TECHNICAL REPORT

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Reaction to fire tests — Ignitability of building products subjected to direct impingement of flame —

Part 1:
Guidance on ignitability

Essais de réaction au feu — Allumabilité des produits de bâtiment soumis à l'incidence directe de la flamme —

Partie 1: Lignes directrices sur l'allumabilité

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.

Technical Reports are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

The main task of technical committees is to prepare International Standards, but in exceptional circumstances, a technical committee may propose the publication of a Technical Report of one of the following types:

— type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;

— type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;

— type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example).

Technical Reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

ISO/TR 11925-1, which is a Technical Report of type 3, was prepared by Technical Committee ISO/TC 92, *Fire safety*, Subcommittee SC 1, *Reaction to fire*.

ISO/TR 11925 consists of the following parts, under the general title *Reaction to fire tests — Ignitability of building products subjected to direct impingement of flame*:

— *Part 1: Guidance on ignitability*

— *Part 2: Single flame source test*

— *Part 3: Multi-source test*

International Organization for Standardization
Case postale 56 • CH-1211 Genève 20 • Switzerland
Internet iso@iso.ch

Printed in Switzerland

Introduction

Ignitability of materials is of basic importance when fire hazard is analysed because of two reasons: First, at the initiation of a fire some object or local area is ignited, and second, during the fire growth period ignitability is an essential factor in fire spread to the other parts of a room or compartment.

In buildings the structural, lining and furnishing materials are solids, which require external heating to achieve flaming combustion. The ignition condition can be characterized by the minimum surface temperature at which the flow of volatiles is sufficient for sustained flaming. However, the difference in these temperatures between materials is not large. Hence it is usually more important to take into account the time of exposure and the thermal properties of the material when assessing risk of ignition.

When a material is exposed to an external heat flux (radiative, convective, conductive or a combination), its surface temperature starts to rise. The temperature inside the solid also increases with time, but at a slower rate. Provided the net flux into the material is sufficiently high, eventually the surface temperature reaches a level at which pyrolysis begins. The vapours generated emerge through the exposed surface and mix with air in the boundary layer. Under certain conditions this mixture exceeds the lower flammability limit and ignites. The initiation of flaming combustion as described above is termed *flaming ignition*. For some materials or under certain conditions, combustion is not in the gas phase but in the solid phase. In such cases no flame can be observed and the surface is glowing. This quite different phenomenon is termed *smouldering ignition*.

The definition of ignition has been debated in many fora. It is most usually defined as the presence of a flame on a surface, or more simply the persistence of flame. Some documents try to subdivide the ignition process in three ways: flashing (less than 1s of flaming); transient ignition (greater than 1s and less than 4s); and sustained ignition (more than 4s of flame). Other documents define ignition as the persistence of flame for greater than 10s. Many of the definitions have been derived from apparatus-dependent parameters. All definitions have their merits and all have been well discussed.

This Technical Report describes and characterizes the "real fire" ignition sources, the ignition sources used in the testing of materials and products, and any correlation between those and "real fire" sources. Some of the theoretical principles of ignition and ignitability are also addressed.

The majority of ignitability tests used internationally are based on the direct application of a flame. A few tests involve radiative heating of the material but generally also require some form of pilot source whether a flame or a spark. In general the ignition sources used have some relevance to end-use hazard.

ISO/TC 92/SC 1 has concentrated on the development of tests to simulate ignitability by a range of flame sources of increasing size and also a piloted (by flame) radiative ignition source, see ISO 11925-2 and ISO 11925-3 and ISO 5657, respectively.

The guidance given in this Technical Report should enable choice of the appropriate ignition source when related to the end-use application of the material or product being assessed.

A comprehensive review of piloted ignition and ignitability test methods is also given in ISO/TR 11696-1. ISO 11093 also provides a brief description for a number (13) of different types of ignition source and is a reference document for persons seeking descriptions of the standardized source apparatus

Reaction to fire tests — Ignitability of building products subjected to direct impingement of flame —

Part 1:
Guidance on ignitability

1 Scope

This Technical Report provides guidance on "ignitability" tests for building products. It describes the principles of ignitability and characterizes different ignition sources.

The results of small-scale ignitability tests may be used as a component of a total hazard analysis of a specified fire scenario. It is therefore important that the flame or radiative source chosen is fully characterized so that relevant conclusions may be made from the test results.

Guidance given in this Technical Report may also have relevance to other application areas (e.g. building contents, plastics, etc.)

2 References

ISO 5657:1997, *Reaction to fire tests — Ignitability of building products using a radiant heat source.*

ISO 5658-2:1996, *Reaction to fire tests — Spread of flame — Part 2: Lateral spread on building products in vertical configuration*.

ISO 5660-1:1993, *Fire tests — Reaction to fire — Part 1: Rate of heat release from building products (Cone calorimeter method).*

ISO 9239-1:1997, *Reaction to fire tests — Horizontal surface spread of flame on floor-covering systems — Part 1: Flame spread using a radiant heat ignition source.*

ISO 9705:1993, *Fire tests — Full scale room test for surface products*.

ISO 10093:1998, *Plastics — Fire tests — Standard ignition sources*.

ISO/TR 11696-1:—[1)], *Use of reaction to fire tests — Part 1: Application of results to predict fire performance of building products by mathematical modelling*.

ISO 11925-2:1997, *Reaction to fire tests — Ignitability of building products subjected to direct impingement of flame — Part 2: Single flame source test.*

ISO 11925-3:1997, *Reaction to fire tests — Ignitability of building products subjected to direct impingement of flame — Part 3: Multisource test.*

[1)] To be published.

3 Typical 'real fire' ignition sources

3.1 General

Fires are caused by a wide range of ignition sources. Statistical analysis of real fires conducted in many countries has identified the most common primary and secondary sources especially in fires within buildings. The most frequent sources of fires may be the following.

a) Cooking appliances (electric and gas)

b) Space heating appliances (electric, gas and solid fuel)

c) Electrical wiring

d) Other electrical appliances (such as washing machines, bedwarmers, televisions, water heaters)

e) Cigarettes

f) Matches and smokers' gas lighters

g) Blow lamps, blow torches and welding torches, hot metal

h) Rubbish burning, e.g. in waste paper baskets or in bins or accumulated piles

i) Candles

The items first ignited are probably the following.

a) Food including cooking fat

b) Gases, i.e. mains gas and bottled gasses

c) Liquids, e.g. petroleum, paint spirits

d) Textiles, e.g. clothing, curtains

e) Upholstery, e.g. chairs, beds, sofas, etc.

f) Floorcoverings

g) Building structures, e.g. wall linings, ceilings, partitions.

h) Electrical wiring

Smouldering ignition sources are particularly insidious in real fire situations since they can involve a considerable induction period before flaming combustion develops. In general, the real source is used in standardized tests (e.g. the cigarette, which is defined in terms of its burning rate).

Primary ignition sources (i.e. sources which directly cause ignition), range from relatively common sources such as matches to fires ignited from radiant heaters. Gas flames (e.g. cigarette lighters, welding torches' etc.) can also cause fires if carelessly used. Gas or electric radiant heaters may raise the temperature of materials above their flash or self-ignition temperatures. Radiant heaters can cause ignition by radiant heat alone. Other radiant heat sources include electric light bulbs which can cause high local temperatures.

Secondary ignition sources do not directly cause ignition but can be ignited using primary sources (e.g. matches or cigarettes) and then burn to produce a large ignition source. Secondary sources include waste paper baskets, newspapers or journals, clothing, loose furnishings, upholstery, etc. These items, once themselves ignited, may then spread the fire either by direct flame impingement or by radiative and convective ignition.

The list below details the type of sources in each category.

a) Primary source

Smouldering	Cigarette
Flaming	Match
	Smoker's gas lighter
	Candle
	Chip-pan
	Blowlamp
Electrical	Wiring
	Appliances
Radiative	Space heater
	Light bulbs
Conductive	Sparks
	Hot coals
Convective	Hot gases
	Hot air guns

b) Secondary sources

Smouldering	Cellulose materials
Flaming	Building contents (e.g. furniture, waste bins, curtains, etc.)
Radiative	Large non-contacting flames from burning items.

3.2 Characteristics of flame sources

A major consideration in the selection of the type of ignition source in any test must come from a knowledge of the real fire and its associated heat fluxes. In theory, this could range from zero to an upper value of FT^4 where T is the maximum flame temperature. The maximum flame temperature for most common fuels is approximately 2300 K [1]. Since the Stefan Boltzman constant F is 5,67 x 10^{-11} kWm^{-2}K^{-4}, a maximum irradiance of 1500 kWm^{-2} can be expected, which is approximately 10 times greater than the maximum actually found.

Since theory gives little guidance on the characteristics of typical ignition sources in real fires, experimental data must be used to characterize real fire sources.

The main characteristics of ignition sources and their relation to the test specimen may be defined by the following factors:

a) The intensity of the ignition source, i.e. the thermal input to the material to be ignited, which includes the conductive, convective and radiative effects of the ignition source.

b) Area of flame contact of the ignition source.

c) Duration of exposure to the ignition source.

d) Orientation of the specimen relative to the ignition source.

e) Ventilation conditions around ignition source.

An ignition source may be as small as an electrical spark or as large as a burning building which can act as an ignition source to an adjacent building. For the purpose of this Technical Report, however, ignition sources are limited to those which are commonly found to be the cause of a room fire, and the range of potential ignition sources will generally have heat fluxes of less than 50 kWm^{-2}.

Table 1 shows the characteristics of various real flame sources in terms of the temperature, area of flame contact and imposed heat fluxes [2].

Table 1

Source	Temperature (°C)	Area of flame contact[a] (mm^2)	Maximum heat flux[a] (kW/m^2)
First flame after electrical failure of cable	800[b]	50	30
Match	850[b]	500	35
Lighter	800[b]	800	30
4 sheets tabloid newspaper	>600	60,000	25
Deep fat fryer fire (Domestic)	>1100	125,000[c]	50
Plumbers blow-torch (Specialist tool)	>1000	4,000	140
Oxyacetylene premixed flame (Specialist welding source)	>1800	2,500	150
Waste paper basket	>900	110,000[c]	50
Cigarette	>1000	100	<5

[a] The values quoted are all nominal and are subject to the conditions of the investigation. The values were derived by measuring against a flat non-combustible thermally thick board.

[b] Measured in the luminous part of the flame.

[c] Function of diameter of the receptacle and its location.

From table 1, it can be seen that diffusion flame sources give very similar imposed heat fluxes. Work by Babrauskas et al. [2] has shown a direct linear relationship between the fuel input to a diffusion burner and the area of flame contact with a significant increase in the imposed heat flux. To increase the heat flux seen by the surface in the area of flame contact, it is necessary to increase the depth of the flame. It is for this reason that higher heat flux values are recorded for the deep fat fryer and waster paper basket fires where the flames may be of an order of 100 mm to 200 mm thick.

In general, therefore, the real fire sources fall into two types, when assessed in terms of their imposed heat fluxes - those with premixed flames giving heat fluxes in the order of 150 kW/m^2 and those with diffusion flames with heat fluxes in the order of 30 to 50 kW/m^2.

Two of the diffusion flames, the deep fat fryer and the waste-paper basket, have heat fluxes in the order of 50 kW/m^2: This is due to the thickness of the flame created, the thicker the flame, the greater the imposed heat flux. This phenomenon should also be considered when producing standardized ignition sources since in general only "thin" flames are used as standard sources, with the exception of the sand burner used in ISO 9705.

3.3 Characteristics of electrical sources

The main ignition sources created by misuse of electrical supply and appliances are:

a) overloaded wires and cables where breakdown of the insulation occurs and adjacent combustible materials are ignited by hot wires (by conduction or radiation);

b) mechanical failure of the insulation resulting from ageing or physical damage (conductive heating);

c) heaters where glowing wires or bars emit high radiant energy (radiative ignition);

d) high temperature arcing (radiative and convective).

3.4 Characteristics of radiative sources

Radiative sources generally consist of either electrical or gas fired radiant panels or elements (e.g. gas fires, electrical bar heaters). They are normally sited remote from the item to be ignited and are the primary source of the fire. The type of scenario envisaged would be the ignition of an object placed too close to the "radiator".

The main characteristics of radiant sources are defined by:

a) the intensity of the radiation and effectiveness of radiation transfer;

b) the duration of exposure;

c) spectral distribution.

NOTE Large flames or hot gas layers produced from an item already ignited (secondary source) can also act as a radiative source to ignite other remote items.

4 Factors affecting ignitability tests

4.1 General

The choice of ignition source in any fire experiment is significant. It is important to identify what real ignition source is being simulated in terms of heat duration, irradiance, area of heat contact, etc.

A typical ignition source could be chosen or a range selected in order of severity. Occasionally, a worst case example could be employed.

The size of the ignition source should be selected with due consideration of the fire to be simulated and should not be excessive in relation to the dimensions, shape and ventilation of the test specimen or construction. The ignition source will also have some affect on the ventilation conditions prevalent in the fire enclosure. The specimen presented for testing should be appropriately sized and not scaled down with relation to the ignition source, i.e. one specimen should be of sufficient size not for the flame to influence or overwhelm the thermal properties of the specimen.

It is important to choose an ignition source which will not adversely affect measurements (for example, by generating high levels of smoke, or toxic gases, or reducing the available oxygen for combustion). For this reason, it may be necessary to carry out preliminary tests to estimate the likely effects of the chosen ignition source on such measurements and to correct these after the test.

When an attempt is made to simulate a real ignition source, it is essential to realize that burning characteristics may be affected by environmental conditions and therefore recognize that the design parameters chosen may not be correct and may require subsequent adjustment.

Possible ignition sources can be characterized by:

a) total fuel content

b) type of fuel

c) rate and nature of fuel release (e.g. ramped, stepped or steady state)

d) rate of heat release

e) height of flame for given location

f) convective and radiative heat

g) time of burning

Annex A gives guidance on the development of ignition sources for fire tests.

4.2 Type of heat source

The complete character of the ignition source should be determined, including mass, material identification, morphology dimensions and all other physical and chemical characteristics necessary to repeat each ignition scenario. Typical ignition sources are solid, liquid or gaseous fuels including gas burners, liquid pool fires, wood cribs, electrical sources, etc.

4.2.1 Gas burners

Gas burner flames have the following advantages:

a) they are reproducible;

b) they are well-defined; i.e. their heat production rate is readily determined from the gas flow rates;

c) they can be varied with time to represent the burning of different products or be maintained constant to facilitate analytical studies;

d) their burning rates are not influenced by heat feedback (unless controlled artificially).

Their disadvantages are:

a) the radiation properties of the flames are different from those of the product simulated;

b) gas flames do not resemble what is seen in real fires;

c) soot production is much less than from real fires therefore flames are less luminous.

Differences between diffusion and premixed burners should be recognized. As an example, the flames from a premixed burner will be hotter, shorter and have lower emissivities. In order to avoid locally high velocities, the gas can be delivered through a large-area diffusing surface, such as a porous plate or a layer of sand.

4.2.2 Liquid pool fires

These fire sources have the following advantages:

a) their rate of fuel production is readily determined from their rate of mass loss or the flow rate necessary to maintain a constant depth in the pool;

b) they have an interaction with the fire environment which can be quantified by their change in heat production rate;

c) they are reproducible under the same exposure conditions;

d) their radiation characteristics can be controlled by the choice of fuel.

Their disadvantages are:

a) the effect of feedback is not quantitatively the same as for real products; and

b) they lack visual realism unless they are intended to represent liquid fuel spills. A variation of the liquid pool fires is obtained by supplying the liquid fuel in a matrix of sand in order to vary its burning rate.

4.2.3 Solid fuels

The solid fuels which have been used routinely as ignition sources have included waste containers and wood cribs, with the latter having the longest history. The dimensions of the sticks, type of wood and spacing as well as total mass have a large effect on the burning rate of the wood cribs.

Waste containers and wood crib fires have the following advantages:

a) they provide the best visual simulation of the burning of products;

b) their interaction with the environment of the fire room is, perhaps, closer to, though not the same as, that of the burning products; and

c) their radiation characteristics more nearly match those of the real product fire.

Waste containers and wood cribs have the following disadvantages:

a) their reproducibility is not as good as that for gas burners; and

b) the ratio of their heat release rates to their measured mass loss rates vary throughout the test.

4.2.4 Radiative sources

Radiative sources are powered either by electricity or gas. These sources have the following advantages:

a) they are reproducible;

b) they can provide either a uniform or gradient of irradiance;

c) the heat output can be quantified;

d) the gas fuelled sources are controllable with rapid responses;

e) they can produce a wide range of irradiance.

The main disadvantages to these sources are that

a) electrical radiant sources are not immediately controllable;

b) for lamp type sources, the radiation properties are different to those of the product simulated;

c) radiant sources generally require a form of piloted ignition and the flame or spark needs to be positioned in an area in which the decomposition gases (from the effects of the radiant heat) are at their most concentrated;

d) radiant sources usually assume a set distance between the source and the item to be ignited (some materials shrink or swell under heat, therefore, this distance changes and this change cannot be quantified).

4.2.5 Electrical sources

Electrical ignition sources for use in large tests can be simulated using sources from smaller-scale fire tests (e.g. glow-wires at temperatures up to 960 °C).

Electrical sources are usually contact (conductive) sources. The advantages of the conductive sources are that they are simple and the tests are easy to conduct. The disadvantages are that the tests are only effective for small scale ignition of materials and are generally a function of the materials autoignition temperatures.

4.2.6 Smouldering sources

The most widely used smouldering source is the glowing cigarette and considerable work has been done to study the effect of this low intensity ignition source [5]. The major disadvantages of using this standardized ignition source, which is generally specified in terms of burning rate and mass, are:

a) it has rather poor repeatability and reproducibility;

b) its behaviour and its ability to act as an effective ignition source is very dependent upon its location which in turn affects its reproducibility.

Its main advantages are that:

a) it is easy to use; and

b) it is the "real" ignition source and therefore should mirror real fire performance.

4.3 Size

The size of the flame or area of radiative influence greatly affects the fire behaviour of the material being exposed to the ignition source, since it affects the area of flame contact. The larger the area of flame contact, the less the influence of the material to be ignited since the ability of the material to dissipate the heat or conduct it away from the area of flame contact is reduced and earlier ignition can be expected.

The depth of the flame source is also important since the greater the depth, the greater the resultant heat flux on the surface of the material exposed.

The ignitability of a flame retardant treated product is also influenced by the relative sizes of the flame source and the object to be ignited.

4.4 Location

The location of the ignition source is one of the most important considerations in conducting compartment experiments. Its position in relation to the wall can significantly influence the rate of burning. When it is close to the wall, there can be major feedback influences and the ignition source will burn more quickly, although this will depend to some extent on the properties of the lining, the availability of air and the type of ignition source. The flame height is affected by the entrainment of air into the plume which itself is critically affected by the position of the ignition source in relation to the wall/corner. For example, if the access of air to the flame is blocked from one side, such as would occur by placing the ignition source against a wall, then an increased flame height for the same rate of gaseous fuel leaving the source would result. This analogy can be extended further to an ignition source in a corner which would give an even higher flame height.

In addition, the height of the flame source from the floor will have an effect on the ignitability of test specimens within a compartment.

4.5 Physical and chemical response of exposed material

In ignitability tests, the thermophysical response of the material can be significant. When a specimen shrinks, flows, melts, deforms, chars, intumesces, etc., it can significantly change the critical distances between the ignition source or flame combustion zone and the material. Therefore, results on the ignitability of these types of materials can be