INTERNATIONAL STANDARD

ISO 11907-1

Second edition
2019-07

Plastics — Smoke generation — Determination of the corrosivity of fire effluents —

Part 1:
General concepts and applicability

Plastiques — Production de fumées — Détermination de la corrosivité des effluents du feu —

Partie 1: Concepts généraux et applicabilité

Reference number
ISO 11907-1:2019(E)

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Published in Switzerland

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 4, *Burning behaviour*.

This second edition cancels and replaces the first edition (ISO 11907-1:1998), which has been technically revised.

The main changes compared to the previous edition are as follows:

- update of the existing test methods;
- clarification of differences between acidity, corrosivity and toxicity;
- clarification of the importance of fire scenarios and global approach for corrosivity assessment.

A list of all parts in the ISO 11907 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Corrosivity of smoke is important in the evaluation of fire damages[1][2][3]. This document constitutes the guidance part of the ISO 11907 series. Clause 3 defines smoke corrosivity as well as smoke acidity and smoke toxicity. Clause 4 details the objectives of this document. Clause 5 presents the scenario-based approach that governs smoke corrosivity. Clause 6 categorizes the different test methods to assess smoke corrosivity at laboratory scale. Clauses 7 and 8 respectively deal with the applicability and post-exposure conditions.

ISO 11907-4[4] describes a dynamic test procedure. Any standard method within the ISO 11907 series should be used solely to measure and describe the properties of materials, products or systems in response to heat or flame under controlled laboratory conditions and should not be considered or used by itself for describing or appraising the fire hazard of materials, products or systems under actual fire conditions or as the sole source on which regulations pertaining to corrosivity of fire effluents are based.

NOTE Two other methods, named ISO 11907-2[5] and ISO 11907-3[6], existed in the past but are no longer used. Related International Standards have been withdrawn.

Smoke corrosivity represents the measured effect of material or product reduction in functionality due to the corrosive effects of smoke. These corrosive effects are an essential factor in the assessment of the extent and cost of fire damage. All fire effluents and effects, including the released heat, are corrosive to some degree. Their potential to cause damage depends on a series of factors including:

- the rate of fire growth, which determines effluent concentrations;
- the volume into which the effluents disperse;
- the conditions of ventilation of the enclosure, including windows, smoke vents and mechanical ventilation;
- the nature of the combustible materials involved in the fire;
- the nature and composition of the exposed surfaces;
- the time of exposure;
- the conditions where pyrolysis occurs (heat flux, oxygen) as well as where combustion occurs;
- the specific environmental conditions at the exposed surfaces (temperature and humidity);
- the efficacy of active and passive fire protection, extinction and smoke management systems.

The corrosive effects of combustion products are not connected to the effect of fire effluents to people such as fire effluents toxicity.

The corrosive effects of fire effluents are not only material or product dependent, but also a systemic parameter. A scenario-based approach is then needed for assessment, i.e. using CFD models in a fire safety engineering approach. Corrosivity tests at laboratory scale might be relevant to assess the corrosion behaviour of smoke. In any given corrosivity test, the effects of the combustion products on the target depend on:

- their concentration;
- their chemical and physical nature;
- the chemical and physical nature of the corrosion target;
- the time of exposure and post-exposure conditions;
- the environmental conditions at the target-effluent interface (humidity, temperature, flow regime);
- condensation phenomena at the target;

- adsorption by smoke particles of corrosive effluents;
- interactions between the fire effluent and surrounding surfaces;
- nature of any cleaning of the target after the exposure.

In the fire, the effluents are carried by buoyancy to regions remote from the fire zone itself, so the potential for corrosion exists even in these areas the smoke reaches. Some particulates and effluent species can also be adsorbed onto on particulates and can deposit on surfaces as the effluents are transported.

Thus, the corrosion potential in the fire zone is, in general,significantly different from that in any given remote area. Given the extent of damage generally occurring within the fire enclosure itself, non-thermal damage by corrosion is likely to be of most significance outside the room of origin of the fire (except in the case of smouldering fires).

The corrosive effects can be broken down into three different processes:

- metal loss from chemical corrosion;
- leakage current from electrolytic corrosion;
- high contact resistance due to galvanic corrosion.

Additional short-circuit effect due to particulates deposition is also of high concern.

Targets used in ISO 11907-4 measures only metal loss corrosion.

Plastics — Smoke generation — Determination of the corrosivity of fire effluents —

Part 1:
General concepts and applicability

1 Scope

The document defines terms related to smoke corrosivity as well as smoke acidity and smoke toxicity. It presents the scenario-based approach that controls smoke corrosivity. It describes the test methods to assess smoke corrosivity at laboratory scale and deals with test applicability and post-exposure conditions. This document is applicable to tests of determination of smoke corrosivity from combustion of materials samples.

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.

ISO 13943, *Fire safety — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 13943 and the following apply.

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
smoke corrosivity
measured effect of material or product reduction in functionality due to the corrosive effects of smoke

3.2
smoke acidity
pH level of fire effluents found in smoke condensate and smoke particles

Note 1 to entry: Smoke acidity relates generally to consequences of the exposure of a given quantity of liquid, generally water, to fire effluents in terms of change of pH. This is an indicator of the acidity of the effluent, and such measurement is often completed with measurement of conductimetry of the same solution.

3.3
corrosion
breaking down or destruction of a material, especially a metal, through chemical reactions

3.4
corrosion damage
physical and/or chemical damage or impaired function caused by chemical action

[SOURCE: ISO 13943:2017, 3.69]

3.5

corrosion target

sensor used to determine the degree of *corrosion damage* (3.4), under specified conditions

Note 1 to entry: The sensor may be a product or a component. It may also be a reference material or object used to simulate the behaviour of a product or a component.

[SOURCE: ISO 13943:2017, 3.70]

3.6

smoke toxicity

toxic effect of smoke to a given target (generally people) in a specific exposure scenario

Note 1 to entry: In general, this concerns acute toxicity, as defined in ISO 13943.

4 Objectives

The objectives of this document are:

- to provide guidance on the applicability of the direct, performance-related tests on combustion effluent corrosivity described in ISO 11907-4;
- to present the other existing test methods;
- to clarify differences between acidity, corrosivity and toxicity.

The definitions in Clause 3 are introduced to limit the frequent confusion between smoke corrosivity, smoke acidity and smoke toxicity. Acid gas emission is sometimes used as an indirect assessment of smoke corrosivity. It is usually assessed by the dissolution of a known quantity of fire effluent in a known volume of water. The resulting solution is then tested. Measurements are made, for example, of pH, conductivity or concentration of acids. That is, however, not fully correct as it has been shown that smoke corrosivity does not fully correlate with acid gas content of solutions. These three notions are related to different causes and effects.

The smoke corrosivity is related to conditions of generation and transportation of fire effluents to a target and their effect on this target, conditioned by a period of exposure and sometimes a period after exposure. It might be due to both organic and inorganic species, some of them being basic and some other being acid. In general, condensation of water is a factor that potentiates corrosivity. The test presented in ISO 11907-4 has been developed in order to improve techniques for the assessment of the corrosivity of burning materials.

The smoke acidity relates to the consequences of the exposure of a given quantity of liquid to fire effluents in terms of change of pH. The acidity of solutions formed from smoke in fires is a function of the release of acid gases, typically hydrogen chloride, hydrogen bromide and hydrogen fluoride, as well as organic acids, such as acetic acid or formic acid.

Methods to measure smoke acidity through the measurement of the pH or electrical conductivity of aqueous solutions of combustion effluents are stated in IEC 60754-2[7]. In this test methods, about 1 g of material is decomposed in a tube furnace at temperatures typically 750 °C to 950 °C. Air is passed over the specimen during this exposure and bubbled though wash bottles containing deionized water. The later are then analysed for pH and for conductivity.

Methods to measure halogen content from combustion effluents are stated in IEC 60754-1[8]. This method is generally applied to study materials from cables. The specimen of mass about 500 mg to 1 g is heated in a tube furnace (typically 800 °C). The decomposition gases are collected and bubbled though wash bottles containing aqueous solution of sodium hydroxide to absorb any acid gas. The later are then analysed with traditional wet chemistry (as stated in ISO 19701[9]), for chloride, bromide and fluoride ions. Results are generally expressed as HCl equivalent.

The toxicity of fire effluent is completely different from the corrosivity of fire effluent. Toxicity is concerned with adverse effects on living organisms whereas corrosivity is concerned with damage to equipment caused typically by damage to metallic components.

NOTE ISO 13344[10] and ISO 13571[11] give useful information on the toxicity of fire effluent.

5 Fire scenarios and general factors conditioning the production of effluents

During recent years, major advances have been made in the analysis of fire effluents. It is recognized that the composition of the mixture of combustion products produced by burning plastics and other products is dependent on the chemical composition of the material and any additives as well as on the prevailing temperature and ventilation conditions. A number of factors which are important in categorizing decomposition atmospheres are listed in ISO 19706[12] and ISO 16312-1:2016, Annex A[13].

Fire involves a complex and interrelated array of physical and chemical phenomena. As a result, it is impossible to simulate all aspects of an actual fire in laboratory-scale apparatus. The question of fire model validity is a complex technical problem associated with all of fire testing.

After ignition, fire development may occur in different ways, depending on the environmental conditions as well as on the physical arrangement of the combustible materials. Local conditions where pyrolysis occurs (heat flux, temperature, oxygen concentration) as well as local conditions where combustion occurs drive the nature and time-dependant release of effluents, which differ spatially and temporally of several orders of magnitude. In each of these conditions, a different mixture of decomposition products is observed and this, in turn, influences the corrosivity of the effluents produced.

NOTE For electrotechnical products, useful guidance on the corrosivity of fire effluent is given in IEC 60695-5-1[15].

6 Types of fire effluent test

6.1 General

All laboratory test methods suffer from several types of limitation. Due to the changing conditions in a fire involving the dynamics of fuel, heat and air interactions, it is unrealistic to expect that any single laboratory test can take account of all decomposition parameters simultaneously. Each laboratory combustion device also possesses certain physical limitations with regard to specimen size, shape and configuration, the ambient pressure, and interactions among products and materials undergoing combustion. ISO 16312-1 details the relevant parameterqs for selection of a physical fire model used at laboratory scale.

6.2 Static method

The static test method available in the past, ISO 11907-2, is not used anymore. This method involved combustion of a specimen within an enclosure and accumulation of the combustion products within this enclosure. Exposure of the target took place within the same enclosure under controlled conditions of relative humidity and temperature. The corrosion target consisted of a precisely defined copper printed wiring board. Corrosivity of the effluents was expressed as a function of the increase in electrical resistance of the printed wiring board during a 1 h exposure to the combustion products.

6.3 Dynamic decomposition methods

6.3.1 General

Dynamic decomposition test procedures involve combustion of the specimen in a stream of air which transports the effluents to the target site.

Limitations of scale are less severe in these procedures, which thus may be suitable for testing certain manufactured products.

The control variables in these procedures include combustion temperature, combustion time, effluent flow rate and effluent-to-air dilution ratio. Neither ambient exposure temperature nor ambient relative humidity nor target temperature is a control variable. This means that the corrosion mode (with or without condensation) is not generally under precise control in dynamic test procedures, except during post-combustion exposure in a separate chamber.

Withdrawn method described in ISO 11907-3 and actual method described in ISO 11907-4 are dynamic test methods.

6.3.2 ISO 11907-4

The method is similar to ASTM D5485[15]. In this test, a portion of products of decomposition or combustion is sampled from above the cone heater during the ISO 5660-1[16] test, and fed continuously through an 11,2 l exposure chamber at a rate of 4,5 litres per minute. This results in the combustion products having an average residence time in the exposure chamber of approximately 150 s. The target is exposed to the corrosion products for 1 h, followed by a 24 h exposure of the target to a controlled humidity and temperature environment in a separate chamber. The increase in electrical resistance of the target is monitored and the reduction in the thickness of the metal on the target is calculated from the increase in electrical resistance.

6.3.3 IEC/TS 60695-5-3[1)][17]

The method is withdrawn but still described in IEC/TS 60695-5-2[18]. It was designed to measure both leakage current and metal corrosion damage. The specimens are decomposed in a quartz tube furnace (the one of IEC 60754-1) and the combustion products are fed into a collection chamber where the targets are placed. Several different targets are used for corrosion damage assessment, and a specifid printed board is used for leakage current assessment. Post exposure is made in increasing humidity conditions.

7 Applicability of test results

The corrosion damage caused by fire effluents can change from one fire scenario to another. The results of corrosion testing need to be thoughtfully analysed before any extrapolation to real scale fires.

It is desirable that a test procedure should be designed so that the results are valid for application in practical analysis of corrosion hazard, and also as part of an analysis of total fire hazard. Work on the design of reaction-to-fire tests to ensure that results are valid in assessment of hazard is in constant development. The guidance in this document, therefore, will be superseded as this and other related work progresses.

The three approaches to testing are listed below.

a) The corrosion target is a manufactured product. The effects of fire effluent on the product can be assessed by degradation of function as determined by inspection or measurement.

b) The corrosion target is a reference material simulating a product. The effects of fire effluent on the reference material can be assessed by measurement of, for instance, a change in aspect or weight or a change in mechanical, physical or electrical characteristics. Details of the principles and general requirements for this type of corrosion assessment are given in ISO 11845[19] and ISO 7384[20].

c) An indirect method of assessment. This is one that uses no corrosion target but measures a characteristic of the gases and vapours evolved, for example the pH or the electrical conductivity of a solution in which the gases and vapours evolved by combustion have been dissolved. This latter case focuses mainly in acidity and not corrosivity. Relation between these two parameters could

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[1)] Withdrawn.

not be generalized. Such assessments have the advantage of being relatively simple, but have the disadvantage that they do not measure corrosion damage. An assumption shall be made that a certain level of the measured parameter corresponds to an unacceptable corrosive potential. This is only valid for a given scenario if independent measurements have been made to establish such a correlation.

8 Post-exposure of corrosion targets

After exposure to fire effluent there may be a post-exposure period before measurements are made. Post-exposure periods may be short (e.g. 1 h to 24 h) to simulate a relatively rapid clean-up of surfaces contaminated with fire effluent, or they may be more protracted (e.g. several months) to simulate longer-term corrosion effects which may occur on surfaces which have not been cleaned soon after the fire.