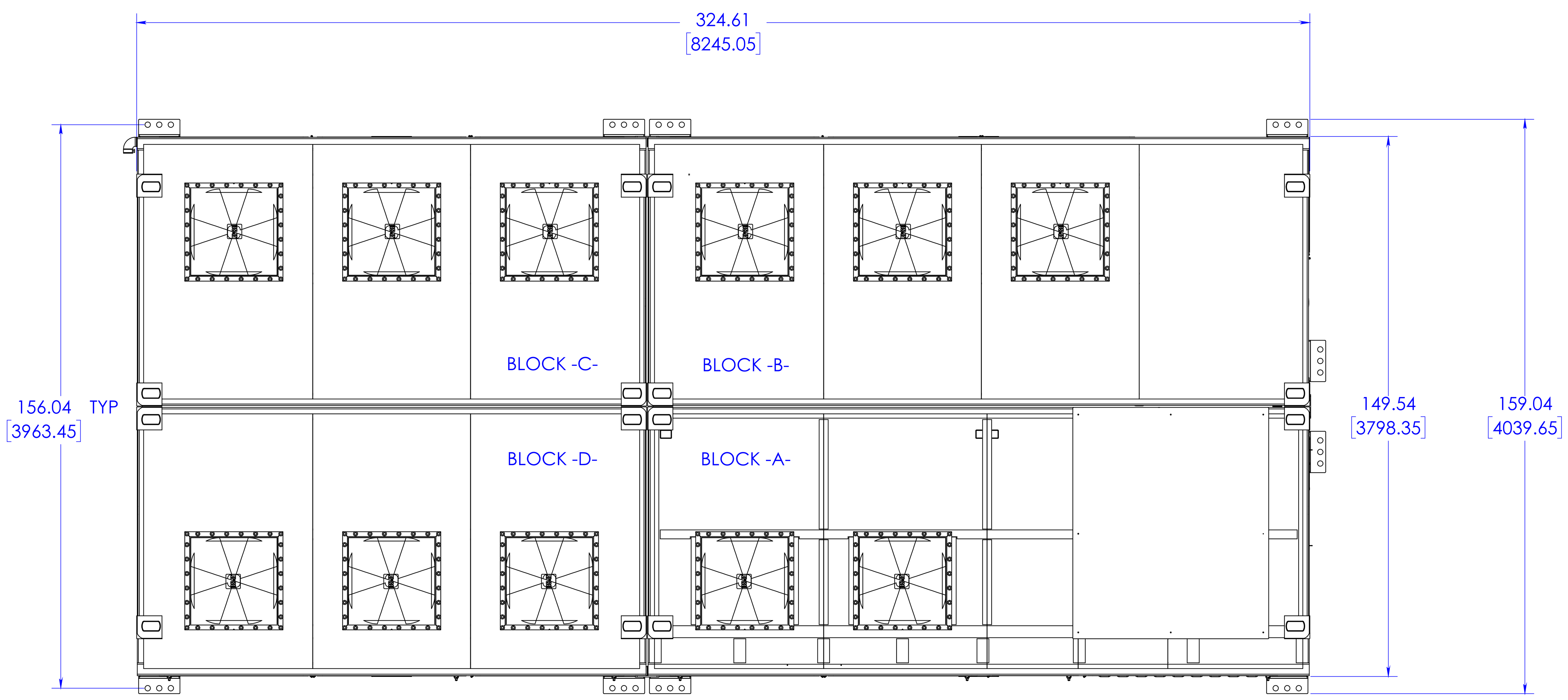
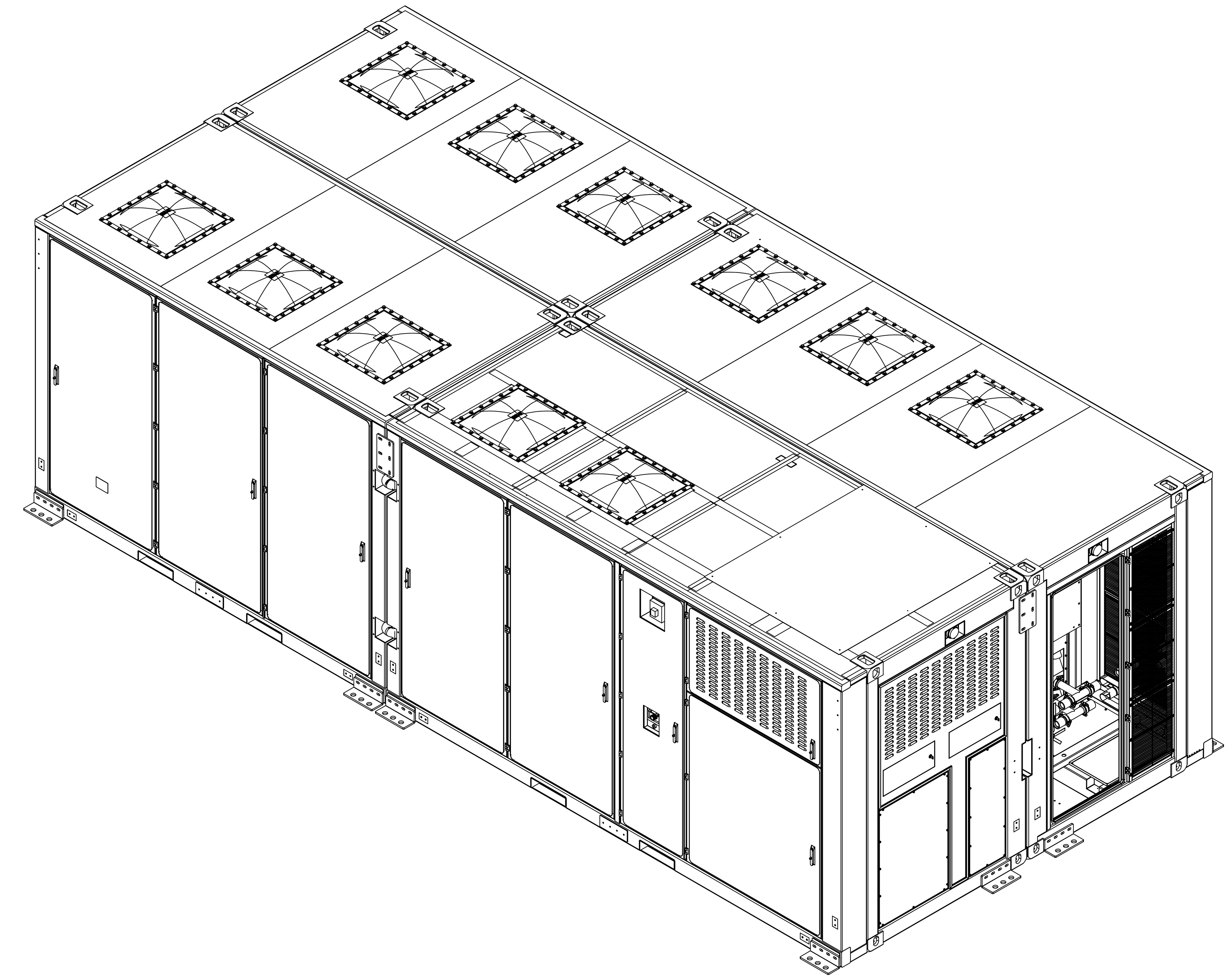
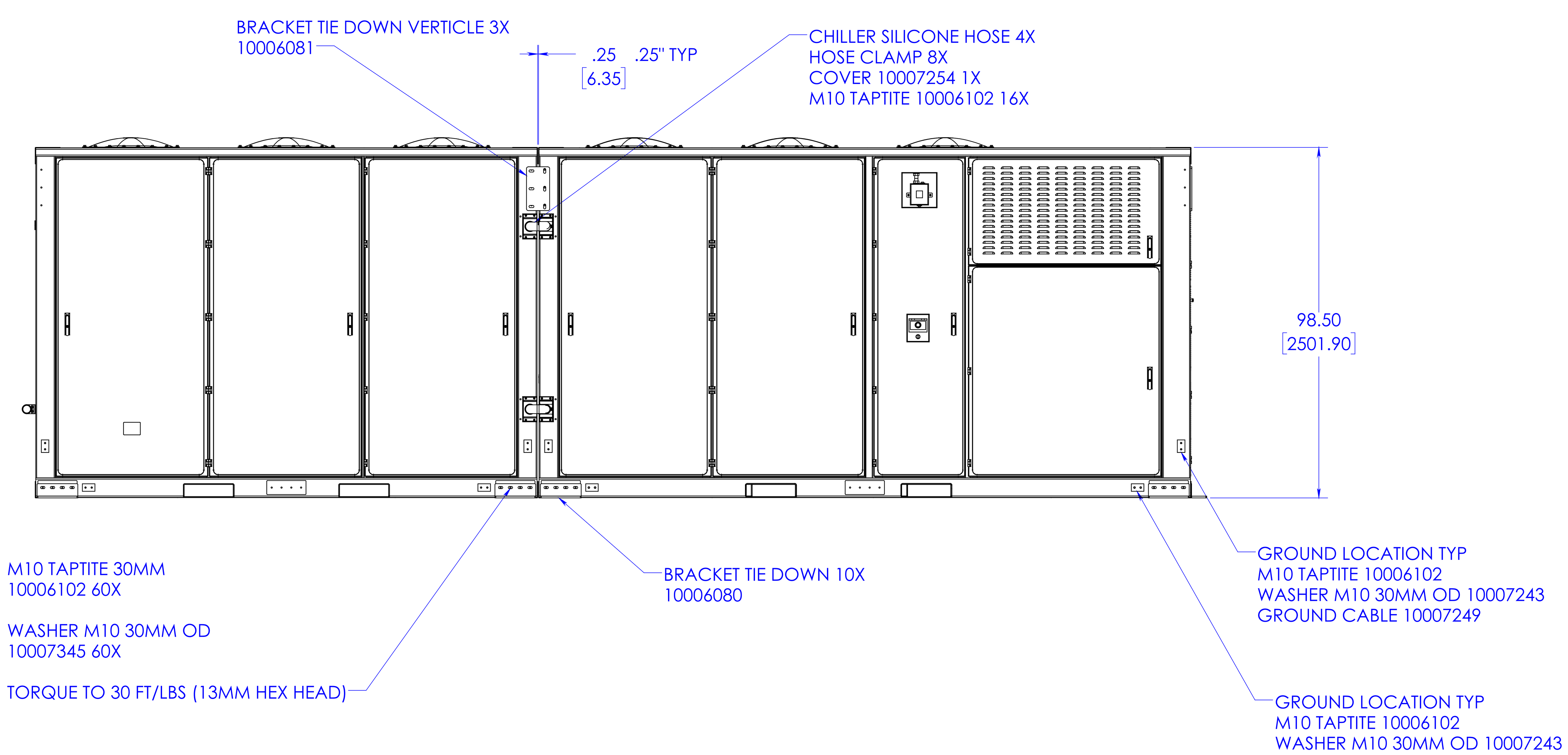
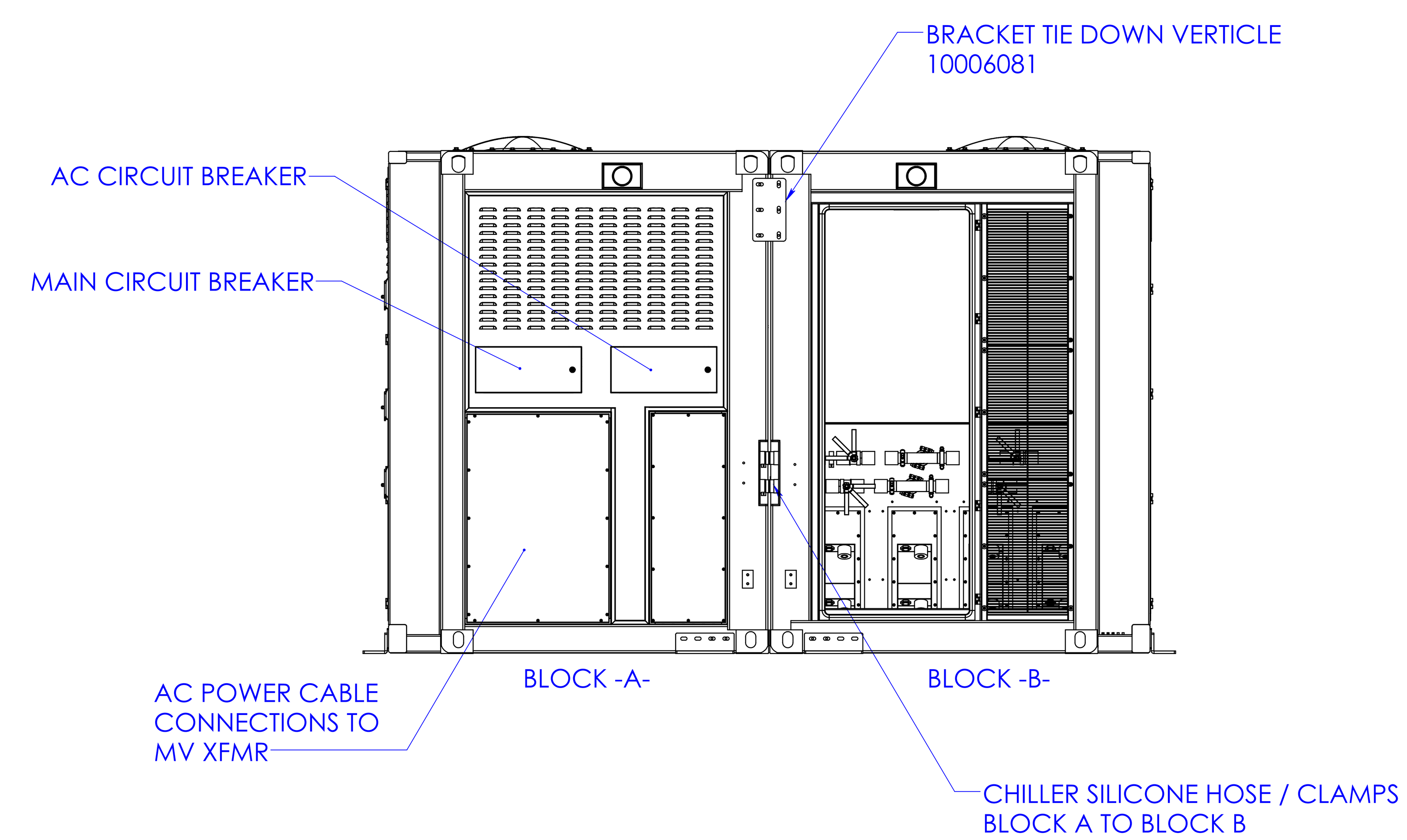
ASSY

REV.	ZONE:	DESCRIPTION:	DR#:	DATE:
01		PROTO-TYPE		









NOTES:

(1) CAD MODEL IS MASTER FOR ANY MISSING DIMENSIONS, REFER TO TLA-TERASTOR-CARROLL.STEP OR .X_T 3D CAD MODEL.
(2) CAD MODEL TOLERANCES FOR SIZE AND POSITION = X.XX
(3) PART TO BE CLEAN, FREE OF OIL, DIRT, CHIPS, ETC.

American Battery Solutions

THIRD ANGLE PROJECTION
ALL UNITS ARE MM UNLESS OTHERWISE NOTED
TOLERANCES EXCEPT AS NOTED
ANGLES ±1°

MM		INCHES	
.X	± 0.25	.XX	± .010
.XX	± 0.10	.XXX	± .005
.XXX	± 0.01	.XXXX	± .0005

INTERPRET THIS DRAWING PER ASME Y14.5-2018
REMOVE BURRS & SHARP EDGES EXCEPT AS NOTED

MATERIAL:		PROJECT:	PROJ. ENG:
FINISH:		DESIGNED BY:	DATE:
WEIGHT: 11522.5 Kg		DRAWN BY:	DATE:
VOLUME: 318943.1 CU CC	DO NOT SCALE DRAWING!	CHECKED BY:	DATE:
		APPROVED BY:	DATE:
		SHEET: -01	SCALE: 1:20 SHT. 1 of 1

DESCRIPTION: ASSY

SIZE: E PART NUMBER: TLA-TERASTOR-CARROLL REV: 01

American Battery Solutions

TeraStor

Large Scale Energy Storage

Safety

Designed to meet or exceed UL, CE & NFPA safety standards and requirements

Capital Costs

180,000 less components + high energy density + fully integrated system = lowest equipment and installation costs

Schedule

Each unit can be installed in less than 6 hours – from landing onsite to cold commissioning

EPC Costs

Highest density +
No auxiliary power +
Quick installation +
Simple foundations +
= Minimum EPC costs

Operational Costs

180,000 less components
= Higher reliability
Highly parallel architecture
= No stranded energy
Advanced liquid cooling
= Lower operating costs

1: Derate above 1000m, 2: Hot and Cold Weather kits available, 3: Storage at high temp will impact cell life and warranty, 4: Depends on operating mode

 CONTACT: energy_storage@americanbatterysolutions.com

American Battery Solutions

TeraStor

Large Scale Energy Storage

Specifications					
Power / Energy		**Mechanical**		**Management**	
AC Energy CP2 – CP/4	7 MWh min	**Dimensions (L/W/H)**	25’ Long / 12’ Wide / 8.2’ Height	**Energy Management**	ABS - integrated
AC Output Power	0.9 - 3.6 MVA	**Weight per Quarter Block**	< 45,000 LBS / Building Block	**Battery Management**	ABS-5th Generation Management System
AC Output Voltage	690 Vac 3Ph	**IP Rating**	IP66	**External interface**	SCADA/DNP3/Modbus TCPIP
Power Configuration Options	Increments of 900 kW	**Seismic Rating**	Zone 4 IBC, CBC	**Standard Communication Data Sets**	MESA/Sunspec; REST API
AC Round Trip Efficiency	88% CP/2 91% CP/4	**Cooling**	Integrated Liquid Cooling	**System Response time**	<100 ms to full power[4]
Operating DC Voltage Range	1150 Vdc – 1560 Vdc	**Operating Temperature Range**	-30 °C – 50 °C [2]		
		Altitude	3000 meters[1]		
Electrical		**Installation**		**Safety**	
Power Conversion System	Fully integrated and factory tested	**Installation time from Landing onsite to Cold Commissioning**	6-hour Installation	**System Certifications**	UL9540, IEC61508, UL 1973
Reactive power	4 quadrant 100%	**Installation handling**	Crane	**Component Certification**	UL 1642, NFPA 69, NFPA 855, IEC 62619, IEC 6100-XX, UN38.3 UL1973, UL991, UL1741SA
Frequency	45-65 Hz compatible	**Density per Acre**	> 300 MWh / Acre	**Fire Suppression**	UL9540A tested (Dry Pipe, Optional)
		Auxiliary Power	Self Generated	**Deflagrations panels**	Yes

American Battery Solutions

TeraStor

Large Scale Energy Storage

American Battery Solutions, we design and manufacture safe, efficient, and reliable energy storage systems that are easy to purchase, install, operate, and maintain.

The all-in-one, energy-dense TeraStor™ is factory-integrated and tested, and it arrives on-site and ready for commissioning in just six hours. With an industry-low number of install connections, the self-powered, self-cooled, and self-managed unit significantly reduces on-site installation and O&M costs. Under the hood, TeraStor's unique architecture significantly reduces the number of parts and potential points of failure compared to any of its competition.

-Highest density in the industry with over 300MWh per acre and 600 MWh per acre if double stacked

-A single-point control interface reduces EMS integration costs and reduces system complexity

-Lower operating losses and reduced maintenance costs, increase profit potential

CONTACT: energy_storage@americanbatterysolutions.com

Executive Summary

Successful 9540A Module-level Testing Results for the TeraStor™

The TeraStor™ has achieved an important milestone with the successful completion of 9540A module-level testing.

With this step complete, the team can now progress to unit-level 9540A testing procedures and demonstrate the methods used to address combustible gas released by any cell in thermal runaway.

The TeraStor's unparalleled combination of module- and unit-level fire safety features is the result of significant research and development, and the team is proud to be able to illustrate efficacy through this series of tests.

Key takeaway – The supercell structural design prevented cell-to-cell propagation.

9540A module-level testing confirmed that the TeraStor supercell's built-in anti-propagation features prevented thermal runaway from spreading to any other cells within the module beyond the predefined initiating and target cells.

Testing Remarks

The 9540A module-level test requires demonstration of thermal runaway propagation, which was only able to be achieved through extraordinary measures—simultaneously initiating runaway in both cells adjacent to the target cell.

Observations:

1. Thermal runaway was artificially induced in the two cells surrounding the target cell
2. They vented and went into thermal runaway within two minutes of each other, with the vent gas igniting and burning as expected
3. After approximately 18 minutes, no visible flames remained
4. 12 minutes later (30 minutes after the first cell vented), the target cell also vented and went into thermal runaway, fulfilling the standard's module-level testing requirement

During the test, the 90-cell TeraStor module, comprising five 18-cell supercells, demonstrated performance consistent with previous R&D testing—no other cell in the system experienced thermal runaway beyond the initiating and target cells.

The TeraStor supercell has been designed with best-in-class anti-propagation features to contain thermal runaway at the cell-level. This is a significant advantage as competitive products only seek to confine it within the affected module.

Test limitations:

- Kapton tape (used to attach test measurement/recording thermocouples to cells surrounding initiating and target cells) was unable to maintain full thermal contact with cells 15-20 during the assessment
- In some cases, the separation was intermittent, and the reported temperature suddenly dropped back to values representative of the neighboring cells; In other cases, the separation was permanent
- Consequently, the graphs display non-physical changes in temperature (alternating between upward and downward values) influenced by the surrounding heated air rather than actual cell temperature
- These measurement errors have no effect on test results

Regardless of the limitations of the tape used in testing, the 9540A module-level test results are consistent with all prior R&D testing. The architectural anti-propagation features prevented thermal runaway from spreading from initiating/target cells to any other cells in the module. The unit-level test will demonstrate the advanced methods used to address combustible gas within any quarter-block of the TeraStor.

As we forge ahead, TeraStor is setting new standards in fire safety and revolutionizing energy storage for a safer sustainable future.

Test Report issued under the responsibility of:

intertek
Total Quality. Assured.

TEST REPORT
ANSI/CAN/UL 9540A:2019
Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems

Report Reference No. .... :	105370934CRT-001CRT
Tested by (name + signature)............................:	Witness by Burl Bhalla/ Rudolph Sporman, report by Sourabh Bagi.
Approved by (name + signature) .... :	Lixin (Mary) Ma
Total number of pages.......... :	31
Date of issue .... :	May 19, 2023
Testing Laboratory .... :	**Intertek Testing Service NA, Inc.**
Address .... :	3933 US Route 11, Cortland, NY 13045, USA
Testing location/ procedure .. :	Witness Testing at ESRG
Testing location/ address...... :	1. ESRG - 9300 OH-66 Piqua OH 2. FRA - 7640 Standish Pl, Rockville, MD 20855
Applicant's name .... :	**American Battery Solutions Inc**
Address .... :	3768 S Lapeer Rd Lake Orion, MI 48359
Test specification:	
Standard............................... :	ANSI/CAN/UL 9540A:2019 (Fourth Edition) + UL CRD's
Test procedure................................ :	Module level test (clause 8.1-8.4)
Non-standard test method…… .... :	N/A
Test Report Form No. .... :	ANSI/CAN/UL 9540A_Module
Test Report Form(s) Originator.............................. :	Intertek
Master TRF .... :	Dated 2022-01

Test item description...................... :	Energy Storage system
Trademark .... :	ABS
Manufacturer .... :	AMERICAN BATTERY SOLUTIONS INC
Model/Type reference........... :	S18280002 (Supercell)
Ratings .... :	Refer Specification tables below

General disclaimer:

List of attachments:	
Attachment 1 – Photos	
Attachment 2 – Conditioning (charge/discharge) profiles	
Attachment 3 – Thermal runaway record	
Attachment 4 – Temperature and voltage profile during thermal runaway	
Attachment 5 – Chemical heat release rate measurement	
Attachment 6 – Gas generation measurement	
Attachment 7 – Smoke release rate measurement	
Attachment 8 – Equipment list	
Test video 2023-03-16 11-04-35 MKV file is provided in addition to this test report.	
Summary of testing:	
Peak chemical heat release rate HRR (kW)....................:	N/A
Peak smoke release rate SRR (m^2/s)...............................:	Refer attachment 7
Total smoke release TSR (m^2) ....:	Refer attachment 7
Total Hydrocarbons (equivalent to C_3H_8, measured by FID) ....:	Refer attachment 6
Module weight loss...:	12.28 kg
Conclusion:	
Thermal runaway was initiated in the two simultaneously heated cells and propagation from initiating cells to target cell occurred during test. Thermal Runaway was achieved in module and flames were visible outside module. Thermal runaway was not contained by module design. According to the standard, a unit level testing in accordance with UL 9540A needs to be conducted on a unit employing this module.	

Possible test case verdicts:	
- test case does not apply to the test object..:	N/A
- test object was not evaluated for the requirement ....:	N/E
- test object does meet the requirement ....:	P (Pass)
-test object was completed per the requirement:	C (complete)
- test object does not meet the requirement .:	F (Fail)
- test object was completed with modification	M (Modification)
Testing:	
Date of receipt of test items ....:	2023-03-14
Date(s) of test performance ....:	2023-03-14 to 2023-03-15

General remarks:

"(see Attachment #)" refers to additional information appended to the report.
"(see appended table)" refers to a table appended to the report.
The tests results presented in this report relate only to the object tested.
This report shall not be reproduced except in full without the written approval of the testing laboratory.
List of test equipment must be kept on file and available for review.
Additional test data and/or information is provided in the attachments to this report.
Throughout this report a ☐ comma / ☒ point is used as the decimal separator.

Determination of the test results includes consideration of measurement uncertainty from the test equipment and methods.

For product manufactured from more than one location, the sample submitted for evaluation is representative of the products from each factory.

Product information:

Cell information

Manufacturer ...:	EVE Power Co Ltd
Model name...:	LF280K
Chemistry ...:	Lithium Iron Phosphate
Physical configuration ...:	1 S, 18 P (Supercell) - 5 Supercells in series
Dimension (W*L*H) ...:	71.5*173.5*204 mm
Weight ...:	5420 +/- 300 g
Nominal voltage...:	3.2 Vdc
Rated capacity...:	280Ah
If the cell compliance with UL 1973 ...:	Yes (MH63503)
Standard charge method	
Charge current ...:	140 A
End of charge voltage ...:	3.65 Vdc
Cut off current...:	14 A
Standard discharge method	
Discharge current ...:	140 A
End of discharge voltage...:	3.65 Vdc
Test result from cell level 9540A test report	
Cell level test report...:	4789795626 (UL)
Average cell venting temperature ...:	146.9 °C
Average cell thermal runaway onset temperature ...:	147.7 °C

Gas composition...:

Gas		Measured %	Component LFL
Carbon Monoxide	CO	11.191	10.9
Carbon Dioxide	CO_2	27.325	N/A
Hydrogen	H_2	48.013	4.0
Methane	CH_4	6.404	4.4
Acetylene	C_2H_2	0.107	2.3
Ethylene	C_2H_4	3.296	2.4
Ethane	C_2H_6	1.326	2.4
Propadiene (Allene)	C_3H_4	0.000	1.9
Propyne	C_3H_4	0.000	1.8
Propene	C_3H_6	0.948	1.8
Propane	C_3H_8	0.321	1.7
-	C4 Total	0.704	N/A
-	C5 Total	0.142	N/A
-	C6 Total	0.005	N/A
-	C7 Total	0.003	N/A
-	C8 Total	0.000	N/A
Benzene	C_6H_6	0.014	1.2
Toulene	C_7H_8	0.000	1.0
Dimethyl Carbonate	$C_3H_6O_3$	0.000	N/A
Ethyl Methyl Carbonate	$C_4H_8O_3$	0.201	N/A
Diethyl Carbonate	$C_5H_{10}O_3$	0.000	N/A
Total	-	100	-

LFL at ambient temperature.......................:	7.15%
LFL at cell venting temperature..................:	6.45 %
Burning velocity..:	79 (Su), cm/s
P_{max} ....:	102 psig

Image of cell with overall dimension, heater, and Tc locations prior to the assembly

Module information	
Manufacturer ....:	American Battery Solutions
Model name..:	S18280002 (Supercell)
Physical configuration	
Enclosure material......................................:	No enclosure, framed
Dimension (W*L*H) ………………………………….:	225*1422*266 mm
Weight ....:	9.8 kg ± 5 %
Cells in series/parallel: ....:	1S18P (1 super cell), 5 supercells in series
Total number of cells: ....:	90
Cooling method ....:	Supercells were supported by liquid cold plate which forms shelves in each bay. Supercells sit in pan made from high thermal conductivity filled polymer and a thin thermal interface material (curing silicone gap filler) is used between cell and pan. No active liquid cooling was used during test and no battery management system was present in the system.
Separation between cells ....:	Silicone Pad
Electrical rating	
Rated capacity..:	280Ah
Rated energy..:	16,300Wh
Nominal voltage..:	18.25 V dc
Standard charge method	
Charge current ....:	1260 A (C/4)
End of charge voltage ....:	18.25 V (3.65 V per supercell)
Standard discharge method	
Discharge current ....:	1260A (C/4)
End of discharge voltage............................:	12.5 V
If the module compliance with UL 1973......:	No

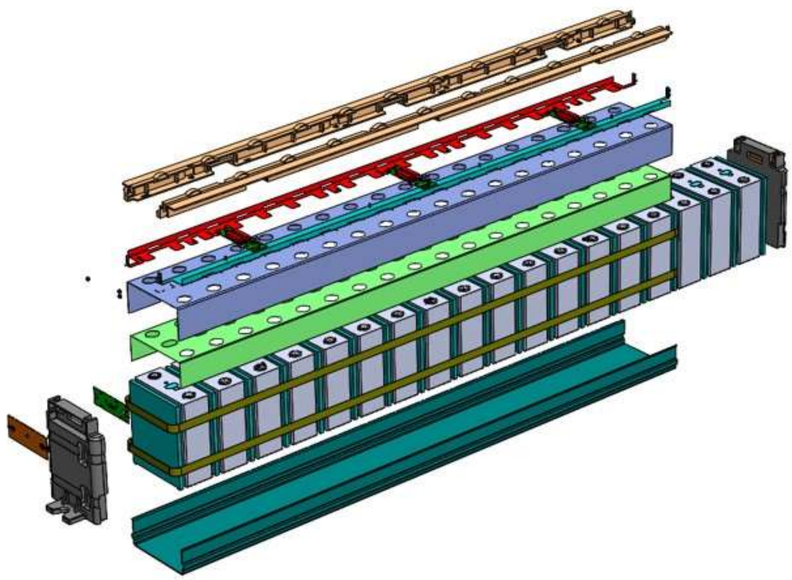
Diagram of one module with overall dimension

The overall dimension of the module is 225*1422*266 mm.

Layout of Supercell,

A "module" is defined for this test as 5 supercells in series.

The cells are arranged in 1s18p configuration and in the end system, a BMS is present to manage the cells. No BMS was present for this test.



Battery pack inside the end product (Test result not included in this report)

Photo of the module Under test

ANSI/CAN/UL 9540A, Edition 4			
Clause	Requirement – Test	Result - Remark	Verdict
5	**Constrution – General**		
5.1	**Cell**		--
5.1.1	The cell info associated with the BESS includes:		C
	• cell chemistry (e.g. NMC, LFP);	LFP (Lithium Iron Phosphate)	C
	• the physical format of the cell;	Prismatic	C
	• the cell electrical rating in capacity and nominal voltage;	280Ah,3.2V	C
	• the overall dimensions of the cell, and weight.	207.5* 173.7* 72 mm and 5420 g.	C
5.1.2	The cells associated with the BESS comply with ANSI/CAN/UL 1973 or not.	Compliant (MH 63503)	C
5.1.3	Further details are included in the cell level test report.		C
5.2	**Module**		--
5.2.1	The modules info associated with the BESS includes:		C
	• the generic enclosure material;	'No enclosure, framed	C
	• the general layout of the module contents;	Cells are arranged in 1s18p configuration (super cell). 5 supercell assembled in series consist of module.	C
	• the electrical configuration of the cells in the modules and the modules in the BESS.	One module consists of 5 supercells connected in series. Each super cell consists of 18 parallel cells. 5 supercells consisting of 90 total cells constitute a module.	C
5.2.2	The modules associated with the BESS comply with UL 1973 or not.	Evaluation pending to UL1973.	F
5.2.3	Further details are included in the module level test report.	Refer to 8.3	C
5.3	**Battery energy storage system unit**		--
5.3.1	The BESS unit info includes:		N/A
	• the units comply with UL 9540 or not;		N/A
	• the manufacturer and model number;		N/A
	• electrical ratings;		N/A
	• energy capacity of all BESS.		N/A
5.3.2	For BESS units, which UL 9540 compliance cannot be determined, to include:		N/A
	• the number of modules in the BESS;		N/A
	• electrical configuration of the module;		N/A

ANSI/CAN/UL 9540A, Edition 4			
Clause	Requirement – Test	Result - Remark	Verdict
	• physical layout of the modules in the BESS;		N/A
	• battery management system (BMS); and		N/A
	• other major components of the BESS;		N/A
	• the BESS enclosure overall dimensions and generic material;		N/A
	• battery system(s) may be tested as representative of the BESS;		N/A
	• battery system complies with UL 1973 or not.		N/A
5.3.3	Any fire detection and suppression systems that are an integral part of the BESS.		N/A
5.3.4	Further details included in the unit level and if applicable, installation level test reports.		N/A
5.4	**Flow Batteries**		**--**
5.4.1	For flow batteries, to include the following info:		N/A
	• the chemistry;		N/A
	• a generic description of the electrolyte (s);		N/A
	• the overall dimensions of the individual stack;		N/A
	• the electrical rating in capacity and nominal voltage of the cell stack.		N/A
	And the Information of the complete flow battery system:		N/A
	• the manufacturer's name and model number of the system;		N/A
	• the electrical rating in volts and rated storage capacity in Ah or Wh;		N/A
	• the number of cells and stacks in the system;		N/A
	• the maximum volume of electrolyte(s) for the system.		N/A
5.4.2	The flow battery system complies with UL 1973 or not.		N/A
5.4.3	Further details included in the flow battery thermal runaway determination level test report.		N/A
6	**Performance – General**		
6.1	The tests in this standard are extreme abuse conditions conducted on electrochemical energy storage devices, which may result in various kind of hazards.		C
6.2	At the conclusion of testing, samples discharged in accordance with the manufacturer' specifications.		C
	All samples disposed of in accordance with local regulations.		C

ANSI/CAN/UL 9540A, Edition 4			
Clause	Requirement – Test	Result - Remark	Verdict
8	**Module Level**		
8.1	**Sample**		--
8.1.1	Module samples shall be conditioned, prior to testing, through charge and discharge cycles for a min. of 2 cycles, to verify that the module is functional.	Charged to 18.25 Vdc	C
8.1.2	The module shall be charged to 100% SOC and allowed to rest a maximum of 8 h before the start of the test.		C
8.1.3	Electronics and software controls such as the battery management system (BMS) are not relied upon for this testing.	BMS protections disabled during the testing	C
8.2	**Test method**		--
8.2.1	Ambient indoor laboratory conditions 25±5°C and 50±25% RH at the initiation of the test.	Temp is 15°C Rh is 35%.	M
8.2.2	The test conducted under a smoke collection hood sized appropriately to collect the gasses generated.		C
8.2.3	The weight of the module shall be recorded before and after testing is completed.	Weight: before test 544.31 kg after test 532.05 kg	C
8.2.4	The number of cells within the module that are forced into thermal runaway.	Two	C
8.2.5	The methodology used for initiating thermal runaway for cells are used to initiate thermal runaway within the module.	Thermal heaters were used to initiate thermal runaway.	C
8.2.6	Occurrence of thermal runaway shall be verified by sustained temperature above the cell surface temperature at the onset of thermal runaway.	See attachment 4	C
8.2.7	The module shall be placed on top of a noncombustible horizontal surface.	Module orientation as intended for final installation	C
8.2.8	The chemical heat release rate of the module in thermal runaway shall be measured with oxygen consumption calorimetry system.	Heat release rate was not measured during the test.	M
8.2.9	The chemical heat release rate shall be measured for the duration of the test.	Refer 8.2.8	M
8.2.10	The chemical heat release rate shall be measured by a measurement system consisting of a paramagnetic oxygen analyzer, non-dispersive infrared carbon dioxide and carbon monoxide analyzer, velocity probe, and a Type K thermocouple.	Refer 8.2.8	M
8.2.11	Chemical heat release rate is calculate at each of the flows as follows: $HRR_t = \left[E \times \varphi - (E_{CO} - E) \times \frac{1-\varphi}{2} \times \frac{X_{CO}}{X_{O_2}}\right] \times \frac{\dot{m}_e}{1 + \varphi \times (\alpha - 1)} \times \frac{M_{O_2}}{M_a} \times (1 - X^{\circ}_{H_2O}) \times X^{\circ}_{O_2}$	See attachment 5	N/A

ANSI/CAN/UL 9540A, Edition 4			
Clause	Requirement – Test	Result - Remark	Verdict
8.2.12	Vent gas composition shall 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, and velocity and temperature measurements respectively shall be obtained in the exhaust duct of the heat release rate calorimeter using equipment specified in 8.2.10.	See attachment 6 see input parameters	C
8.2.13	The hydrocarbon content of the vent gas shall be measured using flame ionization detection. Hydrogen gas shall be measured with a palladium-nickel thin-film solid state sensor	Three different kind of sensors were used. H_2 was detected by the palladium-nickel thin-film solid state sensor and heat conduction sensor.	M
8.2.14	The light transmission in the exhaust duct of the heat release rate calorimeter shall be measured using a white light source and photo detector for the duration of the test.	Light transmission is integerated into the testing system	C
8.2.15	Smoke release rate shall be calculated as follows: $SRR = 2.303\left(\frac{V}{D}\right)Log_{10}\left(\frac{I_o}{I}\right)$	See attachment 7	C
8.3	**Module level test report**		--
8.3.1	The report on module level testing shall include the following:		C
	a) Module manufacturer name and model number (and whether UL 1973 compliant);	ABS , (Supercell) S18280002,not compliant to UL 1973	M
	b) Number of cells in module;	90	C
	c) Module configuration with cells in series and parallel;	1S18P (1 supercell) 5 supercell in series constitute a module	C
	d) Module construction features per 5.2;	See page 7-9 module information	C
	e) Module voltage corresponding to the tested SOC	Verified at test site	M
	f) Thermal runaway initiation method was used including number and locations of cells for initiating thermal runaway;	See Attachment 3	C
	g) Heat release rate versus time data;	Refer 8.2.8	N/A
	h) Flammable gas generation and composition data;	See Attachment 6	C
	i) Peak smoke release rate and total smoke release data.	See Attachment 7	C
	j) Observation(s) of flying debris or explosive discharge of gases;	No flying debris or explosive discharge of gas observed	C

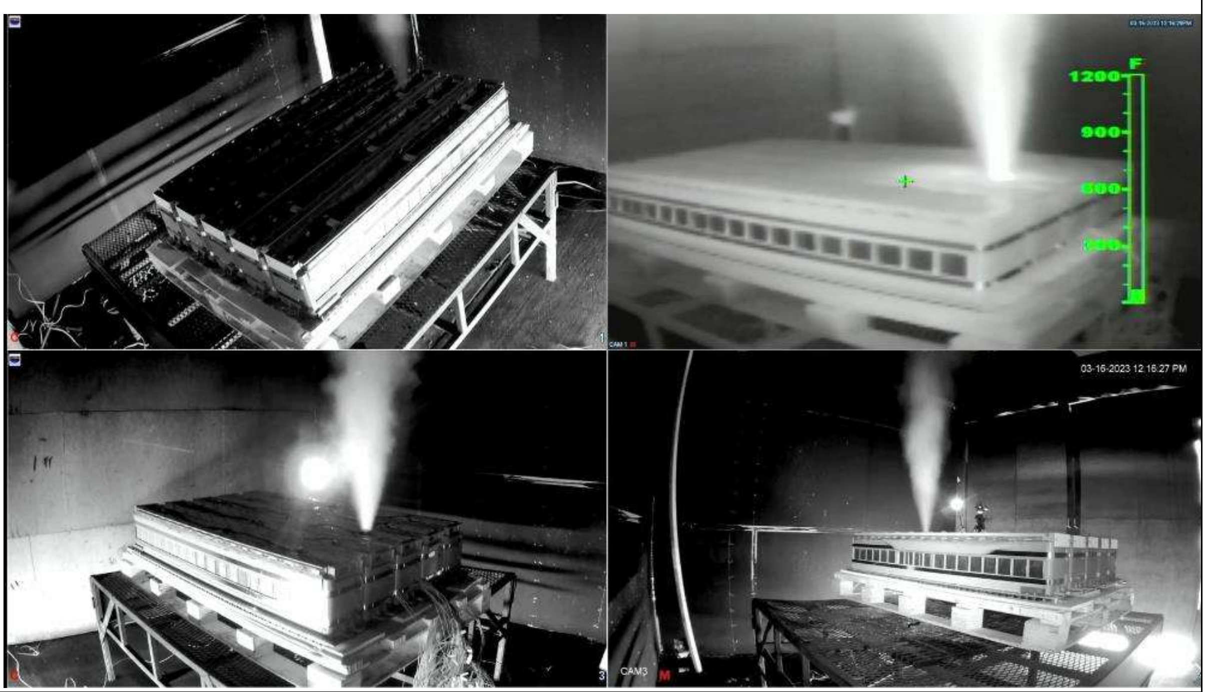
ANSI/CAN/UL 9540A, Edition 4			
Clause	Requirement – Test	Result - Remark	Verdict
	k) Observation(s) of sparks, electrical arcs, or other electrical events;	No sparks, electrical arcs, or other electrical events observed.	C
	l) Identification/location of cells(s) that exhibited thermal runaway within the module;	See Attachment 4	C
	m) Locations and visual estimations of flame extension and duration from the module shall be documented;	See Attachment 1	C
	n) Module weight loss based on measurements per 8.2.3;	12.278 kg	C
	o) Video of the test.	2023-03-16 11-04-35.mp4 is provided.	C
8.4	Performance at module level testing		--
8.4.1	Unit level testing in Section 9 is not required if the following performance conditions are met during the module level test: a) Thermal runaway is contained by module design; and	Thermal runaway was not contained by the module design due to ignition of vented flammable gases. No additional propagation was observed beyond the target cell.	F
	b) Cell vent gas is nonflammable as determined by the cell level test.	The cell level vent gas test produced flammable gases	F

Attachment 1 Photos

Test sample preparation


During test
Test started 

First cell vented observed



Ignition of Vent Gas

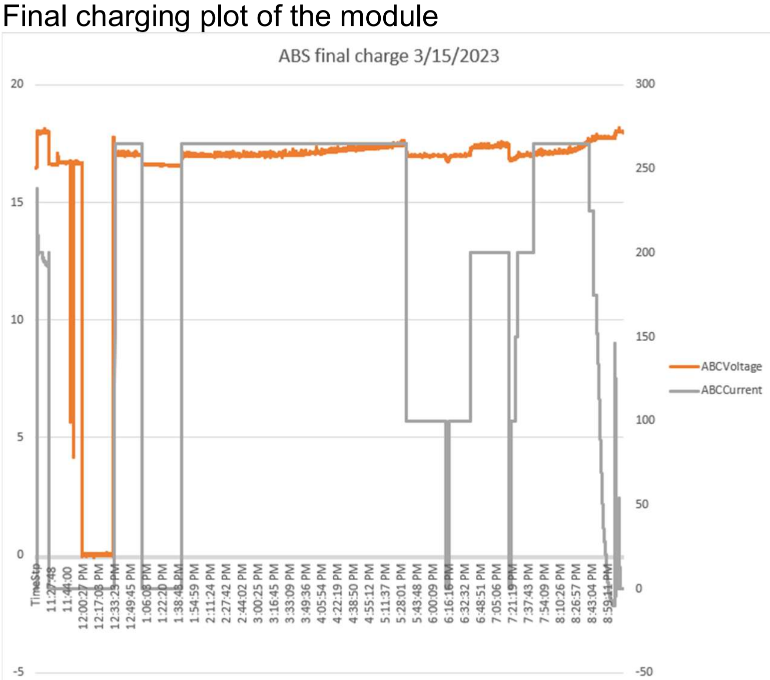
After test
  
  

Attachment 2 Module conditioning (charge/discharge for 2 cycles)

1. Initial Bulk Charge (~4 hrs)
    - Set DC source to 18.25V (3.65V per Supercell); 1260A (C/4).
    - Charge series connected set of Supercells until the first one reaches 3.65V.
    - Disassemble the series connections and top off individual Supercells at 3.65V. Let current taper to 126A (C/40).
2. Rest (~2 hrs; 8 hrs max)
    - Maximum rest period of 8hrs.
3. Discharge (~4 hrs)
    - Set DC load to 12.5V (2.5V per Supercell); 1260A (C/4).
    - Discharge series connected set of Supercells until the first one reaches 2.5V.
4. Rest (~2 hrs; 8 hrs max)
    - Maximum rest period of 8hrs.
5. Charge to 100% SOC (~5 hrs)
    - Set DC source to 18.25V (3.65V per Supercell); 1260A (C/4).
    - Charge series connected set of Supercells until the first one reaches 3.65V.
6. Rest (~2hrs; 8 hrs max)
7. Discharge (~4 hrs)
    - Set DC load to 12.5V (2.5V per Supercell); 1260A (C/4).
    - Discharge series connected set of Supercells until the first one reaches 2.5V.
8. Rest (~2hrs; 8 hrs max)
9. Charge to 30% SOC (~1.5 hrs)
    - Set DC source to 18.25V (3.65V per Supercell); 1260A (C/4).
    - Charge series connected set of Supercells for 1hr, 12mins.

- *Total Time: ~25 hrs*

Final charging plot of the module

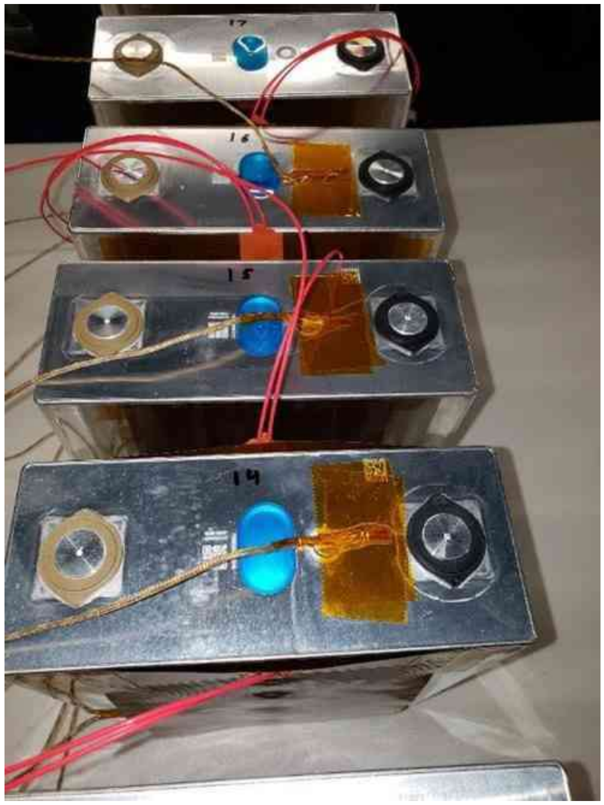


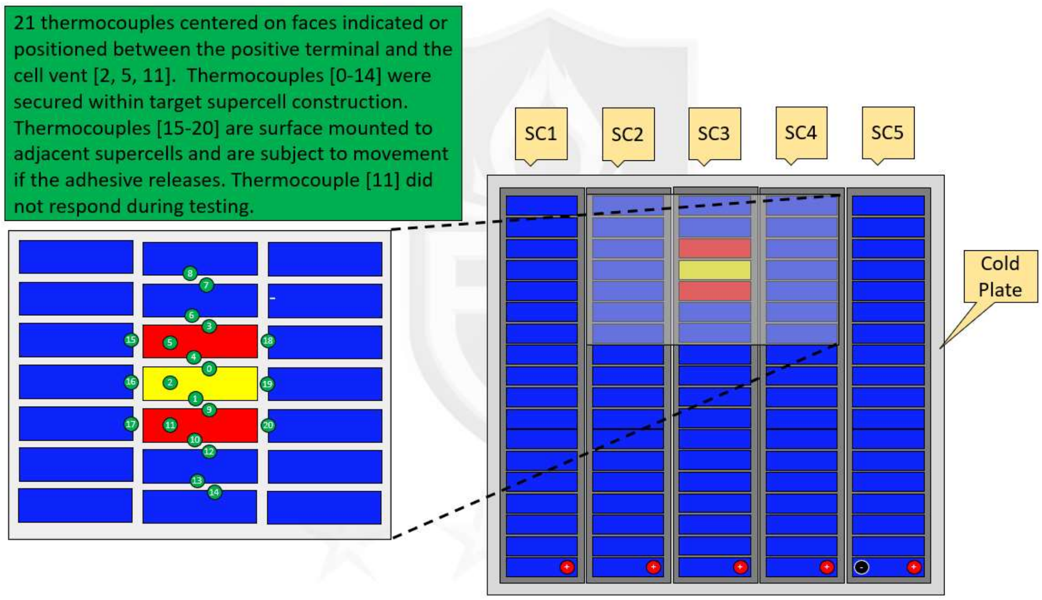
Attachment 3 Module thermal runaway record

The module to be tested was charged to 100% SOC and allowed to stabilize for a minimum of 1 h and a maximum of 8 h before the start of the test.

External heating method was used to initiate thermal runaway in the module. 2 initiating cells were used to trigger thermal run away.

Flexible film heaters and thermocouple's location inside the module.





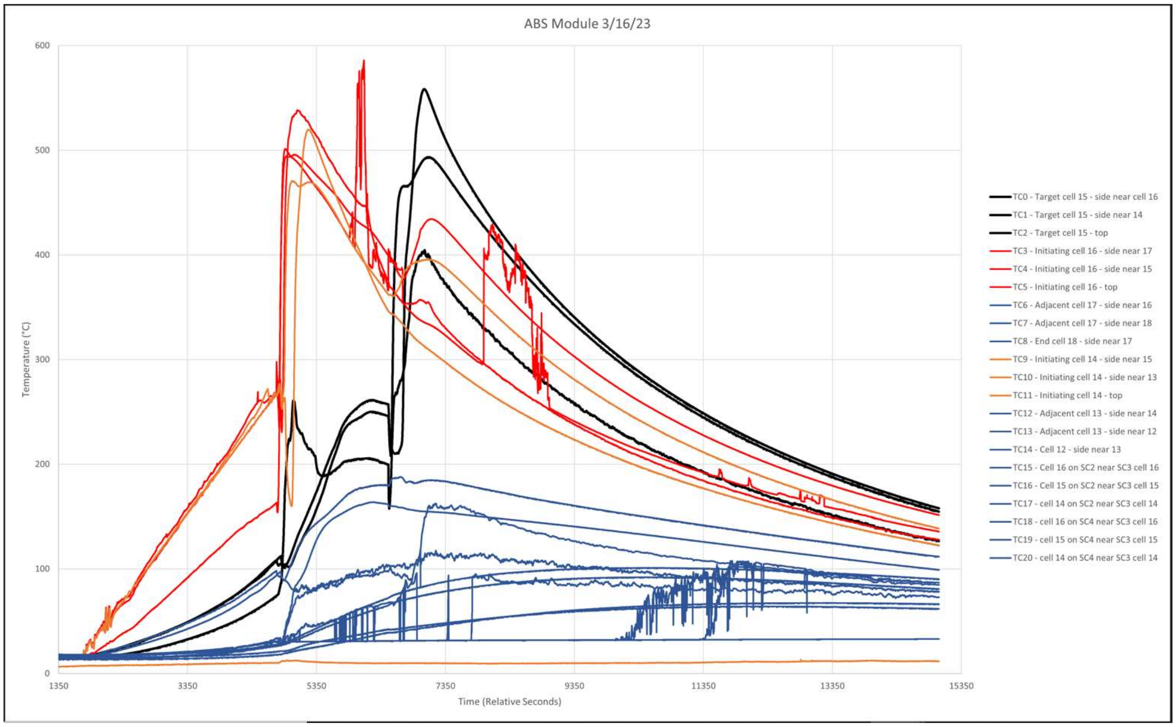
Cell 14 and 16 of SC3 (initiating cells) were heated at a rate of 5°C per minute until thermal runaway occurred. Cell 15 of SC3 was the target cell.

Below table summarizes the details:

Ambient conditions at the initiation of the test:	15 ºC			
Module voltage before test:	18.25 V dc			
Electronics and software controls within the module?	☒ Yes, but not relied upon for this testing ☐ No such controls			
Module weight before test	544.31 kg			
Time when test was initiated:	11:27 am 3/16/2023			
Observations during test:	1st vented	observed	1st thermal runaway	observed
	2nd vented	observed	2nd thermal runaway	observed
	3rd vented	observed	3rd thermal runaway	observed
	No flying debris or explosive discharge of gases observed. No sparks, electrical arcs, or other electrical events. Flame was observed.			
Post-test evaluation:	Charring was observed on super cell 3 on the target and initiating cells.			
Module weight after test	532.03 kg			
Module weight loss	12.278 Kg			

Attachment 4 Temperature and voltage profile during test

Temperature describing cell to cell propagation are show in below figure



Measured temperature inside the module during the test are shown in below figure.

Maximum measured temperature of each location is shown in below table

Thermocouple No.	Location	Maximum Temperature (°C)
TC0	Target cell 15 - side near cell 16	558.4
TC1	Target cell 15 - side near 14	493.44
TC2	Target cell 15 - top	404.6
TC3	Initiating cell 16 - side near 17	585.905
TC4	Initiating cell 16 - side near 15	495.894
TC5	Initiating cell 16 - top	538.4
TC6	Adjacent cell 17 - side near 16	187.9
TC7	Adjacent cell 17 - side near 18	101.1
TC8	End cell 18 - side near 17	67.6
TC9	Initiating cell 14 - side near 15	470.8
TC10	Initiating cell 14 - side near 13	519.8
TC11	Initiating cell 14 - top	N/A
TC12	Adjacent cell 13 - side near 14	163.835
TC13	Adjacent cell 13 - side near 12	92.1
TC14	Cell 12 - side near 13	64.2
TC15	Cell 16 on SC2 near SC3 cell 16	117.5
TC16	Cell 15 on SC2 near SC3 cell 15	162.5
TC17	cell 14 on SC2 near SC3 cell 14	50.9
TC18	cell 16 on SC4 near SC3 cell 16	104.2
TC19	cell 15 on SC4 near SC3 cell 15	102.8
TC20	Cell 14 on SC4 near SC3 cell 14	107.7

Note: Based on analysis of thermocouple data it appears that the thermocouple 16 might be affected by hot flammable gases instead of cell temperature.

Attachment 5 Chemical heat release rate measurement

The chemical heat release rate is to be measured by a measurement system consisting of a paramagnetic oxygen analyzer, non-dispersive infrared carbon dioxide and carbon monoxide analyzer, velocity probe, and a Type K thermocouple. The instrumentation is located in the exhaust duct of the heat release rate calorimeter at a location that minimizes the influence of bends or exhaust devices.

Measured peak chemical heat release rate HRR= N/A

Attachment 6 Gas generation measurement

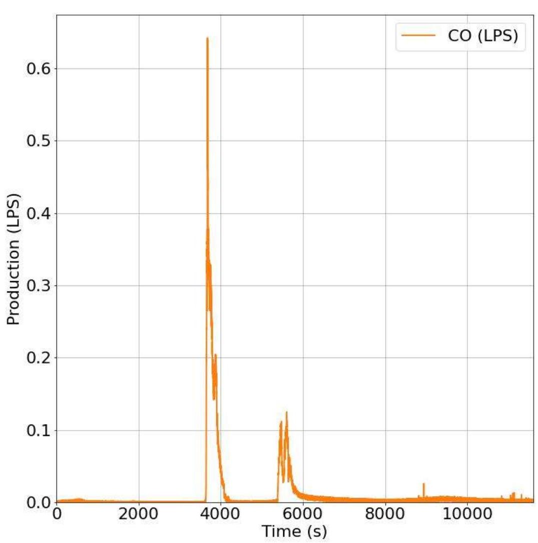
Vent gas compositions were measured using a Fourier-Transform Infrared Spectrometer with a min resolution of 1 cm^{-1} and a path length of at least 2 m within the calorimeter's exhaust duct. And the composition, velocity and temperature of the vent gases were measured within the calorimeter's exhaust duct.

The hydrocarbon content of the vent gas was measured using flame ionization detection. The hydrogen content was measured with a palladium-nickel thin-film solid state sensor, a heat conduction sensor. The hydrogen was detected by the palladium-nickel thin-film solid state sensor and heat conduction sensor.

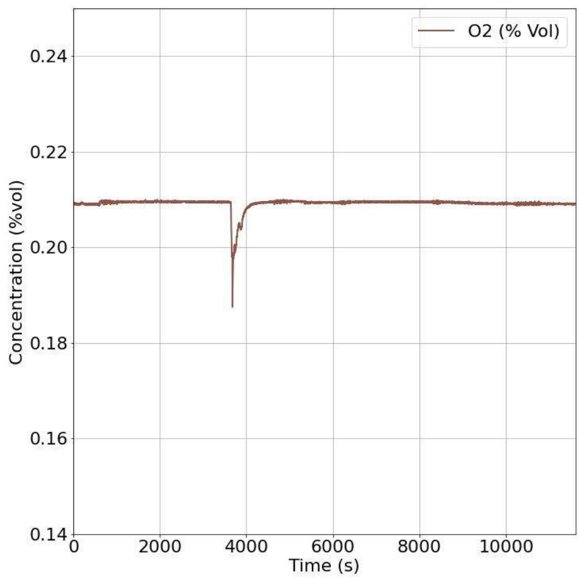
The gas composition and volume are shown in below table. The test results calculation and graphs were provided by FRA test lab.

GAS	Volume measured (Liter)
Carbon Dioxide	1766.556
Carbon Monoxide	119.924
Hydrogen (RKI)	166.0126
Unburned Hydrocarbons	41.73603
Total production	2094.2286

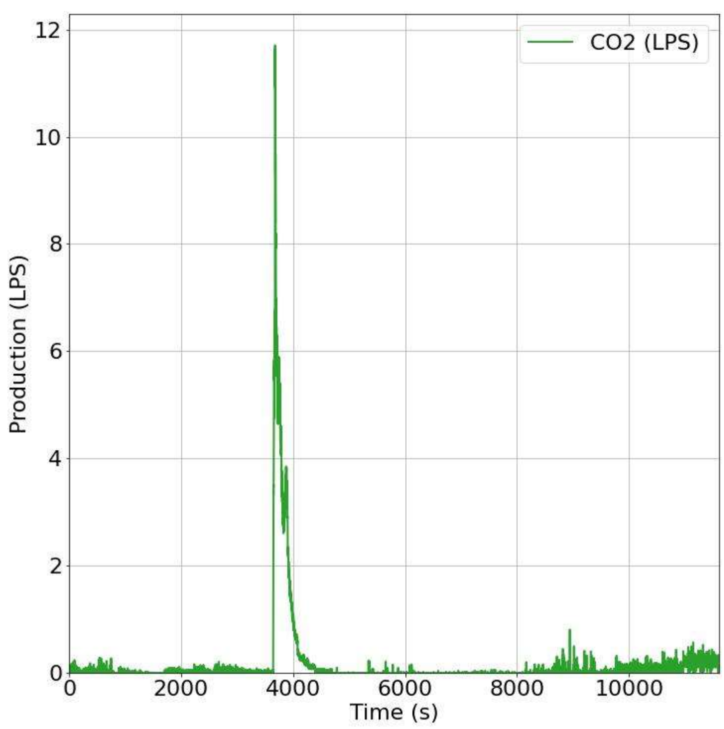
Carbon monoxide concentration and flow rate.



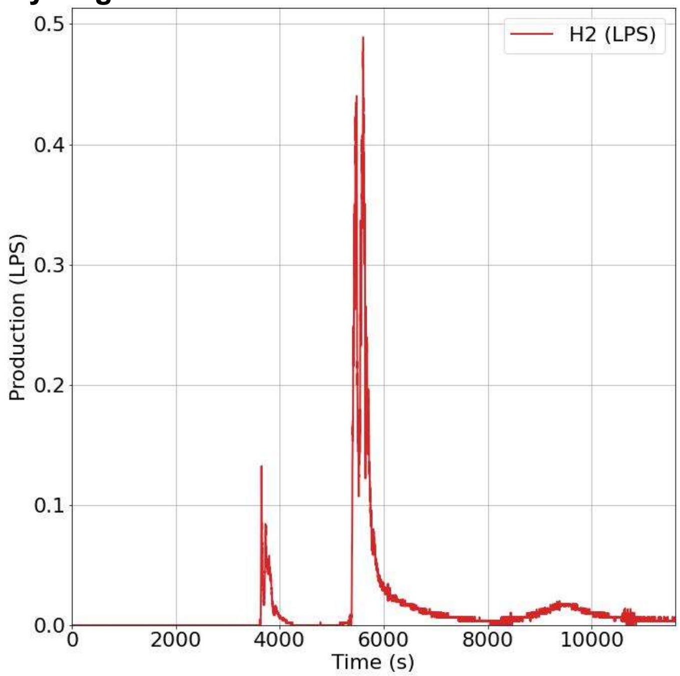
Oxygen concentration in exhaust flow



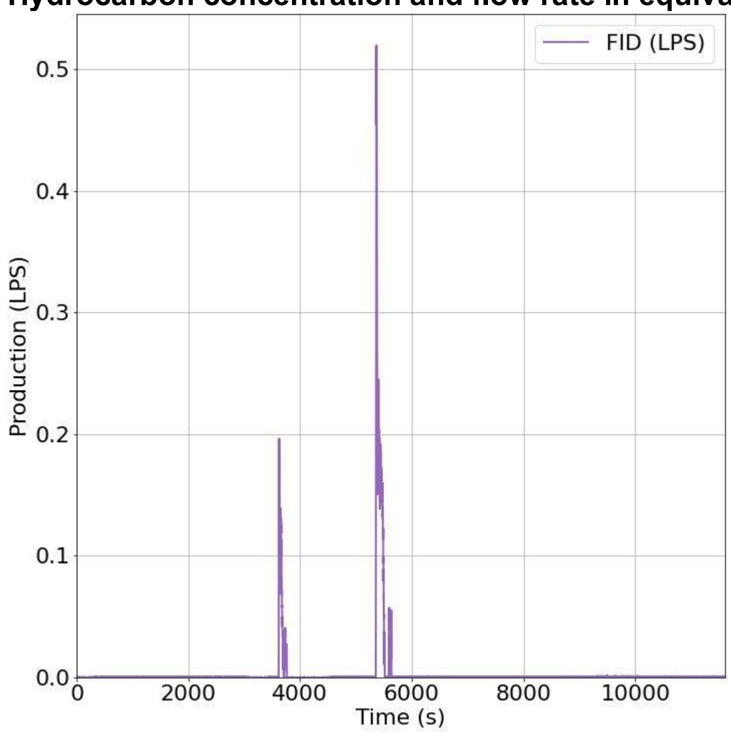
Carbon dioxide concentration and flow rate.



Hydrogen concentration



Hydrocarbon concentration and flow rate in equivalent methane concentration



Attachment 7 Smoke release rate measurement

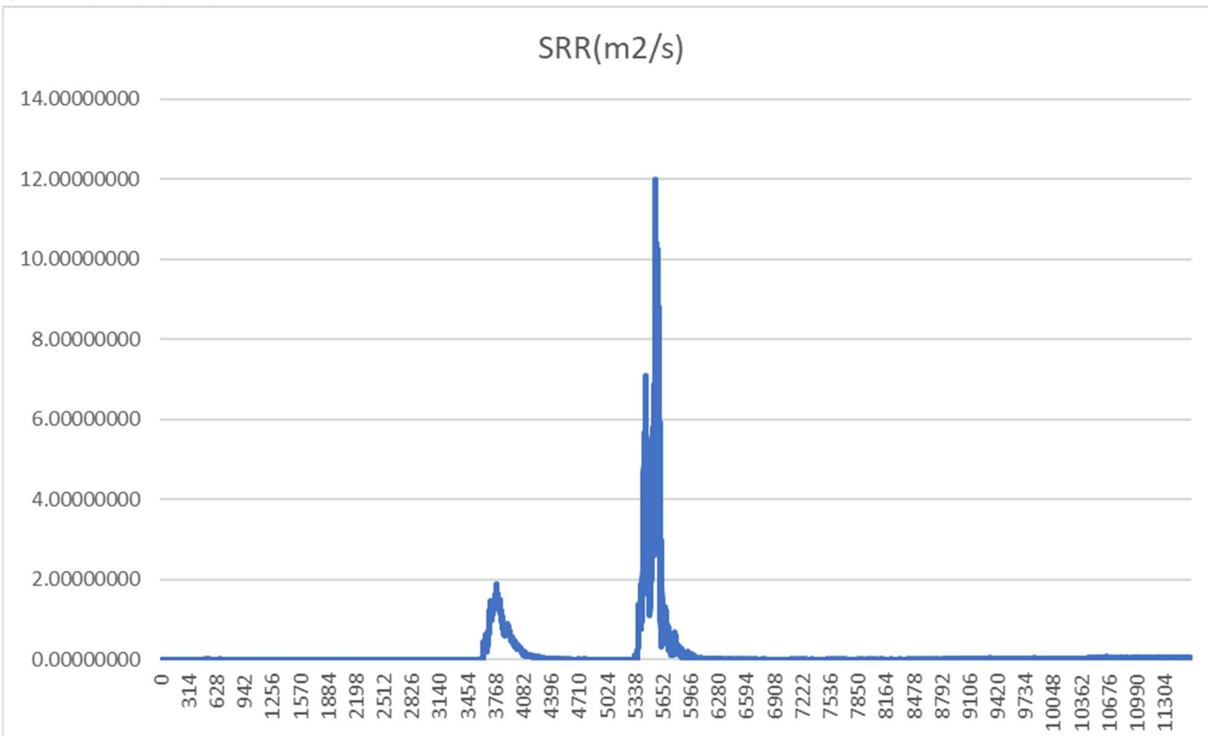
Smoke release rate shall be calculated as follows:

$$SRR = 2.303\left(\frac{V}{D}\right)Log_{10}\left(\frac{I_o}{I}\right)$$

Where:
SRR = Smoke release rate (m^2/s)
V = Volumetric exhaust duct flow rate (m^3/s),
D = duct diameter (m),
Io = Light transmission signal of clear (pre-test) beam (V)
I = Light transmission signal during test (V)

Measured peak smoke release rate SRR= 11.99 m^2/s
Measured total smoke release rate TSR= 1562.819 m^2

Smoke Release Rate

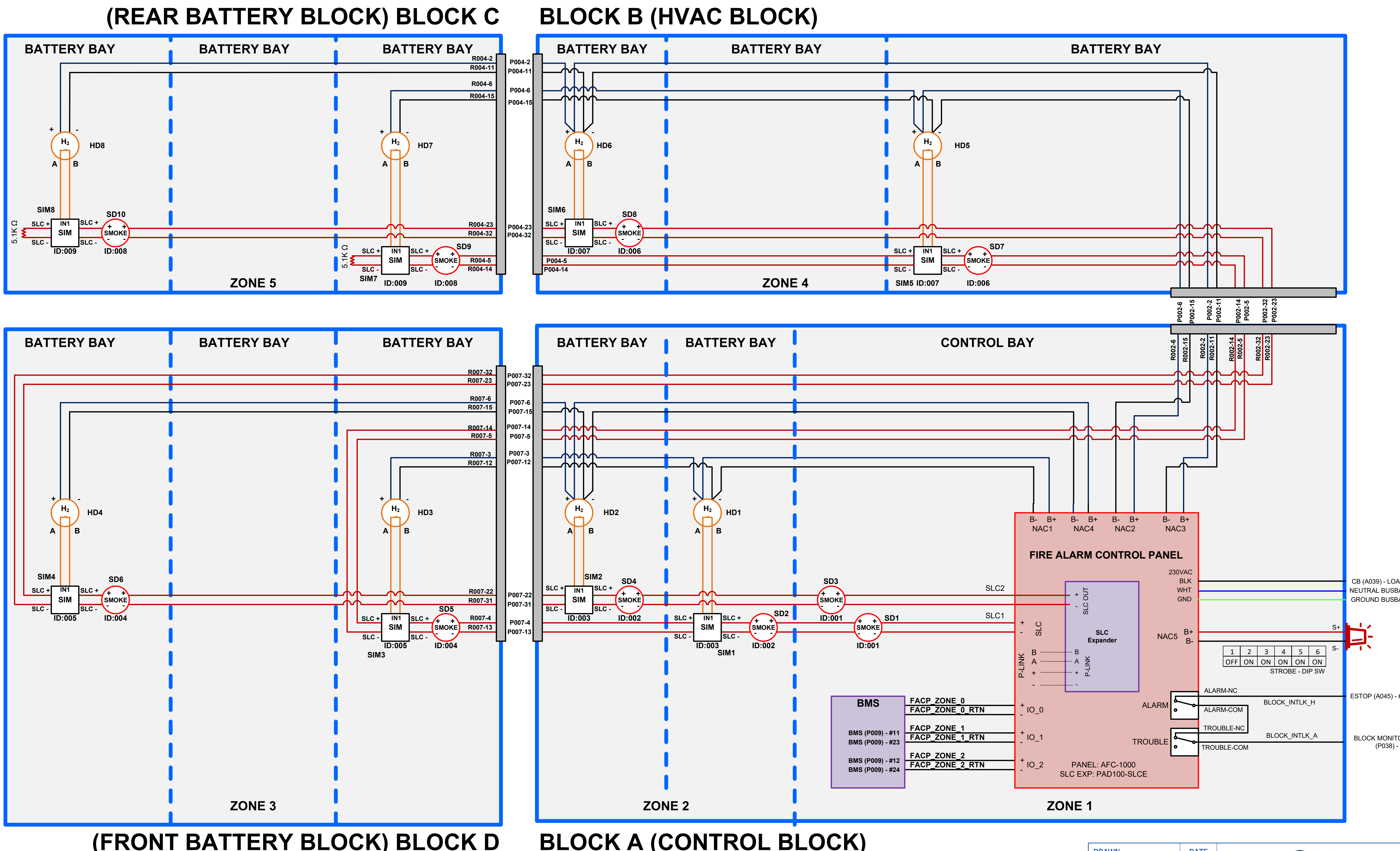


Attachment 8 Equipment list

No	Equipment	Manufacturer	Model	Serial Number	Last Cal date	Owner
1	Gas Cylinder (methan 2894PPM Span) Compressed gas Methane eith Nitorgen balance)	Praxiar	NI ME 2800P-AS	Lot no: 304122216001 Serial number: CC168991	10/17/2022	FRA
2	Gas Cylinder (2%Hydrogen, balanced Nitrogen))	Linde	NI HY2ZC-AS	Lot no: 700012290UG	N/A	FRA
3	Fuel (60% hydrogen + 40% Helium)	Praxiar	IG- FI1-K	Lot no: 700010211D1	N/A	FRA
4	Extra dry Air (providing Oxyen tomaitian Flaime)	Praxiar	-	-	N/A	FRA
5	Gas Cylinder(21%O2, 45000 (4.5%)PPM CO2, 2520PPM CO, balance Nitrogen) Span	Praxiar	NICD4.5C O5P-AS	Lot NO: 700010213UB	7/31/2020	FRA
6	Temp DAQ modules	National Instruments	NI 9210	2136E6E	2/2/2023	FRA
7	Current DAQ modules	National Instruments	NI 99203	18D1425	5/31/2022	FRA
8	Votlage Modules	National Instruments	NI 99205	1581FE9	5/31/2022	FRA
9	FID (unurnt Hydro Carons)	CAI	600 Series		N/A	FRA
10	NDIR (CO2 low)	CAI	600 Series		N/A	FRA
11	NDIR (CO And O2)	Emerson prcess management	Xstream		N/A	FRA
12	NDIR (CO2 High)	Servomax	1400 Series		N/A	FRA
13	H2 Scan (High)	Hy Optima	720B	B000035	N/A	FRA
14	H2 Scan (low) RKI Sensors				N/A	FRA
15	Mass flow controller	ALICAT	MC-10SL	296389	11/22/2021	FRA
16	Chiller	EC plus	728459	N/A	N/A	FRA
17	Humidity and Temp Transmitter	Omega	HX303AV	050768	6/1/2022	FRA
18	Diifferential pressure transdcer	SERTA	2641003W D2DT1F	10144248	5/25/2022	FRA
19	Weight scale	Minebea intec	Combics 2 (CAIS2-vv1)	37966704	10/25/2022	FRA
20	Heat Flux-1	HUKSEFFLUX	SBG01	13515	N/A	FRA
21	Heat Flux-2	HUKSEFFLUX	SBG01	13522	N/A	FRA
22	Heat Flux-3	HUKSEFFLUX	SBG01	13514	N/A	FRA
23	Heat Flux-4	HUKSEFFLUX	SBG01	13523	N/A	FRA
24	Heat Flux-5	HUKSEFFLUX	SBG01	13513	N/A	FRA
25	Heat Flux-6	HUKSEFFLUX	SBG01	13336	N/A	FRA
26	Heat Flux-7	HUKSEFFLUX	SBG01	12329	N/A	FRA
27	Heat Flux-8	HUKSEFFLUX	SBG01	12853	N/A	FRA
28	Heat Flux-9	Medtherm	6410SB-20	210082	N/A	FRA
29	Heat Flux-10	Medtherm	6410SB-20	210084	N/A	FRA
30	Multimeter	Fluke	115	45260379SV	6/15/2022	ESRG
31	Temp Modules	National instruments	NI 9214	PVEL303	8/16/2022	ESRG

No	Equipment	Manufacturer	Model	Serial Number	Last Cal date	Owner
32	Temp Modules	National instruments	NI 9214	150112E	8/18/2022	ESRG
33	Temp Modules	National instruments	NI 9214	PVEL3299	4/15/2022	ESRG
34	Voltage module for Heat Flux	National instruments	NI 9202	Ff81D27	4/14/2022	ESRG
35	Temp Modules	National instruments	NI 9213	01F8135C	4/13/2022	ESRG
36	Temp Modules	National instruments	NI 9213	01F81358	4/13/2022	ESRG
37	Temp Modules	National instruments	NI 9213	01F81356	4/13/2022	ESRG
38	Isolated TC Board (16 channel)	Dataforth	SCMPB01-2		N/A	ESRG
39	Isolated TC input Linierized	Dataforth	SCM5B47 K-13	153673-9 L21	8/31/2022	ESRG
40	Isolated TC input Linierized	Dataforth	SCM5B47 K-13	153673-10 L21	8/31/2022	ESRG
41	Isolated TC input Linierized	Dataforth	SCM5B47 K-13	153673-11 L21	8/31/2022	ESRG
42	Isolated TC input Linierized	Dataforth	SCM5B47 K-13	153673-15 L21	8/31/2022	ESRG
43	Isolated TC input Linierized	Dataforth	SCM5B47 K-13	153673-13 L21	8/31/2022	ESRG
44	Isolated TC input Linierized	Dataforth	SCM5B47 K-13	153673-16 L21	8/31/2022	ESRG
45	Isolated TC input Linierized	Dataforth	SCM5B47 K-13	153673-12 L21	8/31/2022	ESRG
46	Isolated TC input Linierized	Dataforth	SCM5B47 K-13	153673-14 L21	8/31/2022	ESRG
47	Isolated TC input Linierized	Dataforth	SCM5B47 K-13	153673-6 L21	8/31/2022	ESRG
48	Isolated TC input Linierized	Dataforth	SCM5B47 K-13	153673-7 L21	8/31/2022	ESRG
49	Isolated TC input Linierized	Dataforth	SCM5B47 K-13	153673-5 L21	8/31/2022	ESRG
50	Isolated TC input Linierized	Dataforth	SCM5B47 K-13	153673-3 L21	8/31/2022	ESRG
51	Isolated TC input Linierized	Dataforth	SCM5B47 K-13	153673-1 L21	8/31/2022	ESRG
52	Isolated TC input Linierized	Dataforth	SCM5B47 K-13	153673-2 L21	8/31/2022	ESRG
53	Isolated TC input Linierized	Dataforth	SCM5B47 K-13	153673-8 L21	8/31/2022	ESRG
54	Isolated TC input Linierized	Dataforth	SCM5B47 K-13	153673-4 L21	8/31/2022	ESRG

-------------------------------------- End of test report --------------------------------------



COMPONENT LIST

Fire Panel: AFC-1000 (Potter Signal)
Slc Expander: PAD100-SLCE (Potter Signal)
Smoke Detector: PAD300-PD (Potter Signal)
Hydrogen Detector: GD-6-WHITE (Macurco)
Single Input Module: PAD100-SIM (Potter Signal)
Spark Igniter Electrode: DD2CE-1H (Baso)
Spark Control Module: CS222L (Baso)
Wall Strobe: HS-24WR-WP (Potter Signal)

DRAWN	DATE	American Battery Solutions
Ken Steeves	02/20/23	
CHECKED		TITLE
		TeraStor – Fire Detection
MANAGER		Concept #7 – 2 SLC, 2 Smoke, 2 Gas, No Spark
SIZE	PROJECT TeraStor	REV 0.2
SCALE	FILE NAME	SHEET 5 OF 6