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Results of Long Term Life Tests of Large Scale Lithium-Ion Cells

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Introduction

GYT has developed 50, 100 and 175Ah cells.
We fixed their chemical design at 1999 and did not change.

Dimensions	Satellite type (Long cycle life type)		
	Capacity	Mass	Specific energy*
H 263mm W 165mm T 50mm	Nominal 186Ah (Rated 175Ah)	4.65kg	146 Wh/kg
H 208mm W 130mm T 50mm	Nominal 110Ah (Rated 100Ah)	2.79kg	146 Wh/kg
H 123mm W 130mm T 50mm	Nominal 55Ah (Rated 50Ah)	1.50kg	136 Wh/kg

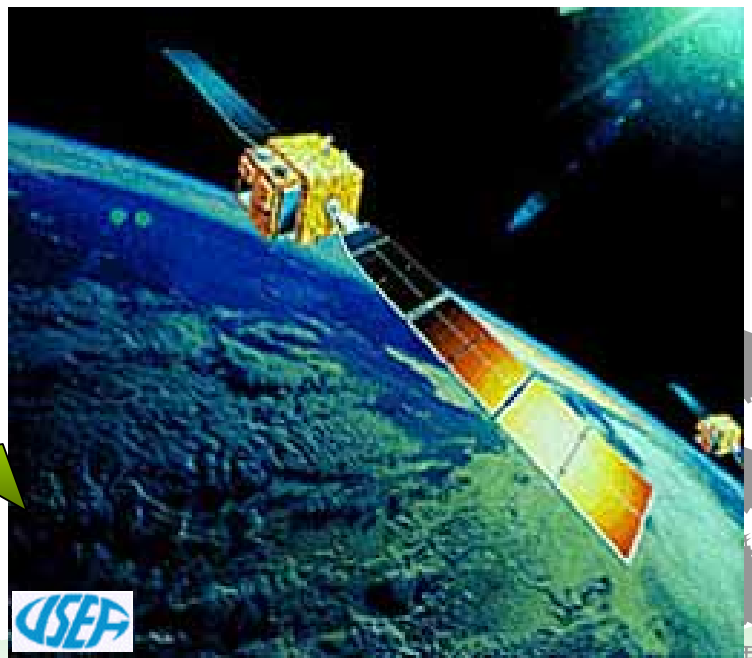
Experience in programs

Launched

SERVIS (Japanese experimental LEO satellite): Installed and launched in 2003
THAICOM4 (Very large commercial GEO satellite): Installed and launched in 2005
INSAT4 (ISRO Communication GEO satellite): Installed and launched in 2007

Near future launch

Other contracts have been made on 15 GEOs, 4 LEO programs(>50 satellites), and other space vehicle programs.



Life tests

GYT has been evaluating the cells at various conditions since May 1999.
This report shows some of long term life test results.
Key parameters: Life, Cycles, Ah, Wh, and Wh/kg

Semi-accelerated GEO (Max.80%DOD)

Test condition

Season consists of (1)and (2), which simulate eclipse season and solstice season, respectively.

1 season includes,

(1) 42variable DOD cycles (Max.DOD80%, Ave.DOD66% at 15degrees C)

(2) Storage

*1-11 season : 2weeks storage at SOC 50% at 25degrees C

(We thought the storage corresponded to 6months storage at 0degrees C.

But now, it is found that the storage corresponds to 10 months storage at 0degrees C from our storage test data.)

*12 season- : 8days storage at SOC 50% at 25degrees C

(Corresponding to 6months storage at 0degrees C)

Capacity check condition (at 15 degrees C)

Charge : 10A/3.98V (CC/CV) for 20hours

*16season- :

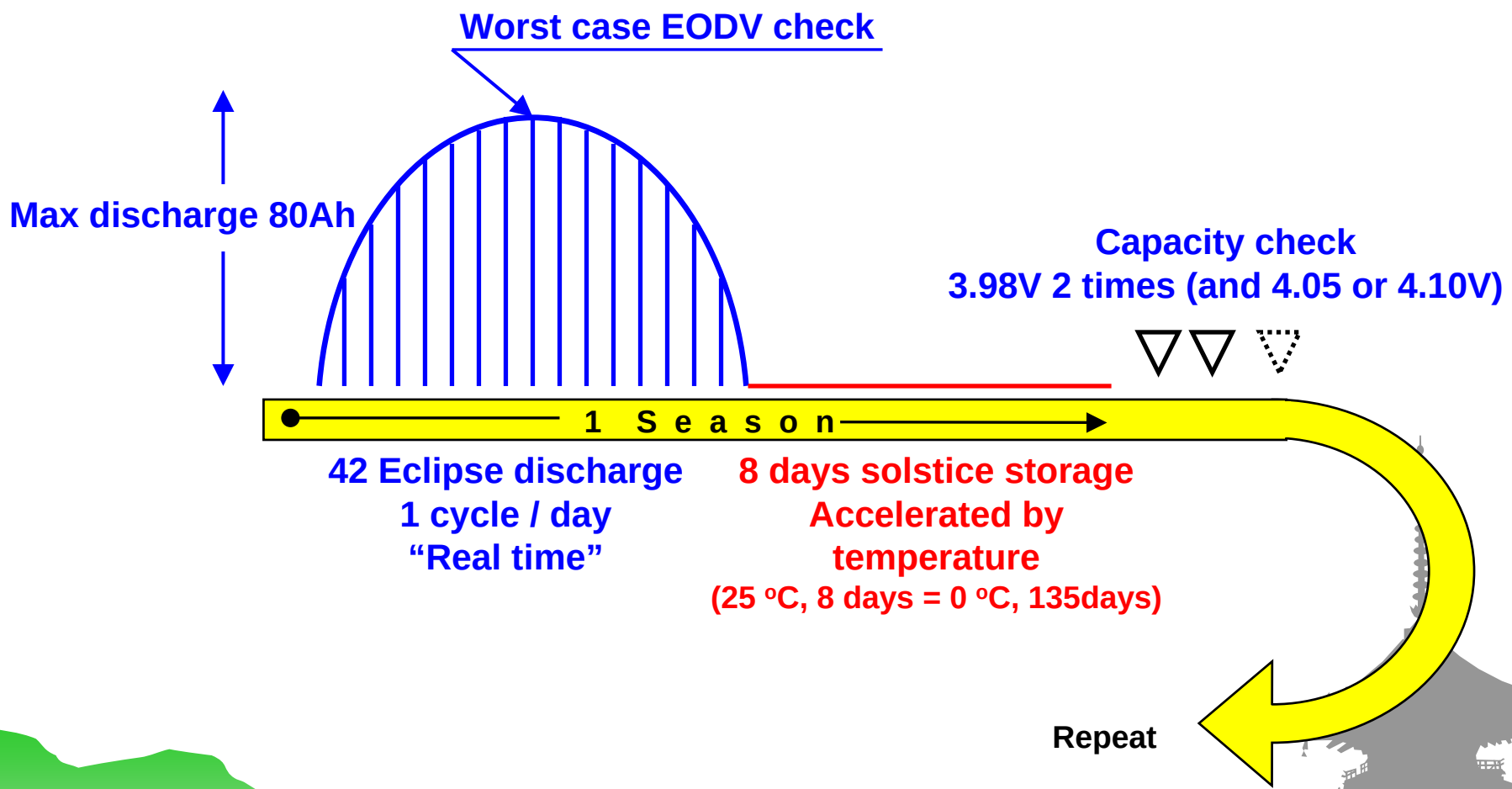
Charge : 1st cycle and 2nd cycle : 10A, 3.98V , 3rd cycle : 10A, 4.05V

*30season- :

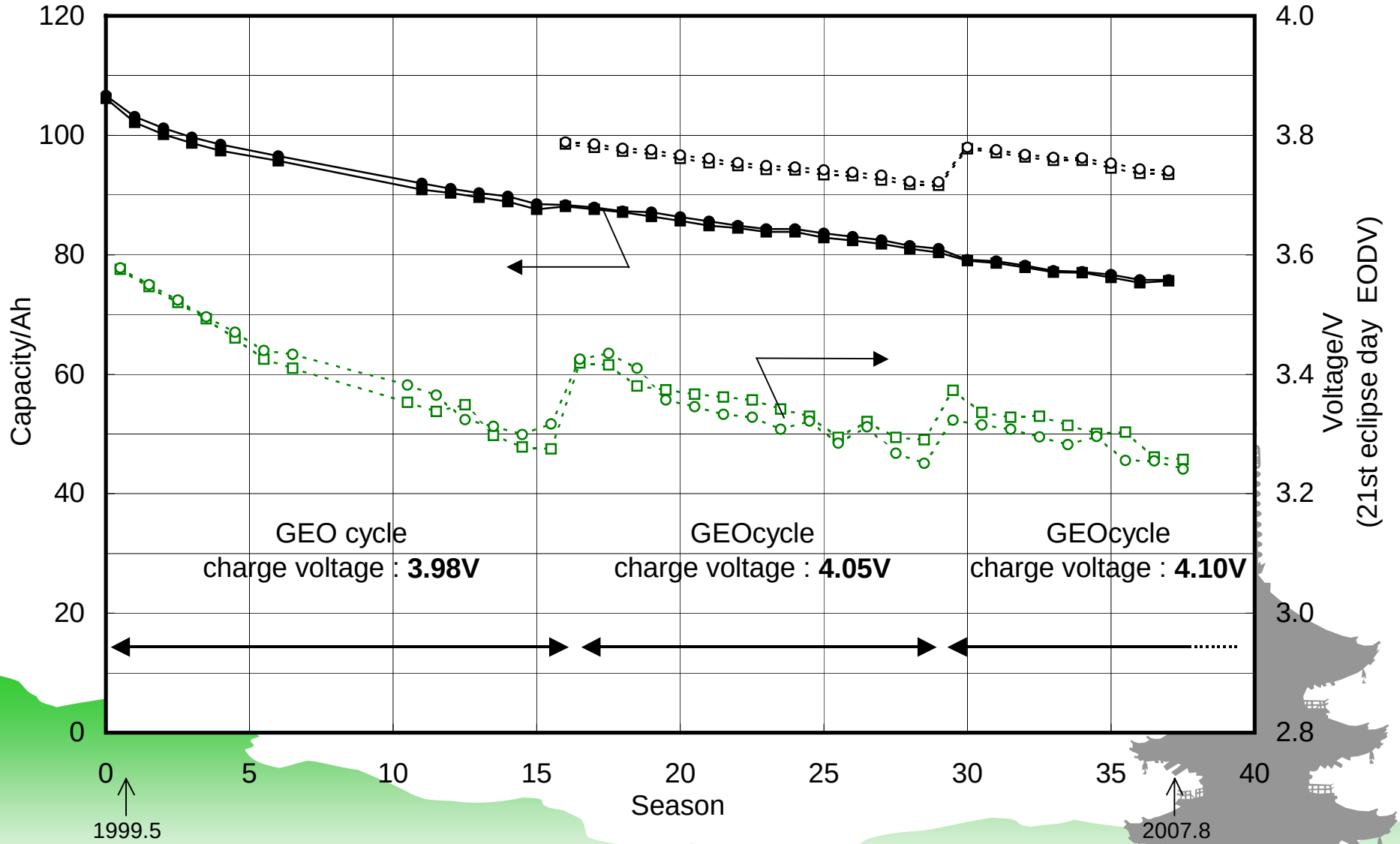
Charge : 1st cycle and 2nd cycle : 10A, 3.98V , 3rd cycle : 10A, 4.10V

Discharge : 1st cycle and 3rd cycle : 66.6A to 2.75V, 2nd cycle : 20A to 2.75V

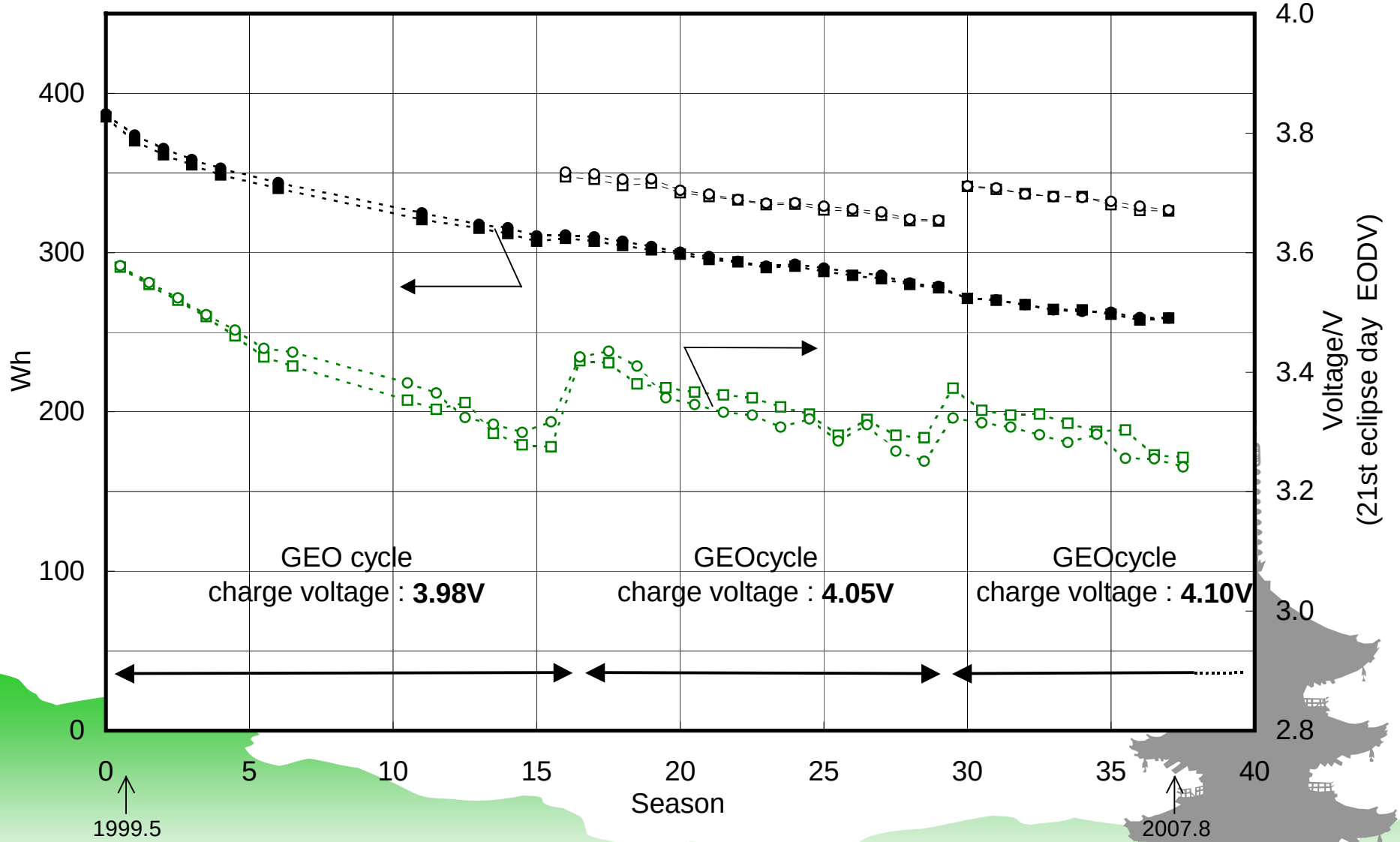
Semi-accelerated GEO (Max.80%DOD) (Continued)



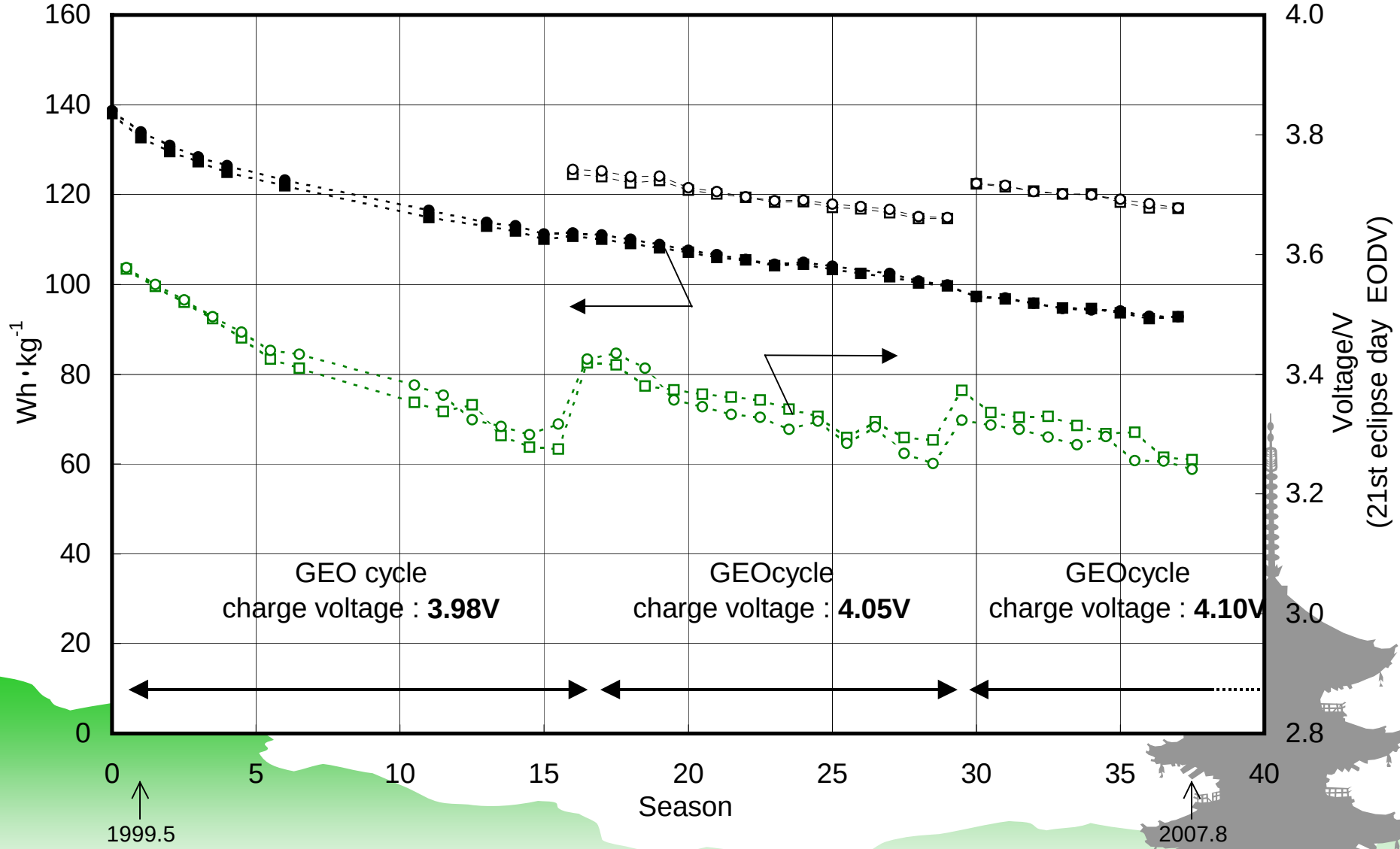
Semi-accelerated GEO (Max.80%DOD) (Continued)



Semi-accelerated GEO (Max.80%DOD) (Continued)



Semi-accelerated GEO (Max.80%DOD) (Continued)



Semi-accelerated GEO (Max.70%DOD)

Test condition

Season consists of (1)and (2), which simulate eclipse season and solstice season, respectively.

(1) 42variable DOD cycles (Max.DOD70%, Ave.DOD58% at 15degrees C)

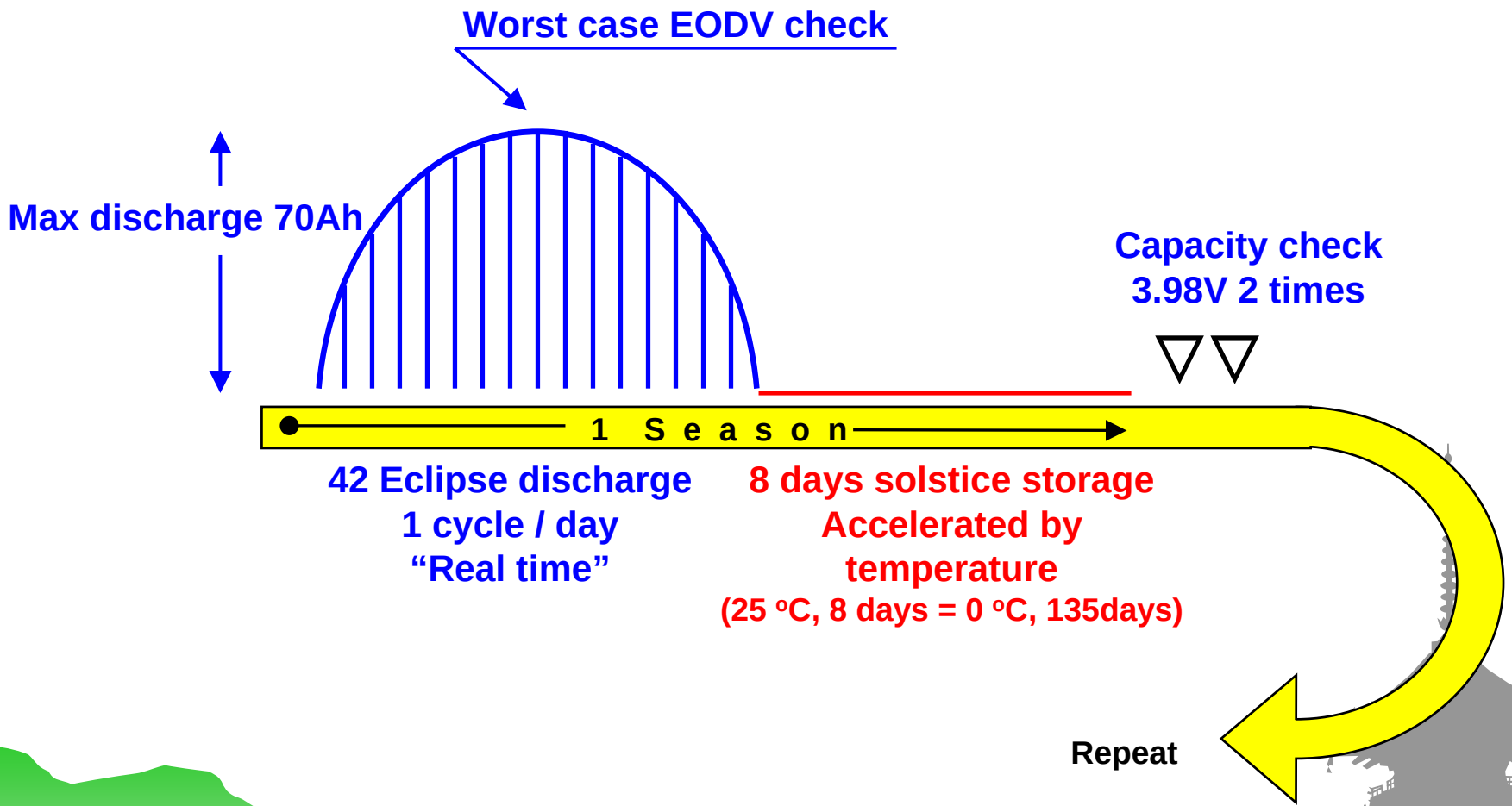
(2) 8days storage at SOC 50% at 25degrees C
(Corresponding to 6months storage at 0degrees C)

Capacity check condition (at 15 degrees C)

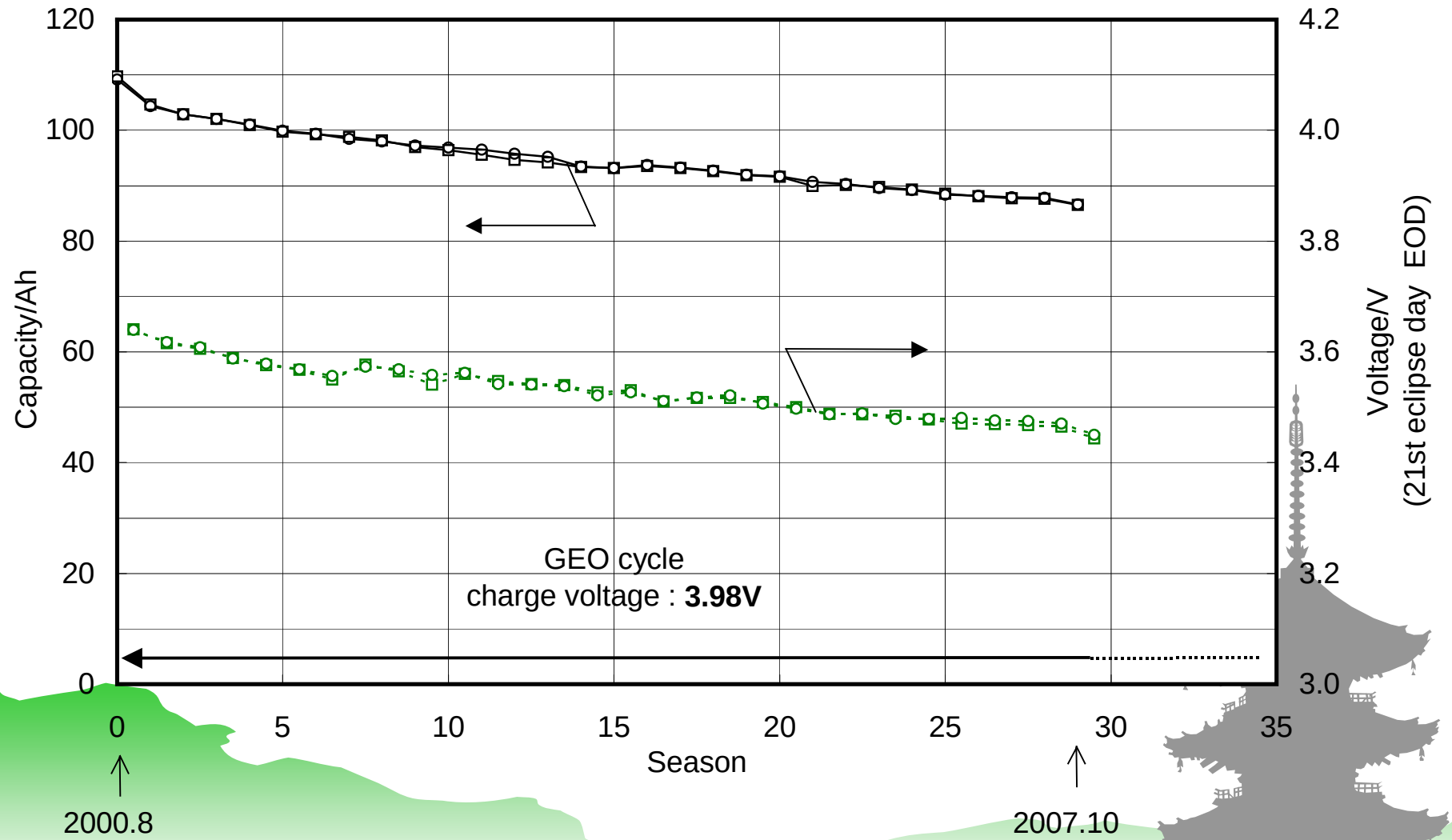
Charge : 10A/3.98V (CC/CV) for 20 hours

Discharge : 58.0A to 2.75V

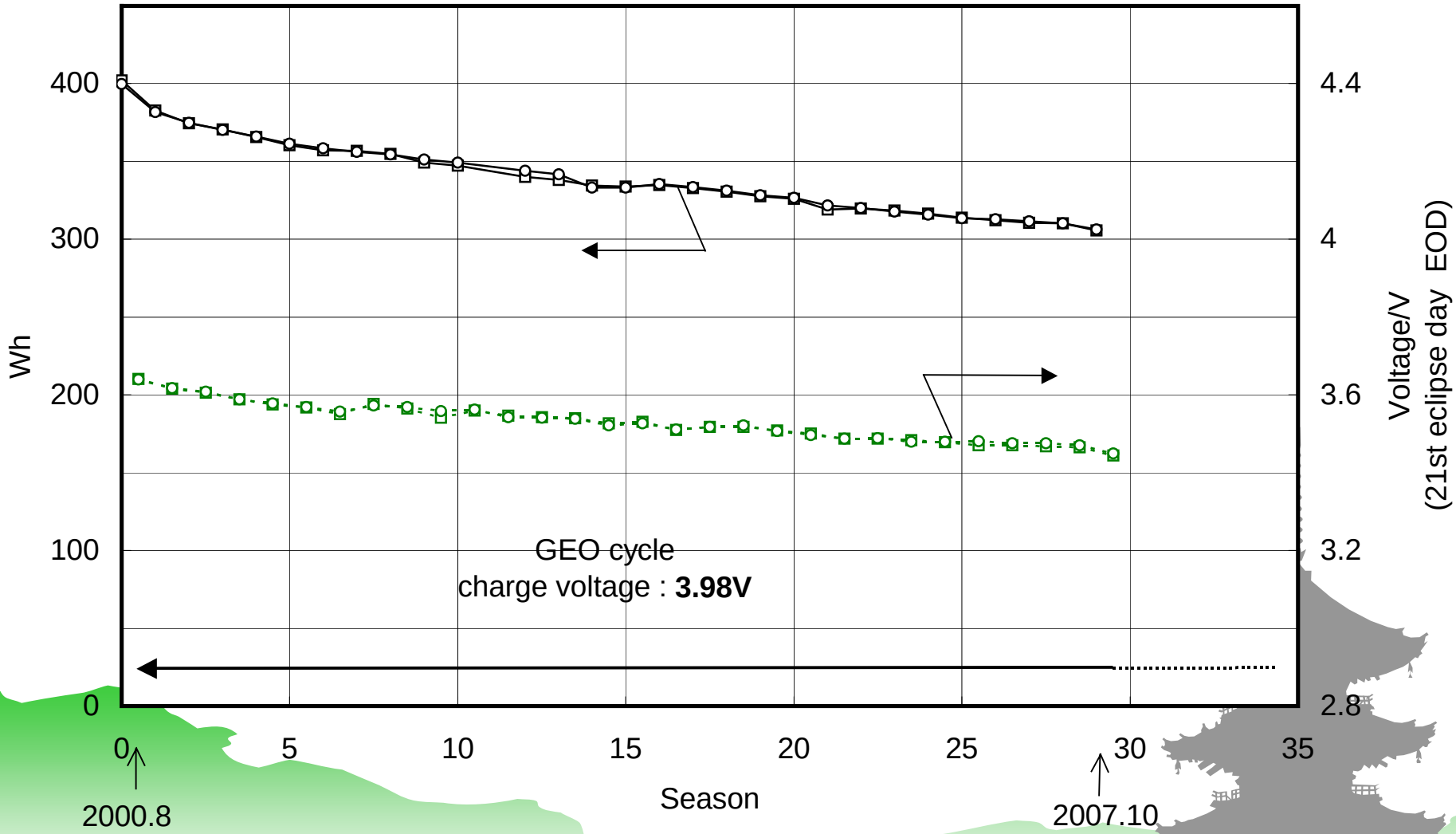
Semi-accelerated GEO (Max.70%DOD) (continued)



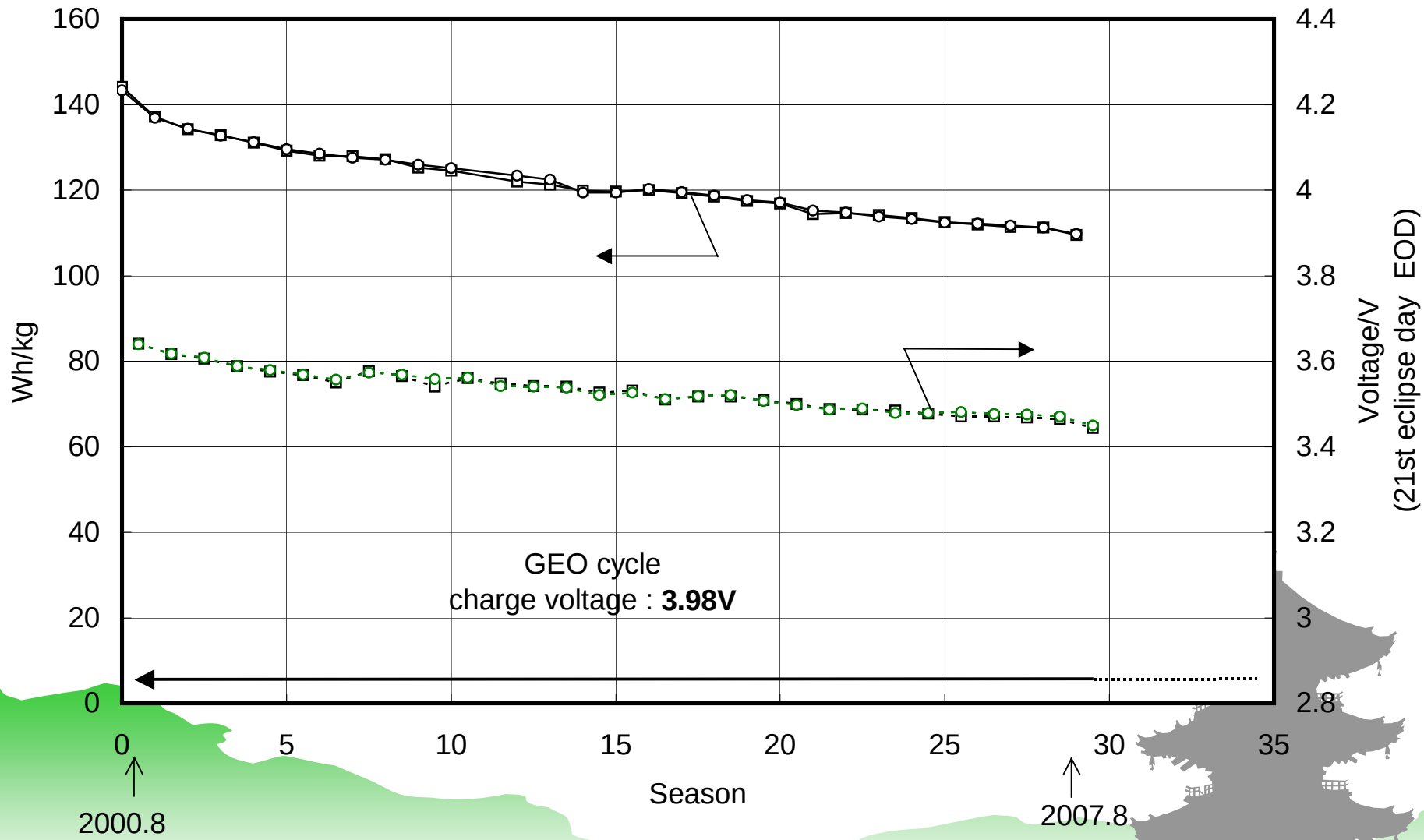
Semi-accelerated GEO (Max.70%DOD) (Continued)



Semi-accelerated GEO (Max.70%DOD) (continued)



Semi-accelerated GEO (Max.70%DOD) (continued)



Real time LEO DOD25% cycling test

Cycling

.

Charge : 50A/3.95V (CC/CV) for 60min

Discharge : 50A CC 30 min

Temperature : 15 degrees C

Capacity check condition (at 15 degrees C)

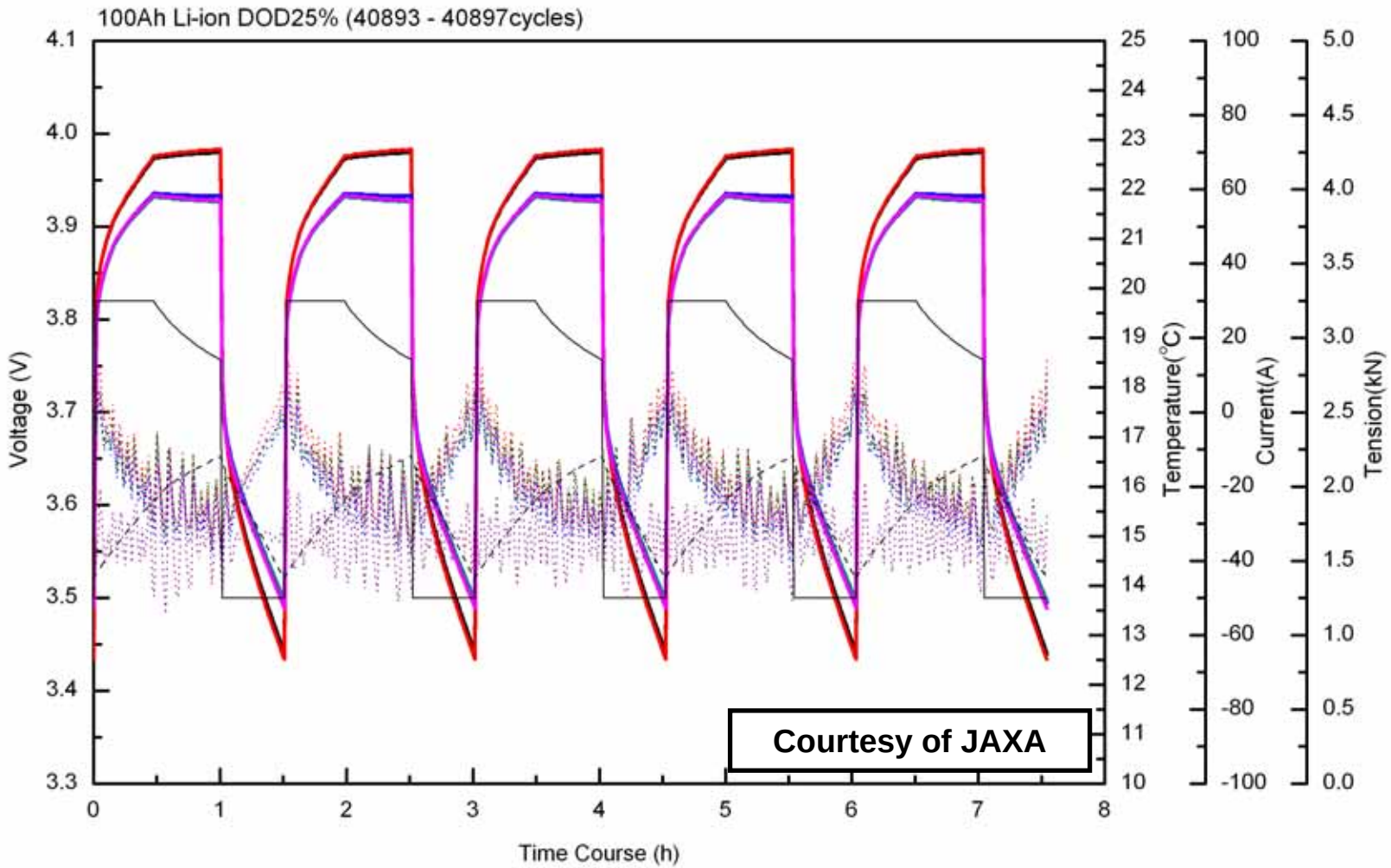
Charge : 50A/3.95V (CC/CV) for 60min

Discharge : 50A to 2.75V

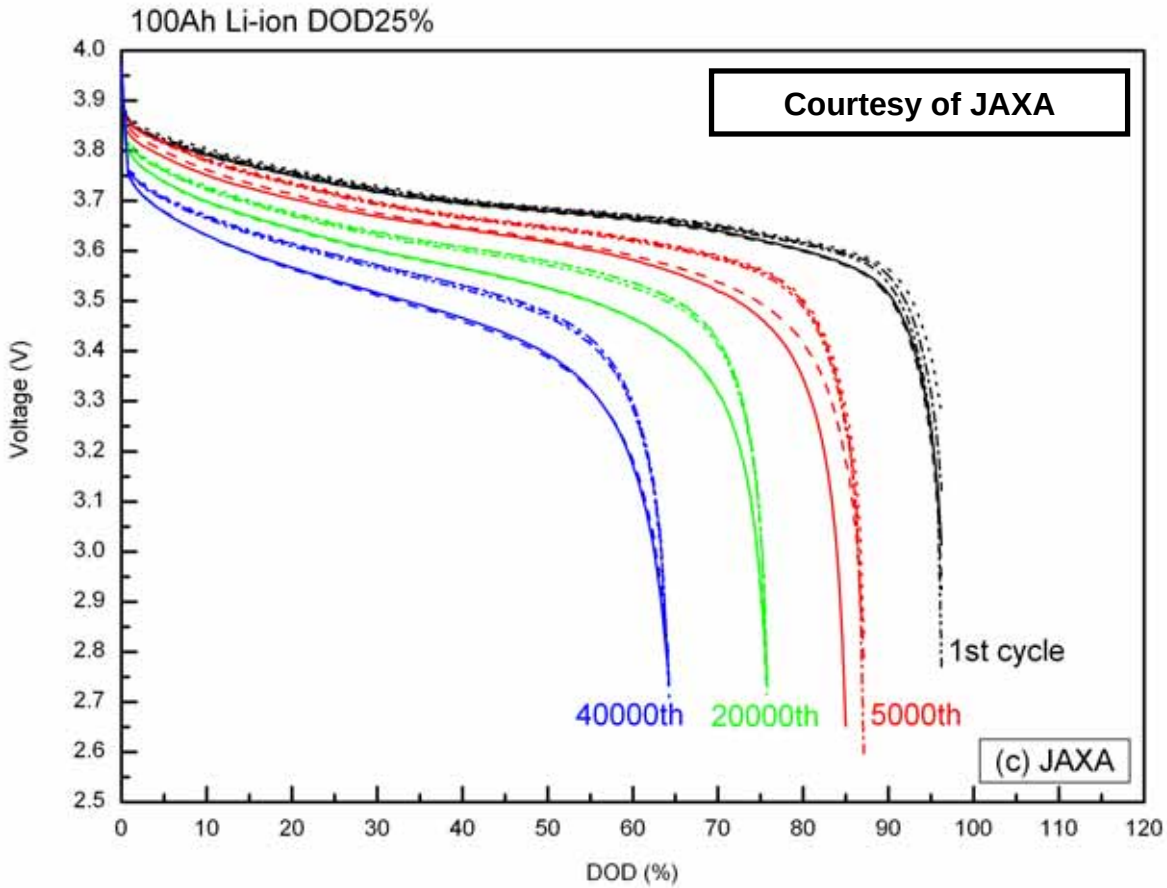
Charge : 10A/3.95V (CC/CV) for 16 hours

Discharge : 50A to 2.75V

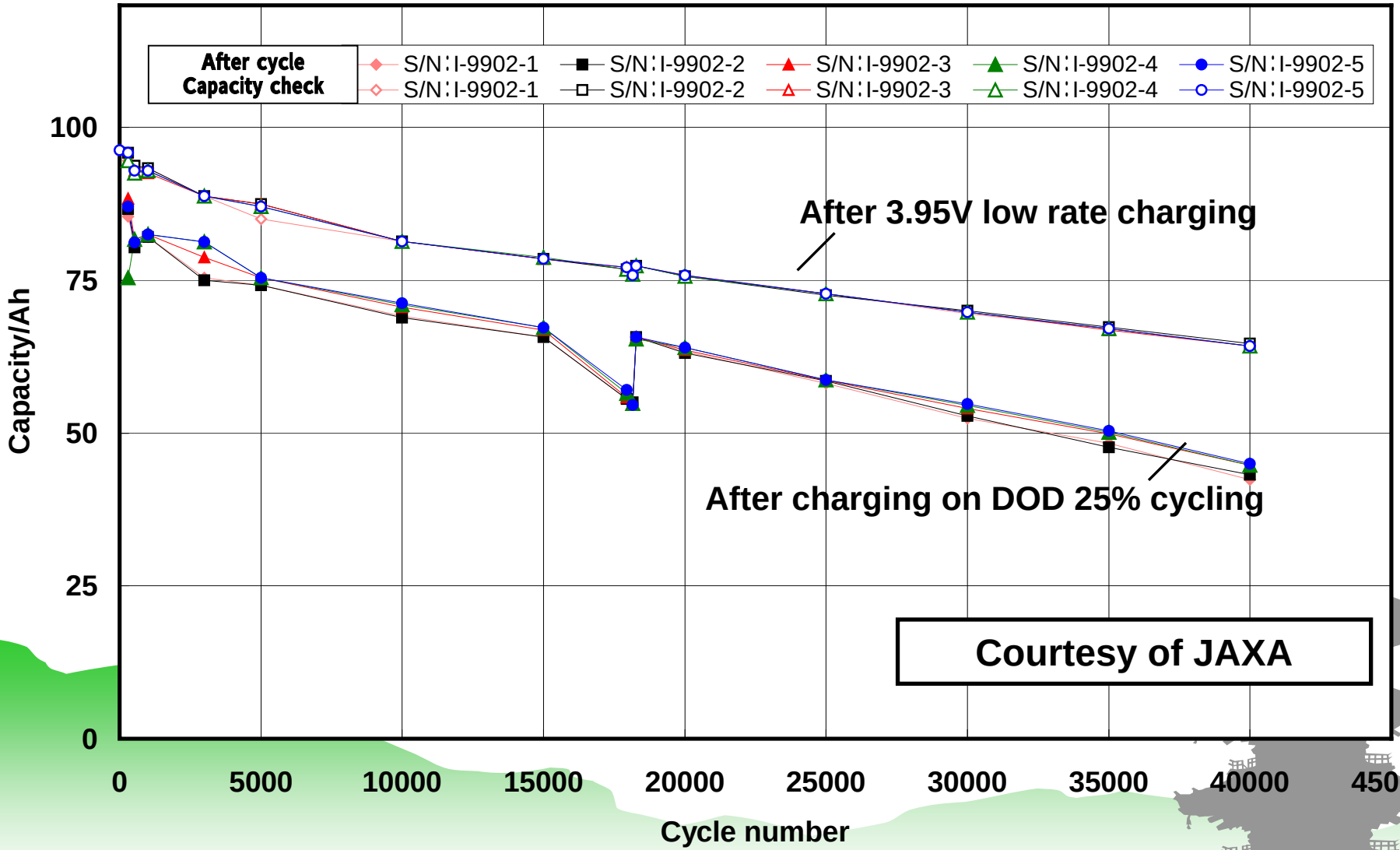
Real time LEO DOD25% cycling test (continued)



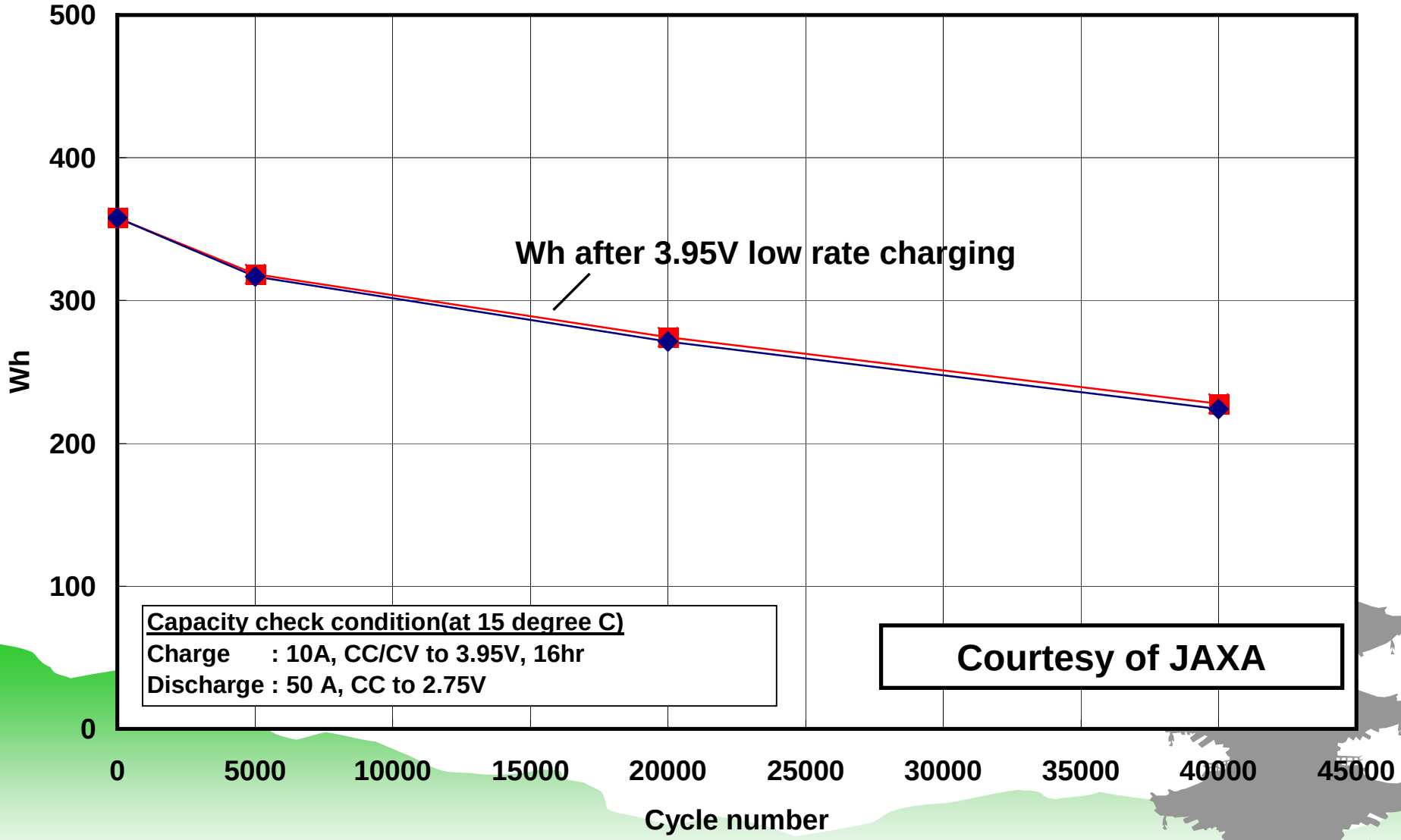
Real time LEO DOD25% cycling test (continued)



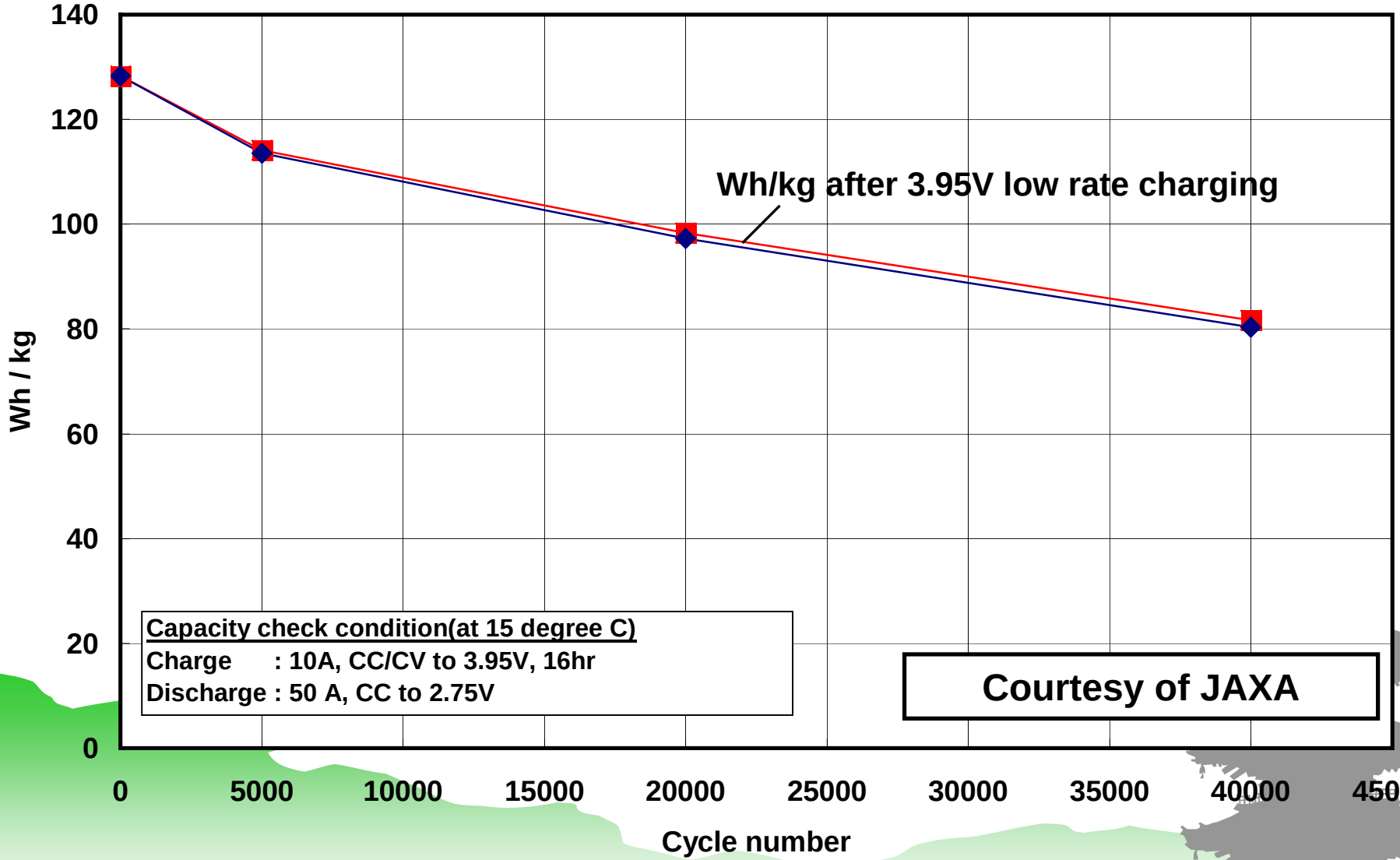
Real time LEO DOD25% cycling test (continued)



Real time LEO DOD25% cycling test (continued)



Real time LEO DOD25% cycling test (continued)



Real time LEO DOD40% cycling test

Cycling

.

Charge : 50A/3.95V (CC/CV) for 60min

Discharge : 80A CC 30 min

Temperature : 15 degrees C

Capacity check condition (at 15 degrees C)

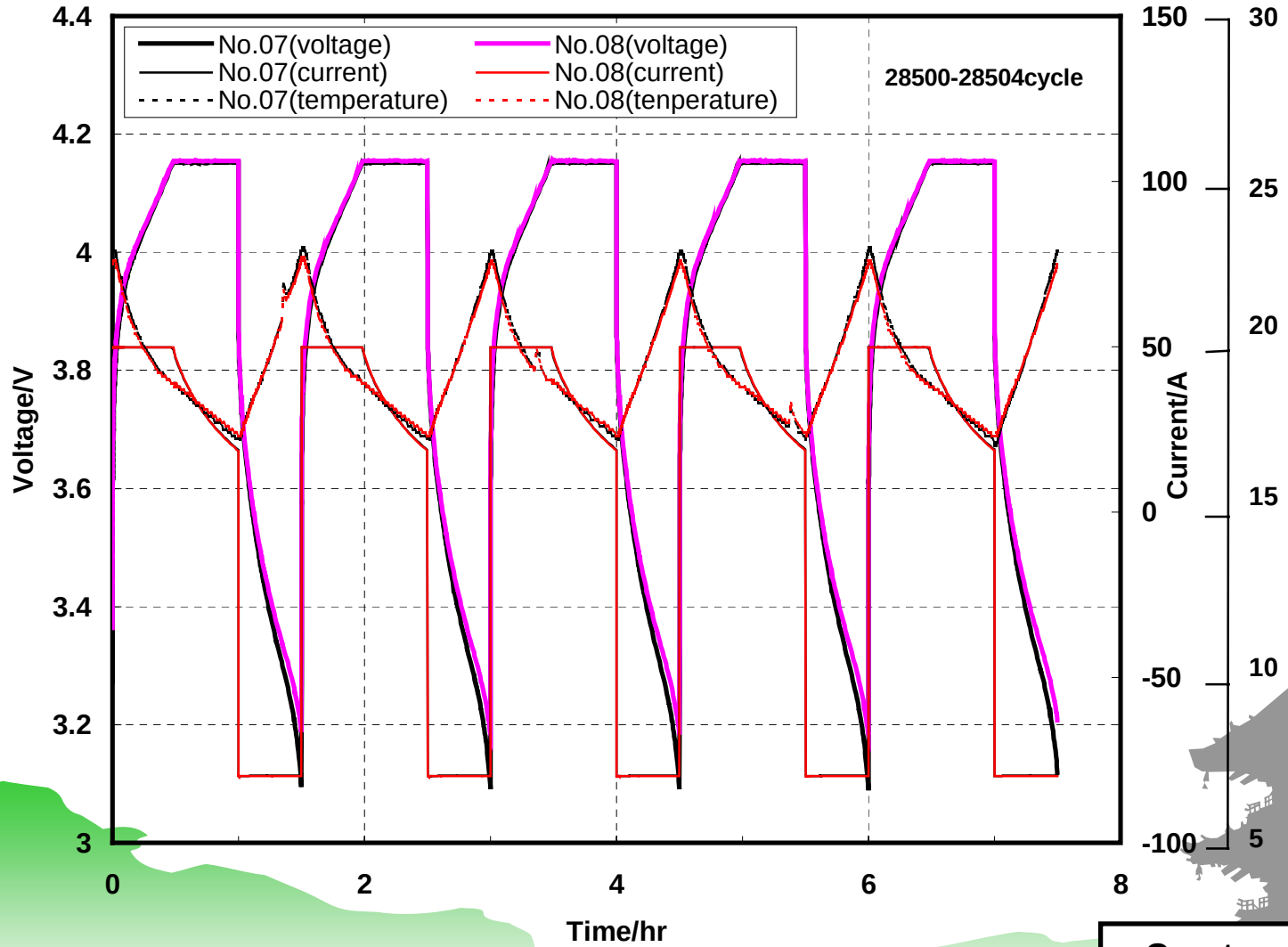
Charge : 50A/3.95V (CC/CV) for 60min

Discharge : 50A to 2.75V

Charge : 10A/3.95V (CC/CV) for 16 hours

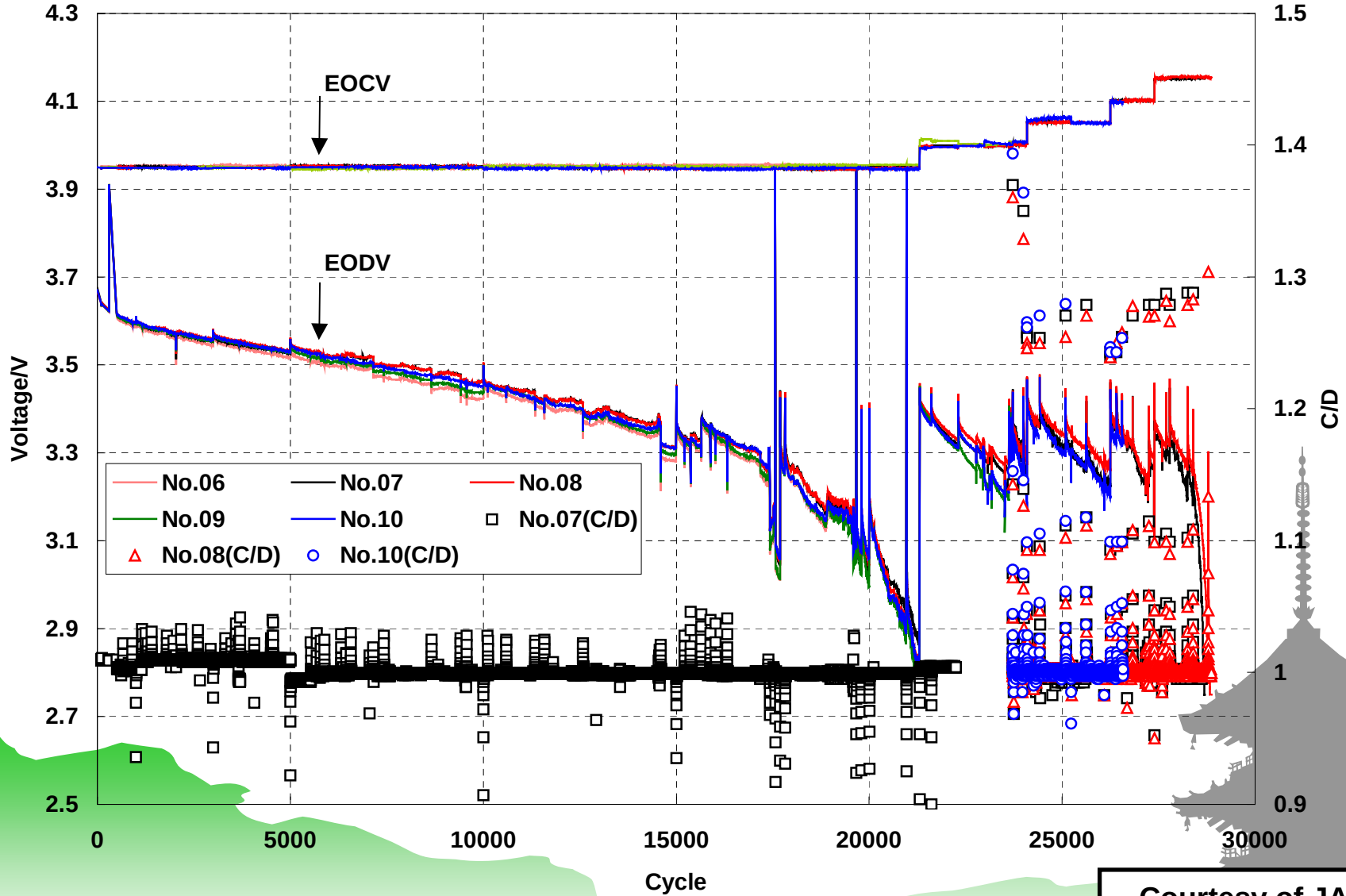
Discharge : 50A to 2.75V

Real time LEO DOD40% cycling test (continued)



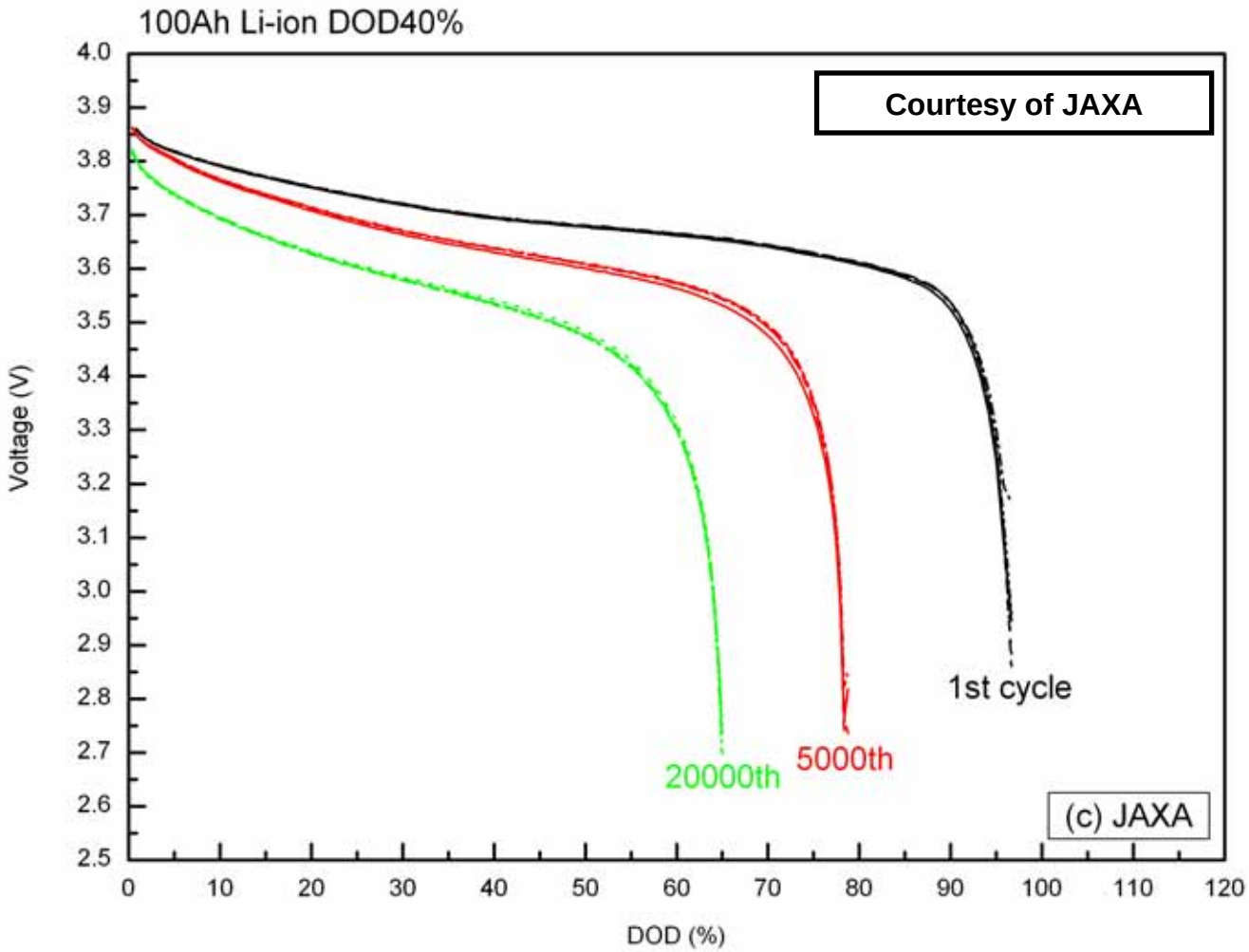
Courtesy of JAXA

Real time LEO DOD40% cycling test (continued)

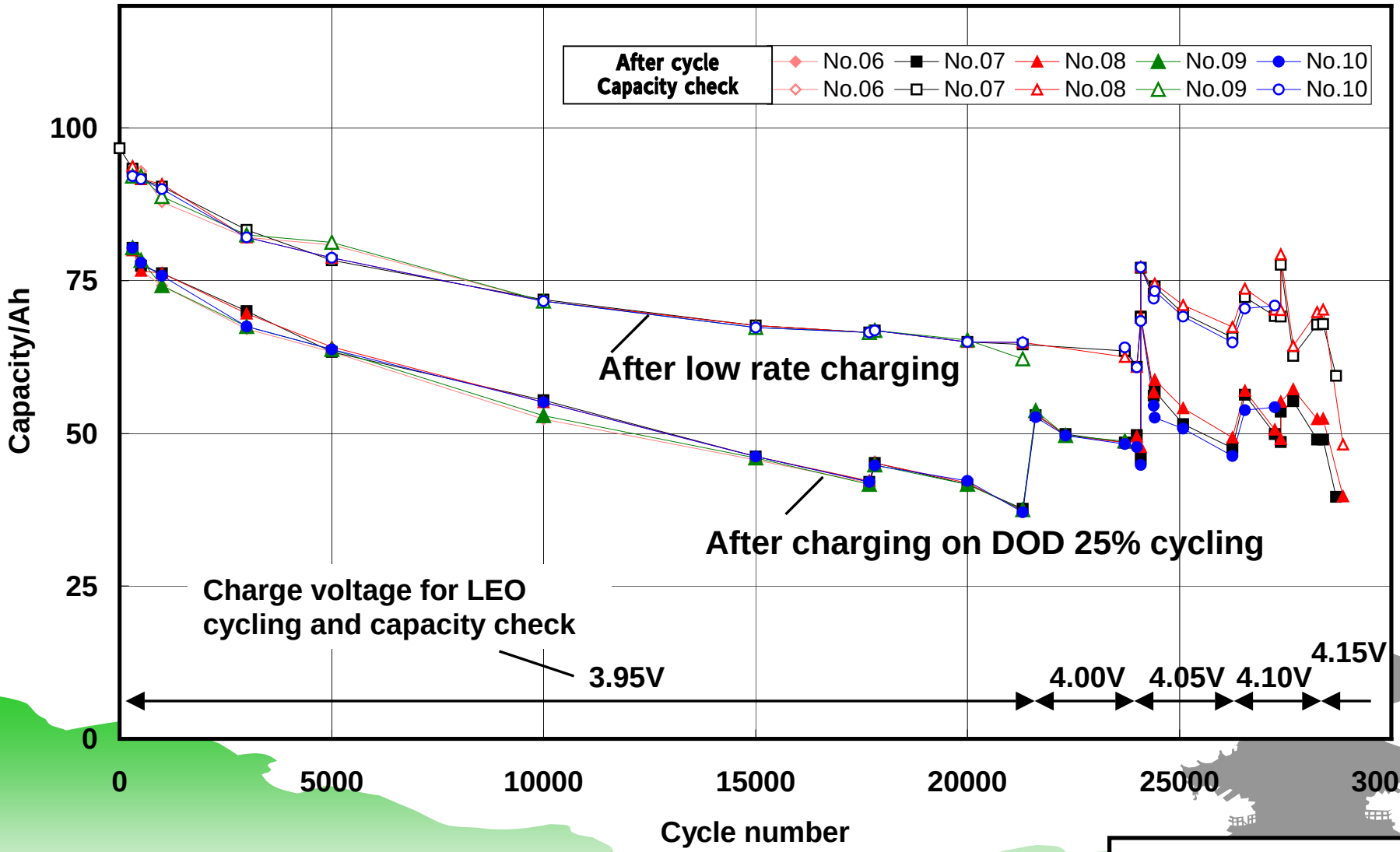


Courtesy of JAXA

Real time LEO DOD40% cycling test (continued)



Real time LEO DOD40% cycling test (continued)



Courtesy of JAXA

Real time LEO DOD30% cycling test

Battery configuration : 3 cells connected in series

Test facility : ESA (European Space Agency) – ESTEC

Test term : May, 1999 – continuing

Cycling condition:

Stage 1: Discharge at 60A for 30 min.

Stage 2: Open circuit for 10 sec (1h every 300 cycles)

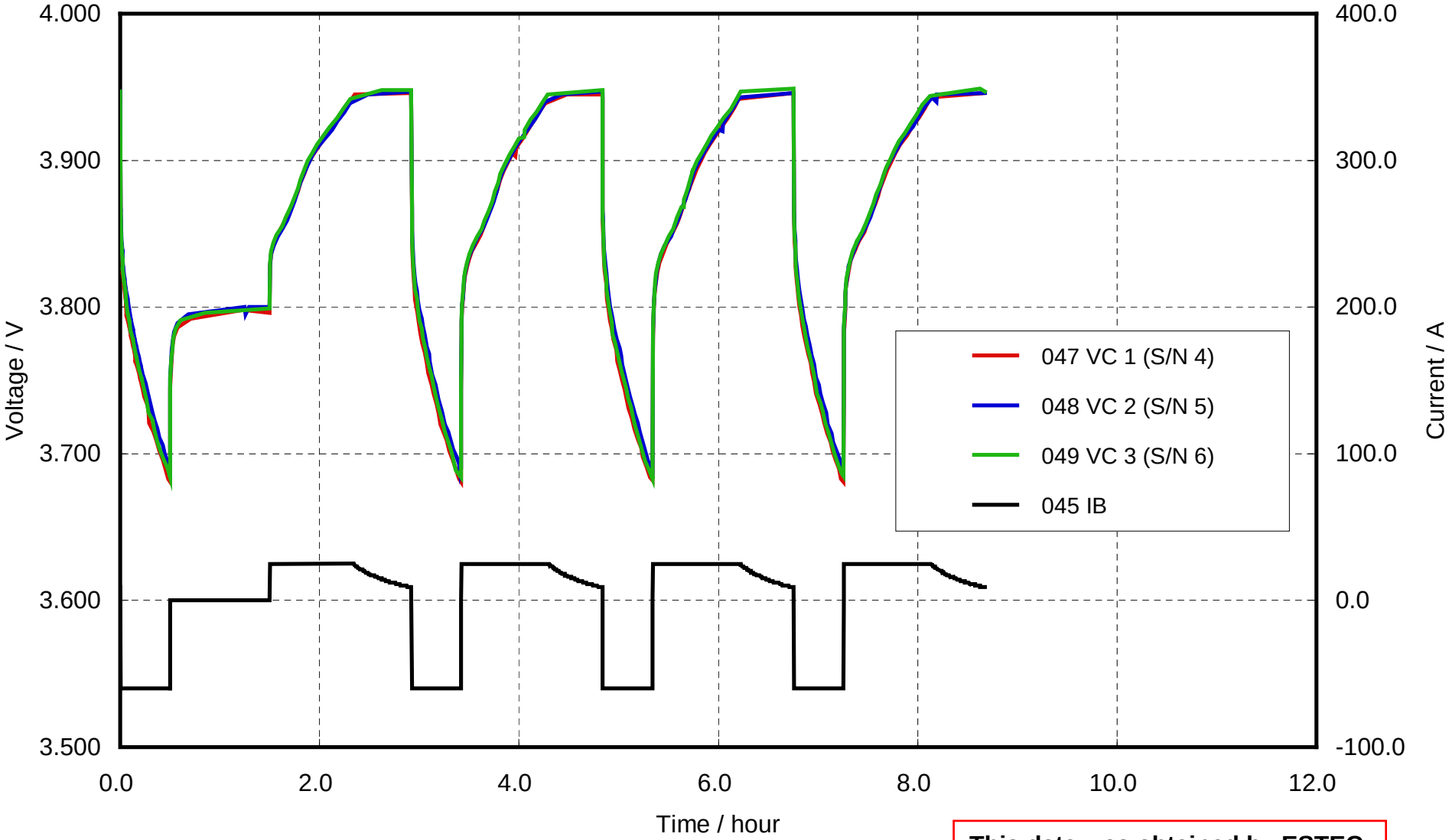
Stage 3: Charge at 25A constant current followed by 3.95V* constant voltage charging for 85min.

Temperature : 20 deg.C.

•Note: The charge voltage is changed shown in the table,

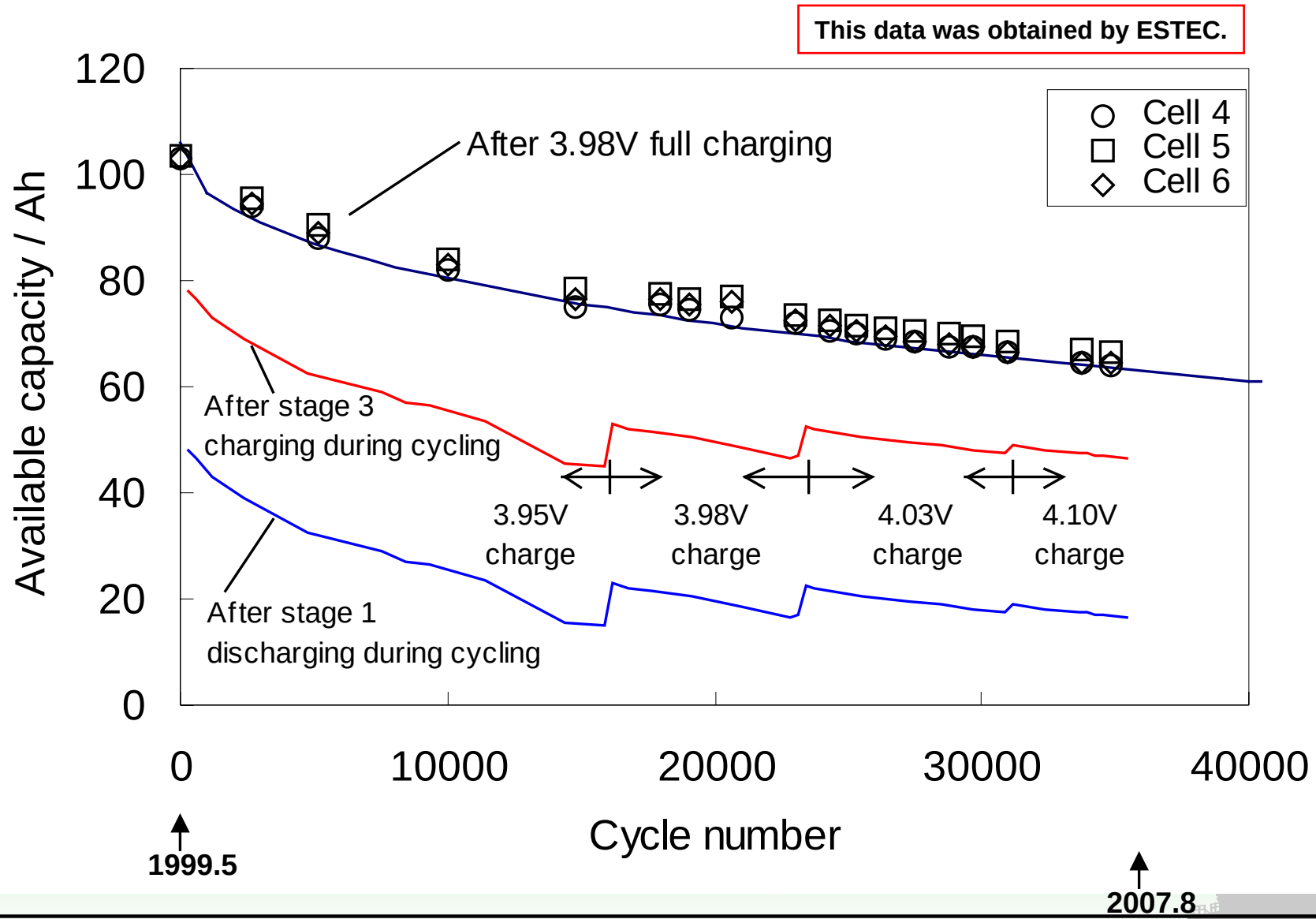
Cycle	Charge voltage
1 – 16,000	3.95V
16,000 – 23,000	3.98V
23,000 - 32000	4.05V
32000 -	4.10V

Real time LEO DOD30% cycling test (continued)

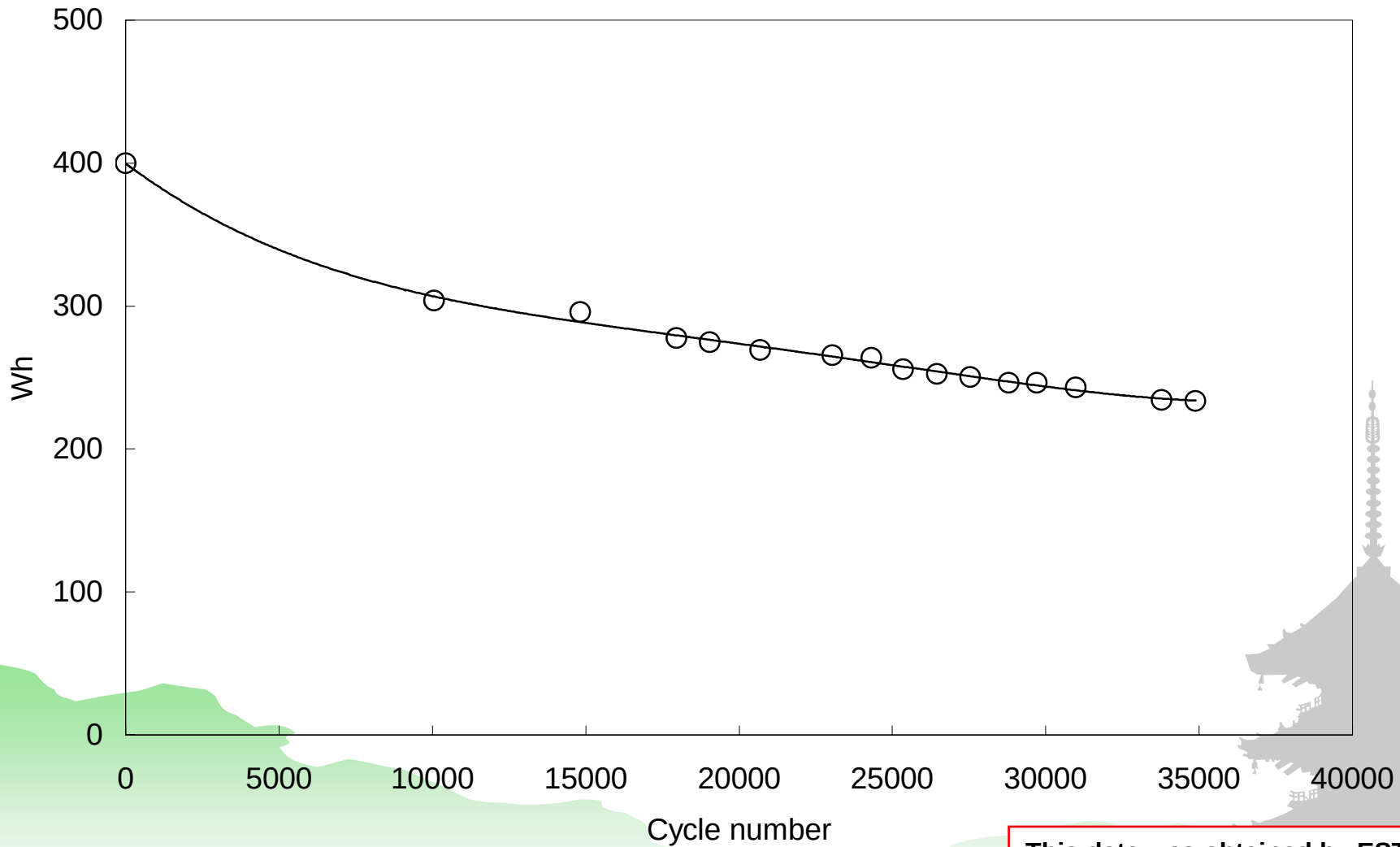


This data was obtained by ESTEC.

Real time LEO DOD30% cycling test (continued)



Real time LEO DOD30% cycling test (continued)



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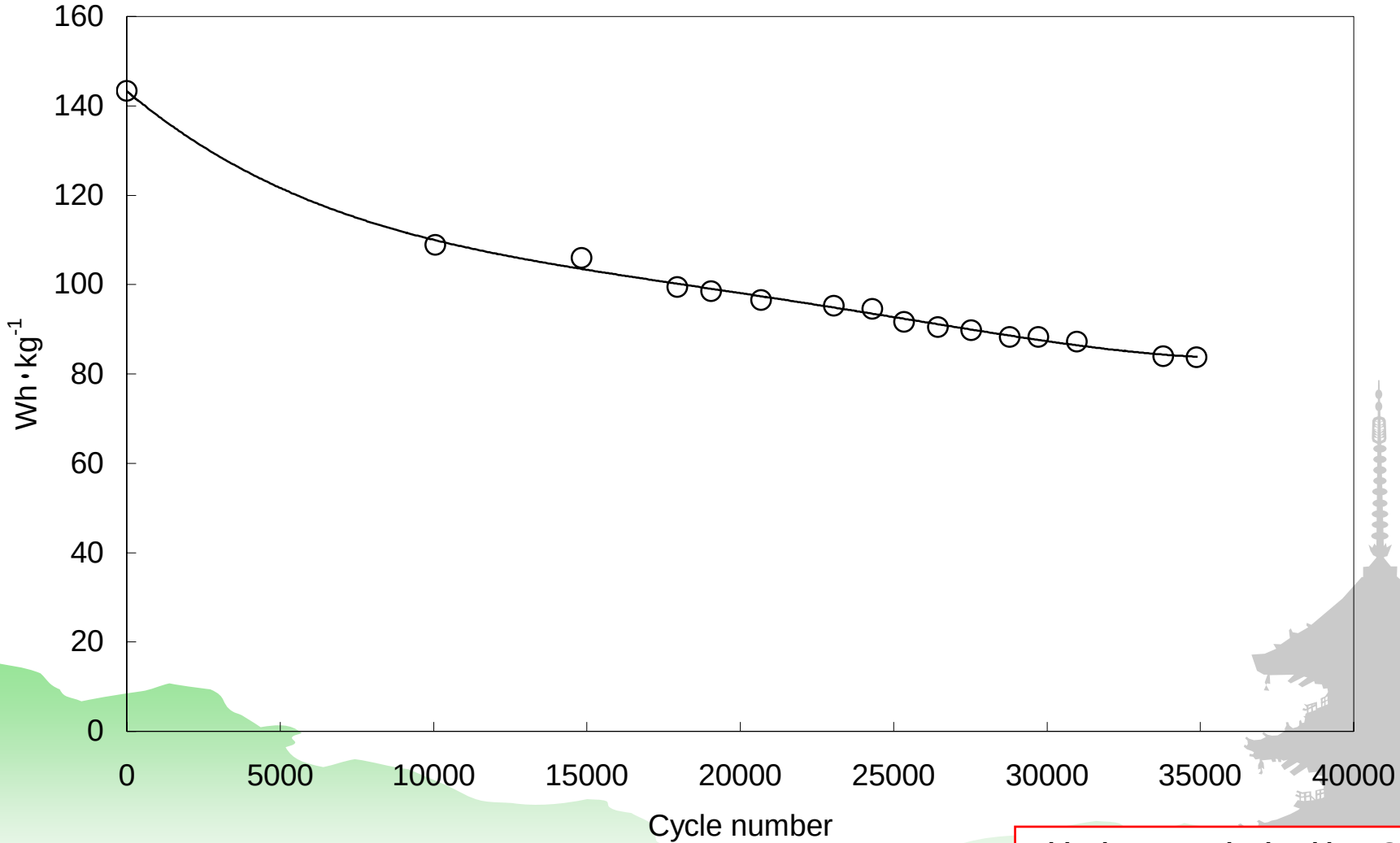
Real time LEO DOD30% cycling test (continued)



This data was obtained by ESTEC.

Real time LEO Variable DOD cycling test

Battery configuration : 3 cells connected in series
Test facility : ESA (European Space Agency) – ESTEC
Test term : May, 1999 – continuing

Cycling condition: 1cycle consists of 10 sub cycles

Sub-Cycle	Discharge power (W)	Discharge duration [min]	Charge duration [min]
1	380	9	24
2	380	19	31
3	380	25	41
4	580	25	28
5	580	19	62
6	580	31	60
7	380	10	30
8	380	10	9
9	380	14	46
10	380	10	36

Temperature : 20 deg.C.

Average discharging energy
45Wh / subcycle

Average discharging capacity
12.4Ah(12.4%) / subcycle

Real time LEO Variable DOD cycling test (continued)

Variable DOD cycling detailcondition

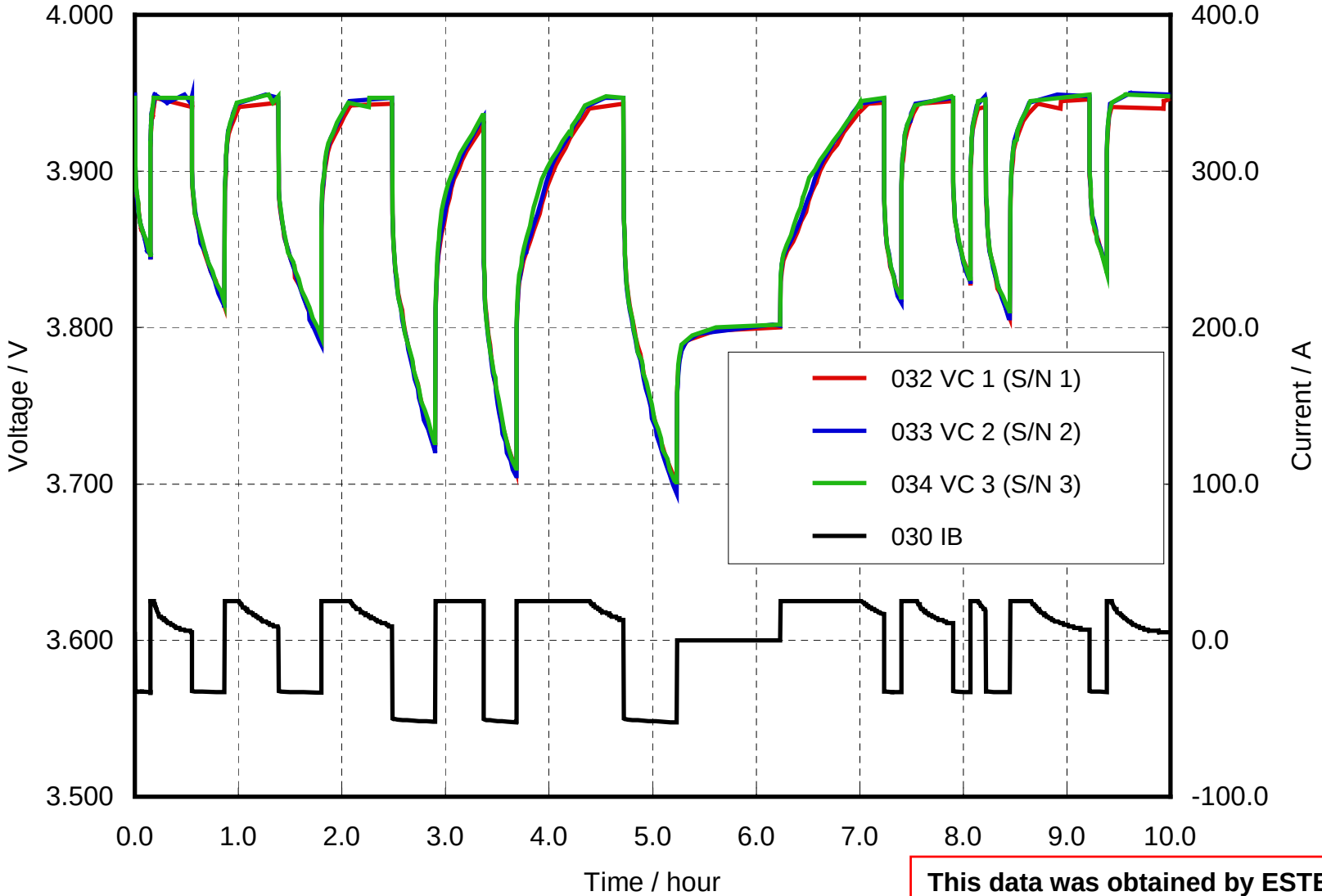
Stage 1: Discharge. at 380 W for 9 min
Stage 2: Charge at 25A / 3.95V** (CC/CV) for 24min.
Stage 3: Discharge at 380 W for 19 min
Stage 4: Charge at 25A / 3.95V** (CC/CV) for 31min.
Stage 5: Discharge. at 380 W for 25 min***
Stage 6: Charge at 25A / 3.95V** (CC/CV) for 41min***.
Stage 7: Discharge at 580 W for 25 min
Stage 8: Charge at 25A / 3.95V** (CC/CV) for 28min.
Stage 9: Discharge. at 580 W for 19 min
Stage 10: Charge at 25A / 3.95V** (CC/CV) for 62min.
Stage 11: Discharge. at 580 W for 31 min***
Stage 12: Open circuit for 10s (1h every 30 cycles)
Stage 13: Charge at 25A / 3.95V** (CC/CV) for 60min***.
Stage 14: Discharge at 380 W for 10 min
Stage 15: Charge at 25A / 3.95V** (CC/CV) for 30min.
Stage 16: Discharge. at 380 W for 10 min
Stage 17: Charge at 25A / 3.95V** (CC/CV) for 9min.
Stage 18: Discharge at 380 W for 14 min
Stage 19: Charge at 25A / 3.95V** (CC/CV) for 46min.
Stage 20: Discharge. at 380 W for 10 min
Stage 21: Charge at 25A / 3.95V** (CC/CV) for 36min.

** Note: The charge voltage is changed as shown as follows

Sub-cycle	Charge voltage
1 – 34,300	3.95V
34,300 – 49,600	3.98V
49,600 - 66,200	4.05V
66,200 -	4.10V

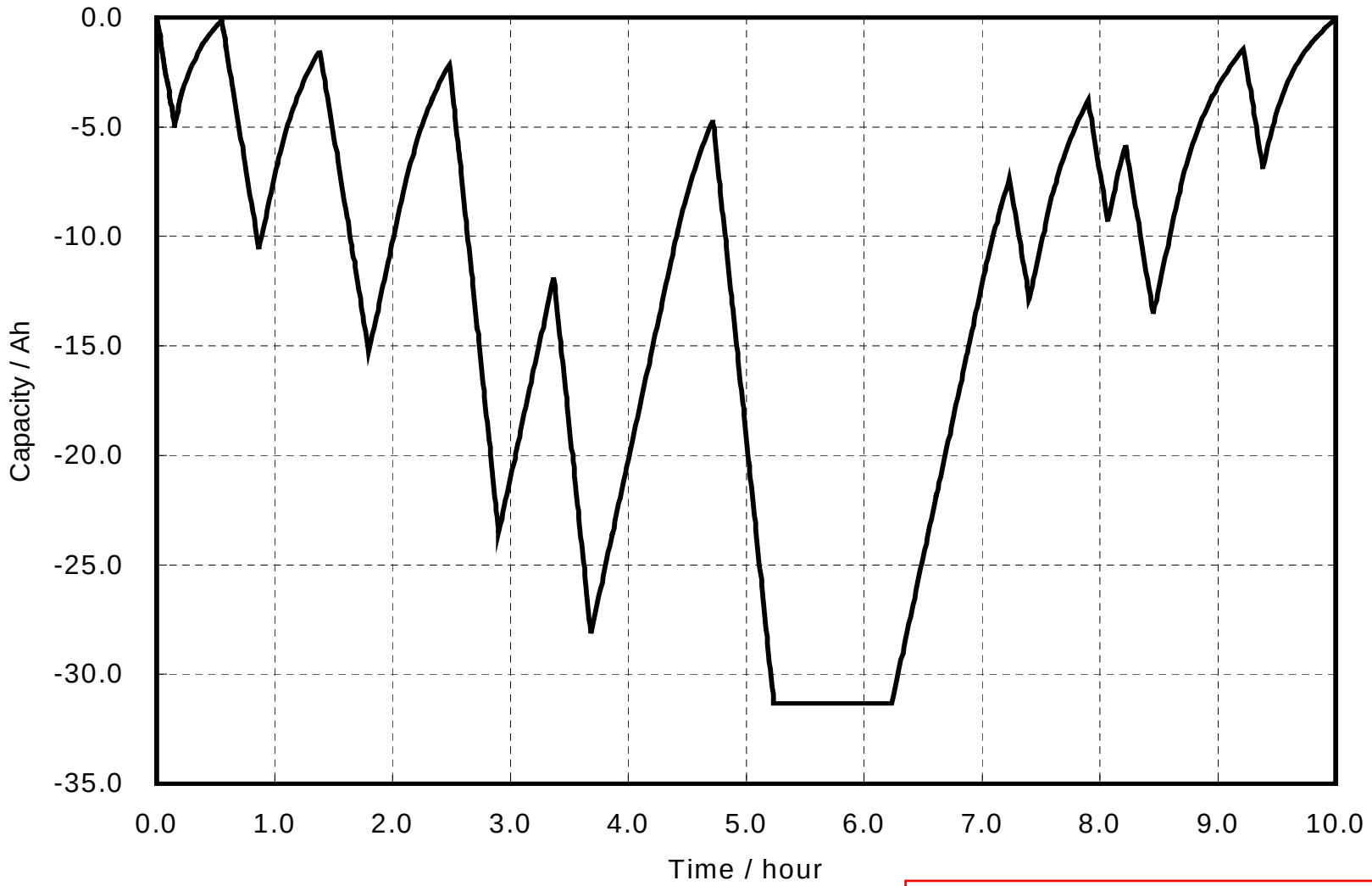
*** Note: Every 30 cycles starting at cycle 31, current-interrupt resistance measurements are made every 4 minutes during stages 5,6,11,and 13, measuring cells 1,2 and 3 on successive cycles.

Real time LEO Variable DOD cycling test (continued)



This data was obtained by ESTEC.

Real time LEO Variable DOD cycling test (continued)



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Real time LEO Variable DOD cycling test (continued)

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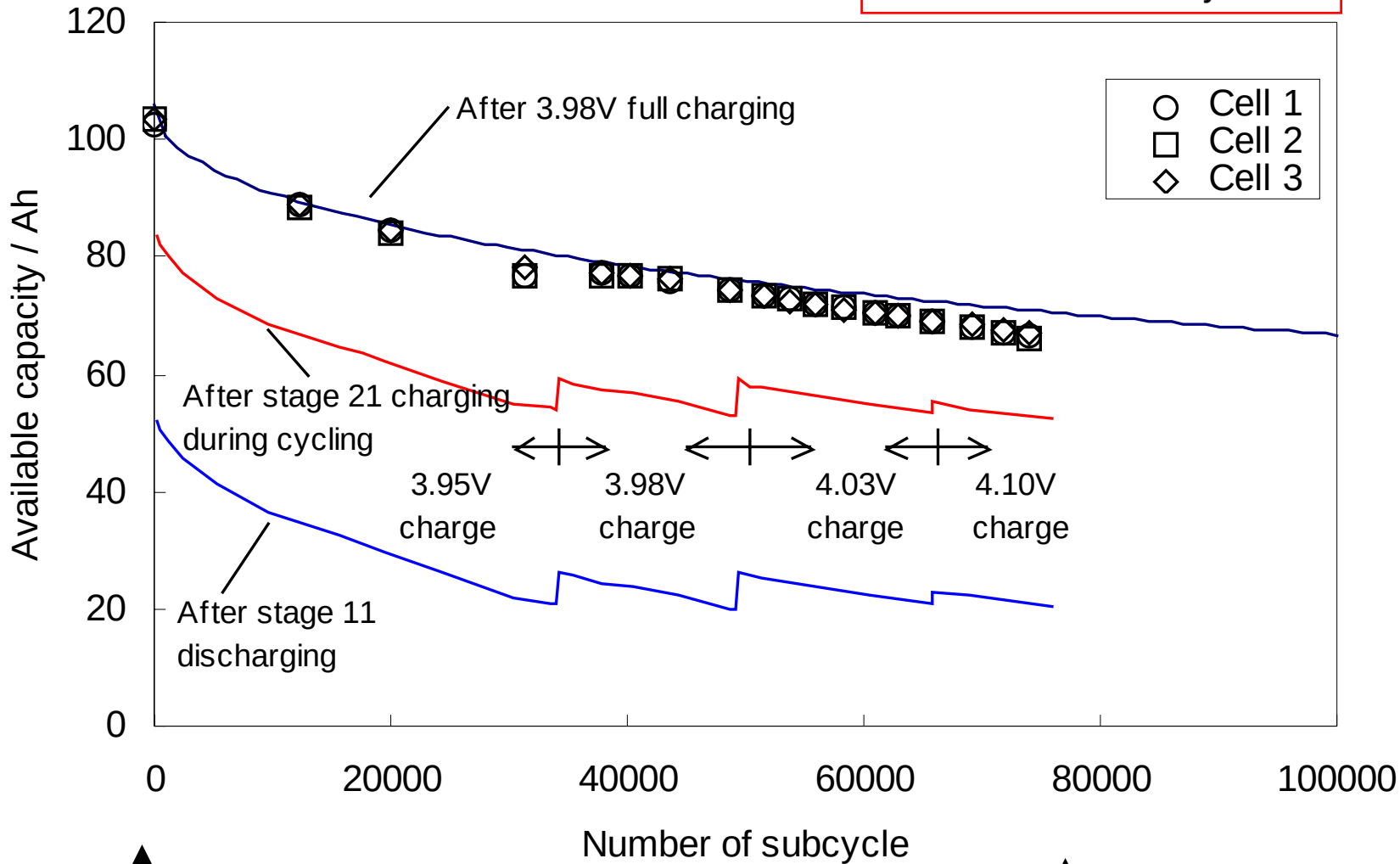

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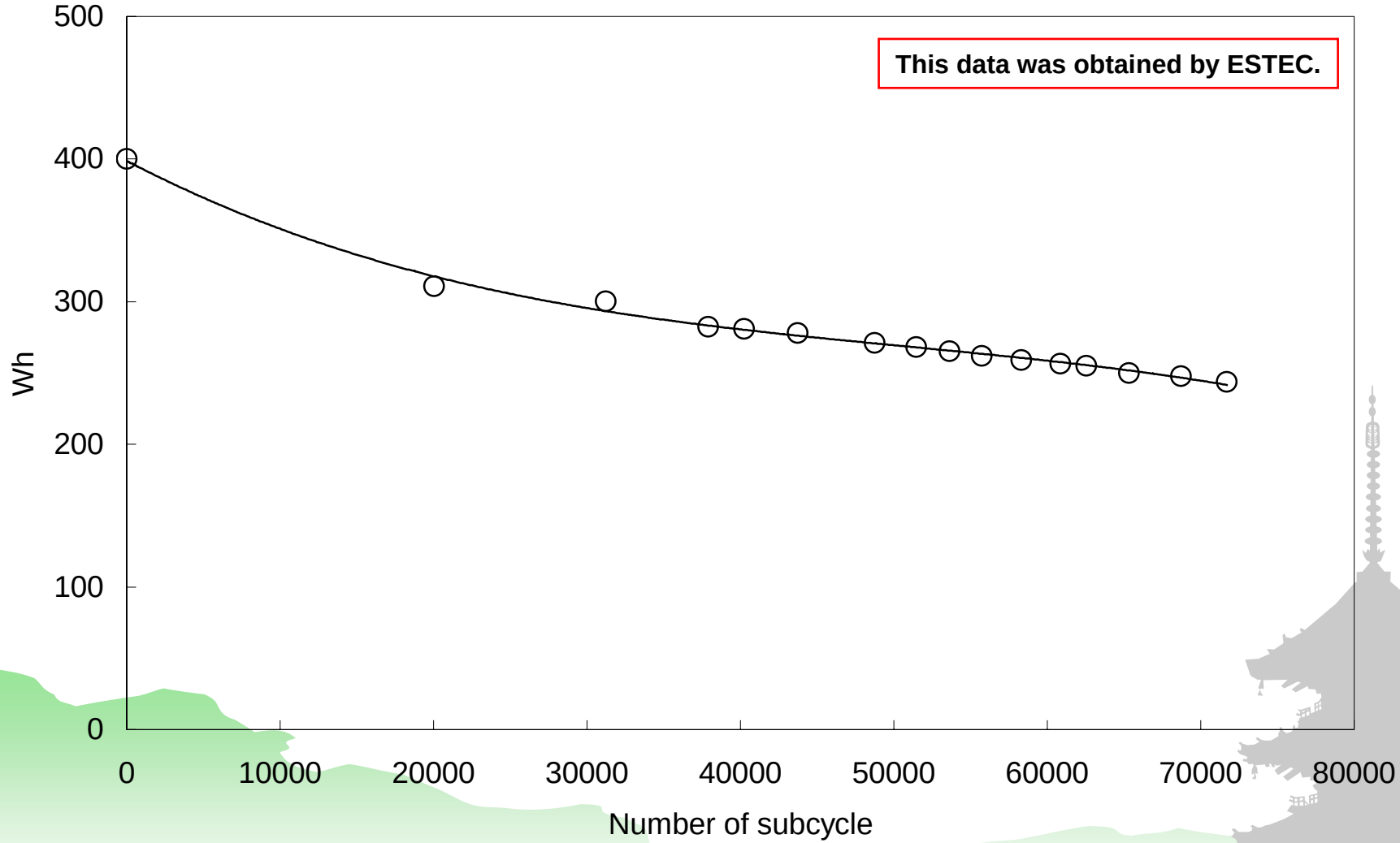
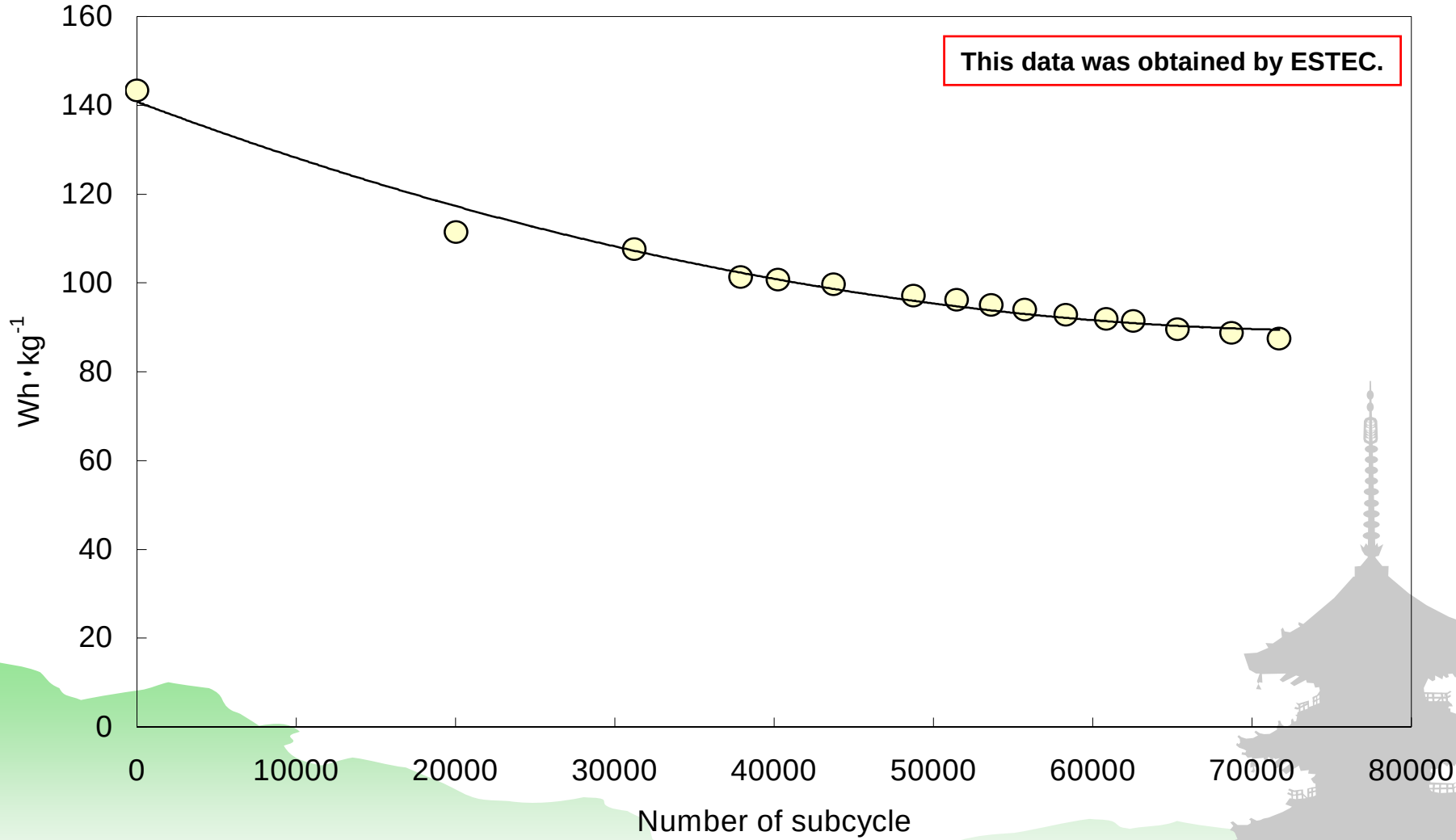
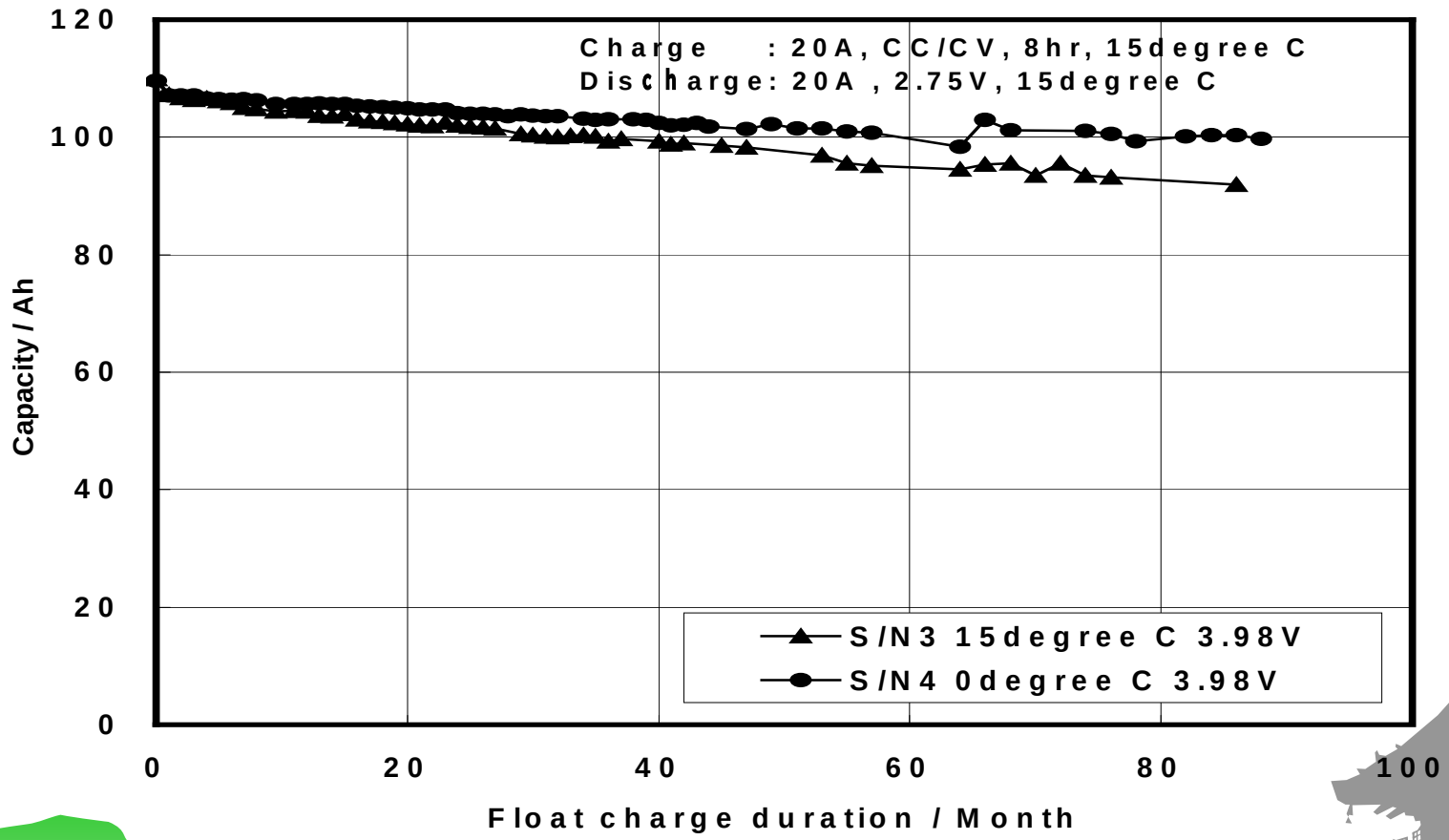
Real time LEO Variable DOD cycling test (continued)



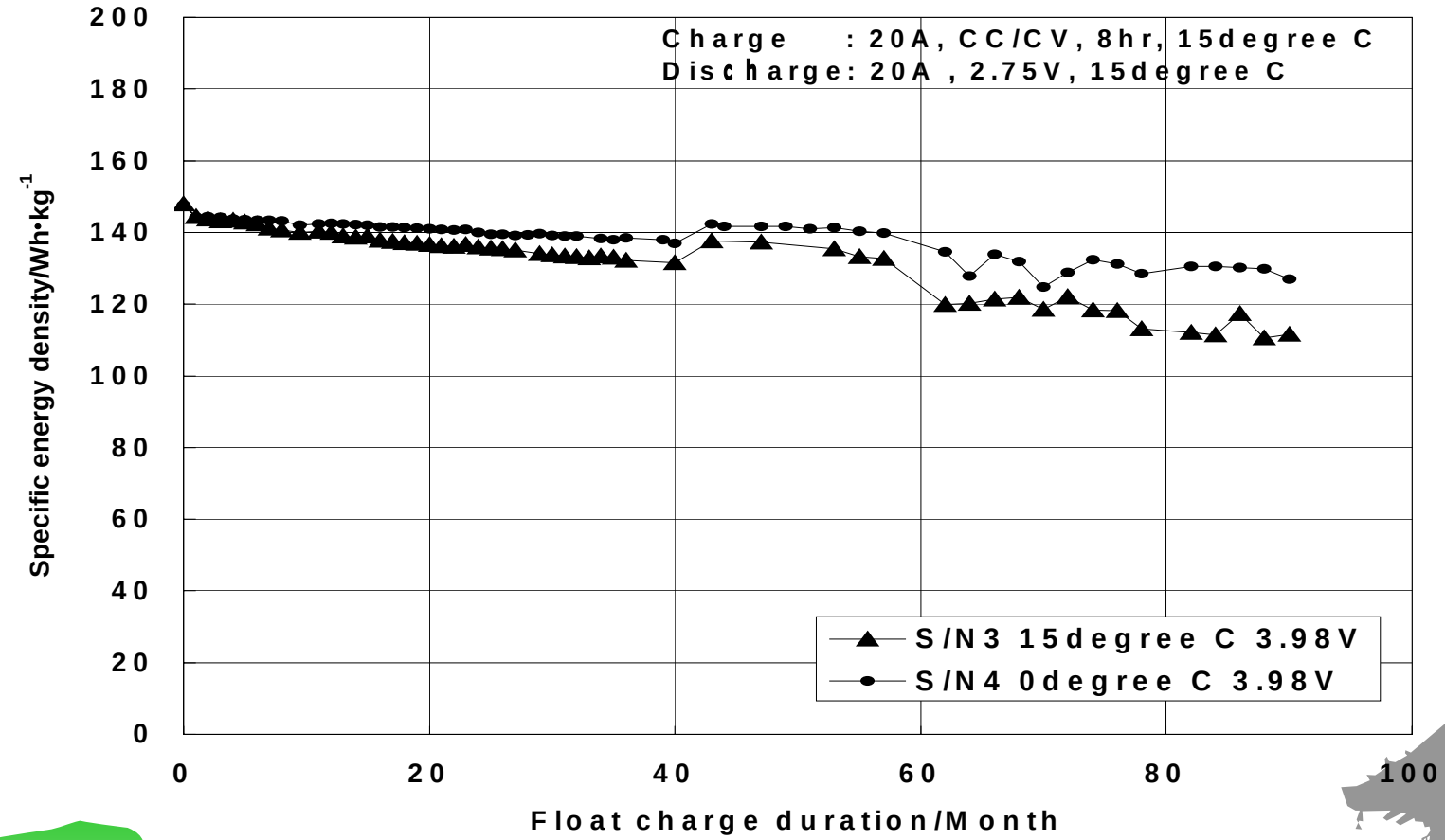
Real time LEO Variable DOD cycling test (continued)



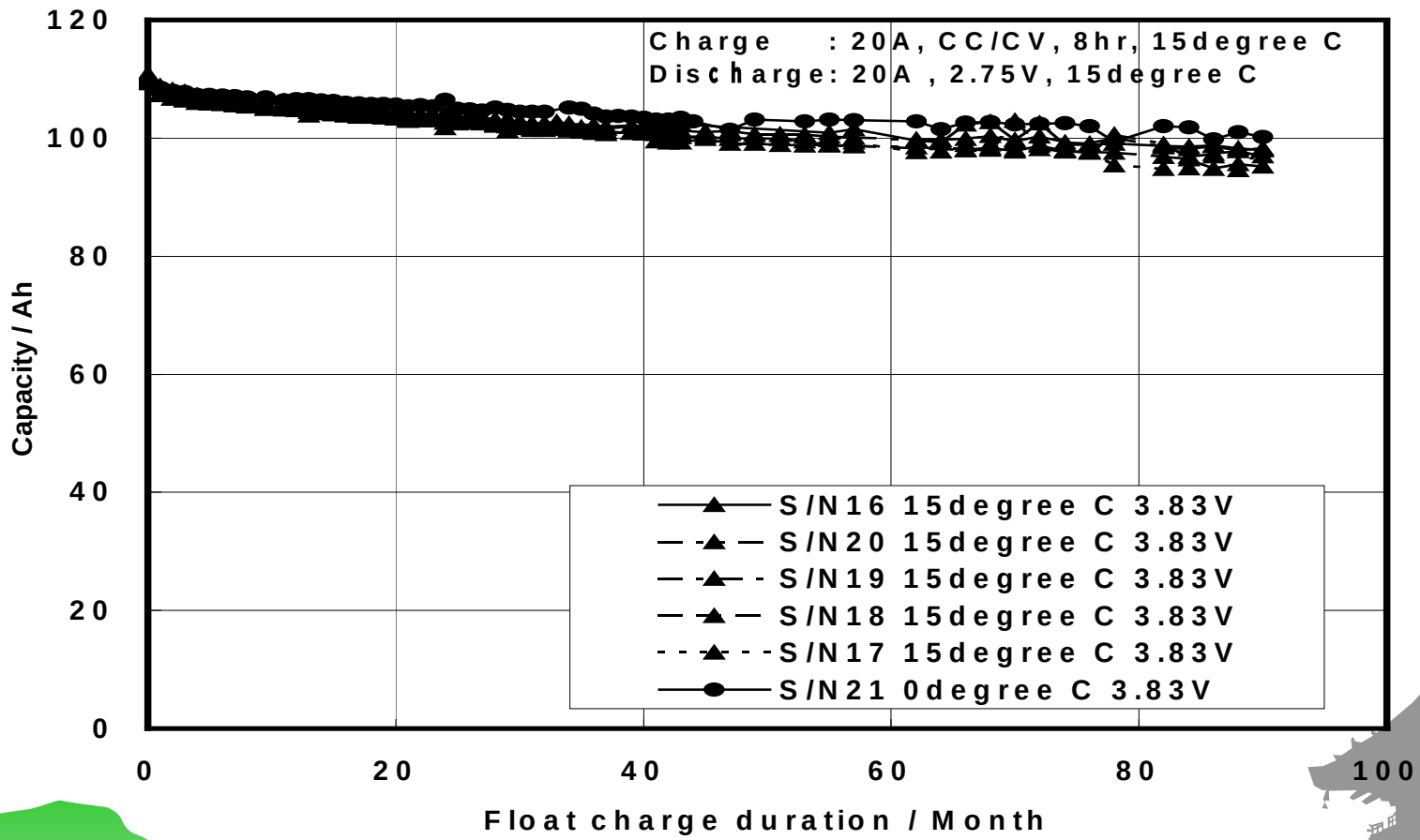
Float charge storage test at SOC100%



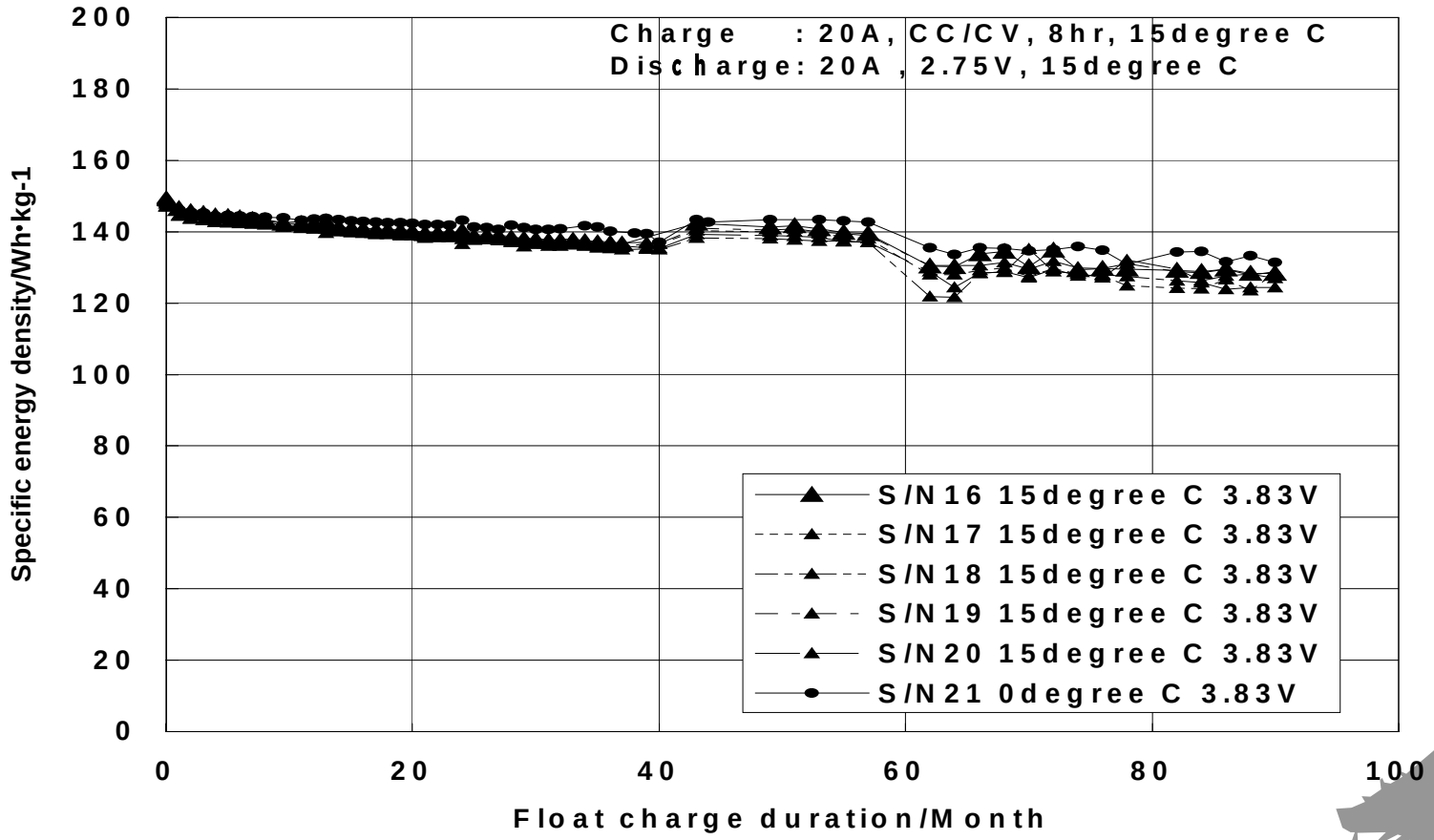
Float charge storage test at SOC100%



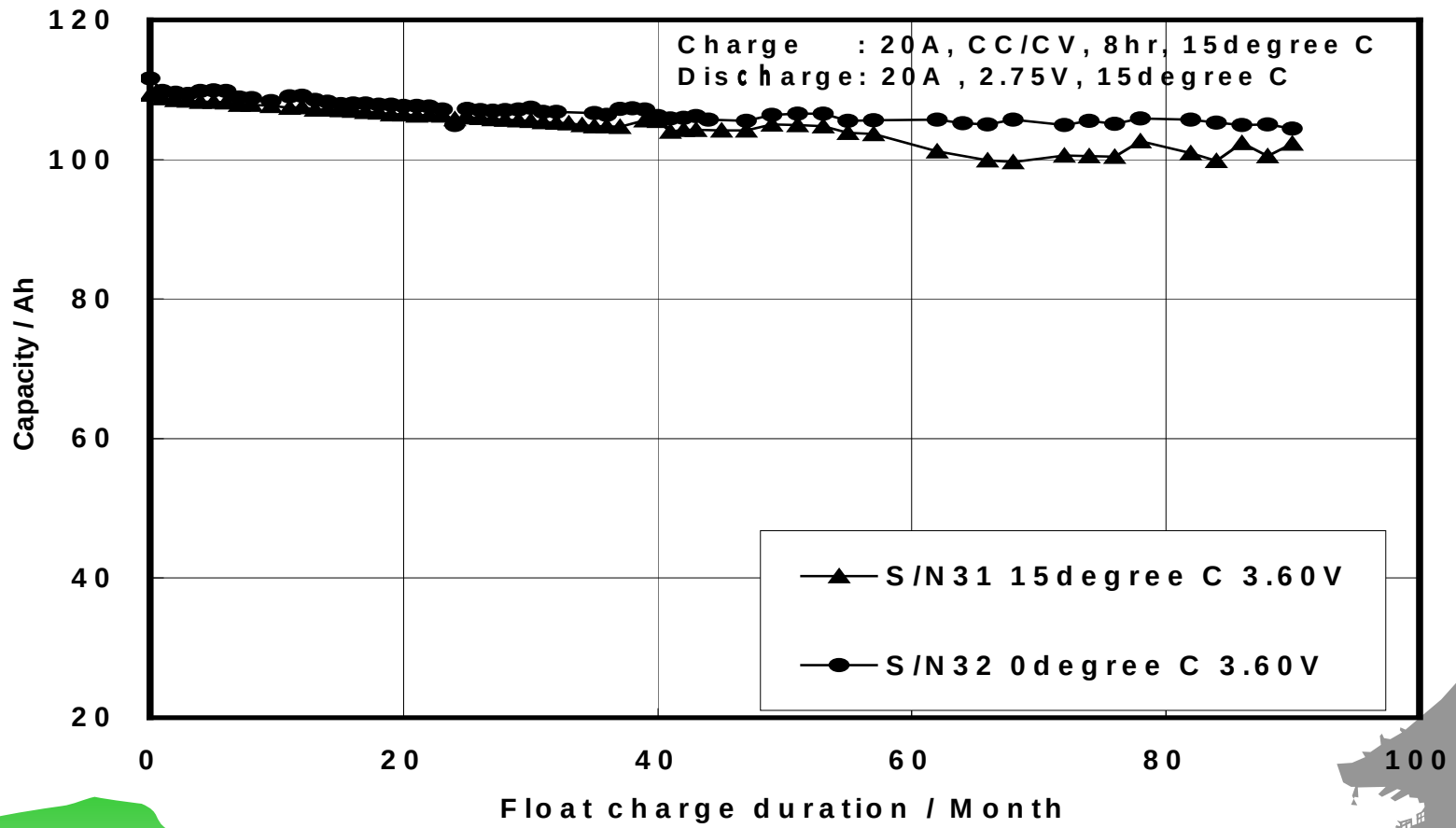
Float charge storage test at SOC60%



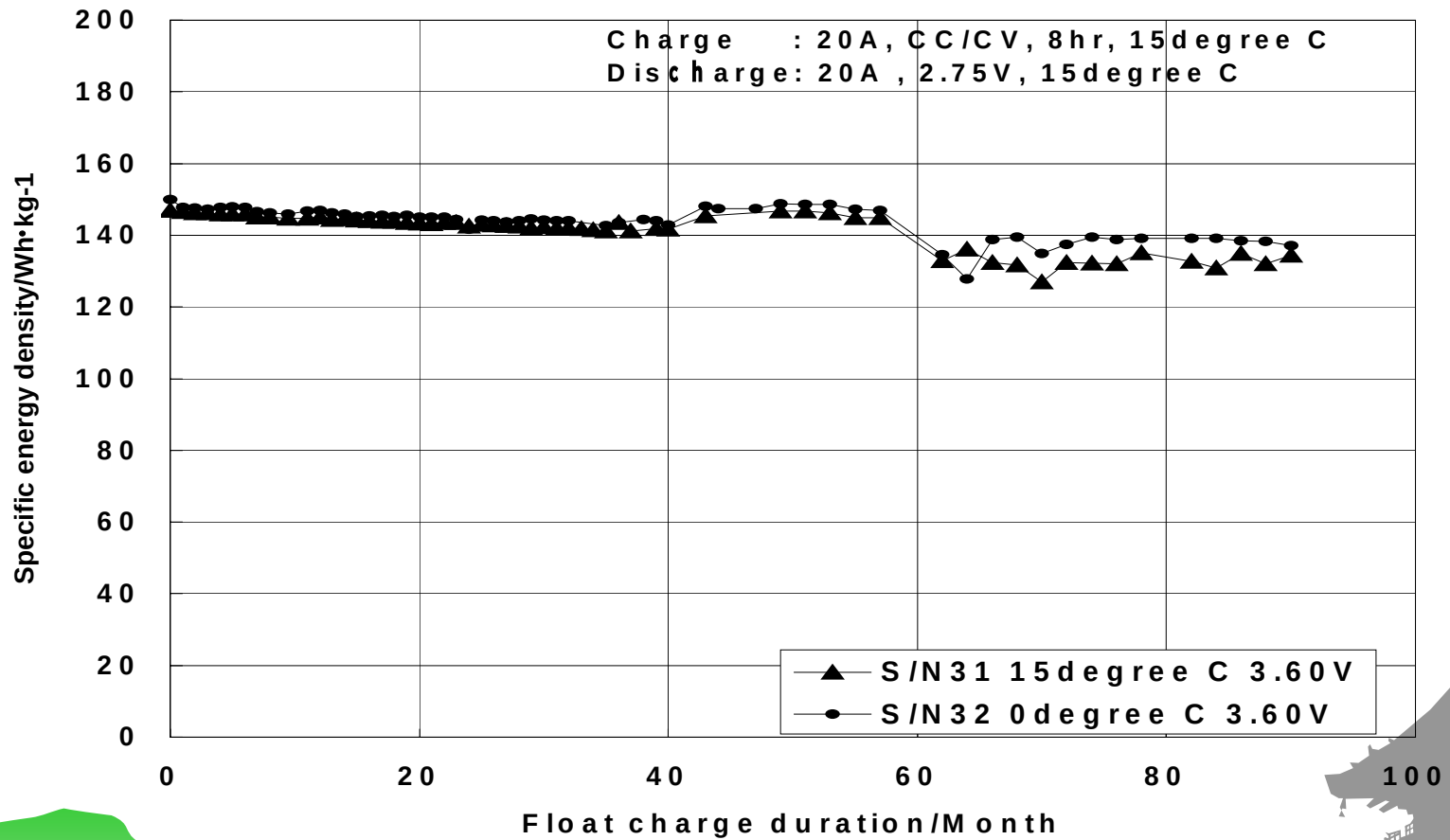
Float charge storage test at SOC60%



Float charge storage test at SOC 5%



Float charge storage test at SOC 5%



Conclusion

1. Semi - accelerated GEO tests which gives both calendar and cycle loss have been reached more than 30 season that corresponds 15 years in orbit.
   The specific energy range is 120 - 130 Wh/kg at EOL.

2. Real time LEO tests have been reached 7 – 7.5 years on orbit. (DOD 40% 28,000 cycles – DOD 12% 72,000 cycles)
   The specific energy range is 100 - 110Wh/kg at EOL.

3. Storage tests have been reached 8 years.
   The capacity losses are 15% at 100% SOC, 15 deg. C and 9% at 5% SOC, 15 deg.C

Acknowledgement

I would like to thank

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MELCO

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