INTERNATIONAL STANDARD

ISO 6944-1

First edition
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Fire containment — Elements of building construction —

Part 1: **Ventilation ducts**

Endiguement du feu — Éléments de construction —

Partie 1: Conduits de ventilation

Reference number
ISO 6944-1:2008(E)

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 6944-1 was prepared by Technical Committee ISO/TC 92, *Fire safety*, Subcommittee SC 2, *Fire containment*.

This first edition of ISO 6944-1, cancels and replaces ISO 6944:1985, which has been technically revised.

ISO 6944 consists of the following parts, under the general title *Fire containment — Elements of building construction*:

— *Part 1: Ventilation ducts*

A Part 2, dealing with kitchen extract ducts, is under development.

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Introduction

The purpose of this test is to measure the ability of a representative duct or duct assembly that is part of an air-distribution system to resist the spread of fire from one fire compartment to another, with fire attack from inside or outside the duct. It is applicable to vertical and horizontal ducts, with or without branches, taking into account joints and exhaust openings, as well as suspension devices and penetration points.

This part of ISO 6944 is very similar to EN 1366-1, but includes an alternative arrangement for testing elbows.

The test measures the length of time during which ducts of specified dimensions, suspended as they normally are in practice, satisfy defined criteria when exposed to fire from either inside or outside the duct.

All ducts inside the furnace are fully restrained in all directions. Outside the furnace, ducts exposed to fire from the outside are tested unrestrained, while ducts exposed to fire from the inside (horizontal only) are tested restrained.

The test takes into account the effect of fire exposure from the outside, where a 300 Pa underpressure is maintained in the duct, as well as the effect of fire entering the ducts under conditions where forced air movement might or might not be present, by maintaining an air velocity of 3 m/s.

Ducts exposed to fire from the inside are supplied with air in a manner that is representative of the “fan off” and “fan on” situations that can arise in practice.

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Fire containment — Elements of building construction —

Part 1: Ventilation ducts

CAUTION — The attention of all persons concerned with managing and carrying out this fire resistance test is drawn to the fact that fire testing can be hazardous and that there is the possibility that toxic and/or harmful smoke and gases can be evolved during the test. Mechanical and operational hazards can also arise during the construction of the test elements or structures, their testing and disposal of test residues.

It is strongly recommended that the duct assembly be allowed to cool completely after the fire test, before dismantling, to minimize the possibility of ignition of combustible residues.

An assessment of all potential hazards and risks to health shall be made and safety precautions shall be identified and provided. Written safety instructions shall be issued. Appropriate training shall be given to relevant personnel. Laboratory personnel shall ensure that they follow written safety instructions at all times.

1 Scope

This part of ISO 6944 specifies a method for determining the fire resistance of vertical and horizontal ventilation ducts under standardized fire conditions. The test examines the behaviour of ducts exposed to fire from the outside (duct A) and fire inside the duct (duct B). It is intended that this part of ISO 6944 be used in conjunction with ISO 834-1.

This part of ISO 6944 is not applicable to

a) ducts whose fire resistance depends on the fire resistance performance of a ceiling,

b) ducts containing fire dampers at points where they pass through fire separations,

c) doors of inspection openings, unless included in the duct to be tested,

d) two- or three-sided ducts,

e) the fixing of suspension devices to floors or walls.

NOTE Annex A provides general guidance and gives background information.

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2 Normative references

The following referenced documents are indispensable for the application 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 834-1, *Fire-resistance tests — Elements of building construction — Part 1: General requirements*

ISO 5167-1, *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full — Part 1: General principles and requirements*

ISO 5221, *Air distribution and air diffusion — Rules to methods of measuring air flow rate in an air handling duct*

ISO 13943, *Fire safety — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 834-1 and ISO 13943, and the following apply.

3.1
fire resisting duct
duct used for the distribution or extraction of air and designed to provide a degree of fire resistance

3.2
suspension device
components used for supporting and fixing a duct from a floor or supporting a duct from a wall

3.3
supporting devices
wall, partition or floor through which the duct passes during the test

3.4
compensator
device that is used to prevent damage from the forces generated by expansion

4 Apparatus

4.1 In addition to the test equipment specified in ISO 834-1, the following apparatus is required.

4.2 Furnace, capable of subjecting ventilation ducts to the standard heating conditions specified in ISO 834-1 and suitable for testing ducts in the vertical (see Figure 1) or horizontal (see Figure 2) orientation.

Figures 1 and 2 show two ducts being tested together. When two ducts are tested together, they shall be separated by a minimum of 500 mm. It is also permitted to test each duct singularly in the furnace.

4.3 Fan A, capable of producing an underpressure of (300 ± 15) Pa within duct A (see Figure 3) at the start and throughout the test, and shall be connected, either directly or by a suitable length of flexible ducting, to the measuring station (4.5).

4.4 Fan B, capable of producing an air velocity when extracting gas from duct B (see Figure 4) of at least 3 m/s measured at ambient temperature in the duct before the test.

It shall be connected, either directly or by a suitable length of flexible ducting, to the velocity-measuring station (4.8). The fan shall be provided with a by-pass vent that can be opened prior to shutting the damper (4.7).

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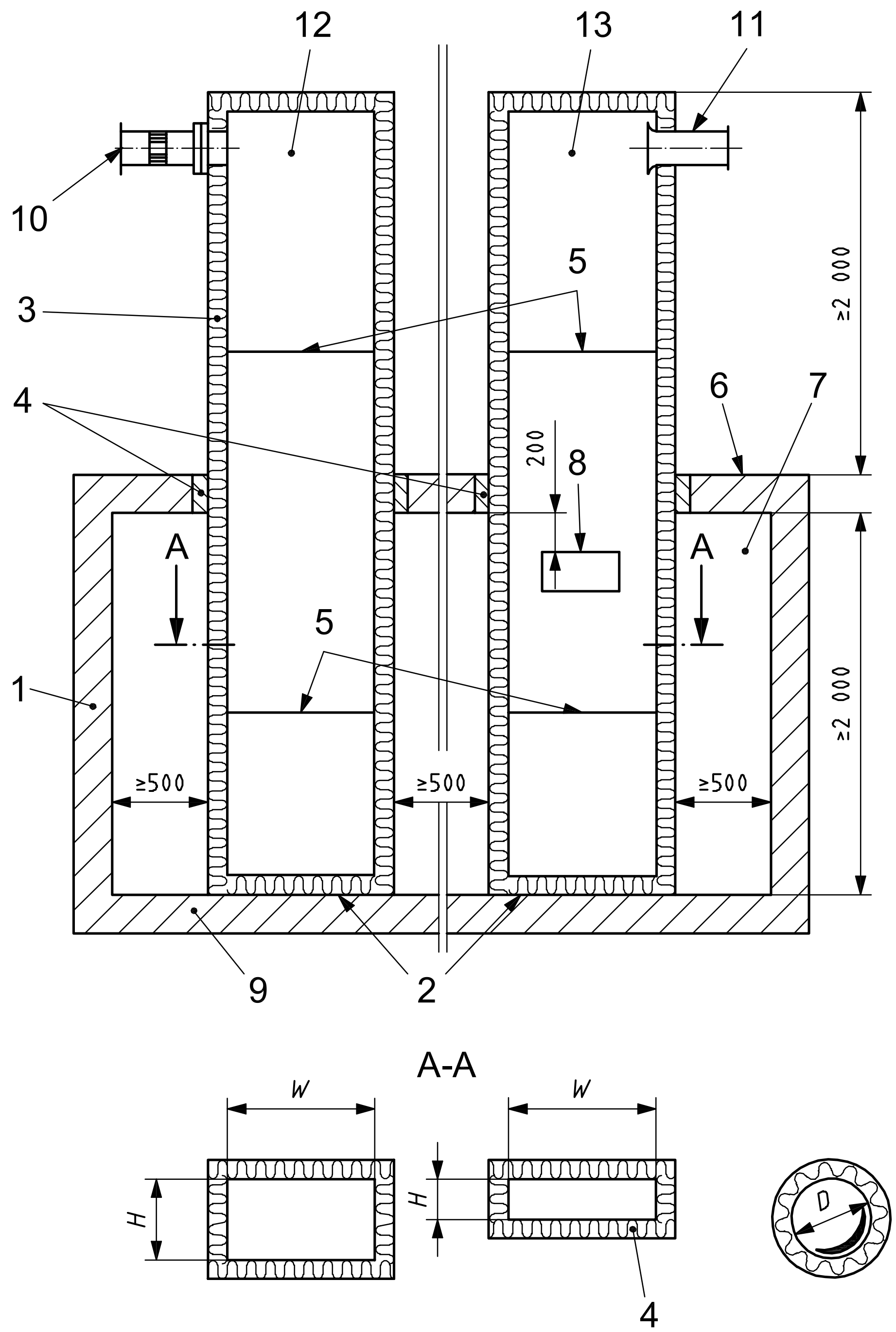
Dimensions in millimetres



Key

1 furnace wall
2 sealed end
3 fire-protection system
4 location for fire stopping (normal practice)
5 joint in fire-protection system
6 furnace roof
7 furnace chamber
8 openings providing a total area of 50% of duct cross-section
9 furnace floor
10 leakage-measuring station (see Figure 3 for details)
11 gas-velocity-measuring station (see Figure 4 for details)
12 duct A
13 duct B

W width
H height
D diameter

See 4.2.

Figure 1 — Test arrangement for vertical ducts

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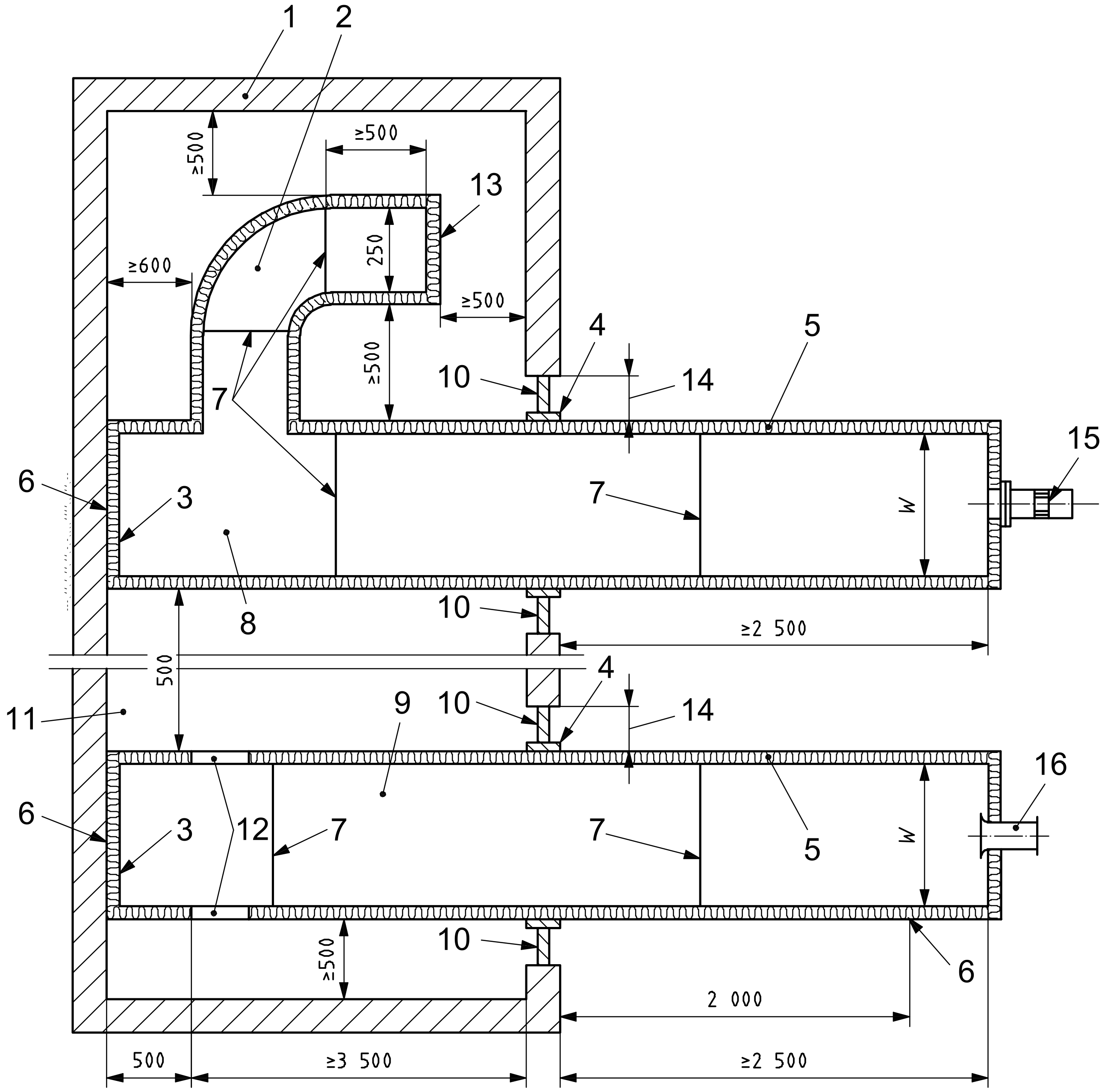
Dimensions in millimetres



Key

1	furnace wall	9	duct B
2	duct with 90° elbow	10	supporting construction
3	sealed end	11	furnace chamber
4	location for fire stopping (normal practice)	12	openings providing a total area of 50 % of duct cross-section
5	fire-protection system	13	sealed end of elbow
6	location of restraint positions	14	200 mm minimum supporting construction
7	joints in fire-protection system	15	leakage-measuring station (see Figure 3 for details)
8	duct A	16	gas-velocity-measuring station (see Figure 4 for details)

W width or diameter

See 4.2.

Figure 2 — Test arrangement for horizontal ducts

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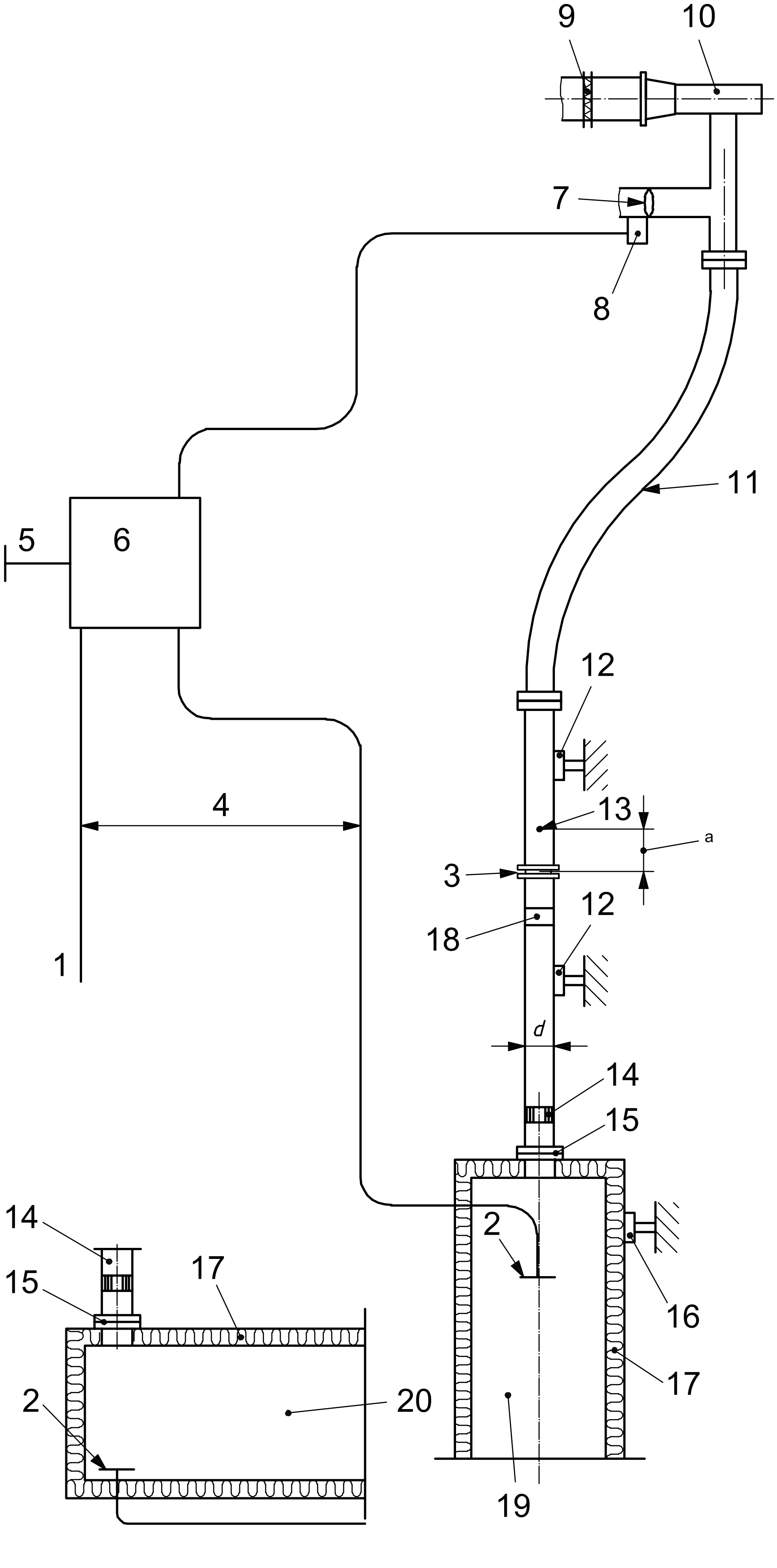

Figure 3 (*continued*)

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Key

1	pressure sensor to furnace	11	flexible connecting duct
2	pressure sensor on centre-line of duct	12	support for flow-measuring system
3	office plate, venture or similar	13	thermocouple, 1,5 mm diameter
4	pressure differential of 300 Pa	14	flow straightener (where necessary)
5	pressure sensor in laboratory	15	flange
6	pressure-differential control box	16	support for duct outside furnace
7	pressure-control dilution damper	17	test duct
8	pneumatic-actuator manual control	18	condensing device
9	balancing damper	19	horizontal duct A
10	fan	20	vertical duct A

[a] Thermocouple located 2d from key item 3; see Note.

NOTE d is the diameter of the measuring duct downstream from the flow-measuring device.

Figure 3 — Leakage-measuring station for duct A

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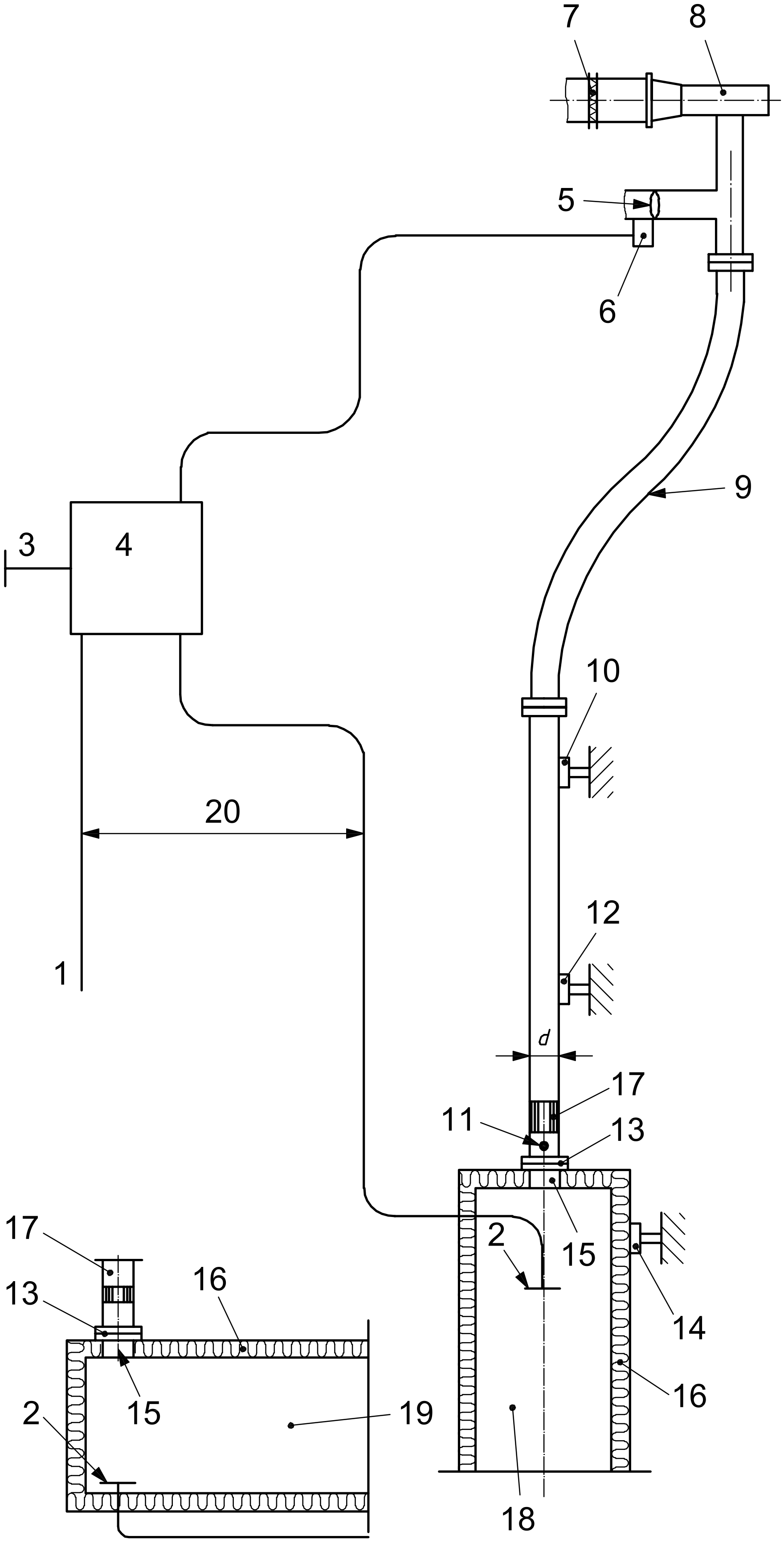

Figure 4 (*continued*)

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Key

1 pressure sensor to furnace
2 pressure sensor on centre-line of duct
3 pressure sensor in laboratory
4 pressure-differential control box
5 pressure-control dilution damper
6 pneumatic-actuator manual control
7 balancing damper
8 fan
9 flexible connecting duct
10 support for velocity-measuring station near flexible duct
11 thermocouple, 1,5 mm diameter
12 support for velocity-measuring station near duct
13 flange
14 support for duct outside furnace
15 inlet nozzle
16 test duct
17 flow straightener (if required)
18 horizontal duct A
19 vertical duct A
20 pressure differential of 300 Pa

Figure 4 — Gas velocity station for duct B

4.5 Volume flow-measuring station, consisting of a venturi, orifice plate or other suitable device and (where necessary) an air-flow straightener, installed in straight lengths of pipe, all sized to ISO 5167-1 and ISO 5221.

It shall be connected to the end of duct A outside the furnace to determine the volume flow rate of gas passing through duct A during the test. The measuring device shall be capable of measuring to an accuracy of ± 5 %. Regardless of whether vertical or horizontal ducts are being tested, the volume flow-measuring station shall always be used in a horizontal orientation.

4.6 Condensing unit, installed between the end of duct A and the flow-measuring device and which shall allow for drainage.

The gas temperature adjacent to the flow-measuring device shall be measured by a 2 mm sheathed thermocouple with an insulated hot junction, arranged pointing downwards to allow the moisture to drain. Its measuring junction shall be located at the centre-line of the measuring duct and at a distance, d, equal to twice the diameter of the measuring duct downstream from the flow-measuring device. The temperature measured by this thermocouple shall not exceed 40 °C.

4.7 Damper, installed between the fan and the velocity-measuring station to shut off the air flow in duct B during evaluation of integrity in the “fan off” condition.

4.8 Velocity-measuring station, to determine the air velocity in duct B and shall consist of one or two inlet nozzle(s), or another suitable device, installed in a straight length of pipe sized to ISO 5167-1 and ISO 5221, connected to the end of both the vertical and horizontal ducts B outside the furnace.

4.9 Equipment for measuring gas pressure, located in the furnace and inside duct A.

4.10 Thermal-movement-measuring device, for measuring the expansion or contraction of duct A, accurate to ± 1 mm.

4.11 Force-measuring device, for measuring forces at the point of applying the restraint in duct B (see Figure 5).

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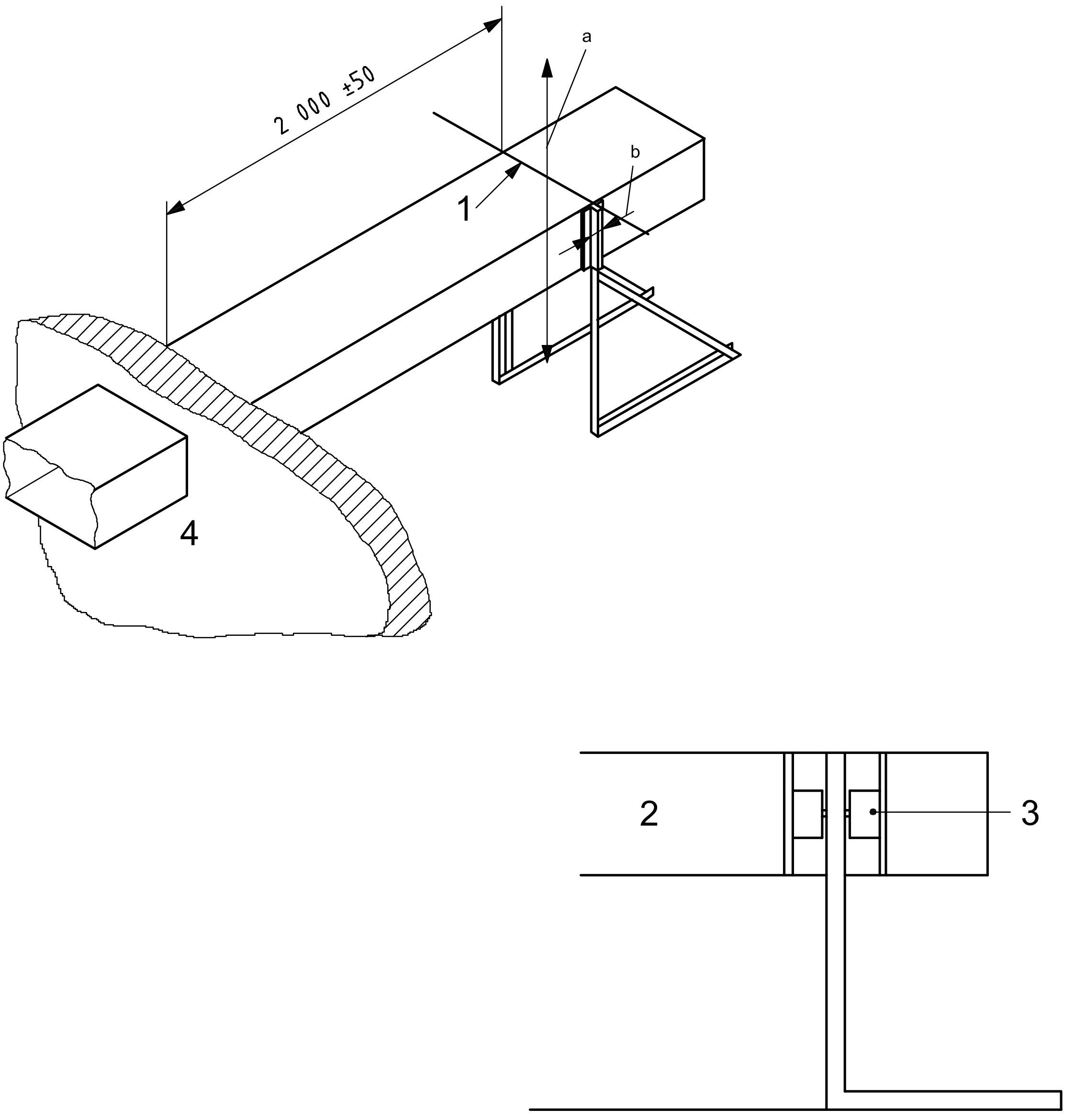

Key

1 location of device measuring the restraining forces
2 duct
3 stiff load cells (used for applying and measuring restraint)
4 furnace

[a] Allow movement in both directions.
[b] Resist movement in both directions.

Figure 5 — Restraint of duct B outside the furnace

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5 Test conditions

The heating conditions and the furnace atmosphere shall conform to those given in ISO 834-1.

The furnace pressure shall be controlled to (15 ± 3) Pa throughout the test at the mid-height position of the ducts.

Details of test conditions within the ducts during the test are given in Clause 10.

6 Test specimen

6.1 Size

6.1.1 General

Ducts of sizes other than those given in Tables 1 and 2 have restricted the field of direct application (see Clause 13).

6.1.2 Length

The minimum lengths of the parts of the test specimen inside and outside the furnace shall be as given in Table 1 (see also Figures 1 and 2).

Table 1 — Minimum length of test specimen

Orientation	Minimum length m	
	Inside the furnace	Outside the furnace
Horizontal	4,0	2,5
Vertical	2,0	2,0

6.1.3 Cross-section

The standard sizes of ducts given in Table 2 shall be tested unless only smaller cross-sections are used.

Table 2 — Cross-sectional dimensions of test specimen

Duct	Rectangular		Circular
	width mm	height mm	diameter mm
A	1 000 ± 10	500 ± 10	800 ± 10
B	1 000 ± 10	250 ± 10	630 ± 10

6.2 Number

One test specimen shall be tested for each type of installation being evaluated.

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6.3 Design

6.3.1 General

The test shall be made on a test specimen representative of the complete duct assembly on which information is required. The edge conditions and the method of fixing or support inside and outside the furnace shall be representative of those used in normal practice.

Ducts shall be arranged as shown in Figures 1 and 2.

6.3.2 Minimum separation

There is no limit to the number of ducts that may be tested simultaneously in the same furnace, provided that there is a minimum space of 500 mm between the ducts, in accordance with the dimensions shown in Figures 1 and 2.

There shall be a separation of (500 ± 50) mm between the top of a horizontal duct and the ceiling. A minimum separation of 500 mm shall be provided between the underside of a horizontal duct and the floor. Similarly, there shall be a minimum separation of at least 500 mm between the sides of ducts and the furnace walls.

6.3.3 Configuration of duct A (horizontal only)

The horizontal duct A shall include one sharp bend, a T-piece and a 500 mm long length of duct forming a short branch duct having a cross-section of 250 mm × 250 mm, and shall be arranged as shown in Figure 2. All specimens, including this branch, shall be mounted with the suspension or fixing devices as intended in normal practice.

An alternative test arrangement where the elbow in horizontal duct A is replaced by a vertical section of duct, which passes through the furnace roof and is then connected to the measuring system and the fan, is illustrated in Figure 6.

6.3.4 Openings in duct B

Two openings shall be provided, one on each vertical side of the duct inside the furnace. For horizontal ducts, the openings shall be positioned (500 ± 25) mm from the furnace wall. For vertical ducts, the openings shall be positioned (200 ± 10) mm below the furnace roof. (See Figures 1 and 2.)

In both vertical and horizontal ducts, the openings shall have the same breadth-to-height ratio as the cross-section of the duct and a total opening area of (50 ± 10) % of the cross-sectional area of the duct, i.e. each opening shall have an area of (25 ± 5) % of the cross-sectional area of the duct.

6.3.5 Joints in horizontal ducts

The test configuration shall include at least one joint inside and at least one joint outside the furnace.

There shall be at least one joint per layer of fire-protection material, both inside and outside the furnace and in any steel duct.

Outside the furnace, the joint in the outer layer of the fire-protection material shall be no further than 700 mm from the supporting construction and no nearer than 100 mm to thermocouples T2; see Figures 10 to 12. Inside the furnace, the joint in the outer layer of fire-protection material shall be located at approximately mid-span.

The distance between joints and suspension devices shall not be less than that used in practice. If the minimum distance has not been specified, suspension devices shall be arranged so that the joint at mid-span lies midway between them. Centres of the suspension devices shall be specified by the manufacturer and shall be representative of practice.

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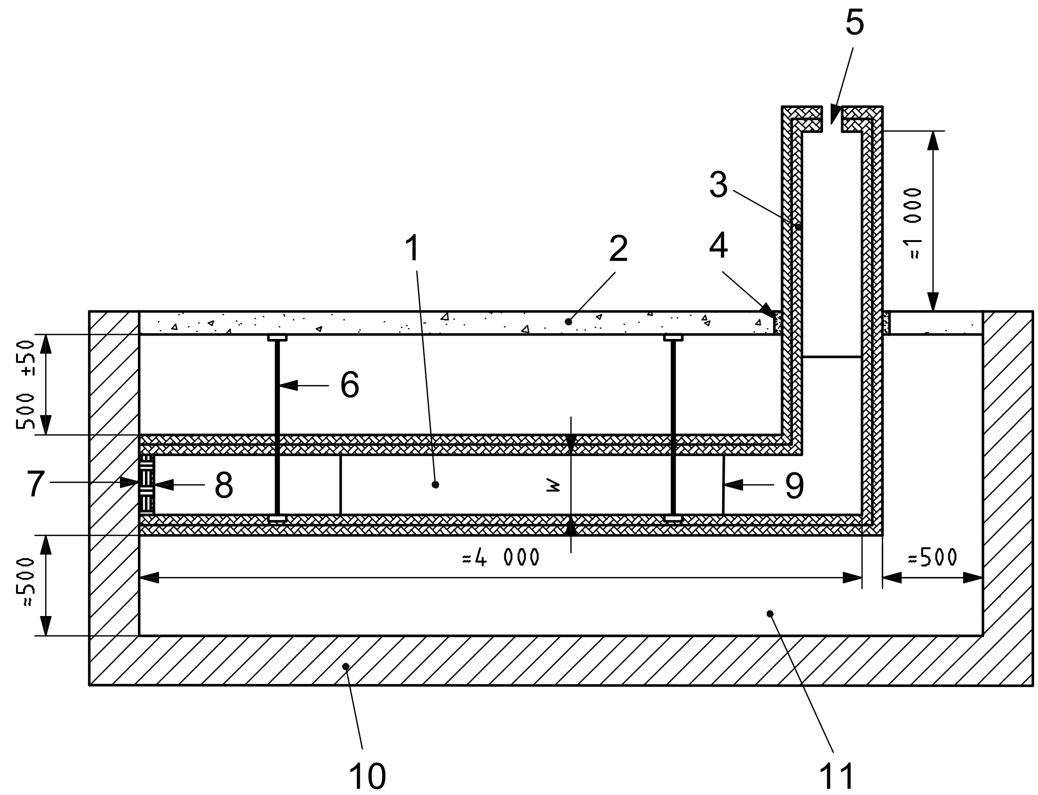
Dimensions in millimetres



Key

1 duct with vertical elbow
2 furnace roof/supporting construction
3 fire-protection system
4 location for fire stopping (normal practice)
5 connection of elbow to measuring system and fan as shown in Figure 3
6 duct supports (normal practice)
7 location of restraint positions
8 sealed end
9 joints in fire-protection system
10 furnace wall
11 furnace chamber

Figure 6 — Alternative arrangement for duct A with vertical elbow

6.3.6 Joints in vertical ducts

The test configuration shall include at least one joint inside and one joint outside the furnace (see Figure 1).

There shall be at least one joint for every layer of fire-protection material, both inside and outside the furnace and in any steel duct.

Outside the furnace, the joint in the outer layer of the fire-protection material shall be no further than 700 mm from the supporting construction and no nearer than 100 mm to the thermocouples T2; see Figures 10 to 12. Inside the furnace, the joint in the outer layer of fire-protection material shall be located at approximately mid-span.

6.3.7 Support for vertical ducts

Vertical ducts shall be supported on the furnace floor and shall penetrate through the furnace roof slab/supporting construction (see Figure 1); the ducts shall be fixed at the furnace-roof level as they are normally fixed in practice when penetrating a floor. This shall be as specified by the sponsor.

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6.3.8 Compensators

Only where compensators are normally used in practice shall they be incorporated in the test specimen. Where a compensator is being tested, it shall be located within the furnace for duct A and, for duct B, outside the furnace approximately 500 mm from the wall or floor.

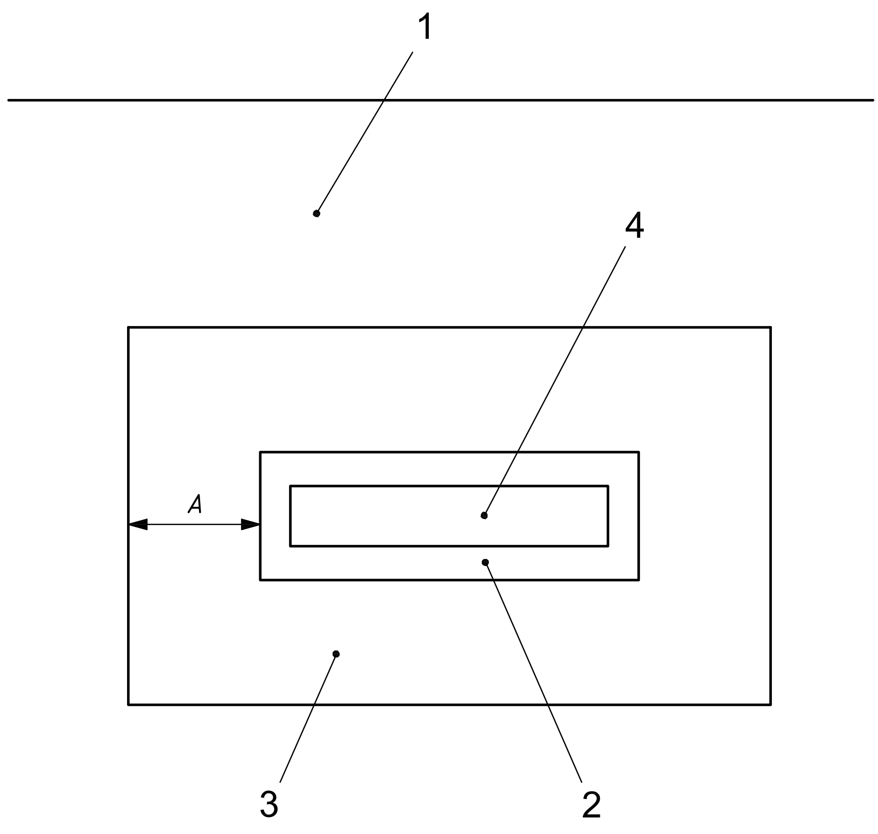
7 Installation of test specimen

7.1 General

The test specimen shall be installed, as far as possible, in a manner representative of its use in normal practice.

The supporting construction selected shall be a wall, partition or floor of the type used in normal practice and shall have a fire resistance greater than the required fire resistance of the duct being tested.

Where the duct passes through an opening in the furnace wall or roof, the opening shall be of sufficient dimensions that the minimum distance between the edge of the fire stopping (see 7.4.5) adjacent to the supporting construction and the outside perimeter of the supporting construction is 200 mm (see Figure 7).



Key

1 furnace wall or furnace roof

2 fire stopping

3 supporting construction

4 duct

The dimension A shall be a minimum of 200 mm.

Figure 7 — Details of duct passing through an opening in the furnace wall or roof

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7.2 Standard supporting construction

Where the type of supporting construction used in normal practice is not known, then one of the standard supporting constructions described in Tables 3 to 5 shall be used.

Table 3 — Standard rigid-wall constructions

Type of construction	Thickness mm	Density kg/m^3	Test duration t h
Normal concrete/masonry	110 ± 10	2 200 ± 200	$t = 2$
	150 ± 10	2 200 ± 200	$2 < t \leqslant 3$
	175 ± 10	2 200 ± 200	$3 < t \leqslant 4$
Aerated concrete [a]	110 ± 10	650 ± 200	$t = 2$
	150 ± 10	650 ± 200	$2 < t \leqslant 4$

[a] This supporting construction may be made from blocks bonded together with mortar or adhesive.

Table 4 — Standard flexible-wall constructions (gypsum plasterboard)

Fire resistance min	Wall constructions			
	Number of layers on each side	Thickness mm	Insulation [a] D/ρ	Thickness [b] mm
30	1	12,5	40/40	75
60	2	12,5	40/40	100
90	2	12,5	60/50	125
120	2	12,5	60/100	150
180	3	12,5	60/100	175
240	3	15,0	80/100	190

[a] D is the thickness in mm of mineral wool insulation inside the wall; ρ is the density in kg/m^3 of mineral wool insulation inside the wall.

[b] Tolerance of ± 10 %.

Table 5 — Standard floor constructions

Type of construction	Thickness mm	Density kg/m^3	Test duration t h
Normal concrete	110 ± 10	2 200 ± 200	$t = 1,5$
	150 ± 10	2 200 ± 200	$1,5 < t \leqslant 3$
	175 ± 10	2 200 ± 200	$3 < t \leqslant 4$
Aerated concrete	125 ± 10	650 ± 200	$t = 2$
	150 ± 10	650 ± 200	$2 < t \leqslant 4$

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7.3 Non-standard supporting constructions

When the test specimen is intended for use in a form of construction not covered by the standard supporting constructions, it shall be tested in the supporting construction intended for use.

7.4 Restraint of ducts

7.4.1 Inside the furnace

All ducts shall be fully restrained in all directions at the furnace wall or floor remote from the penetration point. Where there is a possibility of movement of the furnace wall, the fixings shall be made independent of the furnace structure.

7.4.2 At the penetration point

Where, in practice, the duct is fixed at floor level, then both vertical ducts A and B shall be fixed where the duct penetrates the furnace roof/supporting construction as specified by the sponsor.

7.4.3 Outside the furnace

Only horizontal duct B shall be restrained outside the furnace. The restraining point shall be located at a position (2 000 ± 50) mm from the furnace wall and shall provide restraint on movement in the horizontal directions but shall allow movement in the vertical directions (see Figure 5). The frame used to apply the restraint shall be rigid and have sufficient strength to resist all horizontal forces. All other ducts shall be unrestrained outside the furnace.

7.4.4 Closure

The end of the ducts within the furnace and the end of any branch duct attached shall be closed independently of any furnace enclosure, by materials and construction similar to the remainder of the duct.

7.4.5 Fire stopping

The fire stopping at the penetration through the supporting construction shall be as intended in practice. If the width of the gap for fire-stopping around the duct at the furnace penetration point is not specified, a width of 50 mm shall be used.

7.4.6 Unsupported vertical ducts

Where, in practice, vertical ducts are not fixed to each floor, then the test specimen shall be suitably loaded to simulate the weight of the remaining height of unsupported ducting.

8 Conditioning

8.1 General

Conditioning of the test construction shall be in accordance with ISO 834-1.

8.2 Hygroscopic sealing materials

Hygroscopic materials used to seal the gap between the supporting construction and the duct where the gap is ⩽ 10 mm wide shall be conditioned for seven days before fire testing.

Hygroscopic materials used to seal the gap between the supporting construction and the duct assembly where the gap is > 10 mm wide shall be conditioned for 28 days before fire testing.

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9 Application of instrumentation

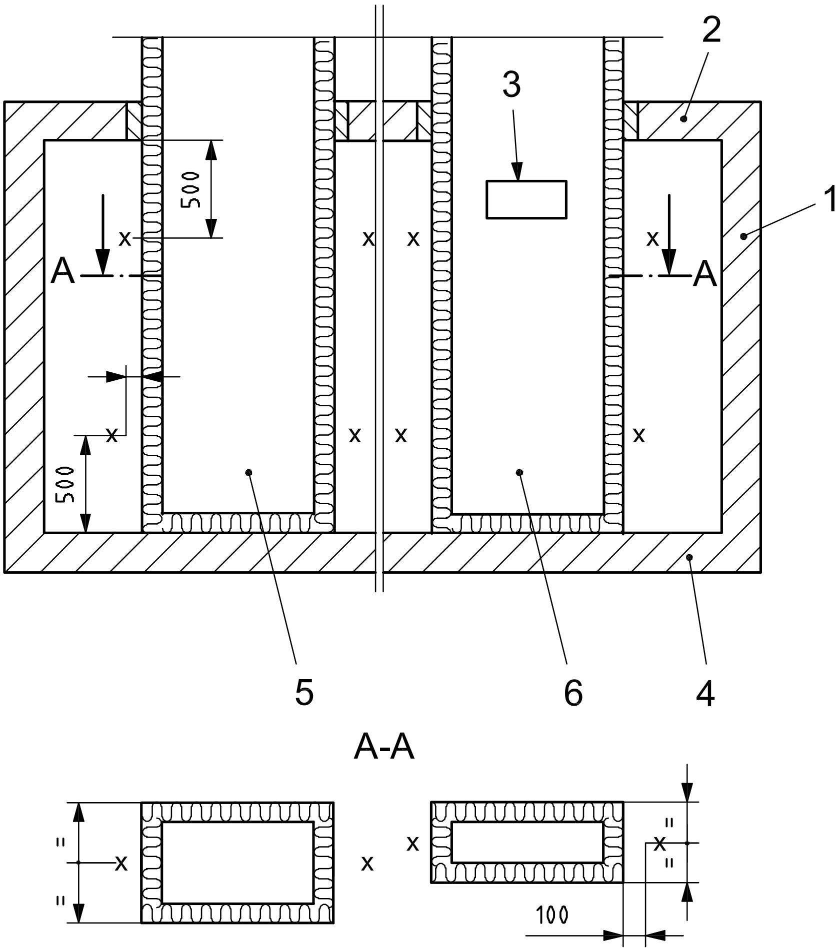
9.1 Thermocouples

9.1.1 Furnace thermocouples (plate thermometers)

Plate thermometers shall be provided in accordance with ISO 834-1 and shall be positioned as shown in Figures 8 and 9.

For all ducts, the plate thermometers shall be oriented so that side ‘A’ faces the walls of the furnace opposite the ducts being evaluated.

Dimensions in millimetres



Key

1 furnace wall

2 furnace roof

3 one opening on each side of the duct, providing a total inlet area of 50 % of the cross-section of the duct (see 6.3.4)

4 furnace floor

5 vertical duct A

6 vertical duct B

X furnace thermocouple locations

The drawing shows two ducts being tested together. It is also permitted to test each duct singularly in the furnace.

Figure 8 — Location of furnace thermocouples for vertical duct testing

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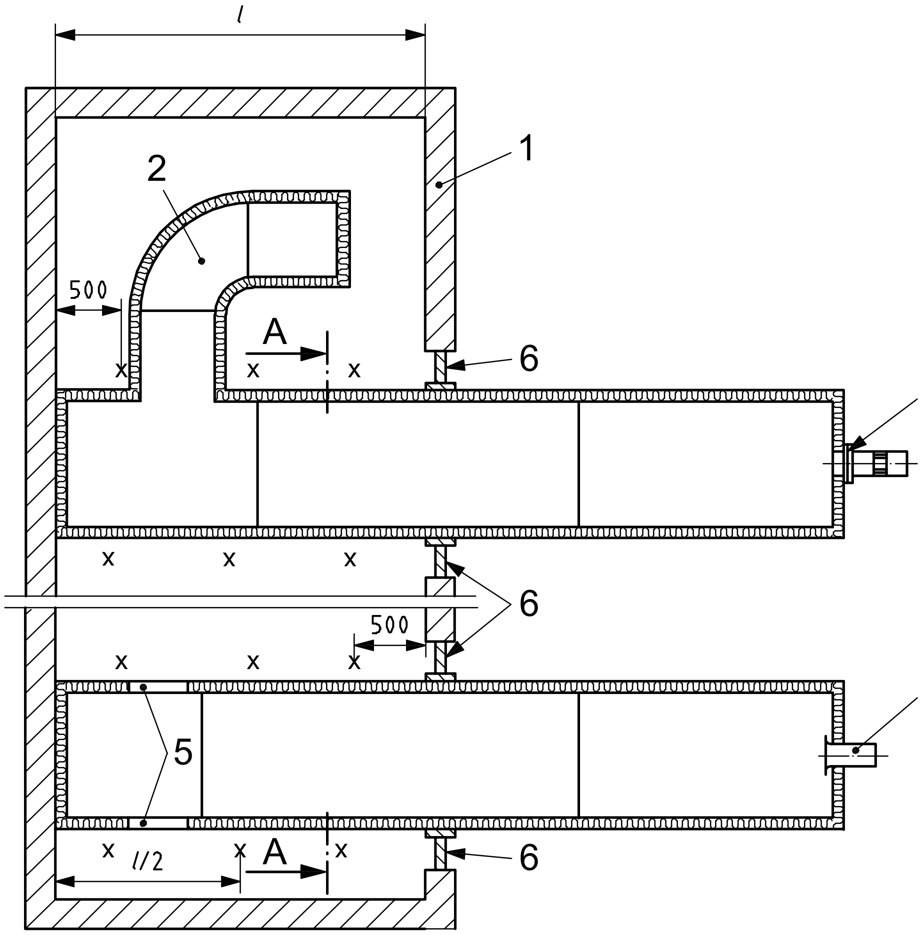
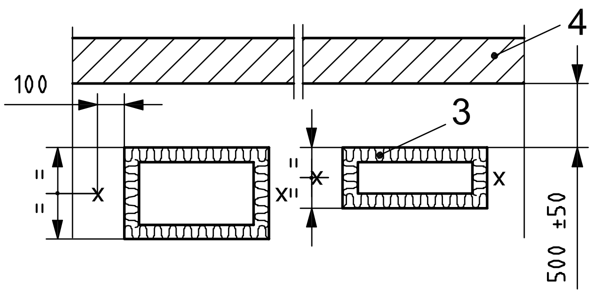
Dimensions in millimetres



A-A



Key

1 furnace wall

2 duct A with 90° elbow (see 6.3.3)

3 fire-protection system

4 furnace roof

5 one opening on each side of duct B providing a total inlet area of 50 % of the cross-section of duct B (see 6.3.4)

6 supporting construction

l span inside furnace

X location of furnace thermocouples

[a] See Figure 3 for details of flow-measuring system.

[b] See Figure 4 for detail of velocity-measuring station.

The drawing shows two ducts being tested together. It is also permitted to test each duct singularly in the furnace. Thermocouples shall be located along the horizontal section of the duct when the L-shaped duct shown in Figure 6 is used.

Figure 9 — Location of furnace thermocouples for horizontal ducts

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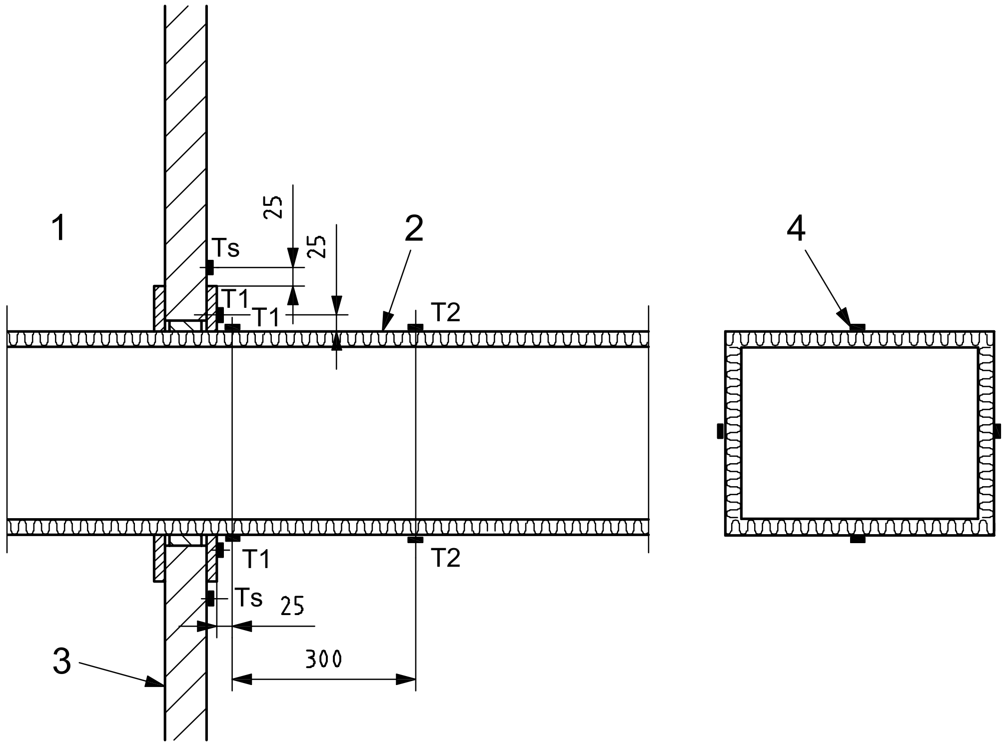
9.1.2 Unexposed surface thermocouples

9.1.2.1 General

The temperature of the test specimens shall be measured with thermocouples as described in ISO 834-1. The position of thermocouples at the point of penetration of the duct through the wall or floor is shown in Figures 10 to 12 for a number of different penetration details. At least one thermocouple of each type shall be positioned on each side of a rectangular duct.

Dimensions in millimetres



Key

1 furnace

2 fire resisting duct

3 supporting construction

4 surface thermocouple

Ts position of thermocouple to measure the maximum surface temperature on the supporting construction; minimum of one on each side of the duct

T1 positions of surface thermocouples for determining the maximum temperature; minimum of one on each side of the duct

T2 positions of surface thermocouples for determining the average and the maximum temperatures; minimum of one on each side of the duct

Figure 10 — Location of surface thermocouples where duct penetrates supporting construction — Example 1

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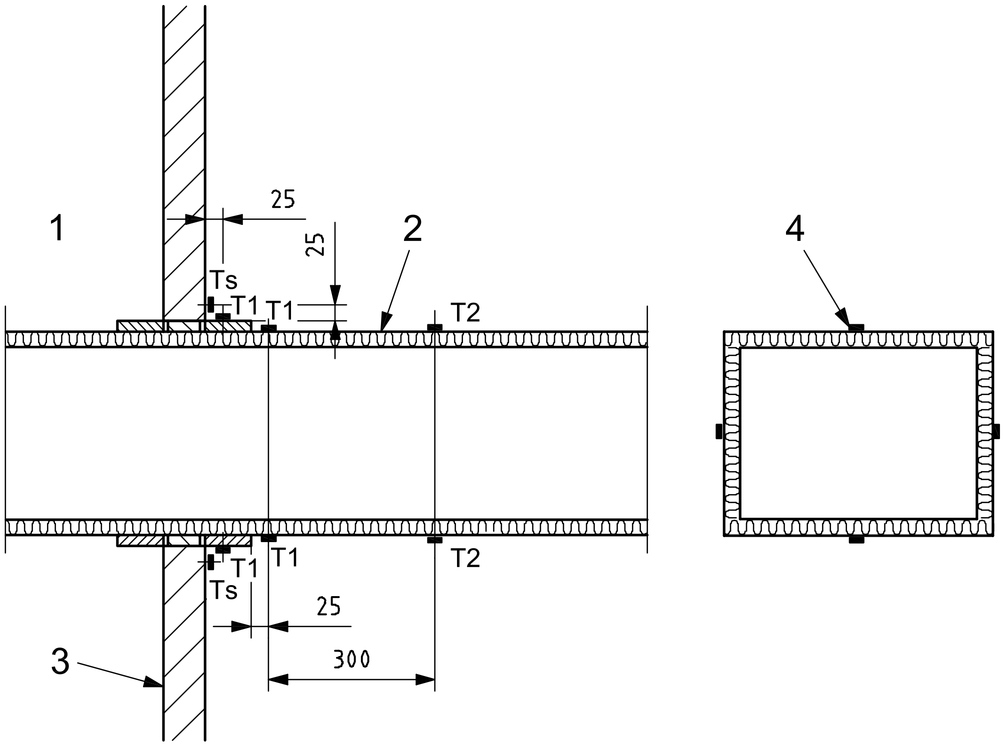
Dimensions in millimetres



Key

1 furnace

2 fire resisting duct

3 supporting construction

4 surface thermocouples

Ts position of thermocouple to measure the maximum surface temperature on the supporting construction; minimum of one on each side of the duct

T1 positions of surface thermocouples for determining the maximum temperature; minimum of one on each side of the duct

T2 positions of surface thermocouples for determining the average and the maximum temperatures; minimum of one on each side of the duct

Figure 11 — Location of surface thermocouples where the duct penetrates the supporting construction — Example 2

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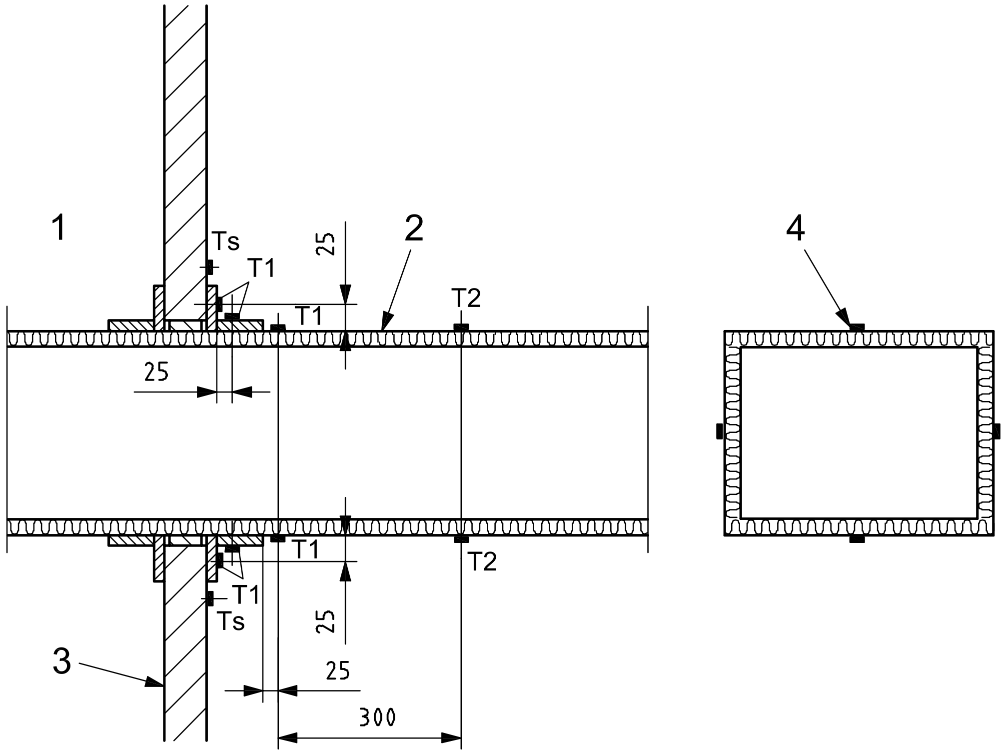
Dimensions in millimetres



Key

1 furnace

2 fire resisting duct

3 supporting construction

4 surface thermocouples

Ts position of thermocouple to measure the maximum surface temperature on the supporting construction; minimum of one on each side of the duct

T1 positions of surface thermocouples for determining the maximum temperature; minimum of one on each side of the duct

T2 positions of surface thermocouples for determining the average and the maximum temperatures; minimum of one on each side of the duct

Figure 12 — Location of surface thermocouples where the duct penetrates the supporting construction — Example 3

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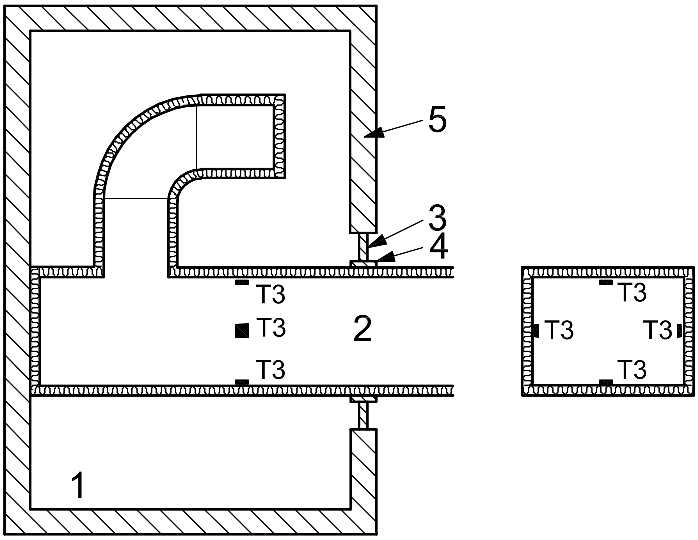

Key

1 furnace
2 duct A
3 supporting construction
4 fire-stopping system
5 furnace wall

T3 location of surface thermocouples for determining the average and the maximum temperatures

Figure 13 — Interior surface thermocouples for ducts with a combustible internal lining

9.1.2.2 Maximum temperature rise

Additional thermocouples, T1, for determining the maximum temperature rise shall be located in positions on the outer surface of the fire-protection material to coincide with all joints, including inner layer joints.

9.1.2.3 Ducts with combustible linings

For ducts where a combustible internal lining is used, four additional thermocouples, reference T3, shall be fixed inside duct A at a position of approximately mid-span within the part of the duct exposed within the furnace. The thermocouples shall be fixed to the inside face of the duct at the locations shown in Figure 13. The thermocouples shall not coincide with joints or cover strips.

9.1.2.4 Compensating devices

Where compensating devices have been incorporated, thermocouples shall be located on the outer surface of the compensator in duct B. These shall be used to check compliance with the maximum temperature rise limits only.

9.1.2.5 Suspension device

Where steel suspension devices are protected, their temperatures shall be measured. A thermocouple shall be positioned on each component of at least two suspension-device systems.

9.2 Pressure

The furnace pressure shall be measured in accordance with ISO 834-1 and the pressure probe(s) located at a position 100 mm below the roof of the furnace and at a position equal to the mid-height of the ducts.

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10 Test procedure

10.1 General

The test shall be carried out using the equipment and procedures in accordance with ISO 834-1.

10.2 Control of conditions to permit assessment of integrity

10.2.1 Duct A

Control the underpressure inside duct A (see Figures 1 and 2) to (300 ± 15) Pa below the ambient (laboratory) pressure at the beginning of the test and maintain it at this value throughout the test.

10.2.2 Duct B

Prior to the start of the test, stabilize the air velocity in duct B (see Figures 1 and 2) to 3 m/s. Adjust the fan during the “fan on” parts of the test to maintain the velocity of (3 ± 0,45) m/s.

At 25 min after the start of the test, open the fan bypass vent and then shut the damper, whilst leaving the fan running. Allow 2 min for the conditions to stabilize in duct B.

Make an assessment of the integrity of the duct assembly outside the furnace in the simulated “fan off” situation for a period of 3 min. Then re-open the damper and close the bypass vent. The damper shall be opened or shut in not less than 10 s and not more than 20 s. Check to verify that velocity of the fan is within the limits defined above.

Repeat this procedure 5 min before the completion of every 30 min period of the test. Make assessments of integrity in the damper open position (“fan-on” situation) at all other times.

10.3 Test measurements and observations

10.3.1 Integrity

10.3.1.1 Ducts A and B, including where the ducts pass through the wall or floor

Evaluate the test specimen for integrity as given in ISO 834-1. Table 6 summarizes the evaluation required to assess integrity.

Table 6 — Summary of appropriate integrity evaluation

Duct	Inside furnace	Outside furnace
Duct A (fire outside duct)	Volume flow rate	Volume flow rate Cotton pad Openings Flaming
Duct B (fire inside duct)	—	Cotton pad Openings Flaming

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10.3.1.2 Duct A only

Record the pressure differential across the venturi, orifice plate or other suitable device at intervals of not more than 2 min throughout the test.

Calculate the leakage from the recorded pressure differential from the venturi, orifice plate or other suitable device using the equations for volume flow rates given in ISO 5167-1 and ISO 5221.

10.3.2 Insulation

Measure the average and maximum temperatures of the unexposed faces of the test specimens as specified in ISO 834-1. Use a roving thermocouple to locate points of high temperature not covered by the fixed thermocouples, at locations where the duct is outside the furnace only.

10.3.3 Restraint forces and thermal elongation or shortening

Measure and record the restraint force in horizontal duct B on the outer surface (see Figure 5) at the point of application of the restraint outside the furnace. Measure and record the thermal elongation or shortening of horizontal duct A (see Figure 2) at the penetration point.

Measure the restraint forces in duct B using the device described in 4.11. In duct A, measure thermal movement using the transducer specified in 4.10.

10.3.4 Additional observations

Throughout the test, make observations of all changes and occurrences that do not affect the performance criteria but that can create hazards in a building, including, for example

a) deflections; this shall cover the general behaviour of the duct, e.g. the direction in which it is deflecting; precise measurements are not required;

b) the emissions of smoke from the unexposed face of the duct; this can, for example, be attributable to its coverings and/or lining; only limited observations can be possible in view of the highly subjective nature of such observations;

c) the time when the suspension or fixing devices can no longer retain a duct in its intended position or when sections of the duct collapse;

d) the expansion or contraction of each layer of protection material on the duct, at the end of horizontal duct A.

10.4 Termination of the test

Terminate the test for the reasons given in ISO 834-1.

11 Performance criteria

11.1 Integrity

Integrity failure shall be deemed to have occurred if any of the following are observed:

a) integrity failure as defined in ISO 834-1;

b) volume flow rate measured in duct A exceeds 15 $m^3/(m^2 \cdot h)$ at normal temperature and pressure, related to the internal surface area of the duct inside the furnace.

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11.2 Insulation

11.2.1 General

Insulation failure shall be as defined in ISO 834-1.

Only thermocouples T2 shall be used to determine the average temperature rise. Thermocouples T1, T2, Ts, and the roving thermocouple shall be used to determine the maximum temperature rise.

11.2.2 Ducts with internal combustible linings only

Insulation failure shall be as defined in ISO 834-1.

Thermocouples T3 shall also be used to determine the average and maximum temperature rise.

11.3 Smoke leakage

Failure of this criterion shall have occurred if the flow rate in duct A during the test exceeds 10 $m^3/(m^2 \cdot h)$ at normal temperature and pressure, related to the internal surface area of the duct inside the furnace.

12 Test report

In addition to the items required by ISO 834-1, the following shall also be included in the test report:

a) a reference that the test was carried out in accordance with ISO 6944-1:2008;

b) the number of sides of the test specimens exposed to fire in the furnace;

c) the method of fixing, support and mounting, as appropriate for the type of test specimen;

d) a description of the method and materials used to seal the gap between the duct and the opening provided in the wall or floor to accommodate the duct;

e) the details of the supporting construction and, where vertical ducts are loaded, the number of storeys that this represents;

f) a graph of the force recorded at the restraint point in horizontal duct B against time;

g) the thermal elongation or shortening of horizontal duct A;

h) other observations made during the test according to 10.3.4, including a complete record of the following test parameters as a function of time:

   — volume-flow-measuring-station gas temperatures,

   — calculated volume flow rate;

i) performance achieved in relation to 11.3;

j) where steel ducts are used, the thickness and whether any external stiffening or internal stiffeners were incorporated.

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13 Field of direct application of test results

13.1 General

The field of direct application includes only circular and four-sided ducts.

13.2 Vertical and horizontal ducts

A test result obtained for horizontal ducts A and B is applicable to horizontal ducts only.

A test result obtained for vertical ducts A and B is applicable to vertical ducts without branch.

A test on horizontal duct A that includes a branch duct also covers the use of branches on previously tested vertical ducts.

13.3 Sizes of ducts

A test result obtained for the standard sizes of ducts A and ducts B specified in Tables 1 and 2 is applicable to all dimensions up to the size tested, together with the increases given in Table 7.

Table 7 — Increase in dimensions of standard size ducts permitted under direct application

Duct type	Rectangular		Circular
	Width mm	**Height** mm	**Diameter** mm
Duct A	+ 250	+ 500	+ 200
Duct B	+ 250	+ 750	+ 370

For ducts tested at a size other than those specified in Clause 6, no extrapolation to a larger size is allowed. However, all smaller sizes are covered.

For tested ducts larger than the allowable upper limits for extrapolation, no extrapolation to a larger size is allowed.

If an independent protection system is used, the internal dimensions of the protection system shall be used to validate the field of application.

13.4 Pressure difference

13.4.1 A test result obtained for the standard underpressure of 300 Pa in duct A is applicable to an underpressure and an overpressure up to the same value providing that the integrity criteria during the duct B test was satisfied.

13.4.2 A test result obtained for a higher underpressure (minimum 500 Pa) in duct A is applicable to an underpressure up to the tested underpressure and to an overpressure of 500 Pa providing that the integrity criteria during the duct B test were satisfied. Where higher overpressures are possible, an additional test can be needed. Guidance is given in A.5.2.

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13.5 Height of vertical ducts

13.5.1 Ducts supported at each storey

The test results are applicable to any number of storeys provided

a) that the distance between supporting constructions does not exceed 5 m, and

b) that the limitations on buckling are satisfied; (see 13.5.3).

13.5.2 Self-loadbearing ducts

Test results obtained from ducts with an additional load are applicable to ducts with an overall height corresponding to the load applied in the fire test. Limitations on buckling shall also be satisfied (see 13.5.3).

13.5.3 Limitations on buckling

In order to prevent damage to the fire-protection material from the buckling of vertical ducts, the test results are applicable only to situations where the ratio between the length of the duct exposed in the compartment to the smallest lateral dimension across the outside face of the duct (or outer diameter) does not exceed 8:1, unless additional supports are provided.

In cases where additional supports are provided, the ratio of the distance between the additional supports, or the distance between the supports and the supporting construction, to the smallest lateral dimension across the outside face of the duct (or outer diameter) shall not exceed 8:1.

13.6 Suspension devices for horizontal ducts

13.6.1 As the test configuration does not allow an assessment of the loadbearing capacity, the suspension devices shall be made of steel and be sized such that the calculated stresses do not exceed the values given in Table 8.

Table 8 — Maximum values of stresses in suspension devices depending on duration of fire resistance

Type of load	Maximum stresses at given values of t N/mm^2	
	$t \leqslant 60$ min	60 min $< t \leqslant$ 120 min
Tensile stress in all vertically orientated components	9	6
Shearing stress in screws	15	10
NOTE The stress is calculated from the supported load only (and ignores assembly stresses).		

13.6.2 The elongation, in millimetres, of the suspension devices of the test ducts can be calculated on the basis of temperature increases and stress levels. For unprotected steel suspension devices, the temperature used shall be the maximum furnace temperature. For protected steel suspension devices, the maximum recorded suspension-device temperature shall be used. The value calculated represents the elongation limit for suspension devices with a length greater than that used in the test.

NOTE For unprotected suspension devices of approximately 1,5 m length an elongation of 40 mm can be expected depending on the fire resistance period.

13.6.3 The largest distance between suspension devices used in the test construction cannot be exceeded.

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13.6.4 If suspension devices have been used at all joints within the furnace, then suspension devices shall be located at all joints in practice.

13.6.5 In cases where the lateral dimension between the outer vertical surface of the duct and the centre-line of the suspension device is less than 50 mm, the test result shall apply to a dimension of up to 50 mm. If it is tested at a distance greater than 50 mm, then it is valid up to the distance tested.

13.6.6 The horizontal loadbearing component of the suspension-device system shall be sized so that the bending stress does not exceed that applied to the equivalent member in the test.

13.7 Supporting construction

A test result obtained for a fire resisting duct passing through a standard supporting construction (see Tables 3 to 5) is applicable to a supporting construction with a fire resistance equal to or greater than that of the standard supporting construction used for the test (thicker, denser, more layers of board, as appropriate).

13.8 Steel ducts

The test results shall apply to those ducts having lower leakage values provided that the steel duct tested represents the highest leakage value.

Test results on a steel duct that has been stiffened shall apply only to ducts that are also stiffened in a similar manner.

The results are applicable to ducts of lower leakage values only when the lower leakage rate is not achieved by means of combustible seals.

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Annex A
(informative)

General guidance

A.1 General

The following explanatory notes are intended to serve as guidance for the planning, performance and reporting of a fire-resistance test carried out in conformity with this part of ISO 6944-1.

A.2 Notes on apparatus

A.2.1 Volume flow-measuring station

A condensing device has been included as the gas flow measurements can be affected by the presence of steam. The content of steam is dependant on the material used in the test specimen. The use of a condensing device should exclude the influence of steam.

To ensure that the condensing device meets this objective, a requirement has been introduced that the temperature at the measuring device should not exceed 40 °C. It is for the test laboratory to provide a condensing device of adequate capacity to meet this requirement.

A.2.2 Extraction fan

A fan that can provide up to 600 m^3/h air flow, at up to 500 °C and 1 000 Pa pressure, should be adequate for testing the standard sizes of ducts given in Clause 6.

A fan for extracting gas from duct B, with a suction capacity of at least twice the velocity in the cross-section of the duct (required capacity: $V_n = 3$ m/s × 1 m × 0,25 m = 0,75 m^3/s), is sufficient to produce the required air velocity in the ducts of 3 m/s.

It can be necessary to provide a supply of fresh air (dilution air) into the extract fan to enable the hot gases to be cooled before passing through the fan. Irrespective of this, the fan shall be capable of extracting gases up to 300 °C.

The fan shall be able to provide sufficient gas flow even when deformation of the duct reduces its cross-sectional area by up to 25 %. Any larger decreases in cross-sectional area are almost inevitably accompanied by an integrity failure and, therefore, this can be disregarded for determining the fan capacity.

The regulation of the gas flow can be achieved by installing a flow-rate controller just before the fan.

A.3 Notes on test specimens

A.3.1 Design

The test specimen should be representative of duct installations in practice.

The cross-section sizes have been selected to cover the most common sizes of ducts used in air-distribution systems.

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It is recommended that ducts should be tested with compensators where expansion or contraction is likely to be significant. This means that joints, suspension and fixing devices, bolts and other hardware should be included and mounted in accordance with the manufacturer's instructions. The distance separating joints and the span between supports should be sufficient to enable interpolation within a range of other smaller dimensions to be made.

In some situations, the furnace can be too small to reproduce a relevant fire exposure in a particular duct assembly. This means that the duct assembly used in practice can need to be modified in order to fit it into the furnace.

In most cases, the largest ducts likely to be tested are those that can be accommodated in the furnace whilst maintaining the specific velocity in the duct of 3 m/s. Unjustifiable extrapolation to ducts restrained in a different manner, supported at greater intervals or of a larger size should not be made. Care should be taken when making any assessment of the performance of ducts that do not entirely conform in practice with the conditions represented in the test. Larger cross-sections of ducts may be tested, provided any surface of the duct is not closer than 500 mm to the furnace walls, floor or roof.

Distortion of rectangular ducts is generally more severe than distortion of square or round ducts. The longest side of the horizontal specimen should normally be orientated horizontally in the furnace.

This part of ISO 6944 requires the testing of a minimum length of 4,0 m for horizontal ducts and 2,0 m for vertical ducts inside the furnace and 2,5 m and 2,0 m, respectively, outside the furnace. These lengths have been chosen in order to use the fire-test furnaces available in most countries.

A.3.2 Thermal elongation, shortening and restraint forces

A.3.2.1 Effect on supporting constructions

During fire exposure, the ducts can expand or shrink due to high temperatures. This can cause premature failure of a non-loadbearing, lightweight partition if the duct is fixed to it or butts against it. The expansion or contraction of the duct applies a force to the supporting construction.

A.3.2.2 Effect on joints, attachments and other devices

During a fire test, joints, attachment devices and a representative wall or floor with fire stopping are considered as parts of the duct system being evaluated. Alternative joints, attachment devices, fire stopping and other devices should not be used unless it can be shown that the performance with respect to integrity is not worse and that the force on the wall or floor resulting from expansion or contraction is not greater.

A.3.2.3 Restraint

In some end-use situations, horizontal ducts, with or without applied fire protection outside the fire compartment, are subject to rigid constraint against elongation. This can result from building works, e.g. a wall against which the duct abuts, or because the rest of the duct assembly outside the fire compartment itself provides a restraint, e.g. ducts with short, rigid supports.

In these situations, the full restraint is reproduced in duct. This is provided (2 000 ± 50) mm from outside the furnace and also at the end of the duct inside the furnace. The restraint in the furnace is provided either by the furnace wall or by an independent structure.

If an independent structure that requires the sealed end of the duct to pass through the wall of the furnace is used, any seals provided between the duct and the furnace wall for this purpose are not subject to evaluation against the criteria of integrity or insulation.

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A.4 Notes on test conditions

A.4.1 Temperature/time development

The ducts are exposed to the furnace curve specified in ISO 834-1. This is intended to represent a fully developed fire.

A.4.2 Anticipated pressure ranges

The movement of air in a duct passing through a compartment on fire, and which has no openings to that compartment, can create an underpressure on the duct walls, which can encourage the fire to exploit any cracks that develop in the duct. An underpressure of (300 ± 15) Pa in horizontal duct A has been chosen as being realistic in this "worst case" situation and is the underpressure at which any integrity failure of the specimen within the furnace should be measured. Applications for higher pressure levels should be assessed on an individual basis.

A.5 Notes on procedure

A.5.1 Air velocity in duct B

The velocity in the duct is determined by multiplying the velocity recorded in the velocity-measuring station by the ratio between the cross-sectional area of the measuring station and the duct.

A.5.2 Evaluation of duct in overpressure conditions

The method of test does not describe a procedure for evaluating ducts in overpressure conditions. The field of direct application allows the result of a test to apply up to an overpressure condition of 300 Pa. If, in practice, part of a duct system is subjected to a higher overpressure, then an additional evaluation may be carried out. This may be undertaken by reversing the fan and subjecting an additional duct A specimen to the specified overpressure. All other procedures and requirements for duct A should be followed.

A.5.3 Insulation and integrity

The procedure includes periods during which the fans are running, interrupted by periods when the "fan off" situation is simulated (duct B). The regime is used to enable a check of the insulation and integrity properties to be made in various typical circumstances, but it is not representative of conditions in practice as far as any one duct is concerned.

Assuming failure of the ventilation fan in the event of a fire, the temperature of the gases within an insulated duct exposed on the exterior to fire conditions rises due both to the heat transfer through the duct wall and to any failure in integrity.

In the event of a fan continuing to operate, the overpressure from a supply fan normally exceeds the buoyancy pressure of the fire, preventing fire gases entering the system; any negative pressure differential maintained by an extraction fan serves only to assist the evacuation of hot gases to the atmosphere.

A.6 Notes on performance criteria

The importance of the various failure criteria of integrity, insulation and leakage can vary according to whether the duct is a normal ventilation duct or a "kitchen extract" duct. For kitchen extraction ducts or where internal combustible linings are used, additional temperature measuring points have been specified, together with a criterion of 140 °C/180 °C, to reduce the possibility of ignition of combustible materials inside the duct when the duct is exposed to an external fire.

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A.7 Use of alternative elbow

This part of ISO 6944 provides for two alternative designs of elbows; see Figures 2 and 6. It is suggested that the most appropriate design be selected, based on the two examples shown.

A.8 Avoidance of flame impingement

In order to minimize the number of tests, it is permissible to increase the number of samples being tested at one time. It is necessary, in some cases, to test ducts of a larger cross-section. In both these circumstances, it is important to avoid flame impingement from the furnace burner.

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Bibliography

[1] EN 1366-1, *Fire resistance tests for service installations — Part 1: Ducts*

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