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

Project Number.....:	**4790294261**
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UL Report Office .....:	**UL(Changzhou) Quality Technical Service Co., LTD**
Applicant's name.....:	**Contemporary Amperex Technology Co Limited**
Address .....:	**No.2 Xingang Road Zhangwan Town, Jiaocheng District, Ningde, FuJian 352100 China**
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 .....:	N/A

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General disclaimer:

The test results presented in this report relate only to the sample tested in the test configuration noted on the list of the attachments.

UL LLC did not select the sample(s), determine whether the sample(s) was representative of production samples, witness the production of the test sample(s), nor were we provided with information relative to the formulation or identification of component materials used in the test sample(s).

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Cell level information	
Cells in Module:	
•Manufacturer Name	Contemporary Amperex Technology Co Limited
•Part Number	CB310, CB2W0
•Chemistry	Lithium iron phosphate
•Format	Prismatic
Ratings (Vdc, Ah) :	3.2V, 280Ah
Cell certified? :	Yes
Standard the cell was certified to:	UL1973
Organization that certified the cell:	UL (MH62898)
Average cell surface temperature at gas venting, °C:	168.2
Average cell surface temperature at thermal runaway, °C:	239.6
Gas Volume:	221.3L
Lower flammability limit (LFL), % volume in air at the ambient temperature:	7.85
Lower flammability limits (LFL), % volume in air at the venting temperature:	6.47
Burning velocity (S_u) cm/s:	64
Maximum pressure (P_{max}) psig:	103

Cell level Gas Composition:

Gas		Measured %
Carbon Monoxide	**CO**	11.086
Carbon Dioxide	**CO_2**	33.290
Hydrogen	**H_2**	35.698
Methane	**CH_4**	10.075
Acetylene	**C_2H_2**	0.164
Ethylene	**C_2H_4**	5.259
Ethane	**C_2H_6**	1.089
Propadiene (Allene)	**C_3H_4**	0.000
Propyne	**C_3H_4**	0.000
Propene	**C_3H_6**	0.571
Propane	**C_3H_8**	0.232
-	**C4 (Total)**	0.382
-	**C5 (Total)**	0.091
-	**C6 (Total)**	0.060
-	**C7 (Total)**	0.005
-	**C8 (Total)**	0.000
Benzene	**C_6H_6**	0.023
Toluene	**C_7H_8**	0.002

Dimethyl Carbonate	**$C_3H_6O_3$**	1.879
Ethyl Methyl Carbonate	**$C_4H_8O_3$**	0.091
Diethyl Carbonate	**$C_5H_{10}O_3$**	0.000
Total	-	**100**

Module level Information

Model No ..... :	M52280-E, M52280-P
Ratings (Vdc, Ah) ..... :	166.4V 280Ah
Module dimensions (X x Y x Z (mm))..... :	810±5mm*1155±5mm*243.4±5mm
Module cell configuration (xS/yP) .....:	52S/1P
Module weight (kgs)..... :	330±5kg
Module enclosure material..... :	Top enclosure is made of plastic bottom enclosure is made of aluminium alloy
Was the module certified? .....:	No
Standard the module was certified to .....:	N/A
Organization that certified test item .....:	N/A
Number of initiating cells failed to achieve propagation.	1
Thermal Runaway Propagation:	Initiating cell went into thermal runaway and propagated to two adjacent cells
External Flaming:	No external flaming occurred.
Location(s) of Flame Venting:	No flaming occurred
Flying Debris:	No flying debris observed.
Re-ignitions:	No further re-ignitions were observed during post test observation.
Test Maximum Smoke Release Rate (m^2/s)	4.9
Test Total Smoke Released: (m^2)	376.7
Test Peak Chemical Heat Release Rate: (kW):	No flaming observed

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

Gas Compound	Gas Type	Pre-Flaming (L)	Flaming (L)	Minimum detectable flow rate (LPM)
Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	150	No flaming	0.52
Carbon Monoxide	Carbon Containing	53	No flaming	0.68
Carbon Dioxide	Carbon Containing	143	No flaming	2.98
Hydrogen	Hydrogen	189	No flaming	8.79

Unit level Information	
Model No.:	Ox52280-E, Ox52280-P
Ratings (Vdc, Ah) .....:	1331.2Vdc, 280Ah
BESS dimensions (W x D x H (mm)).....:	1300(W)x1300(D)x2280(H)
BESS module configuration	8S/1P
Number of modules in BESS	8
Module cell configuration (xS/yP) .....:	52S/1P
Number of cells in module.:	52
BESS weight (kgs)..... :	3650
BESS enclosure material..... :	Galvanized steel
BESS Intended Installation: **Non Residential:** outdoor ground mounted, indoor floor mounted, outdoor wall mounted, indoor wall mounted, roof top, open garage **Residential:** Outdoor ground mounted, indoor floor mounted, outdoor wall mounted, indoor wall mounted	Non Residential: outdoor ground mounted, indoor floor mounted
Residential Indoor Use: Smallest volume room installations specified.	N/A
Original Equipment Manufacturer (OEM):	Contemporary Amperex Technology Co., Limited
Branding Manufacturer (if not OEM):	N/A
Was the unit certified? .....:	Yes
Standard the unit was certified to .....:	UL 1973
Organization that certified the unit .....:	TUV SUD (No.U14 004951 0008 Rev.00/No.U14 004951 0008 Rev.01)
Cell failure test method performed (summary of method and test clause): ☒ External heating using thin film with 4°C to 7°C thermal ramp. ☐ Nail Penetration ☐ Overcharge ☐ External short circuit (***X*** Ω *external resistance*) ☐ Others	
Description of method used to fail cells if other than external thin film heater with thermal ramp, : N/A	
Description of components employed within the BESS unit that serve to suppress propagation (fire protection features) Liquid coolant and aerosol system were employed in the container; however, the pipes for the coolant were empty without the coolant and both coolant system and the aerosol system were not powered during the test at the request of the applicant (CONTEMPORARY AMPEREX TECHNOLOGY CO., LIMITED) Therefore, these systems were neither used nor evaluated in the test; the detailed information on these systems are described in the critical components.	
Deviation from the module level test	

N/A	
Number of initiating cell(s)	1
Thermal Runaway Propagation:	Initiating cell went into thermal runaway and propagated to one adjacent cell.
External Flaming from BESS:	No external flaming occurred
Location(s) of Flame Venting:	No Flaming occurred
Maximum Target BESS Temperature, °C	30
Maximum Wall Surface Temperature[1], °C	29
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	0.23
Maximum Heat Flux on Target Modules, kW/m^2	0
Maximum Heat Flux of Egress Path, kW/m^2	0
Flying Debris:	No flying debris observed
Re-ignitions:	No further re-ignitions were observed during post test observation

Gas Analysis:

☒ Flame ionization detection (FID)

☒ Non-Dispersive Infrared Spectrometer (NDIR)

☐ Fourier-Transform infrared Spectrometer

☒ Hydrogen Sensor (palladium-nickel, thin-film solid state sensor)

☒ White light source with photo detector (smoke release rate)

Summary of Unit level test Gas Analysis Data:

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

Gas Compound	Gas Type	Pre-Flaming (L)	Flaming (L)	Minimum detectable flow rate (LPM)
Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	284	No flaming	0.65
Carbon Monoxide	Carbon Containing	0.23	No flaming	0.26
Carbon Dioxide	Carbon Containing	7.51	No flaming	0.85
Hydrogen	Hydrogen	121.8	No flaming	6.44

Summary of BESS Unit Test Results

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

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

[X] Flaming outside the initiating BESS unit was not observed; **[X]** Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit did not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8; **[X]** For BESS units intended for installation in locations with combustible constructions, surface temperature measurements on wall surfaces did not exceed 97°C (175°F) of temperature rise above ambient per 9.2.15; **[X]** Explosion hazards were not observed, including deflagration, detonation or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases; and **[X]** Heat flux in the center of the accessible means of egress did not exceed 1.3 kW/m^2.
Performance Criteria in accordance with Table 9.1 for Outdoor Ground Mounted non-residential unit **[X]** Separation distances to exposures was farther than the greatest flame extension observed during test. **[X]** Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit did not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8; **[X]** For BESS units intended for installation in locations with combustible constructions, surface temperature measurements on wall surfaces did not exceed 97°C (175°F) of temperature rise above ambient per 9.2.15; **[X]** Explosion hazards were not observed, including deflagration, detonation or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases; and **[X]** Heat flux in the center of the accessible means of egress did not exceed 1.3 kW/m^2.
Necessity for an Installation level test
[ ] The performance criteria of the unit level test as indicated in Table 9.1 of UL 9540A 4th edition has not been met, therefore an installation level testing in accordance with UL 9540A will need to be conducted on the representative the installation with this unit installed. **[X]** The performance criteria of the unit level tests as indicated in Table 9.1 of UL 9540A 4th edition has been met, therefore an installation level testing in accordance with UL 9540A need not be conducted.
Testing Laboratory Information
Testing Laboratory and testing location(s):

Testing Laboratory:	Beijing Building Materials Testing Academy	
Testing location/ address ..... :	#17 Raxin Road, Doudian Town, Fangshan district, Beijing 102402, CN	
Tested by (name, signature) ..... :	5.1.2.e 5.1.2.e	
Witnessed by (for 3rd Party Lab Test Location) (name, signature) ..... :	5.1.2.e	5.1.2.e
Project Handler (name, signature)..... :	5.1.2.e	5.1.2.e
Reviewer (name, signature) ……..:	5.1.2.e	5.1.2.e