

UNIT LEVEL TEST REPORT UL 9540A Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems (AACD)	
Project number	Original: 4791913381 Amendment 1: 4791913381
File number	-
Date of issue	Original: 2025-09-10 Amendment 1: 2025-10-24
Total number of pages	51
UL report office	UL SOLUTIONS, KOREA
Applicant name	SAMSUNG SDI CO LTD
Applicant address	428-5 GONGSE-DONG GIHEUNG-GU YONGIN-SI, GYEONGGI-DO 446-577 REPUBLIC OF KOREA
Standard	UL 9540A:2025, Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems, 5 th Edition, March 12, 2025
Test procedure	Section 9
Non-standard test method	Not applicable
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The test results presented in this report relate only to the sample tested in the test configuration noted. UL Solutions did not select the sample(s), determine whether the sample(s) were representative of production samples, witness the production of the test sample(s), nor were we provided with information relative to the formulation used in the test sample(s). The issuance of this report in no way implies Listing, Classification or Recognition by UL Solutions and does not authorize the use of the UL Solutions' Certification, Listing, Classification or Recognition Marks or any other reference to UL Solutions on the product or system. UL Solutions authorizes the above-named company to reproduce this Report provided it is reproduced in its entirety. UL Solutions' name or Marks cannot be used in any packaging, advertising, promotion or marketing relating to the data in this Report, without UL Solutions' prior written permission. UL Solutions, its employees, and its agents shall not be responsible to anyone for the use or non-use of the information contained in this Report and shall not incur any obligation or liability for damages, including consequential damages, arising out of or in connection with the use of, or inability to use, the information contained in this Report.	



Cell information ¹	
Model number	CM0630R0002+
Rating, Vdc	3.8
Rating, Ah	67
Chemistry of test item	Lithium Ion (Lithium-ion Cell ((Lithium Nickel Cobalt Aluminium Oxide (LiNiCoAlO ₂) + Lithium Nickel Cobalt Manganese Oxide (LiNiCoMnO ₂) + Lithium Manganese Oxide (LiMn ₂ O ₄)))
Format	Prismatic
Overall dimensions, mm	173.9±0.4mm X 46.2mm X 125.7±0.4 mm (Enclosure) With the terminal considered, the height is 132.4±0.4 (Terminal)
Cell weight, g	1880
Original equipment manufacturer (OEM)	SAMSUNG SDI CO LTD
Branding manufacturer (if not OEM)	Not applicable
Standard test item certified to	UL 1973
Organization that certified test item	UL Solutions (UL File No. MH64496)
Summary of cell level test results	
Average cell surface temperature at gas venting, °C	160
Average surface temperature at thermal runaway, °C	167
Gas volume, L	113
Lower flammability limit (LFL), % volume in air at the ambient temperature	8.665
Lower flammability limit (LFL), % volume in air at the venting temperature	7.145
Burning velocity, (S _u) cm/s	49
Maximum pressure, (P _{max}) psig	89

¹ The submitted cells were tested UL Project No. 4791237663 issued on 2024-07-22 according to UL9540A 4th edition, revised on November 12, 2019. The information related to the testing laboratory was referenced from UL Project No. 4788865098.
UL 9540A, Edition 5

Cell gas composition

Gas	Measured %
Carbon Monoxide	16.03
Carbon Dioxide	40.09
Hydrogen	25.72
Methane	5.58
Ethylene	5.29
Ethane	0.94
Propylene	4.70
Propane	0.34
C4 (Total)	1.20
Pentane	0.11
Total	100

Module Information²	
Module Manufacturer	SAMSUNG SDI CO LTD
Model number	EM2031AE00XA ³ EM2031AE00YA
Rating, Vdc	30.4
Rating, Ah	67
Module cell configuration, xS/yP	8S/1P
Module dimensions (W x D x H), mm	216.0 x 404.5 x 163.0
Module weight, kg	16.5
Standard test item certified to	UL1973
Organization that certified test item	UL Solutions (UL File No. MH49407)
Summary of module level test results	
Number of initiating cells	1
Thermal runaway propagation	Yes
Maximum smoke release rate, m ² /s	7.4
Total smoke released, m ²	470
Total smoke released duration	From venting to the end of data recording 0:52:23 to 2:28:52
Peak chemical heat release rate, kW	81
External flaming	Yes
Location(s) of flame venting	On top of the module
Flying debris	Yes
Re-ignitions	No
Maximum temperature measured on module case	N/A ⁴

² The submitted modules were tested UL Project No. 4791232113 issued on 2024-04-30 according to UL9540A 4th edition, revised on November 12, 2019. The information related to the testing laboratory was referenced from UL Project No. 4788881162.

³ For module model EM2031AE00XA and EM2031AE00YA, X=1, 3 or 5, Y=2, 4 or 6

⁴ Accurate temperature could not be measured because of the flames.

Summary of module level test gas analysis data

Gas analysis method:

- ☒ Flame ionization detection
- ☒ Fourier-Transform infrared Spectrometer
- ☒ Hydrogen Sensor (palladium-nickel, thin-film solid state sensor)
- ☒ White light source with photo detector (smoke release rate)

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

Gas Compound	Gas Type	Pre-Flaming, L	Flaming, L	Minimum detectable flow rate, LPM
Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	43	157	0.48
Carbon Dioxide	Carbon Containing	1	259	1.72
Carbon Monoxide	Carbon Containing	1	181	1.95
Hydrogen	Hydrogen	0	56	8.42

Unit Information⁵	
Model number	PHR3462-001A
Rating, Vdc	516.8
Rating, Ah	34.6
BESS dimensions (W x D x H, mm)	650 x 530 x 2055
BESS module configuration	17S/1P
Number of modules in BESS	17
Module cell configuration, xS/yP	136S/1P
Number of cells in module	136
BESS weight, kg	713
BESS enclosure material	Steel
BESS Intended Installation: a) Indoor floor mounted non-residential b) Indoor floor mounted residential c) Outdoor ground mounted non-residential d) Outdoor ground mounted residential e) Indoor wall mounted non-residential f) Indoor wall mounted residential g) Outdoor wall mounted non-residential h) Outdoor wall mounted residential i) Rooftop residential j) Open parking garage non-residential	a) Indoor floor mounted non-residential
Residential Indoor Use: Smallest volume room installations specified.	Not applicable
Original Equipment Manufacturer (OEM)	SAMSUNG SDI CO LTD
Branding Manufacturer (if not OEM)	Not applicable
Was the unit certified?	Yes
Standard the unit was certified to	UL1973
Organization that certified the unit	UL Solutions (UL File No. MH49407)
Summary of unit level test results	
Number of initiating cell(s)	1
Number of initiating modules	1

⁵ The submitted units were tested UL Project No. 4791232121 issued on 2024-03-28 according to UL9540A 4th edition, revised on November 12, 2019. The information related to the testing laboratory was referenced from UL Project No. 4788881169.

Thermal Runaway Propagation:	Thermal runaway propagated in the initiating module.
External Flaming from BESS:	No
Location(s) of Flame Venting:	Not applicable
Maximum Temperature ⁶ , °C - Target BESS	32
Maximum Temperature ⁶ , °C - Wall Surface	43
Peak Chemical Heat Release Rate, kW	No flaming observed during the test.
Peak Convective Heat Release Rate, kW	No flaming observed during the test.
Maximum Smoke Heat Release Rate, m ² /s	0.8
Maximum Heat Flux ⁶ - Instrumented Walls, kW/m ²	0.3
Maximum Heat Flux ⁶ - Ceiling or Soffit, kW/m ²	Not applicable
Maximum Heat Flux ⁶ - Target Modules, kW/m ²	20.6
Maximum Heat Flux ⁶ - Egress Path, kW/m ²	0.3
Flying Debris:	No Flying Debris
Re-ignitions:	No Re-ignitions

⁶ Averaged over 60 seconds.
UL 9540A, Edition 5

Cell failure test method performed for the unit level
☒ External heating using thin film heater with 4°C to 7°C thermal ramp. ☐ Nail Penetration ☐ Overcharge ☐ External short circuit ☐ Overdischarge ☐ Others:
Description of method used to fail cells if other than external thin film heater with thermal ramp: Not applicable
Description of components employed within the BESS that serve to suppress propagation (fire protection features): Compressed polymeric sheet embedded with Novec 1230 capsules; Mica sheet between cells with thickness of 5mm for each module
Deviation from the module level test: Not applicable

Summary of unit level test gas analysis data				
Gas analysis method:				
☒ Non-Dispersive Infrared Spectrometer (NDIR) ☒ Flame ionization detection ☒ Fourier-Transform infrared Spectrometer ☒ Hydrogen Sensor (palladium-nickel, thin-film solid state sensor) ☒ White light source with photo detector (smoke release rate)				
Gas Composition & Volume for Each Compound (Pre-flaming and After flame)				
Gas Compound	Gas Type	Pre-Flaming, L	Flaming, L	Minimum detectable flow rate, LPM
Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	110	280	0.55
Carbon Dioxide	Carbon Containing	80	50	8.18
Carbon Monoxide	Carbon Containing	0	0	3.95
Hydrogen	Hydrogen	0	0	34.53
Summary of test results				
Compliance with performance criteria in accordance with Table 9.1 for indoor floor mounted non-residential unit [was] [was not] achieved. Installation level testing [is] [is not] required. [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 7.3.1.10; [X] Surface temperature measurements on wall surfaces did not exceed 97°C (175°F) of temperature rise above ambient; [X] Explosion hazards were not observed, including deflagration or detonation				

Testing Laboratory information in UL Project No. 4788881169		
Testing Laboratory and testing location(s)		
Testing Laboratory	UL Solutions	
Testing location/ address	333 Pfingsten Road Northbrook, IL 60062 United States	
Tested by (name) in UL Project No. 4788881169	Daniel Wade	
Witnessed by (for 3 rd Party Lab Test Location) (name, signature)	Not applicable	
Project Handler (name, signature) in UL Project No. 4791232121	Leon Lee	
Reviewer (name, signature) in UL Project No. 4791232121	Sean Yang	
Project Handler (name, signature) in UL Project No. 4791425867	Leon Lee	
Reviewer (name, signature) in UL Project No. 4791425867	Sean Yang	
Project Handler (name, signature)	Jinkyong Kim / Donghyun Kim	 Donghyun Kim
Reviewer (name, signature)	Leon Lee	 Leon Lee
Project Handler (name, signature) for Amendment 1	Jinkyong Kim / Donghyun Kim	 Donghyun Kim
Reviewer (name, signature) for Amendment 1	Leon Lee	 Leon Lee
List of Attachments (including a total number of pages in each attachment)		
Attachment	Description	Pages
A	BESS Charge Profiles	31 through 31
B	BESS Construction Photos	32 through 33
C	BESS Instrumentation Photos	34 through 40
D	Temperature Profiles and Heat Flux Measurements	41 through 47
E	BESS Testing Photos	48 through 50
F	BESS Gas Flow Rate, Heat Release Rates, Smoke Release Rate Profiles	51 through 51

Test Verdicts	
Clause Requirement Does Not Apply to the Test Item:	N/A (Not Applicable)
Clause Requirement Met:	M (Met)
Clause Requirement Not Met:	NM (Not Met)
Clause Requirement Completed:	C (Completed)
Clause Requirement Completed with Modification	Mod (Modified)
Test Dates	
Date of Receipt of Test Item	2019-06-04
Date(s) of Performance of Tests	2019-06-12
General remarks	
“(See Attachment #)” refers to additional information appended to the report. Throughout this report a point is used as the decimal separator.	
The unit can be manufactured at more than one location. The manufacturer provided a written declaration stating that the manufacturing process at all manufacturing locations is identical and product from one manufacturing location is representative of all manufacturing locations listed below.	☐ Yes ☒ Not applicable
Name and address of factory(ies) supplying samples for test:	163, Bangudae-ro, Samnam-myeon, Ulju-gun, Ulsan, Republic of Korea

General product information and other remarks:

PHR3462-001A is a li-ion battery unit manufactured by Samsung SDI, utilizing EM2031AE00XA consisting of the prismatic cell CM0630R0002+, manufactured by Samsung SDI.

Testing was done with the model PHR3462-001A (136S), which is considered representative of the following models. since PHR3462-001A has the highest energy capacity when compared to the other models with the same overall design layout and components.

Models. PHR3462-001A (136S), PHR3262-001A (128S), PHR2852-001A (112S), PHR2652-001A (104S), PHR2042-001A (80S).

The original testing was performed under UL Project No. 4788881169 in accordance with the third edition of UL9540A, which was revised on June 15th, 2018. For the purpose of reissuing the report in alignment with the fourth edition of UL9540A, revised on November 12th, 2019, a report was reissued in UL Project No. 4791232121. An additional assessment of the Lower Flammability Limit (LFL) at the venting temperature was conducted at the cell level, and the results have been incorporated into the unit report under UL Project No. 4791425867.

This report is being issued for the purpose of re-publication as the 5th edition.

Report History:

Original: Project No. 4791913381 issued on 2025-09-10

Amendment 1: Project No. 4791913381 issued on 2025-10-24

New battery module models named EM2031AE005A, EM2031AE006A, EM2031AE00XB, EM2031AE00YB (X=1 or 3, Y=2 or 4) have been added respectively in this report.

No testing has been performed with these new models. It's for reference only.

The new battery module models EM2031AE005A and EM2031AE006A are technically identical to the existing battery module models EM2031AE00XA and EM2031AE00YA (X=1 or 3, Y=2 or 4), but they are classified separately to serve different customers of Samsung SDI. Accordingly, the new models are represented by adding the suffix digits 5 and 6 to the existing EM2031AE005A, EM2031AE006A model series, respectively.

The new module models EM2031AE00YB (X=1 or 3, Y=2 or 4) are totally identical to the existing battery module models, EM2031AE00XA and EM2031AE00YA (X=1, 3 or 5, Y=2, 4 or 6) except for overcharge protection part from cell.

Attachment C: BESS Instrumentation Photos - (Pages 34 through 40)

The overall layout of test equipment and measurement locations is illustrated in Figure . The layout includes 1 initiating cabinet, 3 target cabinets, and 2 walls; 2 heat flux gauges and 23 thermocouples were instrumented in the wall that was in the front of the initiating unit.

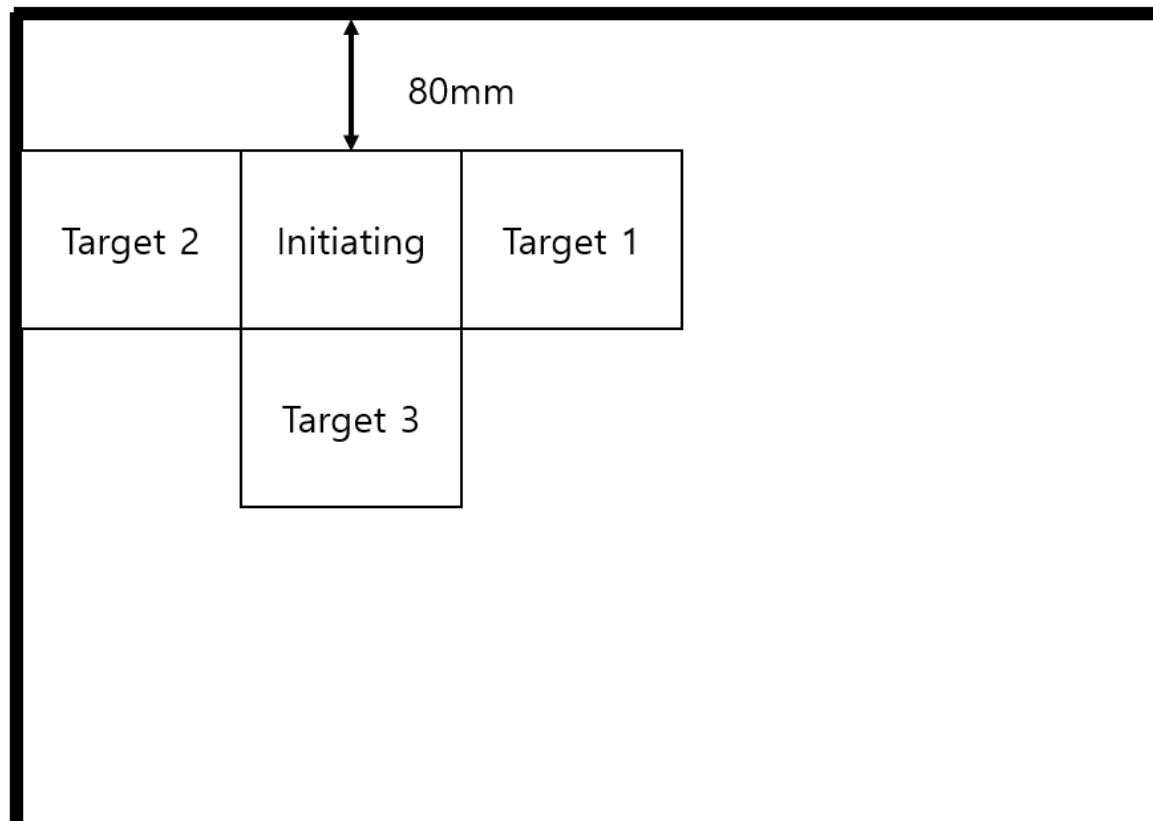


Figure C1 – Test configuration and unit spacing

Test Configuration	
Clearance between Initiating Unit and Target Unit 1	0 mm
Clearance between Initiating Unit and Target Unit 2	0 mm
Clearance between Initiating Unit and Target Unit 3	0 mm
Clearance between Target Unit 2 and the side wall	0 mm
Clearance between Initiating Unit and the front wall	80 mm
Doors	Perforated metal front panels were installed on the front of each cabinet and in front of the BMS on the top of the unit.
Physical barriers between units	No barriers present between racks, but rear panels were installed on the racks aligned back-to-back.

Table C1 -Test configuration