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Environmental testing - Part 3: Background information - Section 1: Cold and dry heat tests

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Umweltprüfungen -- Teil 3: Leitfaden -- Hauptabschnitt 1: Prüfungen mit Kälte und trockener Wärme

Essais d'environnement -- Partie 3: Informations de base -- Section 1: Essais de froid et de chaleur sèche

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Section 1: Cold and dry heat tests
(IEC 60068-3-1:1974 + IEC 60068-3-1A:1978)

Essais d'environnement
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Umweltprüfungen
Teil 3: Leitfaden
Hauptabschnitt 1: Prüfungen mit Kälte und trockener Wärme
(IEC 60068-3-1:1974 + IEC 60068-3-1A:1978)

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Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

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CENELEC
European Committee for Electrotechnical Standardization
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Foreword

The text of the International Standard IEC 60068-3-1:1974 + IEC 60068-3-1A:1978, prepared by SC 50B (transformed into IEC TC 104 "Environmental conditions, classification and methods of test), was approved by CENELEC as HD 323.3.1 S1 on 1985-06-27.

This Harmonization Document was submitted to the formal vote for conversion into a European Standard and was approved by CENELEC as EN 60068-3-1 on 1999-04-01.

The following date was fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2000-04-01

Endorsement notice

The text of the International Standard IEC 60068-3-1:1974 + IEC 60068-3-1A:1978 was approved by CENELEC as a European Standard without any modification.

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FOREWORD

1) The formal decisions or agreements of the IEC on technical matters, prepared by Technical Committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.

2) They have the form of recommendations for international use and they are accepted by the National Committees in that sense.

3) In order to promote international unification, the IEC expresses the wish that all National Committees should adopt the text of the IEC recommendation for their national rules in so far as national conditions will permit. Any divergence between the IEC recommendations and the corresponding national rules should, as far as possible, be clearly indicated in the latter.

PREFACE

This recommendation has been prepared by Sub-Committee 50B, Climatic Tests, of IEC Technical Committee No. 50, Environmental Testing.

It gives background information for Test A: Cold, of IEC Publication 68-2-1, and Test B: Dry Heat, of IEC Publication 68-2-2.

A first draft was discussed at the meeting held in Washington in 1970. As a result of this meeting, a new draft, document 50B(Central Office)161, was submitted to the National Committees for approval under the Six Months' Rule in April 1971.

The following countries voted explicitly in favour of publication:

Australia	Japan
Austria	Netherlands
Belgium	Norway
Czechoslovakia	Portugal
Denmark	Romania
Finland	South Africa (Republic of)
France	Sweden
Germany	Switzerland
Hungary	Turkey
Iran	Union of Soviet Socialist Republics
Israel	United Kingdom
Italy	United States of America

BASIC ENVIRONMENTAL TESTING PROCEDURES

Part 3: Background information

Section One — Cold and dry heat tests

1. Introduction

The performance of components and equipments is influenced and limited by their internal temperatures which depend on the external ambient conditions and on the heat generated within the device itself.

Whenever temperature gradients exist in the system formed by a device and its surroundings, a process of heat transfer will ensue.

The tests cover cold and dry heat testing, with both sudden and gradual change of the temperature, and of non heat-dissipating and heat-dissipating specimens (the latter with or without artificial cooling).

The use of test chambers with and without forced air circulation is covered as appropriate. A general block diagram of the total procedure is given in Appendix K.

1.1 *Reference ambient conditions*

Unfortunately, the actual ambient conditions in which the device will have to work are normally neither accurately known nor well defined, so that it is not possible to use them as a basis for design, specification or testing.

For these purposes, it is necessary to define conventional reference ambient conditions which may be specified taking into account the following considerations.

1.2 *Devices without heat-dissipation*

If the ambient temperature is uniform and constant and there is no generation of heat within the device, heat will flow from the ambient atmosphere into the device if the former is at a higher temperature, and from the device into the ambient atmosphere if the latter is at a lower temperature. This heat transfer will continue until the device has reached in all its parts the temperature of the surrounding atmosphere. From that moment on, the heat transfer ceases and will not start again unless the ambient temperature changes. In this case, the definition of a reference ambient temperature is simple, the only condition being that it shall be uniformly distributed and constant. For the case when the device does not reach the temperature of the surrounding atmosphere, the definition of a reference temperature is more complicated and the conclusions in Sub-clause 1.3 apply.

1.3 *Devices with heat-dissipation*

If heat were generated within the device and there were no heat transfer to the ambient atmosphere, the temperature of the device would rise beyond any limit. It follows that if an ultimate steady temperature is reached, this implies that heat is flowing continuously from the device into the atmosphere whereby the device is always cooled, no matter what the ambient atmosphere is. Only if the ambient temperature rises, a further rise of temperature within the device may occur.

The reference ambient temperature for this case shall obviously be so defined that simple and well reproducible conditions for heat transfer are obtained. Because heat transfer is accomplished by means of three distinct mechanisms, convection, radiation and conduction, well-defined conditions for each of them shall be obtained separately but simultaneously.

If more than one specimen is subjected to one of the dry heat tests in the same chamber, it is necessary to ensure that all specimens are in the same ambient temperature and have identical mounting conditions. It has not, however, been found necessary to differentiate between testing of single specimens and multiple specimens when the cold test is being performed.

1.4 *Ambient temperature*

Users of components and equipments, particularly equipments, require to know the maximum and minimum values of ambient temperature between which the item will operate and these should be specific for the purpose of testing.

Certain difficulties arise here due to the fact that heat transfer is connected with temperature gradients and that therefore the temperature of the medium surrounding the device is necessarily varying in space. Consequently, the "ambient temperature" of the surrounding atmosphere shall be specially defined.

1.5 *Surface temperatures*

Considering on the other hand that the principal influence on the performance of the device is its own temperature, for the purposes of monitoring and adjusting test gear it may be convenient to refer to the temperatures at some significant points on the surface or even in the interior of the specimen.

2. Reasons for the differing test procedures

2.1 *Mechanisms of heat transfer*

2.1.1 *Convection*

2.1.1.1 Heat transfer through convection is a very important part of heat transfer from heat-dissipating specimens exposed to test chamber conditions.

The coefficient of heat transfer from the surface of the test specimen to the ambient air is affected by the velocity of the surrounding air. The heat transfer is more efficient the higher the air velocity. Therefore, with the same temperature of the ambient air, the surface temperature of the test specimen will be lower the higher the air velocity. This effect is illustrated in Figures 2 and 3, pages 24 and 25.

In addition to the influence on the surface temperature of the test specimen at any one location, the airflow will also effect the temperature distribution on the surface of the test specimen. This effect is illustrated in Figure 4, page 26.

2.1.1.2 It is evident from Appendix B that there is no simple relationship between surface temperature and distribution for different air velocities and airflow directions. It is also obvious that if in conformance with actual conditions testing were to be defined with a particular value of air velocity and airflow direction, this would involve problems in the design of chambers.

The necessity for a well-defined, reproducible test condition where the test results can be easily compared with actual conditions leads to the use of "free air" conditions.

2.1.1.3 "Free air conditions" means conditions within an infinite space where the movement of the air is effected only by the heat-dissipating specimen itself, and the energy radiated by the specimen is absorbed. It is not practical for testing purposes to try to reproduce free air conditions (see Clause 3).

It is shown in Appendix A that the use of free air conditions as a reference does not normally lead to expensive or impracticably large testing-chambers. Since free air conditions have certain technical advantages and are normally easier to comply with than specified forced air conditions, they are used as the preferred way of performing cold and dry heat tests on heat-dissipating specimens.

Due to reasons given in Clause 3, there are cases where difficulties in testing with no forced air circulation arise.

Two alternative methods, where forced air circulation with low air velocity is allowed, have therefore been given. The first method applies to the cases where the size of the chamber is large enough to comply with the requirements in Appendix A, but where the heating or cooling of the chamber requires forced air circulation.

The second method applies to the cases where the chamber is too small to comply with the requirements of Appendix A, or where the first method cannot be used for other reasons.

2.1.2 *Thermal radiation*

2.1.2.1 Appendix C shows that heat transfer by thermal radiation cannot be neglected when test chamber conditions for testing of heat-dissipating specimens are discussed. In the case of thermal black test specimens and thermal black chamber walls (emissivity coefficient approaching unity), nearly half of the heat transfer from the test specimen may be due to thermal radiation. Thus, if the heat-dissipating test specimen is subjected to a certain ambient temperature in a thermal white chamber and in a thermal black chamber, the surface temperature of the test specimen will be significantly different. The emissivity coefficient and the temperature of the chamber walls should therefore be limited by specification if *reproducible* test results are to be achieved.

2.1.2.2 If the test specimen is sheltered from the chamber walls by other specimens, heating or cooling elements, mounting devices, etc., which do not comply with the requirements for thermal colour and temperature of the chamber walls, the heat radiation between the test specimen and the chamber walls is affected. The percentage of the chamber walls which can be "seen" by a specific point on the test specimen determines the "*view factor*" of that point. The view factors of each point of the test specimen should not be unduly disturbed by devices which do not comply with the requirements on thermal colour and temperature of the chamber walls.

2.1.2.3 In an ideal "free air" condition, the heat transferred from the test specimen is completely absorbed by the surrounding air. This occurs as a result of free convection and complete absorption of the thermal radiation.

Most equipments and components will be operating in a surrounding which approximates more to thermal black than to thermal white.

It is furthermore easier to make the inside of a chamber approximately thermal black than to make it approximately thermal white. It is especially difficult to keep it thermal white for a long period due to ageing effects. In fact, most paints and materials (unpolished) approximate more to thermal black than to thermal white (see Appendix J).

If the temperature of the chamber walls varies within 3% of the specified test temperature in degrees Kelvin and the emissivity coefficient varies between 0.7 to 1, the resulting variation in surface temperature of the test specimen will normally be less than 3 K. Since the heat radiation is proportional to the difference between the fourth power of the surface temperature of the test specimen and the fourth power of the chamber wall temperature, the thermal radiation is less pronounced at low temperatures and therefore the requirements on thermal colour and temperature of the chamber walls are less stringent when low temperature testing is concerned.

2.1.2.4 The heat transfer due to thermal radiation is considerably dependent on the temperature of the chamber walls. This dependence is the main reason why testing with forced air circulation cannot be used without corrections in accordance with Appendix E when the difference between the surface temperature of the specimen and the temperature of the ambient air is significant.

2.1.3 *Thermal conduction*

2.1.3.1 Heat-dissipation by thermal conduction depends on the thermal characteristics of mounting and other connections.

2.1.3.2 Many heat-dissipating equipments and components are intended to be mounted on heat sinks or other well-conducting devices, with the result that a certain amount of heat is effectively dissipated through thermal conduction.

The relevant specification shall then define the thermal characteristics of the mounting and these should be reproduced when the test is made.

2.1.3.3 If an equipment or component can be mounted in more than one manner with different values of thermal conduction, the worst case should be covered. The worst case is different for differing applications as follows:

a) Dry heat testing of heat-dissipating specimens. Since heat is transported in the direction from the test specimen to the mounting devices, the worst case is reached when this transfer is as small as possible, i.e. when the mounting has low thermal conductivity (thermally isolated).

b) Dry heat testing of non heat-dissipating specimens. As long as thermal stability has not been reached, the heat is transferred from the chamber walls through the mounting devices to the test specimen. The worst case is then where the thermal conductivity of the mounting is high. The thermal capacity of the mounting should be low in order to avoid a considerable warm-up time of the mounting and accordingly a delay in the heat transfer from the chamber walls to the test specimen.

c) Cold testing of heat-dissipating specimens and non heat-dissipating specimens. Since heat is transferred from the test specimen to the chamber walls through the mounting devices, the worst case (lowest temperature of the test specimen) is reached when this transfer is as effective as possible, i.e. when the thermal conductivity of the mounting is high.

2.1.4 *Forced air circulation*

2.1.4.1 Where the chamber is large enough to comply with the requirements in Appendix A, the heating and cooling of the chamber may necessitate forced air circulation.

In such cases, a check is made, at *laboratory temperature* inside the chamber, that the temperature at representative points on the surface of the test specimen is not unduly influenced by the air velocity used in the chamber. If the surface temperature at any point of the test specimen is not reduced by more than 5 deg C by the influence of the forced air circulation used in the chamber, testing is performed as in a chamber with no forced air circulation, and the cooling effect of the forced air circulation is neglected since it may be assumed to be reasonably small.

2.1.4.2 Where the chamber is too small to comply with the requirements of Appendix A, or where the reduction of surface temperature as measured in Sub-clause 2.1.4.1 exceeds 5 deg C, an exploratory test should be made outside the test chamber.

The temperatures of a representative number of points on the surface of the test specimen are measured in the laboratory *outside the chamber* in order to give a basis for calculation of the surface temperatures at the specified test conditions. These measurements are carried out under those load conditions which are specified for the test temperature by the relevant specification.

For small temperature differences $\Delta T1$ between ambient temperature and surface temperature, this difference $\Delta T1$ can be assumed to be the same in different ambient temperatures as long as the differences $\Delta T2$ in ambient temperatures are small.

The error is within 3 deg C if $\Delta T1 < 25$ deg C and $\Delta T2 < 30$ deg C.

The relationships between surface temperatures at different ambient temperatures are given in Appendix E. With nomograms in Appendix E, it is possible to calculate the surface temperature at any ambient temperature if the surface temperature at a certain ambient temperature is known. By using the nomogram, it is possible to extend the range where the surface temperatures in specified test conditions can be calculated if they are known at laboratory temperature. The nomograms in Appendix E can be used to at least $\Delta T1 = 80$ deg C and $\Delta T2 = 65$ deg C.

2.1.4.3 The choice of representative points to be checked when the alternative first and second methods are used should be based on a detailed knowledge of test specimen (thermal distribution, thermally critical points, etc.). Since such a choice is mainly a matter of skilled judgement, the preferred method where no forced air circulation is used is strongly recommended for type approval purposes because of its higher degree of reproducibility.

One exploratory test may cover the chamber performance for a long series of similar tests (e.g. similar components), whereas in other cases an assessment may need to be made prior to each test (e.g. for different equipment).

3. Test chambers

3.1 *General*

It is not practical for testing purposes to try to reproduce free air conditions, but it is however possible to simulate the effects of these conditions.

Even in very large chambers, the air circulation and temperature distribution around the test specimen will not be identical with actual free air conditions.

Nevertheless, it is established by experimental results and test experience that a reasonably large chamber with no forced air circulation will affect the temperature of the test specimen in approximately the same way as would free air conditions.

The requirements on size of chamber in relation to the size and heat dissipation of the test specimen, which are necessary for simulating the effects of free air conditions, are given in Appendix A.

The requirements presented are valid when the ambient temperature is monitored in the lower part of the testing chamber, where the air is not greatly affected by the heat convection from the test specimen.

However, in some cases difficulties in testing with no forced air circulation arise. In a number of existing chambers the heating or cooling of the chamber cannot be performed without forced air circulation, especially for testing of large specimens, or many components in the same chamber.

Table I shows the parameters of a test chamber that will have a considerable influence on the test results of a heat-dissipating specimen.

TABLE I

Transfer mechanism	Convection		Radiation	Conduction
	Free air	Forced air circulation		
Chamber parameters	Dimensions; air temperature	Air velocity; air temperature	Wall temperature; wall emission; view factor	Thermal characteristic of mounting

3.2 *Methods of achieving the required conditions in the test chamber*

3.2.1 *Design of chambers for simulating the effect of free air condition*

Heating and cooling elements should not be situated in the working space, as the controlling of the chamber temperature involves changes in the temperatures of these elements. Large fluctuations in the temperature of the chamber walls should be avoided in order to minimize radiation problems.

For the best results, all the walls of the chamber should be heated. Liquid circulation provides a convenient method of heating or cooling all walls without large fluctuations in wall temperature. The walls of the chamber should fulfil the emissivity requirements of the test.

Where a chamber relies on air circulation for maintenance of the test temperature, it may be possible to place the test specimen inside a box which is then placed in a chamber. The volume of the box should fulfil the dimensional requirements of the test and the walls should meet the emissivity coefficient requirements.

3.2.2 *Design of chambers with forced air circulation*

A chamber with an airflow is intended for use with specimens which make the use of a free air chamber impracticable either by virtue of their large size or high dissipation. All the requirements for free air chambers thus apply except for those relating to dimensions.

The airflow should be large enough to ensure that the specimen is not overheated, yet should not be so large that excessive cooling of the specimen can occur. The effects of airflow are given in more detail in Appendix B. In practice, an airflow of 0.5 m/s has been found to represent a fair compromise, although facility to vary the rate of flow is a useful advantage.

The airflow should be as uniform as possible. The airflow should be directed vertically upward to minimize the variation from that which would occur due to convection above. If the fan causes a pressure build-up in an antechamber, from which the air is allowed to escape through a filter (e.g. fibre-glass mat) a uniform airflow results. This antechamber may also contain the heaters which control the chamber temperature. Alternatively, the heaters and filter may be combined by the use of woven mesh heaters.