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Doc. No: CDART-2447SP	3.0V/3400F Product Testing and Analysis Report
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Product Name	Super Capacitor	Product Model	CNP3400P300 K12/K14
Product Capacity	3400F	Product Internal Resistance (DC)	≤ 0.2mΩ
Charging Limited Voltage	3.0V	Discharge Cut-off Voltage	/
Charging Current	131A（15℃） 230A（45℃）	Discharge Current	131A（15℃） 230A（45℃）
Client	/	Inspection Quantity	1 pcs
Sample Acceptance Date	2024/04/7	Inspection Date	2024/04/07
Sample Source	Randomly selected from final production qualified capacitors.		

Test Item	Standard Value	Test Result	Single Judgment	Remarks
Surge Voltage	Rated Voltage 3.00V Surge Voltage 3.15V	Rated Voltage 3.00V Surge Voltage 3.15V	Pass	
Electrostatic Capacity	Rated Capacity F （Tolerance 0%~+20%）	3428.11F~3494.79F	Pass	
DC Internal Resistance	≤0.2mΩ	0.173mΩ~0.191 mΩ	Pass	
Stored Energy	≥4.25Wh	≥4.285Wh	Pass	
Energy Density	≥8.33Wh/kg	≥8.452Wh/kg	Pass	
Maximum Power Density	≥22.05KW/kg	≥23.18KW/kg	Pass	
Voltage Retention Rate	≥80%（72h）	≥83%	Pass	
Short Circuit Current	/	5.23KA	Pass	Analog Test
Maximum Continuous Working Current	131A（15℃） 230A（45℃）	134A（15℃） 234A（45℃）	Pass	
Durability	65℃1500h	Capacity：80.4% ESR：155.29%	Pass	
High-Temperature Performance	65℃	Capacity：96.64%	Pass	
Low-Temperature Performance	-40℃	Capacity：100.45%	Pass	

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Surge Voltage

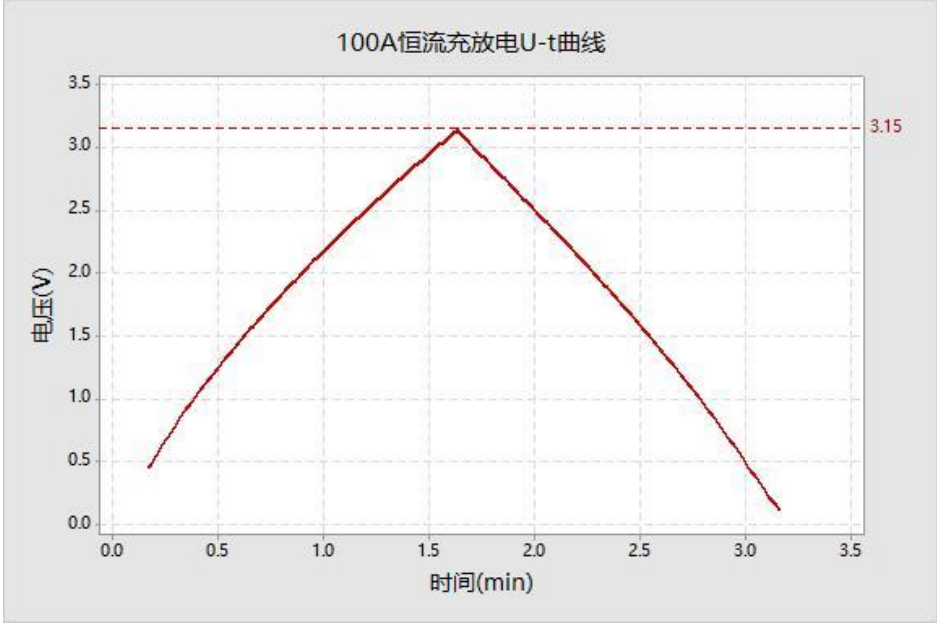
1.Testing Requirements

Surge voltage: 3.15V. Environment: 25℃, 40% RH.

2.Testing Methods

The capacitor cell is charged to the rated voltage of 3.15V with a constant current of 100A and then discharged to 0.1V with a constant current of 100A. The product exhibits no abnormalities.

3.Testing Results



4.Testing Conclusion

The 100A charge-discharge curve of the product shows that there are no abnormalities in the surge voltage of 3.15V during charging and discharging, which complies with the "Outline of Test for 3.0V 3400F Super Capacitor Cell".

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Capacitance and Internal Resistance

1.Testing Requirements

Capacitance: ≥3400F (0%~20%).

DC Internal Resistance (ESR_{DC}): ≤0.2mΩ.

AC Internal Resistance (ESR_{AC}): ≤0.12mΩ.

Environment: 25℃, 40% RH.

2.Testing Methods

(1) Capacity Test:

A) Charge the cell at 100A to 3.0V, pause for 5 seconds, record T1 and V1.

B) After 10 seconds, record T2 and V2.

C) Discharge at 100A to 1.5V, record T3（Time） and V3（Voltage）.

Repeat A)~C) five times, calculate capacitance (C) using C=100*(T3-T2)/(V3-V2). Take the fifth time as its static capacitance.

(2) DC Internal Resistance (ESR_{DC}) Test:

Discharge at 100A to 1.5V, wait 5s, measure voltage V.

Calculate resistance R=(V-V1)/100.

(3) AC Internal Resistance (ESR_{AC}) Test:

HIOKI AC impedance tester @1000Hz direct measurement.

3.Testing Results

No.	Discharge Capacity/F	ESR_{DC}/mΩ	ESR_{AC}/mΩ	No.	Discharge Capacity/F	ESR_{DC}/mΩ	ESR_{AC}/mΩ
1	3468.97	0.181	0.114	6	3443.43	0.183	0.106
2	3456.4	0.185	0.109	7	3454.13	0.178	0.112
3	3468.83	0.173	0.107	8	3439.94	0.189	0.101
4	3440.13	0.175	0.103	9	3428.11	0.178	0.112
5	3444.74	0.182	0.109	10	3494.79	0.191	0.118

4.Testing Conclusion

Static capacitance: ≥3400F (0%~20%). Direct current internal resistance (ESRDC): ≤0.2mΩ. Alternating current internal resistance (ESRAC): ≤0.12mΩ. Compliant with the "3.0V 3400F Super Capacitor Cell Test Outline".

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Energy Storage and Energy Density

1.Testing Requirements

Storage Energy: ≥4.25Wh; Energy Density: ≥8.33Wh/kg; Environment: 25°C, 40% RH

2.Testing Methods

At room temperature, the storage energy and specific energy of the individual capacitor cell are tested as follows:

a) The capacitor cell is charged to the rated voltage of 3V with a constant current of 100A.

b) Maintain the voltage for 30 minutes.

c) After the capacitor cell is allowed to stand for 5 seconds, discharge it to 0.1V with a constant current of 100A.

d) Repeat steps a) to c) three times, recording the voltage (U) and time (t) in real-time.

e) Calculate the storage energy (W) and specific energy (E_{dm}) of the capacitor cell using the formulas $W=\int I*Udt/3600$ and $E_{dm}=W/M$, respectively, and take the average of the three measurements.

3.Testing Results

No.	W（Wh）	M (kg)	E_{dm} (Wh/kg)
1	4.304	0.507	8.489
2	4.318	0.507	8.517
3	4.300	0.507	8.481
4	4.285	0.507	8.452
5	4.368	0.508	8.598
6	4.336	0.508	8.535
7	4.321	0.508	8.506
8	4.336	0.507	8.552
9	4.300	0.507	8.481
10	4.306	0.508	8.476

4.Testing Conclusion

A total of 10 samples were tested, with a minimum storage energy of 4.285Wh and a minimum energy density of 8.452Wh/kg, both meeting the requirements of the Outline for Testing Individual Super Capacitor Cells at 3.0V and 3400F.

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The Maximum Power Density

1. Testing Requirements

The maximum power density is ≥22.05 kW/kg. Environment: 25°C, 40% RH.

2. Testing Methods

a. According to the formula: $P_{dm}=\frac{0.25U_R^2}{RM}$ to calculate the maximum power density.

3. Testing Results

No.	M (kg)）	$ESR_{DC}/m\Omega$	Max. power density/kW/kg
1	0.507	0.181	24.519
2	0.507	0.185	23.988
3	0.507	0.173	25.652
4	0.507	0.175	25.359
5	0.508	0.182	24.336
6	0.508	0.183	24.203
7	0.508	0.178	24.883
8	0.507	0.189	23.481
9	0.507	0.178	24.932
10	0.508	0.191	23.189

4. Testing Conclusion

The maximum power density, calculated to be greater than 23.18 kW/kg, meets the requirements outlined in the "3.0V3400F Super Capacitor Unit Test Outline."

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Voltage Retention Ability

1. Testing Requirements

Voltage retention rate should exceed 80% of the rated voltage over 72 hours.

2. Testing Methods

（1）Procedure

Step Name (control mode)	Jump Condition	Recording Condition
On hold	Step time>10s Next step	Time>1 s
Constant current 10A	Voltage>3.0V Next step	Time>1 s
On hold	Step time>10s Next step	Time>1 s
Constant voltage limiting current 10A 3.0V	Step time＞360min Next step	Time>1 s
On hold	Step time>72s Finish	Time>1 s

（2）Step (1) involves recording the voltage every 24 hours during the execution process, until 72 hours have elapsed. The voltage decay rate, indicating self-discharge, is then calculated.

$$\text{Charge Retention Rate} = \frac{Cut-off\ voltage}{3.0} * 100\%$$

3. Testing Results

No.	U_R/V	12h/V	24h/V	72h/V	Retention Rate/%
1	3.0	2.85	2.72	2.49	83.00%
2	3.0	2.85	2.72	2.48	82.67%
3	3.0	2.85	2.72	2.49	83.00%

4. Testing Conclusion

Three samples were tested, with a minimum voltage retention rate of 83.73%, meeting the requirements of the "3.0V3400F Super Capacitor Single Cell Test Outline"

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Maximum Current and Maximum Continuous Current

1. Testing Requirements

Maximum Current≥5KA, Maximum Continuous Current: 131A (temperature rise of 15°C) / 230A (temperature rise of 45°C). Environment: 25°C 40%RH

2.Testing Methods

（1）The discharge current of the Supercapacitor from rated voltage to half of the rated voltage within 0.5 seconds. Calculation according to the formula:

I_{MAX}=0.5C*U_R(ΔT+ESR*C)

（2）$I_{MCC}=\sqrt{\Delta T/ESR * R_{Th}}$

The working current of the Supercapacitor when heat dissipation by natural convection from the casing is balanced with joule heating in stagnant air.

3. Testing Results

（1）I_{MAX}=0.5*3400*3/（1+0.2*10^{-3}*3400）=3.03 KA

（2）Maximum continuous current at a temperature rise of 15°C: $I_{MCC}=\sqrt{15/0.2 * R_{7h}^{15℃}}$=134A；

（3）Maximum continuous current at a temperature rise of 45°C: $I_{MCC}=\sqrt{45/0.2 * R_{7h}^{45℃}}$=234A；

4. Testing Conclusion

After calculation, the maximum current is 3.03 kA, and the maximum continuous current is 134A (temperature rise of 15°C) / 234A (temperature rise of 45°C), meeting the requirements of the "3.0V3400F Super Capacitor Single Cell Test Outline".

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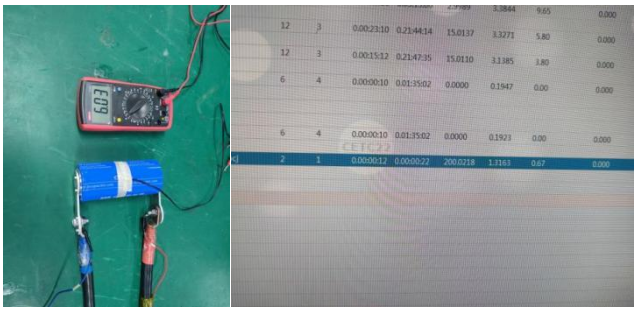
Conclusion Attached:

a. The capacitor cell is charged to the rated voltage of 3.0V with a constant current of 200A.
b. The capacitor cell is discharged to 1.5V with a constant current of 200A.
c. Repeat steps a) to b) for 6 hours. Measure the resistance value of the 10K thermistor, record data every 20 minutes, and calculate the temperature rise of the capacitor.

Measured images:



Time	Resistance Value	Temperature/℃	Time	Resistance Value	Temperature/℃
0	9.5	26	200min	5.30	40
20min	6.4	34	220min	5.24	40
40min	6.0	37	240min	5.30	40
60min	5.86	38	260min	5.31	40
80min	5.62	39	280min	5.31	40
100min	5.56	39	300min	5.27	40
120min	5.47	39	320min	5.22	40
140min	5.35	40	340min	5.31	40
160min	5.36	40	360min	5.30	40
180min	5.37	40	380min		

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Short-circuit Current

1.Testing Requirements

≥15KA. Environment: 25℃ 40%RH.

2.Testing Methods

Calculate according to the formula: $I_s=U_R/ESR$

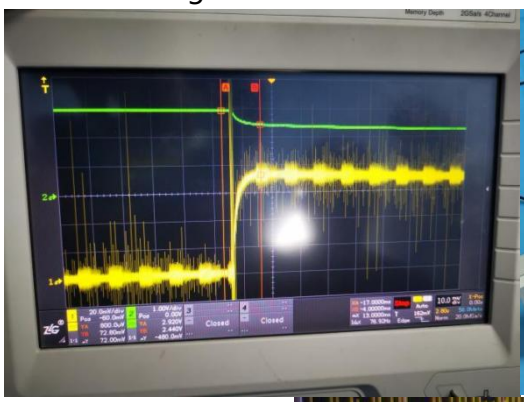
3.Testing Results

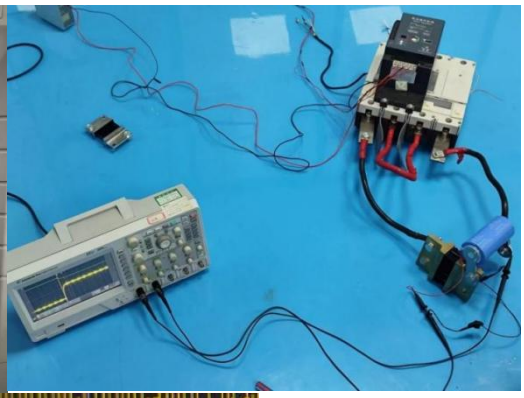
$I_s=3/0.19*10^{-3}=15.7$ KA

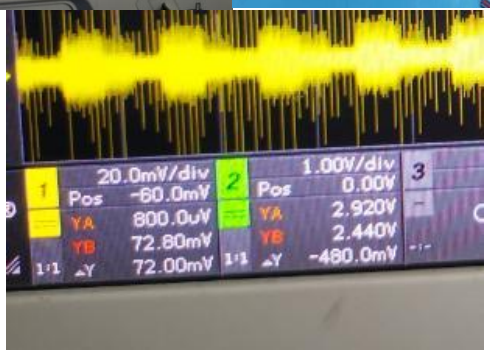
4.Testing Conclusion

After calculation, the short-circuit current is 18.75KA, meeting the requirements of the "Outline for the Test of 3.0V3400F Super Capacitor Unit".

Actual measurement: greater than 5000A.







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High Temperature Durability

1. Testing Requirements

Environment temperature 65℃, voltage 3.0V, time 1000 hours.

2. Testing Methods

Conduct a capacity impedance test according to the method for 100 hours and record once.

3. Testing Results

Time/h	Discharge Capacitance/F	rd/m0hm	Capacity Retention Rate	Internal resistance change rate	Time/h	Discharge Capacitance /F	rd/m0hm	Capacity Retention Rate	Internal resistance change rate
0	3445.162	0.1955	100.00%	100.00%	700	2830.94	0.3013	82.17%	154.12%
	3447.936	0.2001	100.08%	102.35%		2822.326	0.3174	81.92%	162.35%
	3443.118	0.2093	99.94%	107.06%		2873.28	0.3174	83.40%	162.35%
	3202.948	0.253	92.97%	129.41%	800	2810.646	0.322	81.58%	164.71%
100	3096.66	0.2691	89.88%	137.65%		2802.032	0.3174	81.33%	162.35%
	3085.126	0.2668	89.55%	136.47%		2852.402	0.322	82.79%	164.71%
	3081.184	0.2714	89.44%	138.82%	900	2792.396	0.3266	81.05%	167.06%
200	2995.336	0.2806	86.94%	143.53%		2784.512	0.3312	80.82%	169.41%
	2984.97	0.2829	86.64%	144.71%		2837.072	0.3289	82.35%	168.24%
	3019.718	0.2875	87.65%	147.06%	1000	2776.628	0.3335	80.59%	170.59%
300	2943.36	0.2898	85.43%	148.24%		2768.452	0.3312	80.36%	169.41%
	2933.286	0.2944	85.14%	150.59%		2820.72	0.3358	81.87%	171.76%
	2947.156	0.2944	85.54%	150.59%	1100	2762.174	0.3289	80.18%	168.24%
400	2901.02	0.3013	84.21%	154.12%		2753.852	0.3312	79.93%	169.41%
	2897.078	0.3082	84.09%	157.65%		2806.558	0.3312	81.46%	169.41%
	2951.098	0.3174	85.66%	162.35%	1200	2748.742	0.3243	79.79%	165.88%
500	2882.916	0.3128	83.68%	160.00%		2740.566	0.3358	79.55%	171.76%
	2872.988	0.322	83.39%	164.71%		2793.564	0.3312	81.09%	169.41%
	2920.438	0.2898	84.77%	148.24%	1300	2736.332	0.3473	79.43%	177.65%
600	2854.446	0.3013	82.85%	154.12%		2728.594	0.3243	79.20%	165.88%
	2845.54	0.3036	82.60%	155.29%		2781.154	0.3266	80.73%	167.06%
	2894.888	0.3036	84.03%	155.29%	1400	2724.36	0.3427	79.08%	175.29%
						2716.476	0.322	78.85%	164.71%
					1500	2700.058	0.3036	80.40%	155.29%

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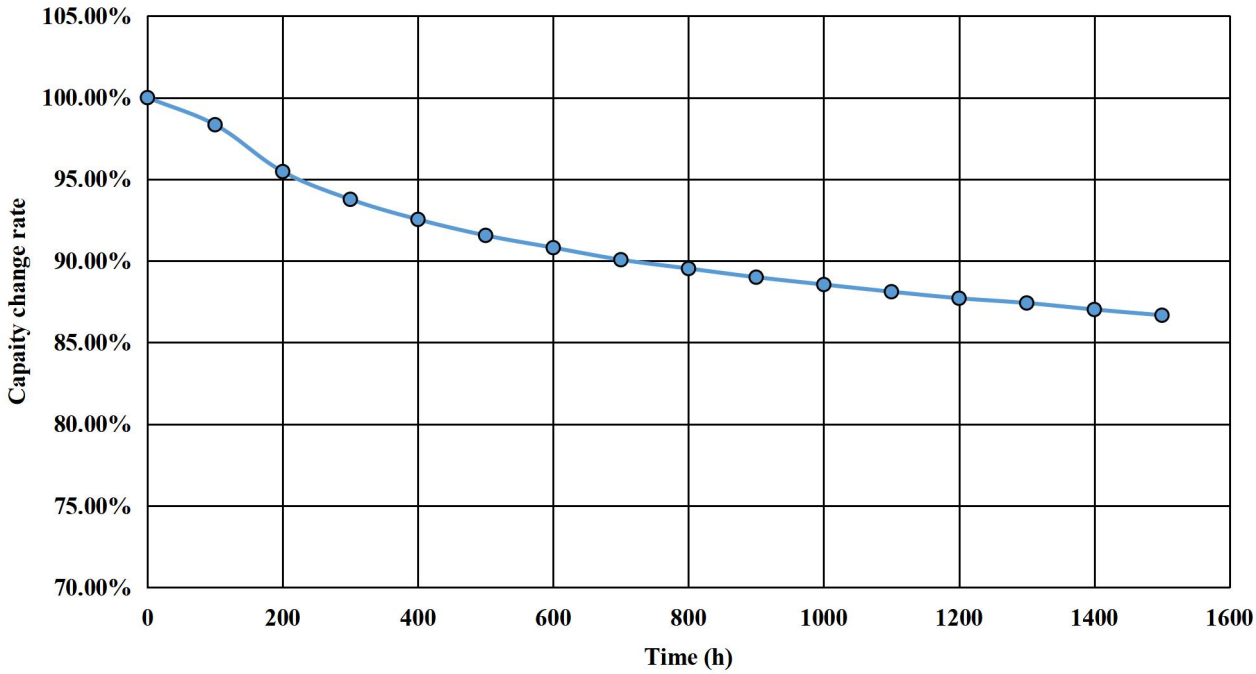

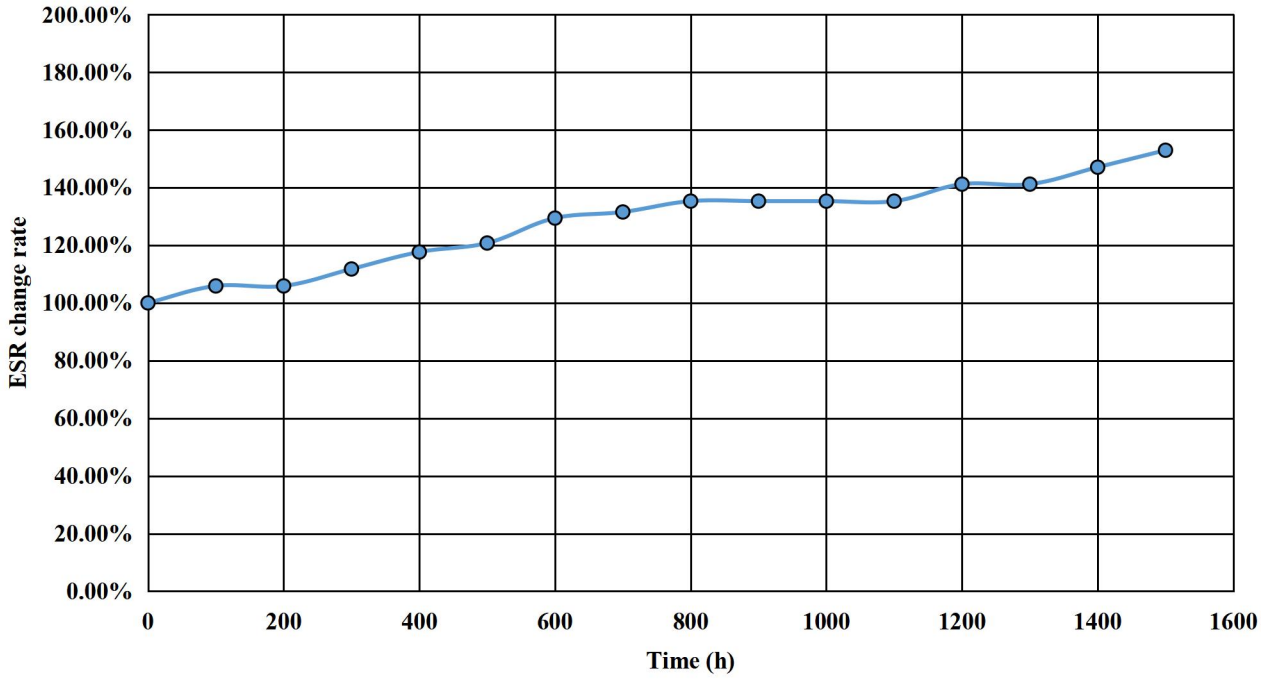

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High-temperature performance

1. Testing Requirements

During testing according to the following method, the performance of the individual meets the following requirements:
The static capacitance is greater than 80% of the initial value, and the stored energy is greater than 80% of the initial value.

2. Testing Methods

a) Set the temperature chamber temperature to 65°C.
b) Place the capacitors in the temperature chamber at this temperature for 6 hours.
c) Test the capacitors according to the methods for static capacitance and stored energy.

3. Testing Results

No.	Testing Items	Individual Identifier	Before Testing	After Testing	Capacity/%
			Capacity/F	Capacity/F	
1	High Temperature	XJG-5	3418.83	3304.25	96.64%
2	High Temperature	XJG-6	3430.13	3332.37	97.14%

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Low temperature performance

1. Testing Requirements

When tested according to the following test method, the performance of the individual cells meets the following requirements:
The static capacity is greater than 60% of the initial value, and the stored energy is greater than 50% of the initial value.

2. Testing Methods

a) Set the temperature chamber temperature to -40°C.
b) Place the capacitor in the temperature chamber at this temperature for 16 hours.
c) Test the capacitor according to the methods for static capacity and stored energy.

3. Testing Results

No.	Testing Items	Individual Identifier	Before Testing	After Testing	Capacity/%
			Capacity/F	Capacity/F	
1	Low Temperature	XJG-5	3422.05	3448.37	100.76%
2	Low Temperature	XJG-6	3450.78	3466.63	100.45%