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**Plastics — Determination of the effects of  
exposure to damp heat, water spray and  
salt mist**

*Plastiques — Détermination des effets d'une exposition à la chaleur  
humide, au brouillard d'eau et au brouillard salin*

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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 4611 was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 6, *Ageing, chemical and environmental resistance*.

This fourth edition cancels and replaces the third edition (ISO 4611:2008), which has been technically revised. The main changes concern the equipment requirements and exposure conditions specified in Clause 4.

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## 0 Introduction

**0.1** Various test methods are available for the exposure of plastics to different aggressive agents acting in a combined and simultaneous fashion, such as natural weathering. Other test methods are available for the purpose of a separate evaluation of the action of individual aggressive agents. Among the latter there are, for example, tests for the resistance to specific chemicals and to radiations of a definite spectral range.

For some applications, it may be desirable to evaluate the behaviour of the materials in a hot damp atmosphere just below the saturation limit of water vapour, as well as in the presence of the liquid phase.

In these conditions not only water absorption or leaching of some ingredients of the composition may be observed but also degradation phenomena due to hydrolysis, exudation of plasticizers, etc.

It may also be desirable sometimes to evaluate the behaviour of materials in the presence of a highly corrosive electrolyte, such as a sodium chloride solution (salt mist), which is the principal aggressive agent present in marine environments and of particular importance in the case of nautical applications. It is well known that sodium chloride has no noticeable action on the polymers that are the basic components of plastics, and that salt solutions, owing to their higher osmotic pressure, are normally absorbed by plastics to a lesser degree than pure water, but it cannot be assumed *a priori* that they have no action on composite materials, containing fillers, reinforcing components or pigments, for instance.

Furthermore, the evaluation of the effect of salt mist can be very important for finished or semi-finished articles which, while basically consisting of plastic materials, do contain some metallic elements, such as moulded-in inserts, thin laminated foils, surface coatings applied by electro-plating or other procedures, or, lastly, metal cores sheathed with plastics by extrusion or by dipping in pastes or fluidized-bed powders.

**0.2** Methods and equipment for obtaining reproducible aggressive environments of the above types are well known and have been described by International Standards relevant to other materials and IEC (International Electrotechnical Commission) standards relevant to electrical and electronic components. The same equipment and procedures described in these standards can also be employed for plastics, with appropriate care and adjustments.

**0.3** The present International Standard is intended to provide general guidance only, on the choice of suitable equipment and procedures for obtaining the exposure conditions described above and for the preparation of test specimens. It also only gives general guidance on the properties to be evaluated. Specific details are given in the various ISO and IEC publications.

For the expression of results, the present International Standard follows, as far as possible, the same criteria adopted in the existing test methods for the exposure to chemicals (see ISO 175) and to natural weathering or artificial light (see ISO 4582).

**0.4** These tests are intended to yield data about the effects of the described exposures on the materials; however, a direct correlation between the experimental results and the behaviour in service is not to be inferred.

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# Plastics — Determination of the effects of exposure to damp heat, water spray and salt mist

## 1 Scope

1.1 This International Standard specifies the conditions of exposure of plastics to

- damp heat,
- water spray,
- salt mist,

and the methods for the evaluation of the change in some significant characteristics after given exposure stages.

1.2 This International Standard is, in general, suitable for all plastics in the form of standard test specimens, and finished articles or parts thereof.

1.3 This International Standard considers separately methods for the determination of

- change in mass,
- change in dimensions and appearance,
- change in physical properties.

## 2 Normative references

The following referenced documents are indispensable for the application 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.

ISO 62, *Plastics — Determination of water absorption*

## 3 Principle

One or more properties are determined before and after given periods of exposure in the specified environmental conditions, and any change in appearance is observed. If required, the determination of one or more properties may be carried out after exposure and a subsequent drying treatment or a reconditioning treatment carried out with the aim of obtaining the same state of equilibrium with atmospheric humidity as that of the initial specimens.

## 4 General test conditions

### 4.1 Equipment requirements

#### 4.1.1 General

Equipment used for exposing specimens to steady state or cyclic exposure conditions involving heat, humidity, and water or salt spray shall be made from corrosion resistant materials that will not interact with or contaminate the specimens being exposed. In addition, the device shall provide a means to programme and time the various portions of the exposure cycles that are used.

Sensing devices for measurement of temperature and relative humidity shall be located within the working volume of the chamber.

Any condensed water shall be continuously drained from the chamber and not re-used until re-purified.

No condensed water from the walls or roof of the chamber can fall on the test specimens.

Water used for the maintenance of the chamber humidity shall have a resistivity of at least 0,05 M $\Omega$  cm.

For the water spray (see 4.2.2) and salt mist (see 4.2.3) tests, the following additional equipment requirements shall be met. The cabinet shall have a volume of not less than 0,4 m<sup>3</sup> since, with smaller volumes, difficulties have been experienced in ensuring an even distribution of spray. For large-volume cabinets, it is nevertheless necessary to ensure that the spray is distributed homogeneously throughout the cabinet. The upper parts of the inside of the cabinet shall be designed so that any drops of spray which form on its surface cannot fall on the specimens being tested.

For the salt mist test (see 4.2.3), the apparatus should, for environmental reasons, preferably be fitted with equipment for treating the salt mist after the test, prior to releasing it to the atmosphere, and also with equipment for treating the salt water produced during the test, prior to discharging it to the sewage system.

For the water spray (see 4.2.2) and salt mist (see 4.2.3) tests, the device for spraying the water or salt solution shall include a supply of compressed air, a reservoir containing the water or salt solution to be sprayed, and one or more atomizers. Before it reaches the atomizers, the compressed air shall be passed through a filter to remove all traces of oil and solid matter, and the atomization shall be carried out at an overpressure of about 70 kPa. The level of the water or salt solution shall be maintained automatically. In order to prevent evaporation of water from the sprayed droplets, the compressed air shall be humidified, before entering the atomizer, by passing it through a saturation tower containing distilled or deionized water at a temperature 10 °C above that of the cabinet.

For the salt mist test (see 4.2.3), the characteristics of the mist produced will depend on the pressure used and on the type of atomizer nozzle. These shall be adjusted so that the concentration of the salt mist in the cabinet (as measured by the rate of deposition of the mist on a collection surface) and the salt concentration in the mist are kept within the limits specified in 4.2.3.

NOTE ISO 9142:2003, Annex E, describes exposure conditions similar to those used in this International Standard.

#### 4.1.2 Temperature

The exposure cabinet shall be capable of controlling the temperature in the exposure chamber to within  $\pm 2$  °C of the desired equilibrium temperature. The temperature tolerance limits of  $\pm 2$  °C are intended to allow for any systematic measurement errors, any temperature drift and any variations in temperature at different points in the chamber. However, in order to maintain the relative humidity throughout the chamber within the required tolerances, it is necessary to keep the temperature difference between any two points in the chamber at any given time within narrower limits. Specimens being exposed in the chamber shall not be subjected to radiant heat from the chamber temperature-control devices.

The chamber temperature shall be measured at least 100 mm from the walls.



## 4.2 Exposure conditions

### 4.2.1 Damp heat

#### 4.2.1.1 General

The preferred exposure conditions correspond to those described in the IEC publications referred to in 4.2.1.2 and 4.2.1.3. Different temperature and/or humidity conditions may be used, however, if specified in the relevant product specifications or by agreement between the interested parties.

#### 4.2.1.2 Steady state test

Unless otherwise specified, the chamber shall be at ambient laboratory temperature and humidity at the start of the test. Place the conditioned specimens (see 4.3.1) in the chamber and adjust the controls to produce the following conditions:

temperature:  $40_{-1}^{+2}$  °C;

relative humidity:  $93_{-8}^{+4}$  %.

As the chamber temperature is increasing to 40 °C, the rate of temperature change shall not exceed 1 °C/min, averaged over a period of not more than 5 min. During the heating-up period, condensation shall not occur on the specimens.

Once the specified temperature is reached, adjust the relative humidity to the specified level within no more than 2 h.

The period of exposure shall be as specified by the specification covering the material or product being tested. When not specified, this period shall be agreed upon by the interested parties. Recommended periods of exposure are 12 h, 16 h, 24 h, 48 h, 96 h and 240 h.

NOTE The conditions given in this subclause correspond to those specified in IEC 60068-2-78:2001.

#### 4.2.1.3 Cyclic test

This test takes the chamber and specimens through a number of 24 h cycles during which the temperature shall be maintained at an upper value and at  $(25 \pm 3)$  °C. One of the following two temperatures shall be chosen as the upper temperature:

- a)  $(40 \pm 1)$  °C (in which case the number of cycles shall be 2, 6, 12, 21 or 56);
- b)  $(55 \pm 1)$  °C (in which case the number of cycles shall be 1, 2 or 6).

The upper temperature shall be reached within the first  $3 \text{ h} \pm 30 \text{ min}$  of each 24 h cycle. During this temperature increase, the relative humidity shall not drop below 95 %, except during the last 15 min when the relative humidity may drop below 95 % but not below 90 %. During the temperature increase, condensation on the specimens is allowed.

In the following hours, the temperature shall be maintained at the upper value chosen and the relative humidity shall be maintained at  $(93 \pm 4)$  %.

After 12 h of the 24 h cycle, the temperature shall be allowed to decrease, within 3 h to 6 h, to the lower temperature of  $(25 \pm 3)$  °C. During this temperature decrease, the relative humidity shall not drop below 80 %.

For the rest of the 24 h cycle, the temperature shall be maintained at  $(25 \pm 3)$  °C and the relative humidity shall not be less than 95 %.

NOTE 1 The conditions given in this subclause correspond to those specified in IEC 60068-2-30:2005 (using variant 2 for the temperature decrease part of the cycle).

NOTE 2 For composite temperature/humidity cycles, with the addition of a number of excursions to sub-zero temperatures, guidance can be found in IEC 60068-2-38.

#### 4.2.2 Water spray

The main difference between this exposure condition and that for damp heat/steady state (see 4.2.1.2) is the constant presence of the liquid phase, in the form of small water droplets.

Suitable equipment for obtaining these conditions is substantially identical to that for the salt mist exposure (see 4.2.3) and is described in the relevant specifications.

Distilled or deionized water, having a pH between 6 and 7, shall be used instead of the salt solution.

The temperature in the test enclosure shall be  $(40 \pm 2)$  °C.

#### 4.2.3 Salt mist

Dissolve a sufficient mass of sodium chloride in distilled or deionized water with a conductivity not higher than 20  $\mu\text{S}/\text{cm}$  at  $(25 \pm 2)$  °C to produce a concentration of  $(50 \pm 5)$  g/l. The specific-gravity range for a  $(50 \pm 5)$  g/l solution is 1,029 to 1,036 at 25 °C.

The sodium chloride shall contain less than 0,001 % by mass of copper and less than 0,001 % by mass of nickel, as determined by atomic absorption spectrophotometry or another analytical method of similar sensitivity. It shall not contain more than 0,1 % by mass of sodium iodide or more than 0,5 % by mass of total impurities, calculated with respect to the dry salt.

Adjust the pH of the salt solution so that the pH of the salt mist collected in the chamber (see below) is between 6,5 and 7,2 at  $(25 \pm 2)$  °C. Check the pH by electrometric measurement or, for routine checks, using short-range pH paper which can be read in increments of 0,3 pH-units or less. Make any necessary correction by adding hydrochloric acid, sodium hydroxide or sodium bicarbonate solution prepared from analytical-grade reagents.

The temperature inside the cabinet shall be  $(35 \pm 2)$  °C.

The chamber shall contain at least two devices for collecting salt mist. These devices shall include a horizontal surface of area 80 cm<sup>2</sup> on which mist will be deposited during the exposure. They shall be placed so that only mist, and not liquid falling from specimens or from parts of the cabinet, is collected. They shall be used to ensure that the following requirements are met:

- the average collection rate shall be 1 ml/h to 2 ml/h when measured over a period of at least 16 h;
- the pH of the mist collected shall be between 6,5 and 7,2 at  $(25 \pm 2)$  °C (see above);
- the sodium chloride concentration in the mist collected shall be  $(50 \pm 5)$  g/l.

NOTE 1 The conditions given in this subclause correspond to those specified in ISO 9227:2006 and IEC 60068-2-11:1981.

NOTE 2 In this test, the exposure temperature used is 35 °C, even though this temperature is not included among those recommended in ISO 3205, because it is specified in ISO 9227 and in the majority of existing national standards.

The period of exposure shall be as specified by the specification covering the material or product being tested. When not specified, this period shall be agreed upon by the interested parties. Recommended periods of exposure are 2 h, 6 h, 24 h, 48 h, 96 h, 168 h, 240 h, 480 h, 720 h and 1 000 h.

### 4.3 Test specimens (see 5.2, 6.2 and 7.2)

#### 4.3.1 Conditioning

Unless otherwise agreed by the interested parties, the test specimens shall be conditioned before testing for at least 86 h at  $(23 \pm 2)$  °C and  $(50 \pm 10)$  % RH.

For certain materials which are known to approach rapidly, or on the contrary very slowly, the state of equilibrium of temperature and, above all, of humidity, shorter or longer conditioning periods may be specified in the particular specifications concerning them (see Annex A).

#### 4.3.2 Treatment after exposure

##### 4.3.2.1 General

The exposed specimens shall be tested either

- a) directly after the exposure, or
- b) after the exposure and subsequent drying or reconditioning.

The first procedure shall be used when it is required to know the state of the material while it still contains the amount of water it had absorbed by the end of the exposure. The second procedure shall be used when it is required to determine the changes in properties of the material as a result of the exposure only. In the case of reconditioning, the specimens shall be brought back, as far as possible, to the same state as the initial state before exposure with regard to equilibrium with atmospheric humidity (see 4.3.1).

##### 4.3.2.2 Test after exposure only

After rinsing with distilled or deionized water, if necessary, and wiping dry, the exposed specimens shall be brought to  $(23 \pm 2)$  °C in a closed container, usually 4 h are sufficient for this purpose.

##### 4.3.2.3 Test after exposure and drying or reconditioning

After rinsing and wiping dry, the specimens shall be dried or reconditioned to equilibrium with the same atmospheric conditions as before the exposure (see 4.3.1), taking due account of the procedures described in A.3.1 and A.3.2 in Annex A. Unless otherwise specified in the relevant product standard or agreed upon between the interested parties, the specimens shall be dried in an oven at  $(50 \pm 2)$  °C for 24 h and cooled to  $(23 \pm 2)$  °C in a desiccator.

Specimens more than 200 µm thick will not be in humidity equilibrium after 24 h (see ISO 62). Therefore, a longer drying time is recommended for such specimens. If a longer drying time is used, it shall be agreed upon by all interested parties and stated in the test report.

## 5 Change of mass

### 5.1 General

**5.1.1** In this type of test, the changes in mass are at least partially due to water absorption, and they are therefore particularly influenced by the conditioning and drying/reconditioning of the test specimens.

It is important, therefore, that the precise conditions of test be specified in the relevant product specifications.

Normally, the specimens are weighed immediately after exposure, rinsing and wiping dry, or are treated as described in 4.3.2.2.