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

Part 1: Guidance

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

Partie 1: Lignes directrices

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Foreword

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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.

International Standard ISO 11907-1 was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 4, *Burning behaviour*.

ISO 11907 consists of the following parts, under the general title *Plastics – Smoke generation – Determination of the corrosivity of fire effluents*:

- *Part 1: Guidance*
- *Part 2: Static method*
- *Part 3: Dynamic decomposition method using a travelling furnace*
- *Part 4: Dynamic decomposition method using a conical radiant heater*

Annex A of this part of ISO 11907 is for information only.

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Introduction

The corrosive effects of combustion products are an essential factor in the assessment of the extent and cost of fire damage. All fire effluents, 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 nature of the combustible materials involved in the fire
- the nature and composition of the exposed surfaces
- the time of exposure
- the specific environmental conditions at the exposed surfaces (temperature and humidity)
- the efficacy of active and passive fire protection, extinction and smoke management systems

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
- 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

In the fire, the effluents are carried by buoyancy to regions remote from the fire zone itself, and so the potential for corrosion exists even in these areas. Some particulates and effluent species, however, may deposit on surfaces as the effluents are transported.

Thus, the corrosion potential in the fire zone will generally be 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).

It is known that 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

Targets used in ISO 11907, parts 1, 2 and 3, measure only metal loss corrosion.

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

Part 1: Guidance

1 Scope

The present guidance document constitutes the first part of ISO 11907, the other parts of which describe one static and two dynamic test procedures. At the present time, the scope of this guide is limited to these three test procedures as indicated in the foreword.

Once sufficient experience has been obtained with these test methods and precision statements have been refined, it is planned to revise this guidance document and to redefine the scope of each of the test methods.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 11907. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 11907 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 7384:1986, *Corrosion tests in artificial atmospheres – General requirements.*

ISO/TR 9122-1:1989, *Toxicity testing of fire effluents – Part 1: General.*

ISO 11845:1995, *Corrosion of metals and alloys – General principles for corrosion testing.*

ISO 11907-2:1995, *Plastics – Smoke generation – Determination of the corrosivity of fire effluents – Part 2: Static method.*

ISO 11907-3:1998, *Plastics – Smoke generation – Determination of the corrosivity of fire effluents – Part 3: Dynamic decomposition method using a travelling furnace.*

ISO 11907-4:1998, *Plastics – Smoke generation – Determination of the corrosivity of fire effluents – Part 4: Dynamic decomposition method using a conical radiant heater.*

IEC 695-5-1:1993, *Fire hazard testing – Part 5: Assessment of potential corrosion damage by fire effluent – Section 1: General guidance.*

IEC 695-5-2:1994, *Fire hazard testing – Part 5: Assessment of potential corrosion damage by fire effluent – Section 2: Guidance on the selection and use of test methods.*

3 Definitions

For the purposes of this part of ISO 11907, the following definitions apply:

3.1 corrosion: The reaction of a metallic material with its environment, resulting in a measurable change of the material and possibly in an impairment of the functioning of a metal part or of an entire system.

NOTE – In most cases, the reaction is electrochemical. In others, however, it may be chemical (non-electrochemical) or physical.

3.2 corrosion damage: The physical and/or chemical damage or impaired function caused by chemical action.

3.3 corrosion target: The sensor used to determine, under specified test conditions, the degree of corrosion damage.

NOTE – This sensor can be a product, a component or a reference material used to simulate them.

3.4 fire effluent: The totality of gases and/or aerosols (including suspended particles) created by combustion or pyrolysis.

3.5 fire model: A laboratory process, including the apparatus, the environment and the test procedure, intended to represent a certain phase of a fire.

3.6 fire scenario: A detailed description of conditions, including environmental, of one or more stages from before ignition to completion of combustion in an actual fire at a specific location, or in a real-scale simulation

3.7 fire simulation: A mathematical representation of one or more different interconnected phenomena governing the development of a fire.

4 Objective

It is the objective of this document to provide guidance on the applicability of the direct, performance-related tests on combustion effluent corrosivity described in ISO 11907-2, -3 and -4.

These tests have been developed in order to improve techniques for the assessment of the corrosivity of burning materials over those given by indirect test methods based on the measurement of the pH or electrical conductivity of aqueous solutions of combustion effluents, or on the halogen content of the material (refer to IEC 695-5-1 and IEC 695-5-2).

5 Fire scenarios

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 is dependent on the chemical composition of the polymer and 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 table 1.

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. A general pattern can be established for fire development within a compartment, however, where the general temperature-time curve exhibits three stages (see figure 1).

Stage 1 is the incipient stage of the fire prior to sustained flaming, with little rise in the fire room ambient temperature. Ignition and generation of effluents are the main hazards during this stage. The second stage (developing fire) starts with ignition and ends with an exponential rise in fire room temperature. Spread of flame and release of heat are the main hazards, in addition to effluents, during this stage. The third stage (fully developed fire) starts when the surfaces of all of the combustible contents of the room have decomposed to such an extent that sudden ignition occurs all over the room, with a rapid and large increase in temperature (flashover).

At the end of stage 3, the combustibles and/or oxygen have been largely consumed and hence the temperature decreases at a rate which depends on the ventilation, and on the heat- and mass-transfer characteristics of the system.

In each of these stages, a different mixture of decomposition products is observed (see figure 1) and this, in turn, influences the corrosivity of the effluents produced during that stage. Moreover, information is required on the fire scenario being considered, in particular on the conditions of incident heat flux and on the oxygen availability.

6 General factors affecting the production of fire effluents

The primary chemical process leading to the formation of combustion products is that of the thermal bond-breaking and decomposition of polymeric materials which, in the presence of oxygen, leads to a variety of oxygenated species. Carbon compounds are pyrolysed into volatile hydrocarbon fragments which may be oxidized to form various oxidized organic species, carbon monoxide and carbon dioxide, depending on the thermal and oxidative conditions. Both carbon dioxide and carbon monoxide are usually present in a fire effluent atmosphere. Their ratio is often used as an indicator characteristic of the particular type of fire or the stage of the fire. In small, developing fires, a CO_2/CO ratio of 100 or more would indicate freely ventilated, fuel-controlled combustion. In large, fully developed fires, which are usually ventilation controlled when they occur in enclosed spaces, a CO_2/CO ratio of 10 or less would be indicative of relatively low ventilation.

Hydrogen is oxidized to water, chlorine is most commonly released as hydrogen chloride, and nitrogen appears principally in the form of organic nitriles, hydrogen cyanide and nitrogen oxides, again depending upon the thermal oxidative conditions. All flaming and non-flaming, including smouldering, fires may yield a great variety of combustion products due to incomplete decomposition and only partial oxidation of the fuels involved. Non-flaming fires produce the highest yields of such products. It is important to remember that these are all chemical reactions, subject to the usual principles of thermodynamics and kinetics. Thus, stoichiometry and thermal energy play significant roles in determining the products of combustion that are formed over the range of fire classifications.

7 Types of fire effluent test

7.1 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.

However, laboratory tests might be expected to be relatable to at least some of the stages of actual fires, as has been shown in certain cases (see figure 1).

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.

7.2 Static method (ISO 11907-2)

The static test procedure involves combustion of a specimen within an enclosure and accumulation of the combustion products within this enclosure. Exposure of the target takes place within the same enclosure under controlled conditions of relative humidity and temperature.

Because of limitations of scale and of ventilation, this procedure is suitable for the comparative testing of materials only, and not for the testing of finished products under various simulated fire conditions.

The control variables in this procedure, apart from the ambient relative humidity and temperature, are the temperature of the combustion device and that of the corrosion target. This last variable, in combination with relative humidity, determines the corrosion mode, i.e. the occurrence or non-occurrence of effluent condensation on the target.

The corrosion target consists of a precisely defined copper printed wiring board. The testing apparatus is a sealed chamber maintained at a defined temperature and relative humidity. The test specimen is ignited by a heated electrical resistance wire at a temperature of $800\text{ °C} \pm 5\text{ °C}$. In the condensing mode, the printed wiring board is cooled to a chosen condensation temperature and kept at this temperature throughout the measurement. In the non-condensing mode, the printed wiring board is maintained at the ambient temperature of the combustion chamber throughout the procedure. Corrosivity of the effluents is expressed as a function of the increase in electrical resistance of the printed wiring board during a one hour exposure to the combustion products.

7.3 Dynamic decomposition methods

7.3.1 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.

7.3.2 ISO 11907-3

The corrosion target consists of the same precisely defined copper printed wiring board as described in ISO 11907-2. The decomposition apparatus consists of an annular furnace which is set to a specified temperature and air flow rate. It is moved over the test specimen which is located in a quartz cuvette inside a quartz glass tube, through which air is passed. The corrosion target is exposed to the combustion effluents. Condensed products react with the copper target if they are corrosive. The change in target resistance is used to assess effluent corrosivity. Condensation may be enhanced by cooling the target. By adjusting the air flow rate and the furnace temperature, the various stages of fire listed in table 1 may be simulated. By varying these parameters, it may be possible to investigate worst-case conditions for the assessment of the maximum corrosion potential of the fire effluents of materials.

This procedure, in which no accumulation of the combustion products occurs, may provide steady-state concentrations of the major effluents, as well as making it possible to vary the combustion mode, i.e. with co-current or counter-current air flow.

7.3.3 ISO 11907-4

In this test, a portion of products of decomposition or combustion is sampled above the cone heater and fed continuously through an 11,2 litre 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 one hour, followed by a 24 hour 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.

8 Applicability of test results

Within the context of ISO 11907, the fire scenarios have to be examined for relevance to the corrosion damage caused by fire effluents.

It is desirable that the 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 ISO 11907-1, therefore, will be superseded as this and other related work progresses.

The three approaches to testing are listed below. Two of these are defined in terms of the type of corrosion target used.

- 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 and ISO 7384.
- 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 (refer to IEC 695-5-1).

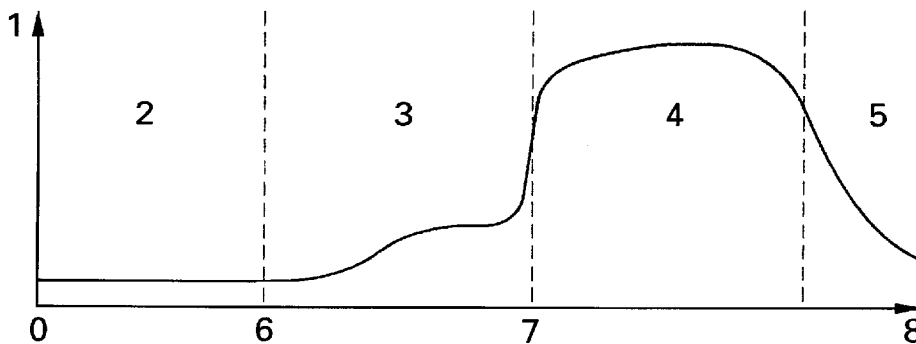
9 Post-exposure of corrosion targets

Corrosion targets may be exposed to fire effluents during the combustion of the test specimen, as in ISO 11907-2 where changes in resistance are recorded over 60 minutes including the time during which the specimen burns and the effluent is retained in the chamber. In ISO 11907-3 and -4, one or more periods of post-exposure of the corrosion target are described. These periods may be either short (e.g. 1 hour to 24 hours) to simulate fast clean-up of surfaces contaminated with fire effluents, or more protracted (e.g. several months) to simulate longer-term corrosion effects which may occur on surfaces which have not been cleaned after the fire.

Table 1 – General classification of real fire stages in accordance with ISO/TR 9122-1

Stage or phase of fire within a compartment	Vol % oxygen ¹⁾	Ratio CO ₂ /CO ²⁾	Temperature of substrate °C	Irradiance kW/m ² ³⁾
a) Non-flaming decomposition (incipient stage)				
1) Smouldering (self-sustaining)	21	not available	< 100	not available
2) Non-flaming (oxidative)	5 to 21	not available	< 500	< 25
3) Non-flaming (pyrolytic)	< 5	not available	< 1 000	not available
b) Flaming, fully developed fire	10 to 15	100 to 200	400 to 600	20 to 40
c) Flaming, fully developed fire				
1) Relatively low ventilation	1 to 5	< 10	600 to 900	40 to 70
2) Relatively high ventilation	5 to 10	< 100	600 to 1 200	50 to 150

¹⁾ Mean value in fire plume.
²⁾ General environmental condition (average) within compartment, assuming some homogenization.
³⁾ Radiation incident on the exposed surface (average).



- Key**
- 1 Compartment temperature
 - 2 Stage 1: incipient stage
 - 3 Stage 2: developing fire
 - 4 Stage 3: fully developed fire
 - 5 Decay stage
 - 6 Ignition
 - 7 Flashover
 - 8 Time, *t*

Figure 1 – Diagram showing the different phases in the development of a fire within a compartment

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