भारतीय मानक **IS/IEC 60068-2-14 : 2023**

Indian Standard

पर्यावरण परीक्षण
भाग 2 परीक्षण
अनुभाग 14 परीक्षण एनः तापमान में परिवर्तन

(पहला पुनरीक्षण)

Environmental Testing
Part 2 Tests
Section 14 Test N: Change of Temperature

(First Revision)

ICS 19.040

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September 2024 **Price Group 12**

Environmental Testing Procedure Sectional Committee, LITD 01

NATIONAL FOREWORD

This Indian Standard (Part 2/Sec 14) which is Identical to IEC 60068-2-14 : 2023 ‘Environmental testing — Part 2-14: Tests — Test N: Change of temperature’ issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendations of the Environmental Testing Procedure Sectional Committee and approval of the Electronics and Information Technology Division Council.

This Indian Standard was first published in 2022 and was identical to IEC 60068 Part 2/Sec 14 : 2009. The first revision of the Indian Standard has been taken up to align it with the latest version of IEC 60068-2-14 : 2023.

The main changes are as follows:

a) Updating of the figures for clarification purposes;

b) Updating of specimen temperature(s) and severities as well as tolerances for change of temperature tests; and

c) Revision of standardized requirements for test reports for Tests Na and Nb.

The text of IEC Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words ‘International Standard’ appears referring to this standard, they should be read as ‘Indian Standard’; and

b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards, which are to be substituted in their places, are listed below along with their degree of equivalence for editions indicated. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies:

International Standards	*Corresponding Indian Standards*	*Degree of Equivalence*
IEC 60068-2-1 : 2007 Environmental testing — Part 2-1: Tests - Test A: Cold	IS/IEC 60068-2-1 : 2007 Environmental testing: Part 2 Tests, Section 1 Test A: cold	Identical
IEC 60068-2-2 : 2007 Environmental testing — Part 2-2: Tests - Test B: Dry heat	IS/IEC 60068-2-2 : 2007 Environmental testing: Part 2 Tests — Test B, Section 2: Dry heat	Identical

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2022 ‘Rules for rounding off numerical values (*second revision*)’. The number of significant places retained in the rounded off value should be same as that of the specified value in this standard.

CONTENTS

INTRODUCTION

A change of temperature test is intended to determine the effect on the specimen of a change of temperature or a succession of changes of temperature.

It is not intended to show effects that are caused by low or high temperature exposure. For these effects, the cold test or the dry heat test, as specified in IEC 60068-2-1 and IEC 60068-2-2, should be used.

The effect of change of temperature tests is determined by

– values of high and low conditioning temperature between which the change is to be affected,
– the conditioning times for which the test specimen is kept at these temperatures,
– the rate of change between these temperatures,
– the number of cycles of conditioning,
– the amount of heat transfer into or from the specimen,
– the thermal conductivity and the materials of the specimen,
– the rate of change of the specimen’s temperature on its surface (respectively in relevant positions) or in its core.

Guidance on the choice of suitable test parameters for inclusion in the detail specification is given throughout this document.

Indian Standard

ENVIRONMENTAL TESTING

PART 2 TESTS

SECTION 14 TEST N: CHANGE OF TEMPERATURE

(First Revision)

1 Scope

This document provides tests with specified ambient temperature changes to analyse their impacts on specimens.

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 60068-2-1, *Environmental testing – Part 2-1: Tests – Test A: Cold*

IEC 60068-2-2, *Environmental testing – Part 2-2: Tests – Test B: Dry heat*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60068-2-1 and IEC 60068-2-2 apply.

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

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

4 Symbols

D	temperature difference between high conditioning temperature T_B and low conditioning temperature T_A
T_A	low conditioning temperature
T_{Ad}	decreased low conditioning temperature
T_B	high conditioning temperature
T_{Bi}	increased high conditioning temperature
T_{STD}	temperature of standard atmospheric conditions for measurement and tests (15 °C to 35 °C)
ΔT_s	temperature difference between the specimen and the test medium (e.g. air)
dT_R	temperature change rate (Test Nb)
t_s	stabilization time of specimen temperature
t_{s*}	stabilization time of specimen temperature during the first cycle, starting from laboratory air temperature
t_1	exposure time of the specimen to each conditioning temperature
t_2	transfer time of the specimen from one test chamber to another (two-chamber test method)
$\pm\sigma_T$	applicable temperature tolerance of the medium temperature during temperature transition (Test Nb)
$\pm\sigma_{Tconst}$	applicable temperature tolerance of the medium temperature during the constant conditioning

5 General

5.1 Field conditions of changing temperature

It is common in electronic equipment and components that changes of temperature occur. Parts inside equipment undergo slower changes of temperature than those on an external surface when the equipment is not switched on.

Rapid changes of temperature can be expected

– when equipment is transported from warm indoor into cold outdoor environments or vice versa,
– when equipment is suddenly cooled by rainfall or immersion in cold water,
– when equipment is attached or in close proximity to components leading to high thermal stress (e.g. combustion engines, central processing units),
– when equipment is artificially cooled or heated,
– in externally mounted airborne equipment or when equipment is located in unheated aircraft or cargo holds,
– under certain conditions of transportation and storage.

Components will undergo stresses due to changing temperature when high temperature gradients build up in an equipment after being switched on, for example in the proximity of high power resistors, radiation can cause rise of the surface temperature on close components while other portions remain cold.

Artificially cooled components can be subjected to rapid temperature changes when the cooling system is switched on. Rapid changes of temperature in components can also be induced during manufacturing processes or the transportation of equipment. Both the number and amplitude of temperature changes, the time interval between them and the thermal responsiveness of the equipment (or specimen) are important.

5.2 Design of tests with temperature change

Change of temperature Tests Na, Nb and Nc comprise alternate periods at a high and a low temperature with well-defined transfers from one temperature to the other. The conditioning run from the laboratory ambient temperature to the first conditioning temperature, then to the second conditioning temperature, then back to the laboratory ambient temperature is considered as one test cycle.

5.3 Test parameters

Test parameters comprise the following:

– laboratory ambient conditions (mainly temperature and humidity);
– high conditioning temperature T_{B};
– increased high conditioning temperature T_{Bi}, if applicable;
– low conditioning temperature T_{A};
– decreased low conditioning temperature T_{Ad}, if applicable;
– exposure time t_1 of the specimen to each conditioning temperature;
– transfer time t_2 or temperature change rate $\mathrm{d}T_{\mathrm{R}}$;
– number of test cycles.

As these tests are intended to validate the effects of temperature changes on the specimen, the specimen’s characteristics should always be taken into consideration (if not specified otherwise):

– thermal responsiveness of the specimen in affected areas or the core;
  • thermal conductivity;
  • specific heat capacity;
– density;
– geometry;
– mass.

The experimental determination of these characteristics is recommended, if unknown and not specified otherwise.

The test is accelerated because the number of severe changes of temperature in a given period is greater than that which will occur under field conditions.

The high and low conditioning temperatures are understood to be ambient temperatures which will be reached by most specimens with a certain time lag. It is recommended to consider the specimen’s characteristics when specifying the test. Annex A gives further information on potential consequences of improper severities of tests.

Only in exceptional cases should these temperatures be specified outside the normal storage or operating temperature range of the object under test.

NOTE If the specimen's characteristics (mass, density, geometry) prevent the specified rate of change, the temperatures can be specified outside the normal storage or operating temperatures to increase the severity of the intended test, if not specified otherwise.

5.4 Purpose and choice of the tests

Change of temperature testing is recommended in the following cases:

– evaluation of electrical performance after a specified number of rapid changes of temperature, Test Na or Test Nc;
– evaluation of the suitability of mechanical components, and of materials and combinations of materials to withstand rapid changes of temperature, Test Na or Test Nc;
– evaluation of the suitability of construction of components to withstand artificial stressing, Test Na or Test Nc;
– evaluation of electrical performance as a consequence of a change of temperature, Test Nb;
– evaluation of mechanical performance as a consequence of a change of temperature, Test Nb.

The change of temperature tests specified in the IEC 60068 series is not intended to evaluate the difference in material constants or electrical performance when operating under the conditioning temperatures T_A and T_B.

5.5 Choice of the exposure time to each conditioning temperature

The duration of the exposure should be based on the requirements stated in 7.2.3, 8.2.3 or 9.2.2, or as stated in the relevant specification, keeping in mind the following points:

a) The exposure begins as soon as the specimen is in the new environment.
b) Stabilization occurs when the temperature difference between the specimen and the test medium (ΔT_s) is within 5 K, or as stated in the test specification. The stabilization time of specimen temperature t_s is from the start of exposure until the moment when the temperature is within the specified difference. A representative point (or points) on the specimen can be used for this measurement.
c) The exposure time t_1 of the specimen to each conditioning temperature shall be longer than the stabilization time of the specimen temperature t_s. Figure 1 provides a graphical representation of the process. It is possible that this will not be appropriate for heat generating specimens.

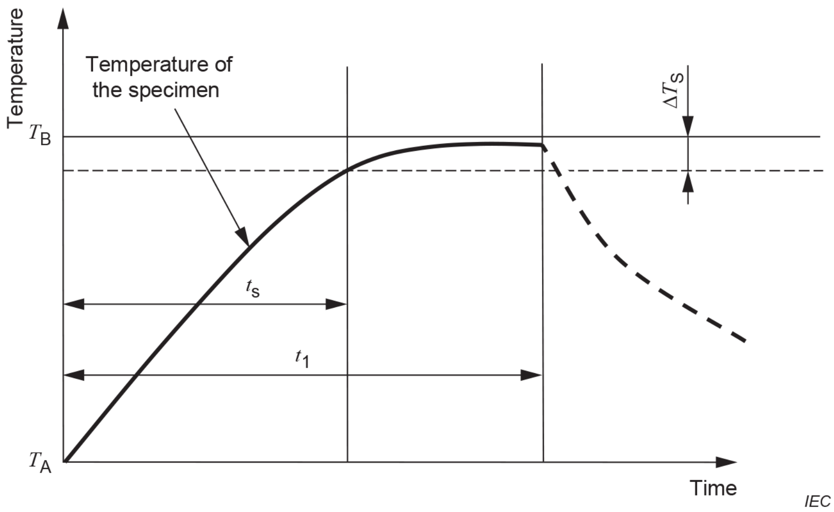


Figure 1 – Determination of the exposure time t_1 of the specimen to each conditioning temperature

5.6 Choice of the duration of the transfer time t_2

If, for example owing to the large size of the specimens, the transfer time t_2 cannot be kept within 3 min, the transfer time can be increased with a negligible influence on the test results as follows:

$$t_2 \leq 0{,}05\ t_s$$

This applies for the two-chamber test (see 7.2.1) method only. When using the one-chamber test method, period t_2 is not applicable.

5.7 Applicability limits of change of temperature tests

Inside a specimen, the temperature change rate depends on the heat conduction of its materials, the spatial distribution of its heat capacity as well as on its dimensions and surface area. A representative point (or points) on (or inside) the specimen can be used for the measurement of the temperature change rates.

NOTE 1 The rate of temperature change of specimens made of the same material and mass can vary if their surfaces differ from each other.

The change of temperature at one point on the surface of a specimen follows approximately an exponential law. Inside large specimens, such alternate exponential rises and decreases can lead to periodic and approximately sinusoidal changes of temperature with much lower amplitudes than the applied temperature swing. Annex B gives further information on the thermal responsiveness of different materials and geometries.

The mechanism of heat transfer between the test specimen and the conditioning medium in the chamber or bath should be considered. Liquid in motion leads to very high rates of change of temperature on the surface of the specimens and still air to very low rates.

NOTE 2 If more than one specimen is tested in the same test chamber, a uniform incoming airflow can be disturbed. For further information on the relation of airflow and specimen temperature, IEC 60068-3-1 can be helpful.

The two-bath method with water as a conditioning medium (Test Nc) should be restricted to specimens which are either sealed or are by their nature insensitive to water, since their performance and properties can deteriorate by immersion.

In particular cases, such as with specimens sensitive to water, a test with liquid other than water should be specified. When designing such a test, the characteristics of heat transfer of the liquid, which can differ from those of water, shall be considered.

NOTE 3 To assess the applicability of the two-bath method, evaluations from Test Q: Sealing (IEC 60068-2-17) can be helpful.

The application of Tests N is preferred as part of a sequence of tests. It is possible that some types of damage will not become apparent by the final measurements of a Test N but will appear only during subsequent tests.

An exemplary sequence of tests can be IEC 60068-2-17 Test Q: Sealing, IEC 60068-2-6 Test Fc: Vibration (sinusoidal), IEC 60068-2-30 Test Db: Damp heat, cyclic (12 h + 12 h cycle) or IEC 60068-2-67 Test Cy: Damp heat.

The change of temperature Test Nc (Two-bath method) should not be used as an alternative to Test Q (Sealing).

When specifying a change of temperature test, the properties of the objects under test which are affected by conditions of changing temperature, and their possible failure mechanisms, should be kept in mind. The initial and the final measurements should be specified accordingly.

6 Initial and final measurements

6.1 General

Tests Na, Nb and Nc all use the same initial and final measurements.

6.2 Initial measurements

The specimen shall be visually examined and electrically and mechanically checked, as required by the relevant specification.

6.3 Final measurements

The specimen shall be visually examined and electrically and mechanically checked, as required by the relevant specification.

7 Test Na: Rapid change of temperature

7.1 General description of the test

This test determines the ability of components, equipment or other articles to withstand rapid changes of ambient temperature. The exposure times adequate to accomplish this will depend upon the nature of the specimen. The specimen shall be either in the unpacked, switched-off, ready for use state, or as otherwise specified in the relevant specification. The specimen is exposed to rapid changes of temperature in air, or in a suitable inert gas, by alternating exposure to a low and a high conditioning temperature.

7.2 Testing procedure

7.2.1 Testing chamber

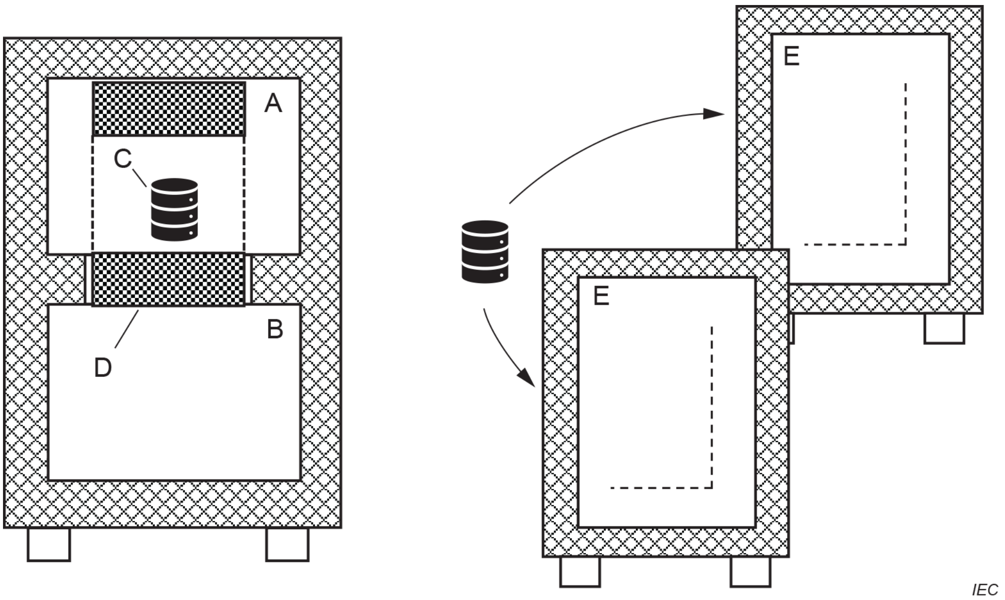
Two separate chambers (two-chamber method, see Figure 2) or one rapid temperature change rate chamber (one-chamber method, see Figure 3) can be used. If two chambers are used, one for the low temperature and one for the high temperature, the location shall be such as to allow transfer of the specimen from one chamber to the other within the specified time. Either manual or automatic transfer methods can be used.

Some two-chamber method systems are known as thermal shock test cabinets. These systems combine characteristics of two separate test chambers and are equipped with a mobile lifting cage (applies for horizontal shock test chambers as well) for the automatic transfer of the specimens from one chamber to another (see Figure 2).

Damper shock test cabinets are another embodiment of a one-chamber test system. These systems contain two conditioning and one test chamber. The test chamber is alternately exposed to conditioned air from a hot respectively cold conditioning chamber via air flaps (see Figure 3). No physical transfer is required and the transfer time t_2 is not applicable, when using this kind of test systems.

Damper shock test cabinets with a stationary test chamber, a hot chamber and a cold chamber are commonly capable of two-zone tests with hot respectively cold exposure. Some are capable of three-zone tests, including exposure to ambient air.

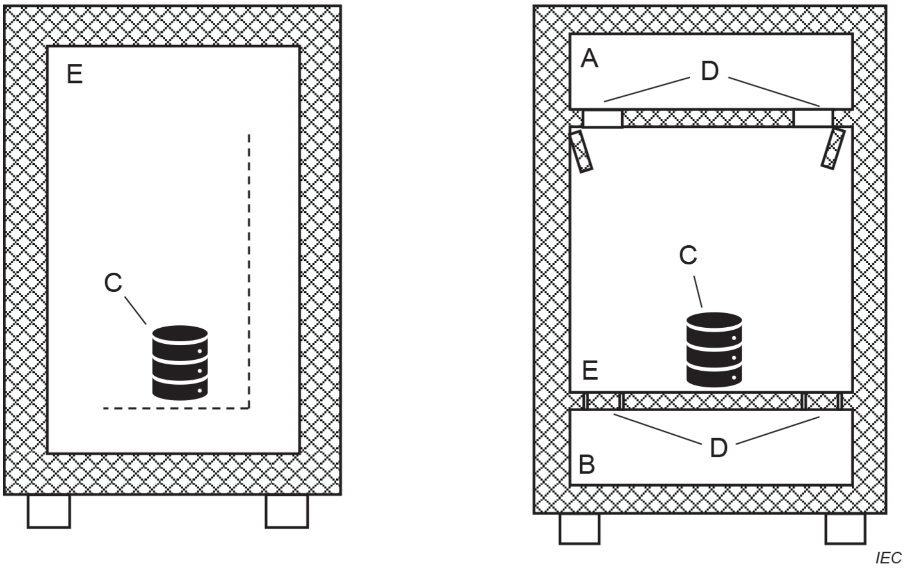
NOTE 1 Damper and basket-type test cabinets are often used for Test Na. Depending on the performance, two separate chambers or one rapid temperature change rate chamber are often used for Test Na as well. One rapid temperature change rate chamber is often used for Test Nb.



Key

A	hot chamber	**B**	cold chamber	**C**	specimen
D	mobile cage	**E**	stationary test space		

Figure 2 – Schematic representation of examples of thermal test cabinets and test procedure with two separate test chambers



Key

A	hot chamber	**B**	cold chamber	**C**	specimen
D	air flaps	**E**	stationary test space		

Figure 3 – Schematic representation of examples of thermal test cabinets with one test chamber

The chambers should be capable of maintaining the working space at the required temperatures.

After insertion of the test specimens, the temperature of the test medium shall be within the specified tolerance after a time of not more than 10 % of the exposure time t_1 of the specimen to each conditioning temperature. The temperature of the test medium refers to the control sensor of the test chamber, if not specified otherwise.

Owing to the specimen's lower rate of temperature change, its temperature can fall below the dew point temperature when bringing the specimens in the hot test environment (see Figure 4) or exposing them to ambient laboratory air (see Figure 5). During the rapid change to the high temperature T_B or when transferring the specimens from the cold chamber to the hot chamber, condensation of ambient air humidity should always be taken into consideration.

NOTE 2 Depending on the heat capacity and mass of the specimen, this phenomenon can be more or less pronounced.

Dehumidification during heating phases or compressed air dryers can be used to prevent condensation on the specimen's surface, if necessary.

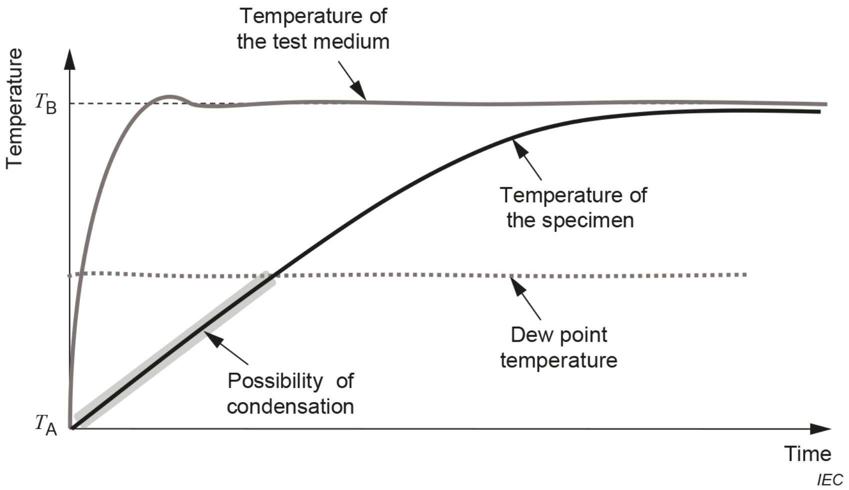


Figure 4 – Possibility of condensation during rapid temperature change

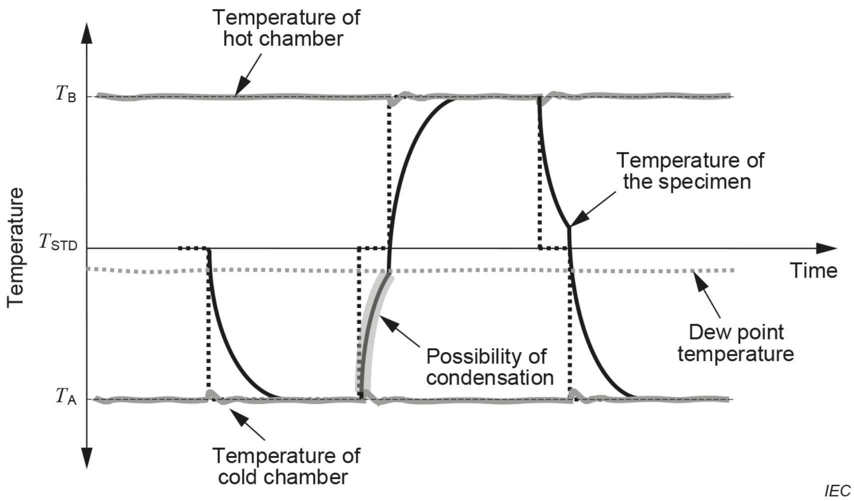


Figure 5 – Possibility of condensation during transfer of the specimen

7.2.2 Mounting or supporting of the test specimen

The thermal conduction of the mounting or supports shall be low, such that for practical purposes the specimen is thermally isolated, if not specified otherwise. When testing several specimens simultaneously they shall be so placed that free circulation shall be provided between specimens, and between specimens and chamber surfaces.

7.2.3 Severities

The severity of the test is defined by the combination of the two temperatures, the transfer time, the exposure time of the specimen and the number of cycles.

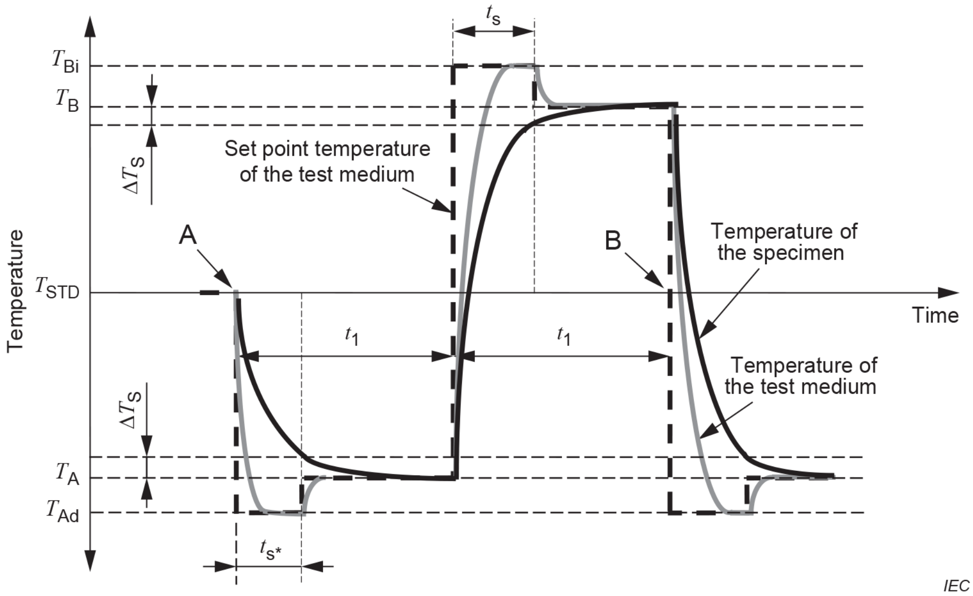
The low conditioning temperature T_A shall be specified in the relevant specification and shall be chosen from the test temperatures of either IEC 60068-2-1 or IEC 60068-2-2 or both, if not specified otherwise.

The high conditioning temperature T_B shall be specified in the relevant specification and shall be chosen from the test temperatures of either IEC 60068-2-1 or IEC 60068-2-2 or both, if not specified otherwise.

The exposure time t_1 to each of the two conditioning temperatures depends on the heat capacity of the specimen. It can be 3 h, 2 h, 1 h, 30 min or 10 min, or as specified in the relevant specification. Where no exposure period is specified in the relevant specification, it is understood to be 3 h.

NOTE The 10 min exposure time often applies to the testing of small specimens that achieve temperature stabilization without a significant time lag.

If temperature stabilization of the specimens cannot be achieved within the chosen exposure time, for example owing to a high heat capacity of the specimens, the severity of the test can be temporarily increased. The severity shall only be increased until temperature stabilization is achieved. A representative point (or points) on (or inside) the specimen can be used for this measurement. A higher severity of the test is achieved by increasing the temperature difference between the low conditioning temperature T_A and the high conditioning temperature T_B. Figure 6 provides a graphical representation of an increased severity.



Key

A start of first cycle

B end of first cycle and start of second cycle

Figure 6 – Increased severity of Test Na

The decreased low conditioning temperature T_{Ad} and the increased high conditioning temperature T_{Bi} should be chosen from the test temperatures of either IEC 60068-2-1 or IEC 60068-2-2 or both, if not specified otherwise.

When choosing the increased high conditioning temperature T_{Bi} and the decreased low conditioning temperature T_{Ad} the temperature limits of the specimen should be respected to avoid possible damage caused by the chosen temperature differences, if not specified otherwise. The chosen conditioning temperatures shall be given in the test report.

The preferred number of test cycles is 5, unless otherwise specified in the relevant specification.

7.2.4 Preconditioning

The specimen and the temperature in the test chamber shall be at the temperature of standard atmospheric conditions for measurement and test T_{STD}, 15 °C to 35 °C. If required by the relevant specification, the specimen shall be brought into operating conditions.

7.2.5 Test cycle

a) One-chamber test method

The specimen shall be brought into the test chamber and be exposed to the temperature change to the low conditioning temperature T_A (see Figure 7).

The low conditioning temperature T_A shall be maintained for the specified exposure time t_1 (see 5.5). t_1 includes an initial time, not longer than 0,1 t_1 for temperature stabilization of the test medium.

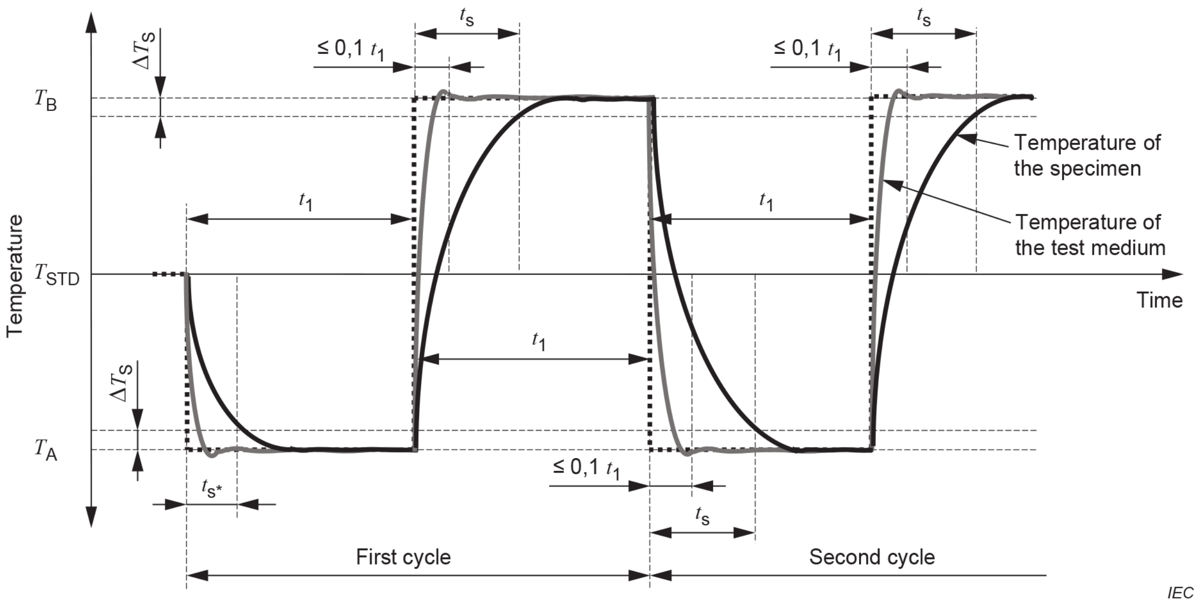


Figure 7 – Na test cycle, one-chamber method

NOTE 1 The exposure time is measured from the beginning of change of temperature within the chamber.

Temperature stabilization of the specimen (ΔT_s) can be achieved in the specified period t_1 (see Figure 7), if not specified otherwise. The time required for this is indicated with t_s.

NOTE 2 In some cases it can become necessary to extend t_1 to promote temperature equalization of the specimen or to initiate a certain relaxation process.

The specimen shall then be exposed to the temperature change to the high conditioning temperature T_B.

The high conditioning temperature T_B shall be maintained for the specified exposure time t_1. t_1 includes an initial time, not longer than 0,1 t_1 for temperature stabilization of the test medium.

Temperature stabilization of the specimen (ΔT_s) can be achieved in the specified period t_1 (see Figure 7), if not specified otherwise. The time required for this is indicated with t_s.

NOTE 3 In some cases it can become necessary to extend t_1 to promote temperature equalization of the specimen or to initiate a certain relaxation process.

For the next cycle the specimen shall be exposed to the low conditioning temperature T_A.

One cycle comprises the exposure time t_1 to both conditioning temperatures. At the end of the last cycle, the specimen shall be subjected to the recovery procedure (see 7.3).

NOTE 4 There are no transfer times required for the one-chamber test method.

b) Two-chamber test method

The test specimen shall be brought into the cold chamber and be exposed to the low conditioning temperature T_A.

The low conditioning temperature T_A shall be maintained for the specified exposure time t_1 (see 5.5). t_1 includes an initial time, not longer than 0,1 t_1, for temperature stabilization of the air temperature in the chamber (see Figure 8).

NOTE 5 The exposure time is measured from the moment of insertion of the specimen into the chamber.

Temperature stabilization of the specimen (ΔT_s) can be achieved in the specified period t_1 (see Figure 8), if not specified otherwise. The time required for this is indicated with t_s.

NOTE 6 In some cases it can become necessary to extend t_1 to promote temperature equalization of the specimen or to initiate a certain relaxation process.

The specimen shall then be brought into the hot chamber in a transfer time t_2, which should not be more than 3 min, and be exposed to the high conditioning temperature T_B.

The transfer time t_2 shall include the time needed for the removal from one chamber and the insertion into the second chamber as well as any dwell time at the ambient temperature of the laboratory.

NOTE 7 For specimens with a large mass or geometry, the transfer time from one chamber to another can be increased as specified in the relevant standard or specification (see 5.6).

The high conditioning temperature T_B shall be maintained for the specified exposure time t_1. t_1 includes an initial time, not longer than 0,1 t_1, for temperature stabilization of the air temperature in the chamber.

NOTE 8 The exposure time is measured from the moment of insertion of the specimen into the chamber.

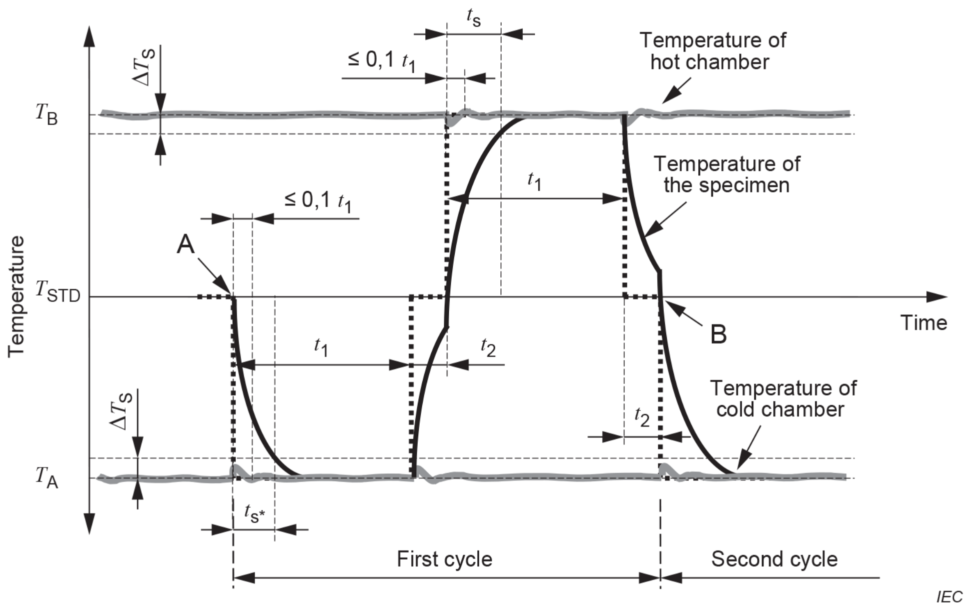
Temperature stabilization of the specimen (ΔT_s) can be achieved in the specified period t_1 (see Figure 8), if not specified otherwise. The time required for this is indicated with t_s.

NOTE 9 In some cases it can become necessary to extend t_1 to promote temperature equalization of the specimen or to initiate a certain relaxation process.

For the next cycle the specimen shall be brought into the cold chamber in a transfer time t_2, which should not be more than 3 min, and be exposed to the low conditioning temperature T_A.

NOTE 10 For specimens with a large mass or geometry, the transfer time from one chamber to another can be increased as specified in the relevant standard or specification (see 5.6).

One cycle comprises the exposure time t_1 to both conditioning temperatures and the two transfer times t_2 (see Figure 8). At the end of the last cycle, the specimen shall be subjected to the recovery procedure (see 7.3).



Key

A start of first cycle

B end of first cycle and start of second cycle

Figure 8 – Na test cycle, two-chamber method

7.3 Recovery

At the end of the test cycle, the specimen shall be brought to the temperature of standard atmospheric conditions for measurement and test T_{STD}, 15 °C to 35 °C. It is recommended that the specimen be brought to this temperature within the specified period t_1, if not specified otherwise.

If this is not possible or specified otherwise, the temperature in the test chamber shall be lowered to the temperature of standard atmospheric conditions for measurement and test T_{STD}, 15 °C to 35 °C. It is recommended that the temperature be lowered to that of standard atmospheric conditions within the specified period t_1, if not specified otherwise.

NOTE Keeping the specimen exposed to the high conditioning temperature for an extended time after completion of the test can be seen as temperature storage, which can cause unintended damages to the specimen.

The specimen shall remain at the temperature of standard atmospheric conditions for measurement and test T_{STD}, 15 °C to 35 °C, for testing for a period adequate for the attainment of temperature stability. The relevant specification should specify a specific recovery period for a given type of specimen.

8 Test Nb: Change of temperature with specified rate of change

8.1 General description of the test

This test determines the ability of components, equipment, or other articles to withstand or function, or both, during changes of ambient temperature.

The specimen shall be either in the unpacked, switched-off, ready for use state, or as otherwise specified in the relevant specification.

The specimen is exposed to changes of temperature in air by exposure in a chamber to specified temperatures varied at a controlled rate. During this exposure the performance of the specimen should be monitored.

8.2 Testing procedure

8.2.1 Testing chamber

The chamber for this test shall be designed so that in the working space, where the specimen under test is placed, a temperature cycle can be performed in such a manner that

a) the low temperature required for the test can be maintained,

b) the high temperature required for the test can be maintained,

c) the temperature change required for the test from low temperature to high temperature or vice versa can be performed at the required rate of change.

8.2.2 Mounting or supporting structure of the test specimen

The thermal conduction of the mounting or supporting structure shall be low, such that for practical purposes the specimen is thermally isolated, if not specified otherwise. When testing several specimens simultaneously they shall be so placed that free circulation is provided between the specimens, and between the specimens and chamber surfaces.

8.2.3 Severities

The severity of the test is defined by the combination of the two temperatures, the rate of temperature change, the exposure time of the specimen and the number of cycles. The severity of the test will increase with an increase in the temperature difference, the increase in rate of temperature change, and the heat transfer to the specimen.

The low conditioning temperature T_{A} shall be specified in the relevant specification and should be chosen from the test temperatures of IEC 60068-2-1 and IEC 60068-2-2.

The high conditioning temperature T_{B} shall be specified in the relevant specification and should be chosen from the test temperatures of IEC 60068-2-1 and IEC 60068-2-2.

The rate of temperature change rate $\mathrm{d}T_{\mathrm{R}}$ shall be specified in the relevant specification. Example rates are as follows, if not specified otherwise:

– 1 K/min,
– 3 K/min,
– 5 K/min,
– 10 K/min,
– 15 K/min,
– 20 K/min,
– 25 K/min.

NOTE Temperature change rates > 15 K/min can result in severe testing conditions.

The exposure time to each of the two temperatures t_1 depends upon the heat capacity and the mass of the specimen. It can be 3 h, 2 h, 1 h, 30 min, or 10 min, or as specified in the relevant specification. Where no exposure period is specified in the relevant specification it is understood to be 3 h.

The specimen shall be subjected to two consecutive cycles, unless otherwise specified in the relevant specification.

8.2.4 Tolerance

Tolerances shall be specified in the relevant specification. If there are no tolerances specified, the following tolerances shall apply.

The calculation of the applicable temperature tolerance $\pm\sigma_T$ during the temperature transition depends on the temperature change rate dT_R and temperature difference D.

The applicable temperature tolerance of the medium temperature during temperature transition $\pm\sigma_T$ shall be selected from the larger of the two calculated values $\pm\sigma_{T,1}$ and $\pm\sigma_{T,2}$, if not specified otherwise. The value $\pm\sigma_{T,1}$ shall be calculated by using the temperature difference D multiplied with an adjustment factor of 0,075. The value $\pm\sigma_{T,2}$ shall be calculated by using the temperature change rate dT_R multiplied with a time constant of ±1 min.

The following applies:

$$\pm\sigma_T = \pm\sigma_{T,1} = \pm D \times 0{,}075 \qquad \text{for } \pm\sigma_{T,1} > \pm\sigma_{T,2} \text{ or}$$

$$\pm\sigma_T = \pm\sigma_{T,2} = \pm dT_R \times (1\ \text{min}) \qquad \text{for } \pm\sigma_{T,1} < \pm\sigma_{T,2}$$

Annex C shows an auxiliary table with temperature tolerances for preferred combinations of high and low conditioning temperatures and rates of temperature change.

The applicable temperature tolerance $\pm\sigma_{Tconst}$ of the medium temperature during the constant conditioning shall respectively be taken from IEC 60068-2-1 and IEC 60068-2-2, if not specified otherwise.

NOTE 1 The constant conditioning temperature periods can be seen as phases of temperature storage.

NOTE 2 For large test chambers the tolerances $\pm\sigma_{Tconst}$ during the constant conditioning can differ, refer to IEC 60068-2-1 and IEC 60068-2-2.

The relevant specification can call for tighter tolerances under special circumstances, if necessary.

The tolerance $\pm\sigma_T$ is applied during transition starting from 10 % to 90 % of the temperature difference D. The tolerance $\pm\sigma_{Tconst}$ is applied after 0,1 t_1 but at least 5 min and at most 15 min from the start of the constant temperature conditioning period.

For the period 0,1 t_1 at the beginning of each constant temperature conditioning as well as at the beginning and end of each transition no tolerance is specified, as indicated by the hatched areas in Figure 9. For better understanding of the periods with and without applicable tolerance, see Figure 9. The tolerances apply to the temperature as measured by the chamber control sensor.

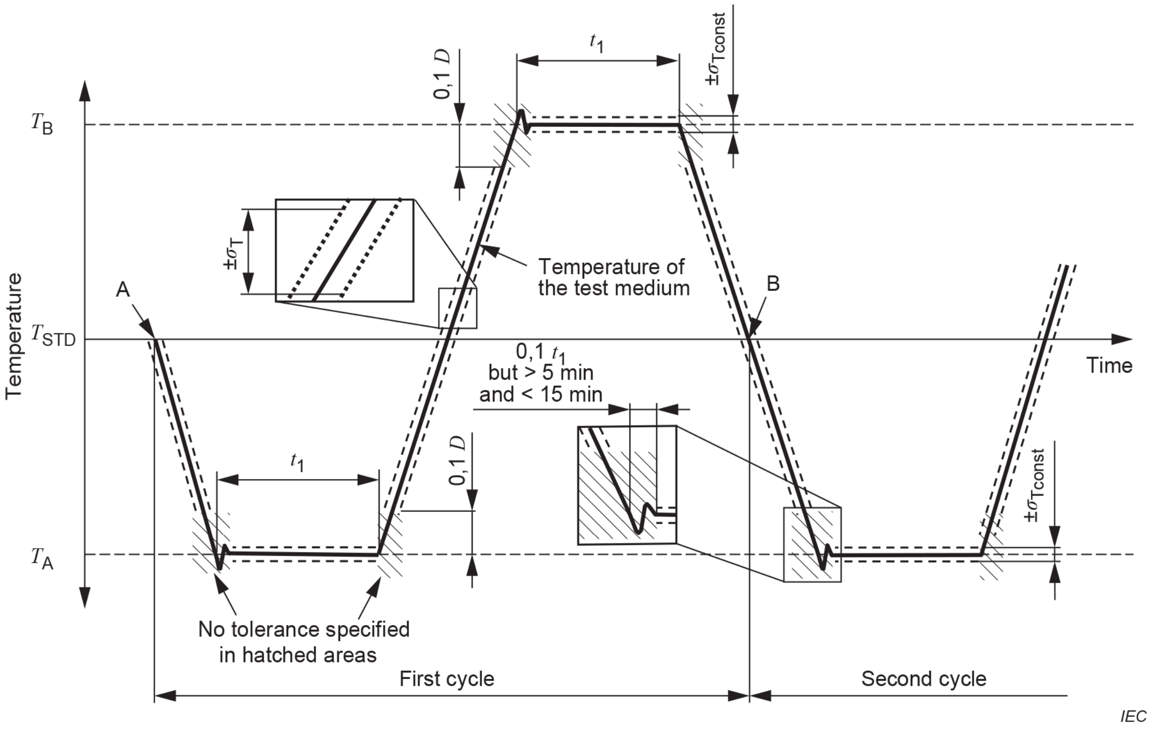


Figure 9 – Tolerance for fluctuation of test temperatures

8.2.5 Preconditioning

The specimen and the temperature in the test chamber shall be at the temperature of standard atmospheric conditions for measurement and test T_{STD}, 15 °C to 35 °C. If required by the relevant specification the specimen shall be brought into operating conditions.

8.3 Test cycle

The air temperature in the chamber shall then be lowered to the low conditioning temperature T_A at the specified rate dT_R (see Figure 10).

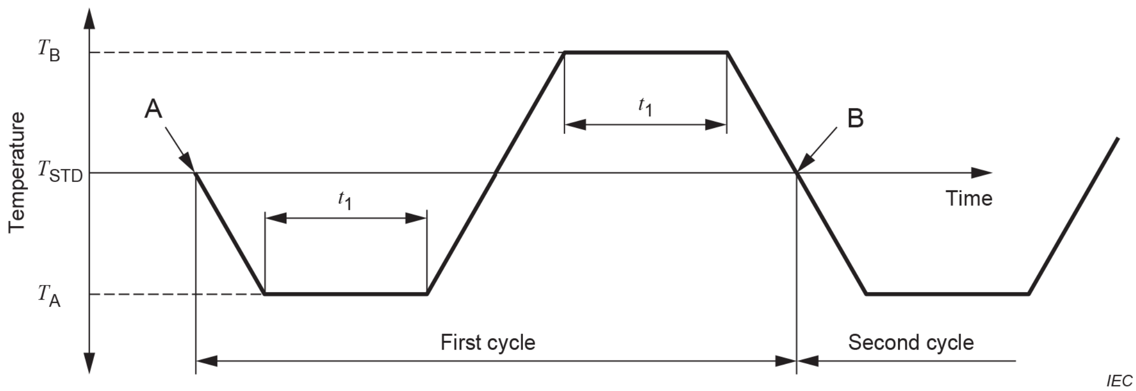
After temperature stability in the chamber has been reached, the specimen shall be exposed to the temperature T_A for the specified exposure time t_1.

The air temperature in the chamber shall then be raised to the high conditioning temperature T_B at the specified rate dT_R.

After temperature stability in the chamber has been reached, the specimen shall be exposed to the temperature T_B for the specified exposure time t_1.

The air temperature in the chamber shall then be lowered to the temperature of standard atmospheric conditions for measurement and test T_{STD}, 15 °C to 35 °C, at the specified rate dT_R.

This procedure constitutes one cycle.



Key

A start of first cycle

B end of first cycle and start of second cycle

Figure 10 – Nb test cycle

To limit the impact of the heat generating specimen on the test severity it is recommended to perform functional checks only during constant temperature phases of each test, if not specified otherwise. Continuous operation of specimen can prevent temperature equalization of the inner parts of these specimens during cooling. The designated time frames are shown in Figure 11, they should be limited to 90 % of the exposure time t_1, if not specified otherwise. The designated time frame for functional tests should start after 0,1 t_1 but at least 5 min and at most 15 min from the start of the constant temperature conditioning period, for temperature stabilization of the medium temperature in the chamber, if not specified otherwise.

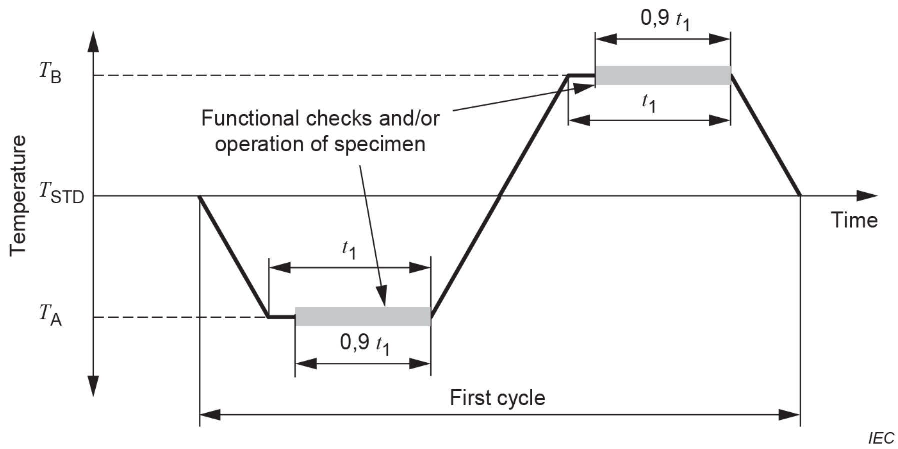


Figure 11 – Test times for intermediate operation of specimens

8.4 Recovery

At the end of the test cycle, the specimen shall remain at the temperature of standard atmospheric conditions for measurement and test T_{STD}, 15 °C to 35 °C, for testing for a period adequate for the attainment of temperature stability.

The relevant specification should specify a specific recovery period for a given type of specimen.

9 Test Nc: Rapid change of temperature, two-fluid-bath method

9.1 General description of the test

This test determines the ability of components, equipment, or other articles to withstand rapid changes of temperature.

This test procedure results in a severe thermal shock and is applicable to glass-metal seals and similar specimens.

The specimen is immersed alternately in two baths, one filled with liquid at a low temperature T_A and one filled with liquid at a high temperature T_B.

9.2 Testing procedure

9.2.1 Testing equipment

Two baths, one at low temperature and one at high temperature, shall be provided in such a way that the specimen under test can be easily immersed and be quickly transferred from one bath to the other.

The low temperature bath shall contain liquid at the low conditioning temperature T_A stated in the relevant specification. If no temperature is stated, the liquid shall have a temperature of 0 °C.

The bath for the high temperature shall contain liquid at the upper temperature T_B as required by the relevant specification. If no temperature is stated, the liquid shall have a temperature of +100 °C.

The baths shall be so constructed that at no moment during the test shall the temperature of the cold bath rise more than 2 K above T_A or the temperature of the hot bath fall more than 5 K below T_B.

The liquids used for the test shall be compatible with the materials and finishes used in the manufacture of the specimens.

NOTE The rate of heat transfer will depend upon the liquids used and will affect the severity of the test for a given temperature range.

9.2.2 Severities

The severity of the test is defined by the specified bath temperatures, the transfer time t_2 from one bath to the other and the number of cycles. The severity of the test will increase with an increase in the temperature difference, the reduction of the transfer time, and the heat transfer to the specimen.

The relevant specification shall specify the duration parameters to be used and the chosen value of the exposure time t_1 to both conditioning temperatures.

The number of test cycles is 10, unless otherwise specified in the relevant specification.

9.2.3 Conditioning

The specimen under test shall not be in operation during immersion. It shall be switched off and its movable parts shall be at rest, if not specified otherwise.

9.3 Test cycle

The specimen under test, while being at the ambient temperature of the laboratory, shall be immersed into the cold bath containing liquid at the low conditioning temperature T_A as stated in the relevant specification.

The specimen shall be maintained immersed in the cold bath for the specified exposure time t_1.

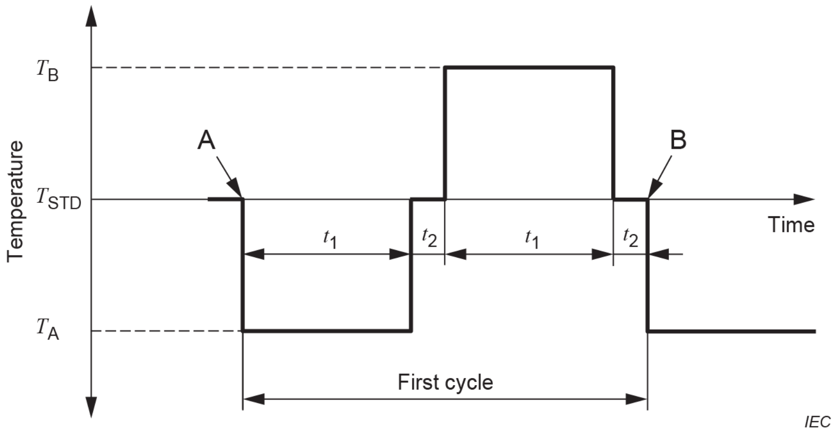
The specimen shall then be removed from the cold bath and immersed in the hot bath containing liquid at the high conditioning temperature T_B as stated in the relevant specification. The transfer time t_2 shall be as stated in the relevant specification.

The specimen shall be maintained immersed in the hot bath for the specified exposure time t_1.

The specimen shall then be removed from the hot bath. The transfer time t_2 between removal from the hot bath and immersion in the cold bath shall be as specified in the relevant specification.

One cycle comprises the exposure times t_1 to both conditioning temperatures and the transfer time t_2 (see Figure 12).

At the end of the last cycle, the specimen shall be subjected to the recovery procedure.



Key

A start of first cycle

B end of first cycle, start of second cycle

Figure 12 – Nc test cycle

9.4 Recovery

At the end of the test cycle, the specimen shall be subjected to the temperature of standard atmospheric conditions for measurement and test T_{STD}, 15 °C to 35 °C. Droplets of liquid shall be removed. If cleaning is necessary, then the method shall be defined by the relevant specification.

The relevant specification should specify a specific recovery period for a given type of specimen.

10 Information to be given in the test report

As a minimum, the test report shall show the following information:

a)	Customer	(name and address);
b)	Test laboratory	(name and address and details of accreditation – if any);
c)	Test dates	(dates when test was run);
d)	Type of test	(Na, Nb, Nc);
e)	Test standard, edition	(IEC 60068-2-14, edition used);
f)	Test specimen description	(drawing, photo, quantity build status, etc.);
g)	Test chamber identity	(unique identity of the chamber, e.g. internal Laboratory Identification number/code);
h)	Test set-up	(details of mounting and supports, measuring points, test medium, etc.);
i)	Initial, intermediate and final measurements	(if performed by the test laboratory);
j)	Required severities	(from relevant specification);
k)	Test severities	(preconditioning, temperatures, duration of exposure, data, etc.);
l)	Performance of test specimens	(results of functional tests, etc.);
m)	Observations during testing and actions taken	(any pertinent observations);
n)	Test results	(test summary, e.g. pass/fail decision).

In addition to the mandatory information the test report can include, for example:

o)	Purpose of test	(development, qualification, etc.);
p)	Relevant laboratory test procedure	(code and issue);
q)	Performance of test apparatus	(set point temperature control, air flow, etc.);
r)	Air velocity or direction or both	(air velocity or direction of incident air to the specimen or both);
s)	Uncertainties of chamber independent measuring system	(uncertainties data);
t)	Calibration data	(last and next due date);
u)	Measurements or loading during conditioning or both;	
v)	Any deviation in procedure as agreed between customer and supplier	(test set-up, applicable severities, etc.).

A test log should be written for the testing which can be attached to the report.

Annex A
(informative)

Potential consequences of improper severities

Accelerated temperature stress tests are an important aspect to evaluate the reliability of products and components over their entire life cycle. Complex geometries and differing materials cause mechanical stress within the specimens during cyclic temperature tests.

To guarantee the reliability of the test results, the intended change of temperature of the specimens should be ensured.

The change of temperature of a specimen follows an approximately exponential law. Inside large specimens or specimens with low thermal conductivity, such alternate exponential rises and decreases can lead to periodic and approximately sinusoidal changes of temperature with much lower amplitudes than the applied temperature swing. It is possible that the intended peak temperatures will not be reached in accelerated temperature tests. Figure A.1 gives a graphical display of this process.

NOTE It is common practice to examine the sample in advance to identify those parts that affect the slow temperature change of the sample. The results of the analysis can then be considered in the stabilization time of the sample.

For this reason, the monitoring of the temperature of the specimens at a representative point (or points) is recommended.

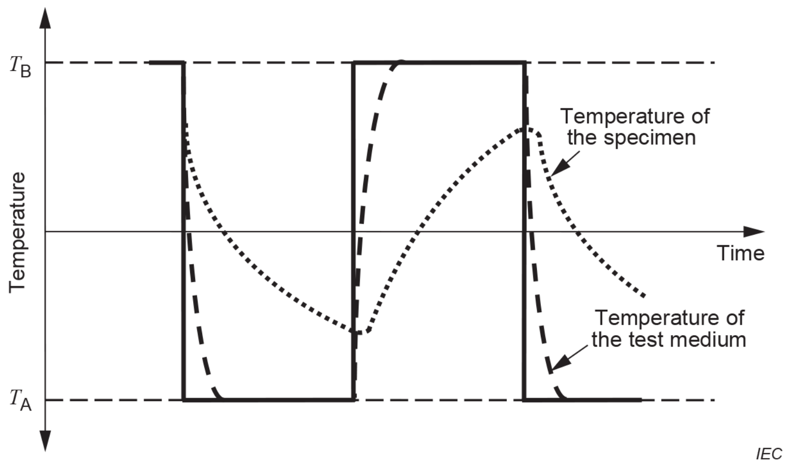


Figure A.1 – Delayed temperature change of the specimen

Annex B
(informative)

Thermal responsiveness of different materials and geometries

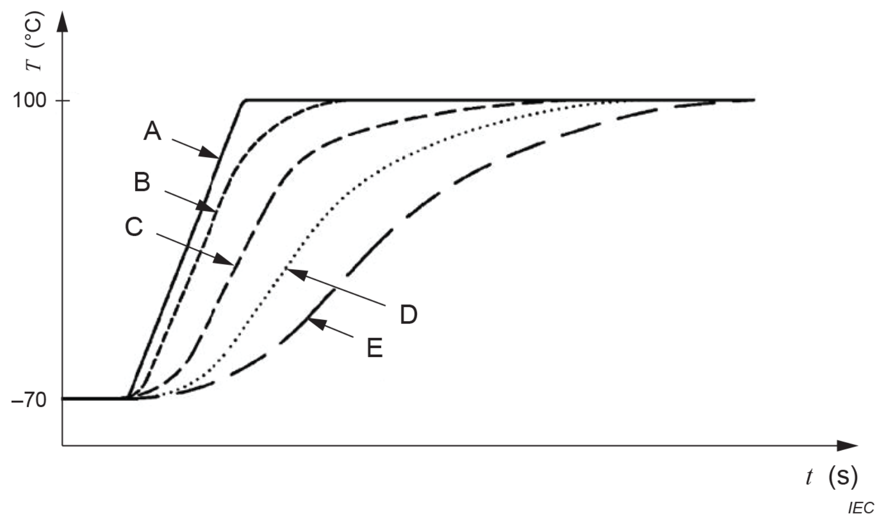
The specimen's characteristics, such as its thermal conductivity, its specific heat capacity as well as its mass and geometry can have a significant effect on the thermal responsiveness of the specimen. The rate of temperature change of the specimen during temperature stress tests is highly affected by its thermal responsiveness.

Small specimens with low specific heat capacity, as well as specimen with a proportionally large surface, will quickly respond to temperature changes of the ambient medium. Big specimens with higher specific heat capacity, as well as specimens with a rather small surface will respond with a significant time lag and lower rates of changes. Figure B.1 gives a graphical representation of the process described above. The figure shows exemplary temperature profiles of specimens with differing thermal responsiveness (C to E).

The specimen with high thermal responsiveness (C) responds almost immediately to the rise of ambient air temperature (B), whereas both specimens with lower thermal responsiveness (D and E) show an increasing time lag.

Furthermore, low thermal conductivities can lead to non-uniform temperature changes within the specimens as seen within the cylindric specimen made of plastic. These can prevent the specimen's core temperature from temperature equalization. This effect can be amplified in specimens with high masses.

These characteristics shall be taken into consideration when specifying any test parameters. If these characteristics are unknown, their experimental determination is recommended. For further information on the thermal responsiveness of specimens IEC 60068-3-1 can be helpful.



A set point test temperature

B air temperature within test chamber

C specimen with high thermal responsiveness

D specimen with medium thermal responsiveness

E specimen with low thermal responsiveness

Figure B.1 – Rate of temperature change of specimen with differing thermal responsiveness

Annex C
(normative)

Auxiliary table with exemplary temperature tolerances ±σ_T for preferred combinations of high and low conditioning temperatures and rates of temperature change (Test Nb)

Tolerances shall be specified in the relevant specification. If there are no tolerances specified, the following tolerances shall apply.

The calculation of the applicable temperature tolerance ±σ_T during the temperature transition depends on the temperature change rate and temperature difference D.

The applicable temperature tolerance of the medium temperature during temperature transition ±σ_T shall be selected from the larger of the two calculated values ±$\sigma_{T,1}$ and ±$\sigma_{T,2}$, if not specified otherwise.

The value ±$\sigma_{T,1}$ shall be calculated by using the temperature difference D multiplied with an adjustment factor of 0,075. The value ±$\sigma_{T,2}$ shall be calculated by using the temperature change rate dT_R multiplied with a time constant of ±1 min.

The following applies:

$$\pm\sigma_T = \pm\sigma_{T,1} = \pm D \times 0{,}075 \text{ , for } \pm\sigma_{T,1} > \pm\sigma_{T,2} \quad \text{(C.1)}$$

$$\pm\sigma_T = \pm\sigma_{T,2} = \pm \mathrm{d}T_R \times (1\ \text{min}) \text{ , for } \pm\sigma_{T,1} < \pm\sigma_{T,2} \quad \text{(C.2)}$$

For a better understanding, the following example and Figure C.1 show the applicable tolerance for exemplary test parameters. Additionally, Table C.1 gives an overview of applicable tolerances for preferred combinations of high and low conditioning temperatures as well as rates of temperature change dT_R.

NOTE For large test chambers the tolerances ±σ_{Tconst} during the constant conditioning can differ, refer to IEC 60068-2-1 and IEC 60068-2-2.

EXAMPLE

T_A = −55 °C

T_B = 85 °C

dT_R = 3 K/min

$$\pm\sigma_{T,1} = \pm D \times 0{,}075 = \pm\left(85\,°C - (-55\,°\text{C})\right) \times 0{,}075 = \pm 140\,\text{K} \times 0{,}075 = \pm 10{,}5\,\text{K} \quad \text{(C.3)}$$

$$\pm\sigma_{T,2} = \pm \mathrm{d}T_R \times (1\text{min}) = \pm 3\ \text{K} / \text{min} \times (1\text{min}) = \pm 3\ \text{K} \quad \text{(C.4)}$$

$$\pm\sigma_{T,1} > \pm\sigma_{T,2} \quad \rightarrow \pm\sigma_{T} = \pm\sigma_{T,1} = \pm 10{,}5\text{K} \tag{C.5}$$

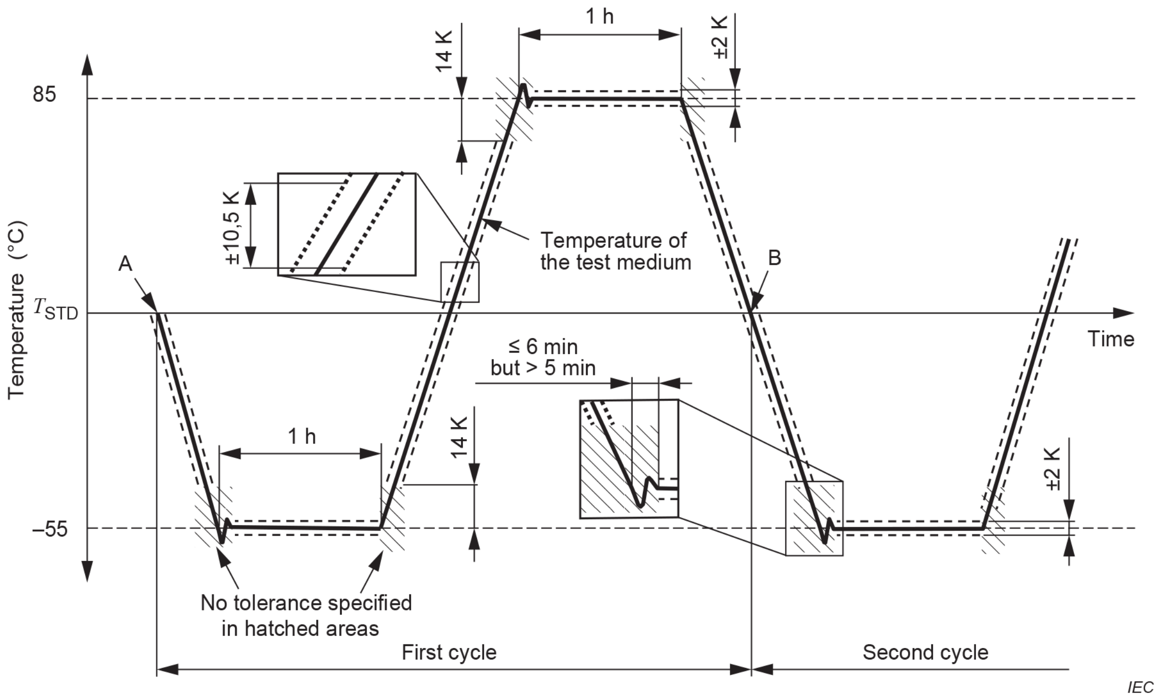


Figure C.1 – Tolerance for fluctuation of test temperatures for exemplary test parameters

Table C.1 – Applicable temperature tolerances ±σ_T in K for preferred combinations of high and low conditioning temperatures and rates of temperature change dT_R

dT_R = 1 K/min		High conditioning temperature T_B														
		30 °C	**35 °C**	**40 °C**	**45 °C**	**50 °C**	**55 °C**	**60 °C**	**65 °C**	**70 °C**	**85 °C**	**100 °C**	**125 °C**	**155 °C**	**175 °C**	**200 °C**
Low conditioning temperature T_A	**−65 °C**	±7,1	±7,5	±7,9	±8,3	±8,6	±9,0	±9,4	±9,8	±10,1	±11,3	±12,4	±14,3	±16,5	±18,0	±19,9
	−55 °C	±6,4	±6,8	±7,1	±7,5	±7,9	±8,3	±8,6	±9,0	±9,4	±10,5	±11,6	±13,5	±15,8	±17,3	±19,1
	−50 °C	±6,0	±6,4	±6,8	±7,1	±7,5	±7,9	±8,3	±8,6	±9,0	±10,1	±11,3	±13,1	±15,4	±16,9	±18,8
	−40 °C	±5,3	±5,6	±6,0	±6,4	±6,8	±7,1	±7,5	±7,9	±8,3	±9,4	±10,5	±12,4	±14,6	±16,1	±18,0
	−33 °C	±4,7	±5,1	±5,5	±5,9	±6,2	±6,6	±7,0	±7,4	±7,7	±8,9	±10,0	±11,9	±14,1	±15,6	±17,5
	−25 °C	±4,1	±4,5	±4,9	±5,3	±5,6	±6,0	±6,4	±6,8	±7,1	±8,3	±9,4	±11,3	±13,5	±15,0	±16,9
	−20 °C	±3,8	±4,1	±4,5	±4,9	±5,3	±5,6	±6,0	±6,4	±6,8	±7,9	±9,0	±10,9	±13,1	±14,6	±16,5
	−10 °C	±3,0	±3,4	±3,8	±4,1	±4,5	±4,9	±5,3	±5,6	±6,0	±7,1	±8,3	±10,1	±12,4	±13,9	±15,8
	−5 °C	±2,6	±3,0	±3,4	±3,8	±4,1	±4,5	±4,9	±5,3	±5,6	±6,8	±7,9	±9,8	±12,0	±13,5	±15,4
	5 °C	±1,9	±2,3	±2,6	±3,0	±3,4	±3,8	±4,1	±4,5	±4,9	±6,0	±7,1	±9,0	±11,3	±12,8	±14,6
dT_R = 3 K/min		High conditioning temperature T_B														
		30 °C	**35 °C**	**40 °C**	**45 °C**	**50 °C**	**55 °C**	**60 °C**	**65 °C**	**70 °C**	**85 °C**	**100 °C**	**125 °C**	**155 °C**	**175 °C**	**200 °C**
Low conditioning temperature T_A	**−65 °C**	±7,1	±7,5	±7,9	±8,3	±8,6	±9,0	±9,4	±9,8	±10,1	±11,3	±12,4	±14,3	±16,5	±18,0	±19,9
	−55 °C	±6,4	±6,8	±7,1	±7,5	±7,9	±8,3	±8,6	±9,0	±9,4	±10,5	±11,6	±13,5	±15,8	±17,3	±19,1
	−50 °C	±6,0	±6,4	±6,8	±7,1	±7,5	±7,9	±8,3	±8,6	±9,0	±10,1	±11,3	±13,1	±15,4	±16,9	±18,8
	−40 °C	±5,3	±5,6	±6,0	±6,4	±6,8	±7,1	±7,5	±7,9	±8,3	±9,4	±10,5	±12,4	±14,6	±16,1	±18,0
	−33 °C	±4,7	±5,1	±5,5	±5,9	±6,2	±6,6	±7,0	±7,4	±7,7	±8,9	±10,0	±11,9	±14,1	±15,6	±17,5
	−25 °C	±4,1	±4,5	±4,9	±5,3	±5,6	±6,0	±6,4	±6,8	±7,1	±8,3	±9,4	±11,3	±13,5	±15,0	±16,9
	−20 °C	±3,8	±4,1	±4,5	±4,9	±5,3	±5,6	±6,0	±6,4	±6,8	±7,9	±9,0	±10,9	±13,1	±14,6	±16,5
	−10 °C	±3,0	±3,4	±3,8	±4,1	±4,5	±4,9	±5,3	±5,6	±6,0	±7,1	±8,3	±10,1	±12,4	±13,9	±15,8
	−5 °C	±3,0	±3,0	±3,4	±3,8	±4,1	±4,5	±4,9	±5,3	±5,6	±6,8	±7,9	±9,8	±12,0	±13,5	±15,4
	5 °C	±3,0	±3,0	±3,0	±3,0	±3,4	±3,8	±4,1	±4,5	±4,9	±6,0	±7,1	±9,0	±11,3	±12,8	±14,6

dT_R = 5 K/min		High conditioning temperature T_B														
		30 °C	35 °C	40 °C	45 °C	50 °C	55 °C	60 °C	65 °C	70 °C	85 °C	100 °C	125 °C	155 °C	175 °C	200 °C
Low conditioning temperature T_A	−65 °C	±7,1	±7,5	±7,9	±8,3	±8,6	±9,0	±9,4	±9,8	±10,1	±11,3	±12,4	±14,3	±16,5	±18,0	±19,9
	−55 °C	±6,4	±6,8	±7,1	±7,5	±7,9	±8,3	±8,6	±9,0	±9,4	±10,5	±11,6	±13,5	±15,8	±17,3	±19,1
	−50 °C	±6,0	±6,4	±6,8	±7,1	±7,5	±7,9	±8,3	±8,6	±9,0	±10,1	±11,3	±13,1	±15,4	±16,9	±18,8
	−40 °C	±5,3	±5,6	±6,0	±6,4	±6,8	±7,1	±7,5	±7,9	±8,3	±9,4	±10,5	±12,4	±14,6	±16,1	±18,0
	−33 °C	±5,0	±5,1	±5,5	±5,9	±6,2	±6,6	±7,0	±7,4	±7,7	±8,9	±10,0	±11,9	±14,1	±15,6	±17,5
	−25 °C	±5,0	±5,0	±5,0	±5,3	±5,6	±6,0	±6,4	±6,8	±7,1	±8,3	±9,4	±11,3	±13,5	±15,0	±16,9
	−20 °C	±5,0	±5,0	±5,0	±5,0	±5,3	±5,6	±6,0	±6,4	±6,8	±7,9	±9,0	±10,9	±13,1	±14,6	±16,5
	−10 °C	±5,0	±5,0	±5,0	±5,0	±5,0	±5,0	±5,3	±5,6	±6,0	±7,1	±8,3	±10,1	±12,4	±13,9	±15,8
	−5 °C	±5,0	±5,0	±5,0	±5,0	±5,0	±5,0	±5,0	±5,3	±5,6	±6,8	±7,9	±9,8	±12,0	±13,5	±15,4
	5 °C	±5,0	±5,0	±5,0	±5,0	±5,0	±5,0	±5,0	±5,0	±5,0	±6,0	±7,1	±9,0	±11,3	±12,8	±14,6
dT_R = 10 K/min		High conditioning temperature T_B														
		30 °C	35 °C	40 °C	45 °C	50 °C	55 °C	60 °C	65 °C	70 °C	85 °C	100 °C	125 °C	155 °C	175 °C	200 °C
Low conditioning temperature T_A	−65 °C	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,1	±11,3	±12,4	±14,3	±16,5	±18,0	±19,9
	−55 °C	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,5	±11,6	±13,5	±15,8	±17,3	±19,1
	−50 °C	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,1	±11,3	±13,1	±15,4	±16,9	±18,8
	−40 °C	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,5	±12,4	±14,6	±16,1	±18,0
	−33 °C	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±11,9	±14,1	±15,6	±17,5
	−25 °C	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±11,3	±13,5	±15,0	±16,9
	−20 °C	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,9	±13,1	±14,6	±16,5
	−10 °C	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,1	±12,4	±13,9	±15,8
	−5 °C	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±12,0	±13,5	±15,4
	5 °C	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±10,0	±11,3	±12,8	±14,6

dT_R = 15 K/min		High conditioning temperature T_B														
		30 °C	**35 °C**	**40 °C**	**45 °C**	**50 °C**	**55 °C**	**60 °C**	**65 °C**	**70 °C**	**85 °C**	**100 °C**	**125 °C**	**155 °C**	**175 °C**	**200 °C**
Low conditioning temperature T_A	**−65 °C**	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±16,5	±18,0	±19,9
	−55 °C	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,8	±17,3	±19,1
	−50 °C	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,4	±16,9	±18,8
	−40 °C	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±16,1	±18,0
	−33 °C	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,6	±17,5
	−25 °C	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±16,9
	−20 °C	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±16,5
	−10 °C	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,8
	−5 °C	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,4
	5 °C	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0	±15,0
dT_R = 20 K/min		High conditioning temperature T_B														
		30 °C	**35 °C**	**40 °C**	**45 °C**	**50 °C**	**55 °C**	**60 °C**	**65 °C**	**70 °C**	**85 °C**	**100 °C**	**125 °C**	**155 °C**	**175 °C**	**200 °C**
Low conditioning temperature T_A	**−65 °C**	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0
	−55 °C	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0
	−50 °C	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0
	−40 °C	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0
	−33 °C	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0
	−25 °C	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0
	−20 °C	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0
	−10 °C	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0
	−5 °C	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0
	5 °C	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0	±20,0

dT_R = 25 K/min		High conditioning temperature T_B														
		30 °C	35 °C	40 °C	45 °C	50 °C	55 °C	60 °C	65 °C	70 °C	85 °C	100 °C	125 °C	155 °C	175 °C	200 °C
Low conditioning temperature T_A	−65 °C	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0
	−55 °C	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0
	−50 °C	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0
	−40 °C	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0
	−33 °C	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0
	−25 °C	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0
	−20 °C	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0
	−10 °C	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0
	−5 °C	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0
	5 °C	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0	±25,0

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This Indian Standard has been developed from Doc No.:LITD 01 (25091).

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