

Testing Laboratory for EX- protection

TÜV Rheinland (Shanghai) Co., Ltd.



Report No: A1624010.001

页码


1 of 20

Applicant: Sungrow Power Supply Co., Ltd.
Address: No.1699 Xiyou Rd.,New & High Technology Industrial Development Zone,
Hefei, Anhui, China

Test item: ST200CS ESS explosion venting test

Reference: ST200CS explosion simulation report, No. CN24S8HG 001
Test date: 2023-12-18

Test lab: TÜV Rheinland (Shanghai) Co., Ltd.
Address: TÜV Building III, No.177, Lane 777, West Guangzhong Road, Jing'an
District, Shanghai, China



23.02.2024

28.02.2024

Statement:

1. The test results provided in this commissioned test report are only valid for the sample(s) tested under the test configuration indicated in the report.
2. TÜV Rheinland is not involved in the selection of samples, determining whether the samples represent production samples, witnessing the production of test samples.
3. This report may not be reproduced.

1 Information of test sample

1.1 Battery

Item	Parameter of cell	Parameter of module
Manufacture	CATL	Sungrow
Type	Lithium ion battery	Lithium ion battery pack
Model	CB310, CB2W0	64S1P
Capacity	280Ah	229.37kWh
Rated voltage	DC 3.2V	DC 934.4V

Table 1 Parameter of battery and battery pack

Item	Parameter
Model No.	CB310, CB2W0
Rating (Vdc, Ah)	3.2Vdc, 280Ah
Test standard	UL 1973
Average Vent Temperature, °C	168.2
Average Onset of Thermal Runaway Temperature, °C	239.6
Gas volume	221.3L
Lower flammability level (LFL), % volume in air at the ambient temperature	7.85
Lower flammability level (LFL), % volume in air at the venting temperature	6.47
Burning velocity (Su), cm/s	64
Maximum pressure (Pmax), psig	103

Table 2 Battery thermal runaway parameters (UL9540A report No: 4789764715)

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 ₂ H ₂	0.164
Ethylene	C ₂ H ₄	5.259
Ethane	C ₂ H ₆	1.089
Propadiene (Allene)	C ₃ H ₄	0.000
Propyne	C ₃ H ₄	0.000
Propene	C ₃ H ₆	0.571
Propane	C ₃ H 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 ₆ H ₆	0.023
Toluene	C ₇ H ₈	0.002
Dimethyl Carbonate	C ₃ H ₆ O ₃	1.879
Ethyl Methyl Carbonate	C ₄ H ₈ O ₃	0.091
Diethyl Carbonate	C ₅ H ₁₀ O ₃	0.000
Total	-	100

Table 3 Gas composition (UL9540A report No: 4789764715)



Figure1 Batterys used in tests



Figure2 Battery packs used in tests

1.2 储能柜

Parameter—ST200CS



Product Name	ST200CS
Battery pack	64S1P Liquid cooling pack
Quantity	4
Capacity	229.37kWh
Voltage range	691.2~934.4V
Output rating	110kW
Rated network voltage	400V
Rated network frequency	50Hz
Maximum efficiency of system	≥90%
Auxiliary power supply	Self-powered (standard) / External power supply (Optional)
Grade of corrosion prevention	C3 (Standard) C5 (Optional)
Protection grade	IP55
Operating humidity	0 ~ 100%
Ambient temperature	-30 to 50°C (power reduction if higher than 45°C)
Maximum working altitude	3000m
Size	1150*2450*1610mm(width * height * depth)
Weight	≤3.1T
Liquid cooling unit	2.5kW refrigerating capacity
Fire safety measures	Standard: smoke detector, heat detector, gas detector, alarm, FK5112 gas extinction, water extinction Optional: aerosol
Transportation	Land: Track Sea: Container(tall)
Cable entry	From bottom or backside (optional)

Table4 Parameter of ST200CS

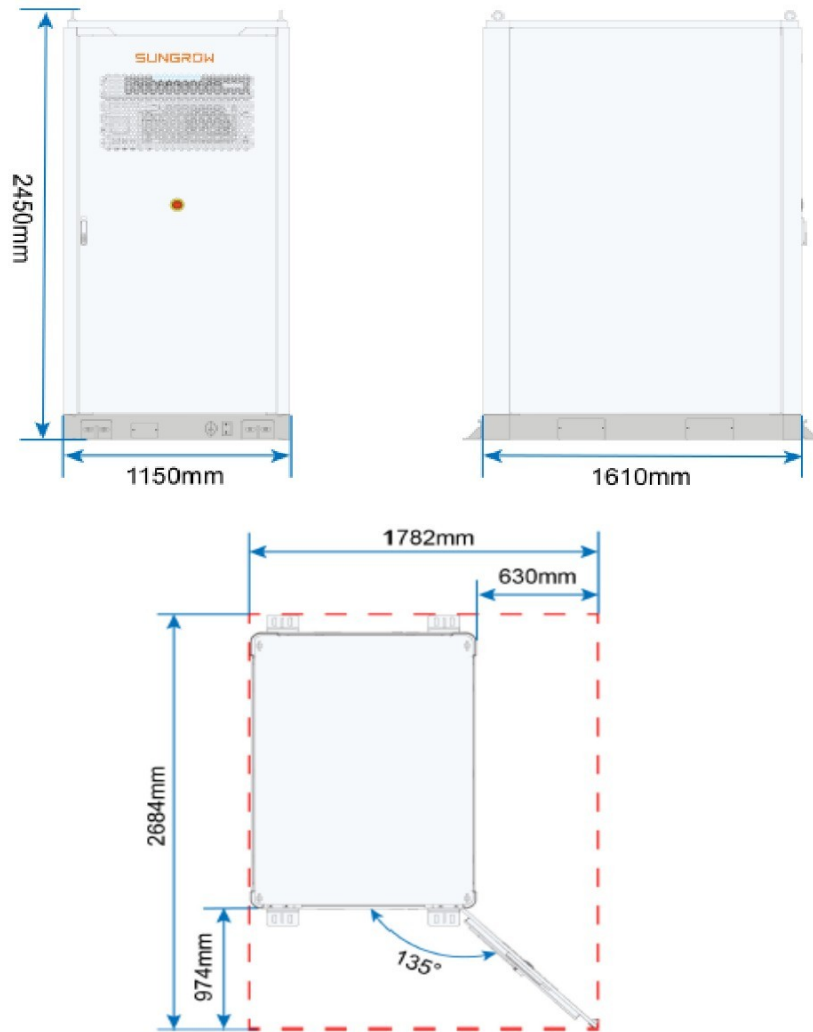


Figure3 Outline dimension

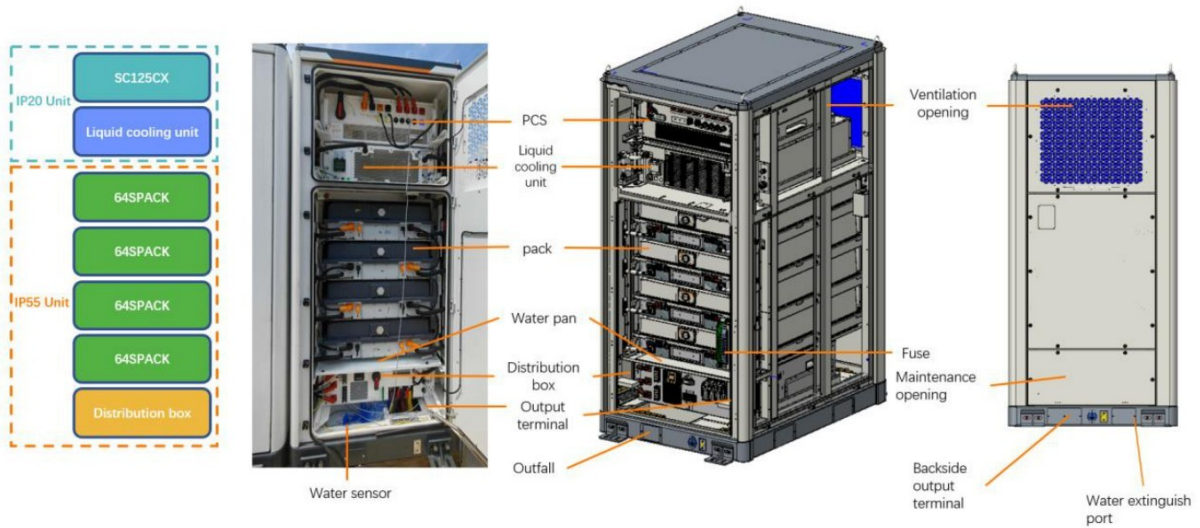


Figure4 Interior structure



Figure5 Test sample



Figure6 Test sample

1.3 Venting panel

Manufacture	Avic Chengdu Kaitian Electronics Co., LTD.
Model	PFTA735×545-0.01-22
Static activation pressure	0.01 MPa±20% (22°C)
Outline diameter	805*615*46mm
Geometric vent area	735*545mm
Venting efficiency	Unknow
Specific mass	19.75 kg/m ²
Gas explosion constant (K _{g,max})	Unknow
Maximum reduced explosion pressure(p _{red,max})	Unknow
Protection grade	IP55

Table5 Parameter of venting panel



Figure7 Venting panel



Figure8 Venting panel used in test

2 Test condition

2.1 Energy storage cabinet

The energy storage cabinet is filled with 4 battery packs, there's 1 real battery cell is installed in the center of 3rd battery pack (bottom to top), and remaining batteries in this pack and other packed are empty battery shells with same size as the real one.

Battery charging preparation:

- Standing at 25°C for 5 hours;
- Discharge at constant power until battery achieve discharge termination voltage, standing 30 mins;
- Charge at constant power until battery achieve charging termination voltage, standing 30 mins;
- Repeat 2.2 and 2.3 charging and discharging processes again
- Standing 8 hours at least



Figure9 The pack with real battery



Figure10 The pack installation in test

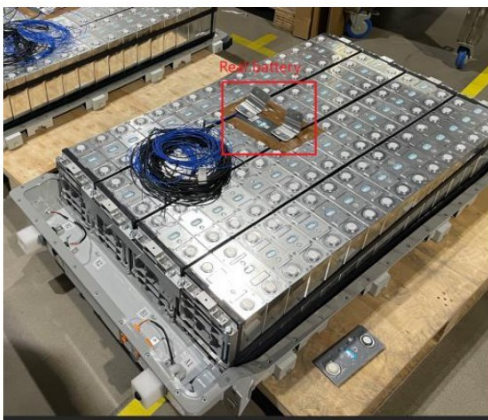


Figure11 Real battery and empty shells



Figure12 Charged and encapsulated battery pack

2.2 Thermal runaway triggering

- Object of thermal runaway: The real battery of 3rd pack

- Triggering method: Activate the heating plate which is fixed on main surface of battery, until complete heat runaway.
- Start point signs of thermal runaway: anyone of below items
 - a) The voltage of battery lower than 3.3V
 - b) The voice of battery vent opening
 - c) Monitoring of internal smoke via camera
 - d) Monitoring of hydrogen concentration exceed 0.5% via gas detector
- Complete point signs of thermal runaway
 - a) The voltage of battery lower than 0.5V
 - b) The value of gas detector decreasing after peak concentration

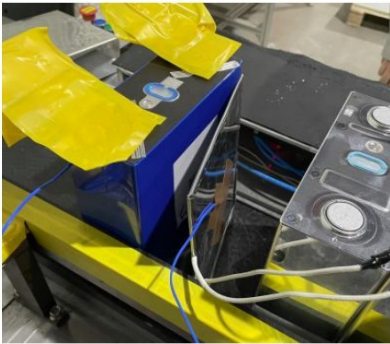


Figure13 Heating plate



Figure14 Sensors for monitoring

2.3 Data acquisition system

Equipment	Model	Series No.	pcs	Function	Calibration certificate
Oscilloscope	HDO4104A	LCRY3506N06166 LCRY3520N56362	2	Pressure data acquisition	35205636202132023123613, SN: LCRY3520N56362 35205640602272023151527, SN: LCRY3520N56406
Charge amplifier	YE5853	1390958 2380957	2	Amplification of pressure signals	J202310111715-0002, SN: 1390958 J202310111715-01-0001, SN: 2380957
Thermocouple	WRNK-191, Type-K	N/A	7	Monitoring of battery runaway state	No calibration requirement
Thermocouple data acquisition	34972A	MY59903734	1	Recording thermocouple data and battery voltage data	202311054
Mini camera	4Gmini	N/A	1	Monitoring smoke release	No calibration requirement as no measurement function
Igniter	Self-made	N/A	1	Ignite the explosive atmosphere	No calibration requirement as no measurement function
Pressure sensor	CY-YD-205	745204 745206	5	Recording pressure on the inner surface of the cabinet during explosion	J202310201630-0001, SN: 745206 J202310201630-0004, SN: 745213 J202310201630-0005, SN: 745204 J202310201630-0008, SN: 745212 J202310201630-0009, SN: 745209
Heating plate	195X160, 220V, 1200W	N/A	1	Trigger battery thermal runaway	No calibration requirement as no measurement function
Pressure field sensor	CY-YD-202	035633 035654 035646	3	Monitoring the effects of external pressure	GFJGJL1001231009818, SN: 035633 GFJGJL1001231009820, SN: 035654 GFJGJL1001231009821, SN: 035646

Hydrogen concentration detector	JFQ-1150E 0~0.8 mol/mol 0~0.4 mol/mol	E2309160 E2208185	2	Monitoring hydrogen concentration of specific point inside cabinet	2310-Y-001-03, SN: E2309160 2310-Y-001-02, SN: E2208185
Fluke infrared camera	Ti480U 348C+	63170004 0402001718	1	Monitoring temperature influence of explosion	CE23AA077260001, SN: 04032001718
Dual cylinder infrared camera	DS-2TD2637T-10/P	J68137417 J73461304	2	Combined normal camera and infrared camera	No calibration requirement as no measurement function
Normal camera	DS-IPC-1314HV3-LT	AC8908374 AC8908397 AC8908381 AC8908383	4	General video records	No calibration requirement as no measurement function
High-speed camera	X150C	62501626007 62501626051	2	Monitoring open process of venting panel and doors	No calibration requirement as no measurement function
Tape	50m	N/A	1	Conforming device locations	CD2023B-017985
Dummy and clothes	1.8m tall plastic dummy	N/A	6	Visualize effects of temperature and pressure on outside terms during explosion	No calibration requirement as no measurement function

Table6 Devices list of data acquisition system



Figure15 Pressure field sensors and dummies



Figure16 Pressure sensor at door side



Figure17 Pressure sensors of back-plate side



Figure18 Sampling hose of gas detectors



Figure19 Video data acquisition equipment



Figure20 Sampling hose and cables

2.4 Ignition of explosive atmosphere

- Ignition measure: Pull arc discharge, 220V
- Ignition location: The igniter is arranged in the middle of top space and near door side
- Ignition time: After battery completely runaway or decide on site artificially



Figure21 The location the igniter

2.6 On-site safety measures

- The test samples are enclosed by explosion-proof plates
- The persons in charge of data acquisition are work in the explosion-proof room, and the rest persons withdraw 100m away
- There're fire engines on standby nearby

3 Test date and environment

Date: 2023-12-18

Ambient humidity: 10% RH, Ambient temperature: -3°C, Wind speed: 0.5m/s

Atmospheric pressure: 100.49kPa

4 Test process

Heating plate power-on	15:01:00
Thermal runaway start	15:18:15
Thermal runaway complete	15:19:43
Ignition	15:22:50

- The venting panel opens and the flame go upward as expected
- No damage was found to the dummy or its clothing
- The door is opened with a gap, but it's not fully opened
- The battery continued to burn for some time after explosion
- Left plate is deformed and 1 fixing bolt is removed
- Right plate is deformed and 3 fixing bolts are removed



Figure22 Gap of door after explosion



Figure23 Venting panel open as expected



Figure24 Deformation of right plate

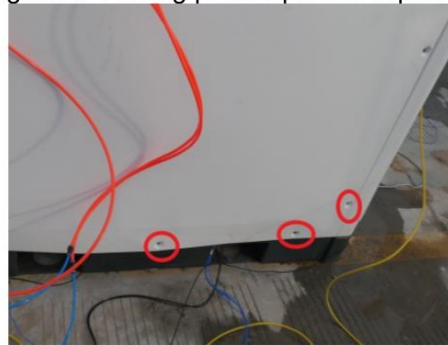


Figure25 Bolts removing of right plate



Figure26 Deformation and bolt removing of left plate

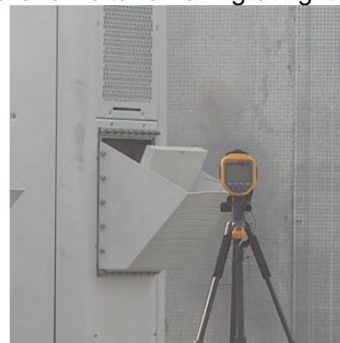


Figure27 At the moment of explosion

5 Test data recording

5.1 Temperature and voltage of battery

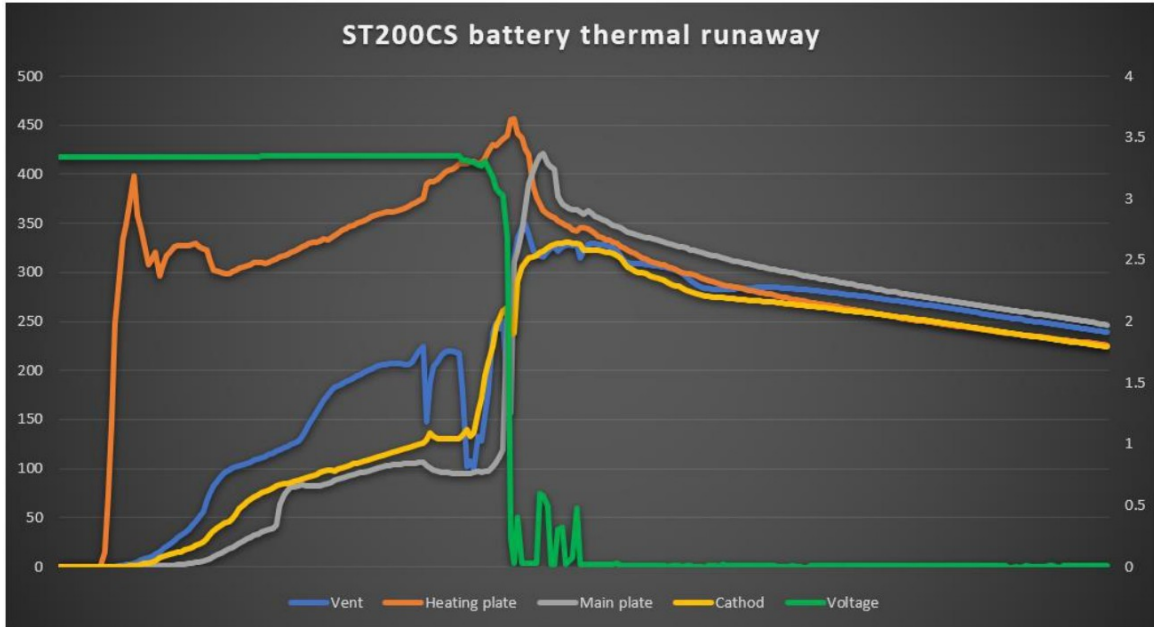


Figure28 Temperature and voltage during thermal runaway

5.2 Pressure on the enclosure of cabinet

No.	Location	Maximum value	Pressure curve
1	Door	0.093bar	
2	Left plate	0.246bar	

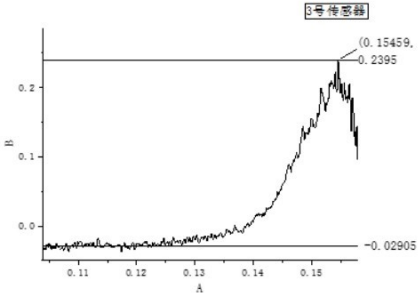
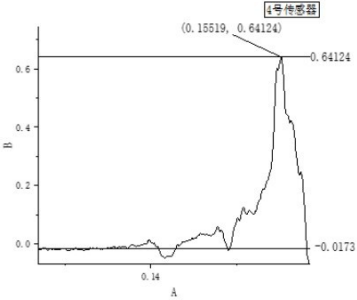
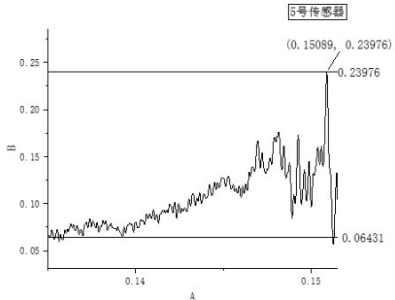
3	Back plate of distribution box	0.268bar	
4	Venting panel	0.658bar	
5	Right plate	0.304bar	



Figure29 Pressure sensor of door



Figure30 Pressure sensor of left plate



Figure31 Pressure sensor of distribution box



Figure32 Pressure sensor of venting panel



Figure33 Pressure sensor of right right plate

5.3 Field pressure out of cabinet

No field pressure data as door is not fully open.

5.4 Gas concentration

➤ 40% gas detector

The sampling point is placed at the same level as thermal runaway battery, near right plate

The maximum value detected is 4.8%

➤ 80% gas detector

The sampling point is placed at the top of battery cabin , near right plate

The maximum value detected is 5.0%

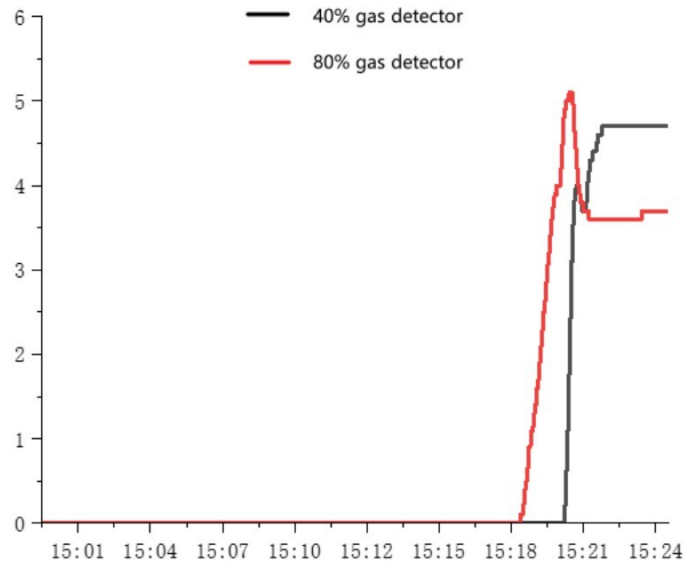


Figure34 Curve of hydrogen concentration

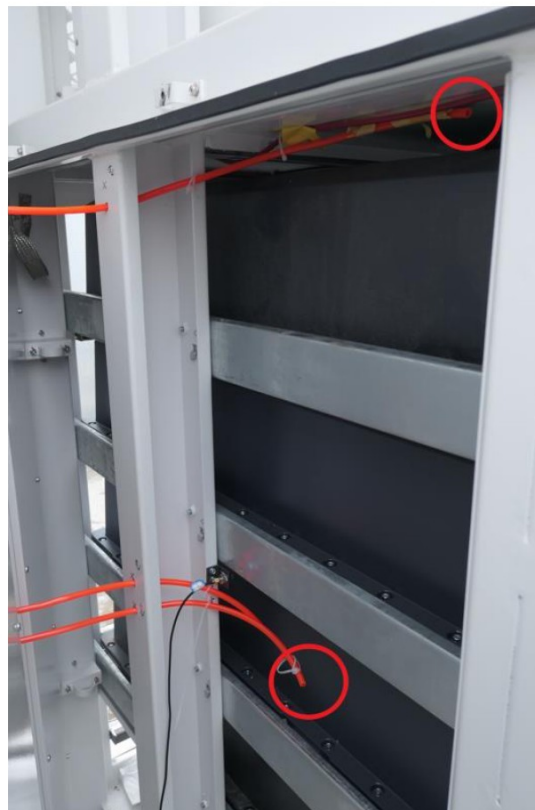


Figure35 Sampling points of detector

High speed cameras are installed at the right front and left rear of the sample, please refer videos for more detail.



Figure36 Moment of venting

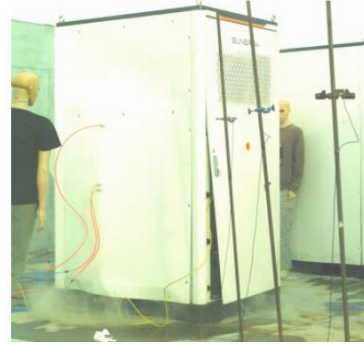


Figure37 Moment of door opening

5.6 Internal camera



Figure38 Before thermal runaway



Figure39 Smoke appears



Figure40 Smoke spread rapidly



Figure41 Visible flame appears after explosion

5.7 Dual cylinder infrared camera and infrared camera

The dual cylinder infrared cameras and infrared cameras are placed at right front and left rear of the sample, please refer videos for detail.

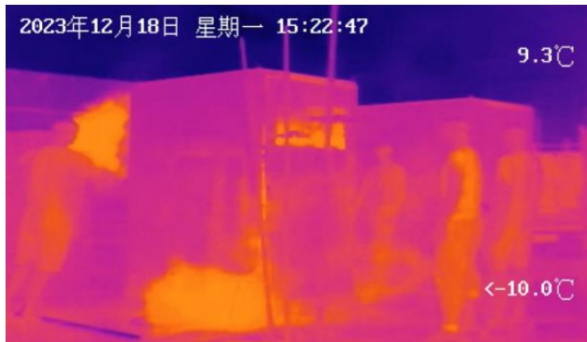


Figure42 The door under explosion

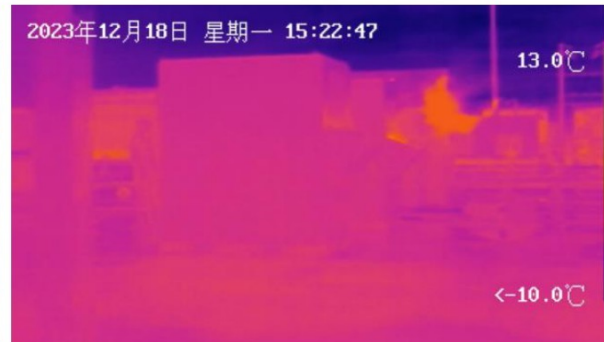


Figure43 Venting panel under explosion

5.7 Normal camera



Figure44 Angle of normal camera



Figure45 Angle of normal camera

6 Conclusion

According to the above test conditions, after the explosion inside ST200CS energy storage cabinet, the venting panel open as expected, and the overall structure of the cabinet remains intact relatively, and no significant adverse impact as explosion is found on the surrounding enviroment.