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**Plastics — Fire tests — Standard  
ignition sources**

*Plastiques — Essais au feu — Sources d'allumage normalisées*

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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.

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](http://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](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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](http://www.iso.org/iso/foreword.html).

The committee responsible for this document is Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 4, *Burning behaviour*.

This first edition of ISO/TR 10093 cancels and replaces ISO 10093:1998, which has been technically revised.

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

- the document has been updated and converted from an International Standard to a Technical Report;
- several additional ignition sources have been added, including some that originate in standards that have not been issued by ISO or IEC;
- no details of wood crib and paper bag ignition sources are included;
- Annex A and Annex B have been deleted;
- the information that used to be in Annex A on confirmatory procedure for evaluating test flames is described in IEC 60695-11 and in ASTM D5207;
- the bibliography formerly contained in Annex B has been extended.

## Introduction

Fires are caused by a wide range of possible ignition sources. Statistical analysis of fires has identified the main primary and secondary sources, especially for fires in buildings. The most frequent sources of fires have been found to be as follows:

- a) cooking appliances;
- b) space-heating appliances;
- c) electric wiring, connectors and terminations;
- 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;
- h) rubbish burning; and
- i) candles.

The above list covers the major primary ignition sources for accidental fires. Other sources can be involved in fires raised maliciously. Research into causes of fires has shown that primary ignition sources (e.g. glowing cigarettes or dropped flaming matches) can set fire to waste paper, which then acts as a secondary ignition source of greater intensity.

When analysing and evaluating the various ignition sources for applications involving plastics materials, it is important to answer the following questions on the basis of detailed fire statistics.

- 1) What is the significance of the individual ignition sources in various fire risk situations?
- 2) What proportion is attributable to secondary ignition sources?
- 3) Where does particular attention have to be paid to secondary ignition sources?
- 4) To what extent are different ignition sources responsible for fatal fire accidents?

The following laboratory ignition sources are intended to simulate actual ignition sources that have been shown to be the cause of real fires involving plastics. Laboratory ignition sources are preferred over actual ignition sources due to their consistency, which results in greater data repeatability within a laboratory and greater reproducibility between laboratories.

These laboratory ignition sources can be used to develop new test procedures.

# Plastics — Fire tests — Standard ignition sources

## 1 Scope

This document describes and classifies a range of laboratory ignition sources for use in fire tests on plastics and products consisting substantially of plastics. These sources vary in intensity and area of impingement. They are suitable for use to simulate the initial thermal abuse to which plastics are potentially exposed in certain actual fire risk scenarios.

Different standards developing organizations have issued many standard test methods, specifications and regulations to assess fire properties of plastics or of products containing plastic materials. Many of those standards contain ignition sources associated with flaming and non-flaming ignition. This document describes the ignition sources and references the associated standard.

This compilation of ignition sources does not discuss the application of the standard where the ignition source is described and is likely not to be a fully comprehensive list of ignition sources.

This document does not address detailed test procedures.

## 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:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

### 3.1

#### **afterflame**

persistence of flaming of a material after the ignition source has been removed

### 3.2

#### **afterflame time**

#### **duration of flame**

length of time for which a material continues to flame, under specified test conditions, after the ignition source has been removed

### 3.3

#### **afterglow**

persistence of glowing of a material after cessation of flaming or, if no flaming occurs, after the ignition source has been removed

**3.4**

**afterglow time**

length of time for which a material continues to glow, under specified test conditions, after the ignition source has been removed and/or cessation of flaming

**3.5**

**combustion**

exothermic reaction of a substance with an oxidizer, generally accompanied by flames and/or glowing and/or emission of smoke

**3.6**

**ease of ignition**

ease with which a material can be ignited under specified test conditions

**3.7**

**exposed surface**

surface subjected to the heating conditions of the test

**3.8**

**flame**

rapid, self-sustaining, sub-sonic propagation of *combustion* (3.5) in a gaseous medium, usually with emission of light

**3.9**

**flame**

to produce *flame* (3.8)

**3.10**

**flaming debris**

material separating from the specimen during the test procedure and falling below the initial lower edge of the specimen and continuing to *flame* (3.9) as it falls

**3.11**

**glowing combustion**

*combustion* (3.5) of a material in the solid phase without *flame* (3.8) but with emission of light from the combustion zone

**3.12**

**ignitability**

measure of the ease with which a specimen can be *ignited* (3.13) due to the influence of an external heat source under specified test conditions

**3.13**

**ignite**, transitive verb  
initiate *combustion* (3.5)

**3.14**

**ignite**, intransitive verb  
catch fire with or without the application of an external heat source

**3.15**

**ignition**

initiation of *combustion* (3.5)

**3.16**

**ignition source**

applied source of heat which is used to *ignite* (3.13) combustible materials or products

**3.17****ignition temperature**

minimum temperature of a material at which sustained *combustion* (3.5) can be initiated under specified test conditions

**3.18****irradiance**

ratio of the radiant flux incident on a small but measurable element of surface containing the point, by the area of that element

**3.19****minimum ignition time**

minimum time of exposure of a material to an *ignition source* (3.16) to obtain sustained *combustion* (3.5) under specified test conditions

**3.20****primary ignition source**

first applied *ignition source* (3.16)

**3.21****punking**

propagation of a smouldering *combustion* (3.5) front after removal of the *ignition source* (3.16)

**3.22****secondary ignition source**

heat source which is activated following *ignition* (3.15) from a primary source

**3.23****sustained flaming**

*flame* (3.8), on or over the surface of a test specimen, which persists for longer than a defined period of time

**3.24****transitory flaming**

*flame* (3.8), on or over the surface of a test specimen, which persists for a defined short period of time

Note 1 to entry: Compare with the term *sustained flaming* (3.23).

**4 Ignition processes**

**4.1** When plastics are exposed to thermal energy, flammable vapours are often generated from their surface. Under suitable conditions (especially high temperatures), it is possible that a critical concentration of flammable vapour will form and spontaneous ignition will result. If a flame is present as the sole energy source, or as a supplementary source, the ignition process will be assisted; this mechanism is sometimes known as piloted ignition.

**4.2** A specimen of plastic is regarded as ignited when flames appear on the surface of the plastic or when glowing combustion is evident.

**4.3** After ignition has occurred, some burning plastics create additional fire hazards by forming flaming debris or drips. If this flaming debris falls on to combustible material, it is possible that secondary ignition will occur and the fire will spread more rapidly.

**4.4** The localized application of a heat source to some plastics results in glowing combustion. With some thermoplastic foams and foams from thermosetting materials, the localized application of a heat source results in punking which produces a carbonaceous char.

## 5 Characteristics of ignition sources

**5.1** The following factors are the main characteristics describing ignition sources and their relation to the test specimen:

- a) intensity of the ignition source, which is a measure of the thermal load on the specimen resulting from the combined conduction, convection and radiation effects caused by the ignition source;
- b) area of impingement of the ignition source on the specimen;
- c) duration of exposure of the specimen and whether it is continuous or intermittent;
- d) presentation of the ignition source to the specimen and whether or not it impinges;
- e) orientation of the specimen in relation to the ignition source;
- f) ventilation conditions in the vicinity of the ignition source and exposed surface of the specimen;

NOTE Factors c) to f) are often a function of the specific fire test conditions.

**5.2** Several of the ignition sources provide a range of intensities and areas of impingement to be considered for use in fire tests of plastics.

## 6 General principles

### 6.1 Flaming ignition sources

#### 6.1.1 Diffusion flame ignition source

To form a diffusion flame ignition source, a gas (usually propane, methane or butane) flows through metallic tubes without ingress of air prior to the base of the flame. These flames simulate natural flames well but they often fluctuate and are not convenient to direct if any angular presentation is required towards the specimen.

#### 6.1.2 Premixed flame source

To form a premixed flame source, a gas burner (usually using propane, methane or butane) fitted with air inlet ports or an air intake manifold is used. Premixed flame sources are typically more directional than diffusion flame sources and are generally hotter than diffusion flame sources.

### 6.2 Issues associated with flaming ignition sources

Gas burners are always set up to conform to precise gas flow rates and/or flame heights. Periodic checks of flame temperature or heat flux precede the setup, but criteria on these parameters are not necessarily an essential part of the laboratory procedure. After setting up the burner for a particular test (i.e. often at an acute angle to the test specimen), it is desirable to leave the burner in this orientation throughout a series of experiments. This objective is conveniently satisfied if the operator only has to maintain the gas flow constant to the burner.

The gas burners are connected to the gas supply by flexible tubing via a cylinder regulator providing an outlet pressure, on-off valve, fine-control valve and flowmeter.

Difficulties sometimes occur with the supply and measurement of butane or propane when the cylinders have been stored in an environment cooler than the defined test conditions and/or some distance from the test rig. When difficulties occur, a sufficient length of tubing is used inside the controlled

environment (15 °C to 30 °C) to ensure that the gas equilibrates to the appropriate temperature before flow measurement.

NOTE One way to facilitate this equilibration is to pass the gas (before flow measurement) through a metal tube immersed in water maintained at 25 °C.

It is important to exercise great care with the measurement and setting of the flow rate of the gas and to check direct-reading flowmeters, even those obtained with a direct calibration for the gas used initially, at regular intervals during testing, with a method capable of measuring accurately the absolute gas flow at the burner tube.

NOTE One way of doing this is to connect the burner tube with a short length of tubing (about 7 mm internal diameter) to a soap bubble flowmeter. Passage of a soap film meniscus in a glass tube (e.g. a calibrated burette) over a known period of time gives an absolute measurement of the flow. Also, fine-control valves that can each be pre-set to one of the desired gas flow rates, with simple means for switching from one to the other, have proved helpful.

### 6.3 Non-flaming ignition sources

The following clauses/subclauses describe ignition sources as follows (see Table 1):

Clause 7: smouldering (cigarette)

Clause 8: Non-flaming electrical ignition sources

8.1 Glow-wire ignition

8.2 Hot-wire ignition

Clause 9: Radiant ignition sources

9.1 Conical radiant ignition

9.2 Other radiant ignition

Clause 10: Infrared heating ignition

Clause 11: Diffusion flame ignition

11.1 Needle flame ignition

11.2 Burning match

11.3 Burners generating 50 W or 500 W flames

Clause 12: Premixed flame ignition

12.1 Premixed burner for 1 kW flame

12.2 Vertical cable tray burners

12.3 Burners for large scale horizontal tests

12.4 Burners for room corner tests

12.5 Burners for individual product heat release tests

Clause 13: Other ignition sources

13.1 Wood cribs

13.2 Paper bags

Table 1 — Classification of ignition sources

| Type of ignition source                           | Standard(s) using ignition source                                  | Clause/subclause |
|---------------------------------------------------|--------------------------------------------------------------------|------------------|
| Smouldering (cigarette)                           | ISO 8191-1, NFPA 260, NFPA 261                                     | 7                |
| Non flaming electrical ignition sources           |                                                                    | 8                |
| Glow-wire ignition                                | IEC 60695-2-10, IEC 60695-2-11, ASTM D6194                         | 8.1              |
| Hot-wire ignition                                 | IEC/TS 60695-2-20, ASTM D3874                                      | 8.2              |
| Radiant ignition sources                          |                                                                    | 9                |
| Conical radiant ignition                          | ISO 5657, ISO 5659-2, ISO 5660-1, ASTM E1354, ASTM E1995, NFPA 270 | 9.1              |
| Other radiant ignition                            | ISO 871, ASTM D1929, ASTM E906, ASTM E1321                         | 9.2              |
| Infrared heating ignition sources                 | ASTM E2058, NFPA 287                                               | 10               |
| +                                                 |                                                                    |                  |
| Diffusion flame ignition sources                  |                                                                    | 11               |
| Needle flame ignition                             | IEC 60695-11-5                                                     | 11.1             |
| Burning match                                     | ISO 8191-2, ISO 11925-2                                            | 11.2             |
| Burners generating 50 W or 500 W flames           | IEC/TS 60695-11-3, IEC/TS 60695-11-4, ASTM D635, ASTM D5025, UL 94 | 11.3             |
| Premixed flame ignition sources                   |                                                                    | 12               |
| Premixed burner for 1 kW flame                    | IEC 60695-11-2, IEC 60332-1-2, IEC 60332-2-1                       | 12.1             |
| Vertical cable tray burners                       | IEC 60332-3-10, ASTM D5424, ASTM D5537, UL 1666, UL 1685, UL 2556  | 12.2             |
| Burners for large scale horizontal tests          | ASTM E84, NFPA 262                                                 | 12.3             |
| Burners for room corner tests                     | ISO 9705-1, ASTM E2257, NFPA 265, NFPA 286                         | 12.4             |
| Burners for individual product heat release tests | ASTM E1537, ASTM E1590, ASTM E1822, NFPA 289                       | 12.5             |
| Other ignition sources                            |                                                                    | 13               |
| Wood cribs                                        |                                                                    | 13.1             |
| Paper bags                                        |                                                                    | 13.2             |

## 7 Smouldering (cigarette) ignition sources

### 7.1 Traditional cigarettes

**7.1.1** This source is typical of a common commercial cigarette, which is known to cause many fires involving upholstered furniture and bedding as discussed in ISO 8191-1. The untipped (unfiltered) cigarette meets the following:

- length:  $(70 \pm 4)$  mm
- diameter:  $(8,0 \pm 0,5)$  mm
- mass:  $(1,0 \pm 0,1)$  g
- smouldering rate:  $(12,0/50 \pm 3,0/50)$  min/mm

**7.1.2** The smouldering rate is verified on one specimen from each batch of 10 cigarettes used as follows:

- a) condition the cigarette before the test for 72 h in indoor ambient conditions and then for at least 16 h in an atmosphere having a temperature of  $(20 \pm 5)^\circ\text{C}$  and a relative humidity of  $(50 \pm 20)\%$ ;
- b) mark the cigarette at 5 mm and 55 mm from the end to be lit;
- c) light the cigarette and draw air through it until the tip glows brightly; do not consume more than 3 mm of the cigarette in this operation;
- d) impale the cigarette in draught-free air on a horizontal wire spike, inserting not more than 13 mm of the spike into the unlit end of the cigarette; and
- e) record the time taken to smoulder from the 5 mm to the 55 mm mark.

**7.1.3** In many countries, including in the European Union and the United States, regulations that apply to commercial cigarettes mean that they meet the characteristics of reduced ignition propensity (RIP) cigarettes, by being tested in accordance with ISO 12863 or ASTM E2187. Thus, such RIP cigarettes have become replacement commercial cigarettes for the commercial cigarettes available when ISO 8191-1 was developed. The new commercial RIP cigarettes are less likely to provide a severe smouldering ignition source than the traditional non-RIP cigarettes.

## 7.2 Non-reduced ignition propensity cigarettes

Standard reference material cigarettes (SRM 1196) were designed to simulate the ignition strength of those cigarettes that were in commercial use in the United States before the development of ISO 12863 or ASTM E2187. They have been identified as having a strong ignition potential and do not conform to the specifications of RIP cigarettes. The cigarettes are described as NIST SRM 1196<sup>1)</sup> cigarettes and they are cigarettes without filter tips, made from natural tobacco ( $83 \pm 2$ ) mm long with a tobacco packing density of  $(0,270 \pm 0,020) \text{ g/cm}^3$  and a total weight of  $(1,1 \pm 0,1) \text{ g}$ . These cigarettes are used in NFPA 260 and NFPA 261.

## 8 Non-flaming electrical ignition sources

### 8.1 Glow-wire ignition

**8.1.1** This ignition source is referenced in IEC 60695-2-10, IEC 60695-2-11 and ASTM D6194. It is called a glow-wire. This source simulates overheating of electrical wiring, particularly within electrotechnical equipment by heating the glow-wire to one of the following temperatures:

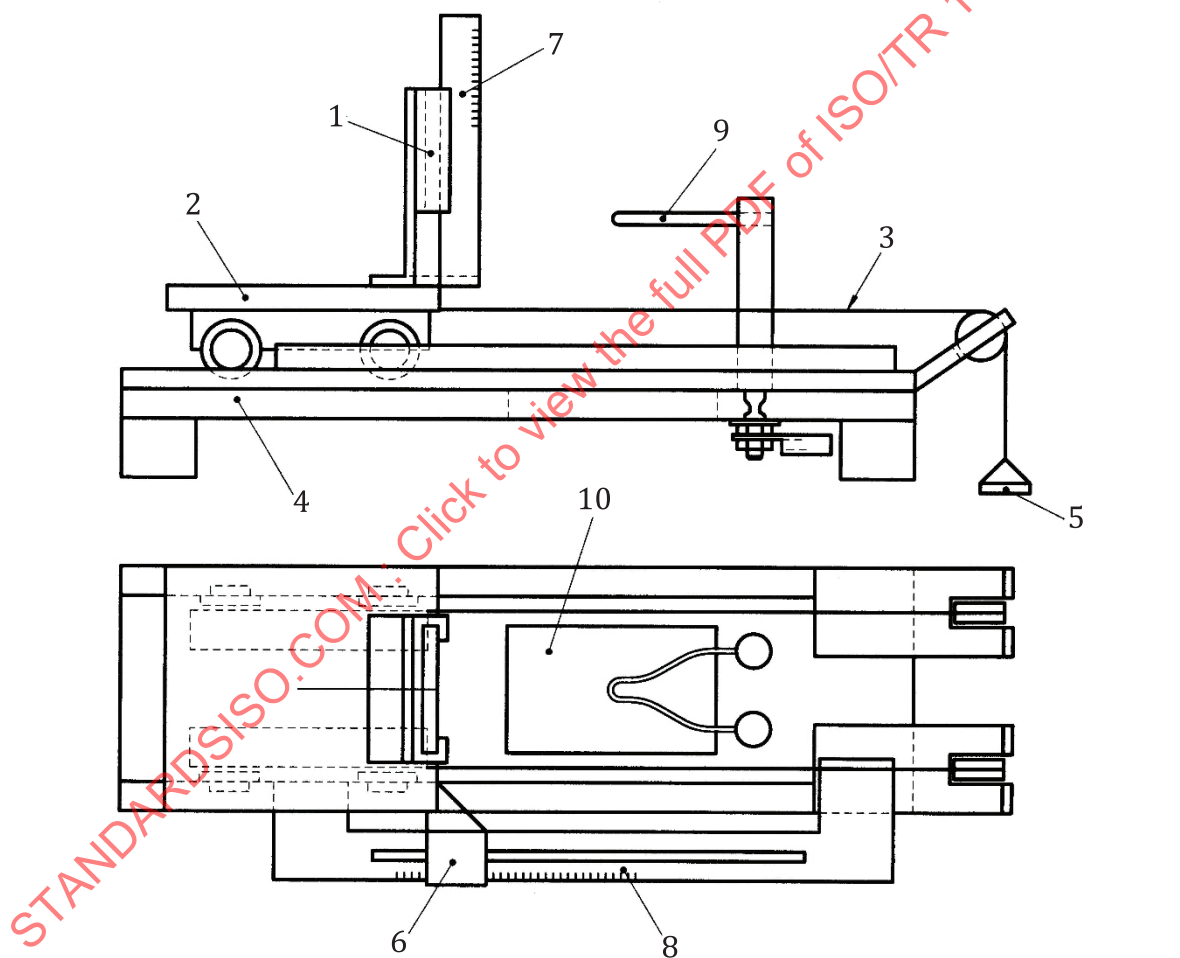
- $(550 \pm 10)^\circ\text{C}$
- $(650 \pm 10)^\circ\text{C}$
- $(750 \pm 10)^\circ\text{C}$
- $(850 \pm 15)^\circ\text{C}$
- $(960 \pm 15)^\circ\text{C}$

**8.1.2** The glow-wire apparatus and ignition source are shown in Figure 1. The glow-wire itself consists of a loop of nickel/chromium (80/20) wire 4 mm in nominal diameter.

1) Available from the US National Institute of Standards and Technology (NIST), <http://www.nist.gov/srm/index.cfm>.

**8.1.3** The temperature of the glow-wire is measured by the use of a sheathed fine-wire Type K thermocouple [Nickel–Chromium (NiCr) or Nickel–Aluminium (NiAl)] having a nominal overall diameter of 0,5 mm or 1,0 mm. The thermocouple sheath is constructed of a metal that will allow the thermocouple to perform its function in air at sheath temperatures of at least 1 050 °C. The thermocouple is arranged in a pocket hole, drilled in the tip of the glow-wire. The thermal contact between the walls of the bored hole in the glow-wire is maintained by pinning the sheathed thermocouple in place. The thermocouple follows the movement of the tip of the glow-wire resulting from elongation caused by thermal heating. A temperature indicator for Type K thermocouples capable of reading up to 1 000 °C is used. It is important that the supply circuit be capable of supplying up to 150 A at 2,1 V, with smooth continuous adjustment of voltage to provide the appropriate current to maintain the desired glow-wire tip temperature.

**8.1.4** The test apparatus positions the glow-wire in a horizontal plane while applying a force of  $(1,0 \pm 0,2)$  N to the specimen. This force is maintained when the glow-wire is moved horizontally towards the specimen or vice versa. The movement of the tip of the glow-wire into the specimen when pressed against it is mechanically limited to 7 mm.



#### Key

- |   |                   |    |                                                           |
|---|-------------------|----|-----------------------------------------------------------|
| 1 | positioning clamp | 6  | stop                                                      |
| 2 | carriage          | 7  | scale to measure height of flame                          |
| 3 | tensioning cord   | 8  | scale for penetration                                     |
| 4 | baseplate         | 9  | glow-wire                                                 |
| 5 | weight            | 10 | cut-out in base plate for particles falling from specimen |

**Figure 1 — Glow-wire ignition source**

## 8.2 Hot-wire ignition

**8.2.1** This ignition source is referenced in IEC/TS 60695-2-20 and in ASTM D3874. It is an electrically heated hot-wire that simulates the overloading of a live part in direct contact with a test specimen.

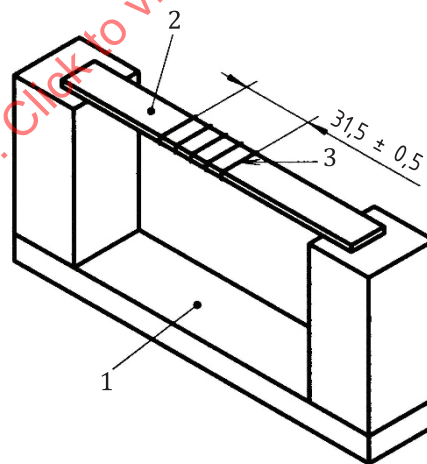
**8.2.2** The heater wire is a loop of iron-free nickel/chromium wire (80 % nickel and 20 % chromium, iron-free), 0,05 mm in nominal diameter. The wire has a nominal cold resistance of 5,28  $\Omega$ /m and has a length-to-mass ratio of 580 m/kg. The wire length for each test is approximately 250 mm and has been previously calibrated. Before testing, each straight length of wire is annealed by energizing the wire to dissipate 0,26 W/mm of length for 8 s to 12 s to relieve internal wire stress.

**8.2.3** The supply circuit used to electrically energize the heater wire has sufficient capacity to maintain a continuous linear 50 Hz to 60 Hz power density of at least 0,31 W/mm over the length of the heater wire at or near unity power factor. When the supply circuit operates at a current of 60 A with a voltage of 1,5 V, this results in an approximate power density of 0,3 W/mm. Essential devices include those for voltage adjustment and power measurement (within  $\pm 2$  %), an easily actuated on-off switch for the test power, and timers to record the duration of the application of test power.

**8.2.4** Hot-wire ignition tests are carried out on bar-shaped specimens, of dimensions  $(125 \pm 5)$  mm long,  $(13,0 \pm 0,3)$  mm wide and  $(3,0 \pm 0,1)$  mm thick. Specimens are wrapped with five turns of 0,5 mm diameter nickel/chromium (80/20) wire of approximate length 250 mm and with a nominal cold resistance of 5,28  $\Omega$ /m, spaced  $(6,35 \pm 0,5)$  mm between turns. The test apparatus and ignition source are shown in Figure 2.

**8.2.5** The specimen is tested in a horizontal position by heating the wire electrically so that 0,26 W is generated per millimetre length of wire, and the wire has a temperature of approximately 930 °C.

Dimensions in millimetres



### Key

- 1 test fixture
- 2 test specimen
- 3 hot-wire (five turns with 6,35 mm  $\pm$  0,5 mm between turns)

**Figure 2 — Hot-wire ignition source**

## 9 Radiant ignition sources

### 9.1 Conical radiant ignition sources

#### 9.1.1 General

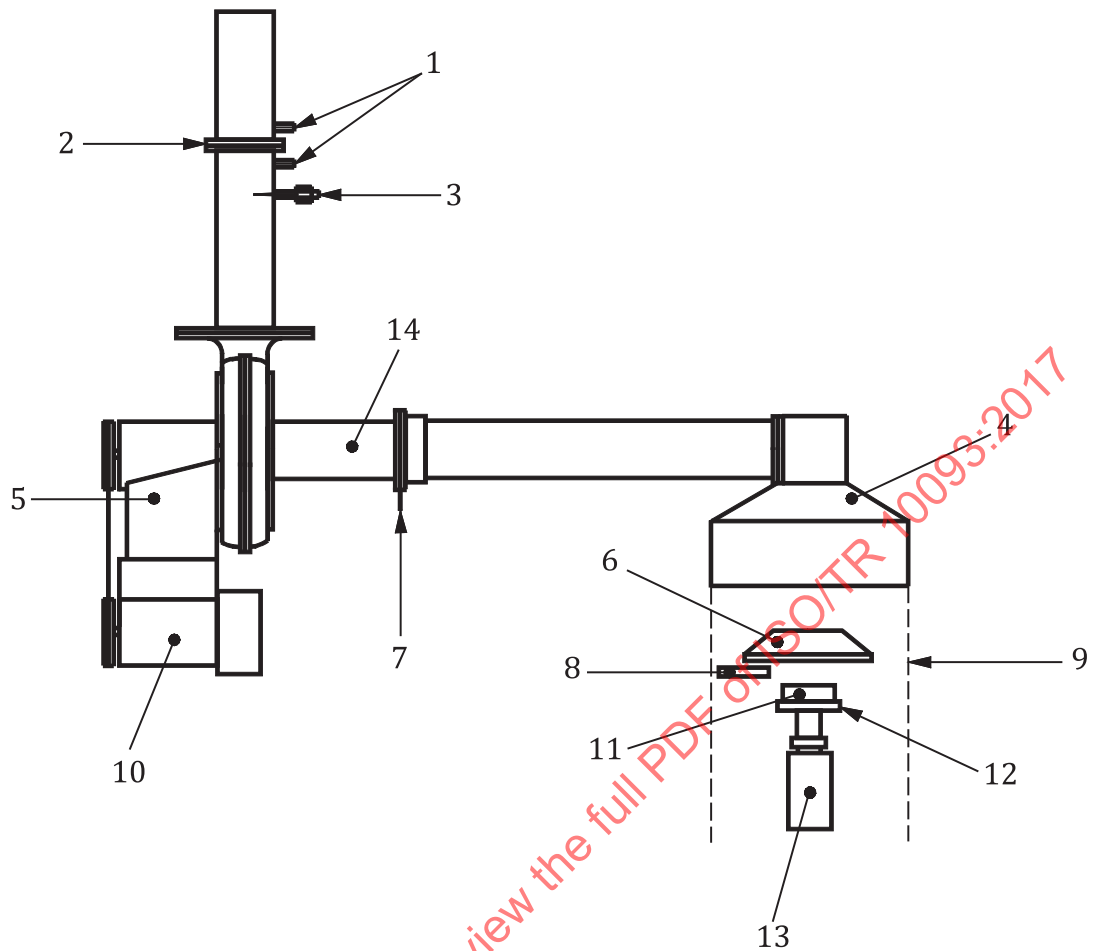
Table 2 compares the three conical ignition sources described below.

**Table 2 — Details of radiant ignition sources with conical radiators**

| Standard                               | Heat flux range<br>kW/m <sup>2</sup> | Specimen size<br>cm <sup>2</sup> | Pilot<br>ignition source | Specimen<br>orientation   |
|----------------------------------------|--------------------------------------|----------------------------------|--------------------------|---------------------------|
| ISO 5657                               | 10 to 50                             | 154                              | Propane flame            | Horizontal                |
| ISO 5659-2,<br>ASTM E1995,<br>NFPA 270 | 10 to 50                             | 56                               | Propane flame            | Horizontal                |
| ISO 5660-1,<br>ASTM E1354              | 10 to at least 75                    | 100                              | Spark igniter            | Horizontal<br>or vertical |

#### 9.1.2 Cone calorimeter ignition source

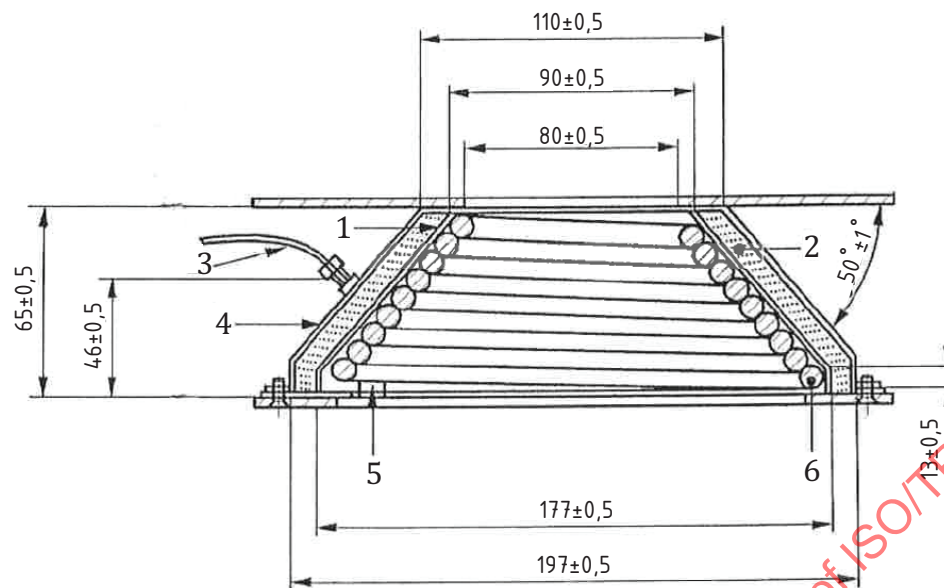
**9.1.2.1** This ignition source is described in ISO 5660-1 and in ASTM E1354. The ignition source is composed of the following major components: a conical radiant electric heater (able to be used in the horizontal or vertical orientations), a temperature controller, a radiation shield, an electric ignition spark plug and a test specimen holder (which depends on the test orientation). The test specimen is (100 × 100) mm and the heat flux range is from 0 kW/m<sup>2</sup> to at least 75 kW/m<sup>2</sup>. There is no pilot flame. A schematic of the apparatus is shown in Figure 3 and one for the conical heater is shown in Figure 4.

**Key**

- |   |                                            |    |                             |
|---|--------------------------------------------|----|-----------------------------|
| 1 | pressure ports                             | 8  | spark plug                  |
| 2 | orifice plate                              | 9  | optional screens            |
| 3 | thermocouple (located on stack centreline) | 10 | blower motor                |
| 4 | hood                                       | 11 | retainer frame and specimen |
| 5 | blower                                     | 12 | specimen holder             |
| 6 | heater                                     | 13 | weighing device             |
| 7 | gas sampling ring probe                    | 14 | smoke measurement section   |

NOTE Source: ISO 5660-1:2015, Figure 1.

**Figure 3 — Cone calorimeter apparatus schematic**



#### Key

- 1 inner shell
- 2 refractory fibre packing
- 3 thermocouple
- 4 outer shell
- 5 space block
- 6 heating element

NOTE Source: ISO 5660-1:2015, Figure 2.

**Figure 4 — Cone calorimeter conical heater schematic**

**9.1.2.2** The active element of the conical heater consists of an electrical heater rod, rated at 5 000 W at 240 V, tightly wound into the shape of a truncated cone (Figure 4). The heater is encased on the outside with a double-wall stainless steel cone, packed with a refractory fibre material of approximately 100 kg/m<sup>3</sup> density. The heater is hinged so that it can be swung into either a horizontal or a vertical orientation. The irradiance is uniform within the central (50 × 50) mm area of the test specimen to within ±2 % in the horizontal orientation and to within ±10 % in the vertical orientation. The heater irradiance from the heater is able to be held at a pre-set level by means of a temperature controller and three type K stainless steel sheathed thermocouples, symmetrical around the heater element. The thermocouples are of equal length and wired in parallel to the temperature controller.

**9.1.2.3** The heater is controlled by a temperature controller capable of holding the element temperature steady to within ±2 °C. A suitable system is a three-term controller (proportional, integral and derivative) and a thyristor unit capable of switching currents up to 25 A at 240 V. The temperature input range of the controller is up to 1 000 °C, with a scale capable of being read to 2 °C or better and automatic cold junction compensation. The heater temperature is monitored by a meter capable of being read to ±2 °C or better, which is often incorporated into the temperature controller.

**9.1.2.4** A removable radiation shield protects the test specimen from the heat flux prior to the start of a test. The shield is made of non-combustible material with a total thickness not to exceed 12 mm. The shield is either

- a) a water-cooled shield coated with a durable matte black finish of surface emissivity  $e = 0,95 \pm 0,05$ , or
- b) a shield that is not water-cooled but is provided with either a metallic reflective top surface or a ceramic non-metallic top surface, in order to minimize radiation transfer.

The shield is equipped with a handle or other suitable means for quick insertion and removal. The cone heater base plate is equipped with the means for holding the shield in position and allowing its easy and quick removal.

**9.1.2.5** The actual ignition is accomplished by a 10 kV discharge across a 3 mm spark gap located 13 mm above the centre of the test specimen (when used for the horizontal location). The sparker power source is either a transformer designed for spark-ignition use or a spark generator. The spark discharge operates continuously at 50 Hz to 60 Hz until sustained flaming is achieved. The igniter is removed when sustained flaming is achieved. The sensitivity of the timing device for measuring time to ignition (also known as time to sustained flaming) is such that it is capable of recording elapsed time to the nearest second and is accurate to within 1 s in 1 h. In the case of testing in the vertical orientation, the spark gap is located in the test specimen face plane and 5 mm above the top of the specimen holder.

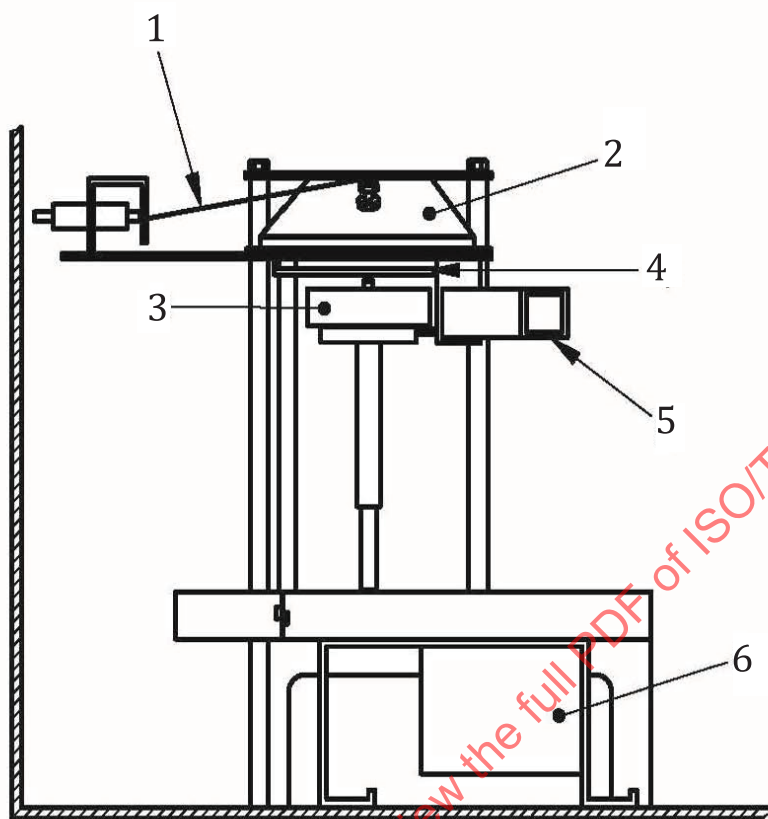
**9.1.2.6** The horizontal test specimen holder has its bottom lined with a layer of low-density (nominal density 65 kg/m<sup>3</sup>) refractory fibre blanket with a thickness of at least 13 mm. The distance between the bottom surface of the cone heater and the top of the test specimen is adjusted to be 25 mm. The vertical test specimen holder includes a small drip tray to contain a limited amount of molten material. A test specimen is installed in the vertical test specimen holder by backing it with a layer of refractory fibre blanket (nominal density 65 kg/m<sup>3</sup>), the thickness of which depends on test specimen thickness, but the blanket is at least 13 mm thick. A layer of rigid, ceramic fibre millboard is placed behind the fibre blanket layer. The millboard thickness is such that the entire assembly is rigidly bound together once the retaining spring clip is inserted behind the millboard. When testing in the vertical orientation, the cone heater height is set so the centre lines up with the test specimen centre.

### 9.1.3 Smoke chamber conical heater

**9.1.3.1** This ignition source is described in ISO 5659-2 as well as in ASTM E1995 and in NFPA 270. The ignition source is similar to that in the cone calorimeter (See 9.1.2) but is smaller. The following are specified in these standards as the essential components: a conical radiant electric heater, a test specimen holder, a radiation shield, a pilot burner and a spark igniter to reignite the pilot burner. The test specimen is (75 × 75) mm and the heat flux range is 25 kW/m<sup>2</sup> or 50 kW/m<sup>2</sup>, either with or without an external pilot flame. Schematics of the conical heater and the arrangement are found in Figure 5 and Figure 6.

**9.1.3.2** The active element of the conical heater consists of an electrical heater rod, rated at 450 W at 240 V, tightly wound into the shape of a truncated cone. The heater is encased on the outside with a double-wall stainless steel cone, packed with a refractory fibre material of approximately 100 kg/m<sup>3</sup> density. The heater provides irradiances on the surface of the test specimen of 10 kW/m<sup>2</sup> to 50 kW/m<sup>2</sup>, as measured at the centre of the surface of the test specimen. The irradiance is also determined at positions of (25 ± 2) mm to each side of the test specimen centre, and the irradiance at these two positions is not less than 85 %, and not more than 115 % of the irradiance at the centre of the test specimen. The heater irradiance is capable of being held at a pre-set level (25 kW/m<sup>2</sup> and 50 kW/m<sup>2</sup>) by means of a temperature controller and three type K stainless steel sheathed thermocouples, symmetrically disposed and in contact with but not welded to the heater element. The thermocouples are of equal length and wired in parallel to the temperature controller. The cone heater is secured from the vertical rods of the

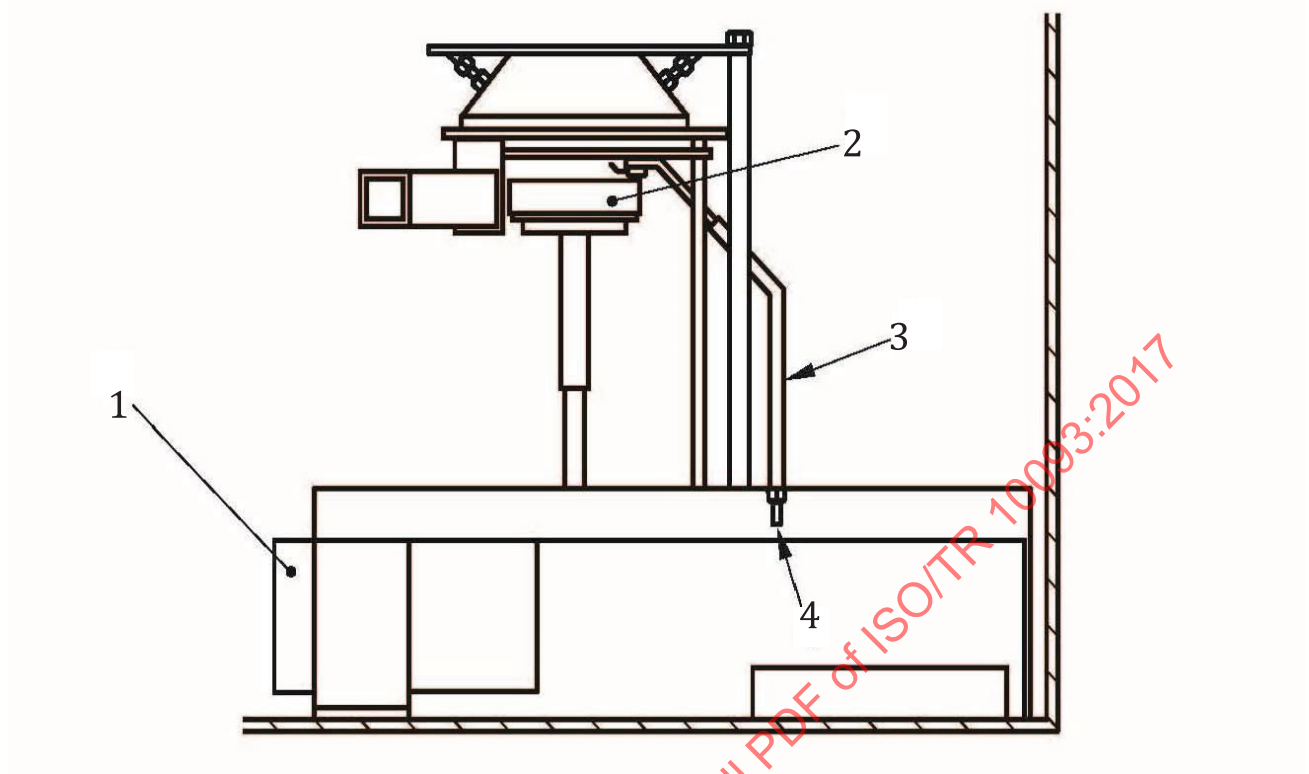
support framework and located so that the lower rim of the cone heater is  $(25 \pm 1)$  mm above the upper surface of the test specimen.



**Key**

- 1 thermocouple
- 2 radiator cone
- 3 specimen holder
- 4 radiator shield
- 5 heat flux meter
- 6 spark ignition housing

**Figure 5 — Typical arrangement of ISO 5659-2 radiator cone ignition source specimen holder and radiator shield (side view)**



#### Key

- 1 spark ignition housing
- 2 specimen holder
- 3 pilot burner and ignition electrode
- 4 propane and air

**Figure 6 — Typical arrangement of ISO 5659-2 radiator cone ignition source specimen holder and radiator shield (front view)**

**9.1.3.3** The heater temperature controller is capable of holding the element temperature steady to within  $\pm 2$  °C. A suitable system is a three-term controller (proportional, integral, and derivative) and a thyristor unit capable of switching currents up to 25 A at 240 V. The controller has a temperature input range of 0 °C to 1 000 °C, a set scale capable of being read to 2 °C or better, and automatic cold junction compensation. The cone heater temperature is monitored by a meter capable of being read to  $\pm 2$  °C, or better, which is often incorporated into the temperature controller.

**9.1.3.4** The cone heater is provided with a removable radiation shield to protect the test specimen from the irradiance prior to the start of the test. The radiation shield is made of a non-combustible material with a total thickness not to exceed 12 mm, and conforms to the same specifications as that of the cone calorimeter radiation shield (see 9.1.2.4).

**9.1.3.5** The actual ignition is caused by a pilot burner. The flame from the single-flame burner has a length of  $(30 \pm 5)$  mm and is positioned horizontally  $(10 \pm 1)$  mm above the top face of the test specimen. The colour of the flame is blue with a yellow tip. The tip of the burner is aligned with the edge of the test specimen.

**9.1.3.6** A small spark ignition device is placed next to the outlet tube of the burner to cause reignition of the flame without the need to open the chamber door. A suitable system is a spark plug with a 3 mm gap, powered from a 10 kV transformer. A suitable electrode length and spark plug location is such that the spark gap is located 13 mm above the test specimen, close to the pilot burner.

#### 9.1.4 Periodic flaming ignition test

**9.1.4.1** This ignition source is used in ISO 5657. It is a conical radiant heater, somewhat similar to those described in 9.1.2 and in 9.1.3 but with different characteristics. It differs from other radiant heaters in terms of the heater itself, the characteristics of the igniter and the test specimen. It is a radiant cone heater which allows specimens to be exposed to thermal radiation on their upper surfaces at selected levels of constant heat flux within the range 10 kW/m<sup>2</sup> to 50 kW/m<sup>2</sup>, at the aperture of a masking plate and in a reference plane coinciding with the underside of the masking plate. It represents a non-contacting thermal radiant exposure from a primary fire at those heat fluxes. A pilot flame is applied at regular intervals to a position 10 mm above the centre of each specimen to ignite any volatile gases given off. The test specimen is (165 × 165) mm and the heat flux range is 10 kW/m<sup>2</sup> to 50 kW/m<sup>2</sup>. Details are shown in Figure 7.

**9.1.4.2** The active element of the heater consists of an electrical heater rod, rated at 3 000 W at 240 V, tightly wound into the shape of a truncated cone. The heater is encased on the outside with a double-wall stainless steel cone, packed with a refractory fibre material of approximately 100 kg/m<sup>3</sup> density. The distribution of the irradiance provided by the heater at the reference plane is such that

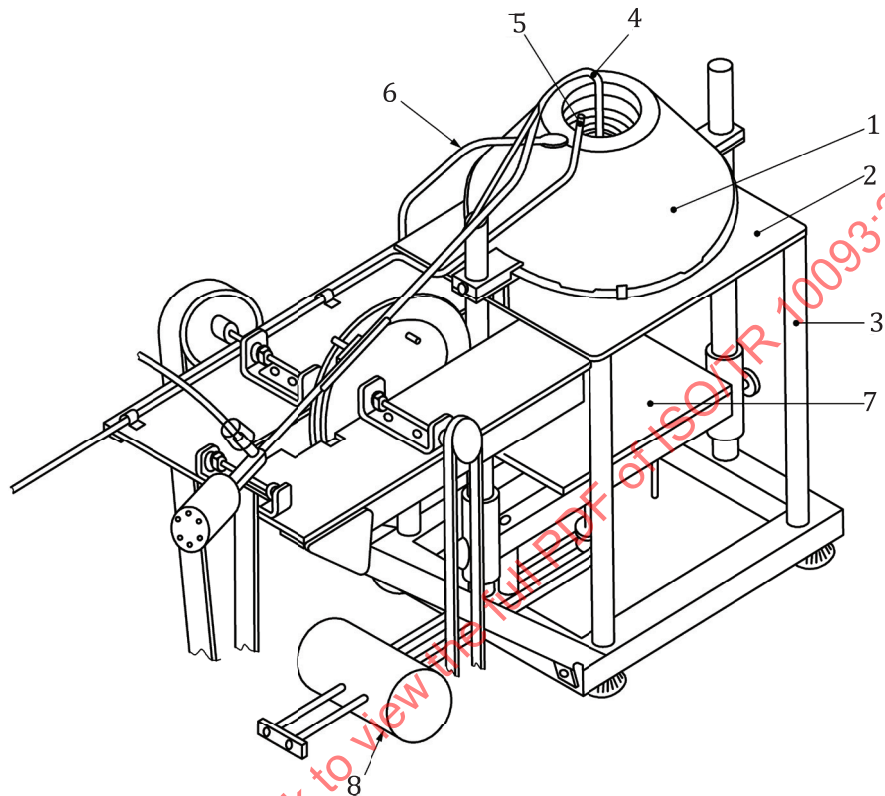
- a) the variation of the irradiance within a circle of 50 mm diameter, drawn from the centre of the masking plate aperture, is not more than ±3 % of that at the centre, and
- b) the variation of the irradiance within a circle of 100 mm diameter, drawn from the centre of the masking plate aperture, is not more than ±5 % of that at the centre.

The surface area of the specimen exposed to this thermal radiation is 154 cm<sup>2</sup>. The heat flux is checked with a calibrated radiometer prior to testing.

**9.1.4.3** The apparatus is provided with a pilot flame and a secondary ignition source. The pilot flame stainless steel nozzle tube is fed with a mixture of propane and air which is achieved by regulating the propane flow rate to 19 mL/min to 20 mL/min and the airflow rate to 160 mL/min to 180 mL/min. The flow rates are fed directly into the pilot flame from the flowmeters.

**9.1.4.4** The apparatus has a mechanism capable of bringing the pilot flame from its “off” position outside and above the cone heater [at a height of (10 ± 1) mm above the underside of the masking plate] to its “test” position within the cone (at a distance of 10 mm above the test specimen), through the cone and through the aperture in the masking plate. When the flame is in the “off” position, it issues horizontally over the centre point of the aperture in the masking plate and perpendicular to the plane of the movement of the pilot arm, with the centre of the orifice in the nozzle positioned at the indicated height. The mechanism is such that the pilot flame moves every 4 s (+0,4 – 0 s) from the “off” position to the “test” position in no more than 0,5 s, then stays there for 1 s (+0,1 – 0 s) and then returns in a time of no more than 0,5 s.

**9.1.4.5** The secondary ignition source is one of the following: a propane gas flame 15 mm long from a nozzle with an internal diameter of 1 mm to 2 mm (50 W in heat output) and a hot-wire or a spark igniter. The dipping of the pilot flame is continuous until ignition of the test specimen.



#### Key

- |                      |                             |
|----------------------|-----------------------------|
| 1 radiator cone      | 5 secondary ignition source |
| 2 masking plate      | 6 heater cable              |
| 3 support framework  | 7 pressing plate            |
| 4 pilot flame source | 8 sliding counterweight     |

NOTE Source: ISO 10093:1998, Figure 9.

**Figure 7 — Conical heater from periodic flaming ignition test schematic**

## 9.2 Other radiant ignition sources

### 9.2.1 Glowbars ignition source

**9.2.1.1** The ignition source described as the radiant heater from the Ohio State University rate of heat release apparatus is described in ASTM E906. A very similar version is used by the aviation authorities for assessing the ignitability and flammability of materials.

**9.2.1.2** It consists of a radiant heat source for generating a heat flux of up to 100 kW/m<sup>2</sup> and uses four silicon carbide elements, Type LL, (508 ± 3) mm × (16 ± 1) mm, with a nominal resistance of 1,6 V.

The silicon carbide elements are mounted in the stainless steel panel box by inserting them through 15,9 mm holes in 0,8 mm thick ceramic fibre. A diamond-shaped mask, constructed of 24-gauge stainless steel, is added to provide uniform heat flux over the area occupied by a (150 × 150) mm vertical sample. The power supply provides 16,5 kVA, adjustable from 0 V to 270 V. The normal orientation of the test specimen is vertical.

**9.2.1.3** The radiant source described in 9.2.1.2 has two pilot burners. The lower pilot burner, with nominally 11,3 mm outside diameter, a nominally 0,8 mm wall, and stainless-steel tubing, is used in all tests and is fed with an air/gas fuel mixture. The gas is methane or natural gas having 90 % or more methane. The fuel mixture is a methane–air mixture (120 cm<sup>3</sup>/min gas, and 850 cm<sup>3</sup>/min air). An upper pilot burner (which is used without air) is used when an impinging flame is used to obtain information at a heat flux below which the pyrolysis rate of the test specimen can maintain a combustible gas phase. It consists of a straight length of nominally 6,3 mm outside diameter, nominally 0,8 mm wall, and stainless steel tubing nominally 360 mm long. At a heat flux above that producing a combustible gas mixture over the surface of the sample there is a choice of piloted or unpiloted ignition. In addition to piloted and non-piloted modes of operation, it is possible to accomplish pilot ignition of a test specimen by locating the pilot flame at different positions relative to the sample surface in such a fashion that the flame will only impinge on the test specimen surface when necessary, with the location chosen depending on the nature of the ignition to be simulated by the test.

## **9.2.2 Lateral ignition and flame spread test (LIFT) radiant panel heater.**

**9.2.2.1** This ignition source is described in ASTM E1321 and consists of a main frame, test specimen holders, a stack, a radiant panel and a pilot igniter. A series of test specimens [of dimension (155 × 155) mm] are exposed to a nearly uniform heat flux and the time to flame attachment, using piloted ignition, is determined.

**9.2.2.2** The main frame consists of two separate sections, the radiant-panel support frame and the test specimen support frame. The two frame sections are joined so as to allow adjustments in the relative position of the radiant panel to the test specimen to be made easily.

**9.2.2.3** The radiant panel consists of a radiation surface of porous refractory tiles mounted at the front of a stainless-steel plenum chamber to provide a flat radiating surface of approximately (280 × 483) mm. The plenum chamber includes baffle plates and diffusers to distribute the gas/air mixture evenly over the radiation surface. The gas/air mixture enters the plenum chamber at one of the short sides to facilitate easy connection when the panel is mounted from the frame. A reverberatory screen is provided immediately in front of the radiating surface to enhance the combustion efficiency and increase the radiant output.

**9.2.2.4** The appropriate air and fuel flow-metering devices, gas control valves, pressure reducer and safety controls to support combustion at the radiant panel are all mounted on the panel support frame. The air supply is specified to be of approximately  $(8,33 \times 10^{-3})$  m<sup>3</sup>/s at a pressure sufficient to overcome the friction loss through the line, metering device and radiant panel. The radiant-panel pressure drop amounts to approximately 20 Pa to 30 Pa. Flow rates are measured with a flowmeter suitable for indicating airflow over the range of 2 to  $(15 \times 10^{-3})$  m<sup>3</sup>/s and with a flowmeter suitable for indicating methane flow rates over the range of 0,1 to  $(1,1 \times 10^{-3})$  m<sup>3</sup>/s. The fuel gas used is either natural gas or methane. A constant supply pressure is maintained by means of a pressure regulator. Gas is either controlled by a manually-adjusted needle valve or by a Venturi mixer. The Venturi mixer allows control of the flux level of the panel by adjusting only the air valve. The fuel gas-flow is specified to be roughly 0,26 to  $(1,03 \times 10^{-3})$  m<sup>3</sup>/s at a pressure sufficient to overcome line pressure losses.

## **9.2.3 Setchkin ignition**

**9.2.3.1** The Setchkin apparatus furnace is described in ISO 871 and in ASTM D1929.

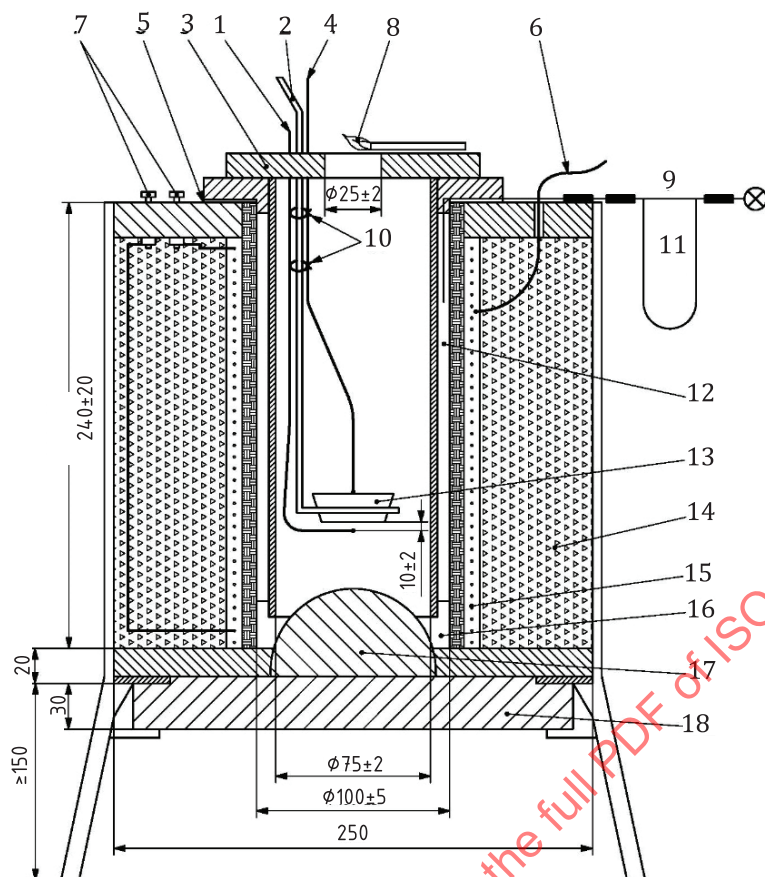
**9.2.3.2** The equipment consists primarily of an electrical heating unit and a test specimen holder. The furnace has a furnace tube and an inner ceramic tube. The furnace tube is a vertical tube with an inside diameter of  $(100 \pm 5)$  mm and a length of  $(230 \pm 20)$  mm, made of a ceramic that will withstand at least  $750^\circ\text{C}$ . The vertical tube stands on the furnace floor, fitted with a plug for the removal of accumulated residue. The ceramic tube is built to withstand at least  $750^\circ\text{C}$ , with an inside diameter of  $(75 \pm 5)$  mm, a length of  $(230 \pm 20)$  mm, and a thickness of approximately 3 mm. It is placed inside the furnace tube and positioned  $(20 \pm 2)$  mm above the furnace floor on three small spacer blocks. The top is covered by a disk of heat-resistant material with a  $(25 \pm 2)$  mm diameter opening in the centre that is used for observation and passage of smoke and gases. The pilot flame is located immediately above the opening. An electrical heating unit, contained within a mineral fibre sleeve and constructed of 50 turns of  $(1,3 \pm 0,1)$  mm Nichrome V alloy wire, is wound around the furnace tube and embedded in heat-resistant cement. Thermal insulation consists of a layer of mineral fibre, approximately 60 mm thick and covered by a metal jacket. The equipment is shown in Figure 8 (ISO 871:2006, Figure 1). Ignition is conducted either with or without a pilot igniter.

**9.2.3.3** An outside air source is used to supply clean air near the top of the annular space between the ceramic tubes through a copper tube at a steady and controllable rate. Air is heated and circulated in the space between the two tubes and enters the inner furnace tube at the bottom. Air is metered by a rotameter or other suitable device.

**9.2.3.4** The pilot igniter consists of a nominal  $(1,8 \pm 0,3)$  mm inside diameter (ID) copper tubing attached to a gas supply of 94 % minimum purity propane and placed horizontally  $(5 \pm 1)$  mm above the top surface of the disk cover. The pilot flame is adjusted to  $(20 \pm 2)$  mm in length and centred above the opening in the disk cover.

**9.2.3.5** The test specimen is placed inside a pan that consists of a metal container of approximately 0,5 mm thick steel measuring  $(40 \pm 2)$  mm in diameter by  $(15 \pm 2)$  mm in depth. It is held in a ring of approximately 2,0 mm diameter stainless steel welding rod. The ring is welded to a length of the same type of rod extending through the cover of the furnace. The bottom of the test specimen pan is located  $(185 \pm 5)$  mm down from the top of the inner furnace tube.

**9.2.3.6** Three thermocouples, 0,5 mm in diameter, either Chromel-Alumel (Type K) or Iron-Constantan (Type J), are used for temperature measurement. They are connected to a calibrated recording instrument with a tolerance not exceeding  $\pm 2^\circ\text{C}$ . Thermocouple TC<sub>1</sub> is used to measure the temperature of the test specimen and is located as close as possible to the centre of the upper surface of the test specimen when the test specimen is in place within the furnace. The thermocouple wire is attached to the test specimen support rod. Thermocouple TC<sub>2</sub> is used to indicate the temperature of the air travelling past the test specimen. It is located  $(10 \pm 2)$  mm below the centre of the test specimen pan. The thermocouple wire is attached to the test specimen support rod. Thermocouple TC<sub>3</sub> is used to measure the temperature of the heating coil. It is located adjacent to the furnace heating coil and used as a reference for temperature adjustment purposes because of its faster response. Heating control is conducted by means of a variable transformer or an automatic controller connected in series with the heating coils.



# Key

- |                                |                                                       |
|--------------------------------|-------------------------------------------------------|
| 1 thermocouple TC <sub>2</sub> | 10 metal fasteners                                    |
| 2 support rod                  | 11 air-flow meter (not part of furnace)               |
| 3 refractory disc cover        | 12 air flow tangential to cylinder                    |
| 4 thermocouple TC <sub>1</sub> | 13 specimen pan                                       |
| 5 gasket                       | 14 mineral fibre wool                                 |
| 6 thermocouple TC <sub>3</sub> | 15 50 turns of no. 16 Nichrome wire in heat-resistant |
| 7 heater terminals             | 16 three refractory blocks to space inner tube and    |
| 8 pilot flame                  | 17 inspection plug (removable)                        |
| 9 air supply                   | 18 thermal insulation (removable)                     |

NOTE Source: ISO 871:2006, Figure 1.

**Figure 8 — Ignition source from Setchkin apparatus schematic**

## 10 Infrared heating system

**10.1** This ignition source is used in the fire propagation test apparatus developed by FM Global and it is described in ASTM E2058 and in NFPA 287. The ignition source consists of the following components: an infrared heating system, a power controller, an ignition pilot flame and an ignition timer.

**10.2** The ignition source is an infrared heating system. Each of four 241 mm long infrared heaters contains six tungsten-filament tubular quartz lamps in a compact reflector body that, for a 120 V input, produces 190 kW/m<sup>2</sup> of radiant flux in front of the quartz window that covers the lamps. The emitter of each lamp is a 127 mm long tungsten filament in an argon atmosphere enclosed in a 9,5 mm outer-diameter clear quartz tube. The emitter operates at a minimum of 2 475 K for a 120 V input to produce a spectral energy peak at 1,15 µm.

**10.3** A power controller maintains the appropriate output voltage for the heater array despite variations in the line voltage and load impedance through the use of phase angle power control to match the hot/cold resistance characteristics of the tungsten-quartz lamps. The controller also incorporates average voltage feedback to linearize the relationship between the voltage set by the operator and the output voltage to the lamps.

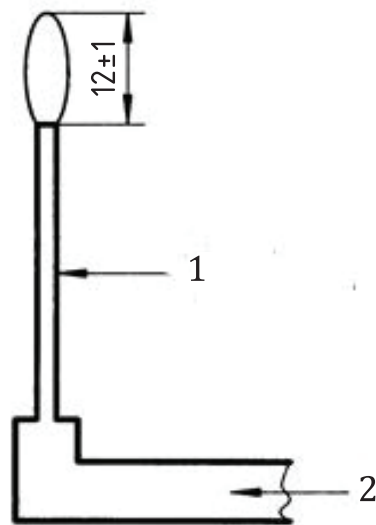
**10.4** A pilot ignition consists of an ethylene-air (60–40 by volume) flame adjusted for a 10 mm length and anchored at the horizontal end of a 50 mm long, 6,35 mm outer diameter, 4,70 mm inner diameter, stainless steel tube. The horizontal section of the tube contains a four-hole ceramic insert to produce a stable flame and prevent flashback. The pilot flame tube is able to be rotated and elevated to position the horizontal flame at specified locations near the specimen.

**10.5** An ignition timer to assess time to ignition (also known as time to sustained flaming) is capable of recording elapsed time to the nearest 0,1 s and has an accuracy of better than 1 s in 1 h.

## 11 Diffusion flame ignition

### 11.1 Needle flame ignition

**11.2.1** This ignition source, which is described in IEC 60695-11-5, consists of a needle flame which provides a low-intensity, low-area diffusion flame. This source is intended to simulate the effect of small flames resulting from fault conditions within electrical equipment. The needle burner consists of a piece of stainless-steel hypodermic tubing with the tapered end cut off. The burner has a minimum length of 35 mm with a bore of  $(0,5 \pm 0,1)$  mm and an outer diameter not exceeding 0,9 mm. The burner is connected with flexible tubing to a cylinder containing butane or propane. The gas purity is specified to be of at least 95 %. Butane gas is the typical standard reference gas, but propane gas is also acceptable. With the axis of the needle burner in the vertical position, the gas supply is adjusted so that the length of the flame is  $(12 \pm 1)$  mm. See Figure 9.

**Key**

- 1 outside diameter: 0,9 mm max.; bore diameter:  $(0,5 \pm 0,1)$  mm  
 2 gas supply from regulated flowmeter

NOTE Source: ISO 10093:1998, Figure 3.

**Figure 9 — Needle flame ignition source schematic**

## 11.2 Burning match

**11.2.1** This ignition source is described in ISO 8191-1 and is a diffusion flame with a calorific output approximating to that of a burning match. A flame exposure time of  $(15 \pm 2,0)$  s is approximately equivalent to the burning of one match.

**11.2.2** The burner barrel consists of a stainless-steel tube with an outside diameter of  $(8,0 \pm 0,1)$  mm, an internal diameter of  $(6,5 \pm 0,1)$  mm and a length of  $(200 \pm 5)$  mm.

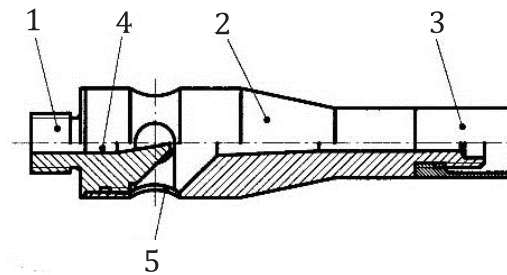
**11.2.3** The burner tube is connected with flexible tubing to a cylinder containing propane and the flexible tubing between the flowmeter and the burner tube has an internal diameter of 8 mm and a length of  $(2,0 \pm 0,2)$  m. The flowmeter is calibrated to supply a propane gas flow rate, at 25 °C, of  $(45 \pm 2)$  mL/min. Under the above conditions, the flame height is approximately 40 mm. The area of impingement on the exposed surface of a specimen is  $(7,5 \pm 0,2)$  cm<sup>2</sup> and the heat flux is  $(40 \pm 2)$  kW/m<sup>2</sup>. Butane gas is the typical standard reference gas, but propane gas is also acceptable.

**11.2.4** An alternate burner with a similarly low intensity is described in ISO 11925-2. This ignition source is a laboratory burner constructed as shown in Figure 10 and designed so that it can be used vertically or tilted at 45° with respect to the vertical axis. The burner is fitted with a fine-adjustment valve to ensure accurate control of the flame height and provides a stable and directable flame.

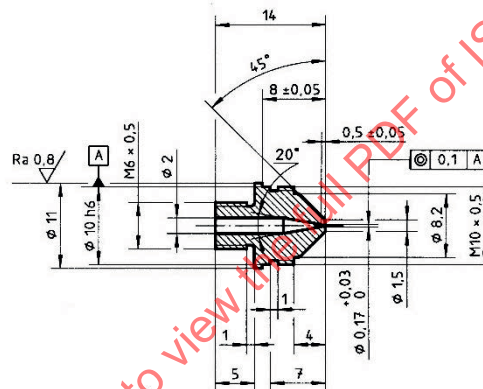
**11.2.5** The burner is connected with flexible tubing to a cylinder containing propane (95 % minimum purity). The burner is brought into a vertical position and the flame adjusted by means of a needle valve to a height of  $(20 \pm 1)$  mm.

**11.2.6** The gas flow rate used in this ignition source is  $(25 \pm 1)$  mL/min at 25 °C. The area of impingement on the exposed surface of a specimen is  $(4,2 \pm 0,3)$  cm<sup>2</sup> and the heat flux is  $(37 \pm 2)$  kW/m<sup>2</sup>.

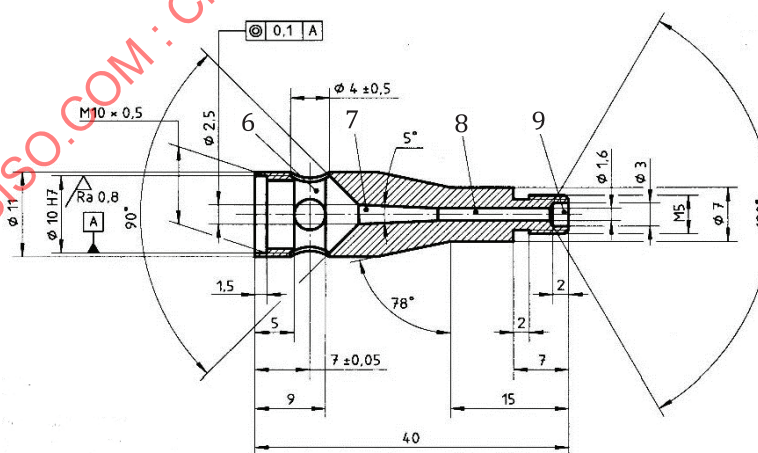
Dimensions in millimetres



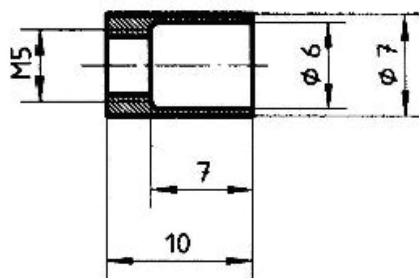
a) Burner assembly



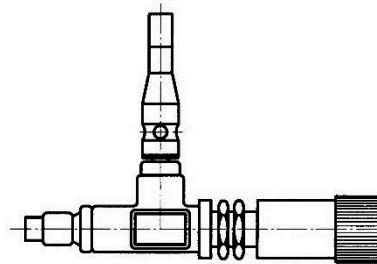
b) Gas jet



c) Burner tube



d) Flame stabilizer



e) Burner and adjustment valve

**Key**

- 1 gas jet
- 2 burner tube
- 3 flame stabilizer
- 4 choke tube
- 5 notch fitted in during assembly
- 6 gas mixing zone
- 7 acceleration section
- 8 conducting section
- 9 outlet

NOTE Source: ISO 11925-2:2010, Figure 2.

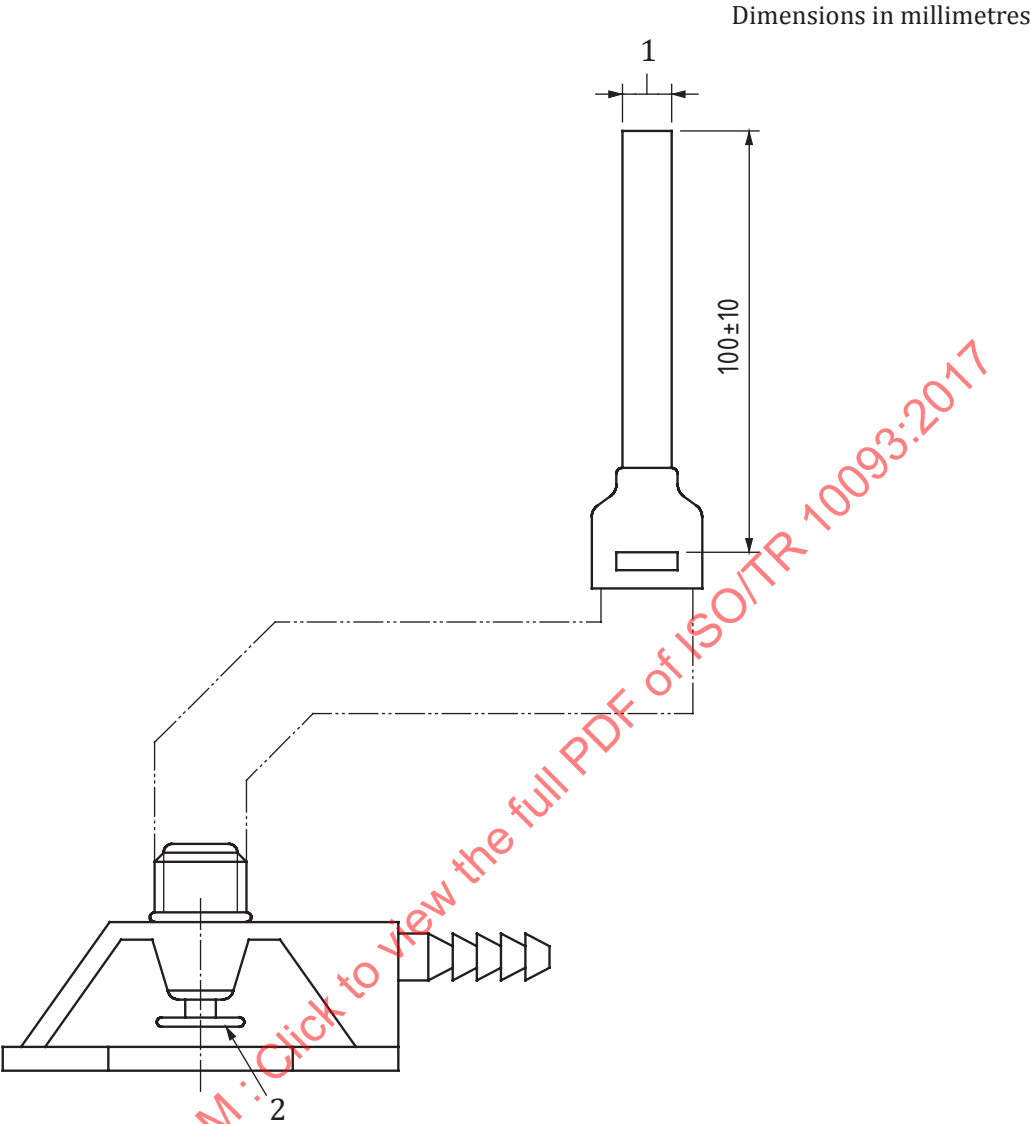
**Figure 10 — Diffusion burner****11.3 Burners generating 50 W or 500 W flames**

**11.3.1** This ignition source is a laboratory burner described in IEC/TS 60695-11-3 for a 50 W flame and in IEC/TS 60695-11-4 for a 500 W flame, as well as in ASTM D5025, for both types of flames. The burner consists of a barrel threading onto a one-piece base and gas inlet. The components are constructed of metal, typically of brass or aluminium. This burner is also suitable for use in the horizontal orientation, for example as used in ASTM D635 or in UL 94, or for testing at an angle of 60°, as used by aviation authorities (see Figure 11).

**11.3.2** The burner barrel consists of a mixing tube and threaded air-inlet adapter. The mixing tube is of seamless construction, with an inside diameter of  $(9,5 \pm 0,3)$  mm. The length of the barrel from the top of the air-inlet openings to the top of the mixing tube is  $(100 \pm 10)$  mm. The top of the mixing tube is not equipped with end attachments, such as stabilizers. The air-inlet adapter, located at the bottom of the mixing tube, is approximately 25 mm high and 20 mm in overall diameter. The minimum area of the air-inlet openings is 225 mm<sup>2</sup> distributed equidistant around the adapter. With the barrel fully screwed into

the base and the lock nut in place, the standards stipulate that it is essential that the air-inlet openings be completely closed.

**11.3.3** The minimum area of the air-inlet openings has commonly been obtained by using three openings, approximately  $(6,5 \times 12,5)$  mm. The base of the burner is equipped with an orifice of  $(0,90 \pm 0,03)$  mm in diameter and  $(1,60 \pm 0,05)$  mm in length and with a machined needle valve to restrict the orifice opening and regulate gas velocity through the burner. A knurled knob is provided for adjustment of the valve. The needle valve is machined with a conical point using an angle of  $40^\circ$  with a maximum flat top of 0,4 mm. The needle aligns with the orifice in the valve seat. Alignment can be confirmed by removing the barrel and igniting the fuel gas directly at the orifice. The standards specify that it is essential for the flame to remain vertical. If the flame slants, possible reasons include, but are not limited to, the orifice being off-centre or the needle being worn. It is important to confirm the alignment periodically and to take appropriate actions to ensure that the flame remains vertical. The base of the burner is provided with a serrated fitting for connection to the gas supply. The burner is also (optionally) provided with a lock nut that threads onto the base. This allows the barrel to be tightened securely against the lock nut when the particular test flames are associated with such positioning of the barrel that the air-inlet openings are partially or fully open.



- Key**
- 1 internal diameter:  $(9,5 \pm 0,3)$  mm
  - 2 needle valve adjustment

**Figure 11 — Burner for 50 W or 500 W flames**

**11.3.4** The characteristics of burners for a 50 W and a 500 W flame, including their associated dimensions, are given in Table 3.

**Table 3 — Characteristics of 50 W and 500 W flame burners**

| Gas composition        | Gas flow rate<br>(mL/min) | Area of impingement<br>(cm <sup>2</sup> ) | Minimum gas purity<br>(%) |
|------------------------|---------------------------|-------------------------------------------|---------------------------|
| 50 W: 20 mm high flame |                           |                                           |                           |
| Methane                | 105                       | 1,8                                       | 98                        |
| Propane                | 42                        | 1,8                                       | 98                        |
| Butane                 | 33                        | 1,8                                       | 95                        |

Table 3 (continued)

| Gas composition                                     | Gas flow rate<br>(mL/min) | Area of impingement<br>(cm <sup>2</sup> ) | Minimum gas purity<br>(%) |
|-----------------------------------------------------|---------------------------|-------------------------------------------|---------------------------|
| 500 W: 125 mm high flame with 40 mm inner blue cone |                           |                                           |                           |
| Methane                                             | 965                       | 18                                        | 98                        |
| Propane                                             | 380                       | 18                                        | 98                        |
| Butane                                              | 300                       | 18                                        | 95                        |

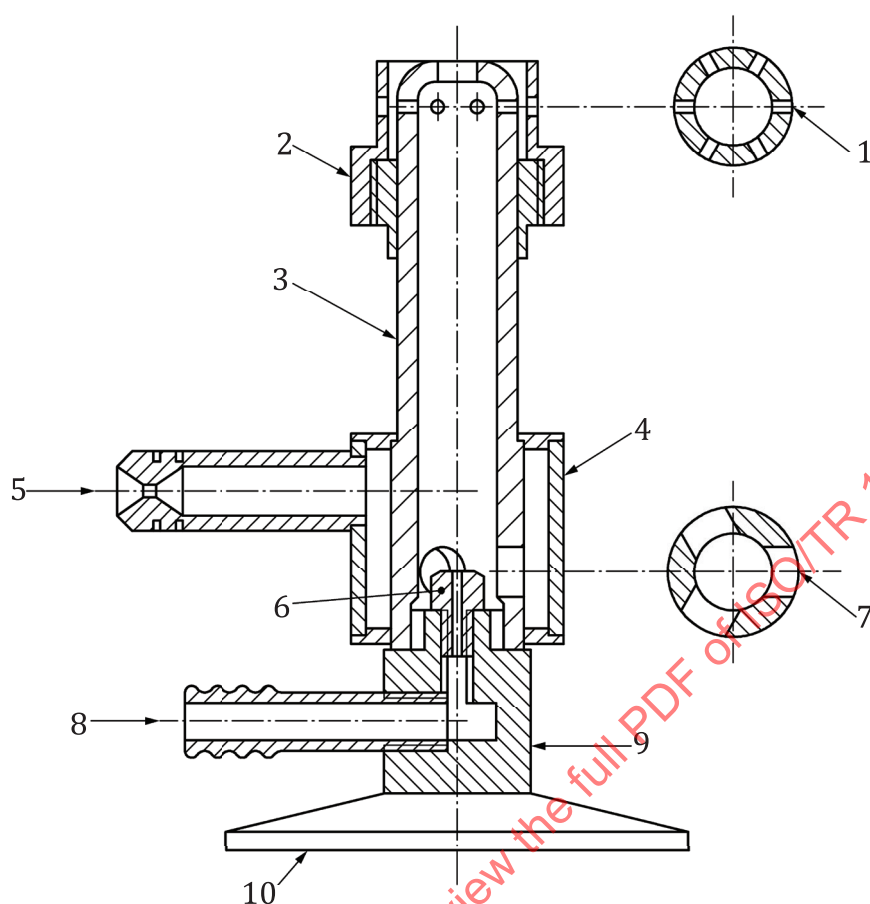
**11.3.5** Information for the calibration of these gas diffusion burners is found in IEC 60695-11 and in ASTM D5207.

## 12 Premixed burners

### 12.1 Premixed burner for 1 kW flame

**12.1.1** This ignition source is described in IEC 60695-11-2 and is also used in IEC 60332-1-2 and in IEC 60332-2-1. It provides a high-intensity premixed flame of uniform flux. It is intended to simulate the effect on materials of a secondary source arising from other flaming items in the vicinity, or from a fire in its early stages.

**12.1.2** The burner (see Figure 12) consists of a brass barrel tube of the following dimensions: 17,0 mm outside diameter, 12,0 mm internal diameter and 110 mm length. The burner barrel is fitted with a gas injector and flame stabilizer which are removable for cleaning purposes. Both air [oil-free laboratory air, metered at  $(10 \pm 0,5)$  L/min, at 23°C, 101 kPa] and propane [of purity greater than 98 % and at a flow rate equivalent to  $(650 \pm 30)$  mL/min, at 23 °C, 101 kPa] are metered separately to the base of the burner barrel. The area of impingement on the exposed surface of a test specimen is approximately 20 cm<sup>2</sup>.



**Key**

- |   |                           |    |                         |
|---|---------------------------|----|-------------------------|
| 1 | diameter of holes: 1,5 mm | 6  | gas injector            |
| 2 | flame stabilizer          | 7  | diameter of holes: 6 mm |
| 3 | burner tube               | 8  | gas inlet               |
| 4 | air inlet tube            | 9  | gas inlet housing       |
| 5 | air inlet                 | 10 | burner basing           |

NOTE Source: ISO 10093:1998, Figure 8.

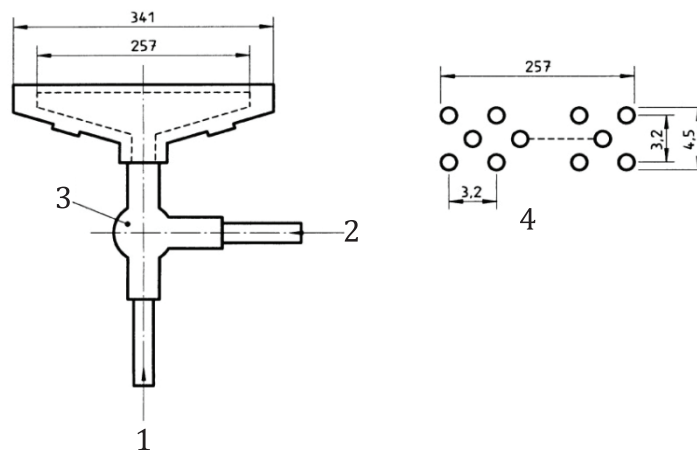
**Figure 12 — Premixed flame burner for 1 kW flame**

## 12.2 Burners for vertical cable tray tests

### 12.2.1 Venturi burners for 20 kW vertical cable tray tests

**12.2.1.1** This ignition source is described in IEC 60332-3-10 and is also used in ASTM D5424, ASTM D5537, UL 1685 and UL 2556. It consists of a gas burner, with a Venturi mixer, which allows vertically oriented test specimens to be exposed to a large-area premixed flame (Figure 13). This ignition source is used in some test methods to expose test specimens with the burner oriented perpendicularly to the vertical tray and in some other test methods with the burner oriented at an angle of 20°. The latter exposure, while providing the same heat input, is more severe. Normal test duration is an exposure period of 20 min.

Dimensions in millimetres

**Key**

- 1 compressed-air entry
- 2 propane gas entry
- 3 Venturi air-gas mixer
- 4 242 round holes, 1,32 mm in diameter, on 3,2 mm centres, staggered in three rows of 81, 80 and 81 holes, centred on the face of the burner

NOTE Source: ISO 10093:1998, Figure 4 a).

**Figure 13 — Venturi burner for 20 kW vertical cable tray tests**

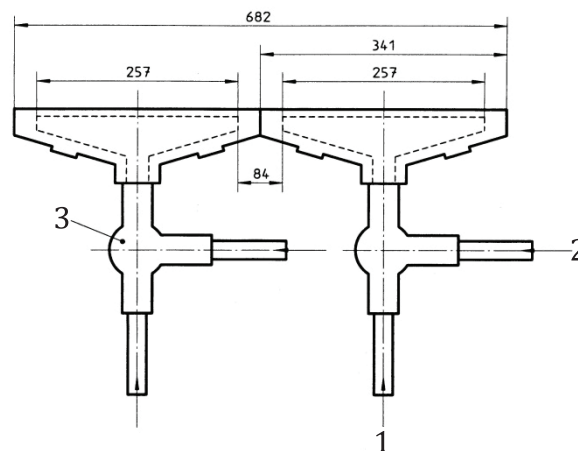
**12.2.1.2** The ignition source is a 254 mm strip or ribbon-type propane gas burner with an air/gas Venturi mixer. The flame-producing surface of the burner consists of a flat metal plate that is 341 mm long and 30 mm wide. The plate has an array of 242 holes drilled in it. The holes are 1,35 mm in diameter, on 3,2 mm centres in three staggered rows of 81, 80 and 81 holes each, to form an array measuring (257 × 5) mm. The array of holes is centred on the plate. A guide is attached to the burner or stand such that the leading edge of the burner face is located quickly and accurately (76 ± 5) mm horizontally away from the nearest surface of the cables during the burn period of the test.

**12.2.1.3** A flowmeter is inserted in both the propane and the air lines feeding the burner to measure the flow rates of these gases during the test. Flow rates are measured with a propane flowmeter capable of measuring at least 230 cm<sup>3</sup>/s and an air flowmeter capable of measuring at least 1 330 cm<sup>3</sup>/s. It is important that flow rate measurements be accurate to within 3 %. Mass flow controllers with recordable outputs are permitted alternatives.

**12.2.1.4** Compressed air is supplied to the burner, either bottled or from a compressed air system. The air is filtered sufficiently so as to eliminate any contaminants that might affect the test results. The air dew point is not greater than 0 °C, as measured by a dew point measuring device. The air flow rate is (1 280 ± 80) cm<sup>3</sup>/s, when corrected to standard temperature and pressure (20 °C and 101 kPa). The propane used is CP grade propane (99 % pure), having a heat content of approximately 50,8 MJ/kg (93,0 MJ/m<sup>3</sup> at 20 °C, 101 kPa) for the burner. The propane flow rate is (220 ± 8) cm<sup>3</sup>/s when corrected to standard temperature and pressure (20 °C, 101 kPa). This propane flow provides a theoretical heat output of 20 kW. The actual heat output is less due to incomplete combustion of the propane at the burner.

**12.2.1.5** This ignition source can also be used for higher heat inputs and it has been used for inputs as high as 60 kW.

**12.2.1.6** Under some circumstances, two Venturi burners (of similar characteristics) are used. When two burners are used, they are mounted side by side as shown in Figure 14.



#### Key

- 1 compressed-air entry
- 2 propane gas entry
- 3 Venturi air-gas mixer

NOTE Source: ISO 10093:1998, Figure 4 b).

**Figure 14 — Double Venturi burner for vertical cable tray tests**

### 12.2.2 Burner for vertical riser cable tests

**12.2.2.1** This ignition source is described in UL 1666. It is a gas burner which allows vertically oriented test specimens to be exposed to a large-area premixed flame and to assess whether test specimens spread flame from one floor to another. It is more severe than the ignition source in 12.2.1 and is used for assessing whether electric cables spread fire from one floor to the floor above.

**12.2.2.2** The burner consists of piping plus a steel diffuser plate. The fuel is commercial grade propane of approximately 83,1 MJ/m<sup>3</sup> heat content. The test flame is to produce approximately 154,5 kW. The burner flame is ignited with a pilot and the burner flame is increased to  $(1\,657 \pm 86)$  cm<sup>3</sup> to start the test. The test flame is normally applied to the cable for 30 min.

### 12.3 Burner for large scale horizontal tests

**12.3.1** This ignition source is described in ASTM E84 (where it is used for building products) and is also similar to that described in NFPA 262 (where it is used for cables) and for a variety of other high fire performing products. Note that the test specimen exposure conditions and other test apparatus considerations are different between ASTM E84 and NFPA 262.

**12.3.2** One end of the test chamber (designated as the “fire end”) is provided with two gas burners delivering flames upward against the surface of the test sample. The burners are spaced  $(292 \pm 6)$  mm from the fire end (or air-inlet end) of the test chamber and  $(191 \pm 6)$  mm below the removable top cover. The burner is located  $(1\,320 \pm 51)$  mm downstream of the air-inlet shutter, as measured from the burner centreline to the outside surface of the shutter. Gas to the burners is provided through a single inlet pipe distributed to each port burner through a tee-section. The outlet is a nominal 19 mm elbow. The plane of the ports is parallel to the furnace floor, such that the gas is directed upward toward the test specimen. Each port is positioned with its centreline  $(102 \pm 6)$  mm on each side of the centreline of the furnace so that the burner flame is distributed evenly over the width of the exposed test specimen surface.