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

Project Number.....:	**4790096490**
Date of issue.....:	**2021-11-17; Revised Date: 2021-12-03**
Total number of pages.....:	**70**

UL Report Office .....:	**UL LLC (UL Northbrook)** **333 Pfingsten Road** **Northbrook, IL 60062** **USA**
Applicant's name.....:	**SIMPLIPHI POWER INC**
Address .....:	**3100 Camino Del Sol** **Oxnard, CA 93030** **USA**
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 .....:	Cell surface temperature heating rate on average of three initiating cells (Cell 1, 5, and 6) was more than 7°C/min (7.5°C/min, 7.41°C/min and 7.97°C/min, respectively)

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	**<Redacted>**
●Part Number	**<Redacted>**
●Chemistry	LiFePO4
●Format	Cylindrical
Ratings (Vdc, Ah):	3.2 V, 3.6 Ah
Cell certified? :	Yes
Standard the cell was certified to:	UL 1642
Organization that certified the cell:	UL
Average cell surface temperature at gas venting, °C:	171.1°C
Average cell surface temperature at thermal runaway, °C:	249.3°C
Gas Volume:	2.6L
Lower flammability limit (LFL), % volume in air at the ambient temperature:	4.83%
Lower flammability limits (LFL), % volume in air at the venting temperature:	N/A – Cell-level testing was performed in accordance with UL 9540A, 3rd Edition, which does not require LFL measurement at venting temperature.
Burning velocity (S_u) cm/s:	94.4 cm/s
Maximum pressure (P_{max}) psig:	120 psig

Cell level Gas Composition:

Gas	Measured %
Carbon Monoxide (CO)	2.842
Carbon Dioxide (CO_2)	11.040
Hydrogen (H_2)	43.284
Methane (CH_4)	3.219
Acetylene (C_2H_2)	1.107
Ethylene (C_2H_4)	1.351
Ethane (C_2H_6)	0.544
Propylene (C_3H_6)	0.871
Propane (C_3H_8)	0.180
C4 Total	0.551
C5 Total	0.453
C6 Total	0.196
C7 Total	0.026
C8 Total	0.159
C9 Total	0.221
C10 Total	0.017
Benzene (C_6H_6)	0.092
Toluene (C_7H_8)	0.054
Dimethyl Carbonate ($C_3H_6O_3$)	30.726
Ethyl Methyl Carbonate ($C_4H_8O_3$)	3.655
Diethyl Carbonate ($C_5H_{10}O_3$)	0.004
Total	100

Module level Information	
Model No.....:	PHI3.8 48V M
Ratings (Vdc, Ah).....:	51.2 Vdc, 75 Ah (3.8 kWh)
Module dimensions (W x **D** x **H** (mm)**)……..:**	342.9 x 355.6 x 203.2
Module cell configuration (xS/**y**P) **…...:**	16S / 21P
Module weight (kgs)…… :	38.28
Module enclosure material…….. :	Powder-coated steel, provided recessed plastic handles on top sides for carrying
Was the module certified? ……..:	Yes
Standard the module was certified to ……..:	UL 1973
Organization that certified test item …….:	Intertek
Number of initiating cells failed to achieve propagation.	7
Thermal Runaway Propagation:	Yes
External Flaming:	No
Location(s) of Flame Venting:	N/A
Flying Debris:	No
Re-ignitions:	No
Test Maximum Smoke Release Rate (m^2/s)	0.01
Test Total Smoke Released: (m^2)	24
Test Peak Chemical Heat Release Rate: (kW):	No flaming observed

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

Gas Compound	Gas Type	Pre-Flaming (L)	Flaming (L)
Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	1	No Flames were Observed
Carbon Monoxide	Carbon Containing	0.0	No Flames were Observed
Carbon Dioxide	Carbon Containing	0.0	No Flames were Observed
Hydrogen	Hydrogen	0.0	No Flames were Observed

Unit level Information	
Model No. :	0-PHI-BOSS-12-12
Ratings (Vdc, Ah).....:	56 Vdc, 900 Ah
BESS dimensions (W x **D** x **H** (mm)**)…….:**	750 by 493 by 1829
BESS module configuration	12 Modules in Parallel
Number of modules in BESS	12
Module cell configuration (xS/**y**P) **…...:**	16S / 21P
Number of cells in module.:	336
BESS weight (lbs)…… :	1460
BESS enclosure material…….. :	Painted Sheet Steel

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:** outdoor ground mounted, indoor floor mounted, roof top, open garage **Residential:** Outdoor ground mounted, indoor floor mounted
Residential Indoor Use: Smallest volume room installations specified.	Minimum 2.5 meters cubed, with the following parameters: 1 ft clearance form side of cabinet 1 in. clearance behind cabinet 3 ft clearance from front of cabinet
Original Equipment Manufacturer (OEM):	Simpliphi Power Inc
Branding Manufacturer (if not OEM):	N/A
Was the unit certified? ……:	Yes
Standard the unit was certified to ……..:	UL 9540
Organization that certified the unit …….:	Intertek
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)	7
Thermal Runaway Propagation:	Yes
External Flaming from BESS:	No
Location(s) of Flame Venting:	N/A
Maximum Target BESS Temperature, °C	23
Maximum Wall Surface Temperature[1], °C	27
Peak Chemical Heat Release Rate, kW	No flaming during the test
Peak Convective Heat Release Rate, kW	No flaming during the test
Maximum Smoke Release Rate, m^2/s	No smoke during the test
Maximum Heat Flux on Target Modules, kW/m^2	0.137
Maximum Heat Flux of Egress Path, kW/m^2	0.015

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

Flying Debris:	No
Re-ignitions:	No

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)
Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	0	No flames observed
Carbon Monoxide	Carbon Containing	0	No flames observed
Carbon Dioxide	Carbon Containing	0	No flames observed
Hydrogen	Hydrogen	0	No flames observed

Summary of BESS Unit Test Results

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

[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 or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases; and
[X] Heat flux in the center of the accessible means of egress did not exceed 1.3 kW/m^2.

Performance Criteria in accordance with Table 9.1 for Outdoor Ground Mounted non-residential unit

[X] Separation distances to exposures was farther than the greatest flame extension observed during test.
[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 or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases; and
[X] Heat flux in the center of the accessible means of egress did not exceed 1.3 kW/m^2.

Performance Criteria in accordance with Table 9.1 for Rooftop and Open Garages non-residential unit

[X] Separation distances to exposures was farther than the greatest flame extension observed during test.
[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 or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases; and
[X] Heat flux in the center of the accessible means of egress did not exceed 1.3 kW/m^2.

Performance Criteria in accordance with Table 9.1 for Indoor Floor Mounted Residential unit

[X] Flaming outside the initiating BESS unit was not observed as demonstrated by no flaming or charring of the cheesecloth indicator;

[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 or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases; and

[X] The concentration of flammable gas did not exceed 25% LFL in air for the smallest specified room installation size.

Performance Criteria in accordance with Table 9.1 for Outdoor Ground Mounted Residential unit

[X] Separation distances to exposures was farther than the greatest flame extension observed during test.

[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 or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases; and

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

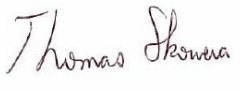
Necessity for an Installation level test

~~**[ ]** 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:	UL LLC (UL Northbrook)	
Testing location/ address ..... :	333 Pfingsten Road Northbrook, IL 60062 USA	
Tested by (name, signature) ..... :	Paul Obrochta, Phil Arnold	
Witnessed by (for 3rd Party Lab Test Location) (name, signature) ..... :	N/A	N/A
Project Handler (name, signature)..... :	Khaja M. Vasay	
Reviewer (name, signature) ……..:	Thomas A. Skowera	

List of Attachments (including a total number of pages in each attachment):
Attachment A: Sample Charging, OCV and SOC Measurement Profiles – (*Pages **27** through **31***)
Attachment B: BESS (including module and any integral fire detection and suppression systems) Construction Photos/Diagrams – (*Pages **32** through **34***)
Attachment C1: Initiating Module Instrumentation – (*Pages **35** through **39***)
Attachment C2: Orientation of Initiating and Target Units During Test – (*Pages **40** through **41***)
Attachment C3: Internal Layout of Unit – (*Page **42***)
Attachment C4: Initiating Unit Instrumentation – (*Pages **43** through **45***)
Attachment C5: Target Unit 1 Unit Instrumentation – (*Pages **46** through **48***)
Attachment C6: Target Unit 2 Unit Instrumentation – (*Pages **49** through **51***)
Attachment C7: Wall and Soffit Instrumentation – (*Pages **52** through **53***)
Attachment C8: Heat Flux Location – (*Page **54***)
Attachment D: Temperature Profiles and Heat Flux Measurements During Testing (Initiating Cell and Module, Target Modules, Wall Surfaces, etc. – (*Pages **55** through **61***)
Attachment E: BESS Unit Testing and Post Testing Photos – (*Pages **62** through **67***)
Attachment F: BESS Unit Gas Flow Rate and Heat Release and Smoke Release Profiles – (*Pages **68** through **70***)

Photo(s) of BESS unit:

Test Item Charge/Discharge Specifications:	
• **Charge current, A:**	450
• **Standard Full charge voltage, Vdc:**	54.4 (56 max)
• **Charge temperature range, °C:**	0°C to 50°C
• **End of charge current, A:**	18
• **Discharge current, A:**	450
• **End of discharge voltage, Vdc:**	48
• **Discharge temperature range, °C:**	-20°C to 60°C

Test item particulars .....:	Seven cells were instrumented with external heaters in order to obtain cell to cell propagation. The condition in which cell to cell propagation was considered achieved is when a cell without a heater went into thermal runaway. See Attachment C for heater locations.
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..... :	See Below
Date of receipt of test item .....:	2021-08-20
Date (s) of performance of tests.....:	2021-10-07

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) ..... :	SIMPLIPHI POWER INC 3100 Camino Del Sol Oxnard, CA 93030 USA

General product information and other remarks:

SimpliPhi's "0-PHI-BOSS-12-12" is a standalone unit with one vent cover on each side, constructed out of painted sheet steel, containing 12 Modules connected in parallel.

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

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		P
	Organization that certified BESS:	**Intertek**	—
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 types: Indoor floor mounted non-residential use BESS Indoor floor-mounted residential use BESS Outdoor ground-mounted non-residential use BESS Outdoor ground-mounted residential us BESS Rooftop and open garage non-residential use BESS installations.	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.		C

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict
	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.	Testing conducted indoor	N/A
9.1.3	Testing to determine fire characterization was done at the battery system level rather than a complete BESS	Unit consisted of 12 battery modules in parallel. Unit did not include power conversion equipment	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.		N/A
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	C
9.1.7	The BESS unit included an 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.	BMS was not relied upon for this test	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

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict
9.2.1	Test room ambient temperature within 10°C (50°F) to 32°C (90°F).	See Table 2	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.		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.		C
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.	Height of wall and soffit was 8ft for worst case to cover indoor applications.	M
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. 19.04 mm (3/4 in.) plywood for worst case to cover outdoor ground-mounted applications	M
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 Attachment F	C
9.2.9	The chemical and convective heat release rates were measured for the duration of the test.	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	C

UL 9540A, Edition 4,			
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.		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.		C

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

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict
	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.	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
9.3	**Test method – Outdoor ground mounted units**		C
9.3.1	Outdoor ground mounted non-residential use BESS for installation: test method described in Section 9.2 was used.		C
	Outdoor use only installations: the smoke release rate, the convective and chemical heat release rate and content, velocity and temperature of the released vent gases were not be measured.	The application is not outdoor use only; it also includes indoor installation.	N/A
9.3.2	Outdoor ground mounted residential use BESS: The test method described in Section 9.2 except as noted in 9.3.3 and 9.3.4.		C
	Heat flux measurements for the accessible means of egress were measured in accordance with 9.2.20.		C
	Outdoor use only installations: the smoke release rate, the convective and chemical heat release rate and content, velocity and temperature of the released vent gases were not be measured.		N/A
9.3.3	Test samples were installed as shown in Figure 9.2 in proximity to an instrumented wall section that is 3.66-m (12-ft) tall with a 0.3-m (1-ft) wide horizontal soffit (under surface of the eave shown in Figure 9.2).	Height of wall and soffit was 8ft.	M
	The sample was mounted on a support substrate and spaced from the wall in accordance with the minimum separation distances. The wall and soffit were constructed with 19.05-mm (3/4-in) plywood installed on wood studs and painted flat black.		C

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict
	The instrumented wall extended not less than 0.49-m (1.6-ft) horizontally beyond the exterior of the target BESS units.		C
	If the manufacturer requires installation against non-flammable material, the test setup may include manufacturer recommended backing material between the unit and plywood wall.		N/A
	The No. 24-gauge or smaller, Type-K exposed junction thermocouple array on the walls extended to the surface of the soffit.		C
9.3.4	Target BESS were installed on each side of the initiating BESS in accordance with installation specifications. The physical spacing between BESS units (both initiating and target) were the minimum separation distances specified.		C
9.6	**Rooftop and open garage installations**		
9.6.1	Testing of BESS intended for non-residential use rooftop or open garage installations were in accordance with 9.2.		C
9.6.2	Intended for rooftop and open garage use only installations: the smoke release rate, the convective and chemical heat release rate and content, velocity and temperature of the released vent gases were not measured.	The application is not rooftop and open garage use only; it also includes indoor installation.	N/A
9.7	**Unit level test report**		C
9.7.1	Installation type tested:		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);	0-PHI-BOSS-12-12	C
	b. Number of modules in the initiating BESS unit	12	C
	c. BESS construction features;	See Attachment C See Critical Components Table	C
	d. Fire protection features/ detection/ suppression systems within unit		N/A
	e. Module voltages corresponding to the tested SOC;	See Table 2	C
	f. Thermal runaway initiation method used;	See Attachment C	C
	g. Location of the initiating module within the BESS unit;	See Attachment C	C

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict
	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	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;	Table 6	C
	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;	Table 7	N/A
	q. Flammable gas generation and composition data;	See Attachment F See Tables 7, 8, 9, and 10	C
	r. Peak smoke release rate and total smoke release data.	See Table 12 See Attachments F and G	C
	s. Indication of the activation of integral fire protection systems and if activated the time into the test at which activation occurred;	Table 13	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 16	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 16	C
	x. Video of the test.		C
9.8	**Performance at Unit level testing**		

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict
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.		C
Non-Residential Installations – Indoor floor mounted:			
	a) Flaming outside the initiating BESS unit is not observed;	No Flames observed	P
	b) Surface temperatures of modules within target BESS units do not exceed the cell venting temperature;	Maximum surface temperature of Modules in Target Units measured 22.8°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;	Maximum wall surface temperature measured 27.1°C	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 explosions or deflagration of vented gasses observed	P
	e) Heat flux in the center of the accessible means of egress did not exceed 1.3 kW/m^2.	Maximum heat flux measured at center of accessible means of Egress was 0.015 kW/m^3	P
Non-Residential Installations – Outdoor ground mounted:			
	a) If flaming outside of the unit is observed, separation distances to exposures were determined by greatest flame extension observed during test.	No Flames observed	P
	b) Surface temperatures of modules within target BESS units do not exceed the cell venting temperature;	Maximum surface temperature of Modules in Target Units measured 22.8°C	P
	c) For BESS units intended for installation in locations near combustible construction, surface temperature measurements on wall surfaces do not exceed 97°C (175°F) rise above ambient;	Maximum wall surface temperature measured 27.1°C	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 explosions or deflagration of vented gasses observed	P
	e) Heat flux in the center of the accessible means of egress did not exceed 1.3 kW/m^2.	Maximum heat flux measured at center of accessible means of Egress was 0.015 kW/m^3	P
Non-Residential Installations – Rooftop and Open Garages:			

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict
	a) If flaming outside of the unit is observed, separation distances to exposures were determined by greatest flame extension observed during test.	No Flames observed	P
	b) Surface temperatures of modules within target BESS units do not exceed the cell venting temperature;	Maximum surface temperature of Modules in Target Units measured 22.8°C	P
	c) For BESS units intended for installation in locations near combustible construction, surface temperature measurements on wall surfaces do not exceed 97°C (175°F) rise above ambient;	Maximum wall surface temperature measured 27.1°C	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 explosions or deflagration of vented gasses observed	P
	e) Heat flux in the center of the accessible means of egress did not exceed 1.3 kW/m^2.	Maximum heat flux measured at center of accessible means of Egress was 0.015 kW/m^3	P
Residential Installations – Indoor floor mounted:			
	a) Flaming outside the initiating BESS unit is not observed as demonstrated by no flaming or charring of the cheesecloth indicator;	There was no charring of the Cheesecloth	P
	b) Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit do not exceed cell venting temperature;	Maximum surface temperature of Modules in Target Units measured 22.8°C	P
	c) BESS units intended for installation in locations with combustible construction, surface temperature measurements on wall surfaces do not exceed 97°C (175°F) of temperature rise above ambient;	Maximum wall surface temperature measured 27.1°C	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 explosions or deflagration of vented gasses observed	P
	e) The concentration of flammable gas does not exceed 25% LFL in air for the smallest specified room installation size.	No detectable flammable gas	P
Residential Installations – Outdoor ground mounted:			
	a) If flaming outside the unit is observed, separation distances to exposures shall be determined by greatest flame extension observed during test.	No Flames observed	P

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict
	b) Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit do not exceed the cell venting temperature;	Maximum surface temperature of Module in Target Units was 22.8°C	P
	c) BESS units intended for near exposures, surface temperature measurements on wall surfaces do not exceed 97°C (175°F) of temperature rise above ambient;	Maximum wall surface temperature measured was 27.1	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 explosions or deflagration of vented gasses observed	P
	e) Heat flux in the center of the accessible means of egress shall not exceed 1.3 kW/m^2	Maximum heat flux measured at center of accessible means of Egress was 0.015 kW/m^3	P

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

Table 1 – Specified Unit charging and discharging parameters			
Charging:		**Discharging:**	
Current (CC), A	450	Current (CC), A	450
Standard Full Charge Voltage ,Vdc	54.4 (56 max)	End of discharge voltage, Vdc	48
End of charge current, A	18	Discharging Test Ambient, °C	-20°C to 60°C
Refer to Attachment A for charge/discharge profiles.			

Table 2 – Test Initiation Details	
Test Date	2021-10-07
Test Start Time (HH:MM:SS)	11:09:42 am
Initial Lab Temperature, °C	21.4
Initial Relative Humidity % RH	79.8
Module OCV at Start of Test, Vdc	53.99

Table 1 – Approximate time of thermal runaway propagation through module			
Locations (Cell #)	**Event**	**Time**	**Temperature of the cell**
Cell No. 6	Thermal Runaway	00:31:10	280.4°C
Cell No. 5	Thermal Runaway	00:31:19	261.0°C
Cell No. M	Thermal Runaway	00:32:19	316.2°C
Cell No. 4	Thermal Runaway	00:34:01	267.3°C
Cell No. 7	Thermal Runaway	00:34:12	291.2°C
Cell No. 2	Thermal Runaway	00:34:14	251.2°C
Cell No. 1	Thermal Runaway	00:34:53	383.4°C
Cell No. 3	Thermal Runaway	00:36:55	338.5°C
Cell No. 8	Thermal Runaway	00:41:23	316.8°C

Table 4 – Test overview timeline		
Time (HH:MM:SS)	**Event**	**Description**
00:00:00	Test Start	(*description of start of cell thermal runaway*)
00:24:30	Venting	Venting of Cell No. 6. No visible smoke
00:31:10	Thermal Runaway	Thermal Runaway of Initiating Cell No. 6
00:31:19	Thermal Runaway	Thermal Runaway of Initiating Cell No. 5
00:32:19	Thermal Runaway	Thermal Runaway of Initiating and Monitored Cell No. M
00:34:01	Thermal Runaway	Thermal Runaway of Initiating Cell No. 4
00:34:12	Thermal Runaway and Propagation	Thermal Runaway of Unheated Cell No. 7 indicates propagation.
00:34:14	Thermal Runaway	Thermal Runaway of Initiating Cell No. 2
00:34:53	Thermal Runaway	Thermal Runaway of Initiating Cell No. 1
00:36:55	Thermal Runaway	Thermal Runaway of Initiating Cell No. 3
00:41:23	Thermal Runaway	Thermal Runaway of Unheated Cell No. 8
03:45:36	End of Test	End of Test

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

Table 5 – Maximum Temperatures in Target Units			
Cell vent temperature from cell test data, °C		171.1°C	
Target Unit 1		**Target Unit 2**	
Module Location No.	Temperature (°C) (+)	Module Location No.	Temperature (°C) (+)
Module 1	22	Module 1	23
Module 4	22	Module 2	23
Module 7	23	Module 3	23
Module 10	23	Module 4	22
--	--	Module 5	22
--	--	Module 6	22
--	--	Module 7	23
--	--	Module 8	22
--	--	Module 9	22
--	--	Module 10	22
--	--	Module 11	22
--	--	Module 12	22
(+) – Measured on surface of Module facing initiating unit.			

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

Table 6 – Maximum Temperatures on Instrumented Wall			
Ambient Temperature: 21 °C			
UL 9540° performance criteria, Ambient + 97°C: 118°C			
Rear Wall Height, mm	Maximum Temperature (°C)	Side Wall Height, mm	Maximum Temperature (°C)
152.4 (6 in.)	22	152.4 (6 in.)	22
304.8 (12 in.)	22	304.8 (12 in.)	22
457.2 (18 in.)	23	457.2 (18 in.)	22
609.6 (24 in.)	25	609.6 (24 in.)	22
762 (30 in.)	27	762 (30 in.)	23
914.4 (36 in.)	26	914.4 (36 in.)	22
1066.8 (42 in.)	24	1066.8 (42 in.)	22
1219.2 (48 in.)	23	1219.2 (48 in.)	22
1371.6 (54 in.)	23	1371.6 (54 in.)	22
1524 (60 in.)	23	1524 (60 in.)	22
1676.4 (66 in.)	23	1676.4 (66 in.)	22
1828.8 (72 in.)	23	1828.8 (72 in.)	22
1981.2 (78 in.)	23	1981.2 (78 in.)	22
2133.6 (84 in.)	22	2133.6 (84 in.)	22
2286 (90 in.)	23	2286 (90 in.)	22
2438.4 (96 in.) (+)	23	2438.4 (96 in.) (+)	23
152.4 (6 in.) (++)	23	152.4 (6 in.) (++)	22
304.8 (12 in.) (++)	23	304.8 (12 in.) (++)	23
Note: Temperatures are measured constantly and then averaged every 60-seconds (+) – Against Soffit (++) – On soffit, indicates distance from wall			

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 Enclosure Surface facing Initiating Unit; Nearest to Initiating Module	0.137	Heat Flux Gauge No.	kW/m^2
Target Unit 1 Centered on Side Enclosure Surface, facing Initiating Unit	0.120	Side Wall nearest to center of initiating Module	0.130
Target Unit 2 Front Enclosure Surface facing Initiating Unit; Nearest to Initiating Module	0.085	Rear Wall nearest to center of initiating Module	0.137
Target Unit 2 Centered on Front Enclosure Surface, facing Initiating Unit	0.086	Side Wall nearest to center of initiating Unit	0.054
Egress path measurement:	0.015	Rear Wall nearest to center of initiating Unit	0.096

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

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	Hydrogen
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**
00:00:00 to 3:45:36	Pre-Flaming
External Flaming of Gas	
Condition	**Duration (s)**
External Flaming of Vent Gases:	No Flames Observed

Table 10 – Summary of battery gas volumes for deflagration hazard calculations			
Gas Component	**Gas Type**	**During Pre-flaming (L)**	**During Flaming (L)**
Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	0	No Flames Observed
Carbon Dioxide	Carbon Containing	0	No Flames Observed
Carbon Monoxide	Carbon Containing	0	No Flames Observed
Hydrogen	Hydrogen	0	No Flames Observed

Table 11 – Smoke and heat release rate			
Heat Release Rate (HRR)		**Smoke Release Rate (SRR)**	
Peak Chemical HRR (kW)	No flaming during the test	Maximum SRR (m2/s)	No smoke observed during the test
Peak Convective HRR, (kW)	No flaming during the test	Total Smoke Released (m2)	No smoke observed during the test

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

Table 12 – Integral Fire suppression system Details of Operation		
Time of operation of Sprinklers/Suppression System:	Time of Operation Start (HH:MM:SS)	Length of Operation (HH:MM:SS)
Sprinkler No. 1	N/A	N/A
Sprinkler No. 2	N/A	N/A
Sprinkler No. 3	N/A	N/A
Sprinkler No. 4	N/A	N/A
Fire Suppression System Operation	N/A	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)
8 (+)	53.99	53.82	0.17
(+) – All Modules connected un parallel			

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	N/A
Explosive discharge of gas	No	N/A
Sparks or electrical arcs	No	N/A

Table 15 – Post Test Observations	
Thermal runaway behavior	None
Re-ignitions	None
Explosions	None
Other Observations	None

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[1)]**
Unit Enclosure	--	CAB-2-01	NEMA Type 3R. Dimensions: Enclosure 72” H X 29.5”W X 18.5” D	--	--
Shelves	--	CAB-2-01-STS	Enclosure Shelf 2.0” H x 27.13” W x 12” D	--	--
Terminal Blocks	--	5P-TB	5P-TB (5 position terminal block)	--	--
HVAC/ Ventilation Systems	--	FAN AXIAL 120X38MM 48VDC WIRE, Louver Kit, Filter Assembly	FAN 48V, Louver Kit, Filter Assembly	--	--
Internal Wiring	--	4/0 WIRE RED & BLACK	WIRE 4/0 RED, WIRE 4/0 BLACK	--	--
Internal Bus Bars	--	BUSBAR4-1000-0187-02; BUSBAR5-1000-0187-01	Dimensions: W: 1.00”, Thickness: 0.1875” Epoxy powder coated, 1000VDC dielectric Rated	--	--
Battery Module	Simpliphi Power Inc	PHI3.8 48V M	12 provided in parallel	UL 1973	Intertek

Attachment A: Sample Charging, OCV and SOC Measurement Profiles – (*Pages **27** through **31***)

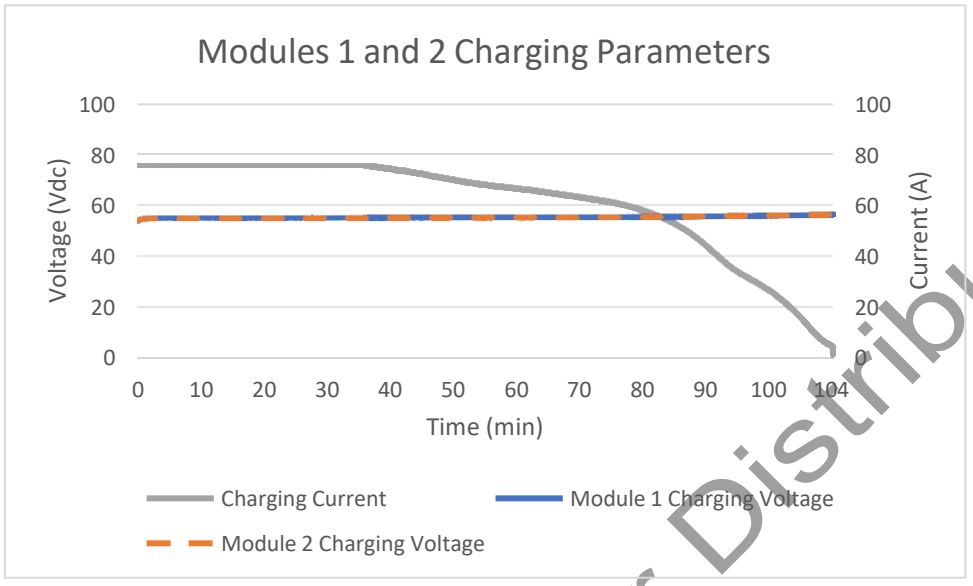


Figure 1 – Modules 1 and 2 Charging Parameters

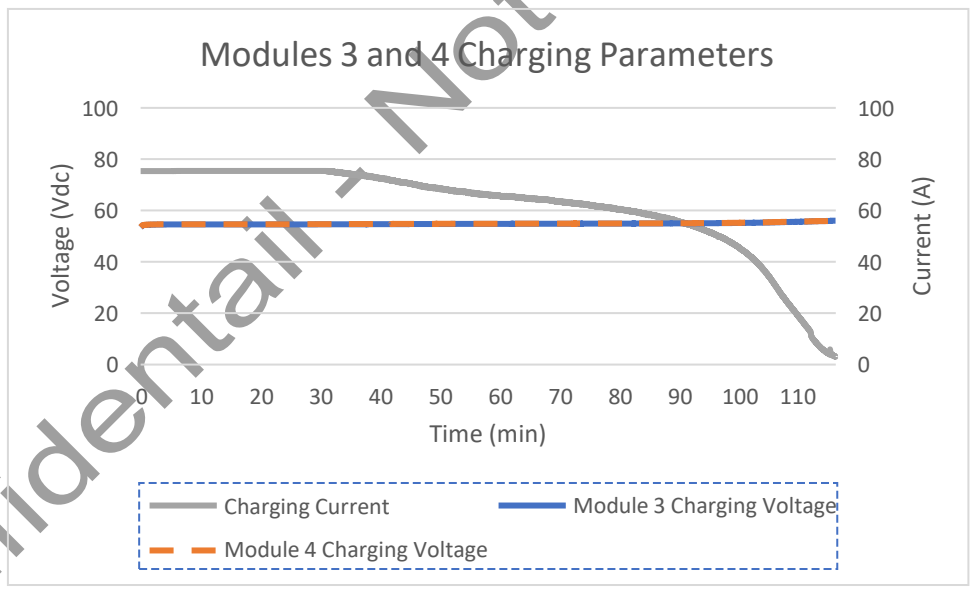


Figure 2 – Modules 3 and 4 Charging Parameters

Attachment A (Cont'd):

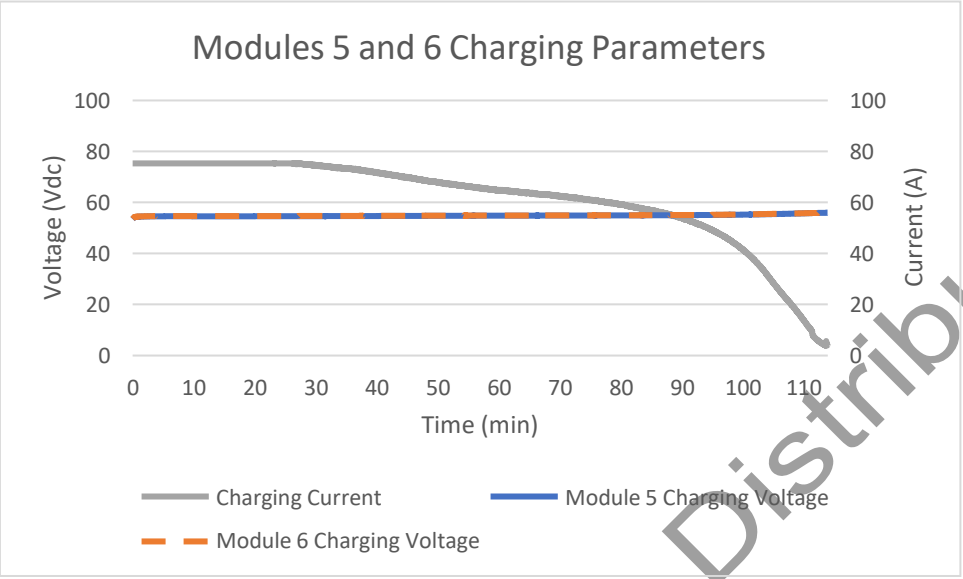


Figure 3 – Modules 5 and 6 Charging Parameters

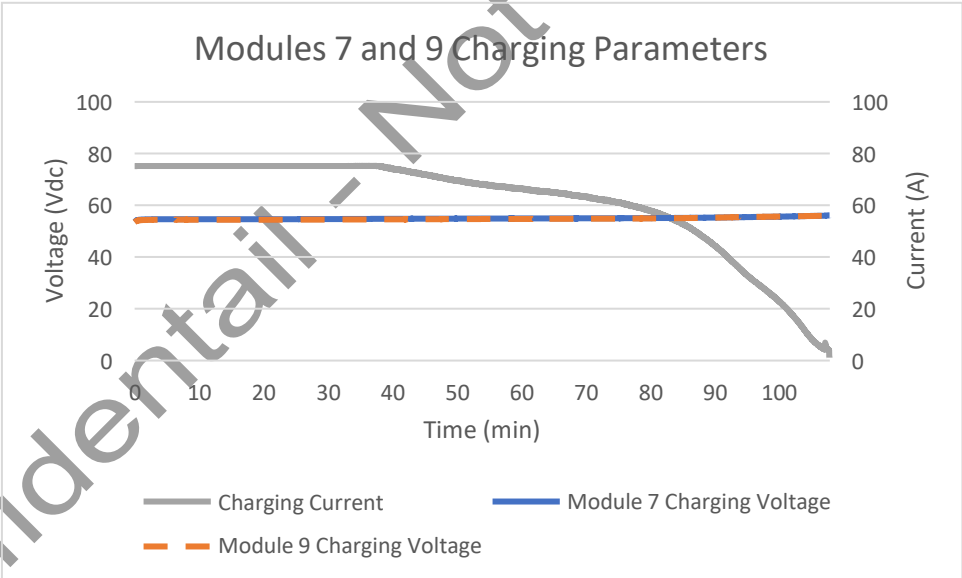


Figure 4 – Modules 7 and 9 Charging Parameters

Attachment A (Cont'd):

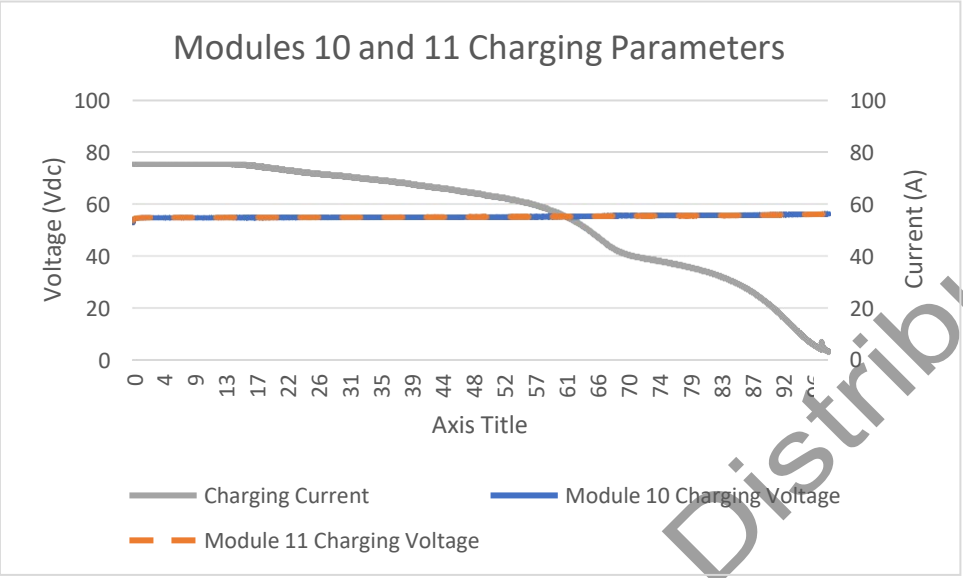


Figure 5 – Modules 10 and 11 Charging Parameters

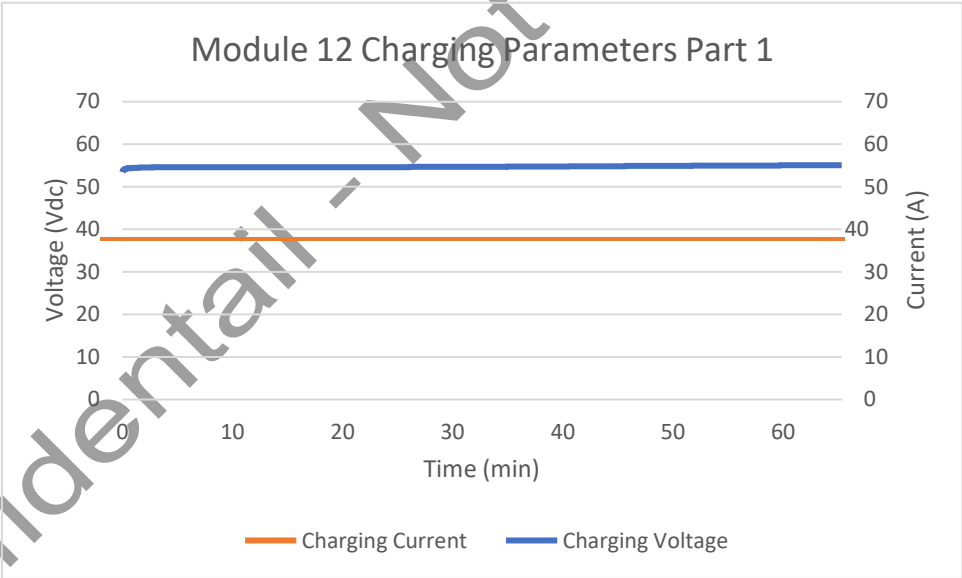


Figure 6 – Modules 12 Charging Parameters Part 1

Attachment A (Cont'd):

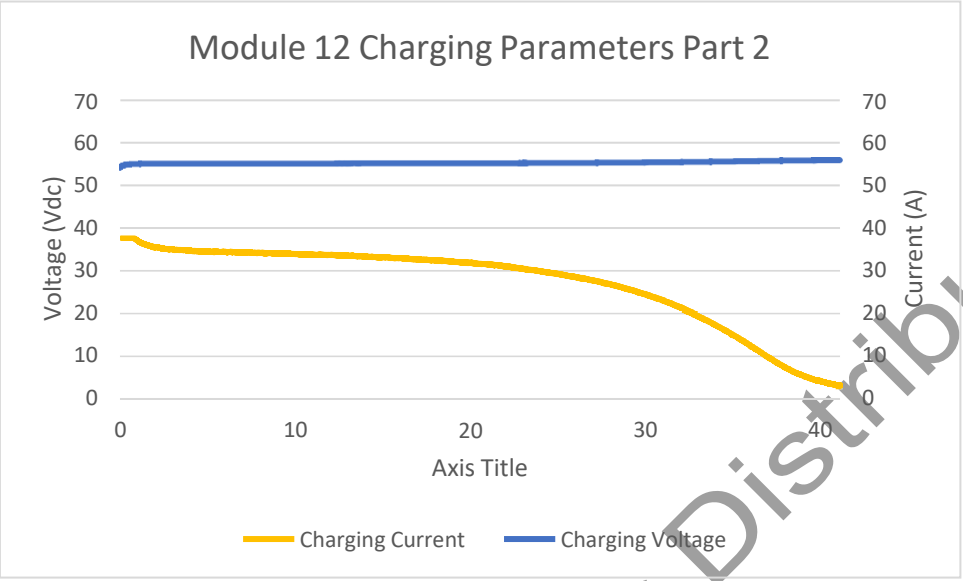


Figure 7 – Modules 12 Charging Parameters Part 2

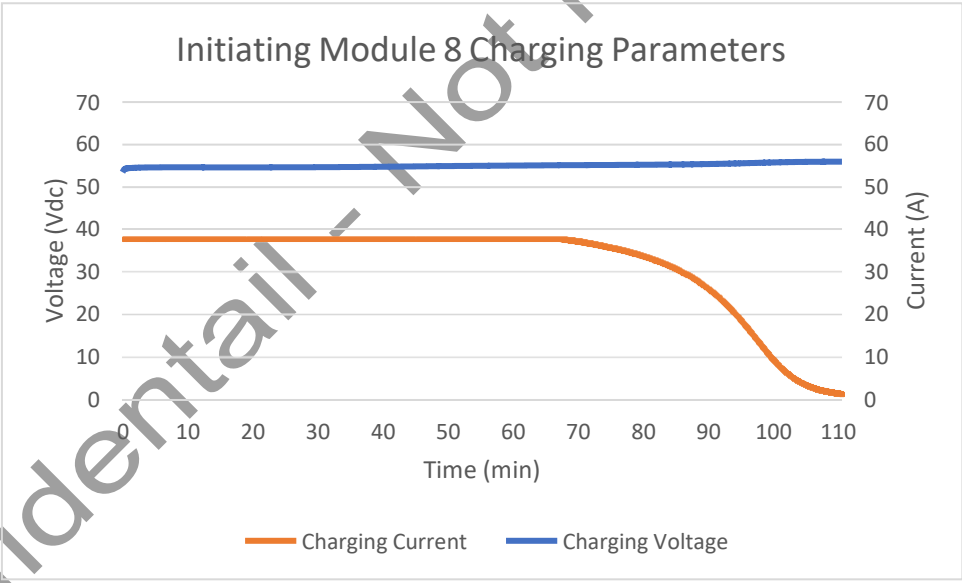


Figure 8 – Initiating Module 8 Charging Parameters

Attachment A (Cont'd):

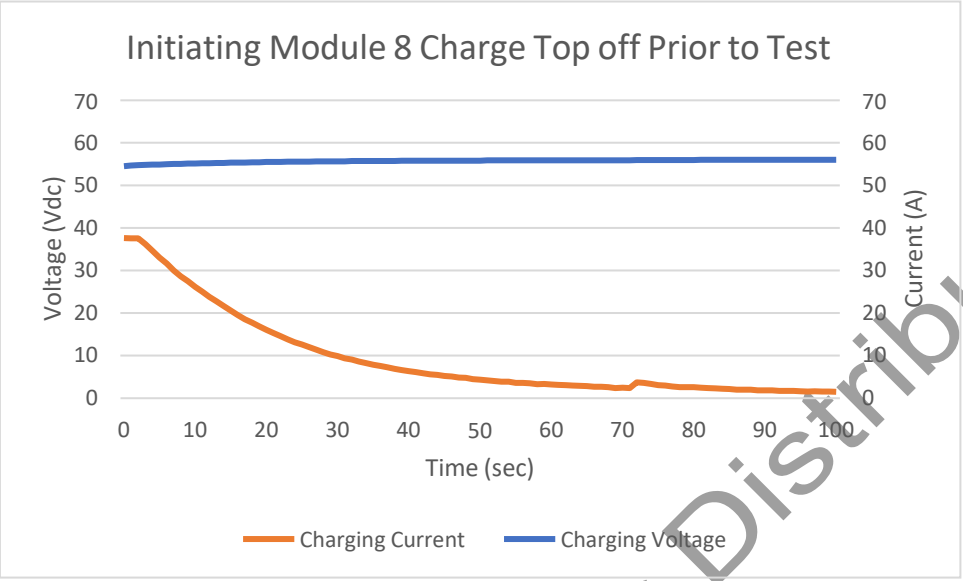


Figure 9 – Initiating Module 8 Charge Top off Prior to Test

Attachment B: BESS (including module and any integral fire detection and suppression systems) Construction Photos/Diagrams – (*Pages **32** through **34***)

Figure 1 - External View

Attachment B (Cont'd):

Figure 2 – Internal View

Attachment B (Cont'd):

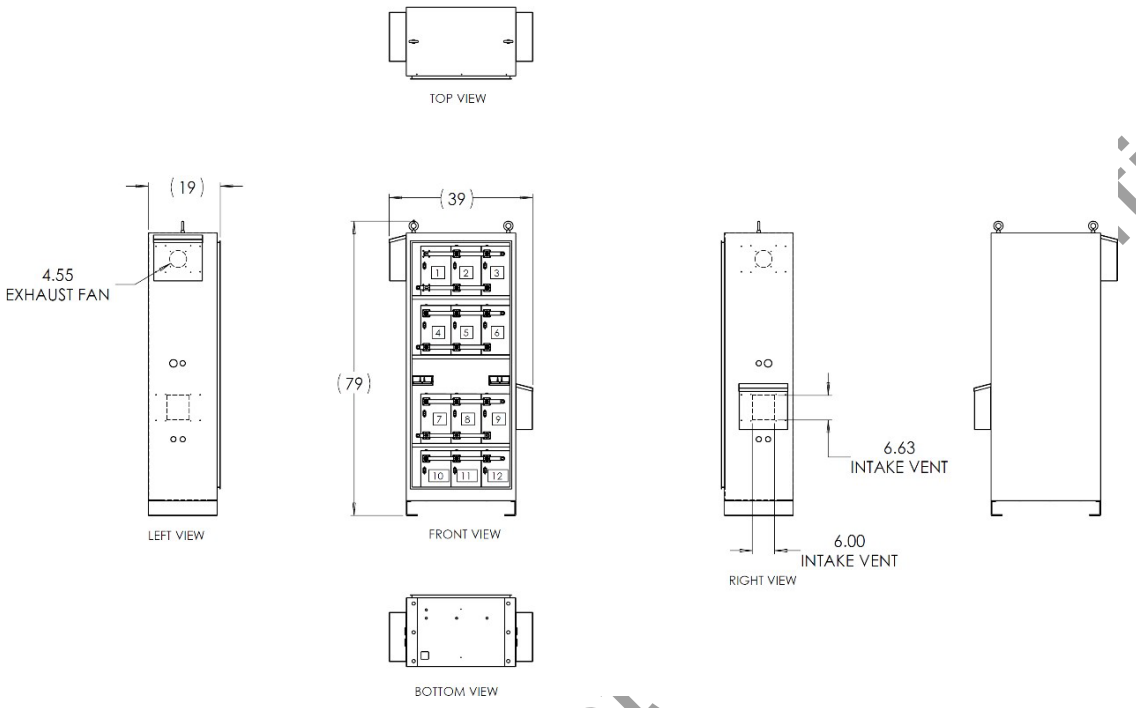


Figure 3 – Detailed Drawing of Cabinet

Attachment C1: Initiating Module Instrumentation – (*Pages **35** through **39***)

NOTE: Initiating Module Instrumentation was identical to that performed during module level test in Test Report No. 4789887084. Figures 1 through 6 below show instrumentation of thermocouples on the initiating module and are taken directly from Test Report No. 4789887084.

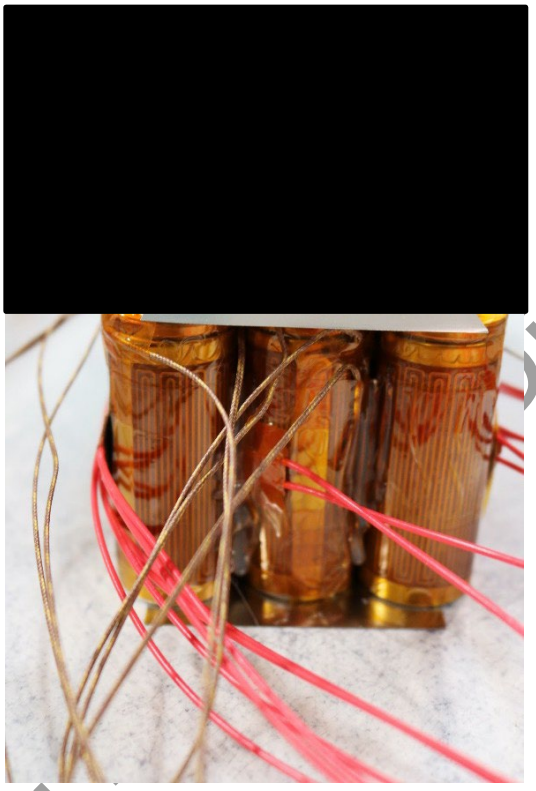


Figure 1 – Thermocouple Position on Initiating Cells (rear view)

Attachment C1 (Cont'd):

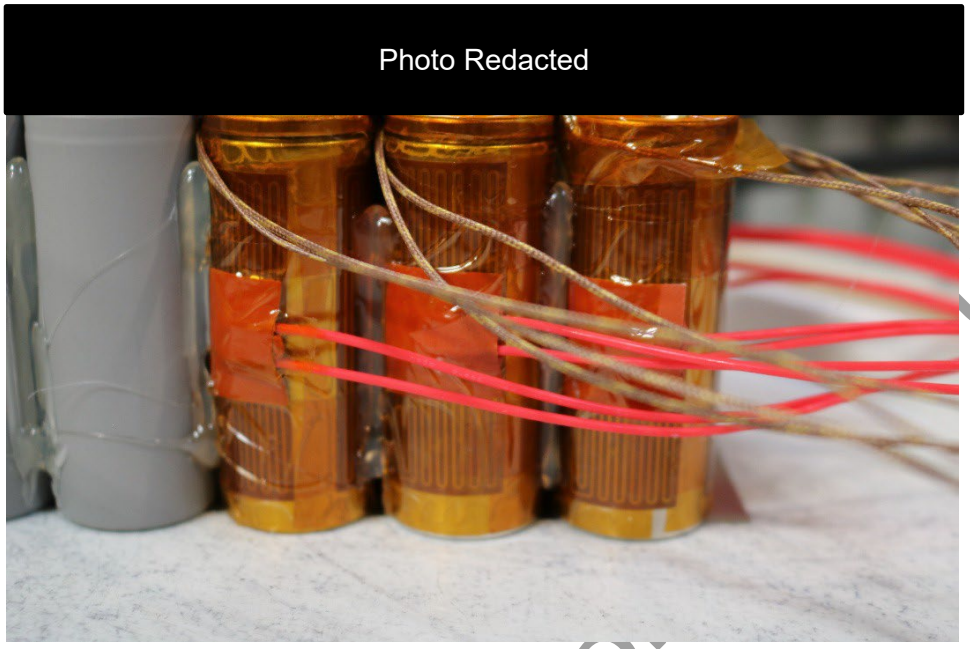


Figure 2 – Thermocouple Position on Initiating cells (side view)

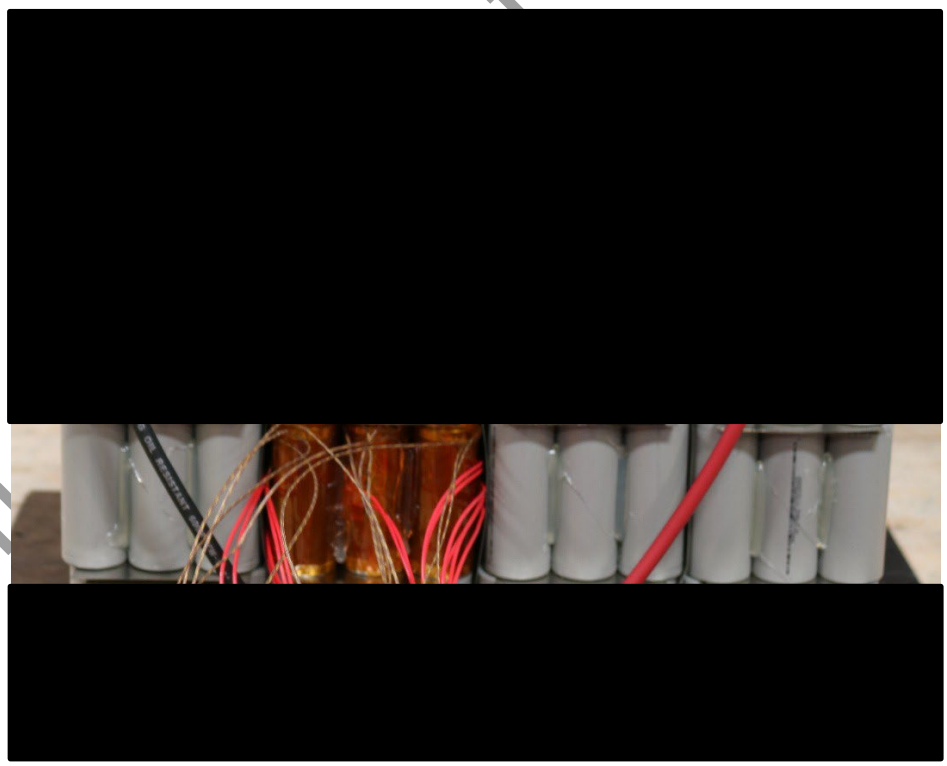


Figure 3 – Thermocouple Routing on Module (internal rear view)

Attachment C1 (Cont'd):

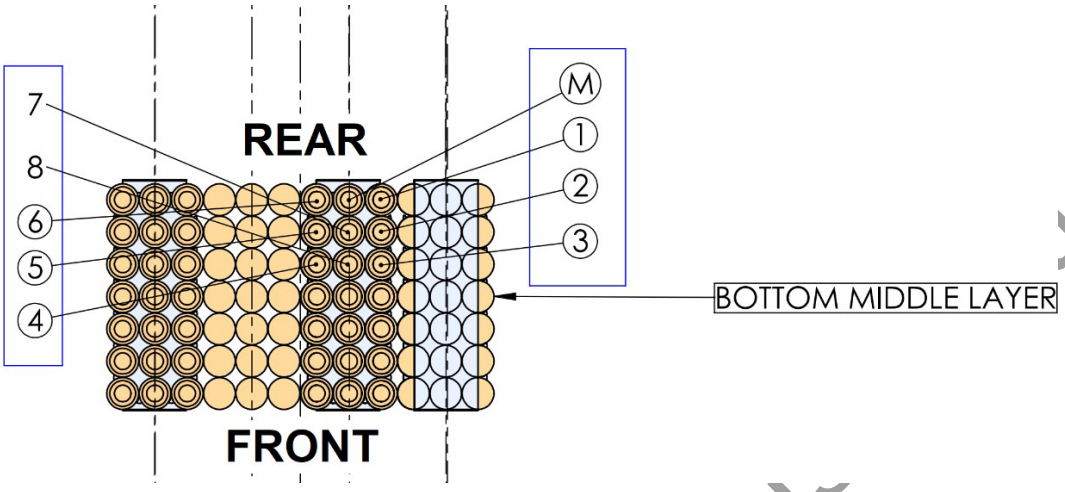


Figure 4 – Cell No. Identification for this report (top view).

Cell No. M: Monitored and Initiating (heated) Cell
Cell Nos. 1 – 6: Unmonitored Initiating (heated) Cells
Cell Nos. 7 and 8: Unmonitored, non-initiating (unheated) Cells

Attachment C1 (Cont'd):

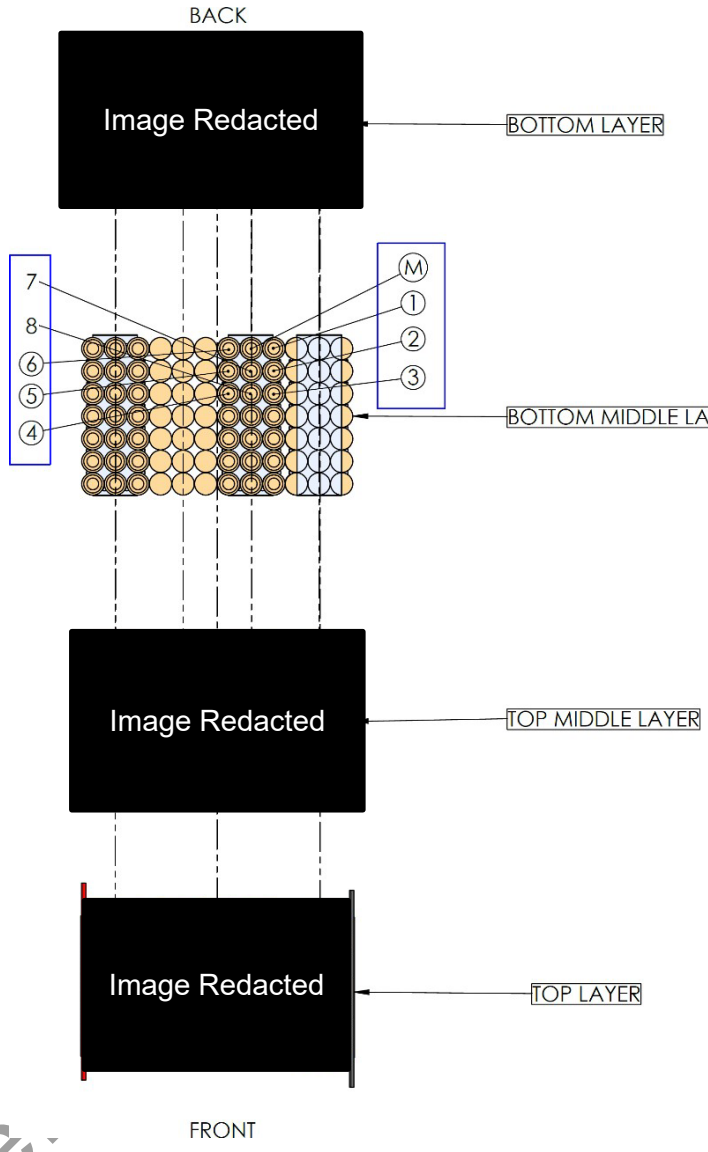


Figure 5 – Thermocouple Location

Attachment C1 (Cont'd):

THERMOCOUPLE NO.	DESCRIPTION	LOCATION
1	Cell M – Heated, Initiating, Monitored	Vertically centered between cell wall and heater wrap
2	Cell M – Heated, Initiating, Monitored	Inserted into cell vent area under positive terminal
3	Cell M – Heated, Initiating, Monitored	Horizontally centered in area not covered by heater wrap, near negative end
4	Cell M – Heated, Initiating, Monitored	Horizontally centered in area not covered by heater wrap, near positive end
5	Cell 1 – Heated, Initiating	Position - vertically centered between cell wall and heater wrap
6	Cell 2 – Heated, Initiating	Vertically centered between cell wall and heater wrap
7	Cell 3 – Heated, Initiating	Vertically centered between cell wall and heater wrap
8	Cell 4 – Heated, Initiating	Vertically centered between cell wall and heater wrap
9	Cell 5 – Heated, Initiating	Vertically centered between cell wall and heater wrap
10	Cell 6 – Heated, Initiating	Vertically centered between cell wall and heater wrap
11	Cell 7 – Unheated	Unheated cell case
12	Cell 8 – Unheated	Unheated cell case
20	Module Case	Top of Module
55	Module Case	Left Side of Module
56	Module Case	Right Side of Module

Figure 6 – Thermocouple Location Table for Initiating Module (inside Initiating Unit)

Attachment C2: Orientation of Initiating and Target Units During Test – (*Pages **40** through **41***)

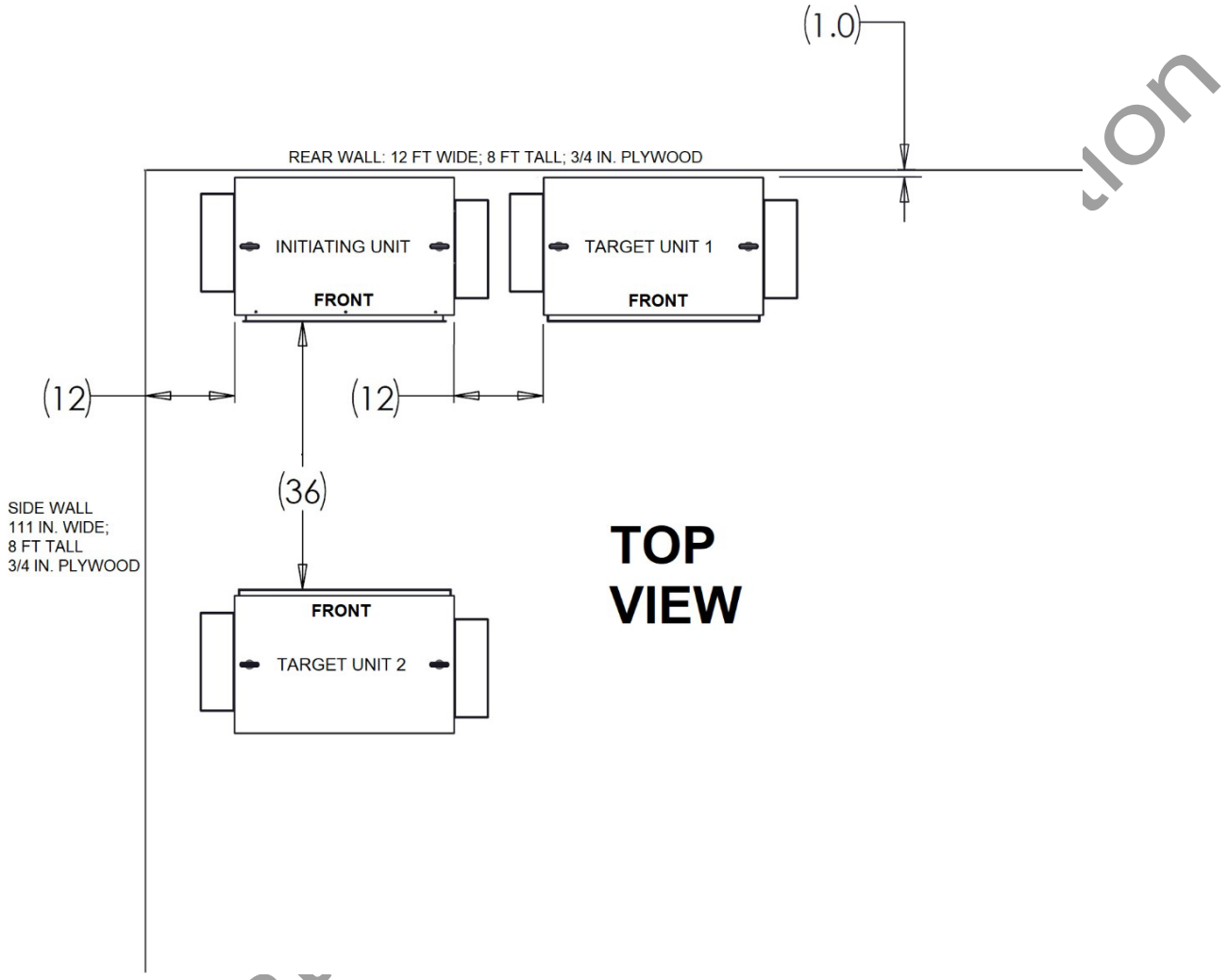


Figure 1 – Orientation of Initiating and Target Units (12 in. soffit not shown; located at top end of side and rear wall)

Attachment C2 (Cont'd):

Figure 2 – Photo Orientation of Initiating and Target Units

Attachment C3: Internal Layout of Unit – (*Page **42***)

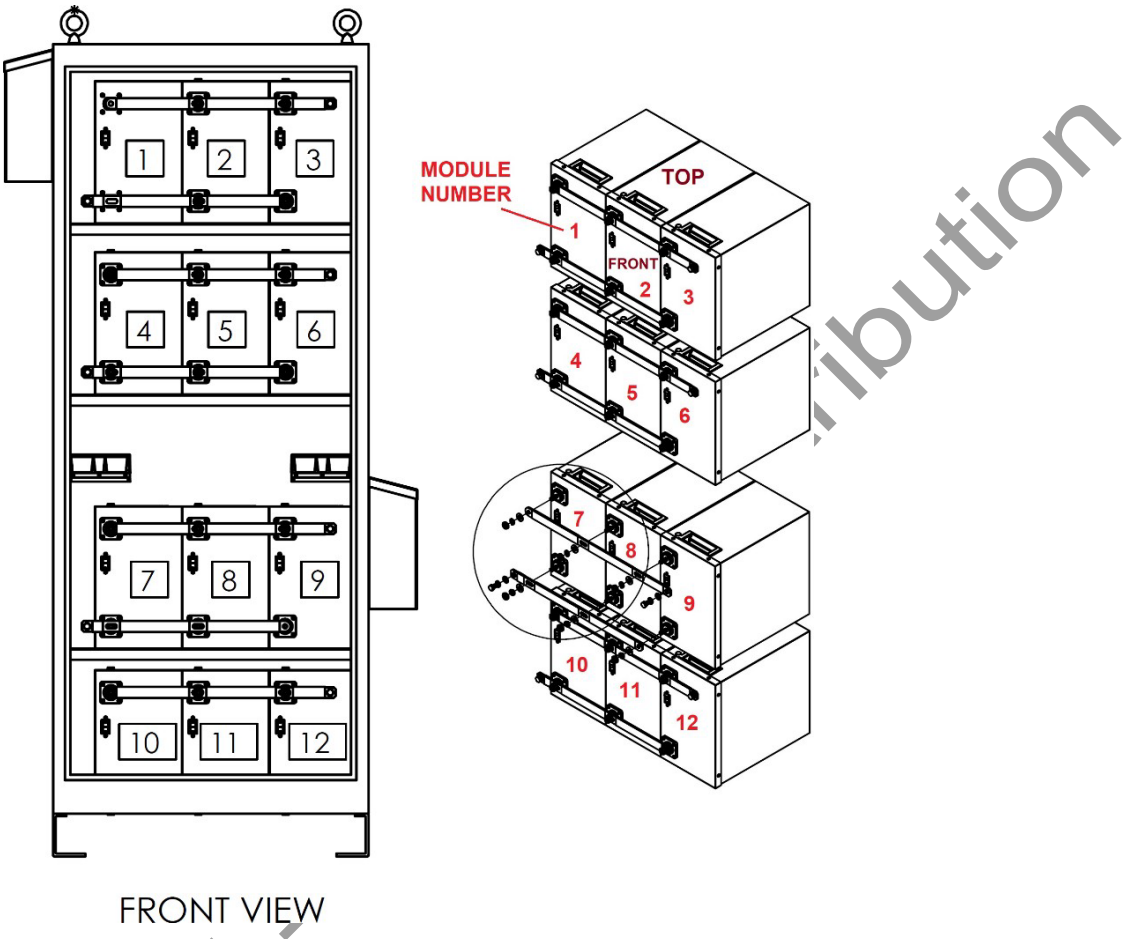


Figure 1 – Internal Layout of Unit

Attachment C4: Initiating Unit Instrumentation – (*Pages **43** through **45***)

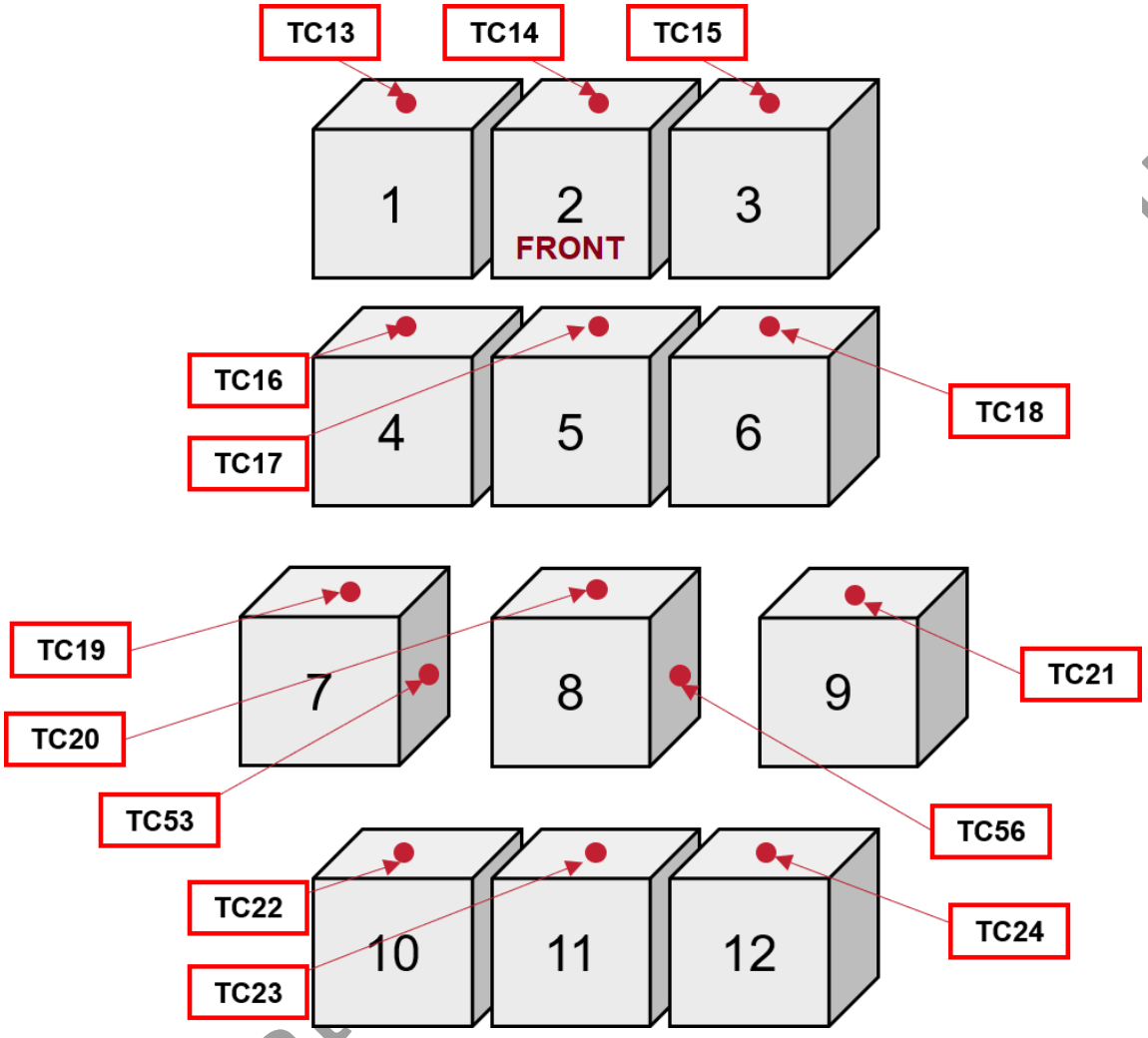


Figure 1 – Thermocouple Locations on top of Modules inside Initiating Unit (TC 54 and 55 not shown above due to viewing angle)

Attachment C4 (Cont'd):

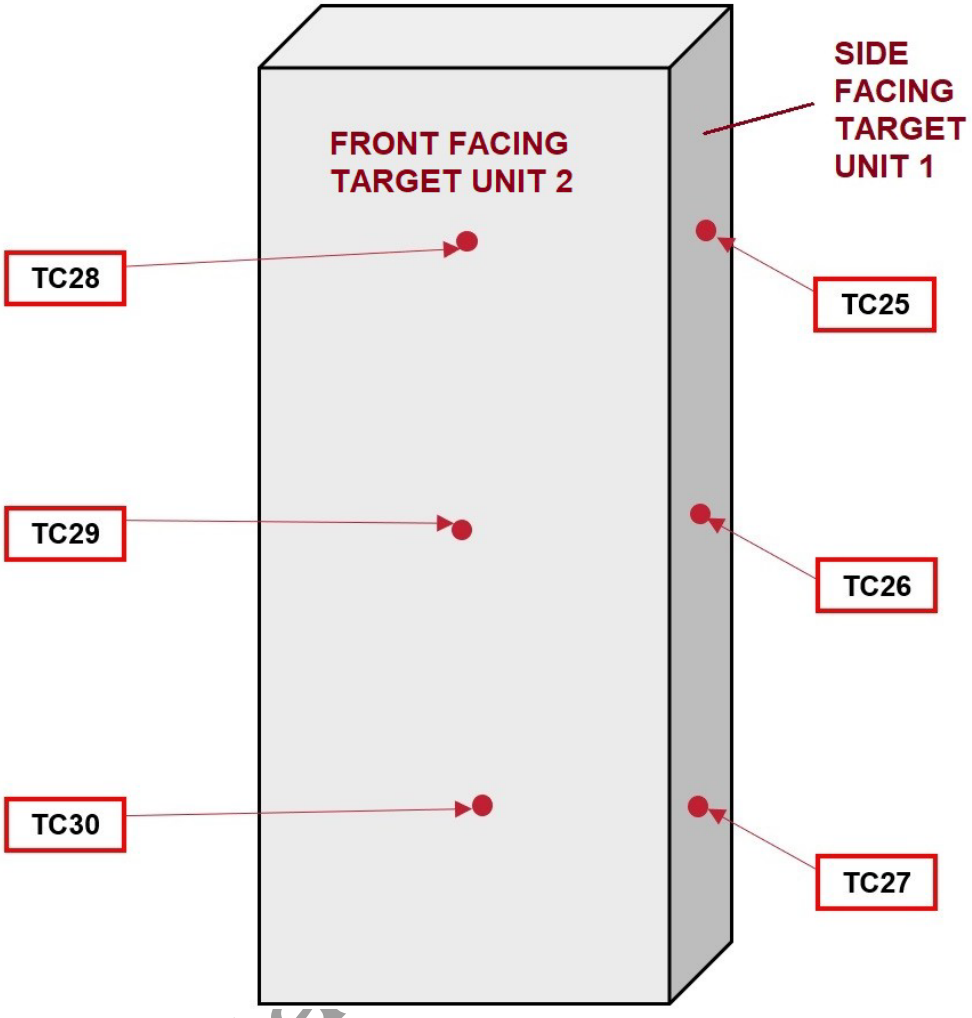


Figure 2 – Thermocouple Locations External Surface of Initiating Unit

Attachment C4 (Cont'd):

THERMOCOUPLE NO.	DESCRIPTION	LOCATION
13	Module 1 Case	Top of Module
14	Module 2 Case	Top of Module
15	Module 3 Case	Top of Module
16	Module 4 Case	Top of Module
17	Module 5 Case	Top of Module
18	Module 6 Case	Top of Module
19	Module 7 Case	Top of Module
53	Module 7 Case	Right Side of Module
20	Module 8 Case	Top of Module
55	Module 8 Case	Left Side of Module (not shown above)
56	Module 8 Case	Right Side of Module
21	Module 9 Case	Top of Module
54	Module 9 Case	Left Side of Module (not shown above)
22	Module 10 Case	Top of Module
23	Module 11 Case	Top of Module
24	Module 12 Case	Top of Module
25	Unit External Surface	Side External Surface Location 1 (top) Facing Target Unit 1 (Side)
26	Unit External Surface	Side External Surface Location 2 (middle) Facing Target Unit 1 (Side)
27	Unit External Surface	Side External Surface Location 3 (bottom) Facing Target Unit 1 (Side)
28	Unit External Surface	Front External Surface Location 1 (top) Facing Target Unit 2 (Front)
29	Unit External Surface	Front External Surface Location 2 (middle) Facing Target Unit 2 (Front)
30	Unit External Surface	Front External Surface Location 3 (bottom) Facing Target Unit 2 (Front)

Figure 3 - Thermocouple Location Table for Initiating Unit

Attachment C5: Target Unit 1 Unit Instrumentation – (*Pages **46** through **48***)

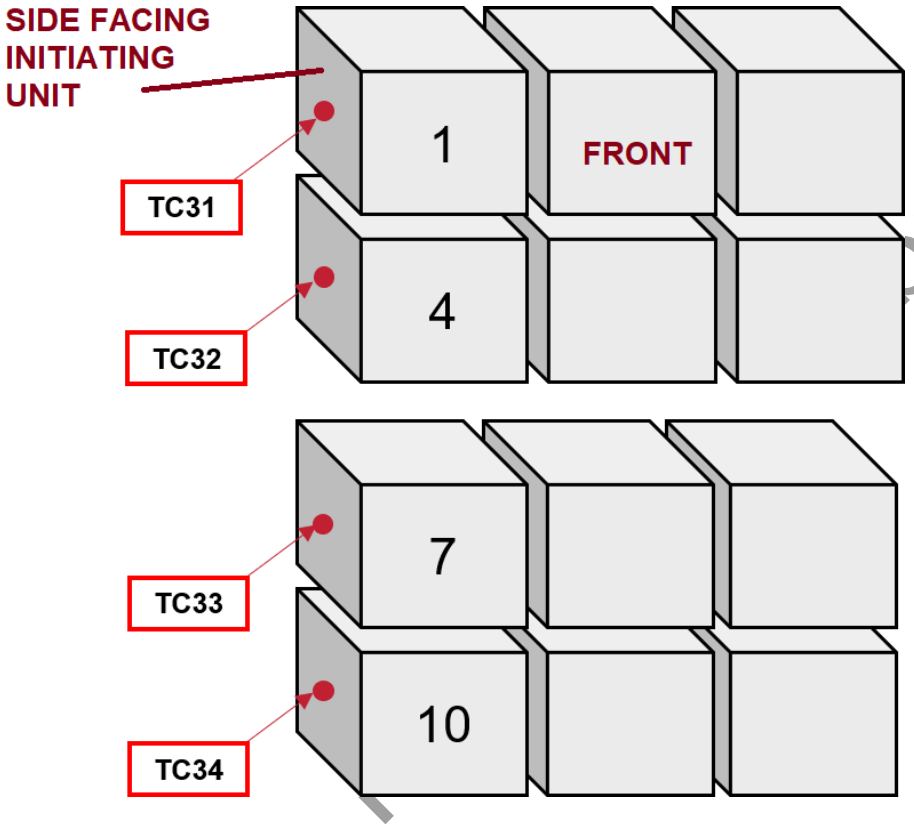


Figure 1 – Thermocouple Locations on Modules inside Target Unit 1

Attachment C5 (Cont'd):

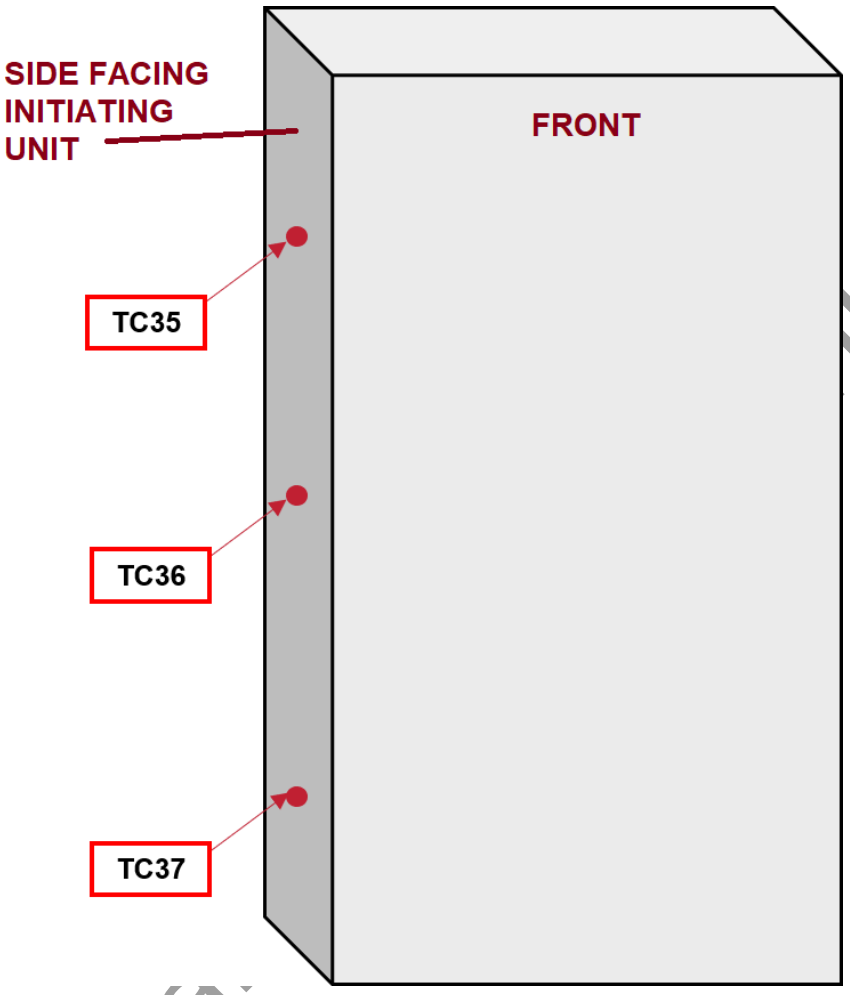


Figure 2 – Thermocouple Locations External Surface of Target Unit 1

Attachment C5 (Cont'd):

THERMOCOUPLE NO.	DESCRIPTION	LOCATION
31	Module 1 Case	Side of Module facing Initiating Unit
32	Module 2 Case	Side of Module facing Initiating Unit
33	Module 7 Case	Side of Module facing Initiating Unit
34	Module 10 Case	Side of Module facing Initiating Unit
35	Unit External Surface	Side External Surface Location 1 (top) Facing Initiating
36	Unit External Surface	Side External Surface Location 2 (middle) Facing Initiating
37	Unit External Surface	Side External Surface Location 3 (bottom) Facing Initiating

Figure 3 - Thermocouple Location Table for Target Unit 1

Attachment C6: Target Unit 2 Unit Instrumentation – (*Pages **49** through **51***)

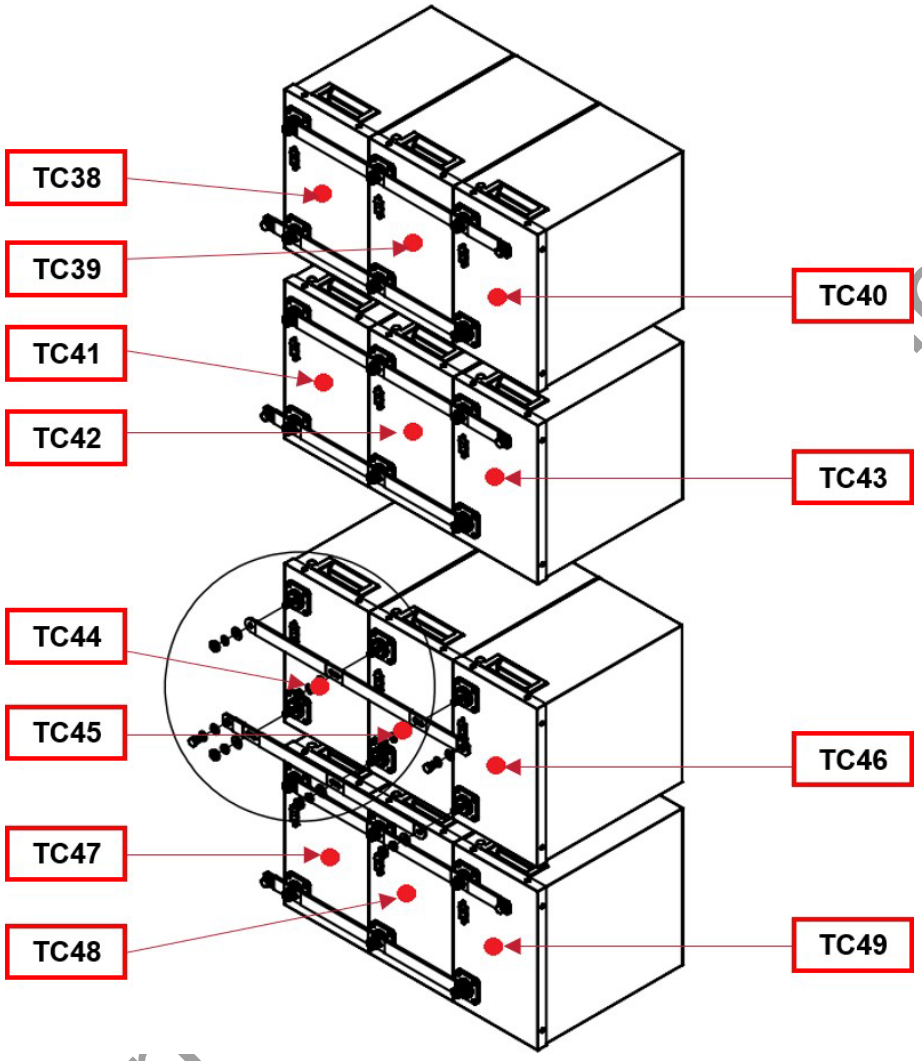


Figure 1 – Thermocouple Locations on Modules inside Target Unit 2

Attachment C6 (Cont'd):

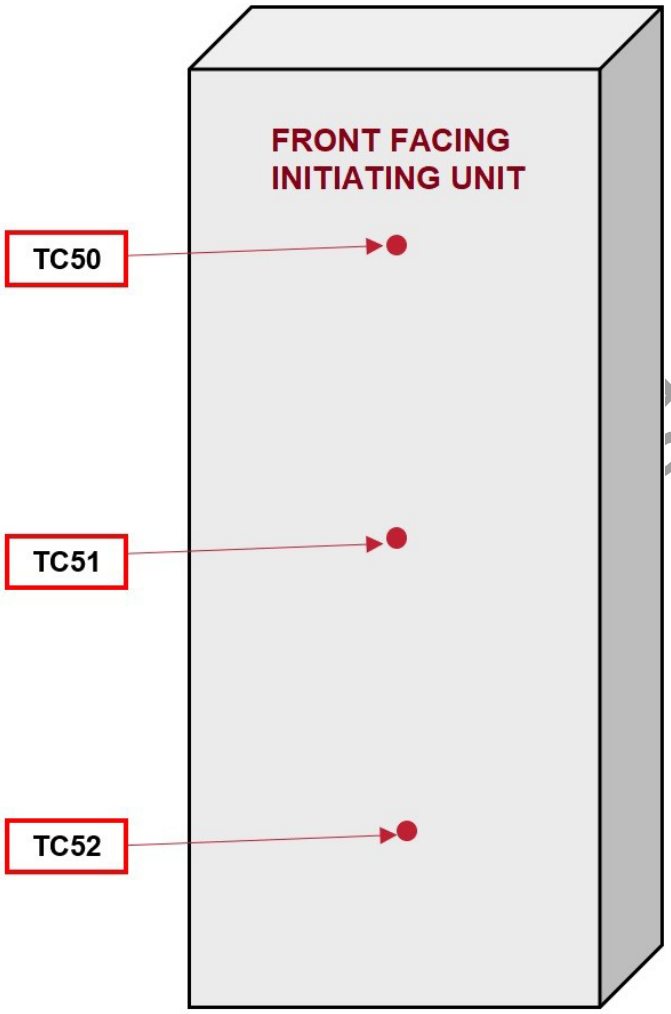


Figure 2 – Thermocouple Locations External Surface of Target Unit 2

Attachment C6 (Cont'd):

THERMOCOUPLE NO.	DESCRIPTION	LOCATION
38	Module 1 Case	Side of Module facing Initiating Unit
39	Module 2 Case	Side of Module facing Initiating Unit
40	Module 3 Case	Side of Module facing Initiating Unit
41	Module 4 Case	Side of Module facing Initiating Unit
42	Module 5 Case	Side of Module facing Initiating Unit
43	Module 6 Case	Side of Module facing Initiating Unit
44	Module 7 Case	Side of Module facing Initiating Unit
45	Module 8 Case	Side of Module facing Initiating Unit
46	Module 9 Case	Side of Module facing Initiating Unit
47	Module 10 Case	Side of Module facing Initiating Unit
48	Module 11 Case	Side of Module facing Initiating Unit
49	Module 12 Case	Side of Module facing Initiating Unit
50	Unit External Surface	Rear External Surface Location 1 (top) Facing Initiating Unit
51	Unit External Surface	Rear External Surface Location 2 (middle) Facing Initiating
52	Unit External Surface	Rear External Surface Location 3 (bottom) Facing Initiating

Figure 3 - Thermocouple Location Table for Target Unit 2

Attachment C7: Wall and Soffit Instrumentation – (*Pages **52** through **53***)

THERMOCOUPLE NO.	DESCRIPTION	LOCATION
58	Rear Wall	Wall Behind Initiating Unit, Aligned with the initiating module6 in. from floor
59	Rear Wall	Wall Behind Initiating Unit, Aligned with the initiating module12 in. from floor
60	Rear Wall	Wall Behind Initiating Unit, Aligned with the initiating module18 in. from floor
61	Rear Wall	Wall Behind Initiating Unit, Aligned with the initiating module24 in. from floor
62	Rear Wall	Wall Behind Initiating Unit, Aligned with the initiating module30 in. from floor
63	Rear Wall	Wall Behind Initiating Unit, Aligned with the initiating module 36 in. from floor
64	Rear Wall	Wall Behind Initiating Unit, Aligned with the initiating module42 in. from floor
65	Rear Wall	Wall Behind Initiating Unit, Aligned with the initiating module48 in. from floor
66	Rear Wall	Wall Behind Initiating Unit, Aligned with the initiating module54 in. from floor
67	Rear Wall	Wall Behind Initiating Unit, Aligned with the initiating module 60 in. from floor
68	Rear Wall	Wall Behind Initiating Unit, Aligned with the initiating module66 in. from floor
69	Rear Wall	Wall Behind Initiating Unit, Aligned with the initiating module72 in. from floor
70	Rear Wall	Wall Behind Initiating Unit, Aligned with the initiating module,78 in. from floor
71	Rear Wall	Wall Behind Initiating Unit, Aligned with the initiating module,84 in. from floor
72	Rear Wall	Wall Behind Initiating Unit, Aligned with the initiating module90 in. from floor
73	Rear Wall	Wall Behind Initiating Unit, Aligned with the initiating module,96 in. from floor (Located in crease of wall and soffit)
74	Soffit	Bottom Surface of Soffit 6 in. from rear wall, aligned with the initiating module
75	Soffit	Bottom Surface of Soffit 12 in. from rear wall, aligned with the initiating module
76	Side Wall	Wall Side of Initiating Unit, Aligned with the initiating module, 6 in. from floor
77	Side Wall	Wall Side of Initiating Unit, Aligned with the initiating module, 12 in. from floor
78	Side Wall	Wall Side of Initiating Unit, Aligned with the initiating module, 18 in. from floor
79	Side Wall	Wall Side of Initiating Unit, Aligned with the initiating module, 24 in. from floor
80	Side Wall	Wall Side of Initiating Unit, Aligned with the initiating module, 30 in. from floor

Figure 1 – Thermocouple Locations on Wall and Soffit Part 1

Attachment C7 (Cont'd):

THERMOCOUPLE NO.	DESCRIPTION	LOCATION
81	Side Wall	Wall Side of Initiating Unit, Aligned with the initiating module, 36 in. from floor
82	Side Wall	Wall Side of Initiating Unit, Centered Aligned with the initiating module, 42 in. from floor
83	Side Wall	Wall Side of Initiating Unit, Centered Aligned with the initiating module, 48 in. from floor
84	Side Wall	Wall Side of Initiating Unit, Centered Aligned with the initiating module, 54 in. from floor
85	Side Wall	Wall Side of Initiating Unit, Centered Aligned with the initiating module, 60 in. from floor
86	Side Wall	Wall Side of Initiating Unit, Centered Aligned with the initiating module, 66 in. from floor
87	Side Wall	Wall Side of Initiating Unit, Aligned with the initiating module, 72 in. from floor
88	Side Wall	Wall Side of Initiating Unit, Aligned with the initiating module, 78 in. from floor
89	Side Wall	Wall Side of Initiating Unit, Aligned with the initiating module, 84 in. from floor
90	Side Wall	Wall Side of Initiating Unit, Aligned with the initiating module, 90 in. from floor
91	Side Wall	Wall Side of Initiating Unit, Aligned with the initiating module, 96 in. from floor (Located in crease of wall and soffit)
92	Soffit	Bottom Surface of Soffit 6 in. from side wall, aligned with the initiating module
93	Soffit	Bottom Surface of Soffit 12 in. from Side wall, aligned with the initiating module

Figure 2 – Thermocouple Locations on Wall and Soffit Part 2

Attachment C8: Heat Flux Location – (*Page **54***)

Heat Flux Gauge Locations:	
1	Side Wall Nearest to initiating Module
2	Side Wall centered with Initiating Unit Enclosure Surface
3	Rear Wall nearest to Initiating Module
4	Rear Wall centered with Initiating Unit Enclosure Surface
5	Target Unit 1 enclosure Surface facing Initiating Unit; nearest to Initiating Module
6	Target Unit 1 centered on Side Enclosure Surface, facing Initiating Unit
7	Target Unit 2 Front Enclosure Surface facing Initiating Unit; nearest to Initiating Module
8	Target Unit 2 centered on Front Enclosure Surface, facing Initiating Unit
9	Path of Egress centered between Initiating Unit and Target Unit 2

Figure 1 – Heat Flux Gauge Locations

Attachment D: Temperature Profiles and Heat Flux Measurements During Testing (Initiating Cell and Module, Target Modules, Wall Surfaces, etc. – (*Pages **55** through **61***)

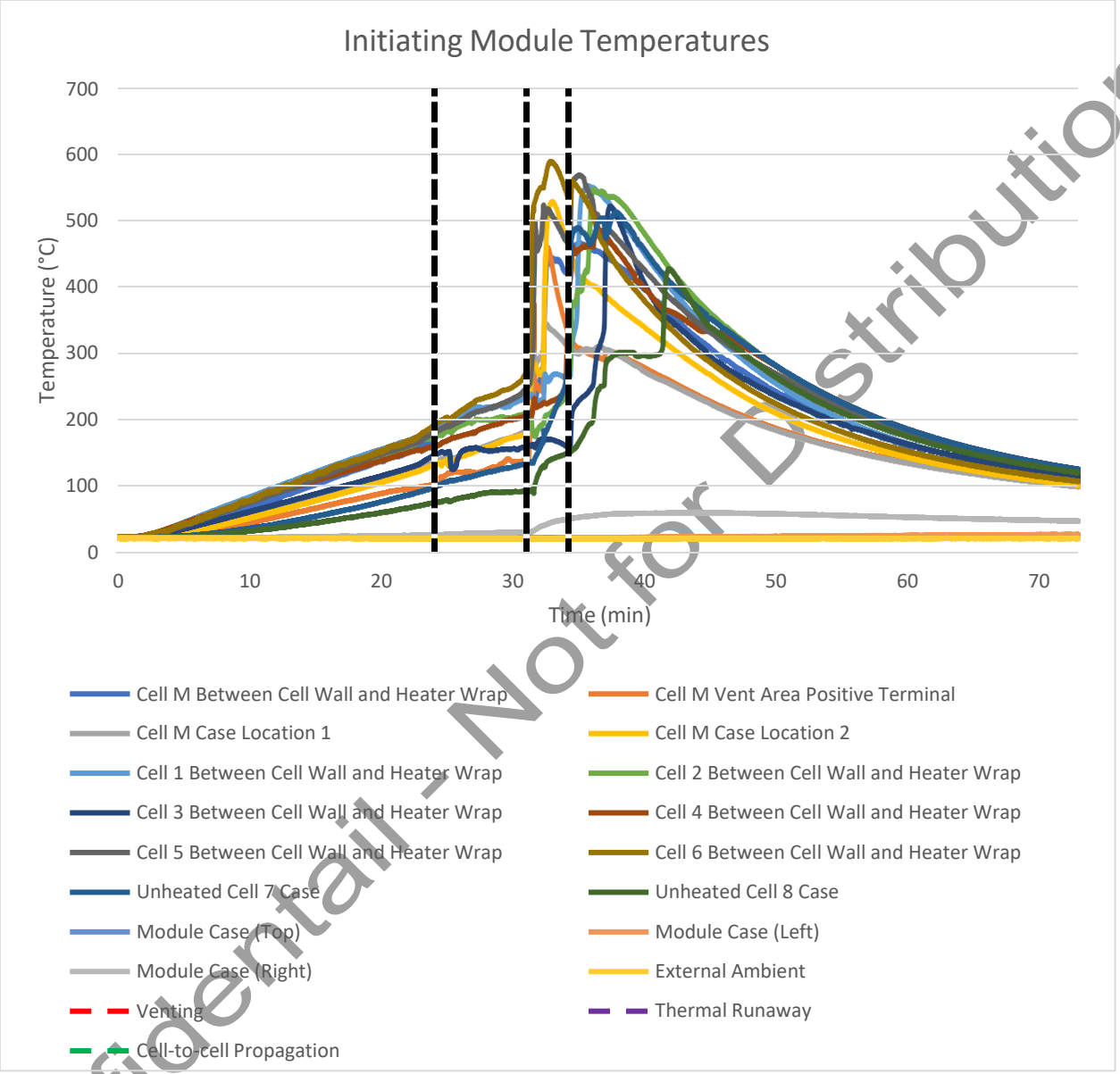


Figure 1 - Initiating Module Temperatures

Attachment D (Cont'd):

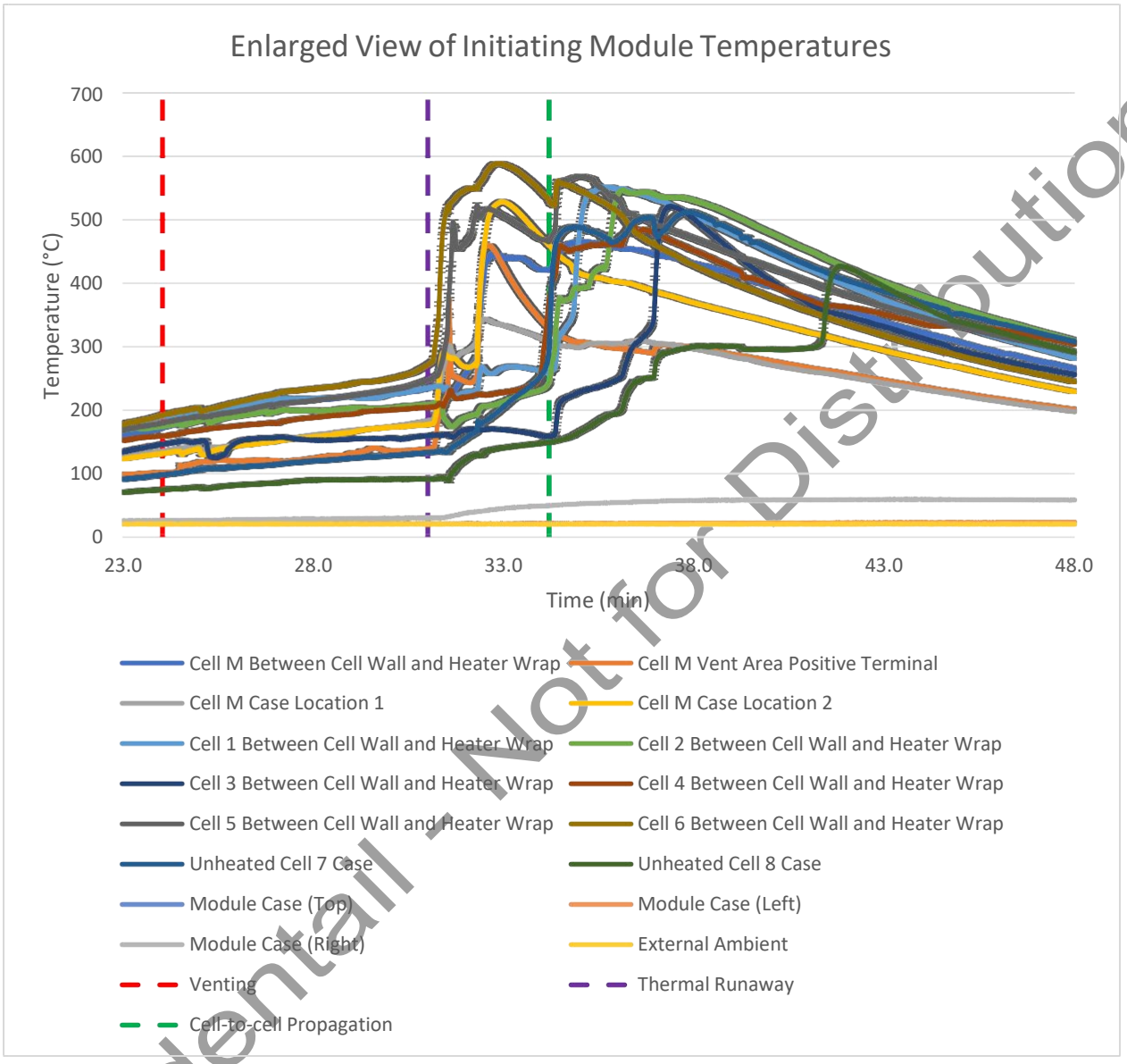


Figure 2 - Enlarged View Initiating Module Temperatures

Attachment D (Cont'd):

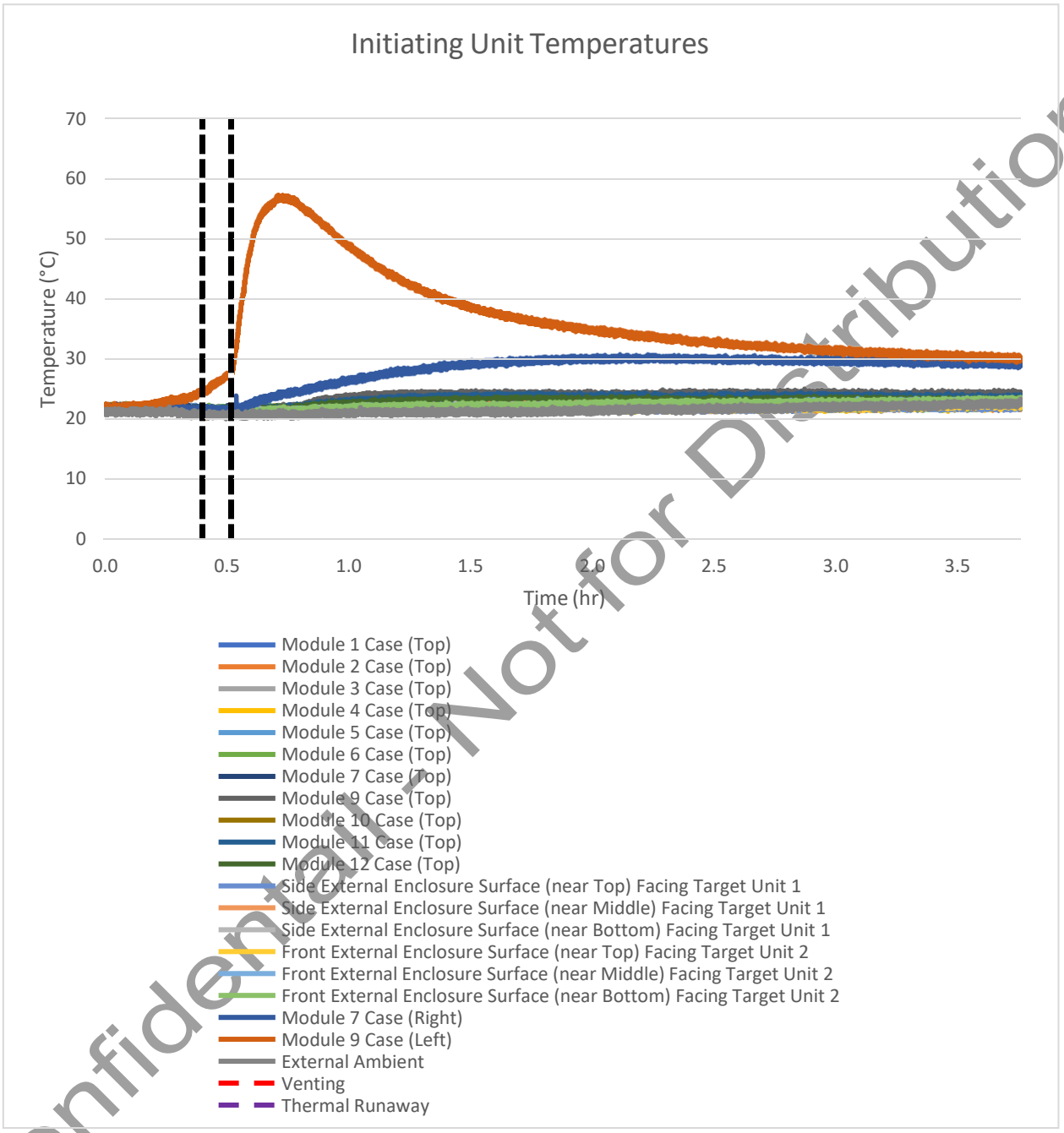


Figure 3 –Initiating Unit Temperatures

Attachment D (Cont'd):

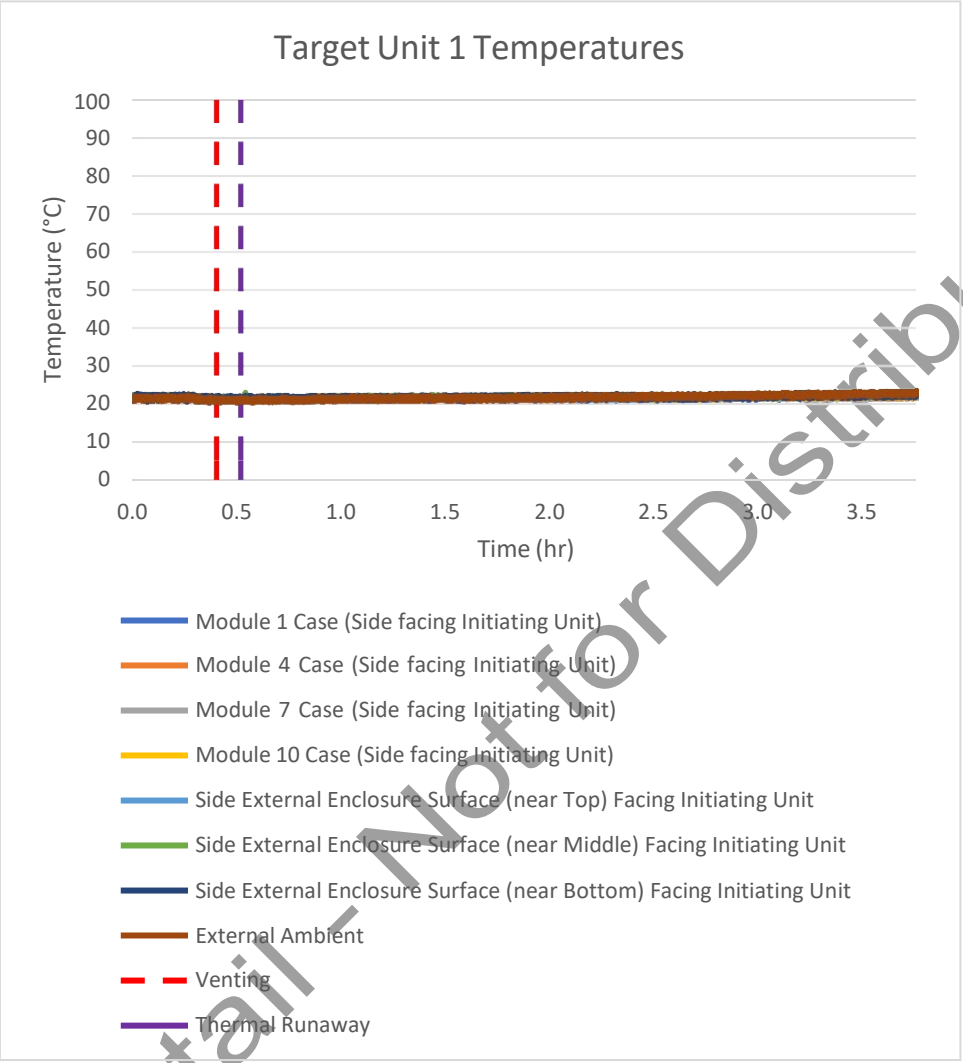


Figure 4 – Target Unit 1 Temperatures

Attachment D (Cont'd):

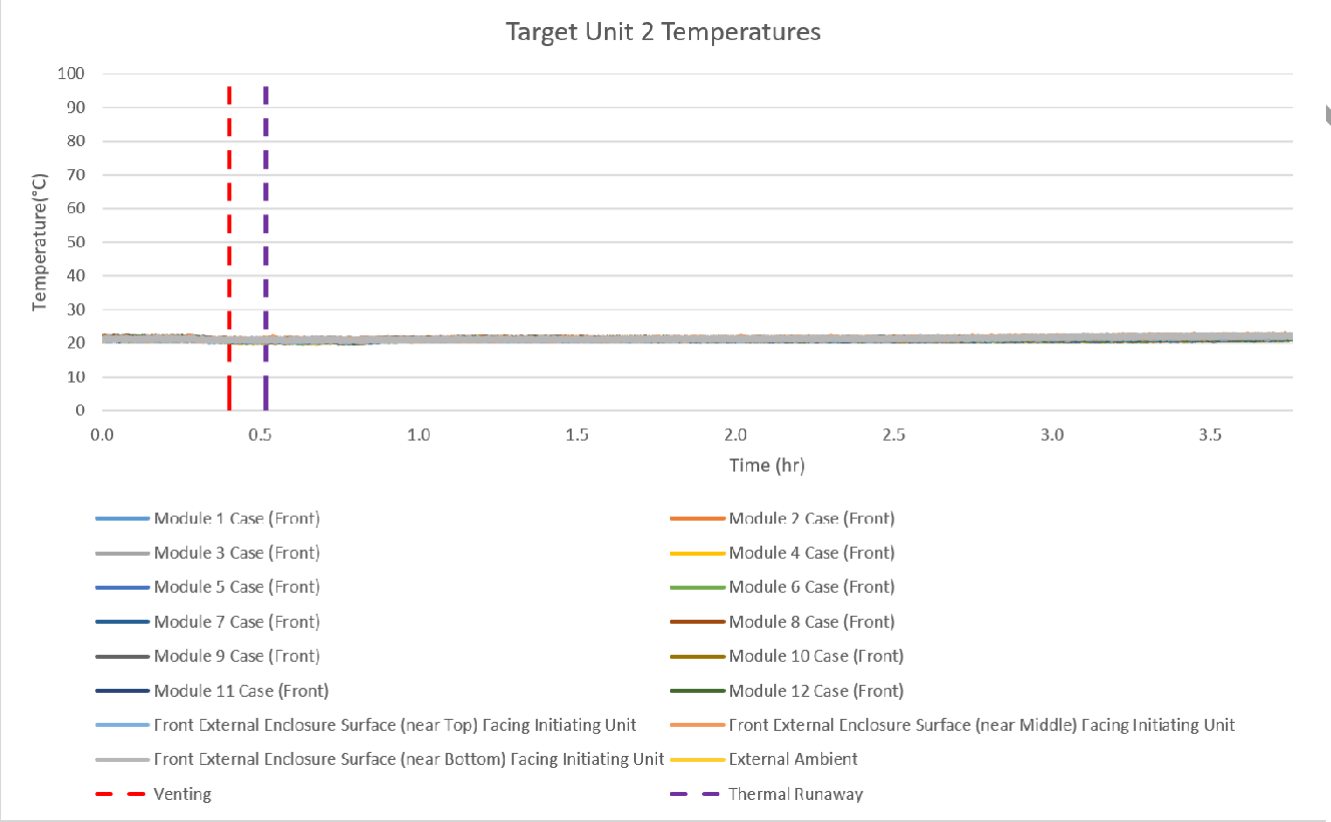


Figure 5 – Temperatures of Target Unit 2

Attachment D (Cont'd):

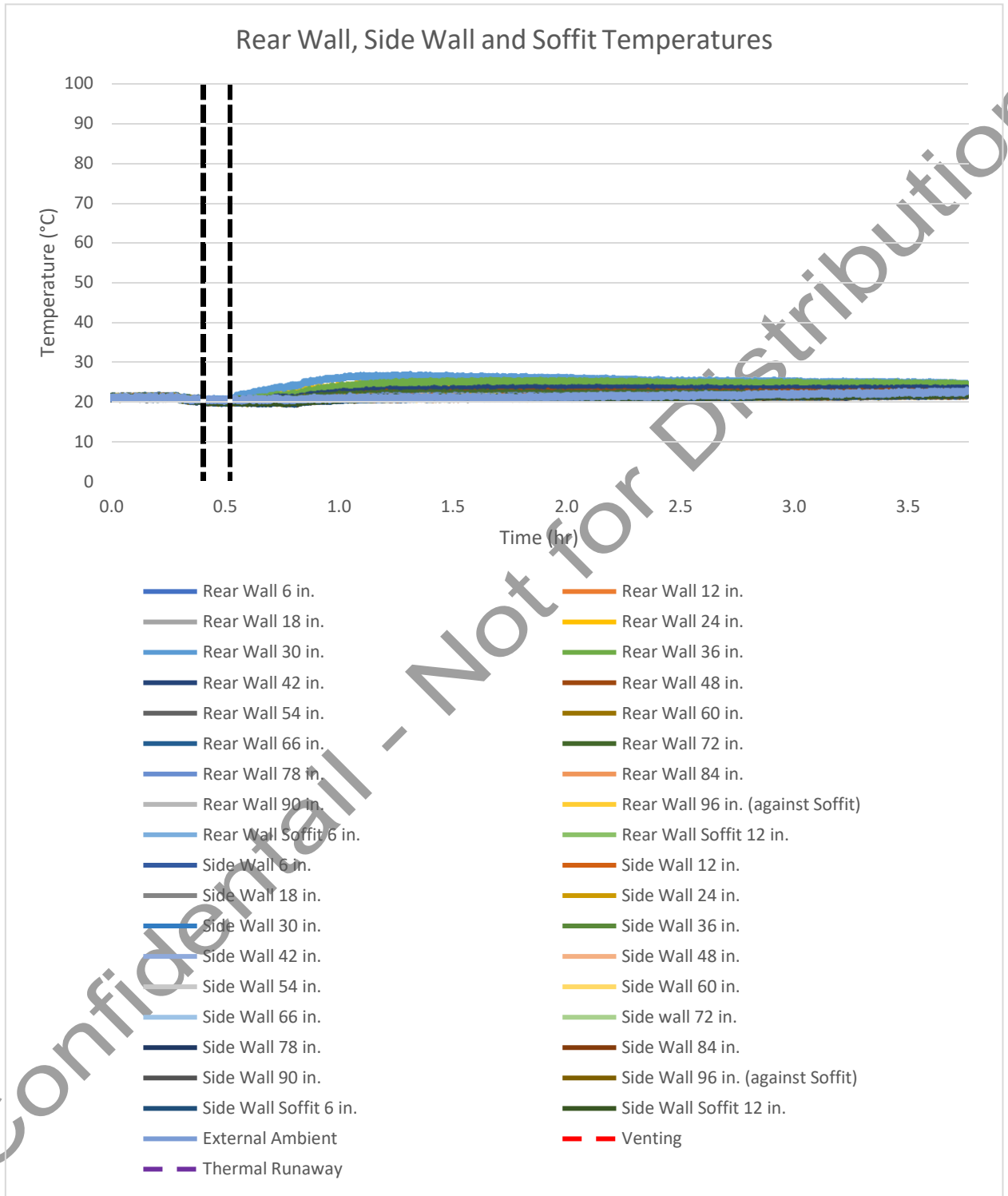


Figure 6 – Temperatures of Rear Wall, Side Wall and Soffit

Attachment D (Cont'd):

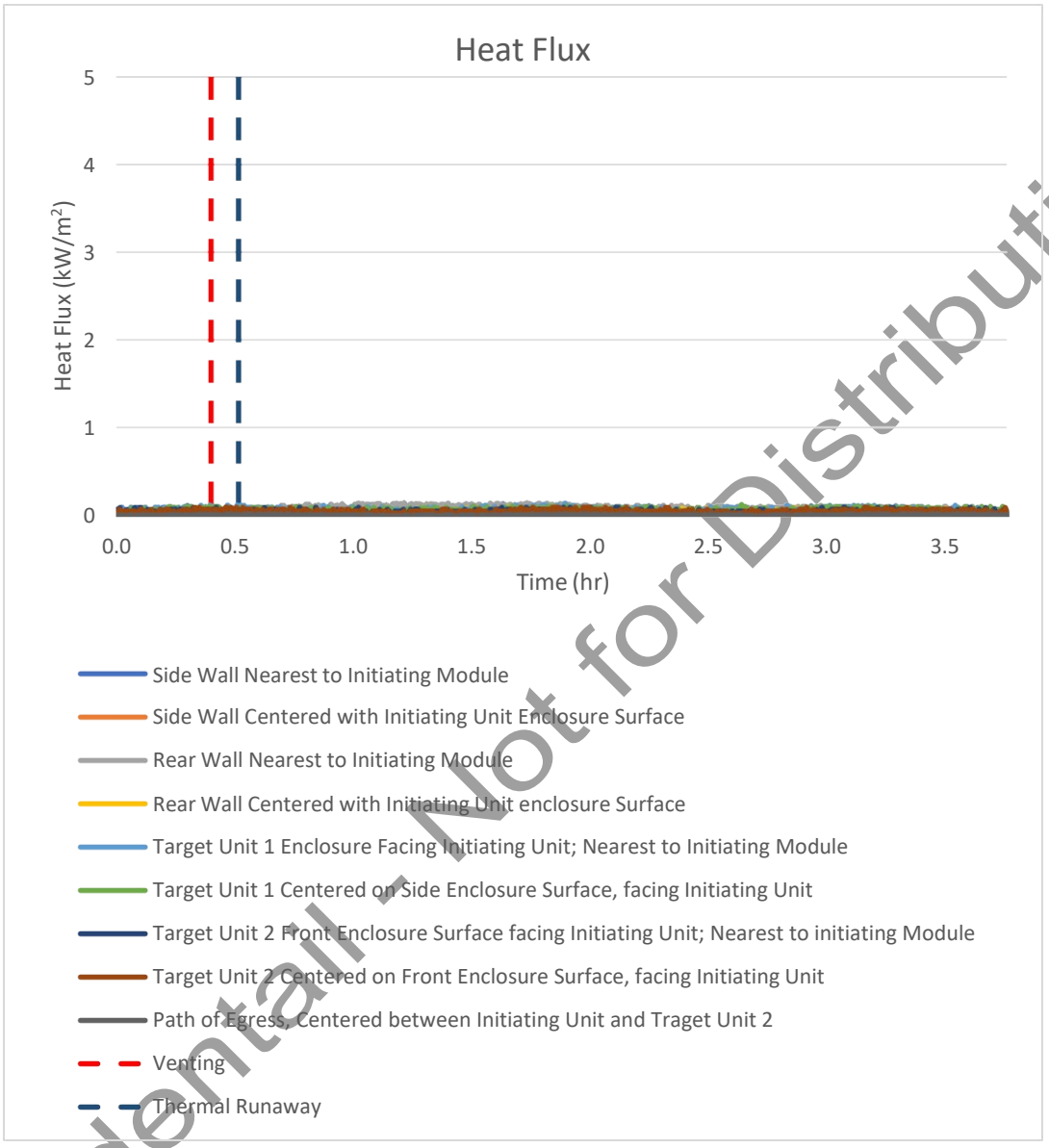


Figure 7 – Heat Flux Measurements

Attachment E: BESS Unit Testing and Post Testing Photos – (*Pages **62** through **67***)

Figure 1 – Start of Recording after Beginning of Test (00:03:00)

Figure 2 – Venting of Cell No. 6 (00:24:30)

Attachment E (Cont'd):

Figure 3 – Thermal Runaway of Cell No. 6 (00:31:10)

Figure 4 – Thermal Runaway of Cell No. 5 (00:31:19)

Attachment E (Cont'd):

Figure 5 – Thermal Runaway of Cell No. M (00:32:19)

Figure 6 – Thermal Runaway of Cell No. 4 (00:34:01)

Attachment E (Cont'd):

Figure 7 – Thermal Runaway of Cell No. 7 (indicates propagation) (00:34:12)

Figure 8 – Thermal Runaway of Cell No. 2 (00:34:14)

Attachment E (Cont'd):

Figure 9 – Thermal Runaway of Cell No.1 (00:34:53)

Figure 10 – Thermal Runaway of Cell No. 3 (00:36:55)

Attachment E (Cont'd):

Figure 11 – Thermal Runaway of Cell No. 8 (00:41:23)

Figure 12 – End of Test (03:46:06)

Attachment F: BESS Unit Gas Flow Rate and Heat Release and Smoke Release Profiles – (*Pages **68** through **70***)

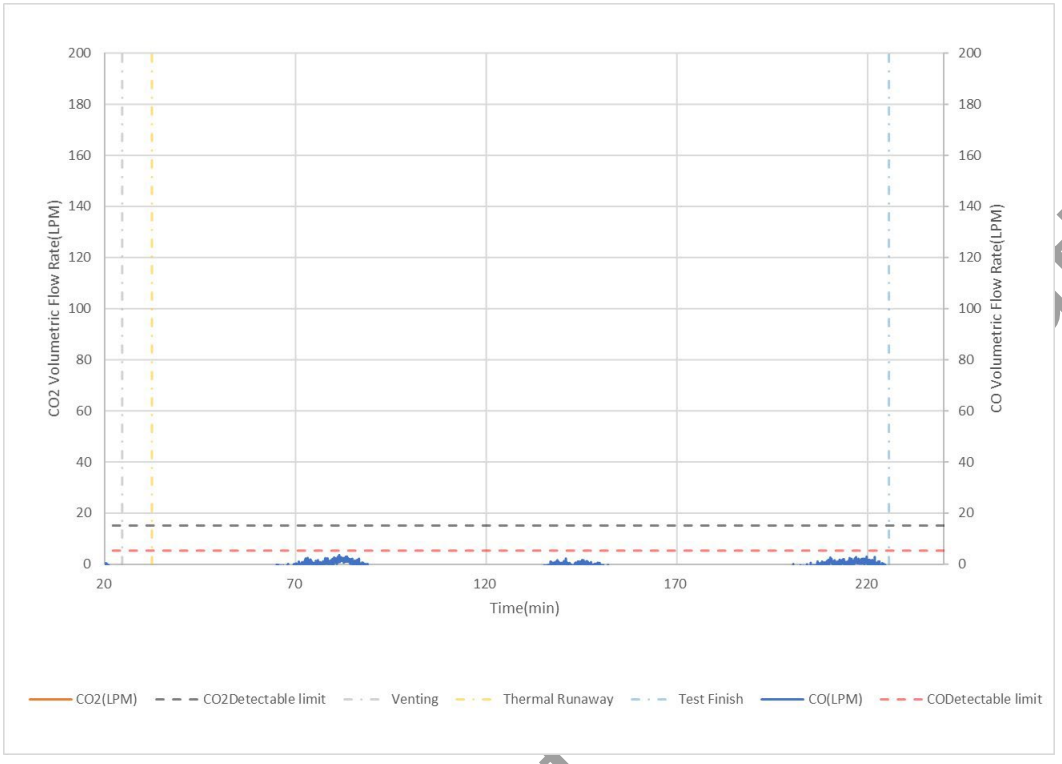


Figure 1 – Volumetric Flowrates of gasses (CO_2 and CO)

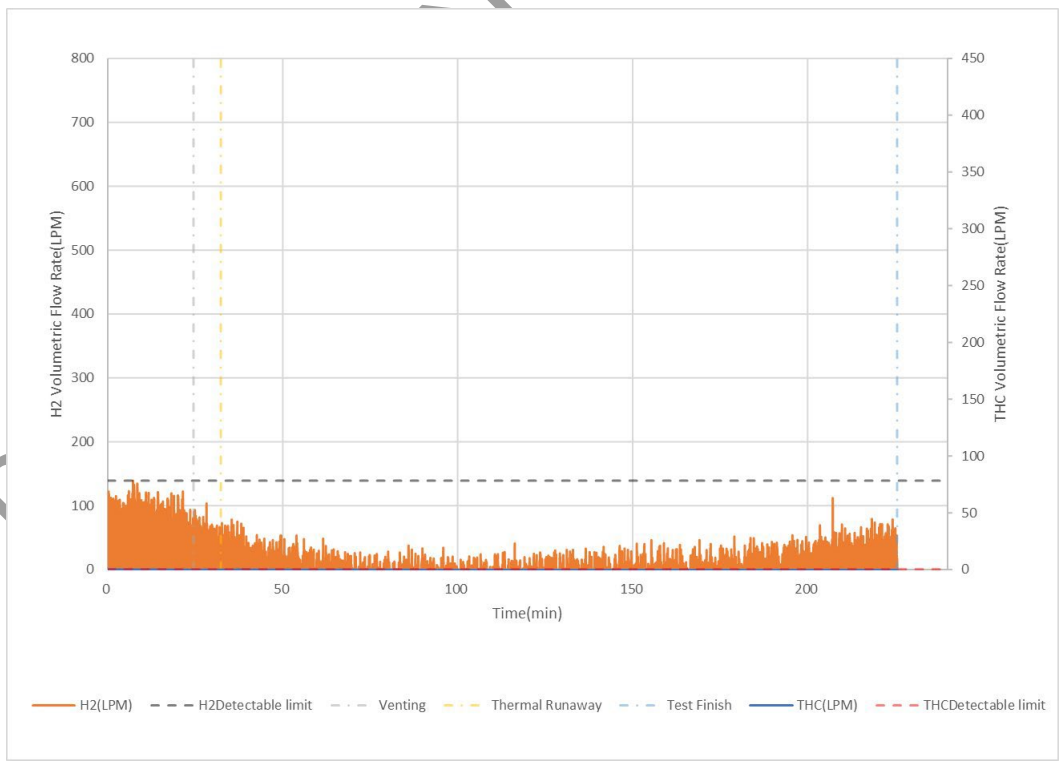


Figure 2 – Volumetric Flowrates of gasses (THC and H_2)

Attachment F (Cont'd):

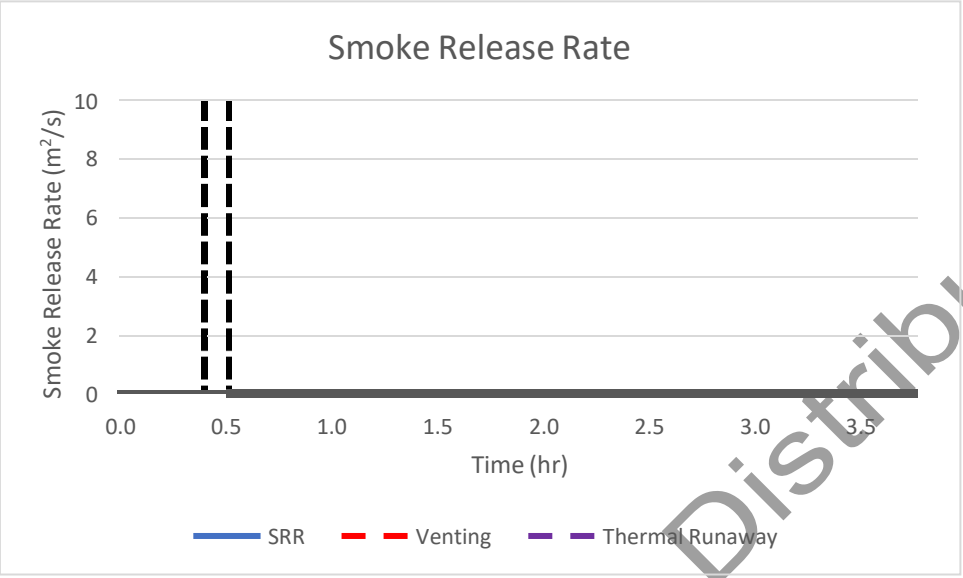


Figure 3 – Smoke Release Rate

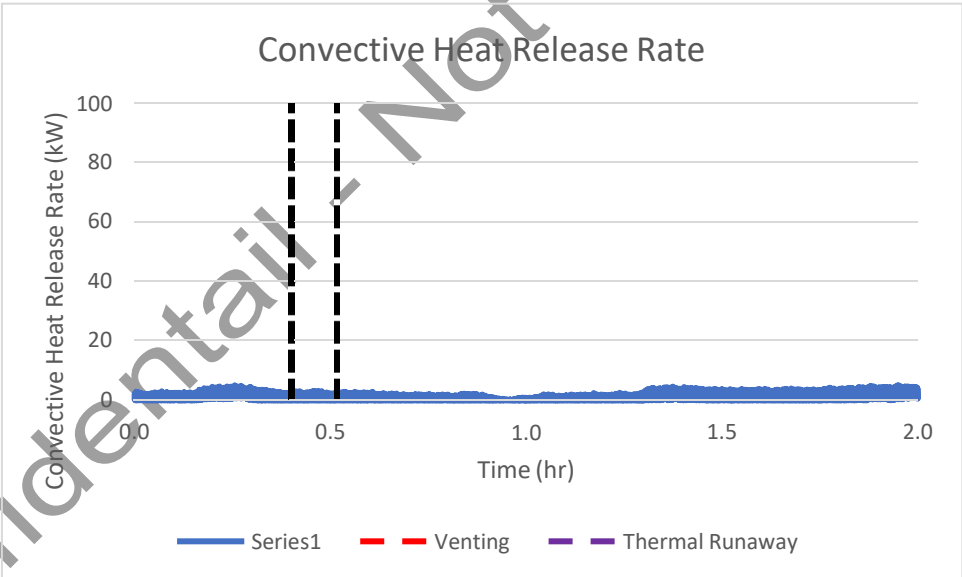


Figure 4 – Convective Heat Release Rate

Attachment F (Cont'd):

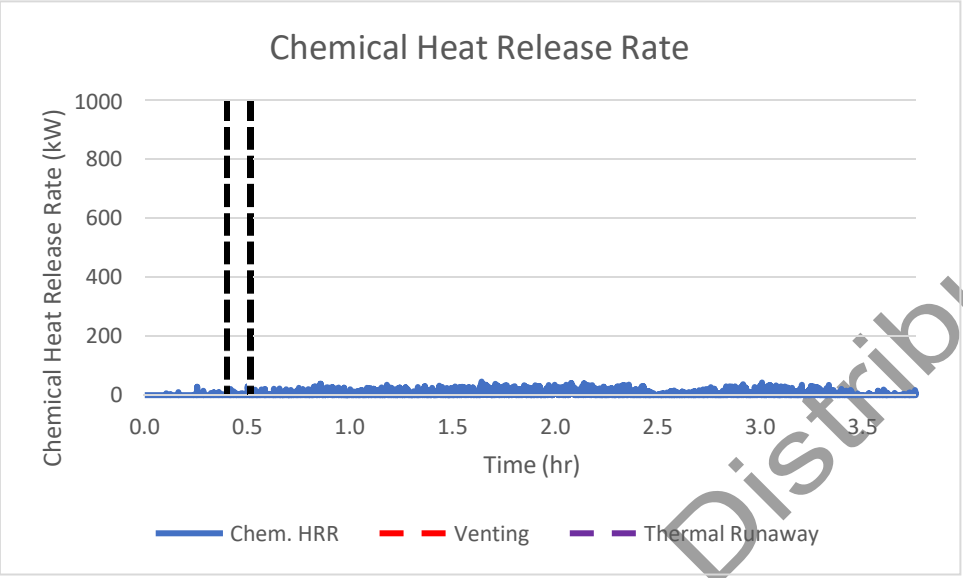


Figure 5 – Chemical Heat Release Rate