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SPECIFICATION of NAS® BATTERY Subunit for the Integration of NAS Battery System

Prepared for Customer, System integrator

by NGK INSULATORS, LTD.

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(3) In this document, only the specifications at DC side are described and values at AC side are for reference only.

(4) This document describes the technical design of NAS battery system only. The commercial terms including warranty shall be defined by the commercial contract.

(5) Color copy is preferable to read this document.

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INPORTANT NOTICE: The Specification and Data provided in this document is based on the laboratory evaluation, simulation and/or testing under certain condition. The actual operation performance, energy capacity, deterioration, lifetime shall depend on the operation condition, environment whatsoever and shall not consistent completely to the figures provided hereto.

1 INTRODUCTION

1.1 NAS Battery System Description Summary

A battery energy storage system (BESS) using a container type NAS battery system is composed of the elementary subunit which consists of 1 to 4 NAS battery container(s). The NAS battery container contains 6 NAS battery modules connected in series, as well as the auxiliaries for control and monitoring in a 20 feet container.

The overview of the specifications of subunit is as shown in table 1. Up to 4 of those containers can be put in series, forming a single power source that can be connected to an AC grid via a Power Conversion System (PCS). The DC strings of the same size of subunit can be connected in parallel to a PCS, depending on its specifications.

Table 1. Data sheet for NAS battery subunit

Type of subunit	1S	2S	3S	4S
Number of battery container(s) connected in series	1	2	3	4
Rated Discharge Power [kW-DC] *2*8	250	500	750	1000
Rated Charge Power [kW-DC] *2*8	250	500	750	1000
Dischargeable Energy [kWh-DC] (BoL) *3	1450	2900	4350	5800
Expected Degradation Ratio *1*4	< 1% Dischargeable Energy (BoL) / 365 equivalent cycle			
Rated DC Voltage [V] *9	139~228	278~456	417~684	556~912
DC Current [A]	-1200~+1500 A			
Expected Battery Lifetime *1*6*7	20years, 7300 equivalent cycle*5			

* BoL = Beginning of Life
* The definition of equivalent cycle is described in the Appendix 1.

Note:
1. These numbers in Table 1 are the designed value under certain condition. These are reference purpose only and NOT a guaranteed value.
2. There are some restriction on the discharge duration, discharge / charge power depending on the discharge or charge profile. (The details are described in Section 4)
3. The value is based on the reference profile that is indicated in section 4.3.1. The actual system might not be achieved this value due to the different operation profile.
4. The expected degradation ratio is an average value of 100MW system (100 sets of 4S-Subunit) based on the simulations under certain condition.
5. 20 years or 7300 equivalent cycle whichever comes first
6. The expected battery lifetime is NOT a part of any guaranty nor warranty of NAS battery including its performance or capacity provided by NGK, unless otherwise specifically agreed in writing by duly authorized representatives.

7. The expected battery lifetime is designed under the condition that the battery module would never be low temperature (less than 250°C) after reaching 15 years operation.
8. “Rated” Power is defined as “Maximum” Power.
9. “Rated” Voltage is the DC voltage range over the lifetime, which is to show the requirements for respective PCS.

1.2 Scope of Supply

1.2.1 Equipment of NAS Battery System

(1) Contents of NAS Battery subunit

A basic layout of assembled 4S-subunit is shown in figure 1. The structure of a container is based on ISO standard 20ft. container: 6.058W x 2.438D x 2.591H (m). In addition, the battery container is with CSC certification which can be delivered as a marine transportable container and double stacked to make achieve high energy density. Each container contains 6 NAS battery modules and the weight of a container is approximately 21 ton.

The containers of a string (up to 4) are monitored and controlled by a single Battery management System (BMS) located in the named “Main Container”. The other containers of the string are named “Sub Container”.

Supply item for each subunit:

1S-subunit: 1 Main Container

2S-subunit: 1 Main Container and 1 Sub Container

3S-subunit: 1 Main Container and 2 Sub Containers

4S-subunit: 1 Main Container and 3 Sub Containers

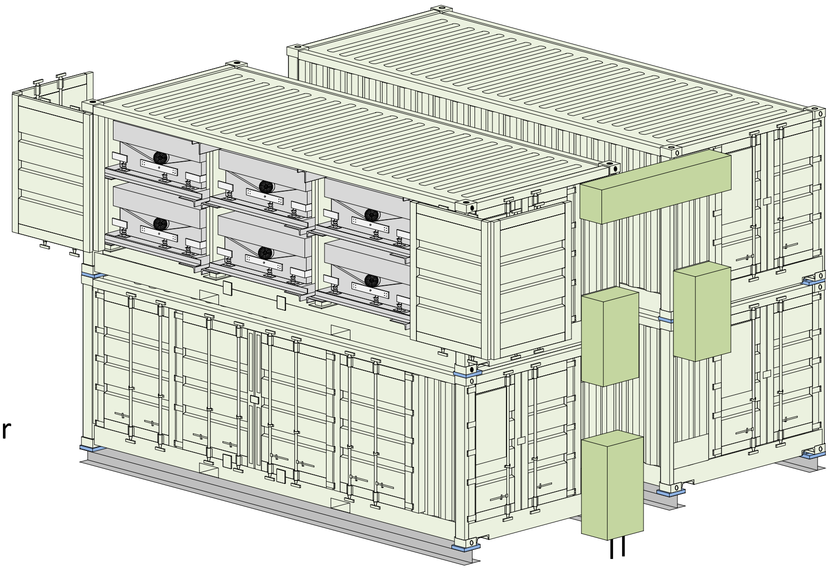


Figure 1. Example of layout for a 4S-subunit

1.2.2 Site Installation and Commissioning Test

The installation work and commissioning test is out of scope of NGK. Manuals (see 1.2.4 below) are provided by NGK to allow the Contractor to perform the installation with skilled, experienced and trained staff. However, witness of Technical Direction Advisory (TDA) engineer for the installation work and commissioning test is necessary and one of conditions of warranty. Depending on the sales contract, TDA can be provided as an optional service to support installation and commissioning test by on-site or remote. The details of scope of TDA shall be discussed and mutually agreed under a contract. For the avoidance of doubt, the TDA provides only technical suggestions and advises. The TDA does not conduct the actual field work and does not have responsibility of installation's quality. In any case, NAS batteries installation and commissioning are performed under the responsibility of the Contractor.

1.2.3 Contents of Factory Test

The standard tests to check the quality of NAS battery system is as follows;

1. Battery Module test — appearance, dimension, heater resistance, insulation test, charge/discharge test
2. Battery container test — appearance, dimension
3. Battery controller test — appearance, dimension, insulation test, function test.

Note: if there is special request or the contents need to be discussed before a contract, otherwise, these NGK standard test items are regarded as accepted factory test in the manufacturing process.

1.2.4 Documentation

Project documentation supplied by NGK is listed below. Unless otherwise specified in these documents, all work shall be in accordance with the principles and intent of International Electrotechnical Commission (IEC) standards.

NGK Documentation for NAS Battery System

- NAS Battery System Specifications
- Approval drawings
- Factory Test Report
- Installation Manual
- Site Test Procedure
- Site Test Report
- Transportation and Storage Manual
- Operation Manual
- Maintenance Manual

Note: if there is special request or the contents such as interpretation of any incomplete or disputed standard, it shall be discussed before a contract.

1.2.5 Standards

1.2.5.1 EC Declaration

The product will be in conformity with EC laws as follows to achieve EC Declaration of conformity.
EC Declaration of Conformity is under preparation.

Note: EC Declaration will be updated to conform the update of applicable standards.

The compliance directives for EC law are shown as below.
(1) Electromagnetic Compatibility Directive, 2014/30/EU
EN 55011: 2016+A1:2017+A11:2020
Industrial, scientific and medical (ISM)
Radio-frequency equipment -
Electromagnetic disturbance characteristics -
Limits and methods of measurement

EN 61000-6-2: 2005
Electromagnetic compatibility (EMC)
Part 6: Generic standards
Section 2: Immunity for industrial environments

(2) Low Voltage Directive (Safety design), 2014/35/EU
EN 60204-1: 2018
Safety of machinery - Electrical equipment of machines
Part 1: General requirements

EN 61010-1: 2010+A1:2019
Safety requirements for electrical equipment for measurement, control, and laboratory use –
Part1: General requirements

Note: The reason of using these standards is as follows;
This decision was made under consultation of Notified body.

1) There is no “product standard” for this kind of product (NAS battery system), so NGK selected EN61010-1 assuming that the standard is a kind of “Generic standard” for this kind of industrial products.

2) This system is assumed as assembly of “Panel”, so NGK selected EN 60204-1 as a standard for panels.

Consistently with above, specific IEC standards are shown as below.
- IEC 61000-4-2: 2008
Electromagnetic compatibility (EMC)
Part 4: Testing and measurement techniques
Section 2: Electrostatic discharge immunity test

- IEC 61000-4-3: 2006+A1: 2007+A2: 2010
  Electromagnetic compatibility (EMC)
  Part 4: Testing and measurement techniques
  Section 3: Radiated, radio-frequency, electromagnetic field immunity test

- IEC 61000-4-4: 2012
  Electromagnetic compatibility (EMC)
  Part 4: Testing and measurement techniques
  Section 4: Electrical fast transient/burst immunity test

- IEC 61000-4-5: 2014
  Electromagnetic compatibility (EMC)
  Part 4: Testing and measurement techniques
  Section 5: Surge immunity test

- IEC 61000-4-6: 2013
  Electromagnetic compatibility (EMC)
  Part 4: Testing and measurement techniques
  Section 6: Immunity to conducted disturbance, induced by radio-frequency fields

- IEC 61000-4-8: 2009
  Electromagnetic compatibility (EMC)
  Part 4: Testing and measurement techniques
  Section 8: Power frequency magnetic field Immunity test – Basic EMC Publication

- IEC 61000-4-11: 2004
  Electromagnetic compatibility (EMC)
  Part 4: Testing and measurement techniques
  Section 11: Voltage dips, short interruptions and voltage variations immunity tests for equipment with input current up to 16 A per phase

1.2.5.2 UL Standards

The NAS Battery Cell and Module are certified by UL Solutions as a recognized component to UL 1973, the Standard for Batteries for Use in Stationary and Motive Auxiliary Power Applications. Additionally, our NAS Battery Cell and Module have been evaluated using UL Solutions UL 9540A, the Standard for Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems.

1.2.6 Warranty Terms

This specification describes the design of NAS battery system only. Any kinds of warranty terms shall be determined by commercial contract.

2 BASIC SYSTEM DESIGN SPECIFICATION

2.1 Site Conditions - Exterior

The site condition for NAS Battery System shall be under the following standard*:

・Site condition: .... Outdoor
・Ambient Temperature: .... -20 to +45 degrees C
・Relative Humidity (annual average):..................... 15% to 85% without dew condensation
・Altitude:... 1,000m or less
・Seismic: .... Static Horizontal Acceleration 1.0G
(with NGK designed standard channel base)
・Snow accumulation:... Less than 1 meter high
・Other Environmental Condition: .... No corrosive gases or salt-air damage

* If the site condition is not in the range of the above standard site condition, some conditions would be relaxed with optional items as follows. The conditions and options shall be discussed before purchase;

・High temperature area (+45~+55 degrees C): Installation of sunshade/roof (prepared by contractor), Additional cabinet cooler
・Low temperature area (-20 ~ -40 degrees C): Additional heater, Installation of heat insulating material inside the container
・Costal area: Anti-salt filters
・Snowing area: the air inlet/outlet for NAS battery system have to be secured.

2.2 System Configuration

NAS battery subunit consists of one Main Container and up to three Sub Containers based on the size of subunit. Six battery modules are arranged in three stacks of two modules high in each Container. The Battery Management System consists of one Main Control Unit (in Main Container) which manages NAS battery subunit including communication with PCS controller (or EMS) and three Sub Control Units (one in each Sub Container) which manages equipment installed in each Sub Container.

2.3 Specifications of NAS battery subunit

Specifications of NAS battery subunit are described in table 2. In addition to the information, Section 4 Operational Characteristics needs to be considered for practical operation.

Table 2. Specification of NAS battery subunit

(1) 1S-subunit (a Main container system)

1	Rated Discharge Power*7	DC 250 kW*1
2	Rated Charge Power*7	DC 250 kW*2
3	Supplementary Charge at near end charge	Stepwise charge process at the charge end*3
4	Dischargeable Energy	DC 1,450 kWh at BoL *4
5	Rated DC Voltage*8	DC 139 - 228 V
6	DC Current	-1200 to +1500 Amps (“-” Charge, ”+” Discharge)
7	DC Current Ripple	<10%p-p / DC 250kW (request for PCS)
8	Auxiliary Power (Control, Heater Power etc.)	3 Phase, 3 Wires AC400 - 480V(50/60Hz) *5, 30kW (for 1 battery containers) at AC440V

(2) 2S-subunit (a Main container and a Sub container system)

1	Rated Discharge Power*7	DC 500 kW*1
2	Rated Charge Power*7	DC 500 kW*2
3	Supplementary Charge at near end charge	Stepwise charge process at the charge end*3
4	Dischargeable Energy	DC 2,900 kWh at BoL *4
5	Rated DC Voltage*8	DC 278 - 456 V
6	DC Current	-1200 to +1500 Amps (“-” Charge, ”+” Discharge)
7	DC Current Ripple	<10%p-p / DC 500kW (request for PCS)
8	Auxiliary Power (Control, Heater Power etc.)	3 Phase, 3 Wires AC400 - 480V(50/60Hz) *5, 60kW (for 2 battery containers) at AC440V

(3) 3S-subunit (a Main container and two Sub containers system)

1	Rated Discharge Power*7	DC 750 kW*1
2	Rated Charge Power*7	DC 750 kW*2
3	Supplementary Charge at near end charge	Stepwise charge process at the charge end*3
4	Dischargeable Energy	DC 4,350 kWh at BoL *4
5	Rated DC Voltage*8	DC 417 - 684 V
6	DC Current	-1200 to +1500 Amps (“-” Charge, ”+” Discharge)
7	DC Current Ripple	<10%p-p / DC 750kW (request for PCS)
8	Auxiliary Power (Control, Heater Power etc.)	3 Phase, 3 Wires AC400 - 480V(50/60Hz) *5, 90kW (for 3 battery containers) at AC440V

(4) 4S-subunit (a Main container and three Sub container system)

1	Rated Discharge Power*7	DC 1000 kW*1
2	Rated Maximum Charging Power*7	DC 1000 kW*2
3	Supplementary Charge at near end charge	Stepwise charge process at the charge end*3
4	Dischargeable Energy	DC 5,800 kWh at BoL *4
5	Rated DC Voltage*8	DC 556 - 912 V
6	DC Current	-1200 to +1500 Amps (“-” Charge, ”+” Discharge)
7	DC Current Ripple	<10%p-p / DC 1000kW (request for PCS)
8	Auxiliary Power (Control, Heater Power etc.)	3 Phase, 3 Wires AC400 - 480V(50/60Hz) *5, 120kW (for 4 battery containers) at AC440V

*1,*2 Charge/Discharge power may be limited in time, depending on the discharge or charge profile

*3 Details are described in section 4.4.

*4 The value is based on the reference profile that is indicated in section 4.3.1. The actual system might not be achieved this value due to the different operation profile.

*5 The auxiliary power at AC380V can be an optional design. In case at AC480V, 35kW per container is required.

*6 The max. power and capacity are confirmed based on the manufacturer’s technical data.

*7 “Rated” Power is defined as “Maximum” Power.

*8 “Rated” Voltage is defined as the “Maximum Range” of the Voltage over the lifetime.

3 NAS BATTERY SYSTEM COMPONENT SPECIFICATION

Component specifications for the NAS Battery Subunit described in Section 2.2 are presented in the following subsections.

3.1 Battery Container (applicable for Main and Sub Container)

1	Structure	20ft container
2	Paint Color	RAL 9010
3	Dimensions	About 6,058W x 2,438D x 2,591H [mm]
4	Weight	Approx. 21,000kg
5	Cooling	Natural air cooling except Main Control Unit area (Air conditioner is used for Main Control Unit Area)
6	Content	Six battery modules (2 rows and 3 columns) [see in table 3.2 for module specifications] One Main Control Unit (in Main Container) [see in table 3.3 for Main Control Unit specifications] One Sub Control Unit (in Sub Container) [see in table 3.4 for Sub Control Unit specifications]
7	Protection Rating	IP54
8	Sound Level (Reference)	60 dB(A) at the 1.5m distance from a container, 1.2m height

3.2 Battery Module (for reference only)

1	DC Voltage	Rated: DC 32V
2	Supplementary Charge	Stepwise charge process at charge end. (Details are described in 4.2)
3	Max. Dischargeable Energy (at initial)	DC 242 kWh at BoL
4	Operational Temperature Range	305 - 340 degrees-C
5	Withstand DC Voltage	3,000V x 10 minutes at 300 degrees C
6	Insulation Resistance	> 30Mohm / DC 1000V at 300 degrees C
7	Heat Insulation System	Doubled-Walled Stainless Steel Thermal Enclosure
8	Cooling System	Forced Air Cooling
9	Heating System	Electric-Heaters Inside Module (3.6kW at 440V-AC)
10	Heat Loss	1,000W (without battery fan operation) >5,700W (with battery fan operation)
11	Dimensions	1,500W x 2,000D x 802H [mm] (including slide base attached)
12	Weight	2,300 +/- 100 kg (including slide base)
13	Cells connection	8 series x 12 parallel x 2 block, 192 cells

3.3 Main Control Unit

1	Structure	Integrated in controller room in the Main Container
2	Auxiliary Power (Control, Heater Power etc.)	3 Phase, 3 Wires AC400 - 480V(50/60Hz) To be supplied from external system such as PCS, customer's LV distribution panel Note: AC 380V (50/60Hz) can be an optional design
3	Built-in Parts	DC load break switch DC Fuse DC current transformer Circuit breakers for auxiliary circuit Main controllers Battery module controller Battery heater control switches
4	Interface with Sub Container	Ether CAT
5	Interface with PCS controller	Modbus TCP
6	Monitoring	
a)	Battery States	- Ready for Operation - Charging/Discharging - Standby
b)	Parameter Monitored	- DC Current - Module Internal Block Voltage - Module Internal Temperature
c)	Failure Indication	- Battery Faults - Control Faults
7	Man-Machine Interface	LCD Display
8	Withstand Voltage	
a)	Between battery module terminals and ground	3,000VDC for 10 minutes
b)	Between heater power supply terminals and ground	2,000VAC for 1minute
c)	Between control power supply terminals and ground	2,000VAC for 1minute
d)	Between other terminals and ground	500VAC for 1minute
9	Main Functions	
a)	Battery Module Protection	Detect and Trip on: - Over-Current - Abnormal Voltage Condition - Abnormal Temperature Condition
b)	Battery Voltage Supervising Function	Detect and Prevent - Over-Charging / Over-Discharging
c)	Measurement	DC Current Battery module voltage Battery module temperature
d)	Battery Temperature Control	Battery module heaters Battery module fans
e)	Communication Function	Transmit Control Signal to PCS (or EMS)

3.4 Sub Control Unit

1	Structure	Integrated in controller room at Sub Containers
2	Auxiliary Power (Control, Heater Power etc.)	3 Phase, 3 Wires AC400 - 480V(50/60Hz) supplied from Main Container 1 Phase AC100V supplied from Main Container Note; AC 380V (50/60Hz) can be an optional design.
3	Built-in Parts	Circuit breakers for auxiliary circuit Battery module controller Battery heater control switches
4	Interface with Main Container	Ether CAT
5	Withstand Voltage	
a)	Between battery module terminals and ground	3,000VDC for 10 minutes
b)	Between heater power supply terminals and ground	2,000VAC for 1minute
c)	Between control power supply terminals and ground	2,000VAC for 1minute
d)	Between other terminals and ground	500VAC for 1minute
6	Main Functions	
a)	Measurement	Battery module voltage Battery module temperature
b)	Battery Temperature Control	Battery module heaters Battery module fans
c)	Communication Function	Transmit Measurement data to Main Container

4 OPERATIONAL CHARACTERISTICS OF “A NAS BATTERY CONTAINER”

4.1 Discharge and Charge at variable power

NAS Battery System can discharge and charge at specified power range (detailed in clause 2.3) and conduct a variety of services such as load leveling of day/night, renewable energy shift, ancillary service, etc. The Battery System can be cycled multiple times in a day as far as the operation condition is within the following “Operational Limitation”. PCS shall control the NAS Battery System within the Operation Limitation, otherwise it may result in accelerating the deterioration, or other unexpected system suspension.

Operational limitation of NAS battery:
For the following three operational limitations, PCS shall control the NAS Battery System according to the signal from BMS.

- Fully charged state:
  The battery system cannot be charged after the battery is fully charged (typically, SOC = 100%). BMS will send the PCS the demand to stop charging. This charge limitation will be activated till the battery is discharged to SOC = 93% to avoid over charging. (Note: the restarting SOC =93% is at initial status only, and will be adjusted by BMS depending on the degradation of battery module)
- Fully discharged state:
  The battery system cannot be discharged after the battery is fully discharged (typically, SOC = 0%). BMS will send the PCS the demand to stop discharging. This discharge limitation will be activated till the battery is charged to SOC = 7% at initial to avoid over discharging. (Note: the restarting SOC =7% is at initial status only, and will be adjusted by BMS depending on the degradation of battery module)
- Maximum discharge/charge power limitation:
  The battery module controller (BMS) monitors the current, voltage and temperature of each battery module under its control. Consequently, BMS will from time to time calculate the resulting range of available maximum charging/discharging power and send the PCS the demand for control of limitation. The factors of the power limitation are shown in section 4.3.2 and 4.4.

For the following two operational limitations, PCS shall control the NAS Battery System according to its own judgement of situation. BMS does not send PCS the signal for these operational limitations.

- Ramp rate and power restriction when the SoC is greater than 80%:
  PCS shall control the ramp rate of discharging and charging power and power restriction of minimum charging power according to the following table when the SoC value sent from BMS is greater than 80%.

Type of subunit			1S	2S	3S	4S
Maximum ramp rate	Discharge (kW-DC/sec)	Increase	52	104	156	208
		Decrease	No limitation			
	Charge (kW-DC/sec)	Increase	10	19	29	38
		Decrease	No limitation			
Minimum Power charging(kW-DC)			48	96	144	192
Range of SOC for this condition			80~100%			

In case PCS efficiency is 96%, ramp rate and power restriction as AC value are as follows.

Type of subunit			1S	2S	3S	4S
Maximum ramp rate	Discharge (kW-AC/sec)	Increase	50	100	150	200
		Decrease	No limitation			
	Charge (kW-AC/sec)	Increase	10	20	30	40
		Decrease	No limitation			
Minimum Power charging(kW-AC)			50	100	150	200
Range of SOC for this condition			80~100%			

- Minimum discharging/charging power:
  In case the target power is less than 3% of maximum power, the output should be 0 kW-AC and PCS should be gate blocked to avoid over discharge/charge by inaccurate measurement of power output.

4.2 Energy capacity of a NAS battery container through the battery life

Likewise other secondary batteries, NAS battery cannot avoid the capacity decrease due to degradation. The expected design value of energy capacity of a NAS battery container through its lifetime is presented in Figure 2. Equivalent cycle is defined in Appendix 1. The graph shows the Base profile, profile A, and profile B considering the 2 kinds of major battery degradation condition:

1. The aging of the cells that results in an increase of their internal resistance.
   The estimated degradation curve of a NAS container considering the effect of aging is shown for reference as the Base Profile in the following chart.

2. Cells failures.
   A battery module contains 192 cells in total which are arranged in 2 blocks of 12 parallel strings of 8 cells each (12parallel x 8series x 2block). When one cell fails, for any reason, the corresponding string becomes electrically inactive and the dischargeable energy capacity of the battery module decreases. As the number of inactive strings increases, it directly affects the degradation of the system capacity.
   Profile A and B in the following chart shows the estimated energy capacity, for reference, linked with one and two inactive strings and the aging degradation respectively.

   Note: With one or two inactive strings, a module as well as the subunit it belongs to is still operational other than lower capacity as estimated in Figure 2. A module with more than three inactive strings needs stronger constraints based on the condition to continue the operation .
   In case of cell failures, the customer can decide to replace or repair the module. The allocation of the replacement and repair costs depends on the terms of the commercial contract.

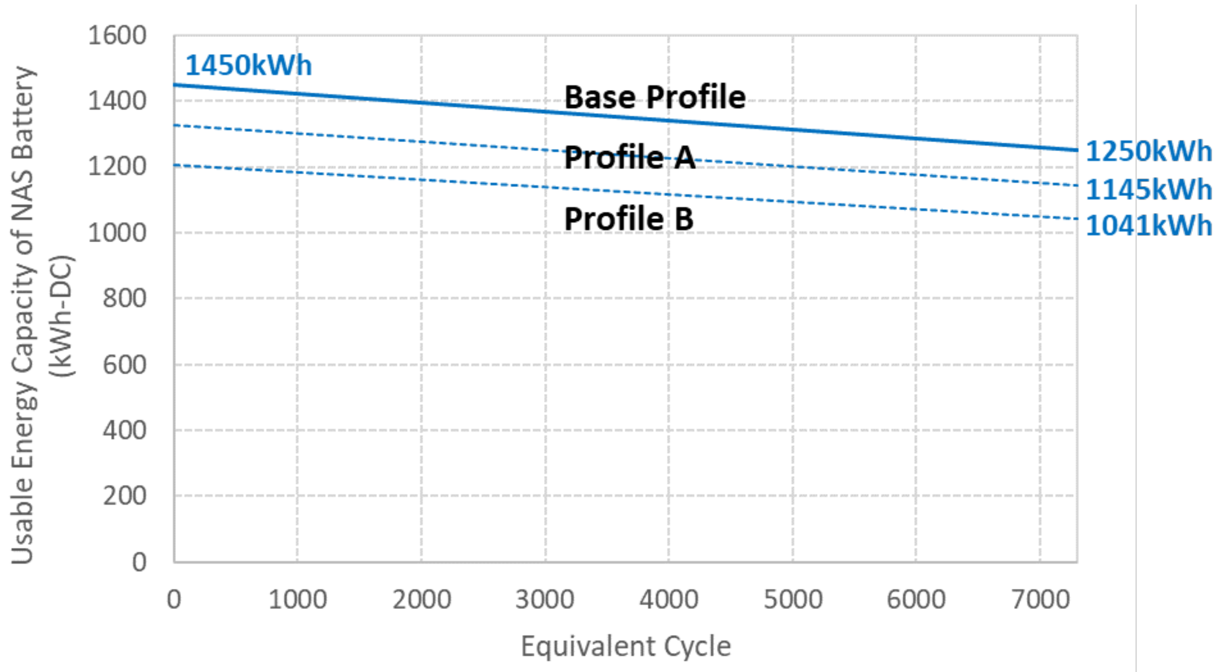


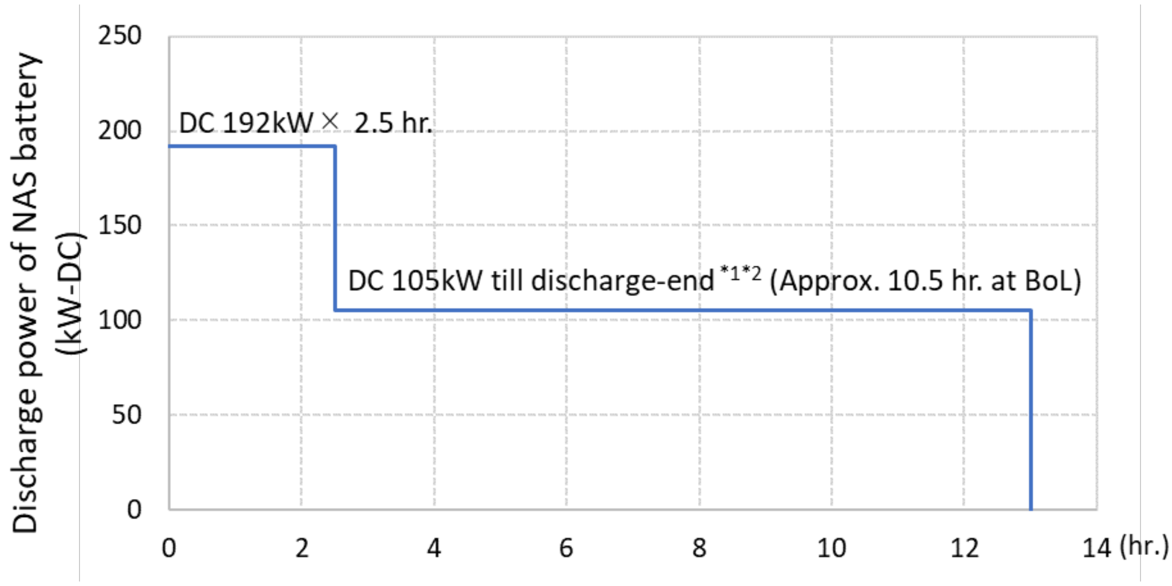
Figure 2. Energy capacity of a NAS Battery Container for equivalent battery cycle

Remark: End of life of a NAS battery system is when its BMS has counted 7,300 equivalent cycles.

4.3 Operational Characteristics for Discharge

4.3.1 Reference discharge profile of a NAS battery container

Figure 3 shows the reference profile for discharge starting from SoC 100% and battery temperature 305-degree C. This profile is used to measure the battery discharge capacity in order to perform the capacity test including the performance guarantee, depending on the commercial contract terms.



*1: Discharge-end means BMS detects fully discharged state.

*2: Discharge power is limited at near discharge-end according to current limitation (Details are described in Appendix 2).

Figure 3. Reference discharge profile per NAS battery Container for capacity test

4.3.2 Discharge Power Limitation

BMS detects the following limitations for discharge power.

(1) Temperature limit:

The temperature of NAS Battery tends to increase during discharging because of its exothermic reaction (In opposition, charging is endothermic reaction). It's a control function so as that all the internal temperature of battery modules are not to exceed maximum operational temperature (around 340 degree C).

(2) DC discharge current limit:

When NAS Battery is discharged by high power, battery current increases due to the decreased open circuit voltage and/or the increased internal resistance. It's a control function so as that the battery current is not to exceed maximum battery current (DC 1,500A).

However, for avoiding the acceleration of the battery degradation, even DC current is less than DC 1,500A, the battery current is limited when battery is deeply discharged. Details are described in Appendix 2.

4.3.3 Continuous discharge duration of a NAS container through the battery life

Continuous discharge duration is generally limited by the battery maximal operation temperature and DC discharge current.

Figure 4 shows the maximal continuous discharge duration through the battery lifetime in function of the equivalent cycle (see Appendix 1), at different power rate in the range DC 125～250kW.

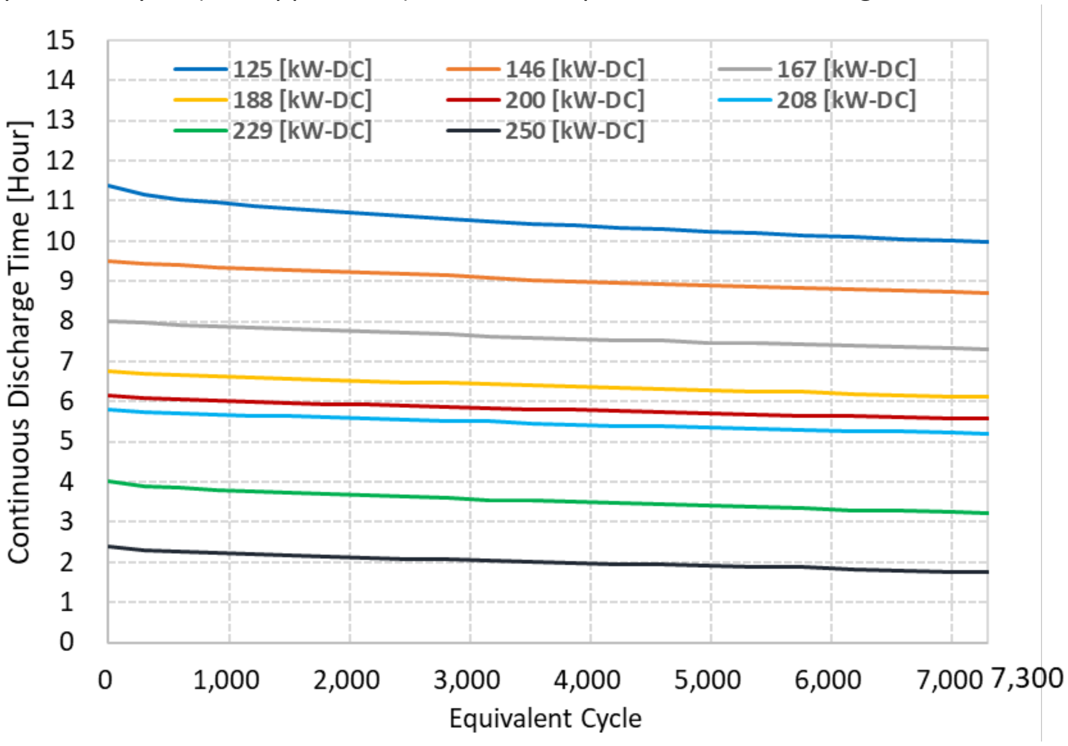


Figure 4. Available continuous discharge duration of a NAS Battery Container over the equivalent battery cycle

*The values in Figure 4 are based on the simulations under certain condition. Therefor the actual continuous discharge duration shall depend on each battery degradation, operating and environment condition.

4.4 Operational Characteristics for Charge (Supplementary charging)

NAS battery can charge continuously, however, the power needs to be reduced at the near charge end (~95% of SoC at initial) in several steps. ("Supplementary Charging")
The conceptual image is shown on figure 5.
BMS will send the PCS a signal of reduced maximum charging power when the measured battery block voltage reaches a certain level. The PCS (or EMS) shall reduce the power accordingly, or otherwise it may result in accelerating the deterioration, or other unexpected system suspension.

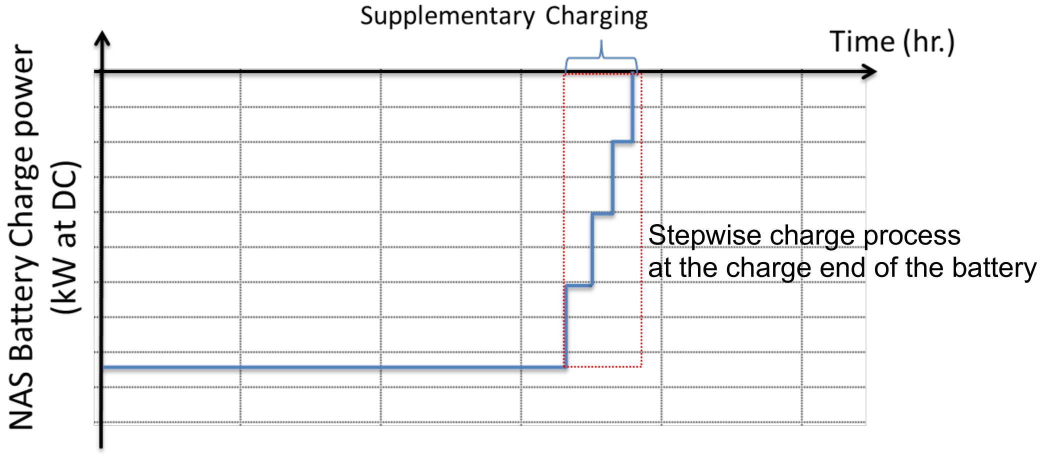


Figure 5. Operational Characteristics of NAS battery (Charge)

4.5 SOC calibration and requirement of SOC calibration

4.5.1 About SOC calibration

Periodic calibration is required to keep the measurement error of SOC within the acceptable level. As the BMS is monitoring SOC to activate the limitation which is described in Appendix 2 to avoid highly stressed operation, the lack of SOC calibration may lead to acceleration of the battery degradation.

There are two kinds of SOC calibration function. Those are (1) "Charge-end calibration" and (2) "Near discharge-end calibration".

(1) "Charge-end calibration" is done immediately after "Full Charging" is completed. So, waiting time at charge end is not required to calibrate.

(2) "Near discharge-end calibration" is done when there is no discharging/charging operation for more than 30 minutes at low SOC by measurement of open circuit voltage of the battery. BMS shows the timing of Near discharge-end calibration by activating the signal of "Gate Block Suggestion (SOC Cal.)".

4.5.2 Requirement of SOC calibration

When the SOC calibration has not been done for consecutive 7 days, "SOC Calibration Suggestion" signal is activated and sent from BMS to PCS to recommend intentional SOC calibration. If "SOC Calibration Suggestion" signal is activated, it is mandatory to make a chance whichever "Charge-end calibration" or "Near discharge-end calibration" within 7 days.

5 REMOTE MONITORING

5.1 Proposed Schematic of Remote Monitoring System

NGK has established the remote monitoring system based on VPN technology. The following figure shows the schematic of the remote monitoring system. Basically, NGK get and check the battery data once a day to monitor the battery data such as the voltage, the current, and the internal temperature of the battery. In case of abnormality occurs, NGK will get and check the data more frequently.

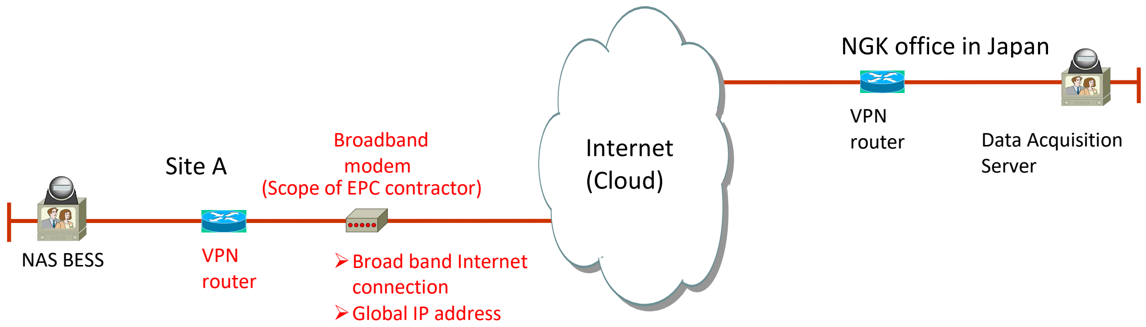


Figure 7. Example of a Schematic Remote Monitoring System

5.2 Required Items and Infrastructures to be prepared by CUSTOMER

CUSTOMER shall prepare and install the following items to enable the NAS battery system to access Internet for building VPN between the installation site and NGK office in Japan by the date of starting of the battery heating during the site testing.

- VPN Router
- Broad band Internet connection such as ADSL (Faster than 1 Mbps is recommended)
- Static IP address for VPN router
- Laying Ethernet cable between the Main Control Unit and the VPN router
  (Optical fiber with SC connectors or LAN cable with RJ45 connectors)

6 SAFETY AND OPERATING PRECAUTIONS

6.1 General

This section provides important information on both safe operation and limiting conditions of operation. Operation beyond the limits prescribed herein will void any warranty provided by NGK.

- The NAS Battery Instruction Manual provides detailed procedures for NAS Battery System operation. Operator training is provided prior to commissioning.
- Only personnel properly trained on the NAS Battery System should be permitted to operate and maintain the installation. Proper knowledge of the NAS Battery System's safety features is essential for safe operation and adequate maintenance.
- The NAS Battery Material Safety Data Sheet (MSDS) 00230252 contains important information on hazardous materials within the battery cells and guidance on response to emergency events.

The following sections provide precautions for potential hazards in two categories:

DANGEROUS *"DANGEROUS" indicates a hazard that may cause serious personal injury or death and/or damage to equipment.*

CAUTIONARY *"CAUTIONARY" indicates a hazard that may cause significant personal injury and/or damage to equipment.*

Notes:

1. A hazard categorized as "CAUTION" may progress to the "DANGER" category, depending on the situation. Be sure to observe precautions in both categories as they provide important safety messages.
2. The phrase "serious personal injury" means injuries such as loss of eyesight, skin burns (high and low temperature), electrical shocks, broken bones, or poisoning that may require hospitalization or long-term medical care.
3. The phrase "significant personal injury" means injuries such as skin burns or electrical shocks that might require medical care.
4. The phrase "damage to equipment" means sufficient loss of equipment functional performance that repair or replacement is expected.

These safety precautions supplement design features that provide for the safe use of the NAS Battery System. The owner is advised to establish an internal safety policy in accordance with prevailing practices for the safe operation of electrical equipment and facilities.

6.2 Safety and Operating Precautions Categorized "DANGEROUS"

(a) Do not touch energized parts of battery modules.

The NAS battery is electrically charged before it leaves the factory and can deliver severe electric shock under all operating and shutdown states, including shipping and storage at ambient temperatures.

(b) Do not touch energized parts of the battery system, including the PCS and battery control unit.

The battery modules, power conversion system (PCS), and battery management supply and control charge and discharge power, heater power, and power for instrumentation to measure battery voltage and temperature. Touching the energized parts of these components will result in electric shock. Inspection of the PCS and battery control unit should be conducted when they are not energized.

(c) Do not remove the main battery connection cables.

Do not remove the main cables connecting the batteries and other system components. Removing the cables while charging or discharging may cause a high intensity electrical arc, potentially resulting in a fire or personnel injuries such as electrical shocks and burns.

(d) Do not go near the battery when a noxious odor is present.

The presence of a noxious odor in the vicinity of the battery may be due to the formation of toxic SO2 gas. Do not go near the battery. Refer to the NAS Battery MSDS. Notify a trained operator to direct the identification of and response to potentially hazardous materials.

(e) Do not disassemble battery modules.

Electrical insulation inside the double-walled, stainless steel module containers is provided to ensure electrical safety. Disassembling the battery modules may degrade insulation performance resulting in electrical shocks, short circuits to ground, etc.

6.3 Safety and Operating Precautions Categorized “CAUTIONARY”

(a) Do not touch the module container.

The temperature inside the insulated double-walled, stainless steel module containers is maintained at 280 to 360°C. The surface of the module container may exceed 60°C. Touching the surface may cause skin burn.

(b) Do not approach close to the air outlet hood at the rear side of the battery container during operation.

The exhaust air suddenly starts emitting from the air outlet hood when the battery module fan starts running based on the battery status. The temperature of the exhaust air may reach maximum 100 degree C. Exposed the high temperature exhaust air may cause skin burn.

(c) Allow sufficient time for automatic voltage cut-off during battery charging when used for continuous Load Leveling operation.

The battery is designed for charging to continue until terminated by the battery control unit at the “charge-end condition” when used for continuous Load Leveling operation. If charging is not allowed to proceed to automatic completion, stored energy capacity may not be enough for discharge pattern on following day.

(d) Do not change system default settings.

Default settings are at optimal values for the protection of the overall NAS Battery System. If a change is being considered due to a perceived deficiency in battery system performance, consult NGK.

(e) Do not tighten or loosen the vacuum seal plug on the battery module (hex head).

The hex head vacuum plug is tightened to the torque specified to seal the module container and maintain the vacuum condition. Tightening or loosening the plug may destroy the vacuum condition of the battery module.

(f) Do not spray water on the battery module.

The NAS cell negative electrode contains water reactive sodium. Although cells are hermetically sealed, any water contact should be avoided. For example, fire suppression sprinklers are not to be used in the vicinity of NAS batteries.

(g) Do not ground the main circuit of the battery system.

The main circuits of NAS Battery System are designed for “non-grounding”. Grounding these circuits will create an electrical path to earth. Thus, an electrical path accidentally created at another location will cause short circuiting and equipment damage.

(h) Do not measure voltage on DC main circuit when the module temperature is below 90°C.

When the internal temperature of the battery is lower than 90°C, the active material in the battery is in a solid state with high electrical resistance, for which voltage measurements are not valid. Besides, the voltage measurement in this condition cause damage to the battery.

(i) Conduct battery thermal cycle (freeze/thaw cycles) prudently.

The battery is designed for a maximum of 10 full thermal cycles, where one full thermal cycle corresponds that a battery internal temperature become less than 150°C from operation temperature. But battery internal temperature shall not be less than 0°C after initial installation. Also, the battery should only be allowed to cool down when it is fully charged as determined by automatic voltage cut-off at the charge-end condition. An additional 30 medium thermal cycles, where one medium thermal cycles corresponds that a battery internal temperature become within the range of 150 to 250°C from operation temperature, are allowed at charge-end condition.

Do not conduct such thermal cycle except inevitable situation (e.g., relocation to a different site, or in emergencies). Excessive thermal cycles will accelerate deterioration of the battery.

Regardless of the above, do not conduct such any thermal cycle after reaching 15 years operation, otherwise it may result in cell damage.

[Note] Number of thermal cycles may be limited as one of warranty conditions determined by commercial contract.

[Note] In the event of excessive thermal cycles and/or such thermal cycle after reaching 15 years operation, total number of replacement of battery module in project life may increase due to accumulated cell damage.

(j) Do not allow battery modules to cool while in a discharged state.

Note that low battery module temperature (frozen(solid) condition) in a discharged state may result in cell damage due to non-uniform stresses upon solidification of sodium polysulfide in the anode area. If outages longer than 10 hours are expected, the owner is advised to provide a standby generator rated at 30kW per a battery container to maintain normal operating temperatures, otherwise it may result in cell damage or even module damage. In some case, it leads to the serious situation where BESS becomes inoperable.

(k) Do not store the battery modules at temperatures less than 0°C.

Note that battery module temperatures less than 0°C AFTER INITIAL OPERATION may result in cell damage due non-uniform stresses even at charge-end condition. If any storage is necessary without heater power, the environmental temperature must be kept no less than 0°C.

(l) Do not maintain the battery modules at operating temperature for an extended period of time prior to battery conditioning.

A minimum of 5 equivalent full discharge/charge operating cycles shall be executed within 30 days after completion of initial heat-up during installation as a necessary battery conditioning process.

New NAS battery modules require this conditioning process soon after initial heat-up to establish uniform sodium and sulfur electrode compositions. If new battery modules are maintained at operating temperature without proper conditioning, cell damage may occur that severely limits battery capacity.

If unforeseen circumstances prevent completion of the conditioning process described above in a timely manner, the battery modules shall be cooled to a frozen (solid) state until such time that system operational readiness can be confirmed; thus, sacrificing one full thermal cycle described above.

(m) Do not continue operating the system without SOC calibration.

BMS may not calculate the SOC with high accuracy without periodical SOC calibration, which may cause the acceleration of battery degradation.

If “SOC Calibration Suggestion” signal is activated, it is mandatory to make a chance whichever “Charge-end calibration” or “Near discharge-end calibration” within 7 days.

7 HISTORY OF REVISION

Prior revisions of this document are listed in Table 7-1.

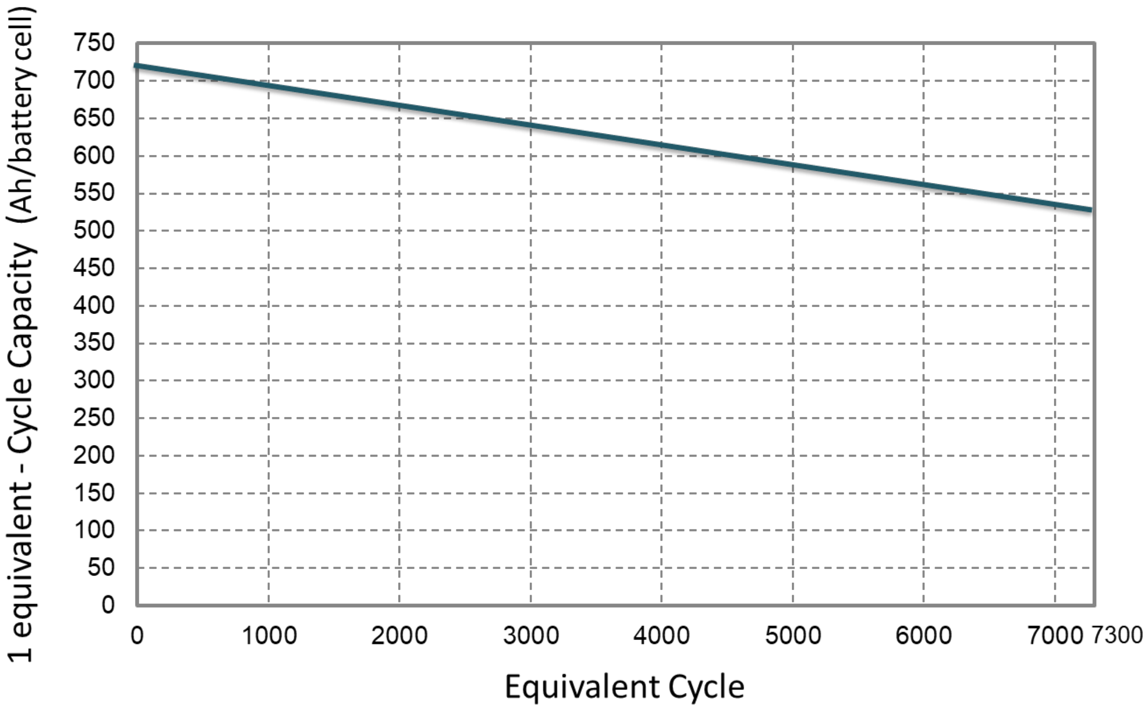
Table 7-1 – Revision History

Rev. No.	Explanations	Approved By	Checked By	Drafted by	Date
0	First version	N. Hirai	H. Abe	T. Sakaguchi	Mar. 7th, 2024

APPENDIX 1. NAS BATTERY EQUIVALENT CYCLE

Equivalent cycle is a unique indicator to count battery cycle of NAS battery systems and used to show the battery specifications through the design lifetime. One equivalent cycle is defined as the accumulated discharged capacity of a NAS cell measured in Ah as shown on Figure A1-1. It is called "1 equivalent-cycle capacity".

During discharge, each battery module controller measures the accumulated discharged capacity in Ah. When the accumulated discharged capacity is reached the value as represented on Figure A1-1, the controller counts 1 equivalent cycle regardless of the actual operation profiles. Equivalent cycles of a subunit are calculated the same way by the Battery Management System (BMS) from the accumulated discharged coulombic capacity measured as [Ah].



equivalent-cycle	0	1000	2000	3000	4000	5000	6000	7000	7300
Ah/cell	725	697	669	641	613	585	557	529	521

Figure A1-1. 1 equivalent-cycle Capacity as a function of the number of Equivalent Cycle

Based on Figure A1-1, Figure A1-2 shows the accumulated discharged capacity of a container over its lifetime represented by its number of equivalent cycles.

For the sake of clarity, one equivalent cycle is counted when the accumulated discharged capacity reaches equivalent-cycle capacity of each cycle of a cell. Additionally, a discharge/charge sequence that involves two half discharges of the equivalent-cycle capacity with a full charge in-between, or any other equivalent combination of discharge and charge is also considered as one equivalent cycle. This means that discharge and charge profiles have no direct impact on cycle counting. Cell aging is more or less proportional to its accumulated discharge capacity, as long as the parameters are kept within operational limits. On the contrary to most battery technologies, the Depth of Discharge (DoD) does not contribute to the degradation of the cell. Aging is therefore much easier to assess and very transparent for the customer. There is no particular risk to daily operate NAS batteries down to 0% SoC, which is a great advantage compare to most battery technologies.

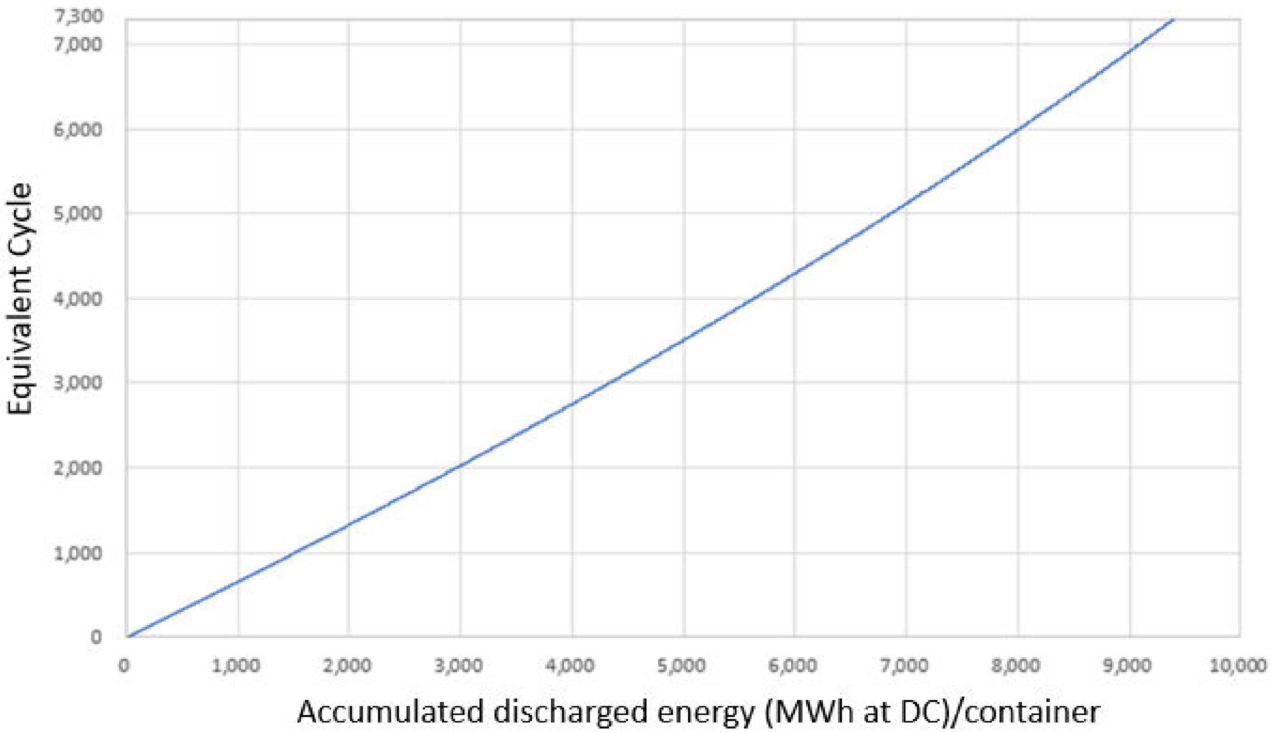


Figure A1-2. Accumulated discharged power per Battery Container vs. Equivalent Cycle

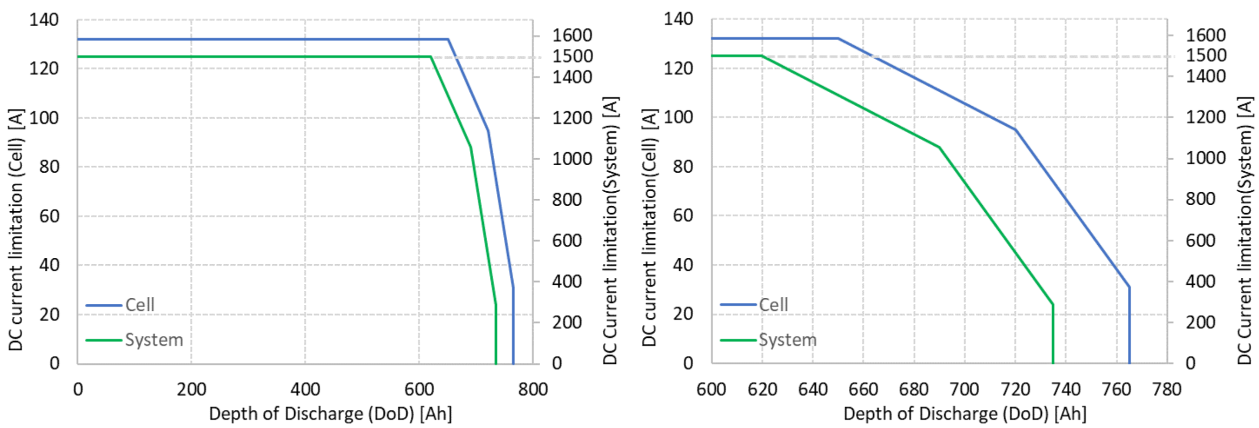
Note)

1. Charging operation does not have to be considered to calculate the equivalent cycle because the coulomb efficiency is 100% for NAS battery thanks to the special feature of no self-discharge.
2. Equivalent-cycle Capacity is not the same as guaranteed capacity. It means Equivalent-cycle Capacity is NOT a part of any guaranty nor warranty of NAS battery including its performance or capacity provided by NGK, unless otherwise specifically agreed in writing by duly authorized representatives.
3. All figures displayed in this Appendix consider modules without any inactive string.

APPENDIX 2. DC DISCHARGE CURRENT LIMITATION

NAS battery can discharge continuously, however, the DC current needs to be reduced at the near discharge end. The conceptual image is shown on figure A2-1.

When the measured Depth of Discharge (DoD) reaches a certain level, BMS will change available maximum discharging power in order not to exceed the DC current limitation and send the PCS the demand for control of limitation. The PCS shall reduce the discharging power accordingly, or otherwise it may result in accelerating the deterioration, or other unexpected system suspension.



Enlarged (from DoD 600Ah to DoD 780 Ah)

Remarks: The above figure shows in case of battery temperature is between 315 and 325 degrees Celsius and no inactive cells in the system at BoL.

Figure A2-1. DC current limitation with Depth of Discharge

BMS manages the DC current at system level (Green line in FigureA-2) to ensure the DC current of each cell (Blue line in Figure A-2) is not beyond the operatable range with considering factors like current dispersion, measurement error. Accordingly, the starting DoD of the limitation may occur earlier and the output limitation value changes lower than the above figure A2-1 due to various factors such as battery module temperature, number of inactive cells. In addition, since the accumulation of DC current measurement error is affected the DoD calculation, the DoD on each limitation value is shifted to lower value than the Figure A2-1 depends on the duration of no SOC calibration.