IEC 62984-3

Edition 1.0 2020-04

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

High-temperature secondary batteries –
Part 3: Sodium-based batteries – Performance requirements and tests

Batteries d'accumulateurs à haute température –
Partie 3: Batteries au sodium – Exigences et essais relatifs aux qualités de fonctionnement

IEC 62984-3:2020-04(en-fr)

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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CONTENTS

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HIGH-TEMPERATURE SECONDARY BATTERIES –

**Part 3: Sodium-based batteries –
Performance requirements and tests**

FOREWORD

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International Standard IEC 62984-3 has been prepared by IEC technical committee 21: Secondary cells and batteries.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
21/1040/FDIS	21/1048/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

This document is to be read in conjunction with IEC 62984-1:2020.

A list of all parts in the IEC 62984 series, published under the general title *High-temperature secondary batteries*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

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- withdrawn,
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HIGH-TEMPERATURE SECONDARY BATTERIES –

Part 3: Sodium-based batteries – Performance requirements and tests

1 Scope

This part of IEC 62984 specifies performance requirements and test procedures for high-temperature batteries based on sodium for mobile and/or stationary use and whose rated voltage does not exceed 1 500 V.

Sodium based batteries include sodium-sulphur batteries and sodium-nickel chloride batteries; both are high-temperature batteries and use a solid, sodium conducting electrolyte. Additional information on sodium-based batteries technology, their chemistries and construction are given in Annex B.

This document does not cover aircraft batteries, covered by IEC 60952 (all parts), and batteries for the propulsion of electric road vehicles, covered by IEC 61982 (all parts).

NOTE High-temperature batteries are electrochemical systems whose cells' internal minimum operating temperature is above 100 °C.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 62902, *Secondary cells and batteries – Marking symbols for identification of their chemistry*

IEC 62984-1:2020, *High-temperature secondary batteries – Part 1: General requirements*

IEC 62984-2:2020*, High-temperature secondary batteries – Part 2: Safety requirements and tests*

3 Terms, definitions, symbols and abbreviated terms

For the purposes of this document, the terms and definitions given in IEC 62984-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1 Battery construction

Refer to IEC 62984-1:2020, 3.1.

3.2 Battery functionality

The definitions of IEC 62984-1:2020, 3.2 and the following apply:

3.2.16
residual capacity
capacity remaining in a cell or battery following a discharge, operation or storage under specific test conditions

[SOURCE: IEC 60050-482:2004, 482-03-16]

3.2.17
discharge voltage
U_d
closed circuit voltage
DEPRECATED: on load voltage
<related to cells or batteries> voltage between the terminals of a cell or battery when being discharged

[SOURCE: IEC 60050-482:2004, 482-03-28, modified – Added symbol, "closed circuit voltage" changed to an admitted term, and term entry updated editorially.]

3.2.18
end-of-discharge voltage
final voltage
cut-off voltage
end-point voltage
specified voltage of a battery at which the battery discharge is terminated

[SOURCE: IEC 60050-482:2004, 482-03-30, modified – Synonyms given as admitted terms, and term entry updated editorially.]

3.2.19
open-circuit voltage
<related to cells or batteries> voltage of a cell or battery when the discharge current is zero

[SOURCE: IEC 60050-482:2004, 482-03-32, modified – Updated editorially.]

3.2.20
battery endurance
numerically defined performance of a battery during a given test simulating specified conditions of service

[SOURCE: IEC 60050-482:2004, 482-03-44]

3.2.21
cycling
<of a cell or battery> set of operations that is carried out on a secondary cell or battery and is repeated regularly in the same sequence

Note 1 to entry: In a secondary battery these operations may consist of a sequence of a discharge followed by a charge or a charge followed by a discharge under specified conditions. This sequence may include rest periods.

[SOURCE: IEC 60050-482:2004, 482-05-28, modified – Updated editorially.]

3.2.22
boost charge
accelerated charge applied at greater than normal values of electric currents or of voltages (for a particular design) during a short time interval

[SOURCE: IEC 60050-482:2004, 482-05-37]

3.2.23
constant current charge
charge during which the electric current is maintained at a constant value regardless of the battery voltage or temperature

[SOURCE: IEC 60050-482:2004, 482-05-38]

3.2.24
two step charge
charging method applied to a secondary battery using two levels of charge rate with feedback control to initiate the changeover from a high to a low charge rate

[SOURCE: IEC 60050-482:2004, 482-05-48]

3.2.25
constant voltage charge
charge during which the voltage is maintained at a constant value regardless of charge current or temperature

[SOURCE: IEC 60050-482:2004, 482-05-49]

3.2.26
energy efficiency
η
ratio of the electric energy provided from a secondary battery during discharge to the electric energy supplied to the battery during the preceding charge

[SOURCE: IEC 60050-482:2004, 482-05-53, modified – The symbol has been added.]

3.2.27
warm-up
process of activation of the cells inside a high-temperature battery by the application of heat from the ambient temperature up to their operating temperature

3.2.28
cool-down
process of inactivation of the cells inside a high-temperature battery due to their decrease of temperature from the operating range down to a value where all the active material is inactivated

3.2.29
freeze-thaw cycle
cycle composed of a warm-up and a subsequent cool-down of a high-temperature battery

3.3 Symbols and abbreviated terms

The list of symbols and abbreviated terms, including some of those already defined in IEC 62984-1:2020, is given in Table 1.

Table 1 – List of symbols and abbreviated terms

Symbol / abbreviated term	Full term	Reference
BMS	Battery management system	See IEC 62984-1:2020, 3.1.19
BSS	Battery support system	See IEC 62984-1:2020, 3.1.20
C_r	Rated capacity	See IEC 62984-1:2020, 3.2.2
DUT	Device under test	
I_{dn}	Nominal discharge rate	
I_{dMAX}	Maximum continuous discharge rate	
I_{dTR}	Maximum transient discharge rate	
I_t	Charge rate	See IEC 62984-1:2020, 3.2.12
I_{tn}	Nominal charge rate	
LTE	Long term endurance	
PCS	Power conversion system	
SOC	State of charge	See IEC 62984-1:2020, 3.2.13
U_d	Discharge voltage	See 3.2.17
U_n	Nominal voltage	See 3.2.8
W_r	Rated battery energy	
η	Energy efficiency	See 3.2.26

4 Environmental (service) conditions

4.1 General

Refer to IEC 62984-1:2020, 4.1.

4.2 Normal service conditions for stationary installations

Refer to IEC 62984-1:2020, 4.2.

4.3 Special service conditions for stationary installations

Refer to IEC 62984-1:2020, 4.3.

4.4 Normal service conditions for mobile installations (except propulsion)

Refer to IEC 62984-1:2020, 4.4.

4.5 Special service conditions for mobile installations (except propulsion)

Refer to IEC 62984-1:2020, 4.5.

5 Performance requirements

5.1 Electrical requirements

5.1.1 Nominal voltage

The preferred values of nominal voltages of high-temperature sodium-based batteries are given in Table 2.

Table 2 – Preferred values of battery nominal voltages

Voltages in Volts DC

Electrochemical technology	Nominal voltage values				
Na-NiCl	48	110	220	400	600
Na-S	48	110	192	640	768

5.1.2 Discharge rate

5.1.2.1 General

The discharge of a sodium-sulphur battery or a sodium-nickel chloride battery is an exothermic reaction. The total heat generated during discharge is the sum of the exothermic reaction heat from the electrochemical reaction and the heat from the Joule effect due to the internal resistance of the battery. Therefore, the temperature of cells inside the module tends to rise during discharge. Thermal related issues are therefore one of the aspects to be considered when defining the maximum discharge ratings, together with efficiency as a function of discharge rate.

5.1.2.2 Nominal discharge rate (I_{dn})

The nominal discharge rate is defined as the continuous discharge current over the rated discharge duration of 8 h, on which sodium-based battery specifications are based, and this value shall be reported in the rating plate. The nominal discharge rate of sodium-based high-temperature batteries is expressed in accordance with the following formula:

$$I_{dn} = \frac{C_r}{n}$$

where

I_{dn} is the nominal discharge rate in amperes;

C_r is the rated capacity in ampere·hours;

n is the rated discharge time in hours = 8 h.

5.1.2.3 Maximum continuous discharge rate (I_{dMAX})

The maximum continuous discharge rate is defined as the maximum continuous current at which the rated battery capacity can be discharged without exceeding the battery temperature limits. This value shall be declared by the manufacturer and reported in the rating plate.

The maximum continuous discharge rate (I_{dMAX}) may be expressed in terms of power (watts) instead of current (amperes).

5.1.2.4 Maximum transient discharge rate (I_{dTR})

It may however be possible, if additionally specified by the manufacturer, to exceed the maximum discharge rate I_{dMAX} for a short period before reaching thermal or other limits.

The maximum transient discharge rate I_{dTR} is the maximum discharge current that the battery can withstand for a definite time starting from specified conditions.

If a maximum transient discharge rate is declared by the manufacturer it shall be marked on the rating plate with the corresponding transient discharge time.

It is allowed that the manufacturer declares the maximum transient discharge rating in terms of discharge power instead of discharge current.

When I_{dTR} is specified, the value of the transient discharge time is at least 1 min.

The manufacturer may specify additional values of maximum transient discharge rate and time, more suited for specific applications.

5.1.3 Charge rate

5.1.3.1 Reference charge process

The charging process of sodium-based high-temperature batteries involves a moderately endothermic reaction, which generally mostly compensates for the heat generated by ohmic losses due to the Joule effect, so that no temperature rise results.

The limitations in the charging process are therefore mainly of electrochemical nature and are related to the respect of the safe operating limits of the cells. This is managed by the control algorithms implemented within the BMS.

The reference charge process is declared by the manufacturer and described in the battery documentation. It is the charge process on which the specification of the battery is based.

In the simplest case it is a two step charge process in which the first step is a constant current or power charge and the second step is a constant voltage or reduced current charge.

The BMS shall manage the overall charging process in order to avoid stress or damage to the battery.

5.1.3.2 Nominal charge rate (I_{tn})

The nominal charge rate is the reference charge current defined by the manufacturer and reported on the rating plate, that is used to charge the battery during the first step phase of the reference charge process, on which all specifications of the battery are based. The nominal charge rate of sodium-based high-temperature batteries is expressed in accordance with the following formula:

$$I_{tn} = \frac{C_r}{n}$$

where

I_{tn} is the nominal charge rate in amperes;

C_r is the rated capacity in ampere·hours;

n is the rated discharge time in hours = 8 h.

5.1.3.3 Boost charge rate

It may be possible, if additionally specified by the manufacturer, to charge sodium-based high-temperature batteries at a higher charging current during the first charging phase.

This is called a "boost charge".

The boost charge rate is the maximum charging current value that can be used to charge the battery during the first step of the charging process without exceeding the safe operating conditions of the cells inside the battery.

NOTE In this case, the state of charge achieved at the end of this first boosted charging phase will be lower than that achieved at the end of the first phase of the reference charging process.

When the boost charge rate is declared by the manufacturer, it shall be reported in the rating plate with the associated maximum SOC achievable after the boosted charge.

5.1.4 Rated battery energy (W_r)

The rated value of battery energy (see definition in IEC 62984-1:2020, 3.2.3) is usually expressed in W·h and shall be declared by the manufacturer and reported on the rating plate. Battery energy is measured in reference conditions during a discharge at constant power.

5.1.5 Battery auxiliary energy consumption

The auxiliary energy consumption includes all electrical consumptions that do not contribute to the charging of the electrochemical cell but are necessary for the correct and safe behaviour of the battery such as, for example (with reference to IEC 62984-1:2020, Figure 1):

– BMS/BSS power supply;
– heating or cooling of cells;
– cooling of electronic circuits;
– supply of monitoring/communication circuits which are part of the battery.

Auxiliary energy consumption depends on various factors, including charge/discharge cycles and environmental conditions. An evaluation of typical energy consumption in reference conditions, representative of one typical application shall be given by the manufacturer and measured according to the test procedure given in 6.3.1.

5.1.6 Energy efficiency (η)

Energy efficiency, η, as defined in 3.2.26, is defined as the ratio between W_{out} and W_{in}, where W_{out} is the net energy discharged (i.e. the difference between discharged energy and the auxiliary (BMS/BMU/BSS) energy consumption during the discharge phase), and W_{in} is the total charged energy (i.e. the sum of the charged energy and the auxiliary (BMS/BMU/BSS) energy consumption during the charge phase), according to following formula:

$$\eta = \frac{W_{\text{out}}}{W_{\text{in}}} = \frac{W_{\text{discharge}} - W_{\text{aux,discharge}}}{W_{\text{charge}} + W_{\text{aux,charge}}}$$

The energy efficiency of sodium-based high-temperature batteries is mainly affected by the energy consumption of auxiliary circuits, whose major contribution is the energy spent to keep cells within their operating temperature range.

NOTE For this reason, the energy efficiency of a sodium-based high-temperature battery is higher with short standby periods.

To get a realistic evaluation of the energy efficiency, the standard test procedure given in 6.3.2 shall be used. This test procedure depicts a realistic application. It may not be consistent with all of the possible applications, but it makes the test reproducible, letting users compare batteries from different vendors with the same testing conditions.

The energy efficiency, measured according to the test procedure given in 6.3.2, shall be declared by the manufacturer.

5.1.7 Long term endurance (LTE)

Long term endurance is the ability of a battery to retain its initial energy content over a specified lifetime in terms of time or number of charge/discharge cycles.

A sodium-based high-temperature battery shall not decrease its energy content by more than the values described in Table 3, where two classes of performance, LTE class 3 and LTE class 5, are defined according to the allowed energy content loss.

Table 3 – Maximum allowed energy content loss after the test

Battery type	LTE class	Energy content loss (α)
All	3	≤ 3,0 %
	5	≤ 5,0 %

The relevant test procedure and assessment criteria for the long term endurance test are given in 6.3.3.

5.2 Thermal requirements

5.2.1 General

Sodium-based high-temperature batteries are based on an electrochemical process that operates correctly in a given temperature range, well above the normal ambient temperature. As a result, the internal parts of the battery cells shall constantly be kept at the correct working temperature to achieve the specified battery performance. Additional information on sodium-based batteries technology, their chemistries and construction are given in Annex B.

The temperature profile during warming-up and cooling-down of active materials of a battery (contained in the battery cells) shall carefully follow the profile specified by the manufacturer in order to avoid cell damage or incorrect behaviour. This task is normally performed automatically by the battery BMS without intervention by the user, however the battery is not operational until it is within the specified internal temperature range.

The battery BMS shall automatically perform, without user intervention, the management and control of the internal battery temperature in order to prevent the possibility of battery damage due to human error. In particular, the BMS shall prevent battery charge or discharge outside its internal operating temperature range. This has to be ensured also in the case of a loss of power supply to the BMS.

The manufacturer shall declare the minimum number of freeze-thaw (warm-up and cool-down) cycles that the battery can withstand during the whole battery lifecycle. This value shall be reported in the battery datasheet and rating plate.

5.2.2 Warm-up

The BMS shall automatically manage the warm-up phase according to the manufacturer-specified temperature profile. The BMS shall also prevent the user from altering the temperature profile; this is in order to prevent battery damage and/or possible incorrect battery behaviour.