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Edition 1.0 2021-05

INTERNATIONAL STANDARD

BASIC SAFETY PUBLICATION

Fire hazard testing –
Part 11-11: Test flames – Determination of the characteristic heat flux for ignition from a non-contacting flame source

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CONTENTS

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FIRE HAZARD TESTING –

Part 11-11: Test flames – Determination of the characteristic heat flux for ignition from a non-contacting flame source

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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IEC 60695-11-11 has been prepared by IEC technical committee 89: Fire hazard testing.

It has the status of a basic safety publication in accordance with IEC Guide 104 and ISO/IEC Guide 51.

The text of this International Standard is based on the following documents:

CDV	Report on voting
89/1482/CDV	89/1507/RVC

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

This international standard is to be used in conjunction with IEC 60695-11-4.

A list of all the parts in the IEC 60695 series, under the general title *Fire hazard testing*, can be found on the IEC website.

Part 11 consists of the following parts:

Part 11-2: Test flames – 1 kW nominal pre-mixed flame – Apparatus, confirmatory test arrangement and guidance

Part 11-3: Test flames – 500 W flames – Apparatus and confirmational test methods

Part 11-4: Test flames – 50 W flame – Apparatus and confirmational test method

Part 11-5: Test flames – Needle-flame test method – Apparatus, confirmatory test arrangement and guidance

Part 11-10: Test flames – 50 W horizontal and vertical flame test methods

Part 11-11: Test flames – Determination of the characteristic heat flux for ignition from non-contacting flame source

Part 11-20: Test flames – 500 W flame test methods

Part 11-30: Test flames – History and development from 1979 to 1999

Part 11-40: Test flames – Confirmatory tests – Guidance

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION

In the design of any electrotechnical product, the risk of fire and the potential hazards associated with fire need to be considered. In this respect the objective of component, circuit and equipment design as well as the choice of materials is to reduce, to acceptable levels, the potential risks of fire even in the event of foreseeable abnormal use, malfunction or failure. IEC 60695-1-10, IEC 60695-1-11 and IEC 60695-1-12 provide guidance on how this is to be accomplished.

Fires involving electrotechnical products can be initiated from external non-electrical sources. Considerations of this nature are dealt with in an overall fire hazard assessment.

The aim of the IEC 60695 series of standards is to save lives and property by reducing the number of fires or reducing the consequences of the fire. This can be accomplished by

– trying to prevent ignition caused by an electrically energised component part and, in the event of ignition, to confine any resulting fire within the bounds of the enclosure of the electrotechnical product.
– trying to minimise flame spread beyond the product's enclosure and to minimise the harmful effects of fire effluents including heat, smoke and toxic or corrosive combustion products.

This international standard is to be used to measure and describe the properties of materials used for electrotechnical products and sub-assemblies in response to heat from a non-contacting flame source or heat source under controlled laboratory conditions which is characterized by quantitative heat input (heat flux) to the materials. Results of this test may be used as elements of a fire risk assessment which takes into account all of the factors which are pertinent to an assessment of the fire hazard of a particular end use. A test specimen cut from an end-product or sub-assembly can be tested by this test method.

This international standard may involve hazardous materials, operations, and equipment. It does not purport to address all of the safety problems associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

Test methods to determine flammability by contact of flame have been developed and standardized already, such as IEC 60695-11-5 [1] [1], IEC 60695-11-10 [2], IEC 60695-11-20 [3] and ISO 4589-2 [4].

This is the first test method to determine the characteristic heat flux for ignition (CHFI) of materials used for electrotechnical products, sub-assemblies or parts from a non-contacting flame source. CHFI characterizes ignition behaviour in terms of incident heat flux. This test method simulates the fire behaviour of materials used for electrotechnical products where a flame source or heat source exists close to, but does not contact with, these items. An example is a candle flame near an electrotechnical product.

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1 Numbers in square brackets refer to the bibliography.

FIRE HAZARD TESTING –

Part 11-11: Test flames – Determination of the characteristic heat flux for ignition from a non-contacting flame source

1 Scope

This part of IEC 60695 describes a test method used to determine the characteristic heat flux for ignition (CHFI) from a non-contacting flame source for materials used in electrotechnical products, sub-assemblies or their parts. It provides a relationship between ignition time and incident heat flux. A test specimen cut from an end-product or sub-assembly can be tested by this test method.

This part of IEC 60695 can be used in the fire hazard assessment and fire safety engineering procedures described in IEC 60695-1-10, IEC 60695-1-11 and IEC 60695-1-12.

This basic safety publication is intended for use by technical committees in the preparation of standards in accordance with the principles laid down in IEC Guide 104 and ISO/IEC Guide 51.

One of the responsibilities of a technical committee is, wherever applicable, to make use of basic safety publications in the preparation of its publications. The requirements, test methods or test conditions of this basic safety publication will not apply unless specifically referred to or included in the relevant publications.

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.

IEC 60695-1-10, *Fire hazard testing – Part 1-10: Guidance for assessing the fire hazard of electrotechnical products – General guidelines*

IEC 60695-1-11, *Fire hazard testing – Part 1-11: Guidance for assessing the fire hazard of electrotechnical products – Fire hazard assessment*

IEC 60695-1-12, *Fire hazard testing – Part 1-12: Guidance for assessing the fire hazard of electrotechnical products – Fire safety engineering*

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

IEC 60695-11-4, *Fire hazard testing – Part 11-4: Test flames – 50 W flame – Apparatus and confirmational test method*

IEC GUIDE 104, *The preparation of safety publications and the use of basic safety publications and group safety publications*

ISO/IEC Guide 51, *Safety aspects – Guidelines for their inclusion in standards*

ISO 13943:2017, *Fire safety – Vocabulary*

ISO 291, *Plastics – Standard atmospheres for conditioning and testing*

ISO/TS 14934-4, *Fire tests – Calibration of heat flux meters – Part 4: Guidance on the use of heat flux meters in fire tests*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 13943:2017 and IEC 60695-4, some of which are reproduced below for the user's convenience, as well as 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 http://www.iso.org/obp

3.1
average ignition time, $\bar{t}_{ig}$
arithmetic mean of three ignition times measured at a given heat flux

3.2
characteristic heat flux for ignition
CHFI
maximum incident heat flux which is a multiple of 5 kW/m^2 and at which $\bar{t}_{ig}$ is greater than 120 s

3.3
draught-free environment
space in which the results of experiments are not significantly affected by the local air speed

Note 1 to entry: A quantitative example is a space in which a wax candle flame remains essentially undisturbed. Quantitative examples are small-scale fire tests in which a maximum air speed of 0,1 m/s or 0,2 m/s is sometimes specified

[SOURCE ISO 13943:2017, 3.83]

3.4
heat flux
amount of thermal energy emitted, transmitted or received per unit area and per unit of time

Note 1 to entry: the typical unit is W/m^2

[SOURCE ISO 13943:2017, 3.201]

3.5
ignition
initiation of combustion which results in a sustained flaming combustion for at least 5 s

Note 1 to entry: The term "ignition" in French has a very different meaning [state of body combustion] .

3.6
incident heat flux
heat flux received by the surface of a test specimen

[SOURCE: ISO 13943:2017, 3.226]

4 Principle of the test

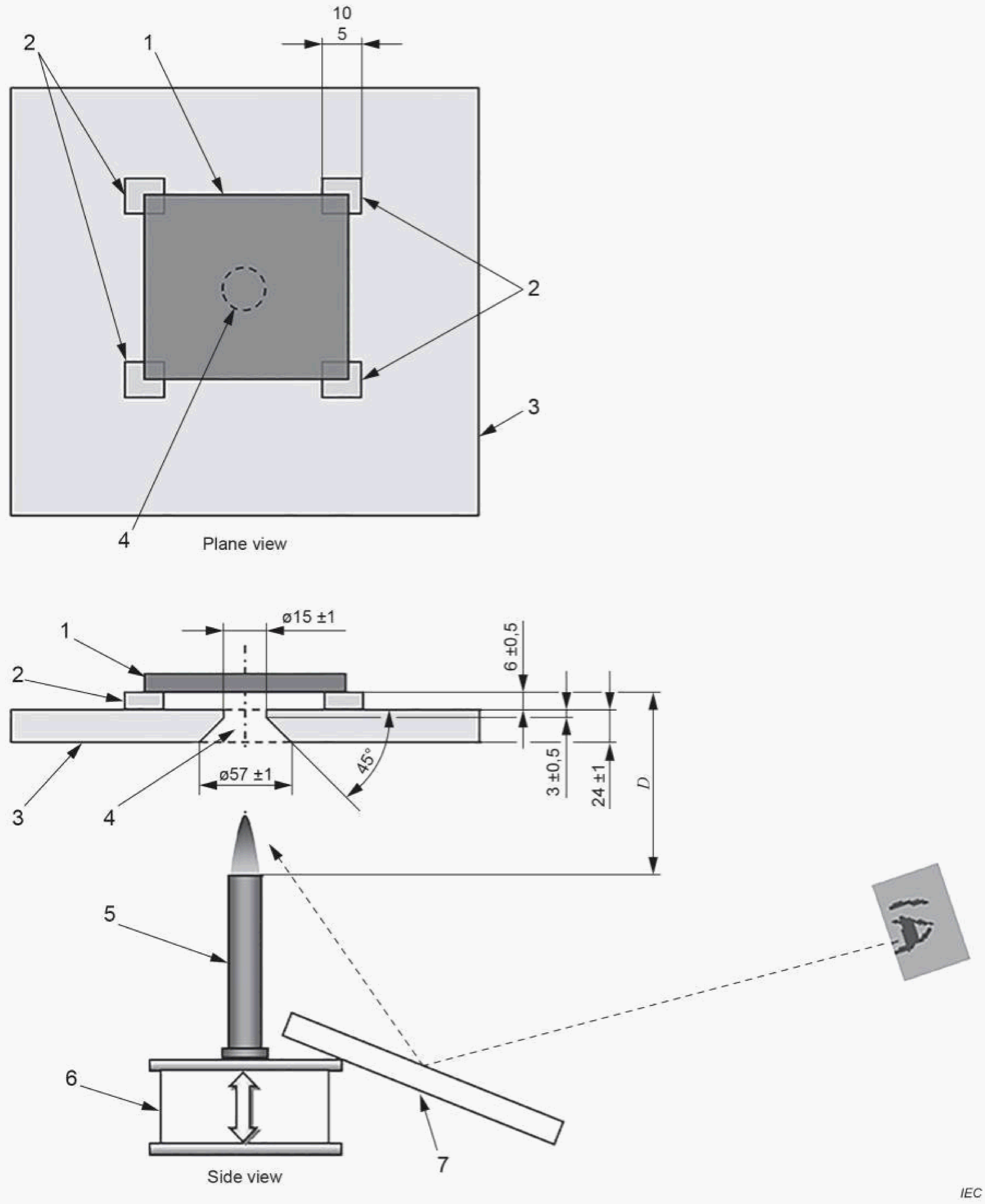
The incident heat flux, Q, is measured using the apparatus described in 5.3 and 5.4. The incident heat flux is controlled by the distance, D, between the top of the burner tube and the lower surface of the test specimen and by the flow rate of fuel gas to the burner (See Annex A). The time required to ignite the test specimen is measured as a function of the incident heat flux. The tests are performed at different levels of incident heat flux until the maximum heat flux, at which the average ignition time $\bar{t}_{ig}$ is greater than 120 s, is obtained. This maximum heat flux is defined as the characteristic heat flux for ignition (CHFI). The incident heat flux values at which the tests are carried out are chosen within the range of 30 kW/m^2 to 75 kW/m^2 and shall be integral multiples of 5 kW/m^2.

5 Apparatus

5.1 Test arrangement

The arrangement of the apparatus and the position of the test specimen and burner are shown in Figure 1. The test specimen and masking board shall be mounted horizontally. The burner tube shall be mounted vertically. The centre of the test specimen, the burner tube, the sensor of the heat flux meter and the conical hole in the masking board shall all be aligned vertically. The sensor of the heat flux meter shall be placed horizontally 6 mm above the upper surface of the masking board with its sensing surface facing down, i.e. the sensing surface of the heat flux meter is placed in the horizontal plane where the lower surface of the test specimen is placed.

Dimensions in millimetres



Key

1 Test specimen

2 Test specimen support

3 Masking board

4 Conical hole (diameter at the top side 15 mm)

5 Burner tube and test flame (inner diameter 9,5 mm)

6 Burner support (adjustable vertically)

7 Mirror

D Distance between the top of the burner tube and the lower surface of the test specimen

Figure 1 – Arrangement and position of test specimen and burner

5.2 Burner and test flame

The burner shall conform to IEC 60695-11-4. The flame size and the gas flow rate will differ from that specified in IEC 60695-11-4 in order to obtain the heat flux necessary for the test. The test flame used for each test shall be kept unchanged throughout the test. The fuel gas shall be methane gas having a purity of 98 % or greater.

5.3 Heat flux meter

The heat flux meter shall be of a water-cooled thermopile type (see ISO/TS 14934-4) which determines the incident heat flux, Q, applied to the test specimen.

When incident heat flux measurements are made, the heat flux meter shall be placed in the centre of a heat flux meter mounting board, and the heat flux meter shall not have any optical filter in-line with the sensor.

NOTE 1 The incident heat flux measurement is of critical importance to the test results. ISO 14934-3 [5] provides the calibration method for the heat flux meter.

NOTE 2 A heat flux meter of Schmidt-Boelter type with a thermopile, which has a measurement range of up to 100 kW/m^2 and a target diameter of approximately 12,5 mm, has been found to be suitable for the purpose of this international standard.

5.4 Data acquisition system

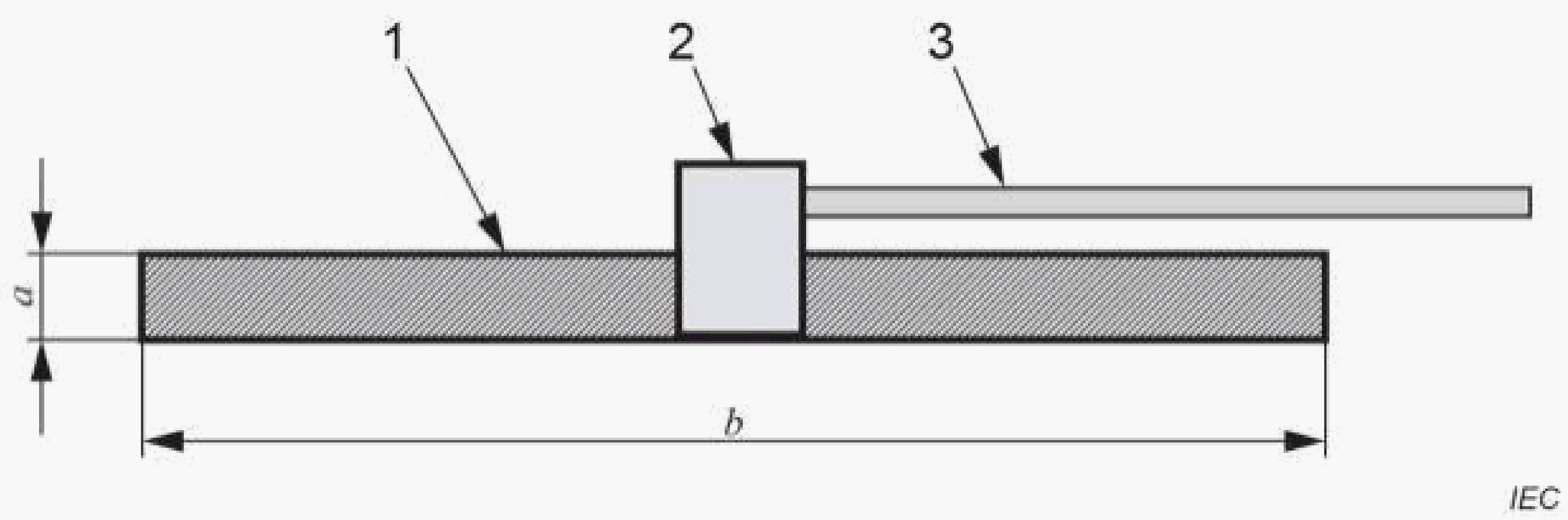
The voltmeter for measuring the output of the heat flux meter shall have a resolution of 0,01 % or better for the maximum output range.

NOTE The usual output level of the heat flux meter is several tens of millivolts.

5.5 Heat flux meter mounting board

The heat flux meter mounting board shall be approximately 75 mm × 75 mm × 12 mm with a centrally located hole whose diameter is slightly larger than the outside diameter of the heat flux meter. The board shall be made from a heat-resistant non-combustible rigid board. The heat flux meter mounting board is used, together with the heat flux meter (see Figure 2), for the determination of incident heat flux, Q (see 8.1).

NOTE A calcium silicate board of approximately 12 mm thickness having a dry density of approximately (850 ± 50) kg/m^3 has been found suitable for the heat flux meter mounting board.



Key

1 Heat flux meter mounting board

2 Heat flux meter

3 Cooling water pipe

a Approximately 12 mm

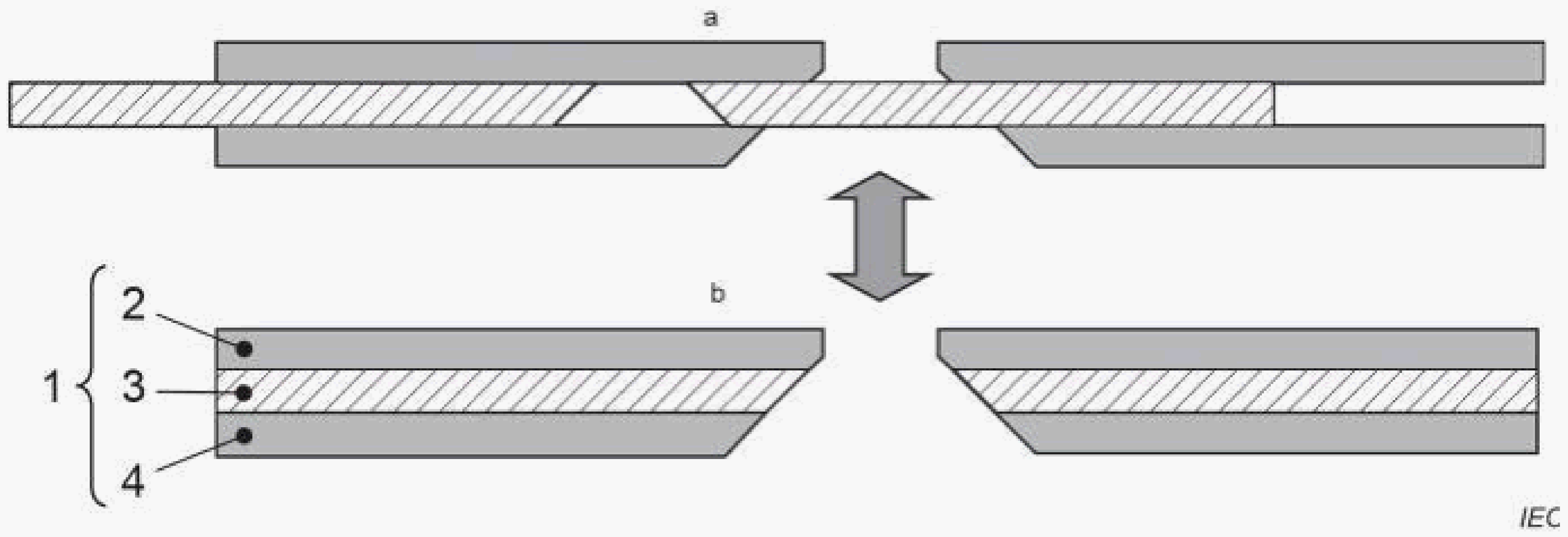
b Approximately 75 mm

Figure 2 – Heat flux meter mounting board

5.6 Masking board

The masking board shall consist of three heat-resistant non-combustible rigid boards, each having a dry density of (850 ± 50) kg/m^3 and a thickness of (8 ± 0,5) mm. The total thickness of the three non-combustible boards shall be (24 ± 1,5) mm. One board is inserted between the upper and lower boards and shall be made moveable. This moveable board works as a radiant heat shield which protects the test specimen from the heat source before the commencement of the test. There shall be a conically shaped opening at the centre of the masking board. The diameter of the opening on the upper surface shall be (15 ± 1) mm and (57 ± 1) mm on the lower surface. An illustration of the masking board and its operation is shown in Figure 3.

NOTE A calcium silicate board of the required density has a thermal conductivity of 0,14 $W \cdot m^{-1} \cdot K^{-1}$ at 200 °C, 0,15 $W \cdot m^{-1} \cdot K^{-1}$ at 400 °C, and 0,17 $W \cdot m^{-1} \cdot K^{-1}$ at 600 °C.



Key

1 Masking board

2 Upper board

3 Moveable board (Radiant heat shield)

4 Lower board

a Position of the moveable masking board prior to a test

b Position of the moveable masking board during a test

Figure 3 – Structure of the masking board

5.7 Timing device

The timing device shall have a resolution of 0,5 s or better.

5.8 Conditioning chamber

The conditioning chamber shall have a capability of maintaining the temperature at (23 ± 2) ºC, and the relative humidity within (50 ± 10) % (see ISO 291).

5.9 Test specimen support

The test specimen support shall maintain a distance of (6 ± 0,5) mm between the lower surface of the test specimen and the upper surface of the masking board.

5.10 Burner support

The burner shall be located on a support which can adjust the position of the burner in the vertical direction. The distance, D, between the top of the burner tube and the lower surface of the test specimen shall be determined using a suitable measuring device which has a resolution of 1 mm or better.

5.11 Observation mirror

To observe the ignition behaviour of the test specimen, an observation mirror approximately 100 mm × 100 mm shall be positioned underneath the masking board (See Figure 1).

5.12 Flow controller

The fuel gas flow controller shall have a control range of between 100 ml/min and 200 ml/min, and have a resolution of 5 ml/min or better.

5.13 Heat flux meter supporting device

In order to correctly place the heat flux meter at the measurement position, the heat flux meter supporting device as shown in Figure 4 shall be used.

Dimensions in millimetres

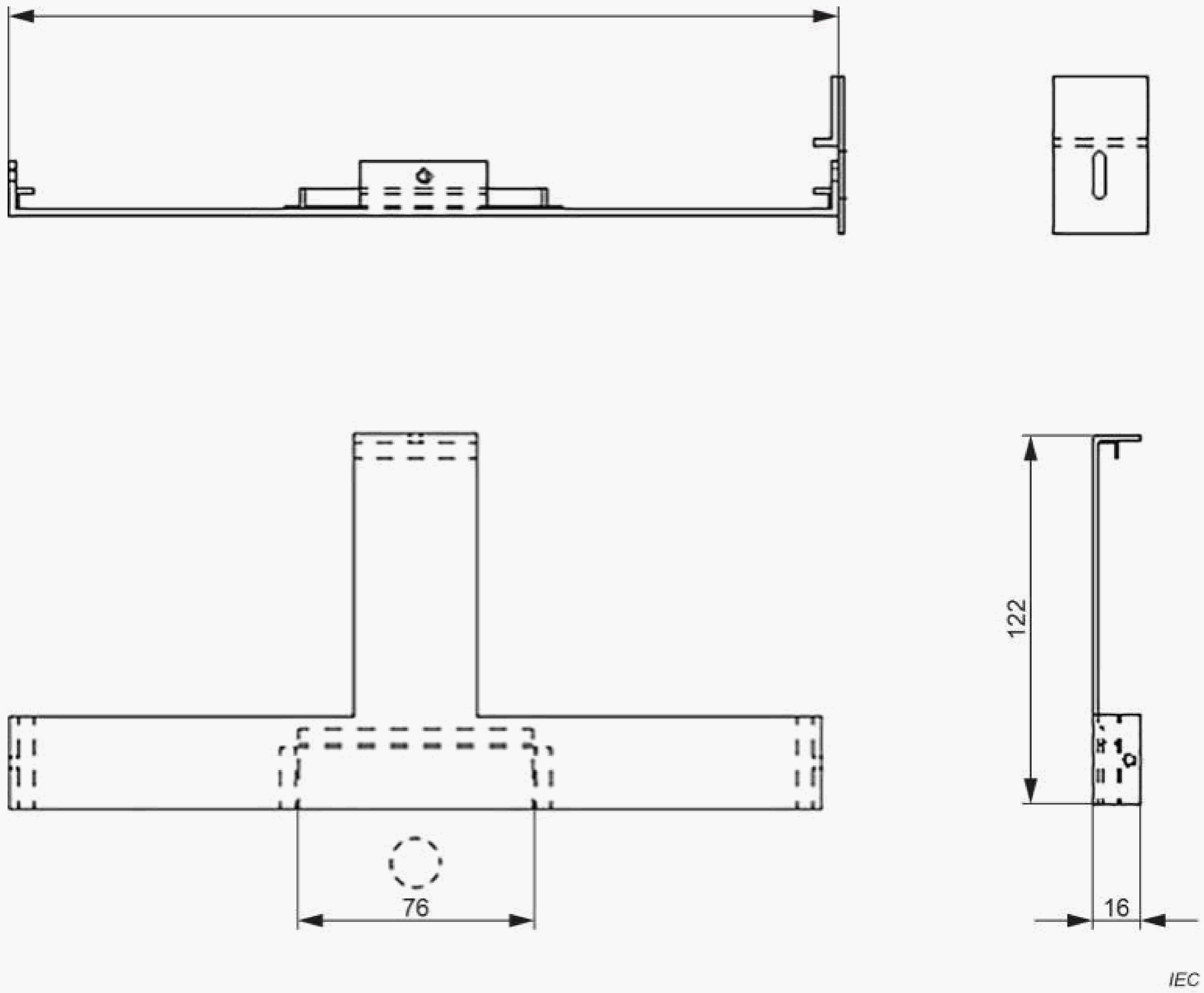


Figure 4 – Heat flux meter supporting device

6 Test specimen

6.1 Dimensions of test specimen

The test specimen shall be a flat plate. Each test specimen shall be at least (77,5 ± 2,5) mm in length and width and at the thickness under consideration. The preferred thicknesses for the presentation of comparative data include (0,4 ± 0,05) mm, (0,75 ± 0,1) mm, (1,5 ± 0,1) mm, (3,0 ± 0,2) mm and (6,0 ± 0,4) mm.

6.2 Testing ranges in formulations

6.2.1 General

The results of tests carried out on test specimen sets of different colour, thickness, density, molecular mass, anisotropic type/direction, additives, fillers, and/or reinforcements can vary.

6.2.2 Density, melt flows and filler/reinforcement

Test specimens covering all combinations of minimum and maximum levels of density, melt flows and filler/reinforcement content may be provided and considered representative of the range if the test results yield the same CHFI. If the test results do not yield the same CHFI for all test specimens representing the range, evaluation shall be limited to the materials with the specific levels of density, melt flows and filler/reinforcement tested. In addition, test specimens with intermediate density, melt flows, and filler/reinforcement content shall be tested to determine the representative range for each CHFI determination. However, as an alternative, the least favorable performance of the specific levels of density, melt flows and filler/reinforcement tested may be considered representative of intermediate levels without additional testing.

6.2.3 Colour

When evaluating a range of colours, uncoloured test specimens and test specimens with the highest level of organic and inorganic pigment loading by weight are considered representative of the colour range if the test results yield the same CHFI. When certain pigments are known to affect flammability characteristics, the test specimens containing those pigments shall also be tested. Test specimens which shall be tested are those that

a) contain no colouring,

b) contain the highest level of organic pigments,

c) contain the highest level of inorganic pigments,

d) contain pigments which are known to adversely affect flammability characteristics.

6.3 Conditioning of test specimens

Unless otherwise specified in the relevant specification, the test specimen shall be conditioned for a minimum of 24 h at (23 ± 2) °C and at a relative humidity of (50 ± 10) %. Once removed from the conditioning chamber, the test specimens shall be tested within 1 h.

7 Testing conditions

All test specimens shall be tested in a laboratory atmosphere in a draught free environment at a temperature of between 15 °C and 35 °C and at a relative humidity of 75 % or less.

8 Test procedure

8.1 Determination of incident heat flux calibration curve

The incident heat flux, Q, which will be received by the surface of the test specimen, shall be determined in terms of the distance, D, between the top of the burner and the lower surface of the test specimen and the flow rate of the fuel gas supplied to the burner. For this purpose, an incident heat flux calibration curve shall be determined by the following procedures.

a) Install the heat flux meter into a heat flux meter mounting board as shown in Figure 2.

b) Place the heat flux meter, which is placed in the centre of the heat flux meter mounting board, in the test specimen position. The detailed method of placing the heat flux meter is described in Annex D.

c) Place the burner (see 5.2) in position.

d) Measure the distance, d, between the top of the burner tube and the lower surface of the masking board. The distance, D, between the top of the burner tube and the sensing surface of the heat flux meter is determined by

$$D = d + 6 + \text{thickness of the masking board in millimeter.}$$

e) Place the radiation heat shield in the shielding position (see Figure 3, position a).

f) Turn on the fuel gas supply to the burner and ignite the gas. Adjust the flow rate.

NOTE For heat fluxes in the range 30 kW/m ^{2} to 60 kW/m ^{2}, a fuel gas flow of 105 cm ^{3}/min has been found to be suitable. For heat fluxes in the range 55 kW/m ^{2} to 75 kW/m ^{2}, a fuel gas flow of 160 cm ^{3}/min has been found to be suitable.

g) Wait for a period of at least 5 min to allow the burner to reach the equilibrium condition.

h) The radiant heat shield shall then be removed (see Figure 3, position b), and the output of the heat flux meter shall be recorded for 2 min.

i) Perform this measurement at several different distances (D) between the sensing surface of the heat flux meter and the top of the burner tube, so as to obtain a relationship of the incident heat flux in the range of 30 kW/m ^{2} to 75 kW/m ^{2} and the distance, D, between the sensing surface of the heat flux meter and the top of the burner.

j) Plot a calibration curve of incident heat flux, Q, as a function of the distance, D, and obtain, by interpolation, the distances which correspond to the heat fluxes of 30 kW/m ^{2}, 35 kW/m ^{2}, 40 kW/m ^{2}, 45 kW/m ^{2}, 50 kW/m ^{2}, 55 kW/m ^{2}, 60 kW/m ^{2}, 65 kW/m ^{2}, 70 kW/m ^{2}, and 75 kW/m ^{2} (see Annex A).

The temperature of cooling water for the heat flux meter shall be maintained above the ambient temperature in order to avoid water condensation on the sensing surface (see ISO/TS 14934-4).

8.2 Determination of ignition time

The test shall be conducted under a selected incident heat flux value, in terms of the distance, D, between the top of the burner and the lower surface of the test specimen and the gas flow rate to the burner, obtained in accordance with 8.1.

For the purposes of this test method, ignition is defined in 3.5.

a) Adjust the distance between the top of the burner and the lower surface of the test specimen and adjust the gas flow rate to the burner in order to obtain the selected incident heat flux value.

b) Ignite the burner and control the fuel gas flow rate. Wait for a period of at least 5 min to allow the burner conditions to reach equilibrium.

c) Place the radiation heat shield in the closed position (see Figure 3, position a).

d) Place the test specimen in the test specimen position (see Figure 1).

e) Pull aside the radiant heat shield to the open position (see Figure 3, position b) and simultaneously start the timing device.

f) Observe the test specimen and note if phenomena such as deformation, cracking and melting occur.

g) If the test specimen ignites within 120 s, observe the flaming combustion for at least 5 s, record the time to ignition (t_{ig}) and return the radiation shield to the closed position (see Figure 3, position a). The test can be stopped if sustained and continuous combustion has been observed for at least 5 s.

h) If the test specimen does not ignite within 120 s, record the failure to ignite, and return the radiation shield to the closed position (see Figure 3, position a).

i) Repeat d) to h) above two more times with a new test specimen each time and under the same test conditions.

j) Calculate and record $\bar{t}_{ig}$, the arithmetic mean of the three ignition times.

If a dripping occurs before igniting, the test is invalid. This is because drips will affect the burner and change the nature of the flame.

8.3 Repetition of the test at different heat flux values

The incident heat flux shall be chosen within the range from 30 kW/m^2 to 75 kW/m^2 and shall be an integral multiple of 5 kW/m^2.

The tests shall be carried out until the highest incident heat flux value at which $\bar{t}_{ig}$ is greater than 120 s is determined.

NOTE It might be efficient to start the test at a incident heat flux which is in the middle of the range from 30 kW/m^2 to 75 kW/m^2, for example 50 kW/m^2.

9 Evaluation of test results

9.1 Average ignition time $\bar{t}_{ig}$

Calculate the average ignition time $\bar{t}_{ig}$ for each incident heat flux value used in the tests. When ignition and non-ignition occurs in the three tests, the average shall not be calculated. When all three specimens do not ignite for 120 s, record "$\bar{t}_{ig}$ is greater than 120 s".

9.2 Report format for CHFI

The CHFI shall be reported in the following manner.

When three test specimens of thickness *X* mm do not ignite after 120 s exposure, and the heat flux *H* is the maximum integral multiple of 5 kW/m^2 at which this occurs, then this incident heat flux shall be determined as the CHFI, and reported in the following format:

CHFI: *H* kW/m^2 / *X* mm

for example, for a test specimen of 3,0 mm thickness and the maximum heat flux, at which $\bar{t}_{ig}$ is greater than 120 s, is 50 kW/m^2:

CHFI: 50 kW/m^2 / 3,0 mm

If the three test specimens do not ignite at the heat flux value of 75 kW/m^2, CHFI shall be reported as:

CHFI: >75 kW/m^2 / thickness

If $\bar{t}_{ig}$ is less than 120 s at 30 kW/m^2, the CHFI shall be reported as:

CHFI: <30 kW/m^2 / thickness

Examples for supporting tools for the purpose of calculations and reporting can be found in Annex B (Figure B.1, Figure B.2 and Figure B.3, and Table B.1).

9.3 Analysis on CHFI (optional)

The inverse of the measured ignition time 1/ t_{ig} can be plotted against the incident heat flux, Q, as shown in Clause C.4. By linearly regressing the data on which 1/ t_{ig} is plotted against incident heat flux at which t_{ig} is obtained, it is possible to predict the ignition time in any incident heat flux. It is also possible to predict the maximum incident heat flux at which the sample does not ignite, by obtaining the incident heat flux where 1/ t_{ig} = 0 (infinite ignition time).

10 Precision data

Precision data for this test method were collected in a preliminary inter-laboratory trial. The results of these tests are summarised in Annex C (including in Table C.1 and Figure C.1, Figure C.2, Figure C.3, Figure C.4, Figure C.5 and Figure C.6).

11 Test report

The test report shall include the following information:

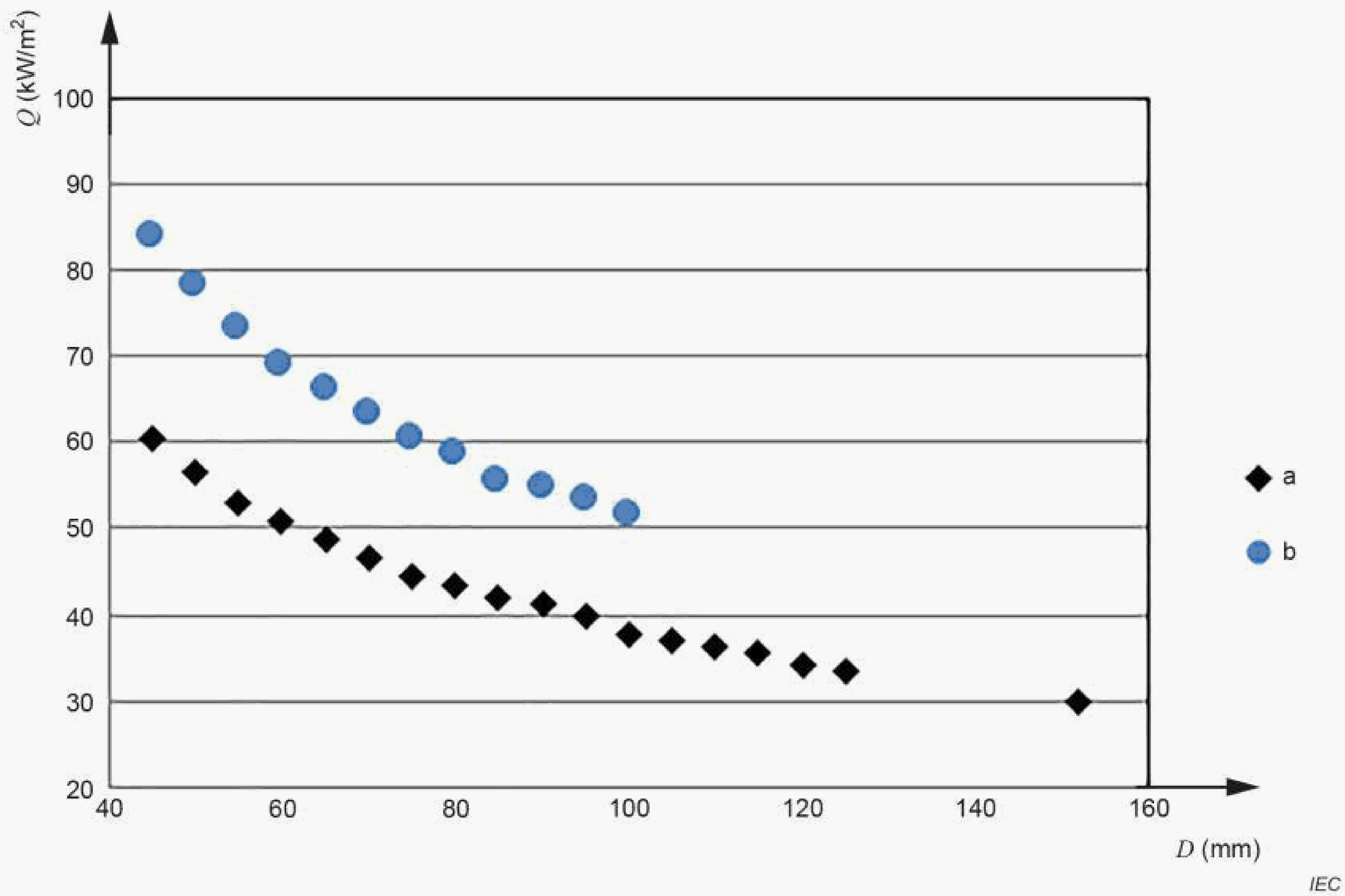
a) a reference to this international standard;
b) the type, description and dimensions of the test specimen (see Clause 6)
c) the method of preparation of the test specimen (see Clause 6);
d) conditioning, if any, of the test specimens (see 6.3);
e) phenomena, if any, other than ignition such as deformation, cracking and melting (see 8.2 f));
f) for each incident heat flux value note the $\bar{t}_{ig}$ values (see Clause 9); and
g) the CHFI value according to 9.2.

Annex A
(informative)

An example of the calibration curve of incident heat flux, *Q*, versus the distance, *D*, between the top of the burner tube and the lower surface of the test specimen

A.1 Calibration curve

An example of a calibration curve of incident heat flux, *Q*, versus the distance, *D*, between the top of the burner tube and the lower surface of the test specimen is given in Figure A.1, and the calibration data used to plot this curve are given in Table A.1 and Table A.2.



Key

a Calibration curve at gas flow rate 105 cm3/min

b Calibration curve at gas flow rate 160 cm3/min

D distance between the top of the burner and the lower surface of the test specimen

Q incident heat flux

Figure A.1 – Calibration curve (example)

Table A.1 – Calibration data (examples of actual measured data as shown in Figure A.1)

D / mm	Q / (kW/m^2)	
	Gas flow rate = 105 cm^3/min	Gas flow rate = 160 cm^3/min
152,0	29,90	-
125,0	33,47	-
120,0	34,17	-
115,0	35,56	-
110,0	36,26	-
105,0	36,96	-
100,0	37,65	51,52
95,0	39,75	53,21
90,0	41,14	54,79
85,0	41,83	55,58
80,0	43,23	58,66
75,0	44,62	60,44
70,0	46,72	63,32
65,0	48,81	66,19
60,0	50,90	69,19
55,0	52,99	73,42
50,0	56,48	78,18
45,0	60,67	83,93

The temperature of cooling water was 40 °C.

Each measurement of heat flux was continued for 5 min.

Table A.2 – Calibration data (examples of interpolated values)

Q / (kW/m^2)	D / mm	
	Gas flow rate = 105 cm^3/min	Gas flow rate = 160 cm^3/min
30	150,0	-
35	117,1	-
40	92,7	-
45	75,0	-
50	62,7	103,4
55	54,1	89,3
60	47,5	77,2
65	-	67,0
70	-	58,8
75	-	52,5

The temperature of cooling water was 40 °C.

Each measurement of heat flux was continued for 5 min.

NOTE The interpolated values in Table A.2 were calculated from a least-squares regression analysis of the data in Table A.1.

Annex B
(informative)

Examples of ignition times with various materials of 3 mm thickness

B.1 Materials – Examples of measurements

Materials tested:

- PMMA – polymethyl methacrylate
- ABS – acrylonitrile-butadiene-styrene copolymer
- HIPS – high impact polystyrene

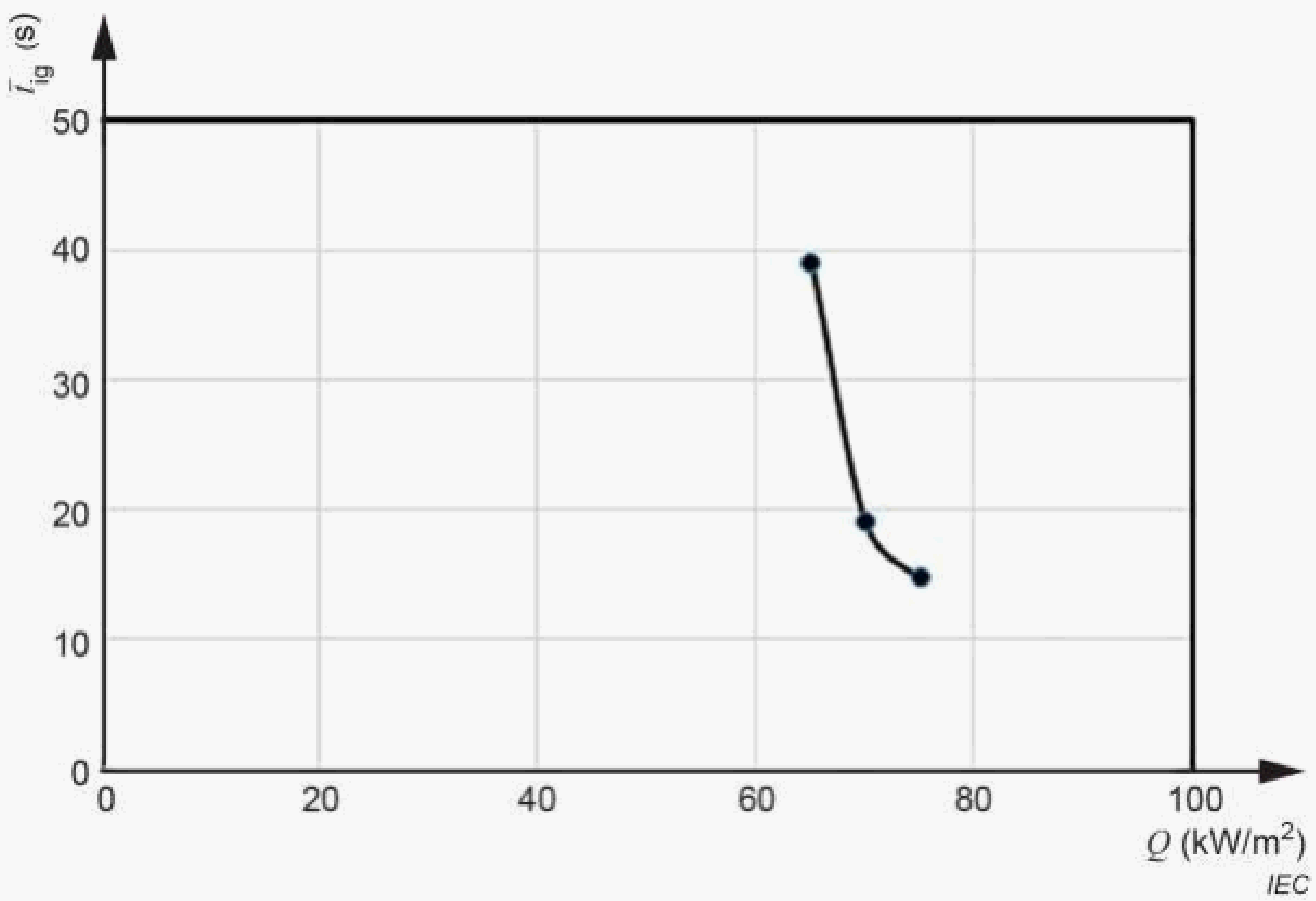
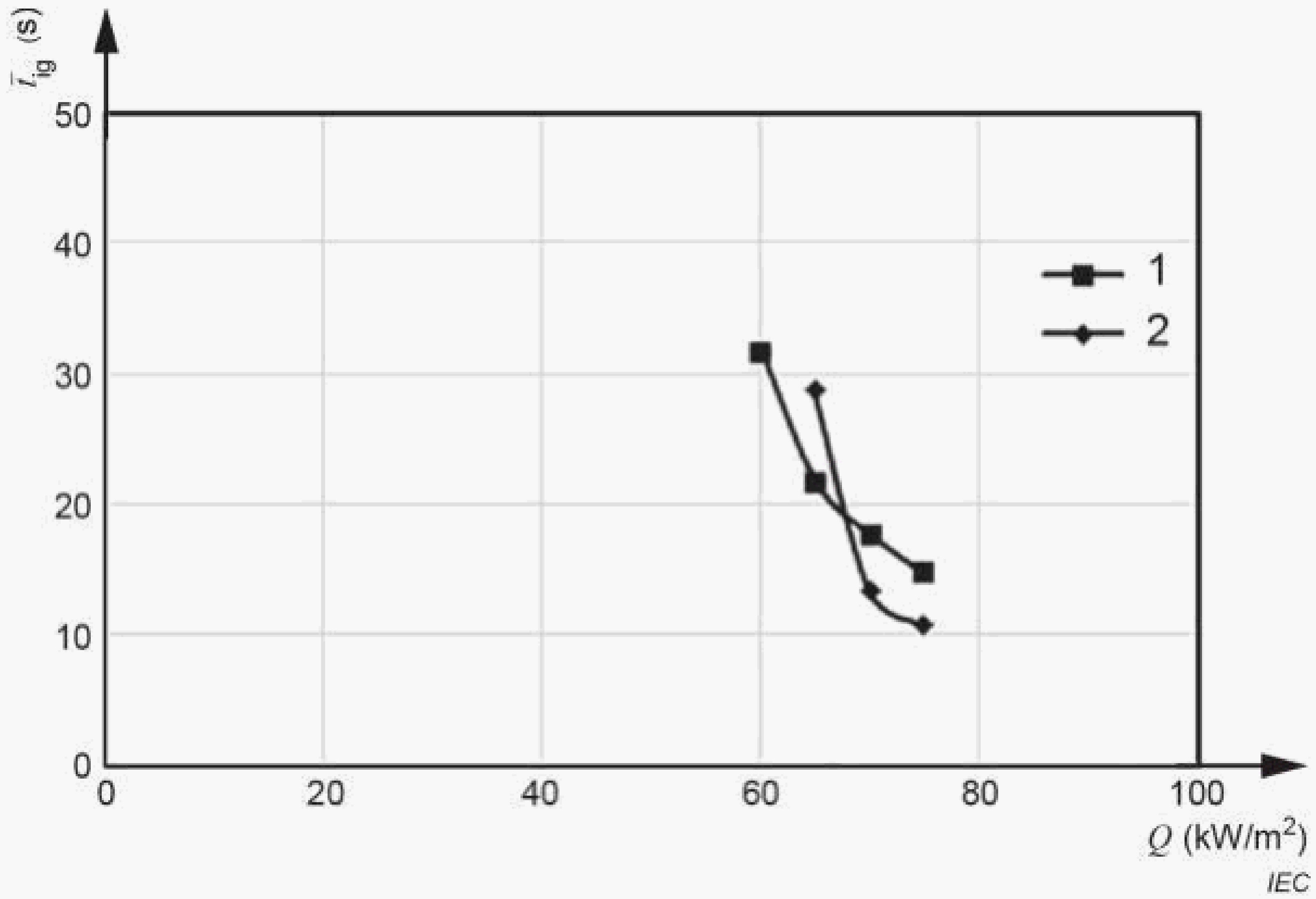


Figure B.1 – Example of ignition times of PMMA

Table B.1 – Value of Figure B.1

Q / (kW/m^2)	$\bar{t}_{ig}$ / s
75	14,6
70	19,0
65	39,0
60	-



Key

1 ABS 1

2 ABS 2

Figure B.2 – Ignition times for ABS (example)

Table B.2 – Value of Figure B.2

Q / (kW/m 2)	$\bar{t}ig$ / s	
	ABS 1	ABS 2
75	14,6	10,6
70	17,7	13,3
65	21,7	28,6
60	31,6	-
55	-	

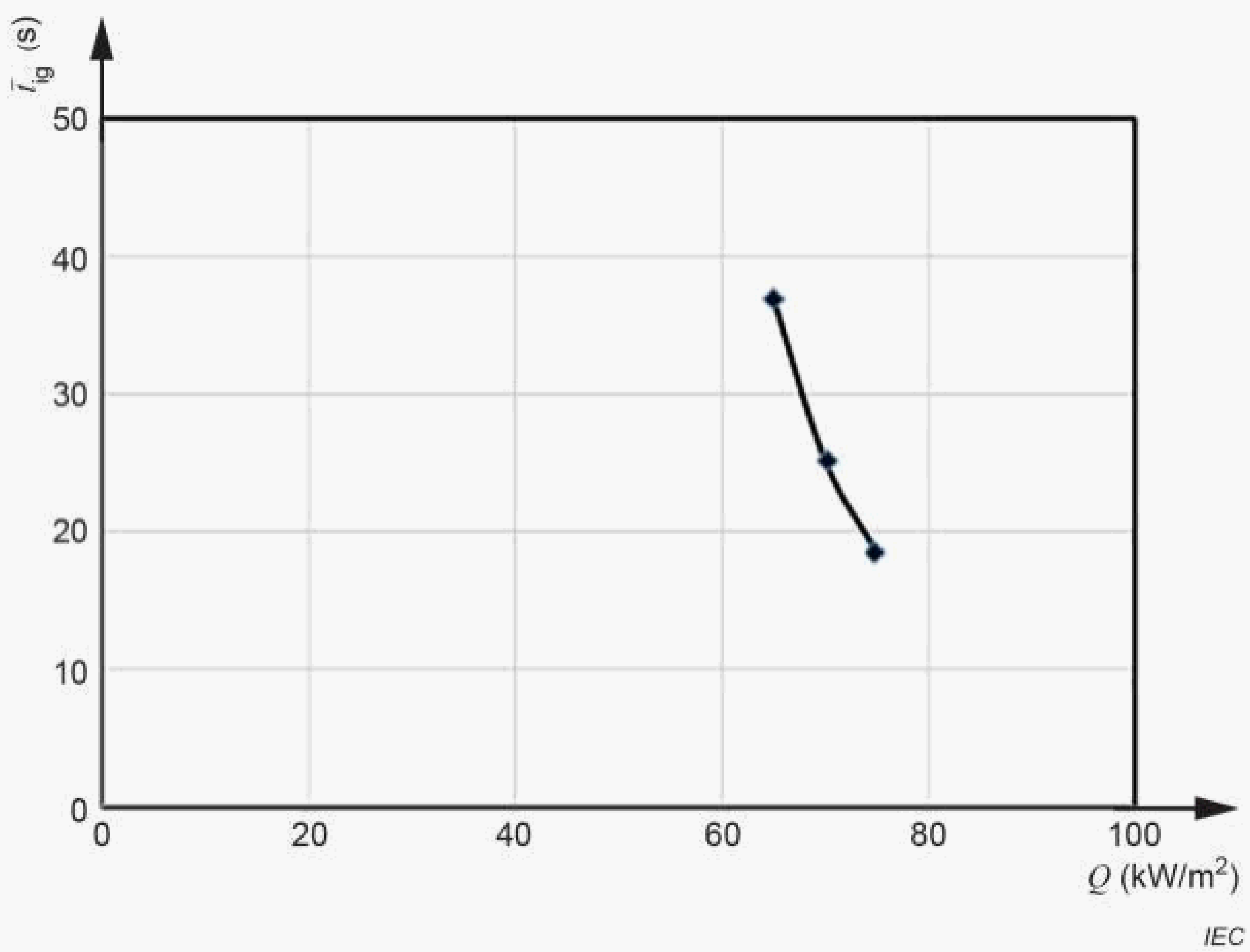


Figure B.3 – Ignition times for HIPS (example)

Table B.3 – Value of Figure B.3

Q / (kW/m^2)	$\bar{t}_{ig}$ / s
75	18,5
70	25,1
65	36,9
60	-

NOTE The temperature of the cooling water used was 40 °C. Measurement of each heat flux was continued for 5 min. The gas flow rate used to obtain each heat flux was 160 cm^3/min.

An example of individual test results is shown in Table B.4.

Table B.4 – Description example of tabulated test results

Q / (kW/m^2)	t_{ig} / s	$\bar{t}_{ig}$ / s
70	26, 24, 22	24
65	44, 50, 56	50
60	N, N, 116	X
55	N, N, N	N
CHFI = 55 kW/m^2		
N = no ignition within 120 s X = Inconclusive test results.		

Annex C
(informative)

Precision data

C.1 General

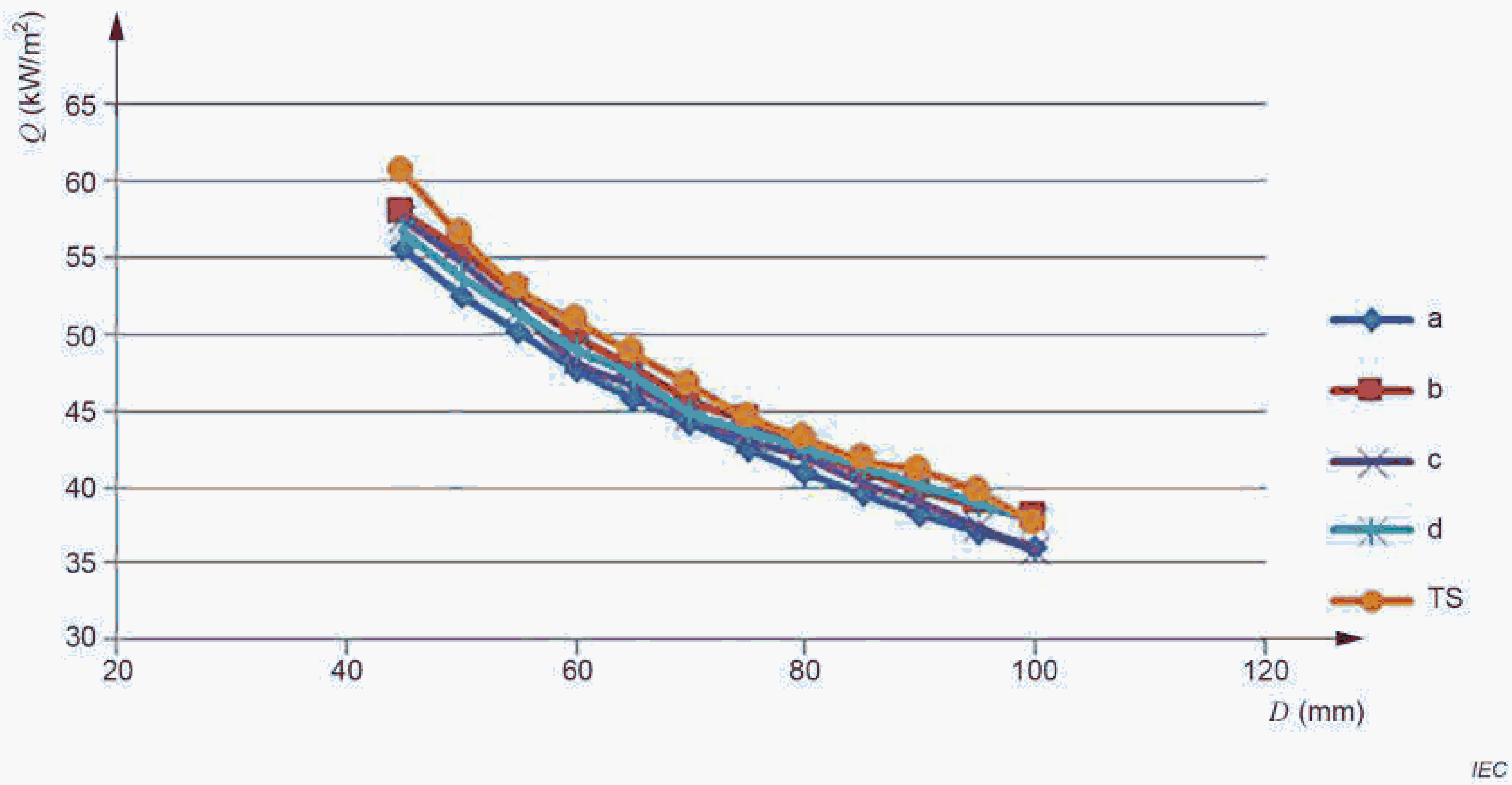
A preliminary inter-laboratory trial has been carried out in which replicate batches of four materials (referred to below as material A, material B, material C and material D) were tested at four laboratories in accordance with this part of IEC 60695.

Since this preliminary inter-laboratory trial did not fully satisfy the condition for international laboratory trials in ISO 5725-2 [7] due to an insufficient number of participating laboratories, repeatability and reproducibility were not obtained in accordance with ISO 5725-2.

Nevertheless, some analysis on the test data was conducted as follows.

C.2 Heat flux versus distance at different gas flow rates

The incident heat flux to the specimen in terms of distance, *D*, between the burner top and the lower surface of the specimen was measured in the participating laboratories (laboratories a, b, c and d) as shown in Figure C.1 and Figure C.2. "TS" in the figures means the value in Annex A. These figures show that relatively good agreement on the test condition of incident heat flux was obtained among participating laboratories.

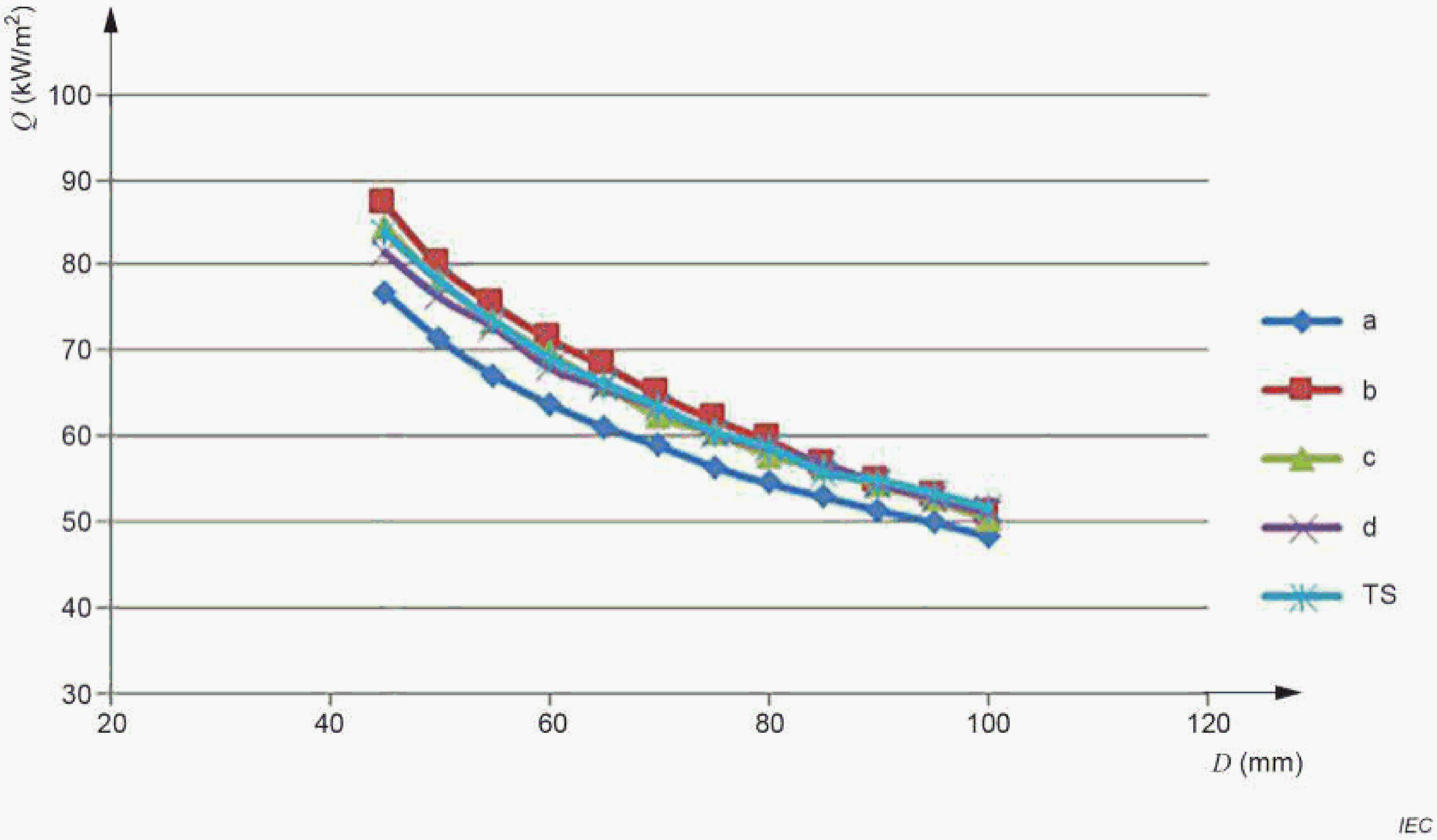


Key

a, b, c and d participating laboratories

TS calibration curve with the value in Annex A

Figure C.1 – Incident heat flux calibration curve (gas flow rate 105 cm^3/min)



Key

a, b, c and d participating laboratories

TS calibration curve with the value in Annex A

Figure C.2 – Incident heat flux calibration curve (gas flow rate 160 cm^3/min)

C.3 Repeatability

Participating laboratories conducted the tests under different conditions of incident heat flux to the specimen. Therefore, while data on repeatability of the tests within the test laboratories were obtained, reproducibility among the test laboratories could not be obtained. Table C.1 presents the repeatability data. Relatively good repeatability (as indicated by the standard deviation values) was observed.

Table C.1 – Precision data of ignition time

	Material A			Material B			Material C			Material D		
	Q / (kW/m^2)	$\bar{t}_{ig}$ / s	r / s	Q / (kW/m^2)	$\bar{t}_{ig}$ / s	r / s	Q / (kW/m^2)	$\bar{t}_{ig}$ / s	r / s	Q / (kW/m^2)	$\bar{t}_{ig}$ / s	r / s
Repeatability of Laboratory a	62.1	36.8	1.5				61.9	52.3	3.3	61.9	34.0	1.9
	68.4	26.4	0.9	67.8	16.8	1.5	67.8	30.2	0.4	67.8	28.4	0.8
	71.4	21.0	1.5	71.7	12.2	0.4	71.7	23.8	0.4	71.7	29.6	2.2
Repeatability of Laboratory b	65.0	43.3	2.3	64.2	41.2	3.6	64.2	48.4	4.8	64.2	37.8	5.4
	70.0	31.3	1.2	67.2	16.6	1.1	67.2	34.8	0.8	67.2	28.4	1.1
	-	-	-	-	-	-	-	-	-	-	-	-
Repeatability of Laboratory c	60.9	40.4	0.9	-	-	-	60.4	56.1	2.5	60.9	39.0	2.1
	67.1	27.4	1,1	65.7	27.8	2.6	66.0	33.6	0.5	67.1	32.0	1.6
	70.2	25.0	0.7	69.2	14.8	0.8	69.7	26.2	0.8	70.2	29.2	1.5
Repeatability of Laboratory d	56.4	49.6	5.3	-	-	-	-	-	-	-	-	-
	61.1	33.4	1.5	-	-	-	-	-	-	-	-	-
	63.8	26.2	0.8	-	-	-	-	-	-	-	-	-

Where:

Q is the incident heat flux;

$\bar{t}_{ig}$ is the average of three ignition times (See 9.1); and

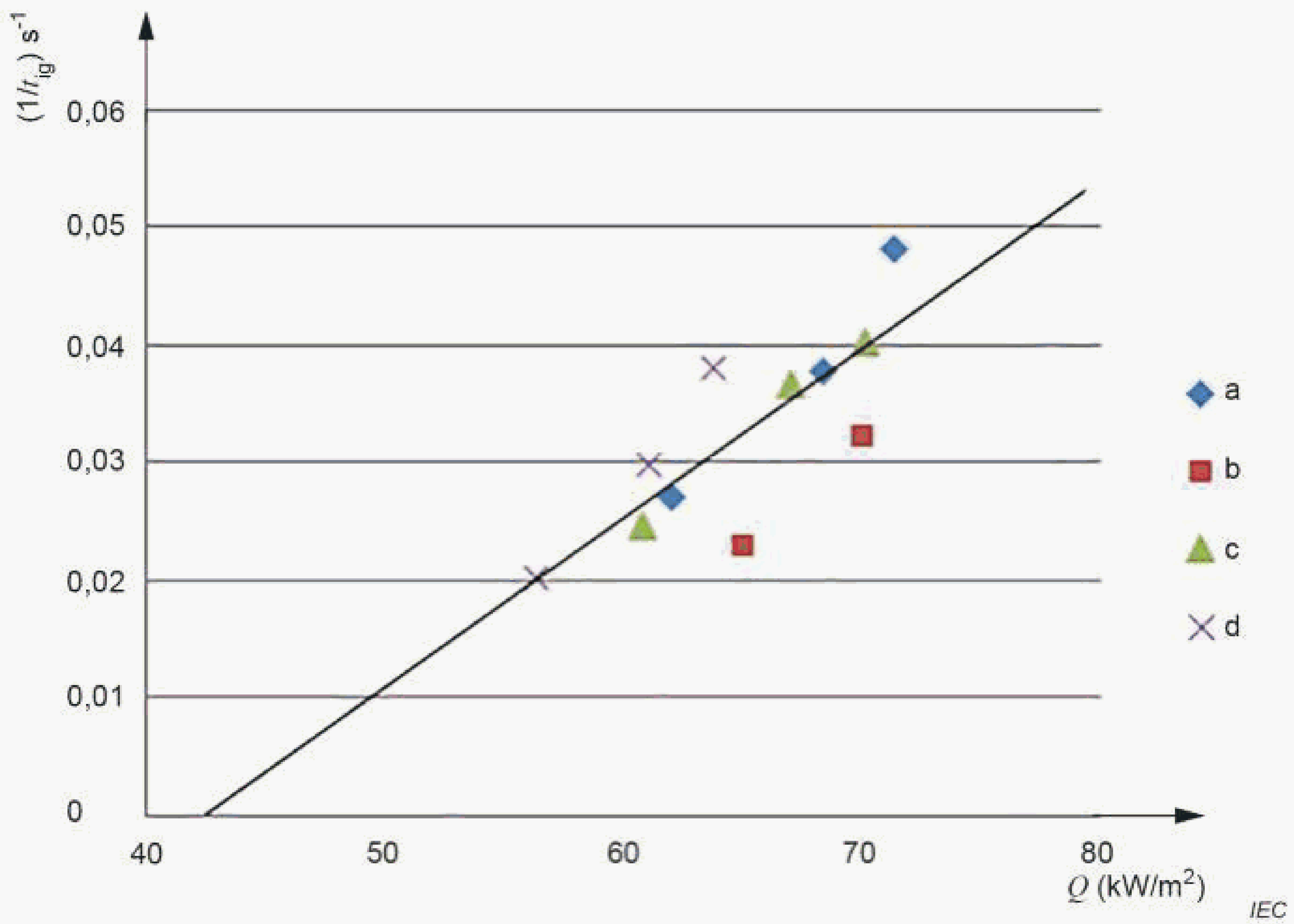
r is the repeatability limit as defined and used in ISO 5725-1[6] and 5725-2[7].

NOTE The repeatability limit, r, as defined in ISO 5725-1 and used in ISO 5725-2, is the value less than or equal to which the absolute difference between two test results obtained under repeatability conditions may be expected to be with a probability of 95 %. It is a measure of precision under the conditions where independent test results are obtained with the same method on identical test items in the same laboratory by the same operator using the same equipment within short intervals of time.

In order to obtain formal precision data in accordance with ISO 5725-2, it will be necessary to conduct a full set of inter-laboratory tests.

C.4 Calculations and plots

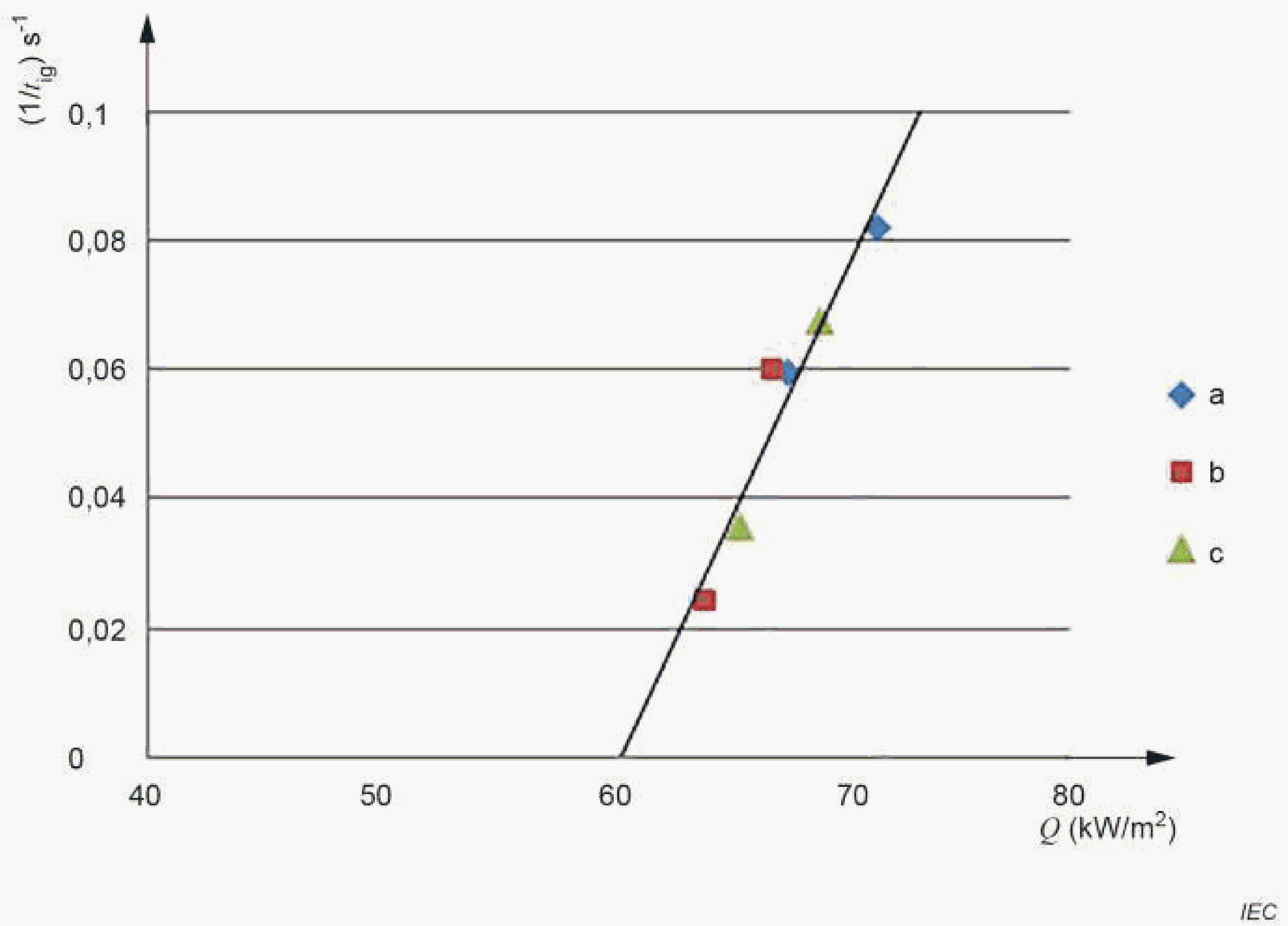
The inverse of the measured ignition time 1/ t_{ig} is plotted against the incident heat flux as shown in Figure C.1, Figure C.2, Figure C.3, Figure C.4, Figure C.5 and Figure C.6. The data of the preliminary inter-laboratory trial show that t_{ig} and 1/ t_{ig} can be obtained among laboratories in relatively good agreement and, as shown in these figures, an approximately linear relationship between 1/ t_{ig} and the incident heat flux can be obtained by this test method.



Key

a, b, c and d participating laboratories

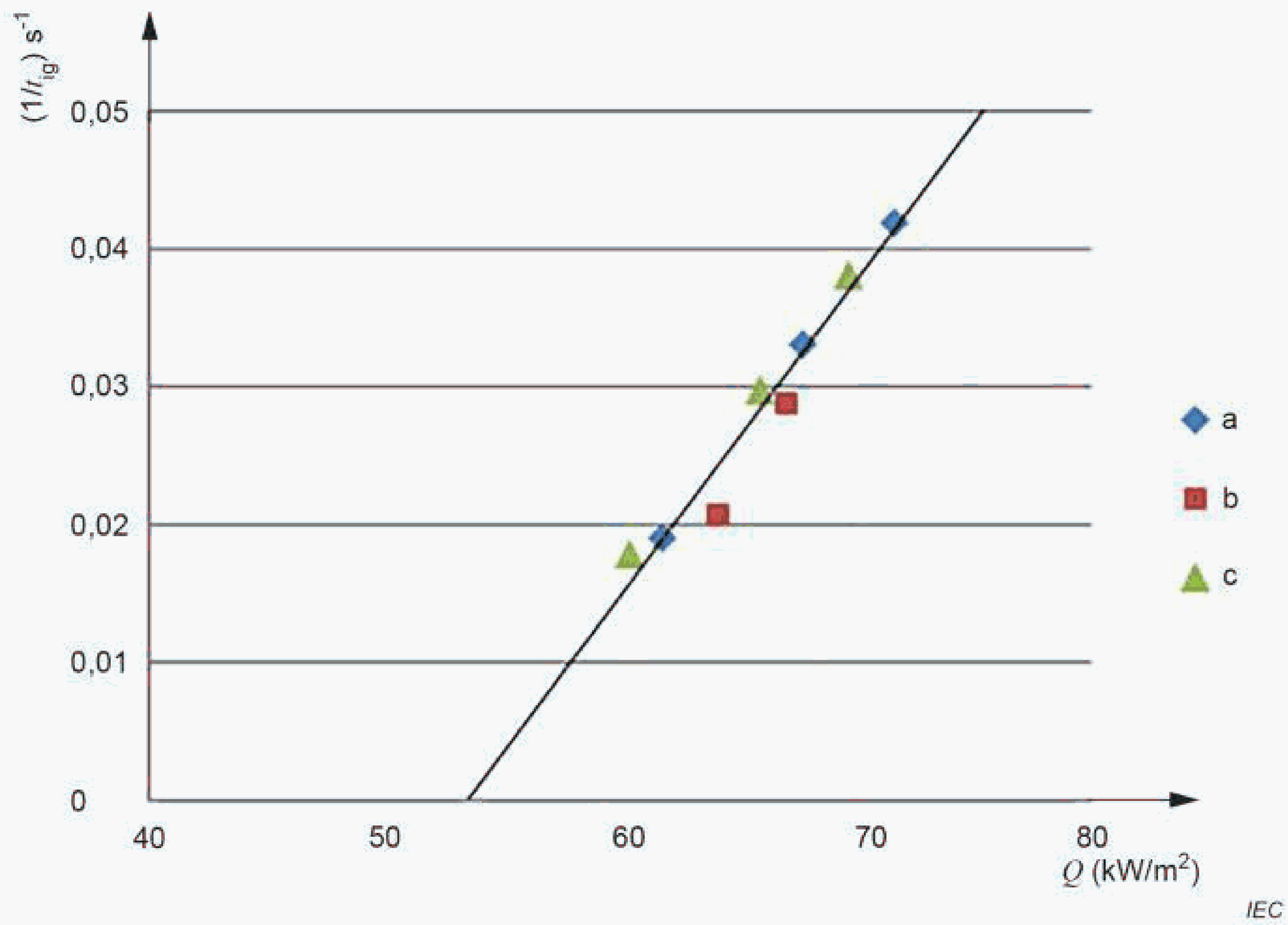
Figure C.3 – Plot of 1/ t_{ig} for material A



Key

a, b and c participating laboratories

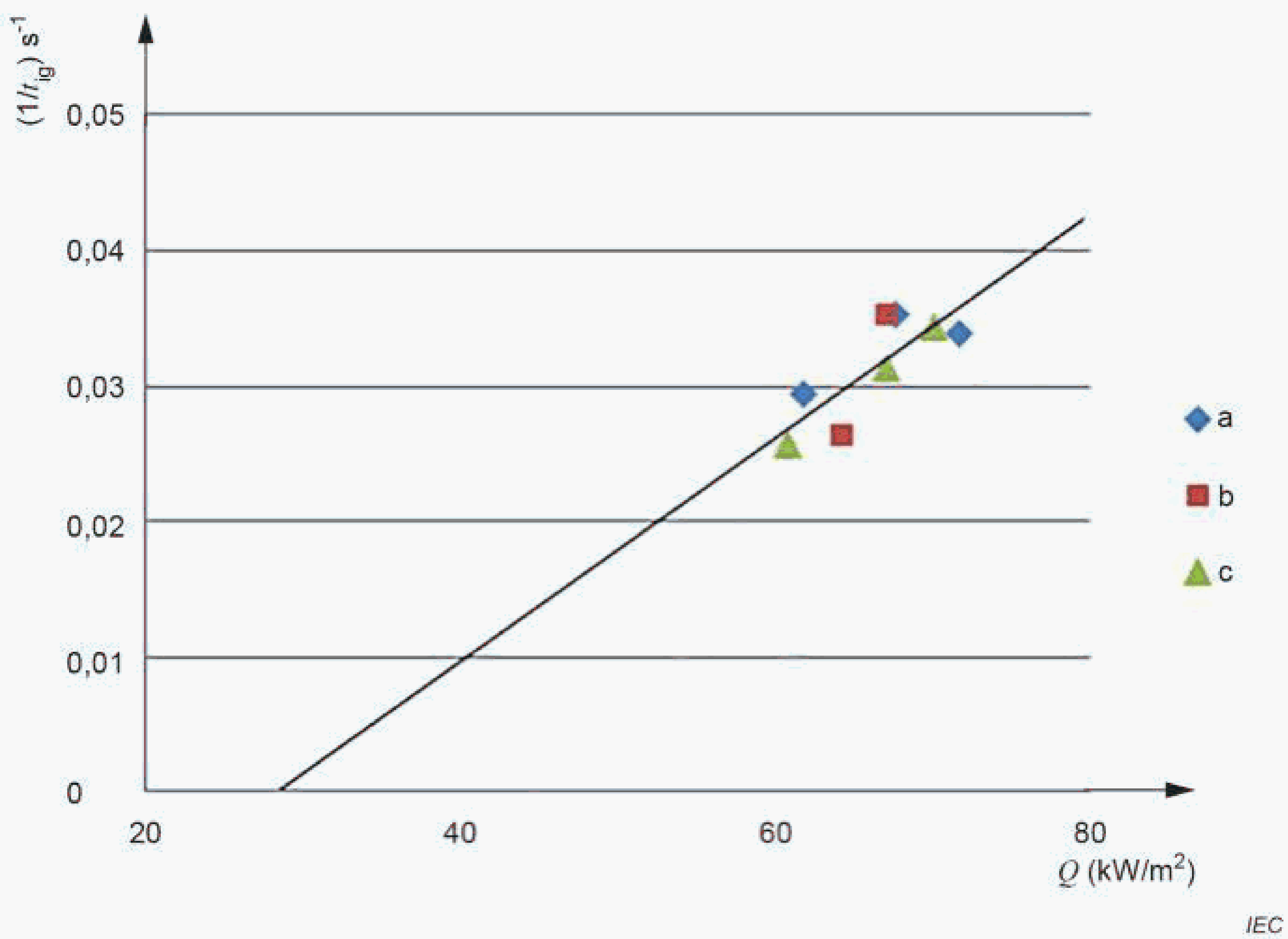
Figure C.4 – Plot of 1/ t_{ig} for material B



Key

a, b and c participating laboratories

Figure C.5 – Plot of 1/ t_{ig} for material C



Key

a, b and c participating laboratories

Figure C.6 – Plot of 1/ t_{ig} for material D

Annex D
(informative)

Method of positioning the heat flux meter

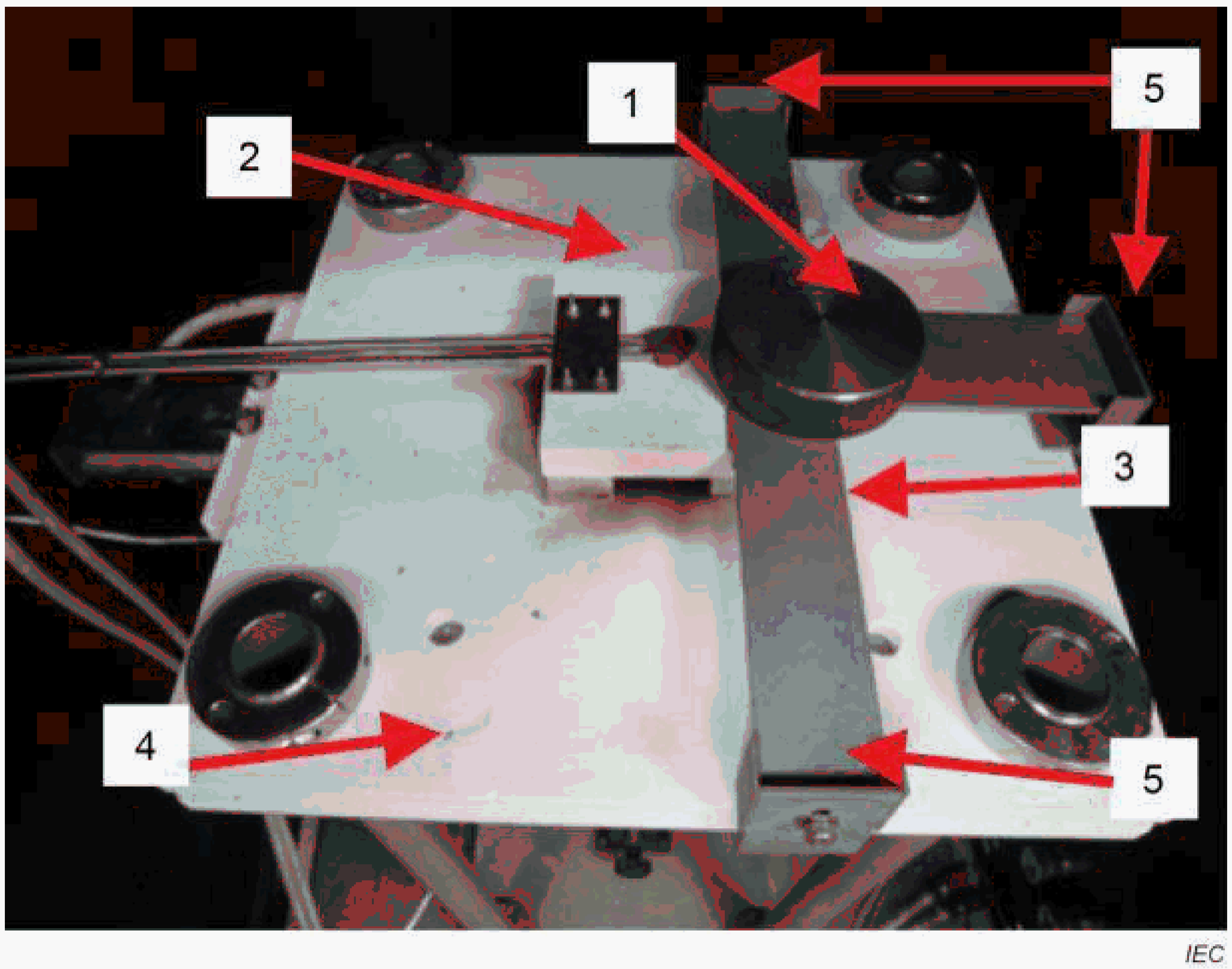
D.1 General

The heat flux meter has pipe connections for supplying the cooling water as well as a lead line for mV output. This means that a supporting device (see 5.13 and Figure 4) is required to position the heat flux meter in the defined position and to keep it in that position during the heat flux measurement.

D.2 Positioning the heat flux meter

Place the heat flux meter mounting board with the heat flux meter on the masking boards above the specimen exposure hole using the heat flux meter supporting device as shown in Figure D.1. The three ends of the heat flux meter supporting device shall touch the corresponding edge of the top plate of the masking board. This ensures that the heat flux meter is positioned correctly above the specimen exposure hole.

To check that the sensing surface of the heat flux meter is correctly positioned, look up the specimen exposure hole from the lower side of the masking board using a mirror as shown in Figure D.2.



Key

1 Weight

2 Heat flux meter mounting board with the heat flux meter

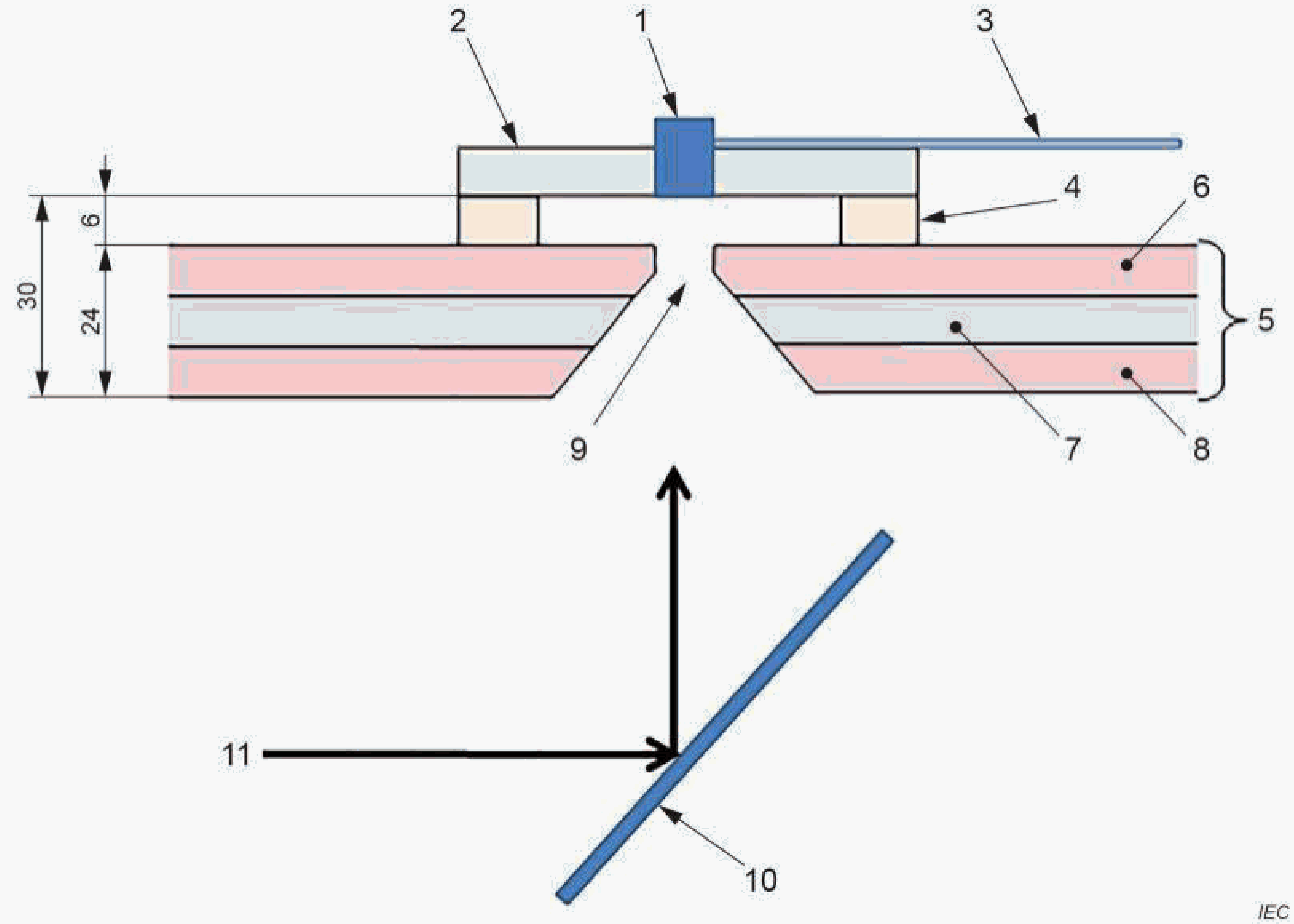
3 Heat flux meter supporting device

4 Top plate of the test apparatus

5 End of the of the heat flux meter supporting device

Figure D.1 – Positioning the heat flux meter

Dimensions in millimetres



Key

1 Heat flux meter (See 5.3)

2 Heat flux meter mounting board (See 5.5)

3 Cooling water pipes of the heat flux meter

4 Test specimen support (See 5.1)

5 Masking board (See 5.6)

6 Upper board (See 5.6)

7 Movable board (Radiant heat shield) (See 5.6)

8 Lower board (See 5.6)

9 Conical hole (See 5.1)

10 Mirror (See 5.1)

11 View to see and check that the heat flux meter is correctly positioned above the conical hole.

Figure D.2 – Correct position of the test specimen support and the heat flux meter

Bibliography

[1] IEC 60695-11-5, *Fire hazard testing – Part 11-5: Test flames – Needle-flame test method – Apparatus, confirmatory test arrangement and guidance*

[2] IEC 60695-11-10, *Fire hazard testing – Part 11-10: Test flames – 50 W horizontal and vertical flame test methods*

[3] IEC 60695-11-20, *Fire hazard testing – Part 11-20: Test flames – 500 W flame test method*

[4] ISO 4589-2, *Plastics – Determination of burning behaviour by oxygen index – Part 2: Ambient temperature test*

[5] ISO 14934-3, *Fire tests – Calibration and use of heat flux meters – Part 3: Secondary calibration method*

[6] ISO 5725-1, *Accuracy (trueness and precision) of measurement methods and results – Part 1: General principles and definitions*

[7] ISO 5725-2, *Accuracy (trueness and precision) of measurement methods and results – Part 2: basic method for the determination of repeatability and reproducibility of a standard measurement method*

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