IEC 60068-3-4

Edition 2.0 2023-06
REDLINE VERSION

INTERNATIONAL STANDARD

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Environmental testing –
Part 3-4: Supporting documentation and guidance – Damp heat tests

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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FOREWORD

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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition IEC 60068-3-4:2001. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

IEC 60068-3-4 has been prepared by IEC technical committee 104: Environmental conditions, classification and methods of test. It is an International Standard.

This second edition cancels and replaces the first edition published in 2001. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) the requirements for distilled and deionized water have been revised;

b) recommendations for the cleaning procedure of test chambers have been included;

c) humidification systems (ultrasonic humidifiers and atomizers) have been added;

d) the description of water penetration mechanisms has been refined.

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

Draft	Report on voting
104/985/FDIS	104/1001/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 60068 series, published under the general title *Environmental testing*, 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 website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION

Temperature and relative humidity (RH) of the air, in varying combinations, are climatic factors which act upon a product during storage, transportation and operation.

Meteorological measurements made over many years have shown that a relative humidity > 95 % combined with a temperature > 30 °C does not occur in free-air conditions over long periods, except in regions with extreme climates. In dwelling rooms and workshops temperatures of > 30 °C ~~may~~ can occur but in most cases are combined with a lower relative humidity than in the open air.

Special conditions exist in certain wet rooms, for example in the chemical industry, metallurgical plants, mines, electroplating plants and laundries, where the temperature can reach 45 °C combined with a relative humidity up to saturation over long periods.

Certain equipment placed under particular conditions ~~may~~ can be subjected to a relative humidity of more than 95 % at higher temperatures. This ~~may~~ can happen when the equipment is placed in enclosures, such as vehicles, tents or aircraft cockpits, since this can result in intense heating through solar radiation while, because of inadequate ventilation, any humidity that ~~may~~ can be developed will be retained permanently within the interior.

In rooms having several heat sources, temperatures and relative humidity ~~may~~ can vary in different parts of the room.

To take these climatic factors over the lifetime of the product into account, environmental testing includes the practice of accelerated testing (see Clause 6).

Atmospheric pollution can intensify the effects of a damp climate on products. Attention is drawn to this fact because of its general importance, although pollutants are not contained in the atmospheres used for damp heat testing. If the effects of pollutants, for example corrosion and mould growth, are to be investigated, a suitable test from the IEC 60068-2 series should be used.

ENVIRONMENTAL TESTING –

Part 3-4: Supporting documentation and guidance – Damp heat tests

1 Scope

This part of IEC 60068 provides the necessary information and the basic principles of the effect of humidity in the context of environmental testing to assist in preparing relevant specifications, such as standards for components or equipment~~, in order to select appropriate tests and test severities for specific products and, in some cases, specific types of application~~. Furthermore, information is provided on operating climatic test chambers.

The object of this document is to present supporting documentation and guidance for a range of damp heat tests which, when specified by the relevant specification, can be applied to demonstrate the performance of equipment for which damp heat testing is required with the main aim of achieving qualification. This information and basic principles are intended to help selecting appropriate tests and test severities for specific products and, in some cases, specific types of application.

The object of damp heat tests is to determine the ability of products to withstand the stresses occurring in a high relative humidity environment, with or without condensation, and with special regard to variations of electrical and mechanical characteristics. Damp heat tests ~~may~~ can also be utilized to check the resistance of a specimen to some forms of corrosion attack.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions 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

NOTE A more detailed explanation of some phenomena is available in A.2.1.

3.1
condensation
precipitation of water vapour on a surface when the surface temperature is lower than the dew point temperature of the ambient air whereby water is transformed from vapour to the liquid state of aggregation

3.2
adsorption
adherence of water vapour molecules to a surface when the surface temperature is higher than the dew point temperature

3.3
absorption
accumulation of water molecules within a material

3.4
diffusion
transportation of water molecules through a material, ~~produced~~ induced by a partial pressure difference

Note 1 to entry: Diffusion results in a balance of partial pressures, whilst flow (such as through leaks, when the dimensions of such leaks are great enough to provide viscous or laminar flow) always finally results in the balance of the total pressures.

3.5
breathing
exchange of air between a hollow space and its surroundings, ~~produced~~ induced by changes of temperature or pressure

4 Procedures for the production and control of humidity

4.1 General

There are a great number of humidity test chambers available, equipped with different methods of humidity generation and of humidity control.

~~Distilled or deionized water should be used. The water should have a pH value between 6,0 and 7,2 and a minimum resistivity of 0,05 MΩ.cm.~~

~~All internal parts of the chamber should be maintained in a clean condition.~~

~~In the following subclauses, only the principal methods of generation of humidity are mentioned.~~

The water resistivity should be between 2 000 Ωm to 500 Ωm corresponding to a conductivity between 5 µS/cm to 20 µS/cm at +23 °C. Before the water is placed in the humidifier or storage tank of the chamber, all internal parts of the chamber should be cleaned.

NOTE 1 A conductivity lower than 5 µS/cm can harm the humidifier system. A conductivity higher than 20 µS/cm can cause limescale or other mineral deposits to form on parts of the humidifier system or specimen.

The chamber and its internal parts can be cleaned using diluted laboratory cleaning agent and a soft brush and rinsed with distilled or deionized water. It is recommended that the chamber is cleaned prior to each test. The test facility should be operated in a clean area.

NOTE 2 Chamber sensors can be affected by the cleaning procedure, as some sensors (e.g. capacitive humidity sensors) can be damaged by some cleaning agents.

NOTE 3 During cleaning, wearing gloves and a protective mask can be helpful as a precaution against the contamination of the test chamber and of the internal fixtures.

4.2 Injection of water (spraying)

Water is atomized to very fine particles or droplets.

The spray produced in this way moistens the air stream before it enters the working space, the greater part of the droplets evaporating on the way. Small droplets of water ~~may~~ can remain in the airflow.

Direct water injection into the working space ~~must~~ should be avoided, otherwise liquid water can accumulate on the test specimen.

These simple systems provide rapid humidification and require little maintenance. Examples of such humidification systems are ultrasonic humidifiers and atomization by means of a nozzle (one- and two-substance nozzles).

4.3 Injection of water vapour (steam)

Evaporated water (steam) is blown into the working space of the chamber.

This system gives rapid humidification and is easier ~~maintained~~ to maintain (steam valve). However, the resultant heat input ~~may~~ can necessitate additional cooling with possible dehumidification effects.

4.4 Saturation type

Air is blown through a vessel containing water, thus becoming saturated with vapour.

At a fixed airflow, the humidity is controlled by changing the water temperature. If an increase of humidification is produced by increasing the water temperature, this ~~may~~ can cause a temperature rise in the working space and, owing to the thermal capacity of the water, the response time ~~may~~ can be longer. This ~~may~~ can necessitate additional cooling with possible de-humidification effects.

If bubbles occur, they ~~may~~ can produce a small amount of spray when bursting.

4.5 Surface evaporation

The air is humidified by passing it over a large surface area of water. Different methods are used, for example repeated airflow over standing water or water-jet scrubbing over a vertical surface with the air stream in counter current. In this system, the spray is minimized. The humidity is controlled by changing the water temperature. Owing to the thermal capacity of the water, the response time ~~may~~ can be longer.

4.6 Aqueous solutions

Relative humidity is generated over standardized aqueous solutions of salts in small, sealed chambers at constant temperature. This system is not appropriate for heat-dissipating specimens or for specimens absorbing large quantities of moisture.

NOTE Salt particles ~~may~~ can be deposited on the surface of the test specimens and can cause stress corrosion in some materials.

WARNING – In some cases, for example with ammonium salts, salt particles ~~may~~ can be hazardous to health ~~and may cause stress corrosion in some materials~~.

4.7 Dehumidification

In order to control humidity, various dehumidification methods are used, including cold surfaces, injection of dry air, desiccants, etc.

NOTE Even with temperature tests, condensation can occur on the test specimen, when humidity in the test space condenses on the cold test specimen during heating.

4.8 Control of humidity

The size of the chamber, the humidifier and the response time of temperature/humidity sensors have important influences on the possible uncertainties of the humidity control system. The chamber performance can degrade, and therefore uncertainty is affected by the quality of maintenance. A regular reference measurement is recommended.

NOTE The humidity can be measured using e.g. psychrometers or capacitive sensors. With capacitive sensors, the dielectric can drift (e.g. due to acetic acid), and outgassing test specimens can damage the measuring system.

5 Physical appearance of the effects of humidity

5.1 General

The test specimen should be tested in the as-delivered condition without any special treatment, if not specified otherwise. It is possible that test items that are specially cleaned before the test will not give an indication of effects which occur in service.

Additional information on the effects of humidity on specimens is given in Annex A.

5.2 Condensation

The dew point temperature depends on the content of water vapour in the air. A direct relationship exists between dew point, absolute humidity and vapour pressure.

When introducing a specimen into a test chamber, condensation ~~may~~ can occur if its surface temperature is lower than the dew point temperature of the chamber air. It ~~may~~ can be necessary to pre-heat the specimen or dehumidify the chamber air according to the test parameters if condensation ~~has to~~ should be prevented.

When condensation is required on the specimen during the conditioning period, the temperature and the water content of the air ~~shall~~ should be raised so that the dew point temperature of the air becomes higher than the surface temperature of the specimen.

~~If the specimen has a low thermal time constant, condensation occurs only if the dewpoint temperature of the air increases very rapidly, or if the relative humidity is very close to 100 %. With the rate of temperature rise prescribed for tests Db, condensation may not occur on very small specimens.~~

~~Condensation may occur on the inner surface of casings subsequent to a fall in ambient temperature.~~

~~In general, condensation can usually be detected by visual inspection, however, this is not always possible, especially with small objects having a rough surface.~~

An example of a test where such condensation can be induced is Test Z/AD of IEC 60068-2-38.

Normally for specimen that are small, lightweight (or more generally have a low thermal time constant) condensation occurs only if the dew point temperature of the air increases very rapidly, or if the relative humidity is very close to 100 %. With the rate of temperature rise specified in IEC 60068-2-30 for Test Db, it is possible that condensation will not occur on very small specimens.

When testing includes condensation, two phenomena should be taken into consideration:

1) Microclimate: When two test specimens are positioned next to each other, one can shield the other. Even though the absolute humidity is the same, the relative humidity can be different.
2) Inner climate in the encapsulation: The water content is constant, but the temperatures are different. Condensation can occur on the inner surface of casings subsequent to a fall in ambient temperature.

Condensation can usually be detected by visual inspection, however, this is not always possible, especially with small objects having a rough surface.

NOTE Condensation can be determined by comparing the dew point and the temperature obtained by IR measurements or temperature measurements on the relevant spots on the specimen.

5.3 Adsorption

The amount of humidity that ~~may~~ can adhere to the surface depends on the type of material, its surface structure, the vapour pressure and the temperature. Separate evaluation of the effects of adsorption is difficult because of the usual effects of absorption being more evident.

5.4 Absorption

The quantity of moisture which will be absorbed depends on the material, the vapour pressure, the temperature and the water content of the ambient air. The absorbing process proceeds steadily until equilibrium is established. The speed of penetration of the water molecules increases with the temperature.

5.5 Diffusion

An example of diffusion, which is frequently found in electronic components, is the penetration of water vapour through encapsulations of organic material, for example into a capacitor or semiconductor device, or through the sealing compound into the casing.

6 Acceleration of tests

6.1 General

The aim of an accelerated test is to obtain as far as possible the same changes of characteristics as would occur in the normal service environment but in a much shorter time. Different failure mechanisms ~~may~~ can occur under severe conditions than would occur under normal conditions of use.

The severity of the test should be chosen, taking into account the limiting conditions of service and storage for which a product is constructed.

While the time required for condensation and adsorption processes is in general rather short, much longer periods of time (up to several thousand hours) ~~may~~ can be ~~needed~~ required for absorption and diffusion processes until the equilibrium state is reached. Therefore, the test times can reach several thousand hours for some test routines (e.g. IEC 60068-2-67: up to 2 000 h test time).

When the relationship between penetration speed and temperature is known, acceleration of a damp heat test ~~may~~ can be achieved by using a higher temperature.

Some additional acceleration ~~may~~ can be achieved by the use of bias voltage (see IEC 60068-2-66: Test Cx and IEC 60068-2-67: Test Cy).

The cycling of temperature as applied in the Db tests (see IEC 60068-2-30) has, in general, no accelerating effect on the absorption and diffusion processes. In view of the fact that the speed of penetration of water vapour increases with a rising temperature, the absorption will proceed more slowly with Test Db if the effective average value of the two temperature levels is lower than the test temperature of Test C (see IEC 60068-2-78, IEC 60068-2-66: Test Cx and IEC 60068-2-67: Test Cy).

6.2 Acceleration factor

It is not possible to give a generally valid acceleration factor for damp heat tests. If it is desired to know the acceleration factor, it can only be determined empirically for each particular product.

For comparative tests, a high degree of acceleration ~~may~~ can be useful and admissible if the failure mechanism does not change for the different specimens.

7 Comparison of steady-state and cyclic tests

7.1 Test C: Damp heat, steady-state

The steady-state test should be used where adsorption, absorption or diffusion plays the main part. When diffusion but not breathing is involved, either the steady-state or the cyclic test should be applied depending on the type of specimen and its application.

In many cases, Test Cab (see IEC 60068-2-78) is applied to determine whether the required electrical characteristics of the dielectric are maintained in the humid atmosphere or whether an insulating encapsulation can guarantee sufficient protection.

An alternate test method for investigating the effects of diffusion can be achieved by the use of Test Cx (see IEC 60068-2-66) or Test Cy (see IEC 60068-2-67).

For some specimens, the stresses produced by a steady-state test ~~may~~ can be similar to those produced by a cyclic test. In such cases, time constraints ~~may~~ can determine the selection of the appropriate test.

7.2 Test Db: Damp heat, cyclic test

When a cyclic damp heat test is appropriate, Test Db described in IEC 60068-2-30 ~~may~~ can be used for all types of specimens. Cyclic tests should be applied in all cases where the effects of condensation, or of the ingress and accumulation of water vapour by breathing, are important.

Variant 1 is preferred in cases where the effects of absorption, or of the ingress and accumulation of water vapour by breathing are important.

Variant 2 requires less sophisticated test equipment and can be used in cases where these effects are of minor importance.

Test Q: sealing, described in IEC 60068-2-17 can quickly detect leaks which ~~may~~ can permit breathing. However, it cannot reproduce the effects of a cyclic humidity test.

7.3 Sequences of tests and composite tests

An example of the need for a sequence or composite test would be the determination of joint tightness or crack detection by the application of one or more temperature cycles. It is not generally necessary to combine temperature cycles with humidity.

The desired effect can be made more stringent when Test N: Change of temperature (IEC 60068-2-14) is applied, followed by Test C or Test Db (IEC 60068-2-30) as appropriate. The effect will also be enhanced if the humidity test is immediately followed by Test A: Cold (IEC 60068-2-1). The large temperature difference with Test N produces a much greater thermal stress than Test Db where the rate of change of temperature is rather slow.

A composite test consisting of several damp heat cycles and a cold cycle is recommended when specimens composed of different materials and including joints, especially specimens including cemented glass joints, are to be tested. Such a test is specified in Test Z/AD and differs from other cyclic damp heat tests in that it derives its added effectiveness from a greater number of temperature variations in a given time, a higher upper temperature and the addition of a number of excursions to sub-zero temperatures. The accelerated breathing and the effect of the freezing of trapped water in cracks or fissures are the essential effects of the composite test.

The introduction of cold cycles between the humidity cycles is intended to freeze water which ~~may~~ can have been retained in any defects and by expansion due to freezing, to convert such defects into faults more rapidly than would occur during normal life.

It is emphasized, however, that the freezing effect will occur only if the fissure dimensions are large enough to allow the penetration of a coherent mass of water, as is normally the case in fissures between seals and metal assemblies or between seals and wire terminations.

For small hairline cracks or porous materials, for example in plastic encapsulation, the absorption effect will prevail and a steady-state, damp heat test should be preferred for investigating these effects.

8 Influence of test environment on specimens

8.1 Change of physical characteristics

Mechanical and optical characteristics of materials~~ may~~ can change in humid atmospheres, e.g. material expansion, variation of surface characteristics such as the coefficient of friction, change of strength~~, etc~~.

To determine such changes of characteristics, it depends on the application, whether a steady-state or a cyclic test is appropriate, and whether or not condensation is required.

8.2 Change of electrical characteristics

8.2.1 With surface moisture

If the surface of an insulating material is affected by condensation or by a certain amount of adsorbed moisture, certain electrical characteristics can change, such as decrease of surface resistance, increase of loss angle (for capacities~~/~~ and inductance with alternating current). Leakage currents can also occur.

In general, Test Db (IEC 60068-2-30) is applied in such cases. If condensation is excluded, Test Cab (IEC 60068-2-78) can be used instead.

In certain cases, specimens are required to be switched on, loaded or measured during conditioning.

In general, changes of electrical characteristics due to surface moisture will become evident after a few minutes.

8.2.2 With penetrated moisture

Moisture absorbed by an insulating material~~ may~~ can cause a variation of electrical characteristics, such as decrease of electric strength, decrease of insulation resistance, increase of loss angle, increase of capacitance.

Since the absorption and diffusion processes occur over long periods of time and the equilibrium state is reached only after some hundreds or even thousands of hours, long conditioning times should be chosen accordingly. The extrapolation of test results is only possible if the time dependency is known. As an example, plastic encapsulation which appears satisfactory after 56 days of exposure to Test Cab (IEC 60068-2-78)~~ may~~ can deteriorate over a longer period due to absorption~~/~~ or diffusion of high moisture quantity.

The evaluation of the influence of absorbed moisture~~ may~~ can become problematic when the functional parts in the encapsulation are additionally protected against humidity, for example by the passivation of semiconductors, by enclosing drying agents~~, etc~~.