



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

Project Number.....: 4789770616

Date of issue: 2021-05-25

Total number of pages.....: 60

UL Report Office: UL LLC

Applicant's name.....: Samsung SDI

Address.....: 428-5 GONGSE-DONG GIHEUNG-GU
YONGIN-SI, GYEONGGI-DO 446-577 REPUBLIC OF KOREA

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:

Copyright © 2020 UL LLC All Rights Reserved.

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).

The issuance of this report in no way implies Listing, Classification or Recognition by UL and does not authorize the use of UL Listing, Classification or Recognition Marks or any other reference to UL on the product or system. UL LLC authorizes the above named company to reproduce this Report provided it is reproduced in its entirety. UL's name or marks cannot be used in any packaging, advertising, promotion or marketing relating to the data in this Report, without UL's prior written permission.


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

Cell level information		
Cells in Module:		
●Manufacturer Name		Samsung SDI Co LTD
●Part Number		CS1120RT001A
●Chemistry		Lithium Nickel Manganese Cobalt Oxide (LiNiMnCoO2)
●Format		Prismatic
Ratings (Vdc, Ah) :		3.63 V , 112Ah
Cell certified? :		Yes
Standard the cell was certified to:		UL 1642
Organization that certified the cell:		UL LLC
Average cell surface temperature at gas venting, °C:		150
Average cell surface temperature at thermal runaway, °C:		176
Gas Volume: (l)		212
Lower flammability level (LFL), % volume in air at the ambient temperature:		9.21
Lower flammability level (LFL), % volume in air at the venting temperature:		7.63
Burning velocity (Su) cm/s:		49
Maximum pressure (Pmax) psig:		129
Cell level Gas Composition:		
Gas		Measured %
Carbon Monoxide	CO	28.382
Carbon Dioxide	CO2	30.241
Hydrogen	H2	24.70
Methane	CH4	6.175
Ethylene	C2H4	7.439
Ethane	C2H6	1.369
Propylene	C3H6	0.999
Propane	C3H8	0.120
Propadiene	C3H4	0.027
-	C4 (Total)	0.523
Iso-Pentane	C5H12	0.003
Pentane	n-C5H12	0.007
Hexane	C6H14	0.012
Total	-	100

Module level Information			
Model No	MS8943E101A		
Ratings (Vdc, Ah)	112Ah, 87.12V		
Module dimensions (W x D x H (mm)).....	370 X 651.6 X 160		
Module cell configuration (xS/yP)	22S 1P		
Module weight (kgs).....	56		
Module enclosure material.....	Metal case, Plastic Cover		
Was the module certified?	Pending Project No. 4789894003		
Standard the module was certified to	UL1973		
Organization that certified test item	UL		
Number of initiating cells failed to achieve propagation.	1		
Thermal Runaway Propagation:	Thermal runaway propagations were observed		
External Flaming:	External flaming was observed during the test		
Location(s) of Flame Venting:	Flame was ejected upward from cell(s)		
Flying Debris:	Debris of electrode assemblies were observed on the floor of the testing room		
Re-ignitions:	No re-ignition observed after the test		
Test Maximum Smoke Release Rate (m ² /s)	6		
Test Total Smoke Released: (m ²)	4315		
Test Peak Chemical Heat Release Rate: (kW):	560		
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	0	7
Carbon Monoxide	Carbon Containing	0	18,834
Carbon Dioxide	Carbon Containing	0	255
Hydrogen	Hydrogen	0	0
Unit level Information			
Model No. :	PHR1433-001A		
Ratings (Vdc, Ah)	1,277.76Vdc, 112Ah		
BESS dimensions (W x D x H (mm)).....	876 x 700.8 x 3134.6		
BESS module configuration	16S 1P		
Number of modules in BESS	16		
Number of cells in module.:	22		
BESS weight (kgs).....	1073.0		

BESS enclosure material..... :	SGHC
BESS Intended Installation: Non Residential: outdoor ground mounted, indoor floor mounted, outdoor wall mounted, indoor wall mounted, roof top, open garage Residential: Outdoor ground mounted, indoor floor mounted, outdoor wall mounted, indoor wall mounted	Non-residential indoor floor mounted
Original Equipment Manufacturer (OEM):	Samsung SDI
Branding Manufacturer (if not OEM):	Not applicable
Was the unit certified?	Pending Project No. 4789894003
Standard the unit was certified to	UL1973
Organization that certified the unit	UL
Cell failure test method performed (summary of method and test clause): <input checked="" type="checkbox"/> External heating using thin film with 4°C to 7°C thermal ramp. <input type="checkbox"/> Nail Penetration <input type="checkbox"/> Overcharge <input type="checkbox"/> External short circuit (<i>X Ω external resistance</i>) <input type="checkbox"/> 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	
Number of initiating cell(s)	1
Thermal Runaway Propagation:	No propagation observed
External Flaming from BESS:	No external flaming observed
Location(s) of Flame Venting:	No external flaming observed
Maximum Target BESS Temperature, °C	65
Maximum Wall Surface Temperature ¹ , °C	38
Peak Chemical Heat Release Rate, kW	No flaming observed
Peak Convective Heat Release Rate, kW	No flaming observed
Maximum Smoke Heat Release Rate, m ² /s	2.0
Maximum Heat Flux on Target Modules, kW/m ²	6.96
Maximum Heat Flux of Egress Path, kW/m ²	0.02
Flying Debris:	No flying debris
Re-ignitions:	No re-ignition
Gas Analysis: <input checked="" type="checkbox"/> Flame ionization detection (FID)	

¹ Maximum wall surface temperature averaged on 60 seconds.

<input checked="" type="checkbox"/> Non-Dispersive Infrared Spectrometer (NDIR) <input type="checkbox"/> Fourier-Transform infrared Spectrometer <input checked="" type="checkbox"/> Hydrogen Sensor (palladium-nickel, thin-film solid state sensor) <input checked="" type="checkbox"/> 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	18	0
Carbon Dioxide	Carbon Containing	0	0
Carbon Monoxide	Carbon Containing	2	0
Hydrogen	Hydrogen	0	0
Summary of BESS Unit Test Results			
Performance Criteria in accordance with Table 9.1 for Indoor Floor Mounted non-residential unit			
<p><input checked="" type="checkbox"/> Flaming outside the initiating BESS unit was not observed;</p> <p><input checked="" type="checkbox"/> 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;</p> <p><input checked="" type="checkbox"/> 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;</p> <p><input checked="" type="checkbox"/> 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</p> <p><input checked="" type="checkbox"/> Heat flux in the center of the accessible means of egress did not exceed 1.3 kW/m².</p>			
Necessity for an Installation level test			
<p><input type="checkbox"/> 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.</p> <p><input checked="" type="checkbox"/> 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.</p>			
Testing Laboratory Information			
Testing Laboratory and testing location(s):			
Testing Laboratory:		UL LLC	
Testing location/ address		333 Pfingsten Rd Northbrook Illinois United States	
Tested by (name, signature)		Paul Obrochta	
Witnessed by (for 3rd Party Lab Test Location) (name, signature)		N/A	N/A
Project Handler (name, signature)		Sean Yang	
Reviewer (name, signature)		Thomas Skowera	<i>Thomas Skowera</i>