

Date: 2024-08-28

NINGBO DEYE ESS TECHNOLOGY CO., LTD No.568, South Rixian Road, Binhai Economic Development Zone, Cixi, Ningbo, Zhejiang P.R. China

Ref: CU US + Canada Certificate

Type of Equipment	:	Rechargeable Li-ion Battery System
Certificate No.	:	CU 72406708 0001
Report No.	:	CN24CL37 001
Engineer/Contact	:	Wilson Zhou
Standards	:	ANSI/CAN/UL 1973:2022

Dear Madame or Sir,

The above referenced technical equipment has been tested and was found to be in compliance with the listed test requirement(s). Enclosed, please find the TUV Rheinland approval document No. CU 72406708 0001. It authorizes you to label the listed product(s) with the TUV Rheinland Mark identified in the approval document. For compliance, the Test Mark must be on the approved unit.

Your product is subject to regular factory follow-up inspections as well as annual certificate and factory registration fees.

In using the TUV Rheinland Mark you are obligated to comply with the TUV Rheinland of North America Service Agreement.

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

With kind regards,

Certification Body

Weichun Li

Enclosure

Certificate

Certificate no.

CU 72406708 0001

License Holder:		Manufacturing Plant:	
NINGBO DEYE ESS TECH	INOLOGY CO., LTD	NINGBO DEYE ESS TECHNOLOGY CO., LTD	
No.568, South Rixiar	Road,	No.568, South Rixian Road,	
Binhai Economic Development Zone,		Binhai Economic Development Zone,	
Cixi, Ningbo,		Cixi, Ningbo,	
Zhejiang		Zhejiang	
P.R. China		P.R. China	
Report Number:	CN24CL37 001	Client Reference: Dai Jiapeng	
Certification acc. to:	ANSI/CAN/UL 1973:202	2	

Product Information

Certified Product:	Rechargeable Li-ion Battery System		
Model Designation:	RW-F10.2-B		
Technical Data:	Nominal voltage : 51.2V Rated capacity : 200Ah Other Data : See Appendix (Construction Data Form)		
Remarks:			
Appendix:	1, 1-124		

Date of issue:



TUV Rheinland of North America, Inc. 400 Beaver Brook Rd, Boxborough, MA 01719 Tel +1 (978) 266 9500, Fax +1 (978) 266-9992



2024-08-28

(yr/mo/day)

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Date: 2024-08-29

NINGBO DEYE ESS TECHNOLOGY CO., LTD No.568, South Rixian Road, Binhai Economic Development Zone, Cixi, Ningbo, Zhejiang P.R. China

Ref: CU US + Canada Certificate

Type of Equipment	:	Low Voltage Hybrid ESS
Certificate No.	:	CU 72406728 0001
Report No.	:	CN24DMK9 001
Engineer/Contact	:	Wilson Zhou
Standards	:	ANSI/CAN/UL 9540:2023

Dear Madame or Sir,

The above referenced technical equipment has been tested and was found to be in compliance with the listed test requirement(s). Enclosed, please find the TUV Rheinland approval document No. CU 72406728 0001. It authorizes you to label the listed product(s) with the TUV Rheinland Mark identified in the approval document. For compliance, the Test Mark must be on the approved unit.

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With kind regards,

Certification Body

Weichun Li

Enclosure

Certificate

Certificate no.

CU 72406728 0001

License Holder:

NINGBO DEYE ESS TECHNOLOGY CO., LTD No.568, South Rixian Road, Binhai Economic Development Zone, Cixi, Ningbo, Zhejiang P.R. China

Manufacturing Plant:

NINGBO DEYE ESS TECHNOLOGY CO., LTD No.568, South Rixian Road, Binhai Economic Development Zone, Cixi, Ningbo, Zhejiang P.R. China

Dai Jiapeng

Report Number:CN24DMK9001Client Reference:

1, 1-81

Certification acc. to: ANSI/CAN/UL 9540:2023

Product Information

Certified Product:	Low Voltage Hybrid ESS			
Model Designation:	RW-FX-5K-US ; RW-FX-8K-US ; RW-FX-12K-US (X=1, 2, 3, 4, 5; which means the number of batteries in parallel)			
Technical Data:	Nominal voltage ac : 120/240V, 120/208V, 220V Rated Energy (kWh) : 10.24*X (X=1, 2, 3, 4, 5) Other Data : See Appendix(Constr.Data Form)			

Remarks:

Appendix:



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TUV Rheinland of North America, Inc. 400 Beaver Brook Rd, Boxborough, MA 01719 Tel +1 (978) 266 9500, Fax +1 (978) 266-9992





Date: 2024-08-29

NINGBO DEYE ESS TECHNOLOGY CO., LTD No.568, South Rixian Road, Binhai Economic Development Zone, Cixi, Ningbo, Zhejiang P.R. China

Ref: CU US + Canada Certificate

Type of Equipment	:	Low Voltage Hybrid ESS
Certificate No.	:	CU 72406730 0001
Report No.	:	CN24FVHT 001
Engineer/Contact	:	Wilson Zhou
Standards	:	ANSI/CAN/UL 9540:2023

Dear Madame or Sir,

The above referenced technical equipment has been tested and was found to be in compliance with the listed test requirement(s). Enclosed, please find the TUV Rheinland approval document No. CU 72406730 0001. It authorizes you to label the listed product(s) with the TUV Rheinland Mark identified in the approval document. For compliance, the Test Mark must be on the approved unit.

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

With kind regards,

Certification Body

Weichun Li

Enclosure

Certificate

Certificate no.

CU 72406730 0001

License Holder:

NINGBO DEYE ESS TECHNOLOGY CO., LTD No.568, South Rixian Road, Binhai Economic Development Zone, Cixi, Ningbo, Zhejiang P.R. China

Manufacturing Plant:

NINGBO DEYE ESS TECHNOLOGY CO., LTD No.568, South Rixian Road, Binhai Economic Development Zone, Cixi, Ningbo, Zhejiang P.R. China

Dai Jiapeng

Report Number:CN24FVHT001Client Reference:

1, 1-78

Certification acc. to: ANSI/CAN/UL 9540:2023

Product Information

Certified Product:	Low Voltage Hybrid ESS		
Model Designation:	RW-FX-15K-US (X=1, 2, 3, 4, 5; which means the number of batteries in parallel)		
Technical Data:	Nominal voltage ac : 120/240V, 120/208V, 220V Rated Energy (kWh) : 10.24*X (X=1, 2, 3, 4, 5) Other Data : See Appendix(Constr.Data Form)		

Remarks:

Appendix:



Date of issue: 2024-08-29 (yr/mo/day)





Prüfbericht - Produkte *Test Report - Products*



Prüfbericht-Nr.: Test report no.:	CN24C5P7 001	Auftrags-Nr.: Order no.:	244569236	Seite 1 von 42 Page 1 of 42
Kunden-Referenz-Nr.: Client reference no.:	2487803	Auftragsdatum: Order date:	2024-01-02	
Auftraggeber: Client:	NINGBO DEYE ESS TECH No. 568, South Rixian Road Zhejiang, P.R. China	NOLOGY CO., LTD d, Binhal Economic D	Development Zone, Ci	xi, Ningbo,
Prüfgegenstand: Test item:	Rechargeable Li-ion Battery	/ System		
Bezeichnung / Typ-Nr.: Identification / Type no.:	RW-F10.2-B			
Auftrags-Inhalt: Order content:	Test report			
Prüfgrundlage: Test specification:	UL 9540A: 2019 (Fourth Ed Propagation in Battery Ener	lition) Test Method fo rgy Storage Systems	pr Evaluating Thermal	Runaway Fire
Wareneingangsdatum: Date of sample receipt:	2024-08-04	12 ala	7	
Prüfmuster-Nr.: Test sample no:	#2024080401		///	
Prüfzeitraum: Testing period:	2024-08-05 - 2024-08-20		Deye	
Ort der Prüfung: Place of testing:	See page 6 of main report		m ?	
Prüflaboratorium: Testing laboratory:	TÜV Rheinland (Shanghai) Co., Ltd.			
Prüfergebnis*: Test result*:	See main report			
geprüft von: tested by: Minhao Hu&Shih	eng Zhang	genehmigt von: authorized by: Sime	on Wang	
Datum: Date: 2024-08-30 Minhau	, Hu Shihery	Ausstellungsdatu Issue date: 2024-0	m: 508-30	8
Stellung / Position:	Project Engineer / Trainee	Stellung / Position	n: Autho	rizer
Sonstiges / Other: N/A				
Zustand des Prüfgegenst Condition of the test item a	andes bei Anlieferung: t delivery:	Prüfmuster vollstä Test item complete	ndig und unbeschädig e and undamaged	gt
* Legende: P(ass) = entspricht o.g * Legend: P(ass) = passed a m	g. Prüfgrundlage(n) $F(ail) = entsprichtertest specification(s) F(ail) = failed a n$	t nicht o.g. Prüfgrundlage(n) n. test specification(s)	N/A = nicht anwendbar N/A = not applicable	N/T = nicht getestet N/T = not tested
Dieser Prüfbericht bezi auszugsweise vervie This test report only relates permitted to	eht sich nur auf das o.g. Prüfn Ifältigt werden. Dieser Bericht to the above mentioned test sam be duplicated in extracts. This te	nuster und darf ohne berechtigt nicht zur V pple. Without permission st report does not entit	Genehmigung der Prü /erwendung eines Prüf n of the test center this le to carry any test mark	fstelle nicht fzeichens. test report is not

TUV Rheinland (Shanghai) Co., Ltd. No.177, 178, Lane 777 West Guangzhong Road, Jing'an District, Shanghai, China Mail: service-gc@tuv.com · Web: www.tuv.com



Prüfbericht-Nr.: CN24C5P7 001 Test report no.:

Seite 2 von 42 Page 2 of 42

Anforderungen Remarks

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

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TEST REPORT				
ANSI/CAN/UL 9540A:2019				
Test Method for Evaluating Therma	I Runaway Fire Propagation in Battery Energy Storage Systems			
Report Number:	CN24C5P7 001			
Date of issue:	See cover page			
Total number of pages:	See cover page			
Name of Testing Laboratory	TÜV Rheinland (Shanghai) Co., Ltd.			
	No. 177, Lane 777, West Guangzhong Road, Jing an District, Shanghai 200072, P. R. China			
Applicant's name:	NINGBO DEYE ESS TECHNOLOGY CO., LTD			
Address:	No. 568, South Rixian Road, Binhal Economic Development Zone, Cixi, Ningbo, Zhejiang, P.R. China			
Test specification:				
Standard:	ANSI/CAN/UL 9540A:2019			
Test procedure:	TÜV Rheinland Test Report			
Non-standard test method:	N/A			
Test Report Form No	UL 9540A-C01			
Test Report Form(s) Originator:	TÜV Rheinland (Shanghai) Co., Ltd.			
Master TRF:	Dated 2023-12-25			
General disclaimer:				
The test 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 Issuing Testing Laboratory. The authenticity of this Test Report and its contents can be verified by contacting the TÜV Rheinland (Shanghai) Co., Ltd., responsible for this Test Report.				
Other / Scope:				
This report presents the result of unit level tests of UL 9540A: 2019.				
All tests were conducted at TUV Rheinland (Shanghai) Co., Ltd. and TUV Rheinland's partner labs that were under supervision of TÜV Rheinland's engineer.				
All tests were under supervision of TÜV Rheinland's engineer.				



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Report No.: CN24C5P7 001

List of Attachments:

Attachment A: Diagrams of setup for unit level testing

Attachment B: Module Conditioning (Charge/discharge) Profiles

Attachment C: Observations and records

Attachment D: Module and Initiating Cell(s) Temperature Profiles During Testing

Attachment E: Convective Heat Release Rate, Chemical Heat Release Rate, Smoke Release Rate and Heat Flux

Attachment F: Flammable gas generation and composition data

Attachment G: Sample Photos and Test Photos

Attachment H: List of Test and Measurement Instruments

Summar	уc	of tes	ting	:

Unit level No. :	RW-F10.2-B
Ratings (Vdc) :	51.2
Cells in series/parallel :	2P16S
BESS dimensions (L x W x H (mm)) :	600±5mm(W)×830±5mm(H)×200±5mm(D)
BESS weight (kg) :	≤108kg
Maximum Target BESS Temperature (°C) :	38.4
Maximum Wall Surface Temperature (°C) :	82.0
BESS enclosure material :	No enclosure provided for BESS unit, racks are directly floor mounted
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	Residential: indoor floor mounted
Total number of cell(s) went into thermal runaway :	8
Thermal Runaway and Propagation :	3 initiating cells went into thermal runaway and propagated to 5 adjacent cells
Maximum Smoke Release Rate (m ² /s) :	31.0
Total Smoke Released (m ²) :	113.9
Total smoke released duration :	10:48 to 16:12
Peak Chemical Heat Release Rate (kW) :	No flaming occurred
Peak Convective Heat Release Rate (kW) :	No flaming occurred
Total Heat Release(kJ) :	No flaming occurred
External Flaming :	No external flaming occurred
Location(s) of Flame Venting :	No flaming occurred
Flying Debris :	No flying debris occurred



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Re-ignitions :	No further post test o	re-ignitions were observed during bservation
Cheesecloth state :	No flamino	g or charring
25% LFL in air for the smallest specified roc installation size :	om Specified The conce Not excee	room installation size: 86 m ³ entration of flammable gas: 2.05% d 25% LFL

Summary of Unit level test Gas Analysis Data:

Gas Analysis:

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

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	259.2	No flaming
Carbon Monoxide	Carbon Containing	632.8	No flaming
Carbon Dioxide	Carbon Containing	980.3	No flaming
Hydrogen	Hydrogen	875.9	No flaming

Note: 1) The collection time is from 10:48 to 16:12.

2) See Attachment F for detail gas analysis data.

Summary of BESS Unit Test Results

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

Flaming outside the initiating BESS unit is not observed as demonstrated by no flaming or charring of the cheesecloth indicator;	\boxtimes
Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit do not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8;	\boxtimes
For 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 per 9.2.15;	\boxtimes
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; and	\boxtimes
The concentration of flammable gas does not exceed 25% LFL in air for the smallest specified room installation size.	\boxtimes



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.				
The performance criteria of the unit level tests as edition has been met, therefore an installation lev need not be conducted	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			
Tests performed (name of test and test clause): Testing location: National Center of Inspection and Testing on Advance Energy Storage Products Quality (Jiangsu) UL 9540A cl 9. Unit Level				
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 (Fass)				
Testing: Date of receipt of test item Date (s) of performance of tests 2024-08-05 ~ 2024-08-20				
General remarks:				
"(See Enclosure #)" refers to additional information appended to the report. "(See appended table)" refers to a table appended to the report.				
Name and address of factory (ies)				
Other: N/A				

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Cell level information		
Manufacturer :	EVE Power Co., Ltd.	
Model number :	LF100LA	
Chemistry :	LiFePO ₄	
Physical configuration :	Prismatic	
Electrical rating :	Rated capacity: 100 Ah	
	Nominal voltage: 3.2 V	
Compliance with UL1973:	 ∑ Yes <u>Report No. MH63503-20221108</u> <u>Cert. No. UL-CA-2240635-0</u> <u>Cert. No. UL-US-2242566-0</u> 	
UL 9540A cell test report number: :	4790509108	
Average cell surface temperature at gas venting :	181 °C	
Average cell surface temperature at thermal runaway :	230 °C	
Gas Volume:	43.6 L	
Lower flammability limit (LFL), % volume in air at the ambient temperature:	8.25%	
Lower flammability limits (LFL), % volume in air at the venting temperature:	6.73%	
Burning velocity (Su):	97.8 cm/s	
Maximum pressure (Pmax):	102.3 psig	
Cell Gas Composition:		
Gas component	Concentration % (v/v)	
СО	6.954	
CO ₂	21.909	
H ₂	61.897	
CH4	4.825	
C ₂ H ₂	0.113	
C ₂ H ₄	2.161	
C ₂ H ₆	0.993	
C ₃ H ₆	0.370	
C ₃ H ₈	0.156	
C4 (Total)	0.282	
C5 (Total)	0.061	



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C6 (Total)	0.030
C ₇ H ₁₄	0.002
C ₆ H ₆	0.010
C7H8	0.002
C ₃ H ₆ O ₃	0.007
$C_4H_8O_3$	0.228
Total	100



Report No.: CN24C5P7 001

General product information

Photo of Battery system:



Product	Rechargeable Li-ion Battery System
Type/model	RW-F10.2-B
Cell Capacity [Ah]	200
Cell Quantity	32
Battery structure	2P16S
Nominal voltage [V]	51.2
Rated capacity [kWh]	10.24
Upper limit charging voltage [V]	57.6
Recommend charging current [A]	100
Maximum charging current [A]	198
Recommend discharging current [A]	100
Maximum discharging current [A]	240



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Discharge cut-off voltage [V]	41.6
Temperature range for charging [°C]	1 to 55
Temperature range for discharging [°C]	-20 to 55
Temperature threshold for protection	60
Overcharge protected voltage supply by battery system	≥3.65V /Cell
Recommend charging method by manufacturer	Charge at constant current 100A until the voltage reaches 57.6V or one cell reaches 3.6V
Dimension [mm]	600±5mm(W)×830±5mm(H)×200±5mm(D)
Weight [kg]	≤108kg
Ingress Protection (IP)	IP65
Protective Class	1
Cooling type	Natural air cooling
Altitude	3000



Module Construction

Figure 1. Layout of the battery system contents



Diagrams of setup for battery system testing

Figure 2. Thermocouples (no. xx) locations of initiating cell







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ANSI/CAN/UL 9540A:2019			
Clause	Requirement – Test	Result - Remark	Verdict
CONSTRUCTION			
5	General		
5.1	Cell		Р
5.1.1	The cells associated with the BESS that were tested shall be documented in the test report	Accepted test report by UL, test report: 4790509108	Р
5.1.2	The cell documentation included in the test report shall indicate if the cells associated with the BESS comply with UL 1973		Р
5.1.3	Refer to 7.6.1 for further details		N/A
5.2	Module		Р
5.2.1	The modules associated with the BESS that were tested shall be documented in the test report	See Product Specification on Page 8	Р
5.2.2	The module documentation included in the test report shall indicate if the modules associated with the BESS comply with UL 1973	Test with unit	N/A
5.2.3	Refer to 8.3 for further details		N/A
5.3	Battery energy storage system unit	DUT complied with UL1973	Р
5.3.1	The BESS unit documentation included in the test report shall indicate the units that comply with UL 9540		N/A
5.3.2	For BESS units for which UL 9540 compliance cannot be determined, the documentation included in the test report shall include the number of modules in the BESS, electrical configuration of the module, and physical layout of the modules in the BESS, battery management system (BMS) and other major components of the BESS. It shall be documented as to whether the battery system complies with UL 1973 in addition to the overall BESS compliance to UL 9540.	DUT complied with UL1973	Ρ
5.3.3	If applicable, the details of any fire detection and suppression systems that are an integral part of the BESS shall be noted in the test report		N/A
5.3.4	Refer to 9.7 for further details		Р
5.4	Flow Batteries	Not applicable for lithium product.	N/A
5.4.1	For flow batteries, the report will cover the chemistry, as well as the electrical rating in capacity and nominal voltage of the cell stack		N/A
5.4.2	The flow battery documentation included in the test report shall indicate if the flow battery system complies with UL 1973		N/A
5.4.3	See 7.6.2 for further details		N/A
PERFORMANCE			
6	General		



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	ANSI/CAN/UL 9540A:2019			
Clause	Requirement – Test	Result - Remark	Verdict	
6.1	The tests in this standard are extreme abuse conditions conducted on electrochemical energy storage devices that can result in fires, explosions, smoke, off gassing of flammable and toxic materials, exposure to toxic and corrosive liquids, and potential exposure to hazardous voltages and electrical energy. See Annex B for recommended testing practices.		Ρ	
6.2	At the conclusion of testing, samples shall be discharged in accordance with the manufacturer's specifications		Р	
9	Unit Level			
9.1	Sample and test configuration		Р	
9.1.1	The unit level test shall be conducted with BESS units installed as described in the manufacturer's instructions and this section. Test configurations include the following:	Applied b). Indoor floor mounted unit level for the indoor floor mounted residential use BESS.	Р	
	 a) Indoor floor mounted non-residential use BESS; b) Indoor floor mounted residential use BESS; c) Outdoor ground mounted non-residential use BESS; d) Outdoor ground mounted residential use BESS; e) Indoor wall mounted non-residential use BESS; f) Indoor wall mounted residential use BESS; g) Outdoor wall mounted non-residential use BESS; h) Outdoor wall mounted residential use BESS; h) Outdoor wall mounted residential use BESS; i) Rooftop and open garage non-residential use BESS 		Ρ	
9.1.2	The unit level test requires 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 figure 4-10 for test installations	Р	
	Exception: Testing can be conducted outdoors for outdoor only installations if there are the following controls and environmental conditions in place:	Indoor floor mounted unit level testing method	N/A	
	 a) Wind screens are utilized with a maximum wind speed maintained at ≤ 12 mph; b) The temperature range is within 10°C to 40°C (50°F to 104°F); c) The humidity is < 90% RH; d) There is sufficient light to observe the testing; e) There is no precipitation during the testing; f) There is control of vegetation and combustibles in the test area to prevent any impact on the testing and to prevent inadvertent fire spread from the test area; and g) There are protection mechanisms in place to prevent inadvertent access by unauthorized persons in the test area and to prevent exposure of persons to any hazards as a result of testing. 		N/A	



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Clause	Requirement – Test	Result - Remark	Verdict		
9.1.3	Depending upon the configuration and design of the BESS (e.g. the BESS is composed of multiple separate parts within separate enclosures), this testing to determine fire characterization can be done at the battery system level	Testing at battery rack level	Р		
9.1.4	The initiating BESS unit shall contain components representative of a BESS unit in a complete installation.		Р		
9.1.5	Target BESS units shall include the outer cabinet (if part of the design), racking, module enclosures, and components		Р		
9.1.6	The initiating BESS unit shall be at the maximum operating state of charge (MOSOC),	100% SOC	Р		
9.1.7	If a BESS unit includes an integral fire suppression system, there is an option of providing this with the DUT	No integral fire suppression system	N/A		
9.1.8	Electronics and software controls such as the battery management system (BMS) in the BESS are not relied upon for this testing.		Р		
9.2	Test method – Indoor floor mounted BESS units		Р		
9.2.1	Samples and test configurations are in accordance with 9.1.	Indoor floor mounted	Р		
9.2.2	Any access door(s) or panels on the initiating BESS unit and adjacent target BESS units shall be closed,		Р		
9.2.3	The initiating BESS unit shall be positioned adjacent to two instrumented wall sections	See figure 5	Р		
9.2.4	Instrumented wall sections shall extend not less than 0.49 m (1.6 ft) horizontally beyond the exterior of the target BESS units.		Р		
9.2.5	Instrumented wall sections shall be at least 0.61-m (2- ft) taller than the BESS unit height		Р		
9.2.6	The surface of the instrumented wall sections shall be covered with 16-mm (5/8-in) gypsum wall board and painted flat black		Р		
9.2.7	The initiating BESS unit shall be centered underneath an appropriately sized smoke collection hood of an oxygen consumption calorimeter		Р		
9.2.8	The light transmission in the calorimeter's exhaust duct shall be measured using a white light source and photo detector for the duration of the test		Р		
9.2.9	The chemical and convective heat release rates shall be measured for the duration of the test, using the methodologies specified in 8.2.11 and 9.2.12, respectively	See attachment E	Р		
9.2.10	With reference to 9.2.9, the heat release rate measurement system shall be calibrated	See attachment E	Р		
9.2.11	With reference to 9.2.9, the convective heat release rate shall be measured using thermopile	See attachment E	Р		
9.2.12	With reference to 9.2.9, the convective heat release rate shall be calculated using the following equation: $HRR_{c} = V_{e'}A \frac{353.22}{T_{e}} \int_{T_{a}}^{T} C_{p} dT$		Р		



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Clause	Requirement – Test	Result - Remark	Verdict	
9.2.13	The physical spacing between BESS units (both initiating and target) and adjacent walls shall be representative of the intended installation		P	
9.2.14	Separation distances shall be specified by the manufacturer for distance between:		Р	
	a) The BESS units and the instrumented wall sections; and b) Adjacent BESS units	See figure 5	Р	
9.2.15	Wall surface temperature measurements shall be collected for BESS intended for installation in		P	
9.2.16	Wall surface temperatures shall be 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,		P	
9.2.17	Thermocouples shall be secured to gypsum surfaces by the use of staples placed over the insulated portion of the wires		Р	
9.2.18	Heat flux shall be measured with the sensing element of at least two water-cooled Schmidt-Boelter gauges at the surface of each instrumented wall:		Р	
	a) Both are collinear with the vertical thermocouple array:		Р	
	b) One is positioned at the elevation estimated to receive the greatest heat flux due to the thermal runaway of the initiating module; and		P	
	c) One is positioned at the elevation estimated to receive the greatest heat flux during potential propagation of thermal runaway within the initiating BESS unit		Р	
9.2.19	Heat flux shall be measured with the sensing element of at least two water-cooled Schmidt-Boelter gauges at the surface of each adjacent target BESS unit that faces the initiating BESS unit:		Р	
	a) One is positioned at the elevation estimated to receive the greatest heat flux due to the thermal runaway of the initiating module within the initiating BESS: and		Р	
	b) One is positioned at the elevation estimated to receive the greatest surface heat flux due to the thermal runaway of the initiating BESS.		P	
9.2.20	For non-residential use BESS, heat flux shall be measured with the sensing element of at least one water-cooled Schmidt-Boelter gauge	Residential	N/A	
9.2.21	No. 24-gauge or smaller, Type-K exposed junction thermocouples shall be installed to measure the temperature of the surface		Р	
9.2.22	For residential use BESS, the DUT shall be covered with a single layer of cheese cloth		Р	
9.2.23	An internal fire condition in accordance with the module level test shall be created within a single module in the initiating BESS unit:		Р	
	a) The position of the module shall be selected to present the greatest thermal exposure		Р	



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Clause	Requirement – Test	Result - Remark	Verdict		
	b) The setup (i.e. type, quantity and positioning) of equipment for initiating thermal runaway in the module shall be the same as that used to initiate and propagate thermal runaway within the module level test		Р		
9.2.24	The composition, velocity and temperature of the initiating BESS unit vent gases shall be measured within the calorimeter's exhaust duct		Р		
9.2.25	The hydrocarbon content of the vent gas shall be measured using flame ionization detection		Р		
9.2.26	The test shall be terminated if:		Р		
	a) Temperatures measured inside each module within the initiating BESS unit return to ambient temperature;	Appilcable	Р		
	b) The fire propagates to adjacent units or to adjacent walls; or		N/A		
	c) A condition hazardous to test staff or the test facility requires mitigation		N/A		
9.2.27	For residential use systems, the gas collection data gathered in 9.2 shall be compared to the smallest room installation		Р		
9.3	Test method – Outdoor ground mounted units		N/A		
9.4	Test Method – Indoor wall mounted units		N/A		
9.5	Test Method – Outdoor wall mounted units		N/A		
9.6	Rooftop and open garage installations		N/A		
9.7	Unit level test report		Р		
9.7.1	The report on the unit level testing shall identify the type of installation being tested, as follows:		Р		
	 a) Indoor floor mounted non-residential use BESS; b) Indoor floor mounted residential use BESS; c) Outdoor ground mounted non-residential use BESS; d) Outdoor ground mounted residential use BESS; e) Indoor wall mounted non-residential use BESS; f) Indoor wall mounted residential use BESS; g) Outdoor wall mounted non-residential use BESS; h) Outdoor wall mounted non-residential use BESS; i) Rooftop installed non-residential use BESS; or j) Open garage installed non-residential use BESS. 	Indoor floor mounted residential use BESS.	Ρ		
9.7.2	With reference to 9.7.1, if testing is intended to represent more than one installation type, this shall be noted in the report	One installation type	N/A		
9.7.3	The report shall include the following, as applicable:		Р		
	a) Unit manufacturer name and model number (and whether UL 9540 compliant);	See the summary of this report	Р		
	b) Number of modules in the initiating BESS unit;	See figure 4	Р		
	c) The construction of the initiating BESS unit per 5.3;	See figure 4	Р		
	d) Fire protection features/detection/suppression systems within unit;		N/A		



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Clause	Requirement – Test	Result - Remark	Verdict	
	 e) Module voltage(s) corresponding to the tested SOC; 	See Attachment C	Р	
	f) The thermal runaway initiation method used;	External heater	Р	
	 g) Location of the initiating module within the BESS unit; 	See figure 4	Р	
	 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 figure 5	Р	
	 i) Observation of any flaming outside the initiating BESS enclosure and the maximum flame extension; 	See Attachment C	Р	
	 j) Chemical and convective heat release rate versus time data; 	See Attachment E	Р	
	k) Separation distances from the initiating BESS unit to target walls (e. g. distances A and C in Figure 9.1);	See figure 5	Р	
	I) Separation distances from the initiating BESS unit to target BESS units (e.g. distances D and H in Figure 9.1);	See figure 5	Р	
	m) The maximum wall surface and target BESS temperatures achieved during the test and the location of the measuring thermocouple;	See Attachment D	Р	
	n) The maximum ceiling or soffit surface temperatures achieved during the indoor or outdoor wall mounted test and the location of the measuring thermocouple;		N/A	
	 o) The maximum incident heat flux on target wall surfaces and target BESS units; 	See Attachment E	Р	
	 p) The maximum incident heat flux on target ceiling or soffit surfaces achieved during the indoor or outdoor wall mounted test; 		N/A	
	q) Gas generation and composition data;	See Attachment F	Р	
	 r) Peak smoke release rate and total smoke release data; 	See Attachment E	Р	
	s) Indication of the activation of integral fire protection systems and if activated the time into the test at which activation occurred;		N/A	
	t) Observation of flying debris or explosive discharge of gases;	See Attachment C	Р	
	u) Observation of re-ignition(s) from thermal runaway events;	See Attachment C	Р	
	 v) Observation(s) of sparks, electrical arcs, or other electrical events; 	See Attachment C	Р	
	 w) Observations of the damage to: 1) The initiating BESS unit; 2) Target BESS units; 3) Adjacent walls, ceilings, or soffits; and 	See Attachment C	Р	
	x) Photos and video of the test.	Recorded	Р	
9.8	Performance at unit level testing		Р	



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Clause	Requirement – Test	Result - Remark	Verdict		
9.8.1	Installation level testing in Section 10 is not required if the following performance conditions outlined in Table 9.1 are met during the unit level test.	Installation level testing is not required according to the performance conditions.	Ρ		
	 a) Flaming outside the initiating BESS unit is not observed; 	No flaming observed	Р		
	b) Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit do not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8;	Max. Temperature during the test: 38.4 °C Criteria Temperature: 181 °C	Ρ		
	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) of temperature rise above ambient per 9.2.15;	Max. Temperature during the test:82.0 °C Criteria Temperature: 128.9°C	Р		
	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; and	No explosion observed	Р		
	a) The concentration of flow mobile and does not	Criteria 25% LFL: 2.06%			
	e) The concentration of flammable gas does not exceed 25% LFL in air for the smallest specified room	Specified room installation size: 86m ³	Р		
		The concentration of flammable gas: 2.05%			

--End of report--



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Attachment A: Diagrams of setup for unit level testing

Diagrams of setup for unit level testing

Figure 5. Test site setup diagram with separation distance. (Top view)



Figure 6. Thermocouple location on modules in target rack 2



Rack(Unit) 2

View direction: towards instrument wall A with reference to Figure 5



TWA22

TWA23

TWA24

152mm

TWA3

TWA2

300mm

INITIAL MODULE



TWA20

TWA21

300mm

TWA1 View direction: towards instrument wall A with reference to Figure 5

Figure 8. Vertical position of the thermocouples on the wall B



View direction: towards instrument wall B with reference to Figure 5



View direction: towards instrument wall C with reference to Figure 5

Figure 10. Heat flux sensor locations on instrument wall



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Attachment B: Module Conditioning (Charge/discharge) Profiles

Module sample was conditioned, prior to testing, through charge and discharge cycles of 2 cycles to verify that the module was functional.

Each cycle was defined as a charge to 100% SOC and allowed to rest several minutes and then discharged to an end of discharge voltage (EODV) determined by the manufacturer. Refer to 2.1 for charge and discharge profile.

The module sample was put in a climate chamber during charge and discharge. The ambient is kept at $25^{\circ}C\pm 2^{\circ}C$ and $50\%\pm 5\%$ R.H.

Figure 11. Module charge and discharge voltage/current profiles



Charge/Discharge Cycle





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Attachment C: Observations and records

Test initiation details		
Ambient conditions at the initiation of the test.:	31.9°C, 52.7% R.H.	
Sample number:	#2024080401	
Open circuit voltage before test (V):	53.5	
Weight before test (kg):	109.91 (with thermocouples)	
Open circuit voltage after test (V)	39.2	
Weight after test (kg):	109.81 (with thermocouples)	
Weight loss (kg):	0.1	

Test overview timeline				
Locations (Cell #)	Event	Time		
-	Test start	10:52		
13	Vent	11:38		
14	Vent	11:38		
13	Thermal runaway	11:38		
14	Thermal runaway	11:48		
12	Thermal runaway	11:48		
11	Thermal runaway	12:02		
15	Thermal runaway	12:15		
16	Thermal runaway	12:26		
10	Thermal runaway	12:44		
9	Thermal runaway	12:53		

Note:

1) No flying debris or explosive discharge of gases during test.

2) No sparks, electrical arcs, or other electrical events during test.

3) No flaming observed.



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Attachment D: Module and Initiating Cell(s) Temperature Profiles During Testing

Figure 12. Temperature of cell #12~#14













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Figure 14. Temperature of cell #1~#8



Note: Thermocouple T14, T18 was damaged during the test.







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Figure 16. Temperature of module surface



Figure 17. Surface temperatures of modules in target unit 2 (refer to Figure 6)



Module Surface Temperature in Target Unit 2

Maximum Temperatures in Target Units			
UL 9540A performance criteria, Cell Surface Temperature at Gas venting: 181°C			
Location	Maximum Module Temperature (°C)		
Surface temperatures of modules in target unit 2	M2-1	38.4	



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Figure 19. Temperature on instrument wall B





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Maximum Temperatures on Instrument Wall					
Ambient Temperature: 31.9	Ambient Temperature: 31.9 °C				
UL 9540A performance criteria, Ambient + 97°C: 128.9 °C					
Location Maximum Wall Temperature (°C)					
Wall A TWA20		82.0			
Wall B TWB23		39.2			
Wall C TWC12 39.8					





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Figure 21. Module Voltage





Attachment E: Convective Heat Release Rate, Chemical Heat Release Rate, Smoke Release Rate and Heat Flux

Smoke and heat release rate				
Smalka Palaasa Pata (SPP)	Maximum SRR(m ² /s)	31.0		
SHOKE RELEASE RALE (SRR)	Total Smoke Released(m ²)	113.9		
	Peak Chemical HRR(kW)	No flaming observed		
Heat Release Rate (HRR)	Peak Convective HRR(kW)	No flaming observed		
	Total Heat Release(MJ)	No flaming observed		

Figure 22. SRR curve









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Figure 24. Heat Flux



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Attachment F: Flammable gas generation and composition data

Measurement method	Gas compound	Gas type	Pre-Flaming(L)	Flaming(L)	
Solid-state Hydrogen Sensor	Hydrogen	Hydrogen	875.9	No flaming	
Fourier-Transform	Carbon Monoxide	Carbon Containing	632.8	No flaming	
Spectrometer	Carbon Dioxide	Carbon Containing	980.3	No flaming	
Flame ionization detection	Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	259.2	No flaming	
Note: The collection time is from 10:48 to 16:12.					

Total volume of gas (L) Measurement **Gas components** Gas type method **Pre-Flaming Post-Flaming** (L) (L) Methane CH_4 182.1 No flaming Fourier-Transform Hydrocarbon Ethylene C_2H_4 140.4 No flaming infrared species Spectrometer Propane C_3H_8 33.5 No flaming Note: The collection time is from 10:48 to 16:12.

Figure 25. Hydrogen concentration





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Figure 26. CO, CO₂ concentration



Figure 27. Total Hydrocarbons concentration





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Figure 28. Hydrocarbon species



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Attachment G: Sample Photos and Test Photos

Figure 29. Sample before test





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Figure 30. Test setup



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Figure 31. Smoke release during test





Figure 32. Photos after test

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Attachment H: List of Test and Measurement Instruments

No.	Equipment	Model	Rating	Inventory no.	Last Cal. date
1	Ambient temperature and humidity	HWP01-10S	-30°C~50°C, 20%RH~100%RH	12005577	2025.2.2
2	Data acquisition equipment	DAQ970A	3-slot cardcage with 6½ digit (22 bit) internal DMM 0.004%, accuracy 0.06% Vac	TY202000013 8	2025.2.2
3	Data acquisition equipment	TP700	Measuring range-60 °C to 1372 °C Measurement accuracy ± (0.05% rdg.+0.5°C) Display resolution0.01°C	TY221100071 6-2	2025.2.2
4	Data acquisition equipment	TP700	Measuring range-60 °C to 1372 °C Measurement accuracy ± (0.05% rdg.+0.5°C) Display resolution0.01°C	TY202000021 7	2025.2.2
5	Electronic scale	CHAOOUC 1	0-500KG	65960494169	2025.2.2
6	Paramagnetic oxygen analyser	SERVOME X4100	O2: paramagnetic sensor, range 0-25%, accuracy 0.02%, response time T90 < 7S	ZY202000001 8-1	2025.2.6
7	Velocity probe	2671-25L-D- 11-G2-E-N	4-20mA output, range 0- 250pa, accuracy ± 1% F.S	ZY202000001 8-2	2025.2.6
8	Photo detector	PDA36A2	Thorlabs optical receiver, wavelength range (350-1000) mm, gain adjustable, voltage output (0-10) V, instability < 0.1%	ZY202000001 8-3	2025.2.2
9	Fourier-Transform Infrared Spectrometer	atmosFIR	Spectral scanning range: 485 - 7500cm-1; Spectral repeatability: < 0.1cm-1	ZY20200000 18-5	2025.3.9



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10	Non-dispersive infrared carbon dioxide and carbon monoxide sensor	SERVOME X4100	CO2: infrared sensor, measuring range 0-10%, accuracy 1% F.S, response time T90 < 7S Co: infrared sensor, measuring range 0-1%, accuracy 1% F.S, response time T90 < 8s	ZY202000001 8-4	2025.2.6
11	Palladium-nickel thin-film solid state sensor	MODEL 2000	Range: 0-2000ppm, temperature less than 100 C, -90~110kPa	ZY202100021 0	2025.2.2
12	Flame ionization detector	3010	Accuracy: 2.0%	19937	2025.3.9
13	Heat flux measurement equipment	MW88- JTC08C	0 ~ ± 99999 w / m2, - 250 ~ 980 °C, accuracy 5%, response time less than 0.1s,	ZY202000001 0	2025.2.2
14	Thermopile	RS-WD- HW-1	0-200 °C, 4-20mA, response speed < 0.15s	28348141942	2025.2.2