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Plastics — Guidance on fire characteristics and fire performance of PVC materials used in building applications

Plastiques — Lignes directrices relatives aux caractéristiques et aux performances au feu des matériaux en PVC utilisés dans les applications de construction

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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).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of 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 www.iso.org/iso/foreword.html.

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

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

Fire safety is an essential consideration in building design regardless of the type and nature of products used. Effective measures should be taken to prevent or reduce the likelihood of fires that may result in casualties, injuries or property damage.

National codes and regulations are the basis of such fire safety measures. Technical details are given in standards and related documents, referred to as specific documents or incorporated in the said codes or regulations. Such details are particularly important when performance-based behaviour is concerned. A specific case is the European Construction Products Regulation [77], which specifies that products need to be tested and classified regarding their fire performance according to the EU harmonized classification systems for reaction to fire and for resistance to fire.

The construction industry makes significant efforts to protect society from the dramatic consequences of fires. As a result, 1 % to 8 % of total construction costs are spent on fire safety measures. These costs are directly dependent on the type of building and can increase considerably for sensitive buildings like schools and theatres. In the case of shopping centres, fire safety measures can amount to 10 % of total building costs.

Plastic products are increasingly specified by architects and used by builders. They contribute to greater energy efficiency, cost savings and to a more comfortable and safer environment. The role of plastics in fire safety should be addressed despite the fact that they are considered as a major combustible contributor only in less than 15 % of fires.

Plastic materials or products can be tailored to meet specific needs and to reduce their contribution to the propagation of a fire. Some families of plastics, such as halogen containing polymers like PVC, inherently have superior fire performance. The same performance can be achieved or even improved with other plastics by:

— adding flame retardants;

— covering them with less combustible layers.

Each type of building has its own specific potential fire hazards and fire risks linked to the permanent elements of the building (i.e. construction products and overall design) as well as its content including furniture, papers, clothes, domestic and leisure articles. Fire hazard and fire risk are also linked to the proper use and installation of construction products in the building structure. This is also valid for PVC and for plastic materials in general, which, like all other construction materials, should be used in the correct applications and under appropriate conditions.

NOTE Data from various market surveys show that only 10 % to 15 % of all plastics contained in a private house are in construction products. 85 % to 90 % of plastics are brought into the building by the occupants in, for example, furniture (including, for example, wooden furniture containing minor plastics elements), decorations, household and media appliances, clothes, toys and packaging. This means that although PVC is a significant component of many construction products, other combustible materials often comprise a more important potential source of fuel, in particular in private houses.

A fire usually involves a combination of different combustible and non-combustible materials. Organic materials (including all plastics, wood and other carbon containing materials) produce a mixture of gaseous substances (making fire smoke always hazardous) in addition to a certain degree of heat release.

As fire is a complex phenomenon, the type and quantity of materials involved are only two of the various parameters influencing the development and consequences of a fire. The other factors that come into play include building design, location, potential ignition sources and other fire scenario parameters.

Fire tests results relate only to the behaviour of test specimens under the particular conditions of the test. They are not intended to be the sole criterion of assessing the potential fire hazard of the product in use.

This document provides information on the fire characteristics and fire performance of PVC based materials and products used in building applications. It is to be considered as a documentary and technical reference document for any entity interested in fire safety in building and construction, when products containing PVC are concerned, including at the design or pre-building phase.

The intended audience for this document includes but is not necessarily limited to:

— materials and products manufacturers;

— building designers, specifiers and architects;

— building owners and managers;

— fire fighters and investigators;

— public health authorities;

— fire testing laboratories.

Plastics — Guidance on fire characteristics and fire performance of PVC materials used in building applications

1 Scope

This document provides information on the fire characteristics and performance in fire tests of PVC materials and products for use in building applications.

It illustrates a number of suitable applications incorporating primarily PVC materials, including unplasticized PVC (PVC-U), plasticized (or flexible) PVC (PVC-P) and chlorinated PVC (PVC-C) based products. Except where otherwise stated, there is no restriction with reference to the content of PVC (in terms of quantity and composition) in the products mentioned in this document.

This document draws attention to the limits of applicability or the unsuitability of some standard fire test methods for certain applications of PVC based products in buildings.

This document applies to products during their use phase in the building and does not apply to the manufacturing phase of plastic products. It neither applies to general safety measures applicable to the installation phase nor to the dismantling or the demolition phase of the building.

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 472, *Plastics — Vocabulary*

ISO 13943, *Fire safety — Vocabulary*

IEC 60695-4, *Fire hazard testing — Part 4: Terminology concerning fire tests for electrotechnical products*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 472, ISO 13943, IEC 60695-4 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
composite
solid product consisting of two or more distinct phases, including a binding material (matrix) and a particulate or fibrous material

Note 1 to entry: Solid product consisting of two or more layers (often in a symmetrical assembly) of, for instance, plastic film or sheet, normal or syntactic cellular plastic, metal, wood or a composite, with or without adhesive interlayers.

[SOURCE: ISO 472:2013, 2.182.1 and 2.182.2, modified —2.182.1 and 2.182.2 have been merged into one entry.]

3.2
compound
intimate mixture of a polymer or polymers with other ingredients such as fillers, plasticizers catalysts and colorants

Note 1 to entry: The terms "formulation" and "composition" are sometimes used as synonyms.

[SOURCE: ISO 472:2013, 2.184, modified — Note 1 to entry has been added.]

3.3
fire effluent
totality of gases and aerosols, including suspended particles, created by combustion or pyrolysis in a fire

Note 1 to entry: For the purpose of this document, fire effluent also includes run-off water generated during fire-fighting activities.

3.4
fire safety engineering
application of engineering methods to the development or assessment of designs in the built environment through the analysis of specific fire scenarios or through the quantification of risk for a group of fire scenarios

[SOURCE: ISO 13943:2017, 3.149]

3.5
flash ignition temperature
minimum temperature at which, under specified test conditions, sufficient flammable gases are emitted to ignite momentarily on application of a pilot flame

Note 1 to entry: Compare with the terms *ignitability* (3.7), minimum ignition temperature and spontaneous ignition temperature (see ISO 13943].

Note 2 to entry: Flash ignition temperature refers to the ignition temperature determined for solid specimens on application of a flame to the specimen, for example in a test method such as ISO 871. Flash point refers to the temperature to which a flammable liquid must be heated for its vapours to ignite.

Note 3 to entry: The typical units are °C.

[SOURCE: ISO 871:2006, 3.1, modified — Notes to entry have been added.]

3.6
heat release
thermal energy produced by combustion

Note 1 to entry: The typical unit is J.

[SOURCE: ISO 13943:2017, 3.205]

3.7
ignitability
measure of the ease with which a test specimen can be ignited, under specified conditions

Note 1 to entry: Also known as ease of ignition.

[SOURCE: ISO 13943:2017, 3.212, modified — Notes to entry have been replaced.]

3.8
plastics products
articles or stock shapes of plastic materials for any type of application

[SOURCE: ISO 11469:2016, 3.2]

3.9
plenum
compartment or chamber to which one or more air ducts are connected and that forms part of the air distribution system

Note 1 to entry: Plenums are typically located above ceilings or below raised floors and they are the areas that contain heating, ventilating or air conditioning ducts. Products such as data and communications cables, associated cable management systems and sprinkler piping are also often contained in plenums.

[SOURCE: NFPA Glossary of terms (2013)]

3.10
profile
extruded plastic product, excluding film and sheet, having a characteristic constant cross-section along the axis of the product

[SOURCE: ISO 472:2013, 2.839, modified — Note to entry has been omitted.]

3.11
chlorinated PVC
PVC-C
polyvinylchloride, which is a thermoplastic obtained by polymerization of vinyl chloride and to which additional chloride is chemically bonded by substitution of hydrogen atoms

Note 1 to entry: It is also commonly referred to as CPVC.

3.12
plasticized PVC
PVC-P
polyvinylchloride, which is a thermoplastic obtained by polymerization of vinyl chloride and plasticized by the addition of specific additives

Note 1 to entry: It is also commonly referred to as flexible PVC and soft PVC.

3.13
unplasticized PVC
PVC-U
polyvinylchloride, which is a thermoplastic obtained by polymerization of vinyl chloride

Note 1 to entry: It is also commonly referred to as rigid PVC.

3.14
spontaneous-ignition temperature
minimum temperature at which ignition is obtained by heating, under specified test conditions, in the absence of any flame ignition source

Note 1 to entry: Spontaneous ignition temperature is typically used in fire tests while auto-ignition temperature is often used as a material or product property.

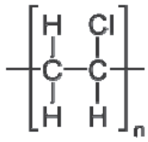
4 PVC building materials and products

4.1 Definition and description

4.1.1 General

PVC is the most widely used polymer in building and construction applications and, for instance, up to 70 % of the World's annual PVC production is used in this sector.

PVC is a thermoplastic composed of 56,8 mass % of chlorine (typically derived from industrial grade salt) and 43,2 mass % of carbon and hydrogen (derived predominantly from oil or gas via ethylene). The chlorine content gives excellent intrinsic fire performance to PVC.



PVC resin is often supplied in powder form and long-term storage is possible since the material is resistant to oxidation and degradation. Various additives such as processing agents, stabilizers, fillers, plasticizers, flame retardants, and pigments are added to the PVC resin during the compounding stage, depending on the desired properties of the final product. The compound is then converted into PVC products.

According to ISO 1043-1, PVC belongs to Group A, homopolymers. PVC compounds are classified in different categories:

— PVC-U: unplasticized PVC, commonly named rigid PVC

— PVC-P: plasticized PVC, also named soft or flexible PVC

— PVC-C: chlorinated PVC, also identified as CPVC

ISO 11469 specifies a system of uniform marking of products that have been fabricated from plastics materials. It refers to ISO 1043-1 (basic polymers), ISO 1043-2 (fillers and reinforcing materials), ISO 1043-3 (plasticizers) and ISO 1043-4 (flame retardants).

NOTE 1 ISO 11469 is not intended to supplant, replace or in any way interfere with the requirements for labelling specified in products standards or legislation.

The same rules apply in the cases of PVC containing, for example, a plasticizer and/or a flame retardant (see 4.1.2 to 4.1.5).

NOTE 2 When possible and appropriate, compounds containing plasticizers can be marked with the abbreviated term for the polymer followed by a hyphen, then the symbol “P” followed by the abbreviated term of the plasticizer in parentheses, as given in ISO 1043-3. The exact marking is generally specified in the product standard. It can be compulsory in case it is specified, for example, in an applicable regulation.

While the marking system is intended to help identify plastics products for subsequent decisions concerning handling, waste recovery or disposal, it is also very useful to identify a material to be subjected to fire testing.

NOTE 3 For characteristics other than the chemical composition of the material or product, such as reaction to fire properties, a complementary and specific marking can be used.

4.1.2 PVC-U based products

Unplasticized PVC products are intended for applications where rigidity is needed. Some common applications for PVC-U products include pipes, window profiles, conduit, siding, fences, decks and railings. The use of plasticizers differentiates flexible vinyl products from rigid ones. The rigidity of PVC is maintained by not introducing plasticizers.

In reaction to fire tests, PVC-U displays a high resistance to ignition, a low rate of heat release, and self-extinguishes when the external ignition source is removed. This is because of its high content of chlorine.

4.1.3 PVC-P based products

PVC is plasticized for applications where the flexibility of the final product is essential such as wire sheathing and insulation, floor and wall coverings and flexible sheets.

The fire properties of PVC generally deteriorate to a certain extent when PVC is plasticized depending on the amount and kind of plasticizer and other additives used. However, many of the plasticized PVC products in use will not continue to burn once the flame source is removed, even if not additionally fire-retarded. Moreover, technologies were developed in the 1980s and 1990s, using combinations of plasticizers and other additives, which resulted in plasticized PVC materials with fire properties similar or better than those of the corresponding native unplasticized PVC.

4.1.4 PVC-C based products

PVC-C is obtained from normal PVC resin to which additional chlorine is introduced in the polymer chain, to reach a chlorine content in the range of 62 % to 68 % by mass, leading to a different family of vinyl polymers. This addition leads to improved fire properties: further decrease in the flammability (including heat release) of the polymer and significant decrease in intrinsic smoke generation. The reason for this effect on smoke generation is likely to be a change in the mechanism of dehydrochlorination.

4.1.5 Flame retardants

The term “flame retardant” refers to a range of additives of various chemical compositions that can be added to materials to improve their fire behaviour and reduce fire hazard. Various species of flame retardants, including smoke suppressants, alone or in combination, can lead to consistent lowering of heat release, flame spread, ignitability, (by increasing the time to ignition or the minimum heat flux for ignition), or smoke release.

NOTE The presence of flame retardants is indicated according to ISO 1043-4.

Altogether, there are over 200 different types of substances that can be used as flame retardants and they are often applied in synergistic combinations with each other. Not all flame retardants provide their functionality for all materials and some are often specific to or incompatible with certain materials. Properties depend on their physical form and use conditions.

A wide range of flame retardants are used with PVC construction products. Flame retardants can act in the condensed phase or in the vapor phase and they may even act in a combination of both. Typical flame retardants for PVC include those based on metal hydroxides (e.g. aluminium hydroxide or magnesium hydroxide), antimony oxide, zinc derivatives (e.g. zinc borate, zinc stannate or zinc hydroxystannate), bromine derivatives (e.g. brominated phthalates), molybdenum compounds, or phosphates (particularly aryl phosphates, aryl alkyl phosphates or halogenated phosphates), and a variety of other additives, often in various combinations.

Smoke suppressants are additives used in PVC compounds to lower the resulting smoke production. Just like other flame retardants, smoke suppressants can act in the solid phase (i.e. the PVC matrix) or in the vapor phase, in each case in a physical or chemical manner.

The following discusses the mechanism of action of some flame retardants and/or smoke suppressants.

— Halogen-containing materials (in which the halogen is mainly either bromine or chorine) tend to act primarily in the vapor phase as free radical scavengers. Some of the additives used are chlorinated paraffins, or polycyclic chlorinated or brominated materials.

— Aluminium trihydrate (or aluminium hydroxide, ATH) ($Al(OH)_3$) and magnesium hydroxide ($Mg(OH)_2$) act primarily by releasing water into the vapor phase and thus both cooling the vapor phase and diluting it to decrease the likelihood of reaching the flammability limit. They typically need to be used in high loadings.

— Antimony oxide (Sb_2O_3) typically needs the presence of halogen-containing materials for action, primarily in the vapor phase, by forming antimony-halogen compounds, so that it is a very effective flame retardant for PVC.

— Zinc borate ($Zn_xB_yO_z.nH_2O$) is a potential partial replacement for antimony oxide, and it is a char promoter which typically needs the presence of halogen atoms. In some cases, it can be synergistic with ATH.