulation acceptable for the highest potential involved.	Each circuit is separated from others.	P

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
7.5.1.4	An insulated conductor shall be reliably retained so that it cannot contact an uninsulated live part of a circuit operating at a different potential. Some examples include clamping or routing of conductors, use of separating barriers of insulating material or other means that provides permanent separation of the parts.	Complied	P
7.5.1.5	There are no minimum spacings applicable to parts where insulating compound completely fills the casing of a compound or subassembly if the distance through the insulation, at voltages above SELV levels is a minimum of 0.4-mm (0.02-in) thick for supplementary or reinforced insulation, and passes the Dielectric Voltage Withstand Test. There is no minimum insulation thickness requirement for insulation of circuits at or below SELV levels for basic or functional insulation. Some examples include potting, encapsulation, and vacuum impregnation.	Complied	P
7.5.1.6	UL 840 shall not be used for clearances between an uninsulated live part and the walls of a metal enclosure, including fittings for conduit or armored cable. UL 840 shall not be used for the clearance and creepage distance at field wiring terminals	Considered	P
7.5.1.7	When determining the clearance for double or reinforced insulation in accordance with UL 840, the clearances of reinforced insulation shall be dimensioned corresponding to the rated impulse voltage, but choosing one step higher in the preferred series of values in the Minimum Clearances for Equipment table of UL 840 than that specified for basic insulation. If the impulse withstand voltage required for basic insulation, is other than a value taken from the preferred series, reinforced insulation shall be dimensioned to withstand 160 % of the impulse withstand voltage required for basic insulation.	Considered	P
7.5.1.8	When determining the creepage for double or reinforced insulation in accordance with UL 840, the creepage distances for reinforced insulation shall be twice the creepage distance required for the basic insulation as determined in UL 840.	Considered	P

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
7.5.1.9	When determining the electrical spacing according to 7.5.1.1, a battery circuit that has no direct connection to a primary circuit and derives its power from a transformer or converter shall be considered a secondary circuit. The phase-to-ground rated system voltage used in the determination of mains transient voltage in UL 62368-1/CSA C22.2 No. 62368-1 or the rated impulse voltage in UL 840 shall be the rated supply voltage of the charging equipment for the battery.		P
7.5.1.10	For batteries intended for installation at high altitudes (i.e. 2000 m and above), see the Multiplication Factors for Clearances and Test Voltages table of UL 62368-1/CSA C22.2 No. 62368-1 or the Altitude Correction Factors for Clearance Correction table of IEC 60664-1 for multiplication factors to be applied to clearance values.	4000m	P
7.5.2	Overvoltage categories applied for electrical creepage and clearance determination		P
7.5.2.1	When determining the creepage and clearance requirements from 7.5.1.2, the overvoltage categories for the battery systems shall be determined based on how the batteries are connected to the supply mains. For equipment or circuits energized from the mains, four categories are considered: a) Category IV applies to equipment permanently connected at the origin of an installation (upstream of the main distribution board). Examples are electricity meters, primary overcurrent protection equipment and other equipment connected directly to outdoor open lines; b) Category III applies to equipment permanently connected in fixed installations (downstream of, and including, the main distribution board). Examples are switchgear and other equipment in an industrial installation; c) Category II applies to equipment not permanently connected to the fixed installation. Examples are appliances, portable tools and other plug-connected equipment; and d) Category I applies to equipment connected to a circuit where measures have been taken to reduce transient overvoltages to a low level.	OCV II used and considered.	P

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
7.5.2.2	For stationary battery systems, Overvoltage Category III is applied. Overvoltage Category II may be applied for a stationary battery system that is isolated from an Overvoltage category III supply source (such as from an Overvoltage category III PCS) through an isolated transformer or protected in a manner that prevents transient overvoltage conditions. For vehicle auxiliary power batteries and on board LER batteries, Overvoltage Category II shall be applied.		P
7.5.3	Pollution degree for electrical creepage and clearance determination		P
7.5.3.1	With reference to 7.5.1.2, the following are conditions for determining the pollution degree to utilize when determining creepage and clearance distances. See also examples noted in Table 7.2. a) Pollution Degree 1 – No pollution or only dry, non-conductive pollution. Normally, this is achieved by having components and subassemblies adequately enclosed by enveloping or hermetic sealing so as to exclude dust and moisture. b) Pollution Degree 2 – Only non-conductive pollution that might temporarily become conductive due to occasional condensation. c) Pollution Degree 3 – Subject to conductive pollution, or to dry non-conductive pollution which could become conductive due to expected condensation. d) Pollution Degree 4 – Pollution that generates persistent conductivity through conductive dust or rain and snow.	PD3(outside) PD2(inside)	P
7.6	Insulation levels and protective grounding and bonding		P
7.6.1	Hazardous voltage circuits shall be insulated from accessible conductive parts and circuits as outlined in 7.6.2 through the following: a) Basic insulation and provided with a protective grounding system for protection in the event of a fault of the basic insulation; or b) A system of double or reinforced insulation; or c) A combination of (a) and (b).		P

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
7.6.2	Safety extra low voltage (SELV) circuits as defined in 6.54 that are insulated from accessible conductive parts through functional insulation only are considered accessible.	Insulation checked for accessible part for SELV circuit.	P
7.6.3	Batteries that rely upon protective grounding, shall comply with 7.6.4 – 7.6.9.	Complied with 7.6.4 - 7.6.9.	P
7.6.4	Accessible non-current carrying metal parts of a battery system with hazardous voltage circuits, that could become live in the event of an insulation fault, shall be bonded to the equipment ground terminal.	Grounding system exists.	P
7.6.5	Parts of the protective grounding system shall be reliably secured in accordance with 7.4.1.2 and provided with good metal-to-metal contact. All connections shall be secured against accidental loosening and shall ensure a thoroughly good connection. The resistance between the protective conductive terminal of 7.6.8 and the accessible non-current carrying conductive parts outlined in 7.6.2 shall not exceed 0.1 Ω.	Measured resistance between the protective conductive terminal and accessible non-current carrying part: 0.014 Ω	P
7.6.6	With reference to 7.6.5, when connecting conductive parts to be bonded, paint or coatings in areas of contact shall be removed or paint piercing lock washers shall be used with securement bolts or screws to provide good metal to metal contact. Thread-locking sealants, epoxies, glues, or other similar compounds, and solder alone shall not be used as a securement means as these are not considered reliable. In addition, rivets, hinges (unless metal-to-metal piano type hinges), and parts that may be removed as a result of servicing shall not be relied upon as connections for ensuring continuity of the protective grounding and bonding system.		P
7.6.7	With reference to 7.6.5, methods of securement considered reliable and ensuring good metal-to-metal contact can consist of the following methods: a) Terminal blocks; b) Pressure connectors, grounding lugs and similar grounding and bonding equipment connectors; c) Exothermic welding processes; d) Machine screw-type fasteners that engage not less than two threads or are secured with a nut; and e) Thread-forming machine screws that engage not less than two threads in the enclosure.	d), e)	P

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
7.6.8	The main ground terminal of the protective grounding system shall be identified by one of the following: a) A green-colored, not readily removable terminal screw with a hexagonal head; b) A green-colored, hexagonal, not readily removable terminal nut; c) A green colored pressure wire connector; or d) The word “Ground” or the letters “G” or “GR” or the grounding symbol (IEC 60417, No. 5019) or otherwise identified by a distinctive green color.	The main ground terminal of the protective grounding system complies with d).	P
7.6.9	Conductors, relied upon for the protective grounding and bonding system, shall be sized to handle intended fault currents and if insulated, the insulation shall be green or green and yellow striped in color. Grounding conductors shall be sized in accordance with Article 250.122 of NFPA 70 or Rule 10-810 of C22.1.	Grounding conductor color: green and yellow.	P
7.7	Transformers	No such parts.	N/A
7.7.1	Transformers shall be evaluated in accordance with UL 1562, UL 1310 or an equivalent standard for overload conditions, and shall have suitable insulation for the circuits they are connected to.		N/A
7.7.2	Transformers in low voltage circuits can alternatively be evaluated in accordance with 26.6.		N/A
7.7.3	Transformers shall be provided with overcurrent protection on the primary side of the transformer and sized in accordance with Article 450 of NFPA 70 or Section 26 of C22.1.		N/A
7.8	System safety analysis	Complied.	P

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
7.8.1	A safety analysis consisting of a hazard identification, risk analysis and risk evaluation shall be conducted on the device under test. This safety analysis shall determine which parts of the system are safety related through an existing methodology such as outlined 7.8.2. This approach should determine the hazard scenarios and define mitigation mechanisms. This safety analysis shall identify safety circuits or software that address each hazardous condition and consider the performance of each safety circuit or software. The following conditions in (a) **–** (c) shall be considered unless sufficient justification (e.g. additional safety analysis) is provided by the manufacturer that these conditions are not hazardous. The following conditions in (a) **–** (c) shall be considered at a minimum, but are not limited to: a) Battery cell over-voltage and under-voltage; b) Battery over-temperature and under-temperature; and c) Battery over-current during charge and discharge conditions.	Evaluated according to UL 60730-1 Annex H.	P
7.8.2	Documents that can be used as guidance for the safety analysis include: a) IEC 60812; b) IEC 61025; c) MIL-STD-1629A; and d) IEC 61508, all parts.	See above.	P
7.8.3	The analysis of 7.8.1 is utilized to identify anticipated faults in the system which could lead to a hazardous condition and is validated by compliance with 7.9. The analysis shall consider the reliability of any monitoring components and systems and any communication systems providing information to the controls that can affect safety. The analysis shall consider single fault conditions in the protection circuit in addition to single faults elsewhere that could lead to a hazardous condition.	See above.	P
7.9	Protective circuit and controls		P

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
7.9.1	Active protective devices shall not be relied upon for critical safety and shall comply with one of the following in (a) – (c) and comply with 7.9.2 and 7.9.3 as applicable. Refer to 6.49 and 6.50 for definitions of active and passive protective devices. a) They are provided with a redundant passive protective device; b) They are provided with redundant active protection that remains functional and energized upon loss of power to, or failure of the first level of active protection; or c) They remain fully operational or fail safe upon loss of power to, or under a single fault condition of the active circuit. *Exception : Active protective devices that comply with IEC 61508 (all parts), meeting minimum Safety Integrity Level (SIL) "2", ISO 13849 (all parts), meeting minimum performance level (PL) "c", or ISO 26262 (all parts), minimum of Automotive Safety Integrity Level (ASIL) "C" are permitted to be relied upon for critical safety. The SIL, PL, or ASIL for a safety function may be reduced if the manufacturer provides additional safety analysis, e.g. Layer of Protection Analysis (LOPA), showing that the required risk reduction level has been reduced by other measures used within the battery system.*		P
7.9.2	Active protective devices relied upon for safety as noted in 7.9.1, shall be evaluated in accordance with: a) The Failure-Mode and Effect Analysis (FMEA) requirements in UL 991 (Section 7); b) The Protection Against Internal Faults to Ensure Functional Safety requirements in UL 60730-1 or CAN/CSA E60730-1 (Clause H.27.1.2); or c) The Protection Against Faults to Ensure Functional Safety requirements (Class B requirements) in CSA C22.2 No. 0.8 (Section 5.5) to determine compliance and identify tests necessary to verify single fault tolerance.	Evaluated according to UL 60730-1 Annex H.	P

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
7.9.3	With reference to 7.9.1, software relied upon for safety shall comply with: a) Software Class 1 requirements of UL 1998; b) Software Class B requirements of CSA C22.2 No. 0.8; or c) The Controls Using Software requirements (Software Class B requirements) in UL 60730-1 (Clause H.11.12) or CAN/CSA E60730-1.		P
7.9.4	Software and its associated hardware determined critical to safety that can be updated remotely shall meet the requirements outlined in UL 5500.		P
7.9.5	Battery systems shall be protected against all hazards identified in the safety system safety analysis of 7.8.		P
7.9.6	With reference to 7.9.5, if relied upon for maintaining the cells within their safe operating limits, the battery management system (BMS) shall maintain cells within the specified cell voltage and current limits to protect against overcharge and over-discharge. The BMS shall also maintain cells within the specified temperature limits providing protection from overheating and under temperature operation. When reviewing safety circuits to determine that cell operating region limits are maintained, tolerances of the protective circuit/component shall be considered in the evaluation. Components such as fuses, circuit breakers or other devices and parts determined necessary for safe operation of the battery system that are required to be provided in the end use installation, shall be identified in the installation instructions.		P
7.9.7	With reference to 7.9.5 and 7.9.6, if safe operating limits are exceeded, a protective circuit shall limit or shut down the charging or discharging to prevent excursions beyond these limits. When a hazardous scenario occurs, as determined in 7.8.1, the system shall continue to provide the safety function or go to a safe state (SS) or risk addressed (RA) state. If the safety function has been damaged, the system shall remain in the safe state or risk addressed state until the safety function has been restored and the system has been deemed safe to operate.		P

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
7.9.8	Solid state circuits and software controls, relied upon as the primary safety protection, shall be evaluated and tested to verify electromagnetic immunity in accordance with Section 27. *Exception: Solid state circuits and software need not comply if it can be demonstrated that the solid state circuits and software are not relied upon as the primary safety protection.*	Complied. Evaluated according to UL 60730-1 Annex H.	P
7.9.9	Battery systems with hazardous voltage circuits, including outputs of 60 V or greater, shall either be provided with a manual disconnect device or be provided with installation instructions for the disconnect device to be provided during installation of the system. The disconnect device shall be located as near as possible to the battery system terminals and it shall be rated for the application including disconnect under load if applicable. The disconnect device shall disconnect both poles of the circuit. The manual disconnect shall not require the use of a special tool or equipment to be operated. The disconnect device shall consist of either a manually operated switch or circuit breaker. *Exception No. 1: A battery system having either a plug or receptacle or connector for connection to the output circuit may be provided without an additional disconnect means. The plug, receptacle and connectors used for this purpose shall be investigated in accordance with UL 1682 and rated for current interruption suitable for the circuit. The required spacing to the hazardous voltage circuits shall be maintained when the plug or receptacle or connector is disconnected.* *Exception No. 2: A flow battery that can be turned off such that no circuits remain at hazardous voltage are not required to have a manual disconnect device.*	Complied	P
7.9.10	Fuses provided for battery overcurrent protection including short circuit protection shall be evaluated for both short circuit and overload conditions. Fuses that are evaluated for short circuit conditions only (type aR fuses), shall be provided with supplementary protection (e.g. the BMS) to ensure protection under overcurrent conditions in ranges below those covered by these types of fuses.		P
7.9.11	Protective components of battery modules intended for series connection in battery systems shall be rated for the maximum voltage of the intended battery system.		P
7.10	Cooling/thermal management system		P

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
7.10.1	Battery systems that rely upon integral thermal management systems to prevent overheating shall be designed to shutdown upon failure of the thermal management system unless is can be demonstrated, that the thermal management system failure does not result in a hazardous situation. Compliance is determined by the Failure of the Cooling/Thermal Stability System Test of Section 24.	Complied with Test of section 24	P
7.10.2	Piping, hose, and tubing used to contain liquid shall be resistant to chemical degradation from the liquid it contains, as well as other liquids reasonably likely to contact such parts during expected life of the equipment. It shall have the strength and material characteristics necessary to withstand the anticipated mechanical and environmental stresses. Compliance is determined as outlined in 7.11.1.	Complied	P
7.10.3	With reference to 7.10.2, piping containing fluids in accordance with the scope of ASME B31.3, shall comply with the applicable requirements of that code. ASME B31.3 applies to piping that contains toxic fluids, flammable fluids, fluids damaging to human tissue, and nonhazardous fluids at pressures greater than 15 psi (105 kPa) or temperatures lower than −29 °C (−20 °F) or greater than 186 °C (366 °F).	A mixture of Ethylene glycol and water for liquid cooling	P
7.10.4	Piping, hose, and tubing containing liquids, shall be routed and secured to prevent leakage that could result in a fire, explosion or shock hazard.		P
7.10.5	Fans or blowers utilized for air-cooling systems shall comply with the applicable requirements in UL 507. *Exception: Fans located in SELV or ELV dc circuits need not be evaluated if shown to comply with the test of 26.1.*		N/A
7.10.6	Battery systems that rely on integral heaters to maintain operating temperatures of the battery system, shall be designed to shutdown upon failure of the heaters unless it can be demonstrated through fault analysis and if necessary an abnormal operation test, that the heater failure does not result in a hazardous situation.	No such parts.	N/A

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
7.10.7	Temperature controls for heaters used to maintain the operating temperature range of a battery system during cold ambient conditions shall be positioned such that they monitor the system temperature and are minimally affected by the outside ambient. For example, temperature controls or regulators should normally be located away from outside vents.	No such parts.	N/A
7.11	Electrolyte containment parts and parts subject to pressure	No such parts.	N/A
7.11.1	Parts that contain electrolyte, such as piping, hose, and tubing shall be resistant to chemical degradation from the electrolyte. Electrolyte containing parts shall have the strength and material characteristics necessary to withstand the anticipated mechanical and environmental stresses. Compliance is determined through review of material datasheets and where determined necessary, an immersion test (using the electrolyte as the test liquid) in accordance with the Volume Change Test after Immersion of UL 157 for elastomeric materials or the Test for Resistance of Polymeric Materials to Chemical Reagents in UL 746A for other than elastomeric materials, (same as ASMT D543, Test Method I), as applicable to the material and part being tested. Elastomeric parts in contact with electrolyte shall be subjected to the volume change and extraction test after 70-h immersion in the electrolyte in accordance with UL 157. The volume change shall be minus 1 to plus 25 % and extraction (change in weight) no greater than 10 %. Plastics other than elastomeric parts in contact with electrolyte shall be subjected to an immersion for 168 h at room temperature followed by a check for volume and weight change in accordance with ASTM D543, Procedure I method. The percentage of change of volume shall not be greater than 2 % of the original and the change in weight shall be no not increase more than 25 % or decrease more than 10 % of the original value. *Exception No. 1: See Annex C for material requirements for flowing electrolyte systems.* *Exception No. 2: Not applicable to individual cell or capacitor casings and materials that have been evaluated to appropriate component requirements per 7.12.*	Not applicable to Lithium Battery System	N/A
7.11.2	Piping, hose, and tubing containing electrolyte, shall be routed and secured to prevent leakage that could result in a fire, explosion or shock hazard.	Not applicable to Lithium Battery System	N/A

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
7.11.3	Parts under pressure shall be acceptable for the maximum anticipated pressure as determined by the tests of Section 36. Exception: See Annex C for material requirements for flowing electrolyte systems.	Not applicable to Lithium Battery System	N/A
7.11.4	Relief valves or rupture members relied upon to relieve overpressure conditions in a battery system shall operate in accordance with their specifications for start to discharge (i.e. pressure at which the relief valve or rupture membrane starts to relieve pressure). Compliance is determined by the tests of Section 37. This requirement does not apply to relief valves or rupture members integral to a cell or monobloc battery such as a VRLA type battery. *Exception: Relief valves and ruptures members stamped with the ASME approval mark for the particular device in accordance with the ASME Boiler and Pressure Vessel Code need not be subjected to the tests of Section 37.*	Not applicable to Lithium Battery System	N/A
7.11.5	A pressure-relief device shall have its discharge opening located and directed so that operation of the device will not deposit moisture on bare live parts or on insulation or components that could be detrimentally affected by the discharge. It shall have a start to discharge (i.e. pressure at which the relief valve or rupture membrane starts to relieve pressure) rating adequate to relieve the pressure.	Not applicable to Lithium Battery System	N/A
7.11.6	The fill port of the electrolyte containment of a monobloc system shall be designed to prevent overfill and spillage of electrolyte during the electrolyte filling.	Not applicable to Lithium Battery System	N/A
7.11.7	Flow batteries shall be provided with a means for spill control such as a spill containment system to prevent electrolyte spills. The spill containment shall be sufficient to handle electrolyte spills for the size of the system. See Spill Containment Systems, Section C6, for means to determine compliance.	Not applicable to Lithium Battery System	N/A
7.11.8	Flowing electrolyte batteries shall be provided with a means of leak detection that shall identify when a leak occurs in the system and initiate controls to mitigate the leak condition.	Not applicable to Lithium Battery System	N/A
7.12	Cells (battery and electrochemical capacitor)		P

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
7.12.1	Sealed nickel metal hydride cells shall comply with the cell tests of the Testing Required for Cells table of UL 2054 in addition to the requirements of this standard. Cells shall be provided with specifications for use (charging and discharging), installation, storage and disposal. *Exception No. 1: The overall dimensions of the projectile test aluminum test screen may be increased from those outlined in UL 2054 to accommodate large cells intended for stationary and LER applications, but the flat panels of the test screen shall not exceed a distance of 305 mm (12 in) from the cell in any direction.* *Exception No. 2: The overall external resistance for the short circuit test shall be less than or equal to 20 mΩ.* *Exception No. 3: The crush test shall be a bar crush test rather than a flat plate crush using a bar with a 15-cm (5.9-in) diameter if the flat plate crush test per UL 2054 is insufficient to create a crush condition in the cell as determined by (a) – (c) below. The force shall be applied until one of the following occurs:* *a) A voltage (OCV) drop of one-third of the original cell voltage occurs;* *b) A deformation of 15 % or more of initial cell dimension occurs; or* *c) A force of 1,000 times the weight of cell is reached.* *Exception No. 4: Nickel metal hydride or nickel cadmium cells that are sealed and formed as part of a monobloc battery, need only comply with the requirements of this standard as part of the assembled battery. If provided with a pressure release vent or flame arrester, the nickel battery shall comply with the requirements outlined in 7.12.8.* *Exception No. 5: Sample numbers tested for each test based upon UL 2054 test program may be reduced from 5 samples tested to 2 samples tested.* *Exception No. 6: During the heating test, the samples are held for 30 min at the maximum temperature rather than 10 min.*	Lithium ion cells used.	N/A
7.12.2	Secondary lithium cells shall comply with the requirements outlined in Annex E, and be marked as required in 44.15 and 44.16. Cells shall be provided with specifications as outlined in 45.7.	The Lithium ion cell has been tested and certified with standards UL1973: 2022.	P

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
7.12.3	Secondary lithium cell design shall ensure sufficient safety measures to mitigate internal short circuits and other hazardous conditions during the life of the cells. Safety measures to maintain cell safety include, but are not limited to, the following: a) The appropriate choice and placement of insulation. IEEE 1625 and IEEE 1725 provide guidance on placement and application of insulation within cells and general cell design safety considerations; b) Sufficient sizing of the negative electrode active materials to cover the positive electrode active materials; c) Proper placement of insulation and separation of parts at opposite polarity including insulation and placement of tabs to prevent inadvertent short circuits during the life of the cell; d) The use of appropriate protection mechanisms such as separator shutdown, protective coatings and electrolyte additives, etc.; and e) The use of separators with sufficient strength, thermal properties and that are sized to prevent short circuit between the positive and negative electrodes during charge and discharge over the life of the cells.		P
7.12.4	With reference to 7.12.3, compliance to (a) **–** (e) is determined through a review of the cell construction as part of a tear down analysis, a review of documentation on the cell construction and components, and the cell tests of Annex E.		P
7.12.5	Sodium-beta cells and batteries shall comply with the cell tests outlined in Annex B. Cells shall be provided with specifications for use (charging and discharging), installation, storage and disposal.	Lithium ion cells used.	N/A
7.12.6	Flowing electrolyte stacks and battery systems shall comply with the requirements outlined in Annex C.	Lithium ion cells used.	N/A
7.12.7	With reference to 7.12.6, flowing electrolyte battery systems shall be designed to mitigate shunt currents. Imbalance conditions and the potential for corrosion of the electrolyte containment parts may occur as a result of excessive shunt currents in a flowing electrolyte battery system. The flowing electrolyte battery manufacturer shall demonstrate through analysis and data that shunt currents have been mitigated as a result of the system design.		N/A

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
7.12.8	Batteries employing pressure release valves or flame arrestors shall comply with the pressure release test or the flame arrester test of UL 1989 in addition to the requirements of this standard. See Annex H for alternative criteria for vented or valve regulated lead acid or nickel cadmium batteries. Cells and multi-cell/monobloc batteries shall be provided with specifications for use (charging and discharging), installation, storage and disposal as outlined in Annex H.		P
7.12.9	Electrochemical capacitor cells and modules shall comply with the requirements outlined in UL 810A in addition to the requirements of this standard.	Lithium ion cells used.	N/A
7.12.10	Sodium ion cells (e.g. Prussian Blue cells or transition metal layered oxide cells) shall comply with Annex E, and be marked as required in 44.15 and 44.16. Cells shall be provided with specifications as outlined in 45.7.	Lithium ion cells used.	N/A
7.13	Repurposed cells and batteries		N/A
7.13.1	Batteries and battery systems using repurposed cells and batteries shall ensure that the repurposed parts have gone through an acceptable process for repurposing in accordance with UL 1974. See also 44.3.		N/A
PERFORMANCE			
8	**General**		**P**
8.1	Unless indicated otherwise the device under test (DUT) shall be at the maximum operational state of charge (MOSOC), in accordance with the manufacturer's specifications, for conducting the tests in this standard. After charging and prior to testing, the samples shall be allowed to rest for a maximum period of 8 h at room ambient. *Exception: For secondary lithium ion cells or batteries in which temperature is not a dependency on the test, the rest time may be extended to 36 h, but shall not be less than 90 % MOSOC.*	Complied	P

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
8.2	Unless otherwise indicated, fresh samples (i.e. not more than 6 months old) representative of production shall be used for the system level tests described in Sections 15 – 42. The test program and number of samples to be used in each test is shown in Table 8.1. *Exception No. 1: At the agreement of the manufacturer, DUT samples may be re-used for more than one test if not damaged in a manner that would affect test results. Minor repairs can be made to samples such as replacement of fuses, etc. in order to reuse samples for multiple tests.* *Exception No. 2: For repurposed batteries and battery systems, the "repurposing manufacturing date" is the date of manufacture used to determine the 6 month threshold.*	Test conducted with fresh sample (within 6 months)	P
8.3	All tests, unless noted otherwise, are conducted in a room ambient 25 ±5 °C (77 ±9 °F). Tests shall be conducted with the DUTs heated to normal operating temperatures unless indicated otherwise in the test. For those tests that require the DUT to reach thermal equilibrium, thermal equilibrium is considered to be achieved if after three consecutive temperature measurements taken at intervals of 10 % of the previously elapsed duration of the test but not less than 15 min, indicate no change in temperature greater than ±2 °C (3.6 °F).	Unless otherwise specified, all tests conducted within a room ambient 25 °C ±5 °C (77±9°F).	P
8.4	Thermocouples shall be attached to the central component cell or module during the system level tests in Sections 15 – 42. Temperatures shall also be measured on any components affected by temperature in the control circuit during the tests of 9.1 and 9.2. Temperature shall be measured using thermocouples consisting of wires not larger than 24 AWG (0.21 mm^2) and not smaller than 30 AWG (0.05 mm^2) connected to a potentiometer-type instrument. Temperature measurements shall be made with the measuring junction of the thermocouple held tightly against the component/location being measured.		P
8.5	Unless noted otherwise in the individual test methods, the tests shall be followed by a 1-h observation time prior to concluding the test and temperatures shall be monitored in accordance with 10.2.		P
9	**Determination of Potential for Fire Hazard**		**P**

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
9.1	In addition to visible signs of fire, non-compliant test results for fire shall also include an evaluation for combustible vapor concentrations during testing if there is the potential for combustible vapor concentrations based upon the technology and design of the battery system. For detection of potential combustible vapor concentrations that may be emitted during testing, a gas monitor suitable for detecting 25 % of the lower flammability limit (LFL) of the evolved gases being measured. A minimum of two sampling locations where concentrations may occur such as at vent openings or vent ducts shall be used for taking measurements. *Exception: As an alternative to using gas detection measurement to determine if there are combustible vapor concentrations, non-compliant tests results for fire may include an evaluation for potential combustible vapor concentrations with the use of a minimum of two continuous spark sources. The continuous spark sources shall provide at least two sparks per second with sufficient energy to ignite natural gas and shall be located near anticipated sources of vapor such as vent openings or at the vent duct.*	No visible signs of fire, flammable concentrations of vapor during test.	P
9.2	Additional precautions shall be taken during tests requiring this analysis due to the potential for combustible vapor concentrations that may occur within the test room or chamber.		P
10	**Important Test Considerations**		**P**

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
10.1	The tests contained in this standard may result in explosions, fire and emissions of combustible and/or toxic vapors, leakage of hazardous chemicals as well as electric shock. It is important that personnel use extreme caution when conducting any of these tests and that they be protected from flying fragments, leaked electrolyte, explosive force, toxic vapors and chemicals and sudden release of heat and noise that could result from testing. To prevent injury, protective equipment and clothing should be utilized when handling batteries and when conducting testing. Short-circuiting can lead to very hazardous currents, and large format batteries may still be hazardous even in an uncharged condition. The test area shall be well ventilated to protect personnel from possible harmful vapors or gases and care should be taken to prevent exposure to leaked electrolyte. Test facilities shall be equipped to contain, mitigate, and exhaust toxic vapors and particulate matter, leaked electrolyte and other hazardous substances that may be generated during the tests of this standard including the External Fire Exposure Test of Section 41. See also 9.2.	Checked	P
10.2	As an additional precaution, the temperatures on surfaces of the DUT shall be monitored during the tests per 8.5. All personnel involved in the testing of battery systems shall be instructed to never approach the DUT until temperatures are falling and are at safe levels.	The temperature was monitored.	P
11	**Single Fault Conditions**		**P**
11.1	Where there is a specific reference to a single fault condition in the individual test methods, the single fault shall consist of a single failure (i.e. open, short or other failure means) of any component in the electrical energy storage system that could occur as identified in the system safety analysis of 7.8 and that could affect the results of the test.	Evaluated for functional safety criteria considering single fault conditions in accordance with 7.8.1.3	P
12	**Test Results**		**P**
12.1	Tests that result in one or more of the following conditions as noted in Table 12.1 and as defined in Section 6, shall be considered as non-compliant for the test. Additional details of passing results criteria are provided in the individual test methods.		P

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
12.2	For the following tests, if the DUT is still operational after the test (a user replaceable fuse may be replaced or user resettable device such as an accessible circuit breaker, etc. reset), it shall be subjected to a minimum single charge/discharge cycle in accordance with the manufacturer's specifications. No noncompliant results as outlined in Table 12.1 shall occur during the charge/discharge cycle of a still operational DUT. a) Overcharge; b) Short Circuit; c) Overdischarge Protection; d) Imbalanced Charging; e) Failure of Cooling/Thermal Stability System; f) Electrostatic Discharge; g) Radio-Frequency Electromagnetic Field; h) Fast Transient/Burst Immunity; i) Surge Immunity; j) Radio-Frequency Common Mode; k) Power Frequency Magnetic Field; l) Operational Verification; m) Vibration; n) Shock; o) Impact or Drop Impact; p) Static Force; q) Thermal Cycling; r) Salt Fog; and s) Resistance to Moisture. NOTE: If the tests of (f) **–** (l) may be done on the battery management system only and not the whole battery system.	Observed as per the standard	P
13	**Determination of Toxic Emissions**		**P**

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
13.1	For those systems for which venting from cells or capacitors could result in the emission of toxic gases as determined by an analysis of the outgassed substances, the concentration of toxic gases during the destructive testing noted in Table 12.1 shall be monitored using one of the sampling methods noted below and as outlined in 13.2. Analysis of the outgassed substances can be obtained through review of MSDS sheets and/or analysis of the outgassed substances. If it can be determined through examination of the cells after testing that they did not vent as a result of the test, the system is in compliance with these criteria. a) ASTM D4490; b) ASTM D4599; c) OSHA Evaluation Guidelines for Air Sampling Methods Utilizing Spectroscopic Analysis; or d) NIOSH Manual of Analytic Methods.	No vent of the cell was occurred as a result of the test.	P
13.2	To determine the concentration of toxic emissions, testing shall be conducted in a closed test chamber of known volume large enough to contain the DUT. Results obtained from continuous sampling the emissions during testing shall be scaled to estimate the anticipated exposure and concentration of toxic materials within either the passenger compartment of a light electric rail (LER) or the anticipated smallest room in which the system can be installed. For walk-in units, continuous monitoring shall also be conducted in the interior of the system enclosure. The results for stationary applications shall be further scaled to consider a 0.5 air changes per hour (ACH) ventilation rate. The 0.5 ACH represents allowable low ventilation rated for construction. *Exception: Stationary systems intended for installation outdoors only and that are not walk-in units are exempted from this monitoring. Stationary systems and systems for LER applications are also exempted from these requirements if provided with a ventilation system or otherwise designed to prevent exposure to toxic vapor releases and vents vapors to a safe location.*	No vent of the cell was occurred as a result of the test.	P
14	**Measurement Equipment Accuracy**		**P**

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
14.1	Unless noted otherwise in the test methods, the overall accuracy of measured values of test specifications or results when conducting testing in accordance with this standard, shall be within the following values of the measurement range: a) ±1 % for voltage; b) ±3 % for current; c) ±4 % for watts; d) ±2 °C (±3.6 °F) for temperatures at or below 200 °C (392 °F), and ±3 % for temperatures above 200 °C (392 °F); e) ±0.1 % for time; f) ±1 % for dimension; g) ±3 % for Ah; h) ±4 % for Wh.		P
ELECTRICAL TESTS			
15	**Overcharge Test**		**P**
15.1	The purpose of this test is to evaluate a battery system's ability to withstand an overcharge condition.		P
15.2	A fully discharged DUT (i.e. discharged to the manufacturer's specified EODV) shall be subjected to an overcharge resulting from a single fault condition in the charging protection/control circuit of the system that could lead to an overcharge condition. See Section 11 for a description of a single fault condition. Single fault conditions can be applied to both passive and active protective devices. During test, the voltage of the cells shall be measured. The test supply equipment used for charging the DUT shall be sufficient to create an overcharge of the DUT to at least 110 % of the maximum specified charging voltage. The charging rate used shall be the manufacturer's specified maximum charging rate. *Exception No. 1: Overcharge testing on a subassembly may be conducted instead of the complete battery system if determined to be representative of the battery system.* *Exception No. 2: Components in circuits evaluated for reliability (i.e. evaluated for functional safety in accordance with 7.9) need not be subjected to single fault conditions.*	Test conducted with 110 % of the maximum specified charging voltage. Single fault condition not applied, it was considered in cl. 7.8 and 7.9. Tested on minimum subassembly battery system	P

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
15.3	The test shall continue until ultimate results occur followed by an observation period per 8.5. Ultimate results are considered to have occurred when one of the following occurs: a) The sample charging is terminated by the protective circuitry whether it is due to voltage or temperature controls or if the DUT reaches 110 % of its maximum specified charging voltage limit. Exceeding the manufacturer's specified charging limit is considered a non-compliant result. The DUT is monitored per 8.5 and 10.2; or b) Battery system failure occurs as evidenced by explosion, fire or other identifiable non-compliant results per Table 12.1.	a)	P
15.4	During the test, detection methods as outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations if determined necessary. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.	No venting, leakage and rupture of the internal cell was occurred.	P
15.5	If the DUT is operational after the overcharge test it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications. See 12.2 for details regarding user resettable devices. An observation period per 8.5 is then conducted.	Operational and cycled, No non-compliant result.	P
15.6	At the conclusion of the observation period, the samples shall be subjected to an "as received" dielectric voltage withstand test in accordance with Section 22. The DUT shall be examined for signs of rupture and evidence of leakage.	No rupture and no leakage after Dielectric Voltage Withstand Test.	P

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Clause	Requirement + Test	Result - Remark	Verdict
15.7	As a result of the overcharge test, the maximum charging voltage measured on the cells or modules shall not exceed their normal operating region. Also, the following in (a) **–** (h) are considered noncompliant results. For additional information on non-complying results refer to Table 12.1. a) E **–** Explosion; b) F **–** Fire; c) C **–** Combustible vapor concentrations; d) V **–** Toxic vapor release; e) S **–** Electric shock hazard (dielectric breakdown); f) L**–** Leakage (external to enclosure of DUT); g) R **–** Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3); h) P **–** Loss of protection controls.	No non-compliant result	P
16	**High Rate Charge**		P
16.1	The purpose of this test is to evaluate a battery system's ability to protect against a high rate charge condition at currents over the battery maximum charging current specification.		P
16.2	A fully discharged DUT (i.e. discharged to the manufacturer's specified EODV) shall be subjected to a high rate charge. There shall be a single fault condition on overcurrent charge protection devices or controls unless they have been evaluated for reliability (i.e. evaluated for functional safety in accordance with 7.9). During the test, the current and voltage of the cells shall be measured. The test supply equipment used for charging the DUT shall be sufficient to provide a current that is 20 % greater than the maximum specified charging rate for the batteries. *Exception: High rate charge testing on a subassembly may be conducted instead of the complete battery system if determined to be representative of the battery system.*	Test conducted with 120 % of the maximum specified charging current. The teat was interrupt by current protective. Single fault condition not applied, it was considered in cl. 7.8 and 7.9. Tested on minimum subassembly battery system	P

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Clause	Requirement + Test	Result - Remark	Verdict
16.3	The high rate charging of the DUT shall continue until ultimate results occur followed by an observation period per 8.5. Ultimate results are considered to have occurred when one of the following occurs: a) The sample charging is terminated by the protective circuitry whether it is due to current, voltage or temperature controls. The DUT is monitored per 8.5 and 10.2; or b) Battery system failure occurs as evidenced by explosion, fire or other identifiable non-compliant results per Table 12.1.	Ultimate results a) observed.	P
16.4	During the test, detection methods as outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations if determined necessary. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.		P
16.5	If the DUT is operational after the high rate charge test, it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications. See 12.2 for details regarding user resettable devices. An observation period per 8.5 is then conducted.		P
16.6	At the conclusion of the observation period, the samples shall be subjected to an "as received" dielectric voltage withstand test in accordance with Section 22. The DUT shall be examined for signs of rupture and evidence of leakage.	No rupture and no leakage after Dielectric Voltage Withstand Test	P

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Clause	Requirement + Test	Result - Remark	Verdict
16.7	As a result of the high rate charge test, the battery protection circuit (e.g. BMS) shall detect the overcharging current and shall prevent the battery from being charged over the maximum battery charging current. The following in (a) **–** (h) are considered non-compliant results. For additional information on noncomplying results refer to Table 12.1. a) E **–** Explosion; b) F **–** Fire; c) C **–** Combustible vapor concentrations; d) V **–** Toxic vapor release; e) S **–** Electric shock hazard (dielectric breakdown); f) L **–** Leakage (external to enclosure of DUT); g) R **–** Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3); h) P **–** Loss of protection controls.	No non-compliant result	P
17	**Short Circuit Test**		**P**
17.1	This test shall be conducted on a fully charged DUT (MOSOC per 8.1) with parallel connected cells or modules to determine its ability to withstand an external short circuit. DUTs with only series connections (i.e. no parallel connections of cells or modules) are tested at the cell or module level if determined to be equivalent to testing at the system level. *Exception: Short circuit testing on a subassembly may be conducted instead of the complete battery system if determined to be representative of the battery system.*	Testing on the complete battery system and battery module	P
17.2	The sample shall be short-circuited by connecting the positive and negative terminals of the sample with a shorting device having resistance as low as practicable. In all cases the resistive circuit load shall have a maximum total resistance of 20 mΩ, as measured from the DUT terminals. For battery systems, the short circuit discharge profile at the terminals for current and time shall be recorded and compared with the manufacturer's specified value in 44.4.	The complete Battery System was short circuit with resistance of 19.561 mΩ	P

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Clause	Requirement + Test	Result - Remark	Verdict
17.3	The direct short circuit test shall also be conducted on the battery module if it is intended to be installed or replaced in the field. The output of the battery module sample shall be short-circuited with a shorting device having resistance as low as practicable with a maximum total resistance of 20 mΩ.	Battery module short circuit with resistance of 19.3 mΩ	P
17.4	Tests shall be conducted at room ambient. The samples shall reach thermal equilibrium temperature as outlined in 8.3 before the terminals are connected.	Tested at Room Ambient.	P
17.5	The sample shall be completely discharged (i.e. discharged until near zero state of charge/its energy is depleted), or protection in the circuit has operated and the temperature on the center module has peaked or reached a steady state condition and 7 h has elapsed, or a fire or explosion has occurred.	Protection in the circuit has operated.	P
17.6	During the test, samples supplied with protective devices shall be subjected to a single component fault using any single fault condition that may be determined to occur during discharge conditions. See Section 11 for details regarding single fault conditions. Single fault conditions can be applied to both passive and active protective devices. *Exception: Components in circuits evaluated for reliability (i.e. evaluated for functional safety criteria considering single fault conditions in accordance with 7.9) need not be subjected to single fault conditions.*	Single fault condition not applied, it was considered in cl. 7.8 and 7.9.	P
17.7	During the test, a detection method as outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations if determined necessary. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.	No venting, leakage and rupture of the internal cell was occurred.	P
17.8	If the DUT is operational after the short circuit test it shall be subjected to a charge and discharge cycle in accordance with the manufacturer's specifications. See 12.2 for details regarding user resettable devices. An observation period per 8.5 is then conducted.	Fuse open, DUT couldn't operation after test	N/A
17.9	At the conclusion of the observation period , the samples shall be subjected to the "as received" dielectric voltage withstand test in accordance with Section 22. The DUT shall be examined for signs of rupture and evidence of leakage.	No rupture and no leakage after Dielectric Voltage Withstand Test.	P

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Clause	Requirement + Test	Result - Remark	Verdict
17.10	As a result of the short circuit test, the following in (a) – (h) are considered non-compliant results. For additional information on non-complying results refer to Table 12.1. a) E – Explosion; b) F – Fire; c) C – Combustible vapor concentrations; d) V – Toxic vapor release; e) S – Electric shock hazard (dielectric breakdown); f) L – Leakage (external to enclosure of DUT); g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3); h) P – Loss of protection controls. *Exception: For modules that do not have integral short circuit protection controls, the compliance criteria is (a) and (b) above only.*	No non-compliant result	P
17.11	For battery systems, the measured maximum short circuit current and duration at that maximum value shall not be greater than the specified value of 44.4.		P
18	**Overload Under Discharge**		P
18.1	This test shall be conducted on a fully charged DUT (MOSOC per 8.1) with parallel connected cells or modules to determine its ability to withstand an overload discharge condition. DUTs with only series connections (i.e. no parallel connections of cells or modules) may be tested at the cell or module level if determined to be equivalent to testing at the system level. *Exception: Overload under discharge testing on a subassembly may be conducted instead of the complete battery system if determined to be representative of the battery system.*		P
18.2	Condition 1 is the overload above the specified maximum discharge current of the battery, but below the BMS overcurrent protection (secondary protection) in accordance with 18.3 – 18.5.		N/A
18.3	With reference to 18.2, the positive and negative terminals of the DUT is to be connected to the external discharging equipment. The fully charged DUT shall then be discharged at a current equal to 90 % of the rated overcurrent protection value of the BMS (secondary protection).	Test conducted with 90 % of the rated overcurrent protection value of the BMS.	P

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Clause	Requirement + Test	Result - Remark	Verdict
18.4	With reference to 18.2, the test shall be continued until: a) The DUT has been completely discharged (i.e. discharged until near zero state of charge/its energy is depleted); b) The protection in the circuit has operated and the temperature on the center cell/module has peaked or reached a steady state condition and 7 h has elapsed; or c) A fire or explosion has occurred. *Exception: The overload condition 1 can be waived if the maximum discharge current of the battery is equal to or higher than 90 % of the overcurrent protection value of the BMS (secondary protection).*		N/A
18.5	With reference to 18.2, during the test, samples supplied with protective devices in the discharge circuit shall be subjected to a single component fault using any single fault condition that may be determined to occur during discharge conditions. See Section 11 for details regarding single fault conditions. Single fault conditions can be applied to both passive and active protective devices. *Exception: Overcurrent protection components in circuits evaluated for reliability (i.e. evaluated for functional safety criteria considering single fault conditions in accordance with 7.9) need not be subjected to single fault conditions.*		N/A
18.6	Condition 2 is the overload above the BMS overcurrent protection, but below the primary overcurrent protection in accordance with 18.7 – 18.9.	Considered in 18.2	N/A
18.7	With reference to 18.6, the positive and negative terminals of the DUT shall be connected to the external discharging equipment. The DUT shall then be discharged at a current equal to 135 % of the main fuse rating. *Exception No. 1: If the secondary overcurrent protection is a contactor, switch or similar disconnecting device, which has been investigated for an overload current higher than 135 % of the primary overcurrent protector rating, then the test shall be conducted at a discharge current of 150 % of the primary overcurrent protector rating.* *Exception No. 2: If the secondary overcurrent protection has be investigated for an overload current higher than 150 % of the primary overcurrent protector rating, then the condition 2 test can be waived.*		N/A

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Clause	Requirement + Test	Result - Remark	Verdict
18.8	With reference to 18.6, the test shall be continued until: a) The DUT has been completely discharged (i.e. discharged until near zero state of charge/its energy is depleted); b) The protection in the circuit has operated and the temperature on the center cell/module has peaked or reached a steady state condition and 7 h has elapsed; or c) A fire or explosion has occurred.		N/A
18.9	With reference to 18.6, during the test, samples supplied with protective devices in the discharge circuit shall be subjected to a single component fault using any single fault condition that may be determined to occur during discharge conditions. See Section 11 for details regarding single fault conditions. Single fault conditions can be applied to both passive and active protective devices. *Exception: Overcurrent protection components in circuits evaluated for reliability (i.e. evaluated for functional safety criteria considering single fault conditions in accordance with 7.9) need not be subjected to single fault conditions.*		N/A
18.10	During the test, a detection method as outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations if determined necessary. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.		N/A
18.11	If the DUT is operational after the short circuit test, it shall be subjected to a charge and discharge cycle in accordance with the manufacturer's specifications. See 12.2 for details regarding user resettable devices. An observation period per 8.5 shall then be conducted.		N/A
18.12	At the conclusion of the observation period, the samples shall be subjected to the "as received" dielectric voltage withstand test in accordance with Section 22. The DUT shall be examined for signs of rupture and evidence of leakage.	No rupture and no leakage after Dielectric Voltage Withstand Test	N/A

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Clause	Requirement + Test	Result - Remark	Verdict
18.13	As a result of the overload test, the following in (a) – (h) are considered non-compliant results. For additional information on non-complying results refer to Table 12.1. a) E – Explosion; b) F – Fire; c) C – Combustible vapor concentrations; d) V – Toxic vapor release; e) S – Electric shock hazard (dielectric breakdown); f) L – Leakage (external to enclosure of DUT); g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3); h) P – Loss of protection controls.	No non-compliant result	N/A
19	**Overdischarge Protection Test**		**P**
19.1	This test shall be conducted on a fully charged sample (MOSOC per 8.1) to determine the DUT's ability to withstand an overdischarge condition and is conducted with all discharge protection circuitry for both temperature and minimum voltage connected to prevent irreparable cell damage. During the test, active protective devices shall be subjected to single fault conditions, unless the protection circuit has been tested for functionality in accordance with 7.9. During test, the voltage of the cells shall be measured. *Exception: Overdischarge protection testing on a subassembly may be conducted instead of the complete battery system if determined to be representative of the battery system.*	Single fault condition not applied, it was considered in cl. 7.8 and 7.9. Tested on minimum subassembly battery system	P
19.2	The DUT shall be subjected to a constant discharging current/power that will discharge a battery at the manufacturer's specified maximum discharge rate. The test will continue until the passive protection device(s) are activated, or the minimum cell voltage/maximum temperature protection is activated, or the DUT has been discharged for an additional 30 min after it has reached its specified normal discharge limit, whichever comes first.	The minimum cell voltage protection is activated.	P

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Clause	Requirement + Test	Result - Remark	Verdict
19.3	During the test, a detection method as outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations as determined necessary. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.	No venting, leakage and rupture of the internal cell was occurred.	P
19.4	If the DUT is operational after the overdischarge protection test it shall be subjected to a charge and discharge cycle in accordance with the manufacturer's specifications. See 12.2 for details regarding user resettable devices. An observation period per 8.5 is then conducted.	Operational and cycled, No non-compliant result.	P
19.5	At the conclusion of the observation period, the samples shall be subjected to the "as received" dielectric voltage withstand test in accordance with Section 22. The DUT shall be examined for signs of rupture and evidence of leakage.	No rupture and no leakage after Dielectric Voltage Withstand Test.	P
19.6	As a result of the overdischarge protection test, the minimum discharge voltage measured on the cells shall not exceed their normal operating range. Also, the following in (a) **–** (h) are considered noncompliant results. For additional information on non-complying results refer to Table 12.1. a) E **–** Explosion; b) F **–** Fire; c) C **–** Combustible vapor concentrations; d) V **–** Toxic vapor release; e) S **–** Electric shock hazard (dielectric breakdown); f) L **–** Leakage (external to enclosure of DUT); g) R **–** Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3); h) P **–** Loss of protection controls.	No non-compliant result.	P
20	**Temperature and Operating Limits Check Test**		**P**

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Clause	Requirement + Test	Result - Remark	Verdict
20.1	This test is conducted to determine whether or not the cells/modules of the DUT are being maintained within their specified operating limits (including voltage and current at specified temperature) during maximum charge and discharge conditions. During this test, it shall also be determined as to whether or not temperature sensitive safety critical components are being maintained within their temperature ratings based upon the maximum operating temperature specifications of the DUT as well as a determination that temperatures on accessible surfaces are not exceeding safe limits. *Exception: Temperature and operating limits check test on a subassembly may be conducted instead of a complete battery system if determined to be representative of the battery system.*	Test was conducted on the complete battery system.	P

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Clause	Requirement + Test	Result - Remark	Verdict
20.2	A fully discharged DUT (i.e. discharged to EODV) shall be conditioned within a chamber set to the upper limit charging temperature specifications of the DUT. After being stabilized at that temperature (refer to 8.3), the DUT shall be connected to a charging circuit input representative of anticipated maximum charging parameters. The DUT shall then be subjected to maximum normal charging while monitoring voltages and currents on modules until it reaches the manufacturer's specified fully charged condition. Temperatures shall be monitored on temperature sensitive components including cells. *Exception No. 1: If the DUT is unable to be tested in a chamber, it can be tested at an ambient temperature of 25 ±5°C (77 ±9°F). If tested at ambient temperatures during the test, the temperature measurement T shall not exceed:* $T \leq T_{max} - (T_{ma} - T_{amb})$ Where: T is the temperature of the given part measured under the prescribed test. T_{max} is the maximum temperature specified for compliance with the test. T_{amb} is the ambient temperature during the test. T_{ma} is the maximum ambient temperature permitted by the manufacturer's specification or 25 °C (77 °F), whichever is greater. *Exception No. 2: If the design of the DUT and its controls result in worse case normal charging conditions when testing at ambient (i.e. due to thermostats or other controls lowering the charge levels at elevated ambient), the test shall be conducted at ambient temperature of 25 ±5°C (77 ±9°F). Temperatures on temperature sensitive components shall not exceed T_{max}.*	Tested at room ambient 55 °C	P

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Clause	Requirement + Test	Result - Remark	Verdict
20.3	While still in the conditioning chamber, the chamber temperature shall be set to the upper limit discharging temperature specifications of the DUT if different from the charging temperature. The fully charged DUT (MOSOC per 6.1) shall then be discharged in accordance with the manufacturer's maximum rate of discharge down to the manufacturer's specified end of discharge condition while monitoring voltage and current on modules. Temperatures shall be monitored on temperature sensitive safety critical components including cells. Temperatures on accessible surfaces are also monitored. *Exception No. 1: If the DUT is unable to be tested in a chamber, it can be tested at an ambient temperature of 25 ±5°C (77 ±9°F). If tested at ambient temperatures during the test, the temperature measurement T shall not exceed:* $T \le T_{max} - (T_{ma} - T_{amb})$ Where: T is the temperature of the given part measured under the prescribed test. T_{max} is the maximum temperature specified for compliance with the test. T_{amb} is the ambient temperature during the test. T_{ma} is the maximum ambient temperature permitted by the manufacturer's specification or 25 °C (77 °F), whichever is greater. *Exception No. 2: If the design of the DUT and its controls result in worse case normal discharging conditions when testing at ambient (i.e. due to thermostats or other controls lowering the discharge rate at elevated ambient), the test shall be conducted at ambient temperature of 25 ±5°C (77 ±9°F). Temperatures on temperature sensitive components shall not exceed T_{max}.*	Tested at 55 °C	P
20.4	The charge and discharge cycles are then repeated for a minimum of two complete cycles of charge and discharge. The DUT is then subjected to an observation period per 8.5.	Total 3 cycles applied.	P
20.5	At the conclusion of the observation period, the samples shall be subjected to the "as received" dielectric voltage withstand test in accordance with Section 22 if it anticipated that there has been deterioration of the insulation during the temperature test. The DUT shall be examined for signs of rupture and evidence of leakage.	No rupture and no leakage after Dielectric Voltage Withstand Test.	P

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Clause	Requirement + Test	Result - Remark	Verdict
20.6	The manufacturer’s specified operating limits for cells/modules (voltage, current at specified temperatures) shall not be exceeded during the charging and discharging cycles. Temperatures measured on components shall not exceed their specifications. Temperatures measured on accessible surfaces shall not exceed allowed limits. See Table 20.1 and Table 20.2 for temperature limit tables. Additional non-compliant results during the temperature test are as noted below in (a) **–** (e). For additional information on non-complying results refer to Table 12.1. a) E **–** Explosion; b) F **–** Fire; c) C **–** Combustible vapor concentrations; d) V **–** Toxic vapor release; e) S **–** Electric shock hazard (dielectric breakdown); f) L **–** Leakage (external to enclosure of DUT); g) R **–** Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3); and h) P **–** Loss of protection controls.	No non-compliant result.	P
21	**Imbalanced Charging Test**		**P**
21.1	This test is to determine whether or not a battery system with series connected cells/modules can maintain the cells/modules within their specified operating parameters if it becomes imbalanced. *Exception No. 1: Testing may be conducted at a subassembly level if that is representative of the battery system.* *Exception No. 2: Testing may be conducted on an alternate configuration if it can be shown to be representative for the battery system.*	Single fault condition not applied, it was considered in cl. 7.8 and 7.9. Tested on minimum subassembly battery system	P
21.2	A fully charged DUT (MOSOC per 8.1) shall have all of its modules/cells with the exception of one discharged to its specified fully discharged condition. The undischarged module/cell shall be discharged to approximately 50 % of its specified state of charge (SOC) to create an imbalanced condition prior to charging.		P

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Clause	Requirement + Test	Result - Remark	Verdict
21.3	The sample shall then be charged in accordance with the manufacturer's maximum normal charging specifications. Charging shall continue until end of charge conditions and the DUT reaches thermal equilibrium. The voltage of the partially charged module/cell shall be monitored during the charging to determine if its voltage limits are being exceeded. During the test, active protective devices shall be subjected to single fault conditions, unless the protective circuit has been tested for functionality in accordance with 7.9.		P
21.4	During the test, a detection method as outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations as determined necessary. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.		P
21.5	If the DUT is operational after the test it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications. See 12.2 for details regarding user resettable devices. An observation period per 8.5 is then conducted.		P
21.6	At the conclusion of the observation period, the DUT shall be subjected to an "as received" dielectric voltage withstand test in accordance with Section 22. The DUT shall be examined for signs of rupture and evidence of leakage.	No rupture and no leakage after Dielectric Voltage Withstand Test.	P
21.7	The maximum voltage limit of the module/cell shall not be exceeded when charging an imbalanced DUT. Also, the following in (a) – (h) are considered non-compliant results. For additional information on non-complying results refer to Table 12.1. a) E – Explosion; b) F – Fire; c) C – Combustible vapor concentrations; d) V – Toxic vapor release; e) S – Electric shock hazard (dielectric breakdown); f) L – Leakage (external to enclosure of DUT); g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3); h) P – Loss of protection controls.	No non-compliant result.	P
22	**Dielectric Voltage Withstand Test**		**P**

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Clause	Requirement + Test	Result - Remark	Verdict
22.1	This test is an evaluation of the electrical spacings and insulation at hazardous voltage circuits within the battery system.		P
22.2	Circuits exceeding 42.4 V peak or 60 Vdc shall be subjected to an electric strength test in accordance with UL 62368-1/CSA C22.2 No. 62368-1, Clause 5.4.9. *Exception: Semiconductors or similar electronic components liable to be damaged by application of the test voltage may be bypassed or disconnected.*		P
22.3	The test voltage shall be applied between the hazardous voltage circuits of the DUT and noncurrent carrying conductive parts that may be accessible and low voltage circuits separated from hazardous voltage circuits by reinforced or double insulation.	See table 22	P
22.4	The test voltage is also to be applied between the hazardous voltage charging circuit and the enclosure/accessible non-current carrying conductive parts of the DUT.		P
22.5	If the accessible parts of the DUT are covered with insulating material that may become live in the event of an insulation fault, then the test voltages are applied between each of the live parts and metal foil in contact with the accessible parts.		P
22.6	The test voltages shall be applied for a minimum of 1 min with the cells/modules disconnected to prevent charging during application of the voltage. Technologies that are required to be at an elevated operating temperature in order to be active, such as sodium-beta chemistries, shall be in a hot state prior to disconnection and applying the test potential.		P
22.7	The test voltages shall be applied for a minimum of 1 min between all the hazardous circuits of the battery and accessible parts or circuits. Technologies that are required to be at an elevated operating temperature in order to be active, such as sodium-beta chemistries, shall be in a hot state prior to disconnection and applying the test potential.		P

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Clause	Requirement + Test	Result - Remark	Verdict
22.8	If the battery system contains hygroscopic materials that may affect spacings, this test is repeated with the DUT or with the subassembly of the DUT containing the hygroscopic materials subjected to humidity conditioning of UL 62368-1/CSA C22.2 No. 62368-1, Clause 5.4.8. As a result of this testing, there shall be no dielectric breakdown as outlined in 22.7.	No hygroscopic material.	N/A
23	**Continuity Test**		**P**
23.1	This test evaluates the continuity of the protective grounding and bonding system of the battery system that is intended to provide an electrically conductive path from the point of a ground fault on a battery system or its representative parts or components through normally non-current-carrying conductors, equipment, or the earth to the electrical supply source.		P
23.2	An alternate test method outlined in 23.7 may be used if the construction of the protective grounding and bonding system adheres to the construction methods outlined in 7.6.5 – 7.6.7. If the connections means vary from that outlined in 7.6.6 and 7.6.7, the fault current method outlined in 23.3 – 23.6 is the default method for evaluating the suitability of the protective grounding system.	An alternate test method outlined in 21.7 conducted.	P
23.3	The grounding system of an battery system shall have no more than 0.1 Ω resistance between any two parts of the system that are measured in accordance with the continuity test of 23.4 and 23.5.		N/A
23.4	The voltage drop in a protective grounding system is measured after applying a test current of 200% of the rating of the overcurrent protection device rating, for a duration corresponding to 200% of the time-current characteristic of the overcurrent protection device. If the duration for 200% is not given, a point closest on the time-current characteristic shall be used. The overcurrent protective device limits the fault current in the protective grounding system, and is either provided in the battery system or external to the battery system and specified in the installation instructions. The supply used to provide the test current shall have a no load voltage not exceeding 60 Vdc.		N/A
23.5	The voltage drop measurement is made between any two conductive parts of the grounding system.		N/A

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Clause	Requirement + Test	Result - Remark	Verdict
23.6	The resistance shall be calculated from the measured voltage drop and current. The determined resistance shall be less than or equal to 0.1 Ω.		N/A
23.7	To check the continuity of the bonding connections, the resistance can be measured between two points on the bonding connections using a milli-ohmmeter. The measured resistance between any two bonding connections shall be less than or equal to 0.1 Ω.		P
24	**Failure of Cooling/Thermal Stability System**		P
24.1	The purpose of this test is to determine if the battery system can safely withstand a failure in the cooling/thermal stability system. *Exception: Testing may be conducted at a subassembly level if that is representative of the energy storage system.*	The product protected with over temperature.	P
24.2	The DUT shall be fully discharged to the manufacturer's end of discharge condition EODV and then conditioned at maximum specified operating ambient for a period of 7 h or until thermally stable per 8.3, whichever is shorter. While still in the conditioning chamber, the DUT, with its cooling/thermal stability system disabled shall then be charged at its maximum specified charge rate until completely charged or until operation of a protective device.		P
24.3	The DUT shall be fully charged (MOSOC per 8.1) and then conditioned at maximum specified operating ambient for a period of 7 h or until thermally stable per 8.3, whichever is shorter. While still in the conditioning chamber, the DUT, with its cooling/thermal stability system disabled shall then be discharged at the maximum discharge rate until it reaches its specified end of discharge condition or until operation of a protective device.		P
24.4	During the test, one of the detection methods outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.		P
24.5	If the DUT is operational after the test it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications. See 12.2 for details regarding user resettable devices. An observation period per 8.5 is then conducted.		P

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Clause	Requirement + Test	Result - Remark	Verdict
24.6	At the conclusion of the observation period, the DUT shall be subjected to an “as received” dielectric voltage withstand test per Section 22. The DUT shall be examined for signs of rupture and evidence of leakage.		P
24.7	The test method of 24.2 – 24.6 shall be repeated with the DUT conditioned at the minimum specified operating ambient.		P
24.8	As a result of the failure of cooling/thermal stability test, the following in (a) – (h) are considered non-compliant results. For additional information on non-complying results refer to Table 12.1. a) E – Explosion; b) F – Fire; c) C – Combustible vapor concentrations; d) V – Toxic vapor release; e) S – Electric shock hazard (dielectric breakdown); f) L – Leakage (external to enclosure of DUT); g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3); h) P – Loss of protection controls.		P
25	**Working Voltage Measurements**		**P**
25.1	This test is to measure the working voltage of a battery system.		P
25.2	The working voltage between live parts of opposite polarity, live and dead metal parts, live parts and a metal enclosure, and live and ground connections under both normal charging and discharging conditions as specified by the manufacture is measured.	See table 25	P
25.3	The dead metal parts and metal enclosure shall be assumed to be connected to the negative terminal of the system for testing purpose.		P
25.4	The values obtained during the measurements outlined in 25.2 shall be used to verify electrical spacings criteria per 7.5.		P
26	**Tests on Electrical Components**		**N/A**
26.1	**Locked-rotor test for low voltage dc fans/motors in secondary circuits**		**N/A**

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Clause	Requirement + Test	Result - Remark	Verdict
26.1.1	The purpose of this test is to determine if a low voltage dc fan or motor does not present a hazard in a locked rotor condition. Fans complying with UL 507 are considered to comply with this requirement without test.	No such components.	N/A
26.1.2	A sample of the fan or motor is placed on a wooden board, which is covered with a single layer of tissue paper, and the sample in turn is covered with a single layer of bleached cotton cheesecloth of approximately 40 g/m^2.		N/A
26.1.3	The sample is then operated at the voltage used in its application and with its rotor locked for 7 h or until steady conditions are established per 8.3, whichever is the longer.		N/A
26.1.4	There shall be no ignition of the tissue paper or cheesecloth.		N/A
26.2	**Input**		P
26.2.1	The input current draw of a control or accessory separate from the pack such as a mains supplied control or an accessory control evaluated independent from a system, shall be subjected to the input test of 24.2.2.		P
26.2.2	The current or watts input to an ac mains supplied unit, when connected to an ac supply adjusted to the test voltage specified in Table 24.1 shall not be more than 110% of the rated/specified value. The current or watts input draw of a dc supplied unit, when connected to a dc supply, shall not exceed the rated/specified value of the device.		P
26.3	**Leakage current**		P
26.3.1	For separate controls or other accessories of the system that are cord connected and supplied by ac mains circuits, the controls shall comply with the Protective Touch Voltage, Touch Current and Protective Conductor Current test of UL 62368-1/CSA C22.2 No. 62368-1, Clause 5.7.		P
26.4	**Strain relief test**		N/A
26.4.1	The purpose of this test is to determine if the strain relief means for a non-detachable accessible cord prevents damage or displacement upon being pulled.	No such parts.	N/A

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Clause	Requirement + Test	Result - Remark	Verdict
26.4.2	The battery system or accessory provided with a strain relief shall withstand without damage to the cord or conductors and without displacement, a direct pull of 156 N (35 lbf) applied to the cord for 1 min. Supply connections within the equipment shall be disconnected from terminals or splices during the test when applicable. If the strain relief is mounted in a polymeric enclosure or part, the test is conducted after the mold stress test after the part has cooled to room temperature.		N/A
26.4.3	As a result of the pull force, there was no damage or displacement of internal connectors. Inner conductors may not elongate more than 2 mm (0.08 in) from the pre-test position.		N/A
26.5	**Push-back relief test**		**N/A**
26.5.1	The purpose of this test is to determine if the strain relief of a non-detachable accessible cord provides adequate protection to connections and prevent hazardous displacement of internal wiring and connections as a result of push back.	No such parts.	N/A
26.5.2	A product shall be tested in accordance with 24.5.3 and 24.5.4 without occurrence of any of the following conditions: a) Subjecting the supply cord to mechanical damage; b) Exposing the supply cord to a temperature higher than that for which it is rated; c) Reducing spacings (such as to a metal strain-relief clamp) below the minimum required values; or d) Damaging internal connections or components.		N/A
26.5.3	The supply cord shall be held 25.4 mm (1 in) from the point where the cord or lead emerges from the product and is then to be pushed back into the product. When a removable bushing, which extends further than 25.4 mm (1 in) is present, the bushing shall be removed prior to the test.		N/A
26.5.4	When the bushing is an integral part of the cord, then the test shall be carried out by holding the bushing. The cord shall be pushed back into the product in 25.4-mm (1-in) increments until the cord buckles or the force to push the cord into the product exceeds 26.7 N (6 lbf).		N/A
26.5.5	The supply cord shall be manipulated to determine compliance with 24.5.1.		N/A

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Clause	Requirement + Test	Result - Remark	Verdict
26.5.6	If the strain relief is mounted in a polymeric enclosure or part, the test is conducted after the mold stress test after the part has cooled to room temperature.		N/A
26.6	**Low voltage transformer evaluation**		**N/A**
26.6.1	The purpose of this test is to determine that transformers located in low voltage circuits (i.e. ≤ 60 Vdc) do not present a fire hazard under overload conditions. Transformers complying with UL 1310 or equivalent standard and evaluated under overload conditions are considered to comply with these requirements without further testing.		N/A
26.6.2	If the tests in this section are conducted under simulated conditions on the bench, these conditions shall include any protection device that would protect the transformer in the complete equipment. Tests shall be conducted under ambient laboratory conditions. A sample of the transformer is placed on a wooden board, which is covered with a single layer of tissue paper, and the sample in turn is covered with a single layer of bleached cotton cheesecloth of approximately 40 g/m^2 (1.18 oz/yd^2).		N/A
26.6.3	If a transformer has more than one secondary winding or a tapped secondary winding, separate tests shall be conducted for each winding, or each section of a tapped winding, with the other windings loaded or unloaded as may occur in service unless it can be determined that one condition will produce the most unfavorable results.		N/A
26.6.4	A resistive load that will draw three times the normal input current or maximum obtainable output current, whichever is less, shall be connected directly to the transformer secondary winding with the transformer connected to the voltage of the circuit the transformer will be installed in. The transformer shall be operated continuously: a) Until ultimate conditions are observed, including opening of a thermal cutoff or a similar device; b) For 7 h if temperatures stabilize or cycling of an automatically reset protector occurs; or c) For 50 cycles of resetting a manually reset protector.		N/A
26.6.5	As a result of the overload test, there shall be no emission of molten metal or fire as evidenced by burning or charring of the cheesecloth indicator or tissue paper.		N/A

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Clause	Requirement + Test	Result - Remark	Verdict

27	**Electromagnetic Immunity Tests**	**CN23NX0R 001**	**P**
27.1	**General**		**P**
27.1.1	Active protective devices (e.g. battery management systems, solid state circuits, software controls, etc.) relied upon as the primary safety protection in 7.8 – 7.9 shall demonstrate sufficient immunity to electromagnetic interference by complying with the tests specified in 27.2 – 27.7. Alternate test procedures and levels specified in other standards may be used, but only if they are equivalent or more severe than the test procedures and levels specified below.		**P**
27.1.2	Each test shall begin with an operational DUT. The DUT may consist of only the battery management system, if that is the only part of the battery system that will be impacted.		P
27.1.3	During specific tests as indicated in 27.2 – 27.7, the DUT shall be subjected to a charge/discharge cycle in accordance with the manufacturer's specification. No non-compliant results as outlined in Table 12.1 shall occur during the charge/discharge cycle. *Exception: It is acceptable if the charge/discharge cycle is not completed at the conclusion of the test.*		P
27.1.4	After each test in 27.2 – 27.7, the DUT shall be inspected to verify that it is still operational and in compliance with Table 12.1. This may require Operational Verification (27.8) of the DUT if it is not possible to determine that it is fully operational by inspection. If the DUT is no longer operational, a failure analysis shall be conducted to determine the reason for the failure and to verify that the DUT has failed safely in accordance with Table 12.1. A DUT that is no longer operational shall not be used on any remaining test.		P
27.1.5	In addition, after all tests in this section have been completed, all samples used during the tests specified in 27.2 – 27.7 shall comply with the Operational Verification in 27.8.		P
27.2	**Electrostatic discharge**		**P**
27.2.1	The DUT shall demonstrate immunity to electrostatic discharges in accordance with the test procedure specified in IEC 61000-4-2.		P
27.2.2	The following test levels shall be used: a) ±6 kV contact discharge; and b) ±8 kV air discharge.		P
27.2.3	After the test, the DUT shall comply with 27.1.4.		P

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Clause	Requirement + Test	Result - Remark	Verdict
27.3	**Radio-frequency electromagnetic field**		**P**
27.3.1	The DUT shall demonstrate immunity to radio-frequency electromagnetic fields in accordance with the test procedure specified in IEC 61000-4-3.		P
27.3.2	The following test levels shall be used: a) 10 V/m from 80 MHz to 1 GHz, 1 kHz (80 % AM); and b) 3 V/m from 1.4 GHz to 6.0 GHz, 1 kHz (80 % AM).		P
27.3.3	During the test, the DUT shall comply with 27.1.3.		P
27.3.4	After the test, the DUT shall comply with 27.1.4.		P
27.4	**Fast transient/burst immunity**		**P**
27.4.1	The DUT shall demonstrate immunity to electrical fast transients/bursts in accordance with the test procedure specified in IEC 61000-4-4.		P
27.4.2	The following test levels in (a) **–** (c) shall be used. If the DUT has a DC power input port connected to an AC/DC converter such as a power supply or charger that is an integral part of the battery pack, the test shall be conducted on the AC input of the AC/DC converter using the test level specified in (c). Otherwise, the test shall be conducted on the DC power input port of the DUT using the test level specified in (b). a) On signal/control ports intended to be connected to cables longer than 3 m (118 in), ±1 kV (5/50 ns, 5 kHz); capacitive clamp shall be used; b) On input and output DC ports, ±1 kV (5/50 ns, 5 kHz); and c) On input and output AC ports, ±2 kV (5/50 ns, 5 kHz).		P
27.4.3	After the test, the DUT shall comply with 27.1.4.		P
27.5	**Surge immunity**		**P**
27.5.1	The DUT shall demonstrate immunity to surges in accordance with the test procedure specified in IEC 61000-4-5.		P

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Clause	Requirement + Test	Result - Remark	Verdict
27.5.2	The following test levels in (a) **–** (c) shall be used. If the DUT has a DC power input port connected to an AC/DC converter such as a power supply or charger that is an integral part of the battery pack, the test shall be conducted on the AC input of the AC/DC converter using the test level specified in (c). Otherwise, the test shall be conducted on the DC power input port of the DUT using the test level specified in (b). a) For I/O signal/control ports intended to be connected to long-distance cables longer than 30 m (98.4 ft), which leave the building, and/or are for outdoor use, ±1 kV line-to-ground; b) For input and output DC ports, ±0.5 kV line-to-line, and ±1 kV line-to-ground; and c) For input and output AC ports, ±1 kV line-to-line, and ±2 kV line-to-ground.		P
27.5.3	After the test, the DUT shall comply with 27.1.4.		P
27.6	**Radio-frequency common mode**		**P**
27.6.1	The DUT shall demonstrate immunity to radio-frequency conducted disturbances in accordance with the test procedure specified in IEC 61000-4-6.		P
27.6.2	The following test levels in (a) **–** (c) shall be used. If the DUT has a DC power input port connected to an AC/DC converter such as a power supply or charger that is an integral part of the battery pack, the test shall be conducted on the AC input of the AC/DC converter using the test level specified in (c). Otherwise, the test shall be conducted on the DC power input port of the DUT using the test level specified in (b). a) For I/O signal/control ports intended to be connected to cables longer than 3 m (118 in), 10 V (150 kHz to 80 MHz, 1 kHz, 80 % AM); b) For input and output DC ports, 10 V (150 kHz to 80 MHz, 1 kHz, 80 % AM); and c) For input and output AC ports, 10 V (150 kHz to 80 MHz, 1 kHz, 80 % AM).		P
27.6.3	During the test, the DUT shall comply with 27.1.3.		P
27.6.4	After the test, the DUT shall comply with 27.1.4.		P
27.7	**Power-frequency magnetic field**		**P**
27.7.1	The DUT shall demonstrate immunity to power-frequency magnetic fields in accordance with the test procedure specified in IEC 61000-4-8.		P
27.7.2	The test level of 10 A/m shall be used.		P

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Clause	Requirement + Test	Result - Remark	Verdict
27.7.3	During the test, the DUT shall comply with 27.1.3.		P
27.7.4	After the test, the DUT shall comply with 27.1.4.		P
27.8	**Operational verification**		**P**
27.8.1	After the tests in 27.2 **–** 27.7 have been completed, all samples used during these tests shall comply with the following.		P
27.8.2	The manufacturer shall declare the anticipated performance of all safety functions performed by active protective devices.		P
27.8.3	The manufacturer shall provide test procedures to verify that each of the safety functions performed by active protective devices is working correctly. This may include, for example, execution of a full charge/discharge cycle, or verification of correct safety function performance by simulation.		P
27.8.4	The test procedures specified in 27.8.3 shall be performed with each DUT in the following conditions: a) Fully-charged; and b) Fully-discharged.		P
27.8.5	During the test procedures specified in 27.8.3 **–** 27.8.4, each DUT shall exhibit one of the following behaviors: a) No loss of safety functions; or b) Transition to an appropriate state to ensure safe operation of the DUT. This could include a DUT that has lost its ability to charge or discharge as long as safety is maintained.		P
27.8.6	If redundant methods of protection are provided for a safety function to comply with 7.9.1, each method of protection shall be evaluated to determine if it functions as intended.		P
MECHANICAL TESTS			
28	**Vibration Test (LER Motive Applications and VAP Applications)**		**N/A**
28.1	The purpose of this test is to determine the battery system's resistance to anticipated vibration in LER motive and VAP installations and applies only to those systems intended for installation in these applications.		N/A

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
28.2	The sample shall be secured to the testing machine by means of a rigid mount, which supports all mounting surfaces of the sample. *Exception: The sample may be mounted within a mounting fixture representative of the intended end use application.*		N/A
28.3	The fully charged sample (MOSOC per 8.1) shall be subjected to a vibration test in accordance with the Simulated Long Life Testing at Increased Random Vibration Levels Tests of IEC 61373, for the appropriate Category and Class of equipment as determined by the intended rail installation. (Category and Class of equipment is defined in IEC 61373.) *Exception: Batteries intended for VAP applications shall be subjected to the Vibration Endurance Test of UL/ULC 2271 or UL/ULC 2580.*		N/A
28.4	The DUT shall be subjected to vibration in 3 mutually perpendicular directions. During the test the OCV of the DUT and temperatures on the center cell/module shall be monitored for information purposes.		N/A
28.5	During the test, one of the detection methods outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.		N/A
28.6	If the DUT is operational after the test it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications. See 12.2 for details regarding user resettable devices. An observation period per 8.5 is then conducted.		N/A
28.7	At the conclusion of the observation period, the DUT shall be subjected to an "as received" dielectric voltage withstand test in accordance with Section 22. The DUT shall be examined for signs of rupture and evidence of leakage.		N/A

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
28.8	As a result of the vibration test, the following in (a) – (h) are considered non-compliant results. For additional information on non-complying results refer to Table 12.1. a) E – Explosion; b) F – Fire; c) C – Combustible vapor concentrations; d) V – Toxic vapor release; e) S – Electric shock hazard (dielectric breakdown); f) L – Leakage (external to enclosure of DUT); g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3); h) P – Loss of protection controls.		N/A
29	**Shock Test (LER Motive Applications and VAP Applications)**		**N/A**
29.1	The purpose of this test is to determine the battery system's resistance to anticipated shock in LER motive and VAP installations and applies only to those systems intended for installation in these applications.	Battery system intended to be used in applications for stationary installation	N/A
29.2	The sample shall be secured to the testing machine by means of a rigid mount, which supports all mounting surfaces of the sample. During the test, temperatures on the center module are monitored for information purposes. Exception No. 1: This sample may be mounted within a mounting fixture representative of the intended end-use rail application. Exception No. 2: Batteries intended for VAP applications shall be subjected to the Shock Test of UL/ULC 2271 or UL/ULC 2580.		N/A
29.3	A fully charged sample (MOSOC per 8.1) shall be subjected to a shock test in accordance with IEC 61373 for the appropriate Category and Class of equipment as determined by the intended rail installation. (Category and Class of equipment is defined in IEC 61373.) *Exception: This test may be conducted at the module level if it can be shown that testing shall be representative of the battery system.*		N/A
29.4	Both positive and negative direction shocks shall be applied in each of 3 mutually perpendicular directions for a total of 18 shocks.		N/A

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Clause	Requirement + Test	Result - Remark	Verdict
29.5	During the test, one of the detection methods outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.		N/A
29.6	If the DUT is operational after the test it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications. An observation period per 8.5 is then conducted.		N/A
29.7	At the conclusion of the observation period, the DUT shall be subjected to an "as received" dielectric voltage withstand test in accordance with Section 22. The DUT shall be examined for signs of rupture and evidence of leakage.		N/A
29.8	As a result of the shock test, the following in (a) – (h) are considered non-compliant results. For additional information on non-complying results refer to Table 12.1. a) E – Explosion; b) F – Fire; c) C – Combustible vapor concentrations; d) V – Toxic vapor release; e) S – Electric shock hazard (dielectric breakdown); f) L – Leakage (external to enclosure of DUT); g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3); h) P – Loss of protection controls.		N/A
30	**Crush Test (LER Motive Applications and VAP Applications)**		**N/A**
30.1	This test is conducted on a fully charged battery system intended for LER motive and VAP applications to determine its ability to withstand a crush that could occur during an accident and applies only to those systems intended for installation in these applications.	Battery system intended to be used in applications for stationary installation	N/A

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Clause	Requirement + Test	Result - Remark	Verdict
30.2	A sample shall be crushed between a fixed surface and a ribbed test platen in accordance with the test fixture described in SAE J2464, with the following exceptions as noted below. Packs with 3 axes of symmetry, are subjected to 3 mutually perpendicular directions of press. A different sample of the DUT may be used for each crush. *Exception No. 1: The maximum force applied to the DUT shall be 100 ±6 kN.* *Exception No. 2: Battery systems with only 2 axes of symmetry, such as cylindrical designs are subjected to 2 mutually perpendicular directions of press.* *Exception No. 3: The DUT may be installed in a protective framework representative of what is provided in the end use application.* *Exception No. 4: A subassembly may be tested instead of a complete battery system if it can be demonstrated to be equivalent to testing a complete battery system.*		N/A
30.3	A detection method as outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations within the sample. Venting of gases may occur, but shall not exceed ERPG-2 levels using the measurement methods outlined in Section 13. The sample shall be subjected to an observation period and the examined.		N/A
30.4	As a result of the crush test, the following in (a) **–** (d) are considered non-compliant results. For additional information on non-complying results refer to Table 12.1. a) E **–** Explosion; b) F **–** Fire; c) C **–** Combustible vapor concentrations; d) V **–** Toxic vapor release;		N/A
31	**Static Force Test**		**P**
31.1	The purpose of this test is to determine if the enclosure has sufficient strength to safely withstand a static force that may be applied to it.		P

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
31.2	The enclosure of a fully charged DUT (MOSOC per 8.1) shall withstand a steady force of 250 N ±10 N for a period of 5 s, applied in turn to the top, bottom and sides of the enclosure fitted to the DUT, by means of a suitable test tool providing contact over a circular plane surface 30 mm (1.2 inch) in diameter. However, this test is not applied to the bottom of an enclosure having a mass of more than 18 kg (39.7 lbs). If the DUT is operational after completion of the application of the static force, it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications. An observation period per 8.5 is then conducted.		P
31.3	If deemed necessary (i.e. due to design of system and anticipation of venting of cells), one of the detection methods outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.		P
31.4	After the observation period, the DUT shall be subjected to an "as received" dielectric voltage withstand test in accordance with Section 22. The DUT shall be examined for signs of rupture and evidence of leakage.		P
31.5	As a result of the static force test, the following in (a) – (h) are considered non-compliant results. For additional information on non-complying results refer to Table 12.1. a) E – Explosion; b) F – Fire; c) C – Combustible vapor concentrations; d) V – Toxic vapor release; e) S – Electric shock hazard (dielectric breakdown); f) L – Leakage (external to enclosure of DUT); g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3); h) P – Loss of protection controls.		P
32	**Impact Test**		**P**
32.1	The purpose of this test is to evaluate the mechanical integrity of the enclosure and its ability to provide mechanical protection to the battery system contents.		P

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
32.2	A fully charged sample (MOSOC per 8.1) shall be subjected to a minimum of three impacts of 6.8 J (5 ft-lb) on any surface that can be exposed to a blow during intended use. The impact shall be produced by dropping a steel sphere, 50.8 mm (2 inches) in diameter, and weighing 535 g (1.18 lb) from a height, H, of 1.29 m (50.8 in). For surfaces other than the top of an enclosure, the steel sphere shall be suspended by a cord and swung as a pendulum, dropping through the vertical height of 1.29 m (50.8 in), with the product being impacted placed against a restraining vertical wall. See Figure 32.1. A different sample may be used for each impact.		P
32.3	If the DUT is operational after the impacts it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications. An observation period per 8.5 is then conducted.		P
32.4	During the test, one of the detection methods outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.		P
32.5	After the observation period, the DUT shall be subjected to an "as received" dielectric voltage withstand test in accordance with Section 22. The DUT shall be examined for signs of rupture and evidence of leakage.		P
32.6	As a result of the impact test, the following in (a) – (h) are considered non-compliant results. For additional information on non-complying results refer to Table 12.1. a) E – Explosion; b) F – Fire; c) C – Combustible vapor concentrations; d) V – Toxic vapor release; e) S – Electric shock hazard (dielectric breakdown); f) L – Leakage (external to enclosure of DUT); g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3); h) P – Loss of protection controls.		P
33	**Drop Impact Test**		**P**

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
33.1	Modules that are intended for field installation into rack mount or similar equipment are subjected to a drop impact test to determine that no hazard exists as a result of an inadvertent drop during installation or removal.		P
33.2	After being equilibrated at room temperature per 8.3, a fully charged module/component pack shall be dropped from a minimum height of 100 cm (39.4 in) for products weighing 7 kg (15.4 lbs) or less, 10 cm (3.9 in) for products weighing >7 kg (15.4 lbs), but less than 100 kg (220.5 lbs), and 2.5 cm (0.98 in) for products weighing > 100 kg (220.5 lbs), to strike a concrete or metal surface in the position most likely to produce adverse results and in a manner most representative of what would occur during maintenance and handling/removal of the battery system during installation and servicing. The orientation of the drop shall be determined by the testing personnel from an analysis of the installation and servicing instructions. If using a metal test surface, it should be provided with some manner of insulation such as insulating film that will prevent inadvertent short circuiting to the surface but will not affect test results.	660kg, 2.5cm	P
33.3	The sample shall be dropped a minimum of one time. However, if only one drop test is performed, it shall not be a flat drop. If one drop test is a flat drop, then at least one other test shall be performed that is not a flat drop.		P
33.4	The concrete surface shall be at least 76-mm (3-in) thick and the concrete or metal drop surface shall be large enough in area to cover the DUT.		P
33.5	After the drop, if the DUT is operational it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications. An observation period per 8.5 is then conducted.		P
33.6	At the conclusion of the observation period, an "as received" dielectric voltage withstand test in accordance with Section 22. The DUT shall be examined for signs of rupture and evidence of leakage.	No rupture and no leakage after Dielectric Voltage Withstand Test	P
33.7	A spark ignition source or gas monitoring as outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations within the sample immediately after the drop and repeated in the instance of increasing temperatures.		N/A

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Clause	Requirement + Test	Result - Remark	Verdict
33.8	As a result of the drop impact test, the following in (a) **–** (g) are considered non-compliant results. For additional information on non-complying results refer to Table 12.1. a) E **–** Explosion; b) F **–** Fire; c) C **–** Combustible vapor concentrations; d) S **–** Electric shock hazard (dielectric breakdown); e) L **–** Leakage (external to enclosure of DUT); f) R **–** Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3); and g) P **–** Loss of protection controls.	No non-compliant result	P
34	**Wall Mount Fixture/Support Structure/Handle Test**		P
34.1	A wall mounting apparatus of a wall mounted battery system, a battery support structure such as a stationary battery system rack, the support structure for a flow batteries stack(s), or a handle(s) provided for handling of a field/rack installed module/pack, shall have sufficient strength to support the battery system or allow for carrying of module/pack. Compliance is determined by the test below. *Exception: This test can be waived for a battery rack complying with UL 2416 and rated for the intended weight of the batteries to be supported.*	Battery support structure was evaluated	P
34.2	The wall mounting apparatus or other support structure and battery system shall be installed in accordance with the manufacturer's specifications. A force equal to three times the weight of the battery system is additionally applied to the center of the mounting apparatus or support structure in a downward direction. The force shall be held for 1 min. For modules/packs with a carrying handle(s), the DUT shall be supported by the carrying handles and a force equal to three times the weight of the DUT is additionally applied in a downward direction. If more than one carrying handle is provided, the added weight shall be distributed between the handles.		P

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
34.3	As a result of the applied force, there shall be no damage to the mounting apparatus or support structure and the securement means when testing the wall mounting fixture or supporting structure. As a result of the applied force, there shall be no damage to handles or the handle mounting/securement means of the DUT.		P
35	**Mold Stress Test**		**N/A**
35.1	The purpose of this test is to determine if an enclosure made from molded polymeric material can withstand an accelerated aging test without compromising the safety of the enclosure.	Metal enclosure used.	N/A
35.2	One complete fully discharged sample (discharged to the manufacturer's specified EODV) shall be placed in a full-draft circulating-air oven maintained at a uniform temperature of at least 10°C (18°F) higher than the maximum temperature of the enclosure measured during the Temperature and Operating Limits Check Test in Section 20, but not less than 70°C (158°F). The sample shall remain in the oven for 7 h.		N/A
35.3	After removal from the oven the DUT shall be subjected to an observation period per 8.5. After the observation period, the sample shall be subjected to an "as received" dielectric voltage withstand test in accordance with Section 22. The DUT shall be examined for signs of rupture and evidence of leakage.		N/A
35.4	As a result of the mold stress conditioning, the sample shall show no evidence of mechanical damage, such as cracking of the enclosure exposing hazardous parts or reducing electrical spacings or leakage of electrolyte from the enclosure.		N/A
36	**Pressure Release Test**		**N/A**
36.1	The purpose of this test is to ensure that the resettable pressure relief valve operates to prevent damage to the battery system and its electrolyte containment. This test is applicable to valve regulated technologies such as valve regulated lead acid batteries and for nickel systems with resettable relief valves.	No such components.	N/A
36.2	A sample of the battery/cell shall be submerged in a container of mineral oil. For large batteries only the pressure relief valve needs to be submerged.		N/A

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
36.3	A charging current shall be caused to flow at an increased rate (to be specified by the manufacturer) until bubbles are observed to rise from the pressure relief valve.		N/A
36.4	Results are acceptable if gas is released normally and the electrolyte containment system does not rupture or leak and the DUT's casing is not ruptured.		N/A
37	**Start-To-Discharge Test**		**N/A**
37.1	The purpose of this test is to determine the average start to discharge pressure of a resettable pressure relief valve not provided with an ASME stamp and rating.	No such components.	N/A
37.2	A calibrated pressure gauge having a range of at least 150% of the anticipated maximum working pressure of the pressure relief valve shall be installed to indicate pressures developed within the battery system during test.		N/A
37.3	To determine the start-to-discharge pressure setting of a pressure-relief valve, each of three samples of the valve shall be subjected three times to a gradually increasing air pressure. The pressure at which the valve begins to open shall be recorded. The start-to-discharge pressure setting of each sample is considered to be the average value of the three trials.		N/A
37.4	The start-to-discharge value mentioned in 37.3 is the highest average value for the three samples tested.		N/A
37.5	The start-to-discharge pressure shall be in the range of 90 – 100% of its assigned start-to-discharge pressure setting.		N/A
ENVIRONMENTAL TESTS			
38	**Thermal Cycling Test (LER Motive Applications and VAP Applications)**		**N/A**
38.1	This test determines the electrical energy storage system's ability to withstand temperature fluctuations that may be anticipated during the end-use application. This test is only applicable to LER motive applications and VAP applications.	Not used for LER Applications	N/A

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
38.2	A fully charged battery system (MOSOC per 8.1) shall be placed in a test chamber and subjected to the following cycles in (a) – (e). At the conclusion of the cycling, the samples shall remain at room temperature, 25 ±5°C (77 ±9°F) for 24 h. a) Raising the chamber-temperature to 75 ±2°C (167 ±3.6°F) within 30 min and maintaining this temperature for 6 h. b) Reducing the chamber temperature to 20 ±2°C (68 ±3.6°F) within 30 min and maintaining this temperature for 2 h. c) Reducing the chamber temperature to minus 40 ±2°C (minus 40 ±3.6°F) within 30 min and maintaining this temperature for 6 h. d) Raising the chamber temperature to 20 ±2°C (68 ±3.6°F) within 30 min. e) Repeating the sequence for a further 9 cycles. *Exception No. 1: Temperatures may need to be held for longer periods for those larger systems where temperature stabilization may take longer. The time required in this case for systems that require longer exposures should be based upon the time it takes for the temperature on internal cells within the DUT to reach thermal equilibrium per 8.3 plus 1 additional hour. This time shall never be less than the exposure times noted in (a) – (d) above.* *Exception No. 2: Testing may be conducted at a subassembly level if that is representative of the energy storage system.*		N/A
38.3	If the DUT is operational after the test, it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications. An observation period per 8.5 is then conducted.		N/A
38.4	During the test, one of the detection methods outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.		N/A
38.5	At the conclusion of the observation period, the sample is then subjected to an "as received" dielectric voltage withstand test in accordance with Section 22. The DUT shall be examined for signs of rupture and evidence of leakage.		N/A

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
38.6	As a result of the thermal cycling test, the following in (a) – (h) are considered non-compliant results. For additional information on non-complying results refer to Table 12.1. a) E – Explosion; b) F – Fire; c) C – Combustible vapor concentrations; d) V – Toxic vapor release; e) S – Electric shock hazard (dielectric breakdown); f) L – Leakage (external to enclosure of DUT); g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3); h) P – Loss of protection controls.		N/A
39	**Resistance to Moisture Test**		P
39.1	The purpose of this test is to determine that the battery system can safely withstand exposure to moisture anticipated in the end use.		P
39.2	With the DUT in its normal operating orientation, it shall be subjected to a moisture resistance test based upon its IP rating in accordance with IEC 60529 or CAN/CSA-C22.2 No. 60529. The battery system shall be installed and connected as intended for this test for the end use application. For batteries located where they may be subjected to flooding conditions, the IP rating will need to minimally cover immersion. If the DUT is operational after the conditioning, it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications. An observation period per 8.5 is then conducted. *Exception No. 1: Enclosures with Enclosure Type Ratings as identified in NFPA 70, Article 110, or Section 2 of C22.1, are subjected to the environmental testing outlined in UL 50E/C22.2 No. 94.2, rather than the IP Code.* *Exception No. 2: Testing may be conducted at a subassembly level if that is representative of the energy storage system.*	Battery room: IP55； Electrical room: IP55 Chiller control box: IP67	P

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
39.3	During the test, one of the detection methods outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations if venting of cells is anticipated. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.		P
39.4	At the conclusion of the observation period, the DUT shall be subjected to an “as received” dielectric voltage withstand test in accordance with Section 22. The DUT shall be examined for signs of rupture and evidence of leakage.		P
39.5	As a result of the resistance to moisture test, the following in (a) – (h) are considered non-compliant results. For additional information on non-complying results refer to Table 12.1. a) E – Explosion; b) F – Fire; c) C – Combustible vapor concentrations; d) V – Toxic vapor release; e) S – Electric shock hazard (dielectric breakdown); f) L – Leakage (external to enclosure of DUT); g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3); h) P – Loss of protection controls.		P
40	**Salt Fog Test**		**P**
40.1	This test determines the electrical energy storage system’s ability to safely withstand anticipated exposure to a salt fog conditions due to use near marine environments, and would apply to those stationary systems installed near sea environments whose internal components may be exposed to deterioration from salt fog through openings in the enclosure. This test would not apply to those systems not intended to be installed near marine environments as indicated in the installation instructions or whose enclosure is designed to prevent ingress of moisture with protection against corrosion (e.g. UL/NEMA 4X).		P

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
40.2	A fully charged electrical energy storage system (MOSOC per 8.1) shall be subjected to the test method per IEC 60068-2-52, with a severity level of 1 or 2 depending upon the application and location of installation. *Exception: A sample at the subassembly level that would be representative of the battery system may be used for this test.*		P
40.3	If the DUT is operational after the conditioning, it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications.		P
40.4	During the cycling, one of the detection methods outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations if venting of cells is anticipated. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the cycling per Section 13. An observation period per 8.5 is then conducted.		P
40.5	At the conclusion of the observation period, the DUT shall be subjected to an "as received" dielectric voltage withstand test in accordance with Section 22. The DUT shall be examined for signs of rupture and evidence of leakage.		P
40.6	As a result of the salt fog test, the following in (a) – (h) are considered non-compliant results. For additional information on non-complying results refer to Table 12.1. a) E – Explosion; b) F – Fire; c) C – Combustible vapor concentrations; d) V – Toxic vapor release; e) S – Electric shock hazard (dielectric breakdown); f) L – Leakage (external to enclosure of DUT); g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3); h) P – Loss of protection controls.		P
41	**External Fire Exposure for Projectile Hazards Test**		**N/A**

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
41.1	The purpose of this test is to determine that a battery system will not explode as evidenced by projectiles landing beyond the test perimeter as a result of being exposed to a hydrocarbon pool fire simulating an external fire exposure that may occur. *Exception No. 1: The battery system may be subjected to the External Fire Exposure Test in UL/ULC 2580 instead of the method outlined in 41.3.* *Exception No. 2: Testing may be conducted on a representative subassembly rather than a complete battery system if determined that equivalent results to testing a battery system can be obtained.* *Exception No. 3: If the secondary lithium cells employed in the system comply with the projectile test of* *Section E9, the system is exempted from this test. This test is not applicable to systems employing lead acid or similar monobloc aqueous electrolyte batteries.* *Exception No. 4: This test does not apply to systems intended for outdoor use only that are mounted on a non-combustible surface such as*	Projectile test evaluated at cells level according to Annex E	N/A
41.2	This test shall be conducted in a controlled setting free from the effects of wind or other environmental factors that may affect the test. The ambient temperature during the testing is to be within the range of 0 °C to 46 °C (32 °F to 114.8 °F).		N/A
41.3	A fully charged DUT at normal operating temperature is subjected to a hydrocarbon pool fire for 20 min. The fuel used shall be heptane or similar hydrocarbon fuel.		N/A
41.4	The pan, which provides the fire containment, shall be constructed of steel of sufficient thickness to prevent warping during the course of the 20-min test. The pan shall be sized in relation to the DUT and to accommodate the fuel and water levels. The walls of the pan shall not project more than 8 cm (3.1 in) above the level of the fuel at the start of the test. The pan dimensions shall be sized to ensure that the sides of the tested-device are exposed to the flame. The pan shall exceed the horizontal projection of the DUT by 20 to 50 cm (7.9 to 19.7 in).		N/A

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
41.5	There should be approximately 15.24 cm (6 in) of water in the pan prior to adding the hydrocarbon fuel to protect the fuel pan and to provide for consistent flame output during the test. The fuel shall be added as needed during the test to provide sufficient fuel for the test duration. The fire shall cover the whole area of the pan during whole fire exposure.		N/A
41.6	A suitable means to extinguish the fire in the fuel pan within 15 s, or remove the battery from above the fire, shall be provided. This may be accomplished by drawing a cover over the pan, or by moving the DUT from over the pan or removing the pan as putting the fire out may be difficult and should not be underestimated.		N/A
41.7	The DUT shall be fully supported and centered above the fire containment pan above the surface of the heptane. The DUT support structure shall be robust enough to withstand the weight of the DUT for the duration of the test without allowing the DUT to lean or topple. The pan shall be sized large enough to cover the dimension of the DUT, and shall be of a sufficient height so that the bottom surface of the DUT is approximately 50 cm (19.7 in) from the top fuel surface in the pan. See Figure 41.1 for details of set up.		N/A
41.8	During the test, the temperature of the cells or modules within the DUT may be monitored for information purposes.		N/A
41.9	After the 20-min fire exposure the fire shall be extinguished, and the DUT shall be subjected to a hose down in accordance with 41.10 to represent fire fighter response the system may be exposed to during a fire. At the conclusion of the hose down, there shall be a one hour observation period in accordance with 8.5.		N/A

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
41.10	The battery shall be subjected to a low impact hose stream delivered through a 38 mm (1-1/2 in) fog nozzle set at a discharge angle of 30° with a nozzle pressure of 517 kPa (75 psi) and a minimum discharge of 4.7 L/s (75 gpm). The tip of the nozzle shall be a maximum of 1.5 m (5 ft) from the center of the exposed surface of the DUT. The minimum duration of the low impact hose stream test shall be 6.5 s/m2 (0.60 s/ft2). The outer surface of the DUT shall be identified as the exposed area, as the hose stream must traverse this area during its application. To prevent potential for exposure to projectiles, the technician conducting the hose down portion of the test shall do so behind a protective barrier.		N/A
41.11	To determine that an explosion hazard has resulted, the DUT with pan fire test set up shall be centered within a circular inner perimeter marked on the floor with paint or a similar marking material. The marking shall be no wider than 12 mm (0.47 in) and the size of the circular inner perimeter area marking shall be no greater than 1.0 m (3.3 ft) from the outer edge of the longest side of the DUT.		N/A
41.12	For protection from projectiles during the test, the DUT, test set up, and inner perimeter marking shall be enclosed within a protective test chamber that can contain the projectiles or within an outer perimeter consisting of a protective barrier wall of a noncombustible material such as masonry or concrete and wall thickness suitable for containing projectiles during the test. The walls of the test chamber or the outer perimeter shall be located a minimum of 1.5 m (4.95 ft) from the inner perimeter marking to prevent the possibility of projectiles bouncing off the walls and back into the inner perimeter.		N/A
41.13	As a result of this test, there shall be no explosion of the DUT that results in projectiles falling outside of the circular inner perimeter described in 41.11. See Table 12.1 for additional details.		N/A
42	**Single Cell Failure Design Tolerance**		**P**
42.1	**General**		**P**

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
42.1.1	There have been field incidents with various battery technologies that have been attributed to a cell failure, which led to a hazardous event. The cell failures in these incidents were the result of either manufacturing defects or insufficient cell or battery design or a combination of both. Since there is a possibility that a cell may fail within a battery system, the battery system shall be designed to prevent a single cell failure from propagating to the extent that there is fire external to the DUT or an explosion.	UL 9540A evaluated and satisfied with UL 1973 requirement.	P
42.1.2	The cell failure mechanism used for this testing shall reflect what is known or anticipated to occur in the field for a given technology. If the cell failure mechanism cannot be exactly replicated, a close simulation of what is known to occur in the field through the use of an external stress such as applied heating or mechanical force shall be utilized for the test. Examples of methods to simulate a single cell failure are outlined in Appendix F. Multiple tests and possible multiple failure methods may need to be conducted as part of the analysis before a final methodology for testing is determined.		P
42.2	**Single cell failure design tolerance (lithium ion)**		**P**
42.2.1	A lithium ion battery system shall be designed to mitigate a single cell failure leading to a thermal runaway of that cell. With lithium ion batteries, it is often the effects of propagation to surrounding cells due to the heating effect of the initial cell failure that leads to hazardous events. The DUT (e.g. battery pack or module) shall be designed to prevent a single cell thermal runaway failure from creating a significant hazard as evidenced by fire propagation outside of the DUT and/or an explosion.		P
42.2.2	Any number of methods can be used to produce a single cell thermal runaway failure. For example, thermal runaway in cells can be achieved through the use of heaters, nail penetration, overcharge, etc. The testing agency is responsible for selecting and demonstrating an appropriate method for inducing thermal runaway. It is recommended to evaluate a candidate method first using a small subassembly of cells to evaluate the cell failure and effects to surrounding cells. During an effort to establish a suitable failure method, temperatures should be taken on the cell casings, and voltages measured for information purposes. See Appendix F for guidance on several methods of inducing cell failure. The method chosen shall be agreed upon by the testing agency.	Heater used	P

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
42.2.3	The details of the method used when analyzing the cell's reaction that can impact the results are to be documented. For example, if heating the cell to achieve failure: e.g. the type of heater and its dimensions, location on the cell where the heater is placed and how it is placed, maximum temperature attained including temperature ramp rate, length of time until reaction, temperatures on cell and voltage, state of charge of the cell at the beginning of the heating phase, etc. The test article shall be representative of the actual battery configuration and any modifications should not significantly impact the test results. For example, if overcharge is to be carried out, the heat conduction path between tabs shall not be hindered as that may reduce the severity of the test.		P

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
42.2.4	Once a suitable method of cell failure has been determined, the fully charged DUT (MOSOC per 8.1) shall be subjected to the single cell failure tolerance test, which consists of inducing a fault in one internal cell that is within the DUT, until cell failure resulting in thermal runaway as defined in 6.58 occurs, and determining whether or not that failure produces a significant external hazard or whether or not that failure does not cause the failure of neighboring cells. If cascading occurs, the cascading shall not propagate beyond the DUT. Prior to choosing the specific cell to fail, an analysis of the DUT design to determine the cell location considered to have the greatest potential to lead to a significant external hazard shall be conducted, taking into consideration the cell's proximity to other cells and materials that may lead to potential for propagation. If it can impact the results, the sample shall be at the maximum specified temperature during charging and operation with some tolerance as necessary for movement of the sample outside of the chamber during testing, but within ±5°C (±9°F). Once the thermal runaway is initiated, the mechanism used to create thermal runaway is shut off or stopped and the DUT is subjected to a 24-h observation period. *Exception No. 1: Testing may be repeated on another sample with a cell in a different location within the DUT if it is not clear which location represents the worst case scenario. The location of the failed cell shall be documented for each test.* *Exception No. 2: Testing may be conducted on a representative subassembly consisting of one or more modules and surrounding representative environment, if it can be demonstrated that there is no propagation beyond the subassembly. When testing at the module or subassembly level, consideration needs to be made of the vulnerability to combustion of those components surrounding the module in the final assembly. Temperatures on DUT external surfaces and surfaces of parts in contact with or near the DUT in the final assembly, shall be monitored to determine if excessive temperature on these adjacent parts could result in a potential for propagation within the full battery system. If there are excessive temperatures on the surfaces that may lead to potential for propagation, testing shall be repeated with all adjacent components in place of a complete battery system.*	Heater used. Testing conducted on a subassembly battery module	P

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
42.2.5	Temperatures on the failed cell and surrounding cells are to be monitored and reported for information purposes.		P
42.2.6	As a result of the testing of 42.2, there shall be no fire propagating from the DUT or explosion of the DUT.		P
42.3	**Single cell failure design tolerance (other technologies)**	**Lithium-ion cell.**	**N/A**
42.3.1	Other technologies such as lithium metal, sodium sulfur, sodium nickel chloride, and lead acid where there may not be enough field data regarding their tolerance to single cell failure events, are to be subjected to a single cell failure test method similar to 42.2, except as modified as noted below. The failure mechanism for these technologies may be different than that of lithium ion and thermal runaway may or may not result from the cell failure. Similar to lithium ion, when choosing a cell failure technique, it should be representative of what can occur in the field for the particular technology. The failure mechanism chosen shall consider failures due to potential cell manufacturing defects for that technology and/or cell and battery design deficiencies that could lead to latent failures of the cell, and that would not be evident under the individual cell safety testing.		N/A
42.3.2	For other technologies, similarly as with lithium ion, it is recommended to evaluate a candidate method first using a small subassembly of cells to evaluate the cell failure and effects to surrounding cells. During an effort to establish a suitable failure method, temperatures should be taken on the cell casings, and voltages measured for information purposes. See Appendix F for guidance on several methods of inducing cell failure. The method chosen shall be agreed upon by the testing agency.		N/A

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
42.3.3	When a suitable worse case representative method for cell failure has been determined, the DUT is to be subjected to the internal cell failure occurring in the location within the DUT considered most vulnerable to the potential for propagation. The DUT shall be in a condition that reflects its operating parameters at the worst moment such a failure could occur. For example, the DUT shall be at its nominal operating temperature. During the test, temperatures shall be monitored in critical locations such as adjoining cells during the test to record the rise in temperature due to the internal failure. If no thermal runaway occurs as a result of the single cell failure, the test is stopped when the DUT temperature has stabilized or reaches ambient room temperature, and the DUT is subjected to a 24-h observation period. If a thermal runaway is initiated, the mechanism used to create thermal runaway is shut off or stopped and the DUT is subjected to a 24-h observation period. *Exception No. 1: Testing may be repeated on another sample with a cell in a different location within the DUT if it is not clear which location tested represented the worst case scenario. The location of the failed cell is to be documented for each test.* *Exception No. 2: Testing may be conducted on a representative subassembly consisting of one or more modules and surrounding representative environment, if it can be demonstrated that there is no propagation beyond the subassembly. When testing at the module or subassembly level, consideration needs to be made of the vulnerability to combustion of those components surrounding the modules in the final assembly.*		N/A
42.3.4	As a result of the testing per 42.3.3, there shall be no fire propagating from the DUT or explosion of the DUT.		N/A
42.3.5	Temperatures on the failed cell and surrounding cells, external enclosure surfaces of the DUT and the supporting surface are to be monitored and reported for information purposes. The number of cells that fail due to propagation from the triggering cell shall be documented.		N/A
MANUFACTURING AND PRODUCTION LINE TESTS			
43	**General**		**P**

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
43.1	Manufacturers of battery systems shall have documented production process controls in place that continually monitor the following key elements of the manufacturing process that can affect safety, and shall include corrective/preventative action to address defects found affecting these key elements: a) Supply chain control; and b) Assembly processes.		P
43.2	Battery systems shall be subjected to 100 % production screening to determine that any active controls utilized for safety are functioning. *Exception: This check of the safety controls can be conducted on subassemblies or components of the system before final assembly.*		P
43.3	An "as received" dielectric voltage withstand test as outlined in the Dielectric Voltage Withstand Test, Section 22 shall be conducted on 100 % production of Assemblies/packs with circuits exceeding 60 Vdc or 42.4 V peak as outlined in Section 22. *Exception: The time for the test may be reduced to 1 s if the test voltage values are increase by 2.4 times the values in Section 22 or as outlined in the routine test criteria of the Electric Strength Test of UL 62368-1/CSA C22.2 No. 62368-1, Clause 5.4.9.*		P
43.4	A continuity check of the grounding system using a milliohmmeter or other method, shall be conducted on 100 % production employing protective grounding. The continuity check shall determine that measurements made on any two points of the grounding system do not exceed 0.1 Ω.		P
43.5	Each resettable non-ASME coded pressure-relief valve shall be tested by the manufacturer for the start-to-discharge pressure by subjecting the pressure-relief valve to a gradually increasing air pressure until the valve begins to open. The start-to-discharge pressure shall be in the range of 90 – 100 % of its rated start-to-discharge pressure rating.		N/A
MARKINGS			
44	**General**		**P**

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
	Advisory Note: In Canada, there are two official languages. Therefore, it is necessary to have CAUTION, WARNING, and DANGER instructions and markings in both English and French. Annex G lists acceptable French translations of the CAUTION, WARNING, and DANGER instructions and markings specified in this Standard. When a product is not intended for use in Canada, instructions and markings may be provided in English only.		P
44.1	Required markings shall be permanent. Examples of permanent marking are ink stamping, engraving and if adhesive labels, compliance to UL 969 or CSA C22.2 No. 0.15 for the surface adhered and conditions of use. Markings required by this standard including nameplate markings per 44.2 and any cautionary markings shall be legible, provided in text color that contrasts with the background color and visible upon installation of the battery system.	The marking was printed on the sheet-metal on the enclosure	N/A
44.2	Batteries shall be marked with the manufacturer's name, trade name, trademark or other descriptive marking which may identify the organization responsible for the product, part number or Model number, and electrical ratings in volts dc and capacity in Ampere-hours or Watt-hours and chemistry. The battery system terminals shall be marked to indicate whether they are positive (+) or negative (-). The battery shall also be marked with its IP rating.		P
44.3	Batteries and Battery systems using repurposed batteries in accordance with 7.13, shall be marked “Repurposed” or “Second Life” and “UL 1974”.	No repurposed batteries used.	N/A
44.4	Battery systems shall be marked with the maximum short circuit current and duration (at maximum short circuit current) at the system output terminals.	Marked on the battery system label	N/A
44.5	Battery systems shall also be marked with the date of manufacture, which may be in the form of a code that does not repeat within 20 years.		P
44.6	A battery system intended for use with specific chargers shall be marked with the following or equivalent: "Use Only ( ) Charger".		P
44.7	A battery system evaluated for protection against ingress of moisture per 7.3.5, shall be provided with the appropriate IP Code rating.	Battery room: IP55； Electrical room: IP55 Chiller control box: IP67	P

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
44.8	Systems shall be marked with a cautionary marking indicating to read all instructions before installation, operation and maintenance of the system. This marking may be in the form of the symbol(s) for example: ISO 7000, “caution” Symbol No. 434 (exclamation point inside triangle) followed by the “read instruction manual” Symbol No. 790 (open book). If using symbols, their meaning shall be explained in the instruction manual.	Symbol used.	P
44.9	Systems that must be operated in a certain orientation for safe operation, shall be provided with markings indicating the correction orientation of the system.		P
44.10	Systems shall be marked with a warning marking indicating risk of electrocution near hazardous voltage battery terminals.		P
44.11	Systems with replaceable fuses, shall be marked with rating and type of fuse for replacement. The marking shall be located near the fuseholder.		N/A
44.12	Separable accessories and controls which are intended for connection to the mains supply shall be provided with markings that include the manufacturer’s name, part number of the accessory and electrical ratings in voltage, frequency, phase if applicable, and current or watts.	See user manual	P
44.13	A ground terminal shall be marked as outlined in 7.6.8.		P
44.14	Additional warning markings for battery systems located in restricted access locations such as warnings regarding hazardous moving or electrical parts, hot surfaces, etc., to alert service or other trained personnel and prevent hazards, shall be provided on the battery systems in locations where they will be visible those persons having access to the location.	Rely on final system, See user manual and installation instruction.	N/A

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
44.15	With reference to 7.12.2, a secondary lithium cell shall be legibly and permanently marked with: a) The manufacturer's name, trade name, or trademark or other descriptive marking by which the organization responsible for the product may be identified; b) A distinctive catalog, model or designation number or the equivalent; and c) The date or other dating period of manufacture not exceeding any three consecutive months. *Exception No. 1: The manufacturer's identification may be in a traceable code if the product is identified by the brand or trademark owned by a private labeler.* *Exception No. 2: The date of manufacture may be abbreviated; or may be in a nationally accepted conventional code or in a code affirmed by the manufacturer, provided that the code:* a) Does not repeat in less than 10 years; and b) Does not require reference to the production records of the manufacturer to determine when the product was manufactured.		P
44.16	With reference to 44.15, if a manufacturer produces a cell at more than one factory, each cell shall have a distinctive marking to identify it as the product of a particular factory.		P

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
44.17	Required markings for single cells and multi-cell/monobloc vented and valve regulated lead acid and nickel cadmium batteries shall be legibly and permanently marked in accordance with 44.1 with the following included: a) The manufacturer's name, trade name or trademark, model designation, and month and year of manufacture; *Exception: The date of manufacture may be in the form of a code that does not repeat in 10 years.* b) The statement "Warning: Risk of fire, explosion, or burns. Do not disassemble, heat above XX °C (or °F), or incinerate." (Where XX is the cell or battery's maximum temperature specification.) *Exception: This statement may be included in the instructions provided with the cell or battery, rather than be marked on the battery.* c) Battery type (e.g. valve regulated lead-acid battery) and rated nominal voltage and capacity; and d) Positive and negative leads or terminals indicated by (+) and (−).		N/A
INSTRUCTIONS			
45	**General**		**P**
45.1	Components of a battery system shall be provided with a complete set of instructions for proper installation and use in a battery system. These instructions shall include normal operating specifications.		P

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Clause	Requirement + Test	Result - Remark	Verdict
45.2	Systems shall be provided with complete instructions for installation in the end use application. Installation instructions shall include the following along with any other instructions necessary for the safe and correct installation of the system and its accessories in the intended end use:		P
	a) Insulated tools, insulated gloves, personal protective equipment, and clothing and other measures necessary for safe installation of the battery system;		
	b) The necessary housing requirements for protection against ingress of moisture and debris or access by persons;		
	c) Ventilation requirements to prevent accumulation of hydrogen greater than 25 % of hydrogen LFL;		
	d) Protective components and devices required in the end use installation such as fuses, circuit breakers, wiring, and other devices such as disconnect devices in accordance with NFPA 70 or C22.1. See 7.9.9;		
	e) Circuit diagrams and instructions for proper connection of the system and any ancillary devices such as separate controllers, monitoring devices, etc.;		
	f) Warnings and instructions regarding the battery electrolyte;		
	g) Instructions regarding any commissioning tests and checks necessary before placing system into service;		
	h) Table or list, etc. of symbols used and their meanings;		
	i) The necessary information to complete an arc flash/blast analysis, including bolted fault current (IBF), 1/2 bolted fault current (1/2 IBF), protective device clearing time, and protective device current interrupt capability at a minimum, if applicable to the system; and		
	j) If applicable, the manufacturer shall provide information on design considerations for maximum		
	and minimum system configurations, such as number of modules installed in series, maximum resistance, and maximum inductance to prevent arc flash incident energy from exceeding the requirements of Personal Protective Equipment Category 4 per NFPA 70E or CSA Z462-15.		

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
45.3	Battery systems intended for installation in a restricted access location per 6.51 shall have installation instructions indicating this with instructions defining the type of location required, its restrictions, signage and other information to be provided.	Rely on Final System.	N/A
45.4	A system shall be provided with instructions for the proper use including charging and discharging, storage, recycling and disposal. These instructions shall include temperature limits, charging and discharging limits as well as instructions regarding the use of any controls or monitoring systems.		P
45.5	A system shall include the following statements or equivalent: a) An attention word, such as "DANGER," "WARNING," or "CAUTION." b) A brief description of possible hazards. c) A list of actions to take to avoid possible hazards regarding disposal of the system such as do not crush, disassemble, dispose of in fire, or similar actions.		P
45.6	The system shall be provided with a maintenance manual that includes a schedule for maintenance of the system and accessories including a check of wiring and connections, etc. The maintenance manual shall include necessary safety precautions regarding handling or conducting maintenance on the system and its connections and accessories.		P
45.7	Cells shall be provided with a complete set of instructions that include operating region specifications for charging and discharging including current temperature range and voltages, installation instructions, storage of batteries and disposal instructions. Guidance on cell specification information that should be provided on cells can be found in the Cell Specification Sheet, Annex E of IEEE 1625.		P
45.8	The installation instructions for vented and valve regulated lead acid and nickel cadmium batteries shall indicate that the batteries and components of the battery systems shall be installed in accordance with Article 480 or 706 of NFPA 70 or Section 64 of CSA C22.1.		N/A

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
45.9	Installation instructions for vented and valve regulated lead acid and nickel cadmium batteries shall indicate that the charging system for these batteries shall prevent charging outside of the battery specifications through the use of voltage (and temperature for VRLA) monitoring and controls, or both current and temperature monitoring and controls. The system may also use current monitoring to prevent out of condition specifications. The instructions shall indicate that chargers shall comply with UL 1012, UL 1741, UL 60335-2-29/CSA C22.2 No. 60335-2-29, CAN/CSA C22.2 No. 107.2, or UL 62368-1/CSA C22.2 No. 62368-1. Instructions for the battery system shall provide information on a specific charger to be used with the battery system if the charger is relied upon to maintain the battery system safety.		N/A
45.10	The instructions for vented and valve regulated lead acid and nickel cadmium batteries shall indicate that battery systems exceeding 60 Vdc shall be provided with a disconnecting means for all ungrounded conductors in accordance with Article 480 of NFPA 70 or Section 64 of CSA C22.1.		N/A
45.11	Installation instructions for single cells and multi-cell/monobloc vented and valve regulated lead acid and nickel cadmium batteries shall be provided with instructions indicating that service disconnects shall be provided as applicable to the end product battery system in accordance with Article 480 of NFPA 70 or Section 64 of CSA C22.1.		N/A
45.12	Installation instructions for vented and valve regulated lead acid and nickel cadmium multibattery/cell systems shall include the short circuit current output from the battery system rather than the marking of 44.4.		N/A
45.13	Vented lead acid or nickel cadmium cell and battery installation instructions shall indicate the need for spill control in accordance with the building, fire and installation codes.		N/A
45.14	The instructions for vented and valve regulated lead acid and nickel cadmium cells and batteries shall indicate that ventilation to address any hydrogen off gassing shall be in accordance with the local fire and installation codes.		N/A
45.15	The instructions for open rack vented and valve regulated lead acid and nickel cadmium battery systems shall indicate that these racks shall be installed in restricted access locations or be installed within a protective enclosure that prevents access in accordance with the end use application.		N/A

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
45.16	Instructions for vented and valve regulated lead acid and nickel cadmium cells and batteries shall indicate recommended wiring for battery connections, the minimum clearance between cells and batteries on the racks and any type of protection device.		N/A
45.17	Instructions for vented and valve regulated lead acid and nickel cadmium cells and batteries shall include maintenance instructions for maintaining the cells and batteries in safe operating condition through the life of the cell and battery including electrolyte maintenance if applicable, examination of terminals and casings for damage, etc.		N/A
45.18	If lead acid and nickel cadmium cells and batteries are intended for installation in an end use that utilizes protective grounding, the installation instructions shall recommend that the grounding and bonding system be checked after the completion of the assembly to ensure that the resistance is less than or equal to 0.1 Ω.		N/A
45.19	The instructions provided with lead acid and nickel cadmium cells and batteries shall indicate the maximum voltage of the end use system they can be installed in. If the voltage in the end use is exceeded, then the instructions shall recommend a repeat of the dielectric voltage withstand test of the assembly for the higher voltage.		N/A
Appendix A Standard for Components			
A1	**Standards for Components**		**P**
A1.1	The CSA Group and UL standards listed below are used for evaluation of components and features of products covered by this standard. Components shall comply with all the applicable CSA Group and UL component standards. These standards shall be considered to refer to the latest edition and all revisions published to that edition.	See appended table Critical components.	P
Appendix B Test program for sodium-beta battery cells			
B1	**General**		**N/A**
APPENDIX C Test program for flowing electrolyte batteries			
C1	**General**		**N/A**
APPENDIX D Metal compatibility table			
D1	**General**		**N/A**
D1.1	For combinations that fall above the line in Table D.1, an evaluation on the parts can be conducted to determine suitability. Protection methods such as coatings can be used, but will need to be evaluated.		N/A

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Clause	Requirement + Test	Result - Remark	Verdict
D1.2	The evaluation method shall consist of a comparison of the part to evaluate with a similar part using construction that is below the line of Table D.1, after corrosion conditioning such as a salt fog conditioning in accordance with ASTM B117, ISO 9227 or similar method. Measurements of the properties of the connection parts (design under consideration as well as comparison design) under test shall be made before and after conditioning with a comparison of the results. Properties to measure will depend upon the part being evaluated, but could include resistance, temperatures on the part during operation, or bond/mechanical strength as applicable to the type of connection.		N/A
D1.3	The deterioration of the devices under evaluation shall not result in unacceptable properties (i.e. reduced performance that would result in malfunction of the connection) nor shall the deterioration be greater than that of the comparison design.		N/A
D1.4	As another approach, a coating with known properties, such as one evaluated to UL 546, along with sealing the area to prevent moisture exposure can be used to establish acceptable protection against galvanic corrosion without additional evaluation.		N/A
APPENDIX E Cell Test Program			
E1	**General**	Certified Lithium ion cell used with UL1973: 2022	**N/A**
E1.1	The following shall be used to evaluate lithium ion cells or other secondary lithium cells.		N/A
E1.2	Samples used for testing shall be representative of production. The number of samples used for each test and the pass/fail criteria for testing is outlined in Table E.1. As an alternate, the lithium ion cell test program outlined in Sections E10 – E11 may be used		N/A
E1.3	Prior to conditioning in E1.4, two samples from the total set of samples as representative samples shall be subjected to the capacity check per E2.2 to confirm the capacity of the samples is correct.		N/A

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Clause	Requirement + Test	Result - Remark	Verdict
E1.4	Prior to testing, the samples shall be conditioned by first discharging them down to the manufacturer's specified end point voltage and then charging them to the manufacturer's specified upper limit charging voltage using the manufacturer's specified maximum charging current. Samples shall be charged at the upper temperature limit of the charging operating region and the lower limit of the charging operating region for those tests as identified in Table E.1. During charging, a minimum of one temperature is measured on the surface of the cell centered on the cell. For prismatic cells, this would be on the largest flat surface.		N/A
E1.5	Some lithium cells are capable of exploding when the tests described in this Annex are conducted. It is important that personnel be protected from the flying fragments, explosive force, sudden release of heat, and noise that results from such explosions. The test area shall be well ventilated to protect personnel from possible harmful fumes or gases.		N/A
E1.6	As an additional precaution, the temperatures on the surface of the cell casings shall be monitored in accordance with E1.7 during the tests described in this Annex. All personnel involved in the testing of lithium cells shall be instructed never to approach a lithium cell while the surface temperature exceeds 90 °C (194 °F) and not to touch the lithium cell while the surface temperature exceeds 45 °C (113 °F).		N/A
E1.7	In accordance with E1.6, the surface temperatures of the cell casing shall be measured as follows: a) By thermocouples consisting of wires not larger than 0.21 mm2 (24 AWG) and not smaller than 0.05 mm2 (30 AWG) and a potentiometer-type instrument; and b) The temperature measurements on the cells shall be made with the measuring junction of the thermocouple held tightly against the metal casing of the cell. *Exception: Placing the thermocouple on a thin piece of paper or label is an acceptable practice.*		N/A
E1.8	For protection, the Projectile Test in E9 shall be conducted in a room separate from the observer or within an appropriate containment chamber.		N/A
E2	**Preconditioning and Capacity Check**		**N/A**
E2.1	**Preconditioning**		**N/A**

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
E2.1.1	The charge/discharge cycling preconditioning in E2.1.2 shall be done before testing and conducted on secondary lithium metal (i.e. lithium metal anode) cells. Lithium ion cells need not be subjected to charge/discharge cycle preconditioning.		N/A
E2.1.2	Secondary lithium metal (i.e. lithium metal anode) cells shall be conditioned at 25 °C ±5 °C (77 °F ±9 °F). The cells shall be continuously cycled as specified by the manufacturer. The specification shall be such that the full rated capacity of the cell is utilized and the number of cycles accumulated shall be at least equal to 25 % of the advertised cycle life of the cell or cycled continuously for 90 days, whichever is shorter. Cycling shall be done either individually or in groups. Cells shall be recharged prior to testing.		N/A
E2.2	**Capacity check**		**N/A**
E2.2.1	Prior to conducting testing, the capacity of the lithium ion and lithium metal cells to be tested shall be checked in accordance with E2.2.2 – E2.2.5 by selecting two samples from the total set of samples.		N/A
E2.2.2	For secondary lithium metal (i.e. lithium metal anode) cells, this capacity check shall be conducted on preconditioned secondary lithium metal cells per E2.1. *Exception : For secondary lithium metal cells subjected to preconditioning per E2.1, the capacity check may be conducted during the preconditioning of these secondary lithium metal cells by checking the discharged capacity during the first few cycles. This capacity confirmation may be done in the manufacturer shipping inspection by checking the capacity discharge curve shipped with the samples.*		N/A
E2.2.3	The cell shall be discharged at 25 °C ±5 °C (77 °F ±9 °F) at a constant current of 0.2C rate, down to a specified end of discharge voltage. The cell shall then be charged in a room ambient temperature, 25 °C ±5 °C (77 °F ±9 °F), at charging parameters specified by the manufacturer until fully charged. The cell shall then be allowed to stabilize at room ambient per 6.52.		N/A
E2.2.4	With the cell in the fully charged condition, the cell shall be discharged at a constant current discharge in accordance with the cell manufacturer's specifications down to the end of discharge voltage. The duration of the discharge shall be monitored and the measured capacity of the cell shall be calculated to three significant figures.		N/A

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
E2.2.5	For cells to be used for the test program outlined in this Annex, their measured capacity shall equal or exceed the rated specifications. All samples shall be subjected to the capacity check test if any representative sample does not meet this criteria. The cells not meeting this criteria shall be excluded from testing.		N/A
E3	**Short Circuit**		**N/A**
	Fully charged, conditioned cells are stored in an ambient temperature of 25 °C ±5 °C (77 °F ±9 °F) until their casing reaches ambient temperature, and then subjected to a short circuit condition using an external resistance of ≤ 20 mΩ. The external resistance shall be applied to the cell terminals for 7 h or until temperatures on the cell cool to within ±10 °C (18 °F) of ambient conditions.		N/A
	Compliance criteria: No fire, no explosion.		N/A
E4	**Cell Impact**		**N/A**
	Fully charged, conditioned cells shall be subjected to an impact test as outlined in E11.4. The cells shall be at an ambient temperature of 25 °C ±5 °C (77 °F ±9 °F) prior to testing.		N/A
	Compliance criteria: No fire, no explosion.		N/A
E5	**Drop Impact**		**N/A**
	Fully charged cells shall be dropped three times from a height of 1 m (3.3 ft) onto a flat concrete or metal surface. The cells shall be at an ambient temperature of 25 °C ±5 °C (77 °F ±9 °F) prior to testing.		N/A
	The cells shall be dropped in a manner that the impacts occur in random orientations. After completion of the impacts, the cells shall be subjected to a minimum one hour observation period before being examined.		N/A
	Compliance criteria: No fire, no explosion.		N/A
E6	**Heating**		**N/A**
	Fully charged, conditioned cells shall be subjected to a heating test as outlined in E11.7.		N/A
	Compliance criteria: No fire, no explosion.		N/A
E7	**Overcharge**		**N/A**

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Clause	Requirement + Test	Result - Remark	Verdict
	Fully charged conditioned cells shall be discharged in accordance to manufacturer's specifications down to the specified end point voltage. The test is conducted in an ambient of 25 °C ±5 °C (77 °F ±9 °F) and with the cell casing at an ambient of 25 °C ±5 °C (77 °F ±9 °F) at the start of the test. The voltage and temperature of the cell shall be monitored during the test. The cells are charged with a constant current at the maximum specified charge current until the voltage of the cell reaches 120 % of the maximum specified charge voltage value or 130 % State of Charge (SOC), whichever is reached first. The charge is then terminated while the cell temperature continues to be monitored. The test is concluded when the cell temperature drops and returns to ±10 °C (18 °F) of the test ambient.		N/A
	Compliance criteria: No fire, no explosion.		N/A
E8	**Forced Discharge**		**N/A**
	Fully charged cells shall be discharged in accordance to manufacturer's specifications down to the specified end point voltage. The test is conducted in an ambient of 25 °C ±5 °C (77 °F ±9 °F). The discharged cells are subjected to a forced discharge at a constant current 1.0 It A for 90 min with the discharge voltage limit not to exceed the numerical value of the upper limit charging voltage specified for the cell. If the discharge voltage limit is reached before the 90 min, the cell shall be discharged at a constant voltage discharge equal to the manufacturer's determined low voltage cutoff, with the current decreasing as necessary until the 90 min time period is reached.		N/A
	Compliance criteria: No fire, no explosion.		N/A
E9	**Projectile**		**N/A**
	Two fully charged cells shall be subjected to the projectile test criteria as outlined in E11.10.		N/A
	As a result of the projectile test, the cells there shall not be an explosion of the cells resulting in projectiles with sufficient force to penetrate the test cage screen.		N/A
ALTERNATIVE TEST PROGRAM FOR SECONDARY LITHIUM CELLS			
E10	**General**		**N/A**

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
E10.1	This cell test program may be used to evaluate secondary lithium cells for use in battery systems that comply with this standard instead of the test program outlined in Sections E1 – E9. Samples used for testing shall be representative of production. The number of samples used for each test and the pass/fail criteria for testing shall be as outlined in Table E.2.		N/A
E10.2	Some lithium cells are capable of exploding when the tests described below are conducted. It is important that personnel be protected from the flying fragments, explosive force, sudden release of heat, and noise that results from such explosions. The test area shall be well ventilated to protect personnel from possible harmful fumes or gases.		N/A
E10.3	As an additional precaution, the temperatures on the surface of the cell casings shall be monitored in accordance with E10.4 during the tests described below. All personnel involved in the testing of lithium cells shall be instructed never to approach a lithium cell while the surface temperature exceeds 90 °C (194 °F) and not to touch the lithium cell while the surface temperature exceeds 45 °C (113 °F).		N/A
E10.4	In accordance with E10.3, the surface temperatures of the cell casing shall be measured as follows: a) By thermocouples consisting of wires not larger than 0.21 mm2 (24 AWG) and not smaller than 0.05 mm2 (30 AWG) and a potentiometer-type instrument; and b) With the measuring junction of the thermocouple held tightly against the metal casing of the cell. *Exception: Placing the thermocouple on a thin piece of paper or label is an acceptable practice.*		N/A
E10.5	For protection, the Projectile Test in E11.10 shall be conducted in a room separate from the observer or within an appropriate containment chamber.		N/A
E10.6	Secondary lithium metal (i.e. lithium metal anode) cells shall be conditioned in accordance with E2.1 prior to the testing.		N/A
E10.7	The capacity of the samples for all lithium chemistries shall be confirmed in accordance with E2.2 prior to testing.		N/A
E11	**Tests**		**N/A**
E11.1	**Short-circuit test**		**N/A**

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Clause	Requirement + Test	Result - Remark	Verdict
	Each test cell shall be short-circuited by connecting the positive and negative terminals with a resistance load of less than or equal to 20 mΩ. The temperature of the cell case shall be recorded during the test. The short circuit shall be applied until the cell case temperature has returned to ±10 °C (±18 °F) of ambient temperature. Tests shall be conducted at 55 ±5 °C (131 ±9 °F). The samples shall reach equilibrium at 55 ±5 °C (131 ±9 °F), as applicable, before the terminals are connected.		N/A
	Compliance criteria: No fire, no explosion.		N/A
E11.2	**Overcharge test**		**N/A**
	A cell shall be subjected to a constant current charge at the maximum specified charging current until the cell reaches 120 % of its maximum specified charge voltage limit or it reaches 130 % SOC, whichever comes first.		N/A
	Compliance criteria: No fire, no explosion.		N/A
E11.3	**Crush test**		**N/A**
	A cell shall be subjected to a bar crush using a bar with a 15-cm (5.9-in) diameter. The force for the crushing shall be applied by a hydraulic ram or similar force mechanism. The force shall be applied until one of the following in (a) – (c) occurs. Once the maximum force has been obtained, the force shall be released. a) A voltage (OCV) drop of one-third of the original cell voltage occurs; b) A deformation of 15 % or more (in the direction of the crush) of initial cell dimension occurs; or c) A force of 1000 times the weight of cell is reached. A cylindrical, pouch or prismatic cell shall be crushed with its longitudinal axis parallel to the crushing apparatus. Each sample shall be subjected to a crushing force in only one direction and the crush shall be conducted only on the wide side of a pouch or prismatic cell. Separate samples shall be used for each test.		N/A
	For other than pouch cells, the crush shall be applied in the center of the cells.		N/A

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
	For pouch type cells, the crushing force shall be applied on the casing near where the cell tabs exit. If the positive and negative tabs are on opposite sides, the crush force shall be applied on the casing near where the negative tab exits.		N/A
	Compliance criteria: No fire, no explosion.		N/A
E11.4	**Impact test**		**N/A**
	A cell shall be placed on a flat surface. A 15.8 ±0.1-mm (5/8 ±0.004-in) diameter bar shall be placed across the center of the sample. A 9.1 ±0.46-kg (20 ±1-lb) weight shall be dropped from a height of 610 ±25 mm (24 ±1 in) onto the sample. The cell shall be impacted with its longitudinal axis parallel to the flat surface and perpendicular to the longitudinal axis of the 15.8-mm (5/8-in) diameter curved surface lying across the center of the test sample. For prismatic and pouch cells, only the wide side shall be impacted. Each sample shall be subjected to only a single impact. Separate samples shall be used for each test.		N/A
	Compliance criteria: No fire, no explosion.		N/A
E11.5	**Shock test**		**N/A**
	The cell shall be secured to the testing machine by means of a rigid mount which supports all mounting surfaces of the cell. Each cell shall be subjected to a total of three shocks of equal magnitude. The shocks shall be applied in each of three mutually perpendicular directions unless it has only two axes of symmetry in which case only two directions shall be tested. Each shock shall be applied in a direction normal to the face of the cell. For each shock, the cell shall be accelerated in such a manner that during the initial 3 ms the minimum average acceleration is 75 g (where g is the local acceleration due to gravity). The peak acceleration shall be between 125 and 175 g. Cells shall be tested at a temperature of 25 ±5 °C (77 ±9 °F).		N/A
	Compliance criteria: No venting, no leakage, no rupture, no fire, and no explosion.		N/A
E11.6	**Vibration test**		**N/A**

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
	A cell shall be subjected to simple harmonic motion with an amplitude of 0.8 mm (0.03 in) [1.6 mm (0.06 in) total maximum excursion]. The frequency shall be varied at the rate of 1 Hz/min between 10 and 55 Hz, and return in not less than 90 nor more than 100 min. The cell shall be tested in three mutually perpendicular directions. For a cell that has only two axes of symmetry, the cell shall be tested perpendicular to each axis. At the end of the vibration conditioning, the open circuit voltage (OCV) of the cell is measured and compared with the pre-test value.		N/A
	Compliance criteria: No venting, no leakage, no rupture, no fire, no explosion, and no OCV change. Note: No "OCV" change would be a drop in the open circuit voltage after testing of less than 10 % of the before test value.		N/A
E11.7	**Heating test**		**N/A**
	A cell shall be heated in a gravity convection or circulating air oven with an initial temperature of 25 ±5 °C (77 ±9 °F). The temperature of the oven shall be raised at a rate of 5 ±2 °C (9 ±3.6 °F) per minute to a temperature of 130 ±2 °C (266 ±3.6 °F) and remain for 10 min. For cells specified for temperatures above 100 °C (212 °F), the conditioning temperature shall be increased from 130 ±2 °C (266 ±3.6 °F), to 30 ±2 °C (86 ±3.6 °F) above the manufacturers maximum specified temperature. *Exception: For cells whose weight is greater than 500 g (1.1 lbs), the maximum temperature of the heating test shall be held for 30 min rather than 10 min.* The sample shall return to room temperature, 25 ±5 °C (77 ±9 °F), and then be examined.		N/A
	Compliance criteria: No fire, no explosion.		N/A
E11.8	**Temperature cycling test**		**N/A**

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
	The cells shall be placed in a test chamber and subjected to the following cycles: a) Raising the chamber-temperature to 85 ±2 °C (185 ±3.6 °F) or T_{max} + 10 °C (T_{max} is the manufacturer's maximum specified temperature) within 30 min and maintaining this temperature for 4 h; b) Reducing the chamber temperature to 25 ±5 °C (77 ±9 °F) within 30 min and maintaining this temperature for 2 h; c) Reducing the chamber temperature to minus 40 ±2 °C (minus 40 ±3.6 °F) within 30 min and maintaining this temperature for 4 h; d) Raising the chamber temperature to 25 ±5 °C (77 ±9 °F) within 30 min; e) Repeating the sequence for a further 9 cycles; and f) After the 10th cycle, storing the cells for a minimum of 24 h, at a temperature of 25 ±5 °C (77 ±9 °F) prior to examination. At the end of the cycling, the open circuit voltage (OCV) of the cell is measured and compared with the pre-test value.		N/A
	Compliance criteria: No venting, no leakage, no rupture, no fire, no explosion, and no OCV change. Note: No "OCV" change would be a drop in the open circuit voltage after testing of less than 10 % of the before test value.		N/A
E11.9	**Low pressure (altitude simulation) test**		**N/A**
	Sample cells shall be stored for 6 h at an absolute pressure of 11.6 kPa (1.68 psi) and a temperature of 25 ±5 °C (77 ±9 °F). At the end of the conditioning, the open circuit voltage (OCV) of the cell is measured and compared with the pre-test value.		N/A
	Compliance criteria: No venting, no leakage, no rupture, no fire, no explosion, and no OCV change. Note: No "OCV" change would be a drop in the open circuit voltage after testing of less than 10 % of the before test value.		N/A
E11.10	**Projectile test**		**N/A**

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
	Each test sample cell shall be placed on a flat screen that covers a 102-mm (4-in) diameter hole in the center of a platform table. The flat screen cover shall be constructed of steel wire mesh having 20 openings per square 25.4 mm (1 in) area and a wire diameter of 0.43 mm (0.017 in). The screen shall be mounted 38 mm (1-1/2 in) above a Meker type burner. The fuel and air flow rates shall be set to provide a bright blue flame that causes the supporting screen to glow a bright red. An eight-sided covered wire cage, 610-mm (24-in) across and 305-mm (12-in) high, made from metal screening shall be placed over the test sample. See Figure E.2. The metal screening shall be constructed from 0.25-mm (0.010-in) diameter aluminum wire with 16 – 18 wires per square 25.4 mm (1 in) in each direction. *Exception No. 1: The overall dimensions of the projectile test aluminum test screen may be increased from those outlined above to accommodate large cells intended for EV applications but the flat panels of the test screen shall not exceed a distance of 305 mm (12 in) from the cell in any direction.* *Exception No. 2: The projectile test cage may be replaced by a visible circular perimeter marking on the supporting surface located 0.5 m (19.7 in) from the longest side of the cell. The marking shall be no greater than 5-mm (0.2-in) thick. The test set-up shall be located within a protective enclosure/room with noncombustible surfaces located a distance from the test perimeter marking where any projectiles that fall beyond the test perimeter marking can be safely contained.*		N/A
	The sample shall be heated and shall remain on the screen until it explodes or the cell has ignited and burned out. It is not required to secure the sample in place unless the sample is at risk of falling off the screen before the test is completed. When required, the sample shall be secured to the screen with a single wire tied around the sample.		N/A
	Compliance criteria: No projectile. Note: Those cells not complying with the Projectile Test of E11.10 can only be used in batteries that comply with the Thermal Exposure for Explosion Hazards Test of Section 41.		N/A
E12	**Test Samples and Results Criteria**		**N/A**
E12.1	**General**		**N/A**

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict
	The test samples and results criteria for the tests in this annex shall be in accordance with Table E.2. Test results compliance criteria are defined in E12.2		N/A
E12.2	**Test results compliance criteria**		N/A
	Venting is determined by evidence of mass loss as noted in Table E.3 below.	Mass of cell > 5.0 g, Mass percent of loss ≤ 0.1%	N/A

Table E.3 Venting and Leakage Mass Loss Criteria

Mass of cell		Maximum mass percent loss
g	(oz)	%
≤ 1.0	(≤ 0.035)	0.5
>1.0, ≤ 5.0	(> 0.035, ≤0.176)	0.2
> 5.0	(> 0.176)	0.1

	Leakage is determined by evidence of visible liquid electrolyte on the external case of the cell or mass loss criteria as outlined in Table E.3.		N/A
	Rupture is determined by a tear in the cell case at a location other than at the designed vent.		N/A
	Fire is determined by evidence visible flames or of charging and burning of the cell and its contents.		N/A
	Explosion is determined by evidence of disassembly of the cell and its contents beyond a rupture of the case.		N/A
APPENDIX F Cell Failure Methods			
APPENDIX G Safety Marking Translations			

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict

Refferen ce	English	French
44.3	"Repurposed "	« Réutilisé »
44.3	“Second Life”	« deuxième vie »
44.3	"UL 1974"	« UL 1974 »
44.6	"Use Only ( ) Charger"	« Utiliser Uniqu ement ( ) Charg eur »
44.8	"caution"	« attention »
44.8	"read instructi on manual"	« Lire le manue l d'instruction »
44.17(b)	“Warning: Ris k of fire, explo sion, or burn s. Do not disa ssemble, hea t above XX °C (or °F), or inc inerate." (Wh ere XX is the cell or battery’ s maximum te mperature sp ecification.)	« Mise en garde : Risque d’ince ndie, d'explosio n ou de brûlure s. Ne pas démo nter, chauffer à plus de XX °C (ou °F) ou incin érer. » (XX correspond à la températur e maximale que peut supporter une pile ou une batterie)
45.5	"DANGER," " WARNING," or "CAUTIO N."	« DANGER », « AVERTISSEM ENT » ou « AT TENTION ».
16.1	“Corrosive flu id inside, only maintained b y the manufa cturer”	« Fluide corrisif à l’intérieur, seu l le fabricant doi t s’occuper de l’ entretien »
16.2	“Indoor Use Only”	« Pour utilisatio n intérieure seu lement »
16.3	“No User Ser viceable part s, only mecha nically rechar ged or refuele d by authoriz	« Aucune des p ièces ne peut êt re réparée par l’ utilisateur; rech arger mécaniqu ement ou ravita

Result - Remark: French Required in Canada. Verdict: P

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict

		ed service pe rsonnel”	iller par un pers onnel d’entretie n qualifié uniqu ement. »
	17.1	“ Do not use a cell stack/an ode metal pla te if it has bee n dropped, as it may result i n a hazardou s condition.”	« Ne pas utilise r un assemblag e de cellules ou une plaque an ode métallique s’ils ont été éch appés, car une situation dange reuse pourrait e n résulter. »

APPENDIX H Alternative Approach for Evaluating Valve Regulated or Vented Lead Acid or Nickel Cadmium Batteries			
H1	**General**		**N/A**
APPENDIX I Test Program for Mechanically Rechargeable Metal-Air Batteries			
I1	**General**		**N/A**

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict

Cl. 2.1	**Table: Critical Components**				**P**
Object/part No.	**Manufacturer/ trademark**	**Type/Model**	**Technical Data**	**Standard**	**Marks of Conformity [1)]**
-	-	-	-	-	-

[1)] Components shall comply with all the applicable CSA Group and UL component standards. License available upon request.

-See attachment CDF for details.

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict

Cl. 15	TABLEL: Overcharge Test			P
Sample No.	OCV of DUT before test, Vdc	Device single faulted	Test Voltage applied to DUT, V	Charging curent, A
Battery 1#	150.51	-	189.8*1.1=208.78	306
-	-	-	-	-
Max Temp Measured, °C	Max Voltage Measured of DUT in Charging, V	The tested DUT, Operational / Inoperational	Dielectric Voltage Test, Brk / No Brk	Results
36.8	185.71	Operational	No Brk	Pass
-	-	-	-	-

Supplementary information:

☐ Testing on the complete battery system
☒ Testing on a subassembly as representative of the battery system
☐ Others:

Results:

As a result of the overcharge test, the following in (a) – (h) are considered non-compliant results. For additional information on non-complying results refer to Table 12.1.

a) E – Explosion;
b) F – Fire;
c) C – Combustible vapor concentrations;
d) V – Toxic vapor release;
e) S – Electric shock hazard (dielectric breakdown);
f) L– Leakage (external to enclosure of DUT);
g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3);
h) P – Loss of protection controls.

Remark: No non-compliant results. No venting, leakage and rupture of the internal cell was occurred.

Cl. 16	TABLEL: High Rate Charge			P
Sample No.	OCV of DUT before test, Vdc	Device single faulted	Max Charging curent, A	Test Voltage applied to DUT, V
Battery 1#	161.81	-	367.21	189.8
-	-	-	-	-
Max Temp Measured, °C	Max Voltage Measured of DUT in Charging, V	The tested DUT, Operational / Inoperational	Dielectric Voltage Test, Brk / No Brk	Results
32	171.33	Operational	No Brk	Pass
-	-	-	-	-

Supplementary information:

☐ Testing on the complete battery system
☒ Testing on a subassembly as representative of the battery system
☐ Others:

Results:

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict

As a result of the overcharge test, the following in (a) – (h) are considered non-compliant results. For additional information on non-complying results refer to Table 12.1.

a) E – Explosion;
b) F – Fire;
c) C – Combustible vapor concentrations;
d) V – Toxic vapor release;
e) S – Electric shock hazard (dielectric breakdown);
f) L– Leakage (external to enclosure of DUT);
g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3);
h) P – Loss of protection controls.

Remark: No non-compliant results. No venting, leakage and rupture of the internal cell was occurred.

Cl. 17	**TABLEL: Short circuit test – test on battery module**						**P**
Sample No.	OCV before test, Vdc	Measured External Short Circuit Resistance, mΩ	Device single faulted	Maximum short circuit current, A	Maximum short circuit duration	Specified short circuit current, A	Specified short circuit duration
Battery 1#	170.5	19.3	-	6452	375ms	-	-
-	-	-	-	-	-	-	-

Max Temp. Measured, °C	Maximum drawed discharging current, A	OCV of discharged DUT after test, V	The tested DUT, Operational / Inoperational	Dielectric Voltage Test, Brk /No Brk	Results
29.1	-	0	Inoperational	No Brk	Pass
-	-	-	-	-	-

Supplementary information:

☐ Testing on the complete battery system
☐ Testing on a subassembly as representative of the battery system
☒ Others: Battery module

Results:

As a result of the Short Circuit Test, the following in (a) – (h) are considered non-compliant results. For additional information on non-complying results refer to Table 12.1.

a) E – Explosion;
b) F – Fire;
c) C – Combustible vapor concentrations;
d) V – Toxic vapor release;
e) S – Electric shock hazard (dielectric breakdown);
f) L– Leakage (external to enclosure of DUT);
g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3);
h) P – Loss of protection controls.

Remark: No non-compliant results. No venting, leakage and rupture of the internal cell was occurred.

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict

Cl. 17	TABLEL: Short circuit test – test on complete battery system						P
Sample No.	OCV before test, Vdc	Measured External Short Circuit Resistance, mΩ	Device single faulted	Maximum short circuit current, A	Maximum short circuit duration	Specified short circuit current, A	Specified short circuit duration
Rack 1#	1396.3	19.561	-	12840	300μs	12940	300μs
Rack 5#	1396.3	19.561	-	12940	300μs	12940	300μs

Max Temp. Measured, °C	Maximum drawed discharging current, A	OCV of discharged DUT after test, V	The tested DUT, Operational / Inoperational	Dielectric Voltage Test, Brk /No Brk	Results
29	-	0	Inoperational	No Brk	Pass
-	-	-	-	-	-

Supplementary information:

☒ Testing on the complete battery system
☐ Testing on a subassembly as representative of the battery system
☐ Others:

Results:

As a result of the Short Circuit Test, the following in (a) – (h) are considered non-compliant results. For additional information on non-complying results refer to Table 12.1.

a) E – Explosion;
b) F – Fire;
c) C – Combustible vapor concentrations;
d) V – Toxic vapor release;
e) S – Electric shock hazard (dielectric breakdown);
f) L– Leakage (external to enclosure of DUT);
g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3);
h) P – Loss of protection controls.

Remark: No non-compliant results. No venting, leakage and rupture of the internal cell was occurred.

Cl. 18	TABLEL: Overload Under Discharge			P
Sample No.	OCV before test, Vdc	Device single faulted	Measured discharging current, A	Passive device rating, A
Battery 1#	171.11	-	306	-

Max Temp. Measured in test, °C	The minimum cell voltage, V	The tested DUT, Operational / Inoperational	Dielectric Voltage Test, Brk/No Brk	Results
28	2.437	Operational	No Brk	Pass

Supplementary information:

☐ Testing on the complete battery system
☒ Testing on a subassembly as representative of the battery system
☐ Others:

Results:

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict

As a result of the Overdischarge Protection Test, the following in (a) – (h) are considered non-compliant results. For additional information on non-complying results refer to Table 12.1.

a) E – Explosion;
b) F – Fire;
c) C – Combustible vapor concentrations;
d) V – Toxic vapor release;
e) S – Electric shock hazard (dielectric breakdown);
f) L– Leakage (external to enclosure of DUT);
g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3);
h) P – Loss of protection controls.

Remark: N/A

Cl. 19	TABLEL: Overdischarge Protection Test			P
Sample No.	OCV before test, Vdc	Device single faulted	Measured discharging current, A	Passive device rating, A
Battery 1#	171.11	-	306	-
Max Temp. Measured in test, °C	The minimum cell voltage, V	The tested DUT, Operational / Inoperational	Dielectric Voltage Test, Brk/No Brk	Results
35	2.437	Operational	No Brk	Pass

Supplementary information:

☐ Testing on the complete battery system
☒ Testing on a subassembly as representative of the battery system
☐ Others:

Results:

As a result of the Overdischarge Protection Test, the following in (a) – (h) are considered non-compliant results. For additional information on non-complying results refer to Table 12.1.

a) E – Explosion;
b) F – Fire;
c) C – Combustible vapor concentrations;
d) V – Toxic vapor release;
e) S – Electric shock hazard (dielectric breakdown);
f) L– Leakage (external to enclosure of DUT);
g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3);
h) P – Loss of protection controls.

Remark: No non-compliant results. No venting, leakage and rupture of the internal cell was occurred.

Cl. 20	TABLEL: Temperature and Operating Limits Check Test			P
Sample No.	Maximum Charging Current, A	Maximum Charging Voltage, Vdc	End of Charging Current, A	Ambient Temperature, °C
Container 1#	1613	1447.9	-	55.1

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict

Maximum Charging Rate, W	End of discharge voltage, Vdc	Maximum Discharging Rate, W	Charging and Discharging Cycle	Dielectric Voltage Test, Brk/No Brk	Results
2020280	-	2079660	3	No Brk	Pass

Max charging current of Cell in Cycle, A	Max Voltage of Cell in cycle, V	Max discharging current of Cell in Cycle, A	Minimum Voltage of Cell in cycle, V
322.6*	3.621	364.2*	2.494

Supplementary information:

☒ Testing on the complete battery system
☐ Testing on a subassembly as representative of the battery system
☐ Others:

Results

Additional non-compliant results during the temperature test are as noted below in (a) – (e). For additional information on non-complying results refer to Table 12.1.

a) E – Explosion;
b) F – Fire;
e) S – Electric shock hazard (dielectric breakdown);
f) L– Leakage (external to enclosure of DUT);
g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3);

Remark: No non-compliant results. No venting, leakage and rupture of the internal cell was occurred.

Notes : * The max charging/discharging current of cell is under the pulse current of the constant power cell(979.2W) of 2 parallel.

Cl. 20	TABLEL: Temperature and Operating Limits Check Test		P

Work condition.............................:	Charging and discharging	
Ambient T_{amb} (°C) ....:	55 °C	
Max operating Temp. T_{ma} (°C) ....:	55 °C	
Measuring location	Max. Measured Temp. [ºC]	Max. Temp. Limit [°C]
Top of cluster 1, 4# electrical box upper cover	35.52	90
Cluster 1, 4# electrical box at CSC center	53.80	125
High voltage wiring harness on the positive bus side	91.25	125
Positive bus bar	84.55	125
Positive bus and insulator joint	66.39	135
Insulating paper	69.76	140
Sealing gasket for the outlet hole of the positive high voltage cable	58.17	80
Air switch	59.31	70
relay	62.27	75
Terminal strip	57.15	105

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict

transformer	81.00	155
AC-DC	62.40	70
DC-DC	58.90	70
PCB of IMM chip accessories (need to open the IMM shell	57.64	130
IMM optocoupler (need to open the IMM shell and lay corresponding	58.55	85
Fire protection system - Control panel center	55.23	65
Isolation switch - ring temperature (Cluster 1 main control box)	72.19	75
Contactor/relay - Ring temperature (Cluster 1 main control box)	73.87	85
Hall Sensor - Ring temperature (Cluster 1 main control box)	73.53	85
Copper bus base body (Cluster 1 main control box)	64.54	100
Fuse- Ring temperature (Cluster 1 main control box)	86.67	100
Fan-ring temperature (Cluster 1 main control box)	70.42	75
Prefilled relay - Ring temperature (Cluster 1 main control box)	69.08	85
SBMU High Voltage Connector body (Cluster 1 main control box)	64.90	125
SBMU isolation chip body (in SBMU of Cluster 1 main control box)	71.89	85
Ambient	55	Ref.

Supplementary information:
The test was conducted at ambient temperature 55°C, Operation mode: Constant power 2036.73kw. The cooling system is continuous working during the test.

Cl. 21	TABLEL: Imbalanced Charging Test				P
Sample No.	Initial OCV of 50% discharged module/cell, Vdc	OCV of the complete battery system, Vdc	Device single faulted	Measured Maximum charging current, A	Measured Maximum charging voltage, Vdc
Battery1# & Battery 2#	172.9	337.6	-	297.4	366.1

Measured Maximum Voltage on 50% discharged module/cell, Vdc	Measured Maximum Temp. on 50% discharged module/cell, °C	The tested DUT, Operational / Inoperational	Dielectric Voltage Test, Brk / No Brk	Results
3.65	30	Operational	No Brk	Pass

Supplementary information:

☐ Testing on the complete battery system
☒ Testing on a subassembly as representative of the battery system
☐ Testing on a altenate configuration as representative of the battery system
☐ Others:

Results:

As a result of the Imbalanced Charging Test, the following in (a) – (h) are considered non-compliant results. For additional information on non-complying results refer to Table 12.1.

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict

a) E – Explosion;
b) F – Fire;
c) C – Combustible vapor concentrations;
d) V – Toxic vapor release;
e) S – Electric shock hazard (dielectric breakdown);
f) L– Leakage (external to enclosure of DUT);
g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3);
h) P – Loss of protection controls.

Remark: No non-compliant results. No venting, leakage and rupture of the internal cell was occurred.

Cl.22	**Table: Dielectric Voltage Withstand Test**				**P**
Sample No.	Battery1#				
Test voltage applied between:	Voltage RMS (V)	Voltage Peak (V)	Voltage shape (Surge, Impulse, AC, DC, etc.)	Test voltage (Vdc)	Breakdown Yes / No
Battery Rack					
Battery system HV (+) to PE (BI)	-	-	-	DC 4414	No
Battery system HV (-) to PE (BI)	-	-	-	DC 4414	No
Battery system HV (+) to Communication circuit (RI)	-	-	-	DC 6000	No
Battery system HV (-) to Communication circuit (RI)	-	-	-	DC 6000	No
Container					
Busbar HV (+) to PE (BI)	DC 4414	-	-	DC 4414	No
Busbar HV (-) to PE (BI)	DC 4414	-	-	DC 4414	No
AC input to PE (BI)	DC 2120	-	-	DC 2120	No
Cooling system AC input to Communication circuit (RI)	DC 4240	-	-	DC 4240	No

Supplementary information:

Results:

As a result of the Dielectric Voltage Withstand Test, the following (e) are considered non-compliant results. For additional information on non-complying results refer to Table 12.1.

e) S – Electric shock hazard (dielectric breakdown);

Remark: No non-compliant results. No venting, leakage and rupture of the internal cell was occurred.

Note(s): N/A

Cl. 25	**Table: Working Voltage Measurements**	**P**

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict

Sample No.	Container 1#		
Location	RMS voltage (V)	Peak voltage (V)	Comments
Battery power circuit (+) to (-)	1437	1500	-
-	-	-	-
Remark:			

Cl.23	Table: Continuity Test			P
Sample No.	Battery 1#			
Part	Tested current	Tested voltage	Measured Resistance	Result
Grounding point of electric compartment to electric compartment door handle	-	-	0.019 Ω	≤ 0.1Ω
-to grounding point of the left door of the electrical compartment	-	-	0.014 Ω	≤ 0.1Ω
-to grounding point of the right door of the electrical compartment	-	-	0.028 Ω	≤ 0.1Ω
-to grounding point of the 1# door of the battery compartment	-	-	0.017 Ω	≤ 0.1Ω
-to grounding point of the 3# door of the battery compartment	-	-	0.018 Ω	≤ 0.1Ω
-to grounding point of the 4# door of the battery compartment	-	-	0.018 Ω	≤ 0.1Ω
-to grounding point of the 5# door of the battery compartment	-	-	0.018 Ω	≤ 0.1Ω
-to grounding point of the 1# main control box	-	-	0.021 Ω	≤ 0.1Ω
-to grounding point of the 2# main control box	-	-	0.022 Ω	≤ 0.1Ω

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict

-to grounding point of the 3# main control box	-	-	0.022 Ω	≤ 0.1Ω
-to grounding point of the 4# main control box	-	-	0.047 Ω	≤ 0.1Ω
-to grounding point of the 5# main control box	-	-	0.024 Ω	≤ 0.1Ω
-to grounding point of the cooling system	-	-	0.019 Ω	≤ 0.1Ω
Grounding point of the 1# main control box to grounding point of 1# rack's 8# module	-	-	0.014 Ω	≤ 0.1Ω
Grounding point of the 2# main control box to grounding point of 2# rack's 8# module	-	-	0.014 Ω	≤ 0.1Ω
Grounding point of the 3# main control box to grounding point of 3# rack's 8# module	-	-	0.014 Ω	≤ 0.1Ω
Grounding point of the 4# main control box to grounding point of 4# rack's 8# module	-	-	0.024 Ω	≤ 0.1Ω
Grounding point of the 5# main control box to grounding point of 5# rack's 8# module	-	-	0.015 Ω	≤ 0.1Ω
Remark:				

Cl. 42	**TABLEL: Single Cell Failure Design Tolerance**					**P**
Sample No.	Initial OCV, V	Location of Failed Cell	Max Temp Measured on Failed cell, °C	Maximum Temp on Adjacent Cells °C	Maximum Temp on DUT enclosure, °C	Results
Battery 2#	173.2	Near module center	579.3	516.7	-	P
Result Key						

Supplementary information:

Results:

1 – Thermal runaway did occur but fire did not propagate outside of the DUT and it did not explode.

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict

2 –Thermal runaway did not occur, there was no explosion or fire outside of the DUT 3 – Thermal runaway occurred and fire propagated outside of the DUT. 4 – Thermal runaway occurred and the sample exploded. 5 - Other
Remark: External heater used to create a thermal runaway. Thermal runaway occured to the adjacent cell.

E2.2	**TABLEL: Capacity check**				**N/A**
Sample No.	OCV before Capacity check discharging, V	Discharging current, A	Discharged duration, h	Measured capacity, Ah	Results
(1) Measured capacity equal or exceed the rated specifications. (2) Measured capacity less than the rated specifications. (3) Others (explain)					
Remark:					

E3 / E11.1	**TABLEL: Short-Circuit Test**				**N/A**
Sample No.	Ambient Temp. °C	Initial OCV, V	Total load resistance of circuit, mΩ	Maximum Temperature of Cell Case, °C	Results
Result: (1) Sample remained intact (i.e. did not vent, Leakage, Rupture, catch on fire or explode) (2) Sample bulged (3) Sample vented (4) Leakage (5) Rupture (6) Sample caught on fire (7) Sample exploded (8) Sample smoldered without flame (9) Other (explain)					
Remark:					

E4 / E11.4	**TABLEL: Cell Impact**	**N/A**

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict

Sample No.	OCV of cell before test, V	Impact from height, m	Maximum Temperature on Cell Casing, °C	Results

Result:

(1) Sample remained intact (i.e. did not vent, Leakage, Rupture, catch on fire or explode)

(2) Sample bulged

(3) Sample vented

(4) Leakage

(5) Rupture

(6) Sample caught on fire

(7) Sample exploded

(8) Sample smoldered without flame

(9) Other (explain)

Remark:

E7 / E11.2	TABLEL: Overcharge test	N/A

Sample No.	OCV of Cell before Test, V	Max Charging current, A	Total Charging duration, h	Maximum charging Voltage in Test, V	Maximum Temp. of Cell in Test, ºC	Results

Result:

(1) Sample remained intact (i.e. did not vent, Leakage, Rupture, catch on fire or explode)

(2) Sample bulged

(3) Sample vented

(4) Leakage

(5) Rupture

(6) Sample caught on fire

(7) Sample exploded

(8) Sample smoldered without flame

(9) Other (explain)

Remark:

E8	TABLEL: Forced Discharge	N/A

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict

Sample No.	OCV before applying reverse charging, V	Target Voltage , V	Measured Reverse Charge Current It, A	Total Time for Reversed Charge Application, min	Results

Result:

(1) Sample remained intact (i.e. did not vent, Leakage, Rupture, catch on fire or explode)

(2) Sample bulged

(3) Sample vented

(4) Leakage

(5) Rupture

(6) Sample caught on fire

(7) Sample exploded

(8) Sample smoldered without flame

(9) Other (explain)

Remark:

E9 / E11.10	TABLEL: Projectile test		N/A
Sample No.	OCV before test, V	OCV after test, V	Results

Result:

(1) Cell did not explode.

(2) Cell exploded but no part of the cell casing penetrated the wire screen.

(3) Cell exploded such that particles from the casing penetrated the wire screen.

(4) Cell vented without exploding.

(5) Cell caught on fire without explosion

(6) Other.

Remark:

E11.3	TABLEL: Crush test		N/A
Sample No.	OCV before test, V	Thickness before test, mm	Weight, kg

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict

Pressure applied, kN	OCV after test, V	Thickness after test, mm	Results

Result:

(1) Sample remained intact (i.e. did not vent, Leakage, Rupture, catch on fire or explode)

(2) Sample bulged

(3) Sample vented

(4) Leakage

(5) Rupture

(6) Sample caught on fire

(7) Sample exploded

(8) Sample smoldered without flame

(9) Other (explain)

Remark:

E11.5	**TABLEL: Shock test**				**N/A**
Sample No.	OCV before test, V	Mass before test, kg	OCV after test, V	Mass after test, kg	Results

Result:

(1) Sample remained intact (i.e. did not vent, Leakage, Rupture, catch on fire or explode)

(2) Sample bulged

(3) Sample vented

(4) Leakage

(5) Rupture

(6) Sample caught on fire

(7) Sample exploded

(8) Sample smoldered without flame

(9) OCV changed (a drop in the open circuit voltage after testing of more than 10% of the before test value)

(10) Other (explain)

Remark:

E11.6	**TABLEL: Vibration test**	**N/A**

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict

Sample No.	OCV before test, V	Mass before test, kg	OCV after test, V	Mass after test, kg	Results

Result:

(1) Sample remained intact (i.e. did not vent, Leakage, Rupture, catch on fire or explode)

(2) Sample bulged

(3) Sample vented

(4) Leakage

(5) Rupture

(6) Sample caught on fire

(7) Sample exploded

(8) Sample smoldered without flame

(9) OCV changed (a drop in the open circuit voltage after testing of more than 10% of the before test value)

(10) Other (explain)

Remark:

E11.8	TABLEL: Temperature cycling test				N/A
Sample No.	OCV before test, V	Mass before test, kg	OCV after test, V	Mass after test, kg	Results

Result:

(1) Sample remained intact (i.e. did not vent, Leakage, Rupture, catch on fire or explode)

(2) Sample bulged

(3) Sample vented

(4) Leakage

(5) Rupture

(6) Sample caught on fire

(7) Sample exploded

(8) Sample smoldered without flame

(9) OCV changed (a drop in the open circuit voltage after testing of more than 10% of the before test value)

(10) Other (explain)

Remark:

UL 1973			
Clause	Requirement + Test	Result - Remark	Verdict

E11.9	**TABLEL: Low pressure (altitude simulation) test**				**N/A**
Sample No.	OCV before test, V	Mass before test, kg	OCV after test, V	Mass after test, kg	Results

Result:

(1) Sample remained intact (i.e. did not vent, Leakage, Rupture, catch on fire or explode)

(2) Sample bulged

(3) Sample vented

(4) Leakage

(5) Rupture

(6) Sample caught on fire

(7) Sample exploded

(8) Sample smoldered without flame

(9) OCV changed (a drop in the open circuit voltage after testing of more than 10% of the before test value)

(10) Other (explain)

Remark:

--End of Report-

APPENDIX 12-I: SAMPLING AND ANALYSIS PLAN

Sampling and Analysis Plan

Corby Battery Energy Storage Project

Solano County, California

May 22, 2025

Prepared for

NEXTera ENERGY RESOURCES

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Acronyms and Abbreviations

BESS	battery energy storage system
bgs	below ground surface
CEC	California Energy Commission
DTSC	Department of Toxic Substances Control
EPA	U.S. Environmental Protection Agency
ESA	Environmental Site Assessment
gen-tie	generation tie
HAZWOPER	Hazardous Waste Operations and Emergency Response
I	Interstate
OCP	organochlorine pesticides (
OSHA	Occupational Safety and Health Administration
PD	Project Design
PG&E	Pacific Gas and Electric
Project	Corby Battery Energy Storage System Project
REC	recognized environmental condition
SAP	Sampling and Analysis Plan
SL	screening level
SMP	Soil Management Plan

1.0 INTRODUCTION

1.1 Purpose

North Bay Interconnect, LLC, and Corby Energy Storage, LLC, propose to construct, own, and operate the Corby Battery Energy Storage System Project (Project). The proposed battery energy storage system (BESS) will be constructed on the approximately 40.3-acre privately owned parcel in Solano County, California (the Project site). The Project will include a 1.1-mile generation-tie (gen-tie) line to connect the proposed facility to the Pacific Gas and Electric (PG&E) Vaca-Dixon Substation.

This Sampling and Analysis Plan (SAP) provides a sampling rationale and design as well as proposed analyses for a surface and subsurface soil investigation. The purpose of the investigation is to evaluate the potential impact of pesticides and metals as a consequence of a release or releases from formal agricultural chemical use on the Project site and associated gen-tie corridor. Implementation of the SAP will be performed under the responsible charge of a California registered Professional Engineer or California registered Professional Geologist.

2.0 BACKGROUND

2.1 Site Description

The Project site consists of a parcel of land (Assessor's Parcel Number 0141-030-090) comprising 40.3 acres located on the southwest intersection of Kilkenny Road and Byrnes Road located within an agricultural area of Solano County, California. The Project site is bound on all sides by existing agricultural lands, with a rural residence located across Kilkenny Road directly to the north. Additional rural residences also exist farther north, as well as to the south, east, and west separated by agricultural lands.

In addition to the Project site, this SAP also addresses the gen-tie corridor and gen-tie laydown area, which together constitute a 65.9-acre Project disturbance area.

Refer to Figure 1 for a Project site location map, Figure 2 for a topographic map, and Figure 3 for a map depicting the Project components.

2.2 Site History

The proposed Project site is currently fallow and has been used as agricultural land for row crops such as wheat or barley most recently. NextEra Environmental Services conducted a Phase I Environmental Site Assessment (ESA) for the Project site in July 2024 (NextEra 2024). Historical aerial photos of the site from 1937 to 2022 were reviewed as part of the Phase I ESA. Based on this review of historical aerial photos, the Project site has been used for agricultural purposes since at least 1937. More specifically, grass crops were observed from 1937 to 1993, orchards were observed from 1997 to 2016, and grass crops were observed again by 2020. The Project site contains no structures and is a crop field that appeared fallow and covered with native grass at the time the Phase I ESA was conducted in July 2024.

The Phase I ESA did not reveal evidence of recognized environmental conditions (RECs), historical RECs, controlled RECs, or vapor encroachment conditions in connection with the Project site. In addition, the Project site was not listed by any agency database as having the potential for hazardous or toxic wastes on-site.

While not a REC, the historic agricultural use of the Project site is considered an environmental concern as residual agrichemical constituents, including organochlorinated compounds and metals, may be present in surficial soils. Given the proposed commercial/industrial use of the Project site, concentrations of the residual agrichemical constituents are considered likely to be below applicable risk-based regulatory levels, but their potential presence should be considered when evaluating potential risks. The Phase I ESA determined that supplemental investigation of the Project site does not appear warranted, unless required by the permitting agency. However, pre-construction surface and shallow soil sampling for residual agrichemical constituents was proposed in the Opt-in Application as Project Design (PD) measure HAZ-03 as described below:

> ***PD HAZ-03:*** *Prior to construction, the Applicant will perform a limited site investigation to collect and analyze representative surface and shallow soil samples for residual agrichemical constituents, including organochlorinated compounds and metals. If there are contaminants identified in areas of the Project site to be disturbed that exceed both published naturally occurring background levels and applicable screening levels (SLs) published by the California Department of Substances Control (DTSC 2022) for the protection of future commercial/industrial workers, the Applicant shall be required to prepare and submit a Soil Management Plan (SMP). The contaminated portions of the Project site above applicable SLs shall be managed in place or removed and disposed of in accordance with the approved SMP; any contaminated soil above applicable SLs removed from the site shall be disposed of at a licensed non-hazardous or hazardous materials disposal site based on environmental testing of the soil and corresponding disposal requirements. In addition, all contractors and subcontractors shall develop a Health and Safety Plan (HSP) specific to their scope of work and based upon the known environmental conditions.*
>
> *Components of the SMP (if required) shall include, but shall not be limited to:*
>
> - *A detailed discussion of the site background;*
> - *Notification procedures if previously undiscovered significantly impacted soil is encountered during construction;*
> - *Development of cleanup levels as based on DTSC modified screening levels (DTSC 2022);*
> - *Sampling and laboratory analyses of excess soil requiring disposal at an appropriate off-site waste disposal facility;*
> - *Soil stockpiling protocols; and*
> - *Protocols to manage groundwater that may be encountered during trenching and/or subsurface excavation activities.*
>
> *Components of the HSP shall include, but shall not be limited to, the following elements, as applicable:*
>
> - *Provisions for personal protection and monitoring exposure to construction workers;*

- *Procedures to be undertaken in the event that contamination is identified above action levels or previously unknown contamination is discovered;*
- *Procedures for the safe storage, stockpiling, and disposal of contaminated soils;*
- *Provisions for the onsite management and/or treatment of contaminated groundwater during extraction or dewatering activities; and*
- *Emergency procedures and responsible personnel.*

Additionally, California Energy Commission (CEC) Staff provided the following data request:

> ***DR WS-17.*** *Please provide additional details regarding Applicant's proposed project design mitigation measure HAZ-03, including a Sampling and Analysis Plan (SAP) for the site and the Gen-Tie line route which includes the proposed locations of soil sampling and justification for those locations, sampling depths, analytical methods, and analytes to be assessed during the investigation. Please also provide a discussion of the worker safety and health measures that would be followed at the PG&E Vaca-Dixon Substation.*

As such, Tetra Tech is providing this SAP to address the required soil sampling prior to the development of the Project.

2.3 Geology and Hydrogeology

The Project site is located on the western side of the southern end of the Sacramento Valley, which constitutes the northern third of the Great Valley geomorphic province. The Great Valley geomorphic province is a mostly intact (i.e., with limited deformation in the central areas), asymmetric structural trough that has been filled with thick sequences of sediment deposits that range in age from the Jurassic to the Holocene. The sequences are broadly categorized into an older (Mesozoic) Great Valley Sequence and a younger (Cenozoic) Great Valley fill. The Sacramento Valley slopes to the south, where the Sacramento River flows into the Sacramento-San Joaquin Delta area.

The primary geologic units include sedimentary deposits from the Holocene, Pleistocene, and Pliocene epochs. Being relatively recent deposits (within the last 3 million years), most of these sediments are unconsolidated to poorly consolidated. All these geologic units are fresh water (i.e. non-marine) sediments laid down primarily in an alluvial fan environment where the valley edge abuts the mountains that provided a source of sediments.

According to the Phase I ESA, the Project site is situated at approximately 78 feet above mean sea level and the local topographic gradient is to the east-southeast. Refer to Figure 2 for a topographic map.

A previous site-specific geotechnical investigation performed for the Project identified the onsite surficial sediments to be alluvial fan deposits from the late Pleistocene (Qpf). The subsurface investigation determined that different thicknesses of sediment layers containing varying amounts of clay with some sand extend down to a depth of 13 feet below the ground surface (bgs).

According to the Phase I ESA, groundwater is expected at approximately 13.5 to 18.3 feet bgs. Groundwater is not expected to be encountered during this investigation.

3.0 FIELD SAMPLING

3.1 Rationale

The Interim Guidance for Sampling Agricultural Properties (Third Revision) from the California Department of Toxic Substances Control (DTSC) dated August 7, 2008, provides guidance for sampling agricultural properties for residual pesticide constituents (DTSC 2008). The DTSC guidance provides an intensive sampling protocol designed to evaluate agricultural properties for proposed school sites, residential development, or other land uses resulting in significant human exposure to surface soils. Because the proposed Project will be an industrial use rather than the sensitive land uses for which the guidance was intended, the sampling frequency has been adapted to provide representative results through a sampling investigation appropriate for the intended use and therefore less intensive.

As discussed in DTSC (2008), parcel ownership and crop history should be considered when developing a sampling plan including multiple parcels. Per the DTSC guidance, properties that generally are continuous, under the same operator/owner, and historically have had similar crops can be addressed as a single unit. There are two distinct units within the Project disturbance area that each have common historical ownership and agricultural uses, within which previous pesticide use would be expected to be uniform:

- Unit A: Includes gen-tie easement north of Kilkenny and gen-tie corridor parcels (including gen-tie laydown area) from Kilkenny to Interstate (I) 80. These parcels are under common ownership (Thiara) and appear to have a similar agricultural production history based on historical aerial imagery review
- Unit B: Includes Project site plus adjacent underground gen-tie easement south of Kilkenny. Both parcels have historically been under common ownership (Gurmail Singh) and appear to have a similar agricultural production history based on historical aerial imagery review.

Based on historical topographic maps provided within the Phase I ESA (NextEra 2024), the PG&E Vaca-Dixon Substation was constructed prior to 1953 and therefore the portion of the gen-tie corridor north of I-80 has not been in agricultural production for at least 70 years. Therefore, sampling and analysis for residual agricultural chemicals is not warranted or proposed at the gen-tie corridor area within the Vaca-Dixon substation property.

3.2 Field Sampling Preparation

Field preparation activities include the development of a Health and Safety Plan, obtaining appropriate boring permits if necessary, and utility clearance activities.

3.2.1 Health and Safety Plan

A site-specific Health and Safety Plan will be prepared prior to the commencement of drilling activities. The Health and Safety Plan will be reviewed by all onsite personnel involved with the Project. All personnel are required to complete the 40-hour Occupational Safety and Health Administration (OSHA) Hazardous Waste Operations and Emergency Response (HAZWOPER) standard training course, with annual refresher courses. Anyone who enters the work zone will be required to read, sign, and conform to the Health and Safety Plan.

3.2.2 Permitting

According to the Solano County Environmental Health Division, permits are not needed for soil borings that are less than 15 feet bgs and do not encounter groundwater. Based on these conditions, permits are not required for this scope of work.

3.2.3 Utility Clearance

In order to help identify subsurface utilities, Underground Service Alert will be utilized. Proposed sampling activities will be very shallow and performed using hand tools/augers minimizing the risk of utility damage.

3.3 Soil Sampling

3.3.1 Sampling Procedures

A total of 14 borings are proposed; see Table 1 of this report for the number of borings and samples proposed for each of the two identified units. The proposed number and location of borings for each unit was developed to provide a representative number of locations within each unit to confirm uniform contaminant levels are below regulatory thresholds consistent with the intended purposes of this investigation and is in keeping with the ASTM Standard E1903-11, Standard Practice for Environmental Site Assessments: Phase II Environmental Site Assessment Process (ASTM International 2011). The approach relies on professional judgement and is based on the expectation that pesticide application was uniform across the defined units due to consistent agricultural uses observed within these areas. Refer to Figure 3 for a map showing the proposed boring locations.

According to the DTSC (2008) Third Revision guidance, only surface samples (i.e., 0 to 0.5 feet bgs) are required for a screening assessment. Since the sampling results may be used to inform an SMP (should elevated contaminant levels be observed), deeper samples will be collected to allow for characterization of the vertical extent of contamination, if necessary. The DTSC Second Revision guidance (DTSC 2002) states that each location to be sampled should include a surface sample (i.e., 0 to 0.5 feet bgs) and one subsurface sample in the 2- to 3-foot range. The guidance notes that “0 feet bgs” means the first encountered soil and does not include roots or extraneous material.

As such, soil samples will be collected at the following depths from each boring:

- 0 to 0.5 feet bgs and below any soil roots or extraneous material, and
- 2 to 2.5 feet bgs

Initially, the soil samples from 0 to 0.5 feet bgs will be submitted for laboratory analysis while the samples from 2 to 2.5 feet bgs will be placed on hold in the laboratory.

3.3.1.1 Sampling Procedure

The shallow surface sample (0 to 6 inches) will be collected with a decontaminated hand shovel or stainless steel spoon. Soil samples will be collected in one 8-ounce jar per sample. The remainder of the boring to 2 feet will be advanced with a hand auger and/or hand shovel/shovel equipment (decontaminated). The hand auger will be advanced until the tip of the hand auger bit is at the desired sample depth (i.e., 2 feet). A slide hammer loaded with one decontaminated 2-inch-diameter and 6-inch-long stainless steel sleeve will be advanced 6 inches to fill the stainless steel sleeve. The sleeve will be removed from the barrel and soil will be collected/removed at both ends of the sleeve into an 8-ounce jar using a clean stainless steel spoon and/or screw driver or putty knife. Alternatively, soil can be collected from the bottom of the decontaminated hand auger if the soil is not too sandy and is representative.

Sampling equipment will be decontaminated between sample intervals and boring locations using a three-step wash rinse and clean rinse process to prevent cross-contamination.

3.3.1.2 Field Quality Control Samples

One field equipment blank will be collected and analyzed for both organochlorine pesticides (OCPs) and arsenic.

3.3.1.3 Logging, Samples, and Backfilling

The soil will be visually inspected for discoloration, monitored for odors, classified in accordance with the Unified Soil Classification System, placed in a sealable plastic bag, and field-screened with a photoionization detector calibrated to isobutylene.

The soil samples will be labeled and placed into a cooler with ice following sampling. All of the samples will be transferred under appropriate chain-of-custody documentation to a state-certified laboratory.

After soil sampling is completed, the proposed shallow borings will be backfilled with cuttings soil.

3.4 Post-Sampling Activities

Any investigation-derived waste, which is anticipated to consist of equipment wash waste water only, will be temporarily contained in U.S. Department of Transportation–approved steel 55-gallon drums. The waste will be profiled and transported under proper waste manifest to an appropriate licensed off-site facility disposal pending the necessary laboratory analysis results for waste profiling.

4.0 LABORATORY ANALYSIS

The soil samples will be transported in an iced cooler under chain-of-custody protocol to a state-certified laboratory for analysis.

4.1 Soil Samples

According to the DTSC Third Revision guidance (DTSC 2008), the only pesticide class requiring analyses at agricultural properties are OCPs. Also, according to the same guidance (DTSC 2008), arsenic is the only metal required for routine analyses for former agricultural properties.

As such, the soil samples will be analyzed for the following:

- OCPs by U.S. Environmental Protection Agency (EPA) Method 8081A
- Arsenic by EPA Method 6010B

Initially, the soil samples from the 14 borings from 0 to 0.5 feet bgs will be submitted for laboratory analysis while the samples from 2.0 to 2.5 feet bgs will be placed on-hold in the laboratory.

Refer to Table 1 for a list of the proposed sample locations and number of OCP and arsenic analyses.

4.2 Regulatory Agency Screening Levels

As noted in Section 2.2, the results of this investigation will be compared with the published naturally occurring background levels and applicable SLs published by the DTSC (2022) for the protection of future commercial/industrial workers.

An upper limit background concentration for arsenic of 12 milligrams per kilogram is provided in the DTSC (2008) guidance. Therefore, 12 milligrams per kilogram will be used as the upper level background for this investigation.

5.0 REPORTING

Following the completion of the field activities and receipt of the laboratory analytical results, a report presenting the results of the investigation will be prepared and submitted to the CEC. The report will include background information, field procedures and observations, boring logs, analytical reports, and conclusions. The report will also include a summary of the laboratory data and comparison to relevant screening levels.

6.0 REFERENCES

ASTM International. 2011. Designation: E1903, Standard Practice for Environmental Site Assessments: Phase II Environmental Site Assessment Process. July 2011.

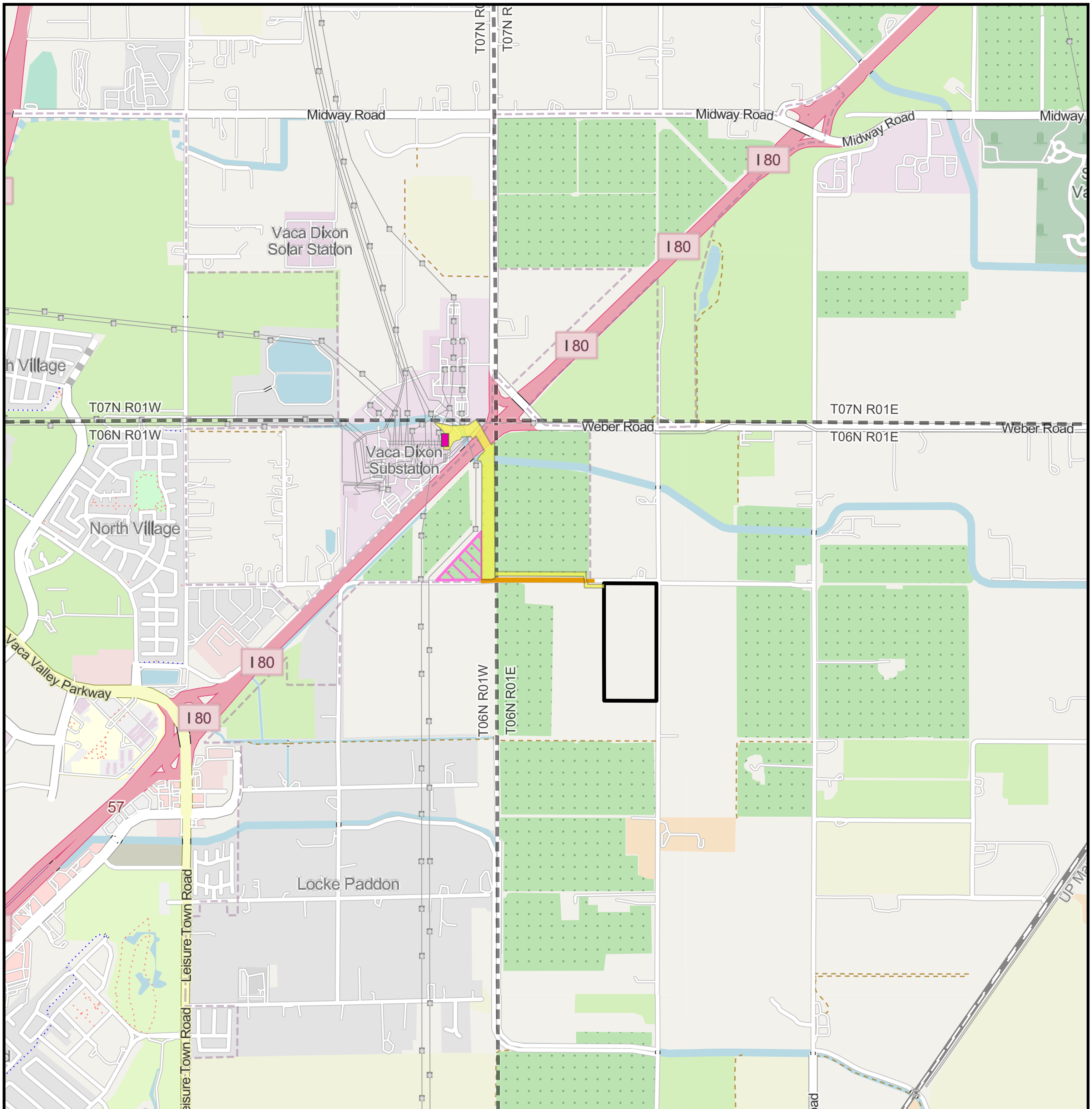
DTSC (Department of Toxic Substances Control). 2002. Interim Guidance for Sampling Agricultural Properties (Second Revision). August 26, 2022.

DTSC. 2008. Interim Guidance for Sampling Agricultural Properties (Third Revision). August 7, 2022.

DTSC. 2022. Human Health Risk Assessment (HHRA) Note Number 3, DTSC-modified Screening Levels. Revised May 2022.

NextEra (NextEra Energy Environmental Services). 2024. Phase I Environmental Site Assessment, Corby Battery Energy Storage System Project, Solano County, California. July 10, 2024.

FIGURES



Source: Esri, et al., 2020

Coordinate System: NAD 1983 StatePlane California II FIPS 0402 Feet

Legend

- Project Site
- Gen-tie Laydown Area
- New Corby Bay
- Gen-tie Corridor (Option 1)
- Gen-tie Corridor (Option 2)
- Township Range

0 0.25 0.5 Miles

N

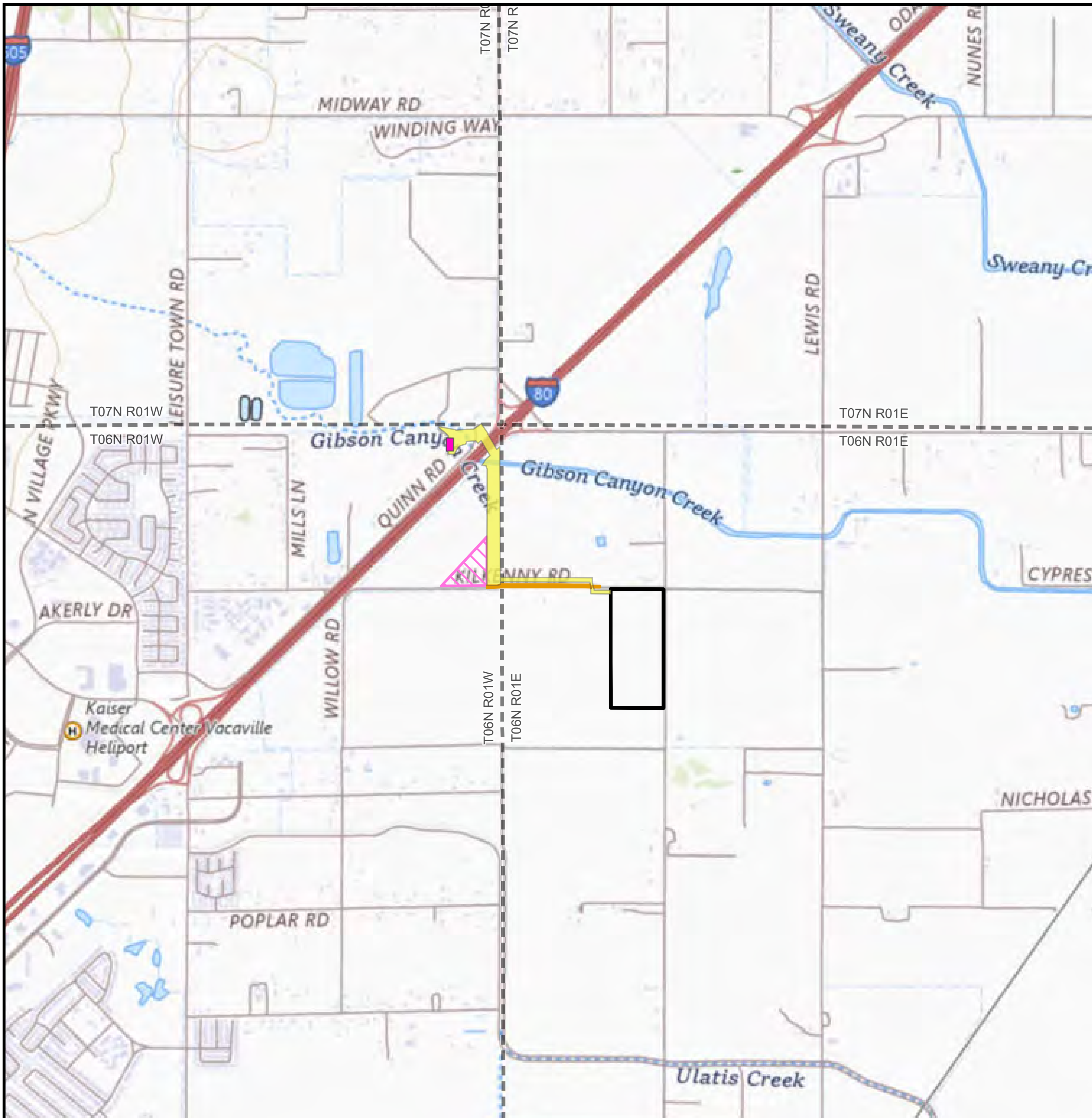
Figure 1
Site Location Map

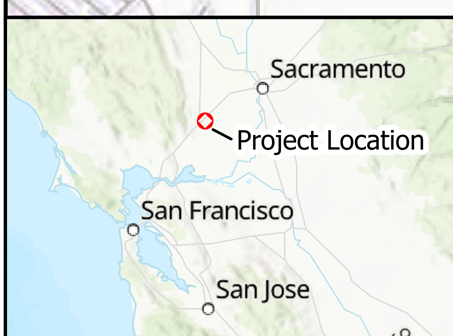
Corby Battery Energy Storage System Project

Solano County, California

Prepared for: NextEra
Prepared by: Tetra Tech
Date: 05/2025

Not for Construction





Source: USGS 7.5 Minute Allendale Topographic Quadrangle 2022

Coordinate System: NAD 1983 StatePlane California II FIPS 0402 Feet

Legend

- Project Site
- Gen-tie Laydown Area
- New Corby Bay
- Gen-tie Corridor (Option 1)
- Gen-tie Corridor (Option 2)
- Township Range

0 0.25 0.5 Miles

N

Figure 2
Topographic Map

Corby Battery Energy Storage System Project

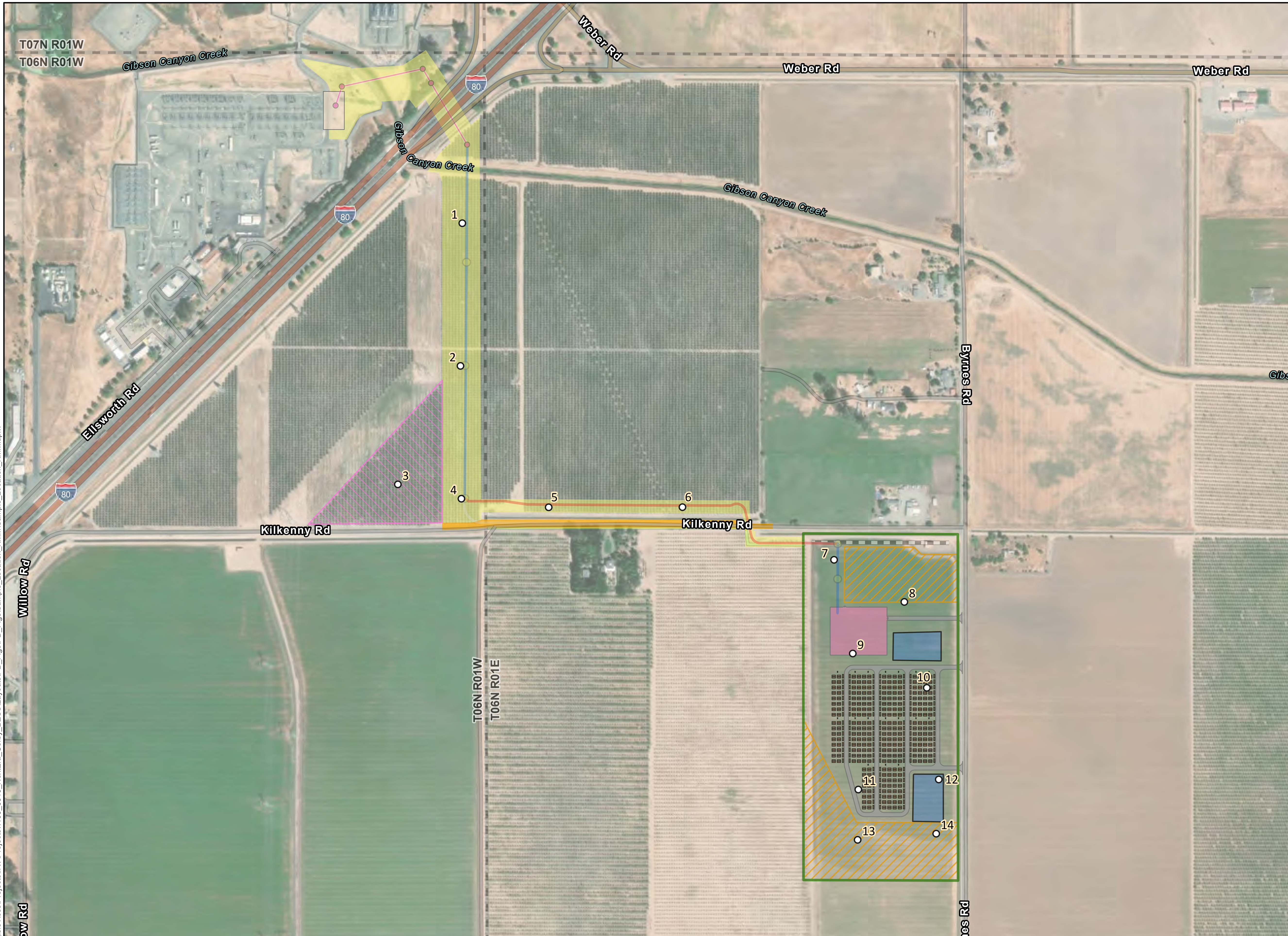
Solano County, California

Prepared for: NextEra
Prepared by: Tetra Tech
Date: 05/2025

NextEra Energy
Corby Battery Energy Storage System Project

Figure 3
Sample Location Map

Solano County, CA



Map Legend

- Township Range

Proposed Features

- Proposed Pole
- Gen-tie (Overhead)
- Gen-tie (Underground; Option 1)
- Gen-tie (Underground; Option 2)
- Sound Barrier
- Telecommunications Line
- Access Road
- Construction Laydown Area
- Gen-tie Corridor (Option 1)
- Gen-tie Corridor (Option 2)
- Gen-tie Laydown Area
- BESS Array
- Project Site
- Stormwater Pond
- Project Substation
- New Corby Bay

PG&E Features

- Pole Locations (PG&E)
- Gen-tie (Overhead; PG&E)

Proposed Locations

- Proposed Boring

TETRA TECH

NOT FOR CONSTRUCTION

Reference Map

1:6,405 NAD 1983 StatePlane California II FIPS 0402 Feet

0 500 1,000 Feet

Source: ESRI, USDA NAIP, US CENSUS, BTS

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TABLE

Table 1
Summary of Proposed Investigation Scope
Corby Battery Energy Storage System Project, Solano County, California

Unit/Parcel	Location ID	Location	Acreage	Total Borings	Sampling Depths[1/] (feet bgs)	Terminal Depth (feet bgs)	Matrix Sampled	Discrete Samples for OCP/Arsenic Analysis	Field QC Samples	Laboratory Analysis
A	A1 to H4	Thiara parcels (includes gen-tie corridor components north of Kilkenny and south of I-80)	21.1	6	0 - 0.5 2 - 2.5	2.5	Soil	6	0	Organochlorine Pesticides by EPA Method 8081A Arsenic by EPA Method 6010B
B	I1 to U4	Project site plus adjacent underground gen-tie easement (Singh parcels)	40.8	8	0 - 0.5 2 - 2.5	2.5	Soil	8	1	Organochlorine Pesticides by EPA Method 8081A Arsenic by EPA Method 6010B
	Total		**61.9**	**14**				**14**	**1**	

Notes:

bgs - below ground surface; OCP - organochlorine pesticide

1/ Initially, the soil samples from 0 to 0.5 feet bgs will be submitted for laboratory analysis while the samples from 2 to 2.5 feet bgs will be placed on hold in the laboratory.