# Examination of the fire resistance requirements for ducts and dampers

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## Executive Summary


The overall aim of this project was to assess the fire resistance of ducts and the effectiveness of dampers and to produce best practice guidance for ducts and dampers including installation details. The project originated from questions that have arisen concerning the adequacy of appropriate guidance. In particular, the significance of a number of factors in influencing the fire performance required systematic study and the results of the work evaluating to establish any impact upon the existing guidance.

The primary source of advice on the fire protection of ducted air distribution systems within the UK is BS 5588 - 9, Fire precautions in the design, construction and use of buildings, Part 9 - Code of practice for ventilation and air conditioning ductwork. From the literature review and discussions with Industry, it is clear that many specialist publications also rely on this standard. The general view was that BS 5588 part 9 could be further developed into a stand-alone definitive guide on the use of ventilation and air conditioning ductwork in relation to fire safety and fire protection. Further, any proposals to incorporate this into BS 9999 should be avoided.

All the data presented from UK and USA relates to fires which entered the HVAC system. Data from both the London Fire Brigade and the USA give some indication of fires that go beyond room of origin. However, it should be noted that the room of origin may not be the compartment in terms of the Building Regulations. Only about 10-15% of fires appear to go beyond the room of origin. Fire tends to spread through a building in a number of ways, including through the HVAC system.

Further, examination of fire loss reports has tended to indicate that kitchen extract systems pose a significant risk primarily in terms of property loss. This is probably due to the build-up of grease inside the duct. Due to the these findings, it is suggested that more guidance on issues associated with management and maintenance of kitchen extract ducts would be useful.

A comparison of the different test methods available for assessing the performance of ducts and dampers, including the new European approach was carried out. Some of the limitations of the different approaches are presented.

A detailed experimental programme of work was carried out during this project which included a fire resistance test plus a series of activation tests.

The results of this work showed that dampers vary in terms of their activation characteristics. In the early stages of a developing fire, this project has indicated that dampers relying only on fusible links may not shut in a fan-off situation because the gas temperatures recorded at the fusible link at the damper position may be below the operating temperature of the fusible links (70ºC).

In some cases, it has also been shown that dampers may not close in the fan-on situation and this is because the gas temperatures recorded at the fusible link at the


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damper position may be below the operating temperature of the fusible links (70ºC). This is partly dependent on the position of the fusible link within the duct.

In some applications, it is therefore considered that fire and smoke combination dampers intended to prevent the spread of smoke and fire that are activated only by fusible links may not be suitable.

The multi-blade, circular single blade and intumescent fire dampers functioned extremely well in the fire resistance test which was designed to replicate three typical damper/duct/wall installations. All dampers closed/sealed and were able to provide the required fire resistance. Therefore, in a post-flashover fire situation, as represented by the fire resistance test, our work has shown that dampers can close and contribute to the maintenance of compartmentation.

The results did highlight the importance of the issues associated with the installation of duct and damper systems showing that there are a number of significant variables that influence the fire performance in a test.

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# 1 Introduction

This project was developed in response to a request from ODPM Building Regulations Division to critically examine the Fire Resistance requirements for dampers and ducts, ODPM Contract reference CI 71/5/6, BD 2454. This project is commissioned under the ODPM Fire Safety Research Framework Agreement with the BRE led consortium with Buro Hapold/University of Ulster as Partners.

Over a period of time, some questions have arisen concerning the adequacy of appropriate guidance in relation to dampers and ducts. In particular, the significance of a number of factors influencing their fire performance required systematic study and the results from the work evaluating to establish any potential impact on the existing guidance. In relation to Approved Document B (AD B) of the Building Regulations 2000, the guidance is currently provided in the context of two particular areas;

- Part B1 – Means of escape and warning
- Part B3 – Internal fire spread (structure)

In addition, the primary source of advice on the fire protection of ducted air distribution systems within the UK is BS 5588-9, Fire precautions in the design, construction and use of buildings-Part 9: Code of Practice for ventilation and air conditioning ductwork. This project sought to identify any limitation in the standard including consideration of inclusion of the new European standards where appropriate, as well as any supporting codes identified during the project.

It should be noted that the project concentrated on the fire protection of HVAC systems. It did not include consideration of smoke extraction systems although the methods of test used did provide information on gas leakage, but only in the context of containment of hot gases.

This report summarises the work carried out during this project. This includes a literature search and review of fire loss reports and data from actual fires relating to fires involving HVAC systems from UK and US sources which sought to identify relevant trends in performance during different fire situations. In addition, the results of the experimental programme are presented. The experimental work was carried out in two stages, one stage looked at the fire resistance of three different duct and damper installations built to current industry based codes. The second stage consisted of a detailed examination of the activation of dampers contained within the ductwork when exposed to developing fires.

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## 2 Description of the project

The overall aim of this project was to assess the fire resistance of ducts and the effectiveness of dampers and to produce best practice guidance for ducts and dampers including installation details.

The specific objectives of this project were to;

- Undertake a critical examination of current regulations and codes relating to fire protection of HVAC systems and identify any potential areas where improved guidance may be given.
- Identify aspects that may particularly influence fire performance such as speed of operation, orientation of duct, hanger spacing and type of wall or floor that the duct/damper is installed in.
- Advise regulators what changes or additional guidance in supporting guidance to regulations was necessary.
- Matters relating to any limitations in test methods to be fed directly into CEN TC 127 as part of the UK contribution to that committee.

The project was supported by a Steering Group (see Appendix A). The contributions from the Steering Group members and the organisations that they represent are all gratefully acknowledged.

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# 3 Literature Search

## 3.1 Review of National Regulations and Supporting Guidance

### 3.1.1 Approved Document B

The guidance provided in AD B - Fire safety, amended 2002, is summarised below.

#### 3.1.1.1 Mechanical ventilation and air conditioning systems

In clause 6.46, B1, it states that any system of mechanical ventilation should be designed to ensure that in a fire, the air movement in the building is directed away from protected escape routes and exits. Alternatively, the system may be closed down (or appropriate section of it). Reference made to recirculating air in BS 5588-9, Fire precautions in the design, construction and use of buildings, Part 9: Code of Practice for ventilation and air conditioning ductwork .

In clause 6.47, cross reference also made to BS 5588:Part 6, Code of practice for places of assembly.

Clause 6.48 requires that where a pressure differential system is installed, ventilation and air conditioning systems in the building should be compatible with it when operating under fire conditions.

Clause 6.49 references BS 5720 Code of practice of mechanical ventilation and air conditioning in buildings for guidance on the designs of mechanical ventilation and air conditioning plant.

#### 3.1.1.2 Protected shafts

In 9.37, ducts are allowed in protected shafts. Reference to allowed openings in protected shafts are allowed for a ventilation duct, provided it meets the provisions of section 11. (See 3.1.1.1 above).

#### 3.1.1.3 Pipes for oil or gas, and ventilating ducts in protected shafts

In clause 9.41, B3, it states that if a protected shaft contains a stair and or a lift, it should not also contain a pipe conveying oil (other than in the mechanism of an hydraulic lift) or contain a ventilating duct (other than a duct provided for pressurizing the stairway to keep it smoke free or a duct provided solely for ventilating the stairway).

#### 3.1.1.4 Dampers and ducts

Dampers or ducts are not specifically referenced in Table A1, except for duct described in paragraph 10.14e.. This relates to openings in cavity barriers and unless ducts that pass through are fire resisting, they must be fitted with suitably mounted automatic fire dampers. No guidance is given on what may be regarded as “suitably mounted.”

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### 3.1.1.5 Ventilation

Ventilation is referenced in 11.10, B3,. This refers directly to BS 5588-9, Fire precautions in the design, construction and use of buildings, Part 9: Code of practice for ventilation and air conditioning ductwork. It is stated that this code provides a number of alternative approaches to maintenance of compartmentation and any one of these is equally acceptable.

### 3.1.1.6 Flues

Flues from appliances used for ventilation purposes are covered in 11.11 but are outside the scope of this project.

### 3.1.1.7 Basement car parks

Provisions for mechanical ventilation of basement car parks is referred to in 12.7, but apart from a reference to ductwork and fixings to have a melting temperature of not less than 800°C, there are no relevant requirements relating to this project.

### 3.1.2 Technical Standards, Scotland

Clause D5.1, Meets the provisions of BS 5588: Part 9: 1999 Section 3 or

i) is provided, where the ventilating duct passes through an element of structure, with an automatic damper or shutter or other sealing device which in the event of fire, will close to maintain the fire resistance required for the element of structure, and prevent the flow of air or hot gases, except – an automatic damper or shutter or other sealing device is <u>not</u> required in the case of a ventilating duct passing through a cavity barrier where the duct is constructed of mild steel at least 1.2mm thick which is continuous through the cavity on both sides of the barrier; or

ii) is of a construction or within a construction which has the same fire resistance as the element of structure and the duct is provided at each point where it or the construction enclosing the duct no longer has the same fire resistance as the element of structure with an automatic damper or shutter or other sealing device, which in the event of fire will close to maintain the fire resistance, for integrity only, required for any element of structure through which it passes or

iii) passes through a compartment wall or compartment floor and has openings within only one compartment of the building and in any other compartment has at least the fire resistance required for the compartment wall or compartment floor; or

iv) is a non-combustible duct for mechanical extraction which passes through a separating floor of a building of purpose group 1 and serves only sanitary accommodation, the vertical part of the duct having at least the fire resistance, or being within a construction which has at least the same fire resistance, required for the separating floor and the branches to the duct being shunt ducts which enter the main duct not less than 900mm above the inlets and

v) in any case is provided with extract grilles with non-return shutters

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Clause E7.6 requires that the ventilation system must be of suitable design and construction and as far as possible, air movement is directed away from protected and unprotected zones. For purpose group 2 (excluding hospitals and dwellings) a duct serving sleeping accommodation must meet the requirements of D5.1 if the duct penetrates above or below the ceiling. Any damper must be activated by smoke.

### 3.1.3 Technical Booklet E (Northern Ireland)

#### 3.1.3.1 General

In the event of a fire, mechanical ventilation systems are required to shut down or air movement in the building is required to move away from escape routes. Where air re-circulates, it shall comply with BS 5588: Part 9: 1989. Where a pressurization system is installed in a protected stairway all mechanical ventilation and air conditioning systems in the building shall be compatible with it when operating under fire conditions.

Tests for fire resistance shall be in accordance with, in the case of –
**(iv)** ventilation ducts – BS 476: Parts 20 and 24: 1987.

Where an element or structure or other component forms part of more than one building or compartment, the fire resistance of that element or component shall be not less than the greater of the relevant provisions.

Fire-resisting ducts are required to have a minimum fire resistance of 30 minutes (integrity).

#### 3.1.3.2 Pipes for oil or gas and ventilation ducts in protected shafts

**Clause 3.20** Where a protected shaft contains –
(ii) a ventilation duct, other than a duct provided for the purposes of pressurizing the shaft to keep it free from smoke in the event of fire.

#### 3.1.3.3 Ventilation ducts penetrating compartment walls, compartment floors, protected shafts and cavity barriers

**Clause 3.35** Where a ventilation or air conditioning duct passes through a compartment wall or compartment floor (unless it is within a protected shaft) or through a protected shaft or a cavity barrier it shall comply with one of the methods for maintaining the fire resistance of the wall, floor or barrier given in BS 5588: Part 9: 1989.

#### 3.1.3.4 Flues and heating appliance ventilation ducts penetrating compartment walls and compartment floors

**Clause 3.36** Where a flue, a duct containing more than one flue, or an appliance ventilation duct –
**(a)** passes through a compartment floor or compartment wall; or
**(b)** is built into a compartment wall, the walls enclosing the flue or duct shall have a period of fire resistance of not less than half that required for the compartment wall or compartment floor and be of non-combustible construction, as shown in Diagram 3.12.

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### 3.1.4 Fire code, Health Technical Memorandum 81

#### 3.1.4.1 General

Ventilation ductwork should comply with BS 5588: Part 9 and HTM 2025-ventilation in healthcare premises . Ductwork passing through compartment and sub-compartment walls should be provided with fire dampers.

In diagram Figure 14 i, note ii, reference is made to actuation using a fusible link operating at 74°C (also clause 6.83). This would tend to suggest that an intumescent damper is not permitted. An alternative is shown in diagram figure 14 ii, where the ductwork only serves one compartment, but passes through sub-compartments, a damper is not required if the duct has fire resistance of 30 minutes when tested to the relevant parts of BS 476.

Where a duct passes through a fire hazard room, but does not serve it, fire dampers are not required but the duct must have fire resistance of 30 minutes in respect to integrity and insulation. (figure 15 i.) As an alternative to this, a fire rated ceiling having a minimum fire resistance of 30 minutes (including light fittings) may be used (Figure 15 ii).

When ducts serve a hazard room, then fire dampers are required. (Figure 15 iii).

Ductwork passing through cavity barriers is covered in Figure 16, with both damper and fire resisting ducts being covered.

In clause 6.48, the document recognises that “the complexities of ventilation ductwork above operating departments mean that the provision of cavity barriers would seriously compromise service access and means of escape for maintenance staff”.

Clause 6.77 covers additional requirements for the operation of HVAC systems. Basic principles are covered in 6.78 which states that:

a) prevent a fire from entering or leaving the ductwork;

b) limit the spread of fire, smoke and other products of combustion within the ductwork

c) prevent a breach in the integrity of an enclosing fire-resisting element of construction where penetrated by ductwork

#### 3.1.4.2 Activation of fire dampers

Fire dampers passing through compartment walls should be actuated in accordance with BS 5588: Part 9 and by the operation of the alarm and detection system in the compartments either side of the compartment wall.

Activation by the alarm and detection system does not appear to be required for fire dampers used in ductwork passing through sub-compartment walls, cavity barriers and walls enclosing fire hazard rooms, where the thermal release method is considered adequate, see clause 6.82.

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#### 3.1.4.3 Operation of ventilation plant

In clause 6.84, it is stated:

"The ventilation plant should not be automatically shut down on the operation of the automatic fire alarm and detection system. The shut-down of the system should be under the direct control of the fire brigade and should be controlled from panels located either at department entrances or adjacent to the main fire alarm indicator panels"

#### 3.1.4.4 Fixing of fire dampers

The fixing of fire dampers is covered in Appendix D of Fire Code, Technical Memorandum 81..

**D1.** All fire dampers should be installed so that they maintain their integrity against the passage of fire for the required period of fire resistance. A fire damper should be adequately fixed into or to the construction it is protecting. A fire damper which is supported only by the ductwork in which it is located, or by timber battens, frames or other methods which do not provide the fire resistance required, is not acceptable.

**D2.** Fire dampers provided in 30 minute fire-resisting ceilings should be adequately supported either by the ceiling or from the structural soffit. In the ceiling situation it is also essential to ensure that the integrity of the fire-resisting ceiling is maintained. It is not acceptable to form an opening, install a diffuser or grille and fit a damper above, if the gap between the ceiling opening and the fire damper does not achieve 30 minutes fire resistance.

## 3.2 Test methods

### 3.2.1 Comparison between tests

A comparison between the methods of test used for fire resisting dampers is presented in table 1 below..

**Table 1**
**COMPARISON BETWEEN TEST METHODS FOR FIRE DAMPERS**

| BS 476:Part 8<br>BS 476:Part 20 | BS EN 1366-2<br>ISO 10294-1,2 and 3 |
|---|---|
| No standard is directly available for testing fire dampers so ad-hoc methods used. | EN and ISO standards available for specifically testing mechanical fire dampers. |
| No leakage measurements taken so limited data available that is relevant to end-use conditions. | Leakage measurements are an essential part of establishing the integrity criterion. A more onerous leakage criterion is available when smoke leakage is considered an important factor. |
| Dampers not tested in a duct. | Requirement is that damper is tested installed in a representative duct. Several different locations of damper in duct are included to better represent end-use conditions. |
| No application rules. | Some guidance on field of application rules. |

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| | |
|---|---|
| | More extensive rules are currently being drafted in CEN TC 127. |
| Little relevance to end use conditions. | Tests try as far as possible to be representative of HVAC practices with variations such as higher under-pressure conditions being covered as an option for special applications. |
| No opening and closing test prior to fire test. | An opening and closing test is undertaken prior to the fire test. This represents the minimum amount of opening and closing cycles a damper would be subjected to in its operating life. |

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### 3.2.2 Brief description of damper tests

The test method prescribed by BS ISO 10294-1, Fire resistance tests, Part 1, Test method and BS EN 1366-2, Fire resistance tests for service installations, Part 2 Fire dampers are essentially the same and, in summary, includes the following:

- The damper (of the largest size to be manufactured as a single section) is installed in a wall, partition or floor in the manner that would normally be used for installation on site
- A section of plenum/duct is attached to the damper unit on the non-furnace side. This is in turn connected via measuring stations to a high temperature fan
- Prior to the test the damper is subjected to 50 closure cycles in the manner that it would normally close on receipt of a fire signal
- The cold leakage of the damper is tested at various under pressures above and below the test pressure (normally 300Pa)
- The test is started with the damper open – i.e. it is required to close due to exposure to the fire. There is a nominal velocity of 0.15m/s passing through the damper controlled by the fan.
- The furnace is started and the damper having closed, the leakage is recorded from 5 minutes in to the test for the duration of the test. Adjusting the fan controls the pressure drop across the damper and this is normally maintained at 300Pa.
- The furnace follows the standard fire test curve of either ISO 834-1 or EN 1363-1
- The integrity of the joints between the damper and the wall or partition is regularly assessed for gaps etc.

The basic concept is illustrated below:

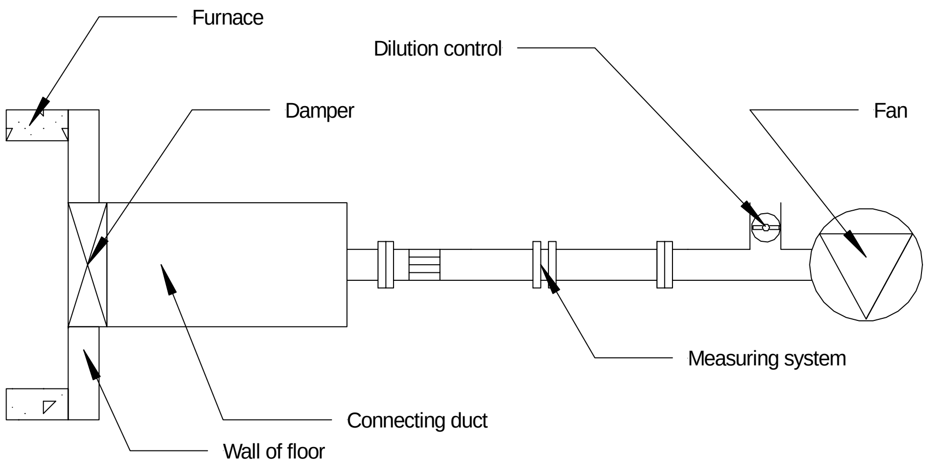


**Figure 1 Example of general test arrangement used in ISO 10294-1 and BS EN 1366-2**

Note: A test method based on the above has also been developed in ISO for intumescent fire dampers, ISO DIS 10294-5.

The results from the EN 1366-2 test method are used to derive a classification for a damper. The classification is in accordance with prEN 13501-3. Classification using data from fire resistance tests, Part 3 Components of normal building service installations and is designated E or ES where,

E is integrity and is defined as leakage during the fire test of less than 360m3/hr/m2 and no loss of integrity where the damper penetrates the wall or floor and

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S is the leakage and is defined as leakage during the test of less than 200m3/hr/m2 and no loss of integrity where the damper penetrates the wall or floor. In addition, this same leakage requirement must be satisfied for a second unit of the smallest section to be manufactured and this is measured at ambient conditions only.

#### 3.2.3 Limitation of damper tests

Generally speaking, the ISO/CEN method is a more representative test method and obviously better standardised than the original BS 476 ad-hoc methods used. However, there are some potential limitations and these include:

The damper is normally directly exposed to the furnace, with no duct section being within the furnace. In practice it may be sited well away from the fire and the test provides no guidance on potential response times in such situations or where it is exposed to relatively cool gases in the early stage of a fire development. Whilst dampers connected to a smoke detector system may be assumed to operate quickly, the response times of fusible link triggered dampers or intumescent dampers in a variety of situations will be more variable.

The duct section connected to the damper in the test is really part of the test rig rather than a representative and realistic length of typical HVAC duct section. The interaction of an unprotected duct and a damper may not therefore be properly evaluated.

### 3.3 Important Codes

#### 3.3.1 BS 5588-9, Fire precautions in the design, construction and use of buildings, Part 9: Code of Practice for ventilation and air conditioning ductwork

Approved Document B relies on BS 5588 part 9:Code of practice for ventilation and air conditioning ductwork to provide details of appropriate methods for protection of ducted systems for Heating, Ventilating and Air-conditioning (HVAC).

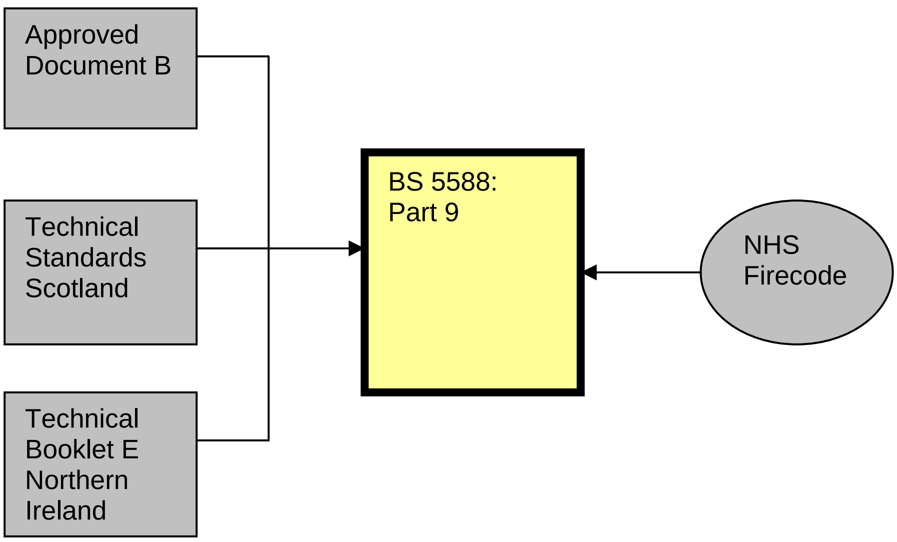


**Figure 2. Regulatory Framework**

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In addition, the principle codes relating to HVAC also refer directly to this code.

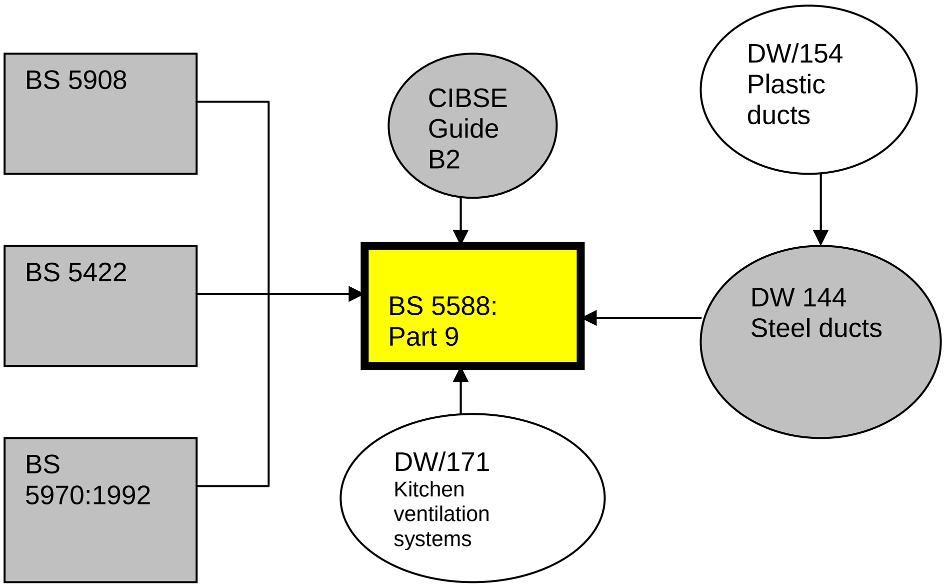


**Figure 3. Basic Code framework for HVAC systems**

There are three alternative systems for the fire protection of HVAC systems that are provided within BS 5588 part 9.These are not mutually exclusive and very often combinations of the methods are found in ductwork systems. The three methods are as follows:

Method 1 – Protection using fire dampers

This method relies upon fire dampers located within a duct at the point of penetration of a compartment wall or floor or the enclosure of a protected escape route, activating automatically to isolate a fire, when it occurs.

Method 2 – Protection using fire resisting enclosures

In this method a ventilation duct is protected by an enclosure that is constructed around it to provide fire resistance equivalent to that required of the structure that it penetrates. Fire dampers are only required where the ductwork leaves the fire resisting enclosure.

Method 3 – Protection using fire-resisting ductwork

The ductwork itself or with applied protective material achieves the required fire resistance.

It is the principles embodied within these methods that form the basis of design of HVAC systems where fire protection is an issue. Generally, BS 5588 part 9 provides more guidance for situations when dampers are to be used. This may be a reflection of the relative market share of dampers compared to fire resisting ducts. However, the document could usefully provide more guidance for situations when fire resisting ducts are specified.

The standard recommends that where the use of the building presents a high or special life hazard consideration should be given to the actuation of fire/smoke dampers by smoke detectors.

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The use of ducting in more specialist applications is covered in other standards, such as:BS 5908, Code of practice for fire precautions in the chemical and allied industries, BS 5422, Method for specifying thermal insulating materials for pipes, tanks, vessels, ductwork and equipment within the temperature range -40ºC to + 700ºC and BS 5970:1992,Thermal insulation of pipe work and equipment (in the temperature range -100ºC to +870ºC.

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### 3.3.2 Heating and Ventilating Contractors Association (HVCA) Codes

The principle code used by the HVCA is DW/144, Specification for sheet metal duct work. This relates to a detailed specification of steel ducts and it has been reported during our investigation that it tends to be used in conjunction with the CIBSE guide B2, Ventilation and air conditioning.

DW/144 appears to offer no guidance relating to controlling deformation of unprotected steel ducts that are directly exposed to fire, or to quantify such deformation based on the performance of the fire damper and the area of the wall or floor around the penetration point in order to maintain the required fire resistance.

With respect to smoke control dampers, no suitable leakage criterion for judging their suitability are given, but it could be possible to link to the leakage classification given in prEN 13501-3 as the "S" classification. It is also possible that the term "smoke control damper" will need reviewing in the near future as it maybe confused with dampers used in smoke extraction systems.

There appears to be no reference to the fact that when mechanical fire protection devices such as fire resisting dampers, roller shutters and curtains are connected to a smoke detection or alarm system, a faster response may be achieved than reliance on fusible links. However, such a benefit is clearly dependant on the existence of a suitable alarm/detection system.

Plastic ducts are covered in DW/154, Specification for Plastics Ductwork,. These are used particularly where contaminated, corrosive or otherwise exceptional fumes are concerned. There is very limited guidance available on how to maintain compartmentation when using this type of ductwork. It is suggested that externally mounted intumescent crush type devices are used, but these tend to be limited to pipe closing applications.

DW/171, Standard for Kitchen Ventilation Systems is a standard for kitchen ventilation systems. It states that in accordance with BS 5588: Part 9, fire dampers must not be used in the extract system from a kitchen as the fire authorities may use the extract fan to clear smoke from the kitchen.

### 3.3.3 CIBSE Guide B2 – Ventilation and air conditioning

This standard makes a recommendation that dampers are used to protect kitchen extract systems in domestic premises.

With respect to hospitals, patients are dependant to varying degrees on the staff for evacuation in the event of fire, combined with various fire risk rooms (no clear definition of fire risk rooms could be found). This is stated to result in a higher than normal requirement for sub-compartments and compartmentation of risk rooms. CIBSE Guide B2 recommends minimising the number of fire and smoke-operated dampers by appropriate routing of ducts when compartmentation requirements are determined. The reason for this recommendation is not discussed but may relate to the requirements given in the Health Technical Memorandum 81.

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# 4 Review of fire reports and data

## 4.1 Case studies – UK

### 4.1.1 FPA data

Table 2 is a summary of data that have been obtained from the FPA data base when “fire in ductwork” was the search subject:

**Table 2**
**FPA data, UK**

| Date | Special features' | Occupancy | Point of origin |
|---|---|---|---|
| 28-Mar-96 | Spark from Kebab unit ignited fat deposits in extraction system from cooking appliance | Hotel | Kitchen |
| 26-Jan-95 | 50 % possibly due to residue dust in ducting & 50% possibly due to loose connection to motor operating extractor | Food industry | Production area |
| 26-Apr-95 | radiated heat in extractor flue of oil fired oven | Bakery | Production area |
| 07-Jul-95 | radiated heat from fish frying range ignited residue fat in the extraction unit, 289.41 | Shop | Kitchen |
| 27-Aug-95 | youths smashed roof extract and set fire to extract fan assembly | School | External structure |
| 18-Sep-95 | Fault in extraction plant | manufacturer | Production area |
| 13-Jul-94 | build up of extraction dust around 1 rotating cutter | Furniture industry | Production area |
| 22-Nov-94 | Overheated extractor fan, electrical fault | Engineering industry | Workshop |
| 25-Feb-92 | Wood dust allowed to build up in commercial extractor unit heat from motor caused fire | Furniture Industry | Production Area |
| 02-Oct-92 | Ignition of fat deposits in extraction duct | Restaurant | Kitchen |
| 16-Jan-89 | friction overheating of sanding machine ignited sawdust waste/ by-product in extractor trunking | Furniture industry | workshop |
| 03-Mar-89 | ignition of dust in extraction plant | workshop | unknown |
| 01-Sep-90 | fire started in sawdust extraction plant | Timber Industry | Extraction plant |
| 16-Jul-96 | Extractor fan overheated and ignited wood stain | Furniture industry | Production area |
| 09-Feb-97 | ignition of kitchen extraction equipment | Hotel | Internal structure |
| 07-Apr-97 | fire started in dust extraction unit serving shot blaster | Factory | Production area |
| 20-Feb-97 | ignition of solvent in extract flue in spray booth | Factory | Production area |
| 17-Apr-97 | dust extraction unit possible ignition of static electricity | Furniture industry | Internal structure |
| 25-Mar-98 | ignition of accumulated dust in extraction ductwork | Factory | Internal structure |
| 24-Oct-98 | fire started within extraction system | Restaurant | Kitchen |
| 07-Aug-00 | Ignition of accumulated fat in extract ducting - other insurers Royal & Sun Alliance | Restaurant | Kitchen |
| 21-Feb-01 | Air extraction hood over gas fired kitchen range | Restaurant | Ducting |

The FPA data was not that comprehensive compared to the NFPA data in respect to fires involving the HVAC system. Clearly, both restaurants and factory buildings have been shown to be particularly vulnerable. Analysis of the above tends to suggest that ducting fires are only listed by FPA when they are the point of initiation or the seat of the fire.

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### 4.1.2 Data from London Fire Brigade

The data presented in table 3 were obtained from the London Fire Brigade. They have been examined and the analysis has found the following information based upon property type which involved the HVAC system:

#### 4.1.2.1 Property type

**Table 3**
**London Fire Brigade data-fires involving HVAC systems**

| Property type | Number of fires involving HVAC system | Number of fires that spread beyond room of origin |
|---|---|---|
| Assembly | 78 | 17 |
| Car park | 2 | 0 |
| Commercial | 3 | 2 |
| Dwelling | 357 | 43 |
| Industrial | 40 | 5 |
| Institutional | 17 | 2 |
| Medical | 20 | 2 |
| Office | 79 | 0 |
| Other | 11 | 1 |
| Shop | 90 | 18 |
| Storage | 3 | 1 |
| **Total sample** | **700** | **73** |

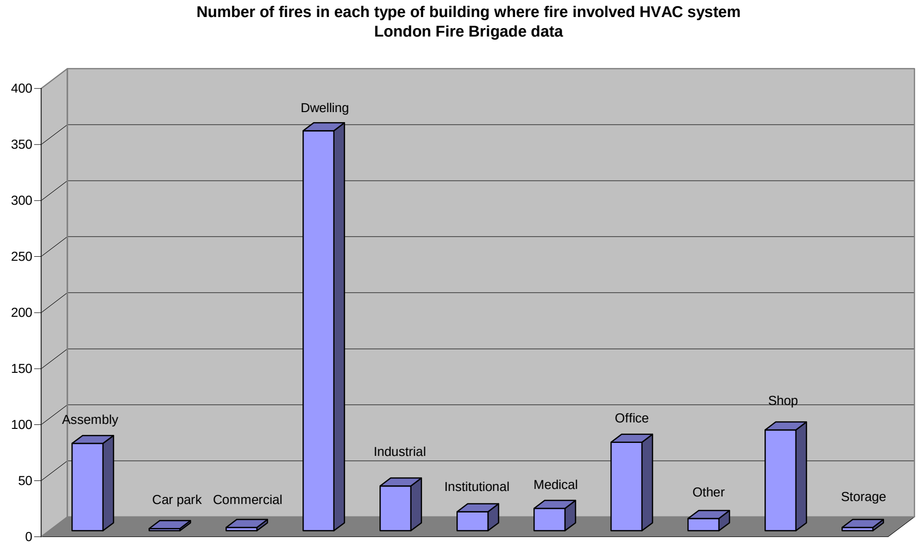


**Figure 4 Breakdown of fires involving HVAC system-LFB data**

The data presented in figure 5 show the proportion of fires where it was reported that fire involved more than one room, and ignoring the purpose groups where less than 15 fires occurred, the data supplied yielded the following:

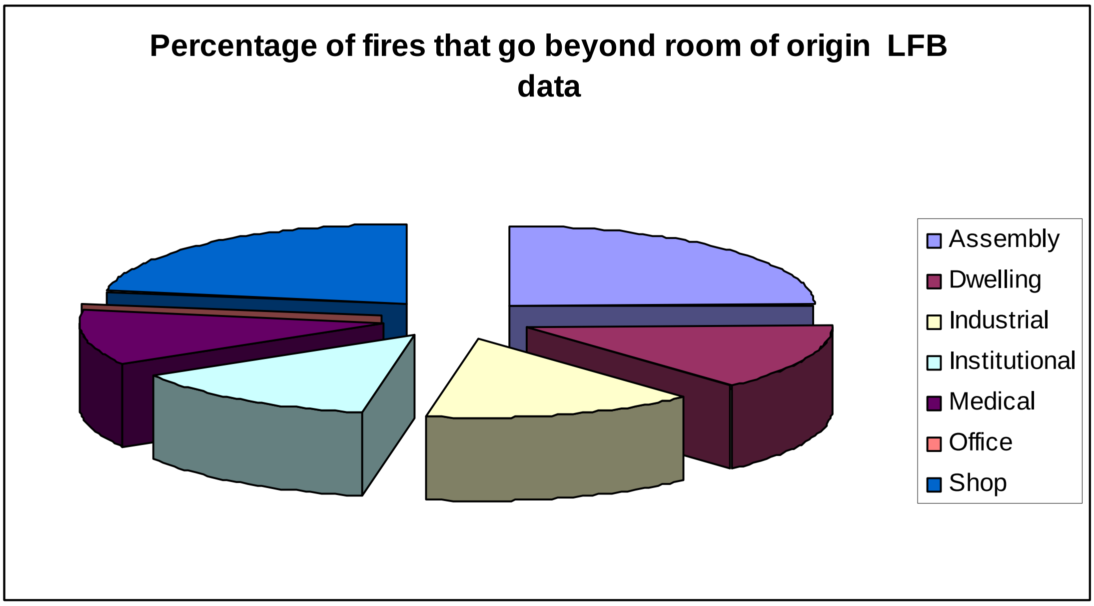


**Figure 5. Breakdown of fires that go beyond room of origin based on purpose group**

It should be noted that in relation to offices, no fire appeared to have gone beyond the room of origin. The reason for this is not clear, but it could possibly be associated with the current trend to open plan office types.

#### 4.1.2.2 Cause of ignition where fire involved ductwork

Table 4 is a summary of the information relating to cause of ignition where the fire involved ductwork.

**Table 4**
**Causes of ignition involving ductwork**

| Group ref | Material first ignited | Number of fires | % of total sample |
|---|---|---|---|
| 1 | Electrical wiring/insulation | 169 | 24 |
| 2 | Fat/oil/food residue/soot/grease/dirt | 105 | 15 |
| 3 | Fluff or dust or airborne particles | 64 | 9 |
| 4 | Extractor fan casing/vent casing/fan components/grille | 73 | 10 |
| 5 | Accumulated debris/refuse/rubbish | 22 | 3 |
| 6 | Electrical equipment/component | 39 | 6 |
| 7 | Flammable vapours, propellant | 9 | 1 |
| 8 | Air filter/dust filters | 11 | 2 |
| 9 | Insulation | 99 | 14 |
| 10 | Flooring, joists, timber boarding, plastic sheet, building components, sealants, wall panel, adhesive | 14 | 2 |
| 11 | Paint particles, paint | 2 | 0.3 |
| 12 | Natural gas | 1 | 0.15 |
| 13 | Furnishings, fittings | 22 | 3 |
| 14 | Storage, paper, tissue, tyres, scaffold boards | 11 | 2 |
| 15 | Unknown or not easily categorised | 59 | 8 |
| **Total** | | 700 | 100 |

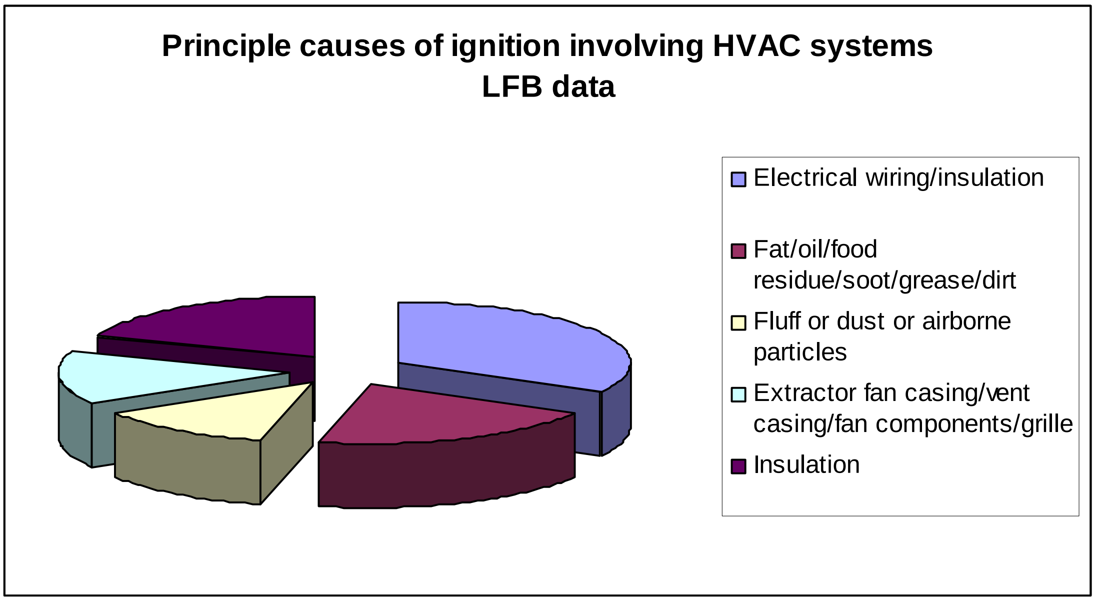


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**Figure 6. Principle causes of ignition involving HVAC systems**

Figure 6 ignores causes below 9% of the total sample and gives principle first material ignited that subsequently involves the air distribution system through the extract duct system.

### 4.1.2.3 Materials that made most contribution to fire spread

**Table 5**
**Materials that made most contribution to fire spread**

| Group ref | Materials that made most contribution to fire spread | Number of fires | % of total sample |
|---|---|---|---|
| 16 | Electrical wiring/insulation/trunking | 38 | 5 |
| 17 | Fat/oil/food residue/soot/grease/dirt | 84 | 12 |
| 18 | Fluff or dust or airborne particles | 10 | 1 |
| 19 | Extractor fan casing/vent casing/fan components/grille/air vents, plastic duct, air conditioner components, cooker hood | 141 | 20 |
| 20 | Accumulated debris/refuse/rubbish | 5 | 1 |
| 21 | Electrical equipment/component/appliance | 29 | 4 |
| 22 | Flammable vapours, propellant | 4 | 1 |
| 23 | Air filter/dust filters | 41 | 6 |
| 24 | Insulation | 16 | 2 |
| 25 | Flooring, joists, timber boarding, plastic sheet, building components, sealants, wall panel, adhesive, roof construction materials, ceiling, duct enclosure, timber ducting, door | 74 | 11 |
| 26 | Paint particles, paint/painted surfaces | 4 | 1 |
| 27 | Natural gas, petrol/fuel | 4 | 1 |
| 28 | Furnishings, fittings, room contents | 101 | 14 |
| 29 | Storage, paper, tissue, tyres, scaffold boards | 9 | 1 |
| 30 | Unknown or not easily categorised | 140 | 20 |
| **Total** | | 700 | 100 |

A significant number of fires in the assembly buildings involved either restaurants, cafes or public houses. A significant cause was ignition of grease or oil.

Many of the references to fan casings related to plastic fittings of the light duty type.

Figure 7 is for those materials that were stated to have been mainly responsible for fire spread, ignoring those that contribute less than 10% of the total sample and those where the material could not be identified.

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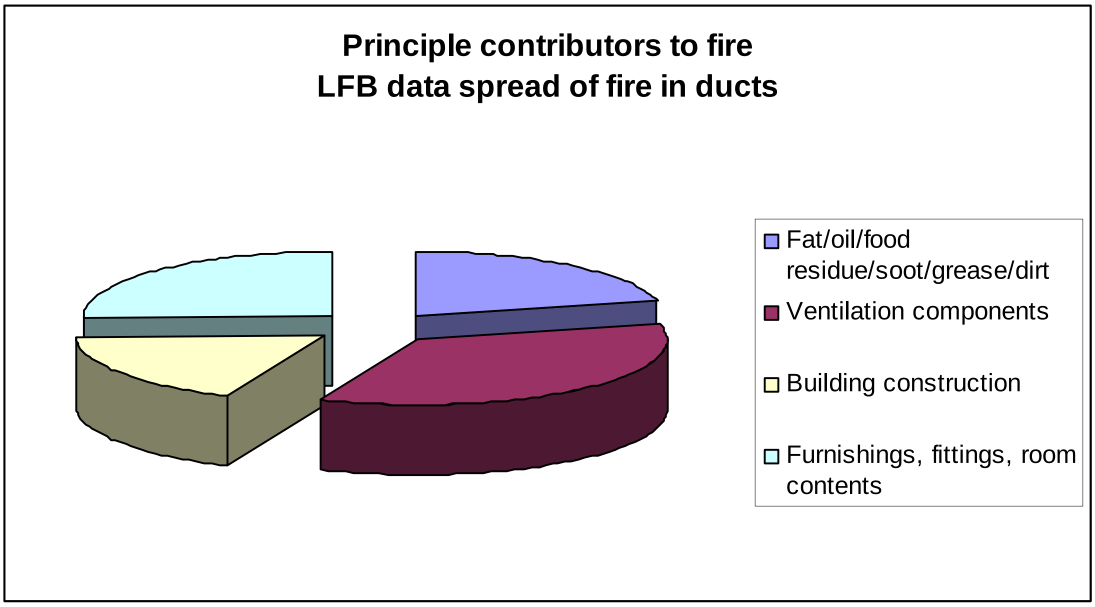


**Figure 7. Principle causes of fire spread in ducts**

## 4.2 Case studies from National Fire Protection Association, NFPA, USA

### 4.2.1 Athletic Club fire, February 5th 1992, Indianapolis, NFPA journal.

Fire spread because of combustible linings, but HVAC system not linked to smoke detector system and did not shut off. Believed that air from the operating HVAC system and natural ventilation increased the growth of the fire. Two fire fighters killed.

### 4.2.2 New York, February 26th 1993, NFPA journal

Fire caused by bomb blast in public car parking area. Burning cars provided high fire load. Smoke spread through HVAC ductwork, stairwells and elevator shafts. Fire damage limited to underground parking areas. Five people killed on the floor of origin and one on the floor above.

### 4.2.3 California, Supermarket, NFPA journal March/April 1991

Open access door in the HVAC duct allowed fire to spread horizontally, pushing smoke into occupied area. This however made early discovery of fire possible. The HVAC system also carried hot gases away from the sprinklers and delayed their activation. However, the sprinklers did prevent serious fire damage.

### 4.2.4 Montreal high rise, October 1986, Fire Journal

Fire spread through several routes but did spread through damaged HVAC ducting. Distortion of ducts pulled them away from floor slab. Fire spread included leaks through duct penetration holes, presumably indicating lack of or failure of the fire stopping system.

Reported that several dampers in the shaft enclosure walls were not closed. System not designed to shut down if fire detected.

### 4.2.5 Nursing Home, Arkansas, January 1984, Fire Journal

HVAC system did not comply with the provisions of NFPA 90A. A waiver was granted; this stipulated that smoke detectors were to close down the HVAC system if a fire was detected. However, at an inspection prior to the fire, the correct functioning of the detectors that should have closed the system down had not been verified. A sprinkler system had been installed but the water supply had been shut off because of damage to supply pipe-work.

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Fire spread from the TV room where the fire started, into the attic space above it through an aluminium grille connected to flexible fibreglass HVAC ductwork. Smoke was distributed from the HVAC system into the patient rooms.

The distribution of smoke through the HVAC system was linked directly to the use of corridors as return-air plenums. Corridors were stated to have become filled with intense heat and smoke. Two people died in the fire.

### 4.2.6 High-Rise Hotel, Virginia Beach, September 1974, Fire Journal

Whilst exhaust ducts leading from the bathrooms were provided with curtain-type, gravity-drop fire dampers designed to close when a link fused. One of these dampers failed to operate as intended. Although the fusible link fused, the retaining bands failed to fall away and prevented the damper closing. Fire spread into a corridor when the door leading to the fire was opened to attempt to fight the fire. One member of the hotel staff died in the fire.

### 4.2.7 Military Park Hotel, Newark, December 1965, Fire Journal

Fire and smoke spread throughout the building by means of sub-standard stair-wells and through vertical HVAC ducts not fitted with automatic fire dampers. The ducts from the units servicing the first to sixth storey were interconnected. The air conditioning unit spread smoke throughout the first six storeys. Two people died due to the fire.

### 4.2.8 Manufacturing plant, Virginia, November 1992, NFPA Journal

Fire spread into exhaust duct and was stated to have spread throughout the system. Fire walls contained the spread further. No fire dampers had been installed in the ductwork. Failure of aluminium ducting contributed to the spread.

### 4.2.9 Hotel, Ohio, Fire Journal March/April 1990

Fire and smoke spread through elevator shafts and the HVAC systems. The HVAC did not close down automatically once the fire was detected. Fire started in a sub-basement of the 29 storey hotel building. Smoke spread throughout the hotel and into an adjoining 49 storey office building.

### 4.2.10 High School, California, June 1981, Fire Journal

Fire originated in an office. A vertical ventilation shaft allowed the fire to reach an attic and crawl-space area. The fire then spread rapidly through the crawl-space area and downward through masonry ventilation shafts, involving the entire building.

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#### 4.2.11 Luxury Resort Hotel, Nevada, November 1980, Fire Journal

This serious fire claimed 83 lives. Fire started in a closed restaurant on the Casino level. Flashover occurred in this area. Fire and smoke spread to upper floors via elevators, stairways, shafts located at seismic joints and in the HVAC system.

## 4.3 Comments on above case studies

### 4.3.1 Fan operation

The importance of shutting off the fan quickly after the start of a fire is highlighted. If the fan is not shut off, the air can feed the fire as well as aiding the spread smoke and hot gases around the building.

### 4.3.2 Access doors into the HVAC system

There is a need to have self closing HVAC system access doors or at least a notice to say keep shut should be provided near the access door. This is because if an access door is left open, it will impair the operation of the HVAC system.

### 4.3.3 Limit distortion of duct

It may be important to ensure that the duct does not distort significantly. Therefore, the hanger system should be designed to continue to support duct under fire conditions without the hangers elongating significantly or fixings pulling away from floor (or wall).

### 4.3.4 Regular checking

The importance of regular checking of HVAC and fire protection systems is noted. Such checking could possibly have reduced the extent of fire spread in a number of cases reported above.

### 4.3.5 Return-air plenums

In one of the above cases, 4.2.5, The use of corridors as return-air plenums has been questioned. Further consideration is required to establish if similar issues would be related to ceiling spaces used for the same purposes..

### 4.3.6 Gravity type dampers

A question was raised regarding the ability of a gravity type damper to close due to link mechanism failure. Lack of servicing with this type of device may be an issue.

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### 4.3.7 Inadequately protected ducts

It was shown that unprotected ducts can allow spread of smoke throughout thebuilding. Failure of aluminium ducting was noted. However, the ducting was recognised as only one path for fire and smoke to spread,  other paths such as elevators, stairwells also vulnerable if under protected.

### 4.3.8 Standard of Fire Safety management and maintenance

Study of the above indicated that a significant common factor was poor fire safety management and maintenance of facilities.

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## 4.4 Fire loss data from the USA 1982-1996 (NFPA DATA)

Data from USA have been incorporated because whilst their regulatory system is different to that in the UK, the types of fire dampers used are similar and so the data from USA fires are considered relevant. However, it should also be recognised that the data do not make clear whether dampers were fitted within the HVAC systems or not.

### 4.4.1 Fires in sprinklered buildings that spread though HVAC system

The number of fires and percentage of fires in sprinklered buildings that have involved the HVAC system are summarised in table 6 below.

**Table 6**
**Fires that spread through HVAC systems where building sprinklered**

| Property type | Sprinkler operates | | Sprinkler did not operate | | Fire too small to activate sprinkler | |
|---|---|---|---|---|---|---|
| | Number of fires | % of fires | Number of fires | % of fires | Number of fires | % of fires |
| Restaurant | 30 | 16.3 | 20 | 45.5 | 70 | 14.4 |
| Factory | 60 | 34.9 | 5 | 13.2 | 50 | 8 |
| Office | 10 | 2.7 | 1 | 1.8 | 30 | 7 |
| Shop/store | 4 | 2 | 1 | 3.3 | 30 | 5.6 |
| Mall | 2 | 1.1 | | | 10 | 2.2 |
| Hospital | 4 | 2.1 | 1 | 3.4 | 60 | 13.8 |
| Prison | | | | | 10 | 1.5 |
| School | | | | | 20 | 2.5 |
| Church/Chapel | | | | | | |
| Vacant property | | | | | | |
| Nightclub | | | | | | |
| Residential parking garage | | | | | | |
| Other | 90 | 40.9 | 12 | 32.1 | 180 | 45 |
| Total* | 200 | 100 | 40 | 100 | 460 | 100 |

*relates to total reports, but sub totals not available in all cases.

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### 4.4.2 Fires in unsprinklered buildings that spread though HVAC system

The number of fires and percentage of fires in unsprinklered buildings (or where sprinkler status was unknown) that have involved the HVAC system is summarised in table 7.

**Table 7**
**Fires that spread into HVAC system and building not sprinklered or sprinkler status not known**

| Property type | No sprinklers | | Sprinkler status not known | |
|---|---|---|---|---|
| | Number of fires | % of fires | Number of fires | % of fires |
| Restaurant | 220 | 22.1 | 50 | 20.3 |
| Factory | 30 | 2.8 | 10 | 6.2 |
| Office | 90 | 10 | 10 | 7.9 |
| Shop/store | 60 | 5.8 | 8 | 4.3 |
| Mall | | | | |
| Hospital | 30 | 2.6 | 10 | 4.1 |
| Prison | | | 3 | 1 |
| School | 50 | 4.9 | 10 | 5.7 |
| Church/Chapel | 20 | 2.2 | 3 | 1.3 |
| Vacant property | 10 | 1.2 | | |
| Nightclub | 10 | 1 | 3 | 1.1 |
| Residential parking garage | 10 | 1.1 | | |
| Other | 440 | 47.5 | 113 | 48.1 |
| Total* | 970 | 100 | 220 | 100 |

### 4.4.3 Fires where spread into the ductwork was reported

The total number of fires where the fire was reported to have spread into the ductwork is presented in table 8 below along with the split between sprinklered and unsprinklered buildings.

**Table 8**
**Total fires which spread into ductwork**

| | Total | Percentage |
|---|---|---|
| Sprinklered | 700 | 37% |
| Un-sprinklered | 1190 | 63% |
| Total | 1890 | 100% |

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#### 4.4.4 Fires spreading into HVAC ductwork system by property type

Based on a detailed analysis of NFPA fire data, table 9 summarises the % of all fires by property type that spread into an HVAC ductwork system.

**Table 9**
**Total percentage of fires spreading into HVAC systems**
**From above NFPA data**

| Property type | % of fires |
|---|---|
| Restaurant | 23.72 |
| Factory | 13.02 |
| Office | 5.88 |
| Shop/store | 4.2 |
| Mall | 0.66 |
| Hospital | 5.2 |
| Prison | 0.5 |
| School | 2.62 |
| Church/Chapel | 0.7 |
| Vacant property | 0.24 |
| Nightclub | 0.42 |
| Residential parking garage | 0.22 |
| Other | 42.72 |
| Total | 100.1 |

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### 4.4.5 Extent of spread of fire

To give an indication of how many fires spread beyond the room of origin, the NFPA data has yielded the information summarised in table 10. It should be noted that room of origin is not necessarily the same as the compartment of origin as defined in AD B.

**Table 10**
**Extent of fire damage where fire spread into HVAC system**

| Extent of fire damage | Number of fires | Percentage of total |
|---|---|---|
| Confined to object of origin | 1200 | 63.5% |
| Confined to area of origin | 310 | 16.2% |
| Confined to room of origin | 100 | 5.4% |
| Confined to fire-rated compartment of origin | 20 | 1.2% |
| Confined to floor of origin | 30 | 1.3% |
| Confined to structure of origin | 120 | 6.45 |
| Beyond structure of origin | 20 | 1% |
| Unknown extent of damage | 90 | 4.9% |
| **Total** | **1890** | **100** |

### 4.4.6 Comments on NFPA data

a) This data provides information on the number of fires that get into HVAC systems. There is no available data on the fires that didn’t penetrate the HVAC systems.
b) Under factory fires, there was a very broad based spread across the manufacturing sector. Strangely, fewer fires got into the HVAC system in non-sprinklered premises. This might indicate that only a small percentage of manufacturing premises are unsprinklered in USA. Additional follow up data has indicated that of the new factories and major refurbishments in the USA, about 50% are now sprinkler protected.
c) Restaurants appear to be particularly vulnerable to fire breaking into HVAC systems. Presumably, these are mainly kitchen fires where grease gets sucked into the duct.
d) Offices, shops and hospitals have also some vulnerability to fire breaking into the ducting systems.
e) Whilst about 85% of fires were limited to the room of origin or less, a relatively high number of buildings were sprinkler protected (37%) which may have influenced this statistic.

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## 4.5 Discussion and analysis of all the above data

All the data presented from UK and USA relates to situations where a fire entered the HVAC system. Both USA data and LFB data give some indication of fires that did not spread beyond the room of origin (see table 11). The room of origin is not the compartment in terms of Building Regulations, but for the purposes of this report it has been used as an approximate indication of the number of fires where a damper may be required to close in the presence of hot gases.

**Table 11**
**Percentage of fires that involved HVAC systems that did not spread beyond the room of origin**

| LFB data | USA data |
|---|---|
| 90% | 85% |

It is not possible, based on the available data; to know if fire dampers prevented the spread of fire into other rooms, neither is it certain if smoke penetration into other rooms was included or ignored.

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**Table 12**
**Comparison between UK and USA data**

| UK DATA | | USA DATA | |
|---|---|---|---|
| **Property type** | **% of fires (LFB UK)** | **Property type** | **% of fires (USA)** |
| Assembly | 11.1 | Restaurant | 23.71 |
| Car park | 0.3 | Factory | 13.02 |
| Commercial | 0.4 | Office | 5.88 |
| Dwelling | 51 | Shop/store | 4.2 |
| Industrial | 5.7 | Mall | 0.66 |
| Institutional | 2.4 | Hospital | 5.2 |
| Medical | 2.9 | Prison | 0.5 |
| Office | 11.3 | School | 2.62 |
| Other | 1.6 | Church/Chapel | 0.7 |
| Shop | 12.9 | Vacant property | 0.24 |
| Storage | 0.4 | Nightclub | 0.42 |
| | | Residential parking garage | 0.22 |
| | | Other | 42.72 |
| | | Total | 100. |

With respect to assembly buildings in the UK data, a significant number involved restaurants or similar. This suggests that kitchen extract systems may be a significant factor in both the UK and USA.

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# 5 Analysis and discussion of experimental results

## 5.1 General

This report analyses the data and discusses the potential implications for currently available guidance.. Relevant details of the activation test is given in Appendix B.

The experimental work was carried out in two stages;

- Detailed examination of dampers contained within ductwork when exposed to developing fires (see appendix B and section 6.3.1)
- Fire resistance determination of three different duct and damper installations built to current industry based codes (section 6.3.2).

## 5.2 Analysis of damper closing times

In the experimental work, all of the dampers did not have their thermal release in the same position. Because of a temperature bias across the cross-section of the duct (from bottom to top), some thermal releases would have been subjected to different temperatures. This may have been a significant factor in determining the performance of the insulated damper. It should be noted that alternative methods of closing dampers, such as motorised operating mechanisms, were not examined in the test programme.

**Plate 1 Activation rig**

The times for damper closing, were noted and grouped under the variations covered in the experiments.

For the purposes of this analysis, the behaviour of the remote damper 2 has not been included.

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Near vent relates to the extract vent nearest to the damper at the fan end of the system but within the fire chamber. Far vent refers to the extract vent furthest away from the damper but still within the fire chamber.

**Plate 2. Photograph of a test to determine the activation time of a damper showing the fire source under the ceiling area with downstand.**

### 5.2.1 Results from the scenario with the fan on and a 500kW fire exposure

**Table 13**
**FAN ON- 500kW**

| Test code | Time for damper to close Damper (sec) | Fire below near vent | Fire below far vent | Main duct velocity m/s |
|---|---|---|---|---|
| 9 | 400 | YES | | 4 |
| 11 | 479 | | YES | 4 |
| 18 | 455 | YES | | 3 |
| 19 | 220 | YES | | 2 |
| 30 | 476 | YES | | 4 |
| 32* | DID NOT ACTIVATE | YES | | 4 |
| 33+ | DID NOT ACTIVATE | YES | | 4 |

*Note: this damper was an insulated single blade damper with its fusible link mounted in a lower position in the duct than other dampers. Temperatures vary from the top to the bottom of the duct. Therefore, the failure to activate was probably due to the exposure of the fusible link to a lower temperature in the duct.

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+Intumescent damper had started to activate but had not sealed. This is probably due to the fact that intumescent devices are designed to activate at a higher temperature than fusible links and the duct temperature was lower than the activation temperature.

The average time to activate for the dampers that did actuate in the tests was 406 seconds. Figure 8 is a graph of the temperatures (°C) measured close to each of the dampers during the tests, as a function of time (minutes).

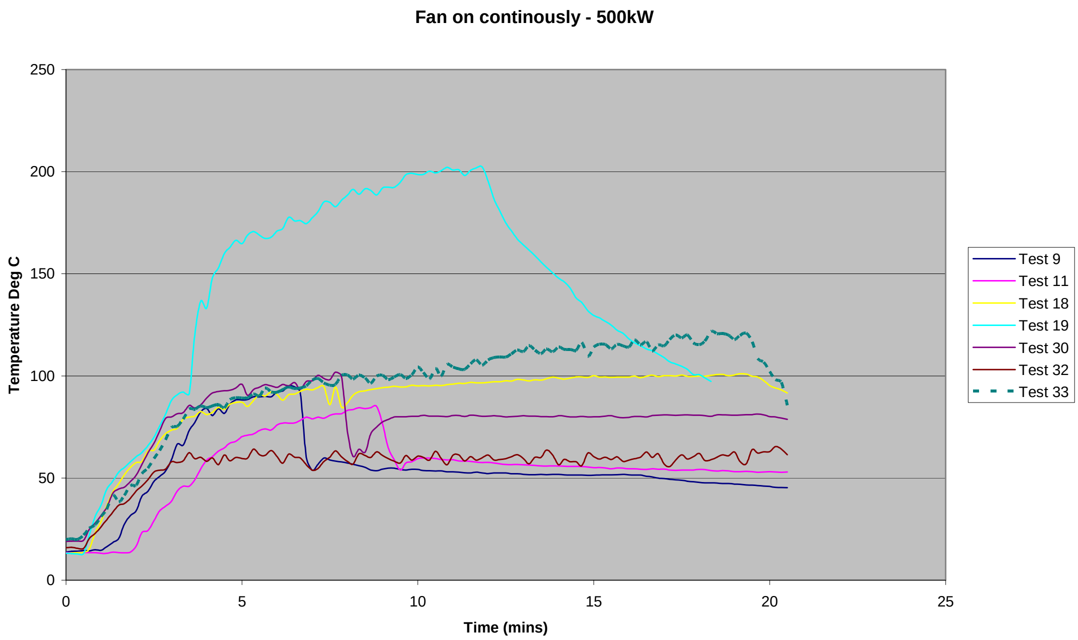


**Figure 8. Temperatures near damper for the fan on and 500kW fire exposure.**

#### 5.2.2 Results from the scenario with fan on and 300kW fire exposure

| Table 14<br>FAN ON- 300kW exposure | | | |
|---|---|---|---|
| Test code | Time for Damper to close (sec) | Fire below near vent | Main duct velocity duct (m/s) |
| 10 | 661 | YES | 4 |
| 17 | 818 | YES | 3 |
| 22 | 403 | YES | 4 |
| 26 | 243 | YES | 4 |
| 25 | 238 | YES | 4 |
| 27 | 676 | YES | 4 |
| 28 | 777 | YES | 4 |
| 29 | 591 | YES | 4 |
| 31* | DID NOT ACTIVATE | YES | 4 |

* Note that this damper was an insulated single blade damper with its fusible link mounted in a lower position in the duct than other dampers. Temperatures vary from the top to the bottom of the duct. Therefore, the failure to activate was probably due to the exposure of the fusible link to a lower temperature in the duct.

The average time to activate for the dampers that did actuate in the tests was 551 seconds.

Figure 9 is a graph of the measured temperatures (°C) close to the dampers as a function of time (mins).

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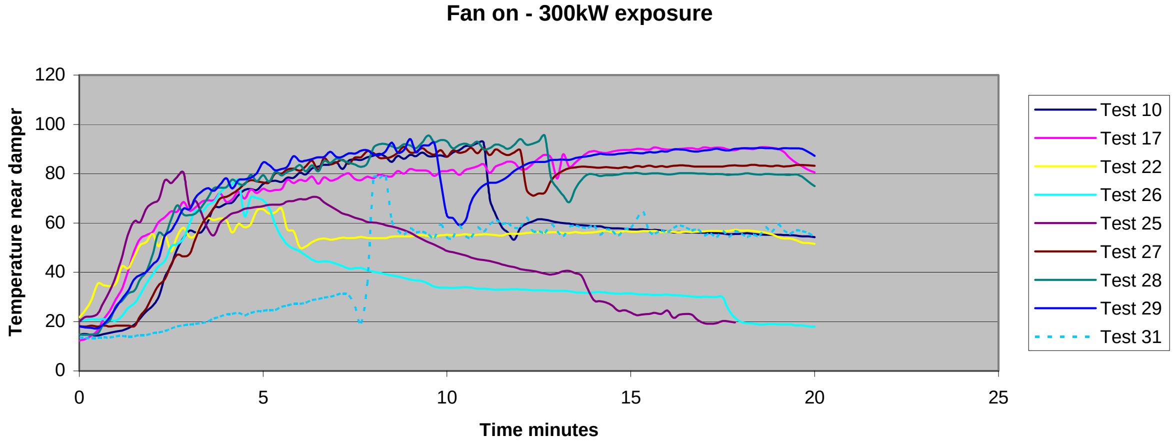


**Figure 9. Temperatures near damper for the fan on and 300kW fire exposure.**

### 5.2.3 Results for the scenario in which the fan was shut off after 2 minutes

The fan was shut off at two minutes to represent a system in which the fan is shut off as soon as smoke is detected.

**Table 15**
**FAN OFF AFTER APPROX 2 MINUTES**

| Test code | Time for Damper to close (sec) | Fire below near vent | Fire below far vent | Heat output (kW) |
|---|---|---|---|---|
| 12 | DID NOT ACTIVATE | | YES | 500 |
| 13 | DID NOT ACTIVATE | YES | | 500 |
| 23 | DID NOT ACTIVATE | YES | | 300 |
| 24 | DID NOT ACTIVATE | YES | | 300 |

From table 15 it can be seen that in all cases none of the dampers operated. Figure 10 shows the measured temperatures (°C) close to the dampers as a function of time (mins). It can be seen that the measured gas temperatures were below the typical operating temperature of fusible links (circa 70ºC). It was possible that the baffles in the extract vents, which were made from steel, might have contributed to reducing the amount of hot gases that entered the main duct in these particular tests. In practice, the baffles may be made from plastic or aluminium. It was therefore decided to undertake some additional experiments with the baffles removed after a period of time into the test to examine the role of the baffles in the extract vents on the temperatures within the duct and therefore, the operability of the dampers. The results of these additional tests are detailed in section 5.2.4 below.

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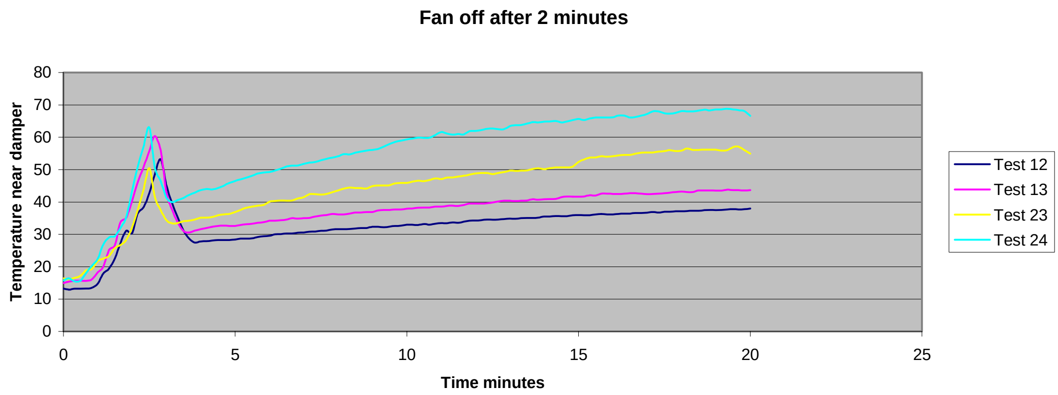


**Figure 10. Temperatures near damper for the scenario in which the fan is shut off after 2 minutes.**

### 5.2.4 Results from the scenario in which the vents were opened during test

These results were obtained from additional experiments conducted to investigate the influence of the baffles in the extract vents. In each case, the baffles/vents were fully opened at two minutes. The results summarised in table 16 clearly show that the dampers tested activated, even in the situations with the fan shut off.

**Table 16**
**VENT OPENED AT 2 MINUTES**

| Test code | Time for damper to close(sec) | Fire below near vent | Fire below far vent | Heat output (kW) | FAN |
|---|---|---|---|---|---|
| 14 | 190 | YES | NO | 500 | ON |
| 15 | 184 | YES | NO | 300 | ON |
| 16 | 285 | YES | NO | 300 | OFF |
| 20 | 191 | YES | NO | 300 | ON |
| 21 | 288 | YES | NO | 300 | OFF |

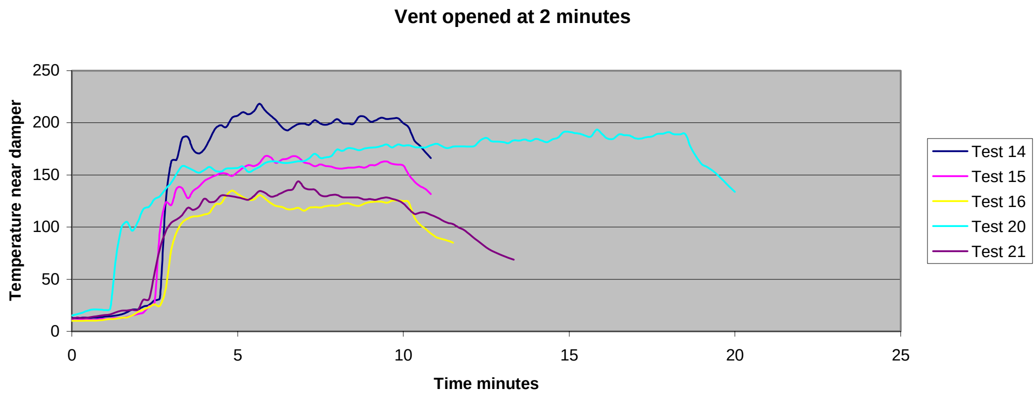


**Figure 11. Temperatures near the damper with the vent open at 2 minutes.**

Figure 11 shows the measured temperatures (°C) close to the dampers as a function of time (mins).

When compared with the data presented in section 5.2.3, it can be clearly seen that opening of the baffles in the extract vents resulted in an increase in the temperatures measured in the extract duct and generally a subsequent reduction in the activation time of the dampers for all of the scenarios studied.

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## 5.3 Fire resistance data

### 5.3.1 General

For the fire resistance test, the performance of a test construction comprising an uninsulated horizontal steel ventilation duct connected either side of a damper installed in a dry-lining partition, when exposed on one side of the partition to the hot gases of a furnace both inside and outside the duct, was examined (see plate 3 – right hand side of wall). Generic details of all of the components in the fire resistance test are provided in table 17. The furnace was controlled to follow the heating conditions specified in BS EN 1363-1, during the course of the test the performance of the damper was evaluated by adopting the procedures and criteria of BS EN 1366-2. In addition, the behaviour of two small duct systems each carrying a damper and passing through a rock fibre fire barrier installed in a portion of the partition assembly was examined (see plate 3 – left hand side of wall).

**Plate 3. Photograph of the furnace test set up showing the arrangements of ducts/dampers through the wall of the furnace.**

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**Table 17**

**Summary of test components**

| Type of damper | Duct specification | Wall construction | Fan mode represented | Hanger spacing from damper inside furnace |
|---|---|---|---|---|
| 1000mm by 400mm multi-blade fire resisting damper | 1000mm by 400mm steel duct fitted to damper spigot by aluminium cased steel mandrel rivets | EI 60 plasterboard dry-lining partition | On | 3m as in DW/144 |
| Pivoting blade circular damper (160mm diameter) | 160mm diameter spiral wound duct fitted to damper spigot by aluminium cased steel mandrel rivets | EI 60/90 rock-fibre fire barrier | Off | |
| Intumescent damper (300mm x 105mm) | 300mm by 105mm rectangular steel duct | EI 60/90 rock-fibre fire barrier | Off | |

### 5.3.2 Review of data and observations recorded during test

#### 5.3.2.1 Partition and flexible barrier

The maximum deflection measured at the centre of the assembly was 29mm away from the furnace. This was recorded after 70 minutes, at the conclusion of the test.

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The temperatures recorded by thermocouples attached to the partition and flexible barrier exceeded the temperature limits defined for insulation in BS EN 1363-1. The times taken to reach the defined limits are summarised below:

Partition:

Maximum temperature rise limit (180$^o$C rise) 60 min

Mean temperature rise limit (140$^o$C rise) 61 min

Flexible barrier:

Maximum temperature rise limit (180$^o$C rise) 60 min

Mean temperature rise limit (140$^o$C rise) 36 min

#### 5.3.2.2 Multi-blade damper in 1200mm x 400mm duct system through partition (Duct 1):

The damper started to close 1min: 05s from the start of the test and was fully closed at 1min: 20s.

The maximum movement of the duct relative to the furnace was approximately 12mm outwards after 9mins from the start of the test, the duct then started to move back towards furnace; the maximum inwards movement, relative to its starting position, was 16mm after 36min.

The length of ductwork exposed within the furnace collapsed after 23min: 30s from the start of the test. The break from the damper was clean, causing no apparent damage to the damper or partition. Prior to its collapse, the ductwork had started to sag only slightly and had not suffered from any significant deformation of its cross sectional profile.

During the course of the test the performance of the damper and the supporting construction in the vicinity of the ductwork (Duct 1), was evaluated by adopting the procedures and criteria of BS EN 1366-2.

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The temperature recorded by thermocouples attached to the unexposed face of the test construction exceeded the temperature limits defined for insulation. The times at which the defined temperature limits were exceeded are summarised below:

On supporting construction:

Maximum temperature rise limit (180$^{o}$C rise) 44 min

On surface of duct:

| | |
|---|---|
| Maximum temperature rise limit (180$^{o}$C rise) | 21 min |
| Mean temperature rise limit 25mm from damper (140$^{o}$C rise) | 18 min |
| Mean temperature rise limit 325mm from damper (140$^{o}$C rise) | 23 min |

After the damper closed, the airflow measuring system measured a maximum leakage after 70 minutes, at the conclusion of the test of 162m$^3$/(hm$^2$) corrected to 20$^{o}$C. The leakage did not exceed either the maximum limit of 360m$^3$/(hm$^2$) for integrity or the maximum limit of 200m$^3$/(hm$^2$) for leakage. The leakage in this test being through gaps in the unexposed length of ductwork and across the damper.

#### 5.3.2.3 160mm diameter single blade damper in circular duct system through barrier (Duct 2):

The damper closed after 28s from the start of the test.

The length of ductwork exposed within the furnace did not collapse during the course of the test. The ductwork showed signs of sagging after approximately 39min from the start of the test. It should be remembered that this 160mm diameter duct would be substantially stronger than larger diameter spirally wound ducts and therefore,,a larger diameter circular duct may well have collapsed in the furnace.

The temperature recorded by thermocouples attached to the barrier and to the ductwork around its emergence from the barrier exceeded the temperature limits defined for insulation adopted from BS EN 1363-1. The times at which the defined temperature limits were exceeded are summarised below:

On supporting construction:

Maximum temperature rise limit (180$^{o}$C rise) 35 min

On surface of duct:

Maximum temperature rise limit (180$^{o}$C rise) 19 min

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#### 5.3.2.3.1 Intumescent damper, 300mm x 105mm duct system through barrier (Duct 3)

The temperature recorded by the thermocouples monitoring the temperature of the gases within the unexposed length of ductwork indicated that the flow through the duct was substantially reduced 5 minutes after the start of the test. The damper was, therefore deemed to be effectively closed at this time.

Most of the length of ductwork exposed within the furnace collapsed after 15min:30s from the start of the test. The break in the ductwork was at the end of the duct section emerging from the collar extending from the barrier. The insulated length of duct section emerging from the barrier folded down with the collapse of the duct. Prior to its collapse, the ductwork had started to sag and was significantly deformed at the time of collapse.

The temperature recorded by thermocouples attached to the barrier and to the ductwork around its emergence from the barrier exceeded the temperature limits defined for insulation adopted from BS EN 1363-1. The times at which the defined temperature limits were exceeded are summarised below:

On supporting construction:

| | |
|---|---|
| Maximum temperature rise limit (180$^{o}$C rise) | 54 min |

On surface of duct:

| | |
|---|---|
| Maximum temperature rise limit (180$^{o}$C rise) | 31 min |

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### 5.3.3 Comparative results

Table 18 is a summary of the results from the fire resistance test.

**Table 18**

**Summary of results-fire resistance test**

| Damper/duct | Time damper closed | Time duct inside furnace collapsed (minutes) | Time to insulation failure on duct outside furnace | | Time to maximum insulation failure on supporting construction |
|---|---|---|---|---|---|
| | | | MEAN (140ºC) | MAXIMUM (180ºC) | |
| Multi-blade damper in 1200mm x 400mm duct system through partition (Duct 1): | 1min-20s | 23min:30s | 18 min | 21 min | 44 min |
| 160mm diameter single blade damper in circular duct system through barrier (Duct 2): | 0min 28s | Did not collapse | | 19 min | 35 min |
| Intumescent damper, 300mm x 105mm duct system through barrier (Duct 3) | Started to activate at 30s, judged to have sealed at 1min:30s | 15min:30s | | 31min | 54 min |

The comparative air temperatures (°C) recorded in each duct (position 1, 500mm from damper) are shown in figures 12, 13 and 14 as a function of time (minutes). This data is

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potentially useful in terms of understanding the operational characteristics and the differences between the three different dampers tested.

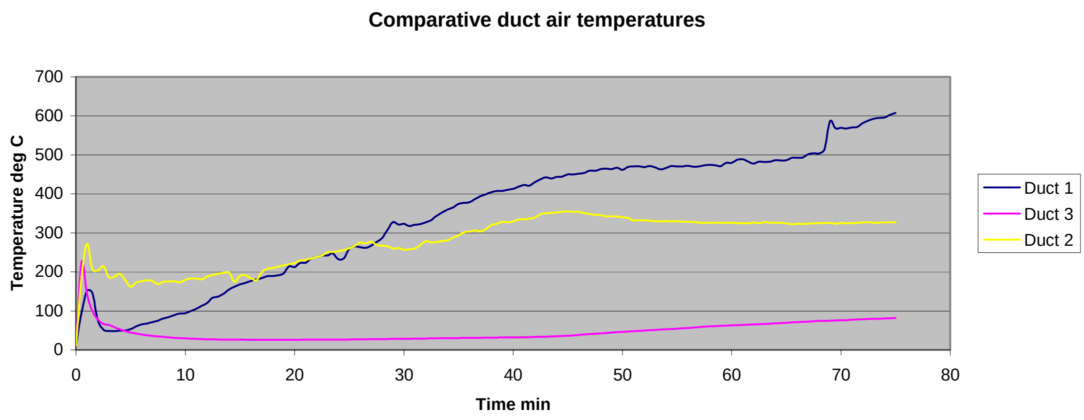


**Figure 12. Temperatures 500mm from damper during test**

**Duct 1 = 1200mm x 400mm duct with multi-blade damper**

**Duct 2 = 160mm diameter duct with single blade damper**

**Duct 3 = 300mm x 105mm duct with intumescent damper**

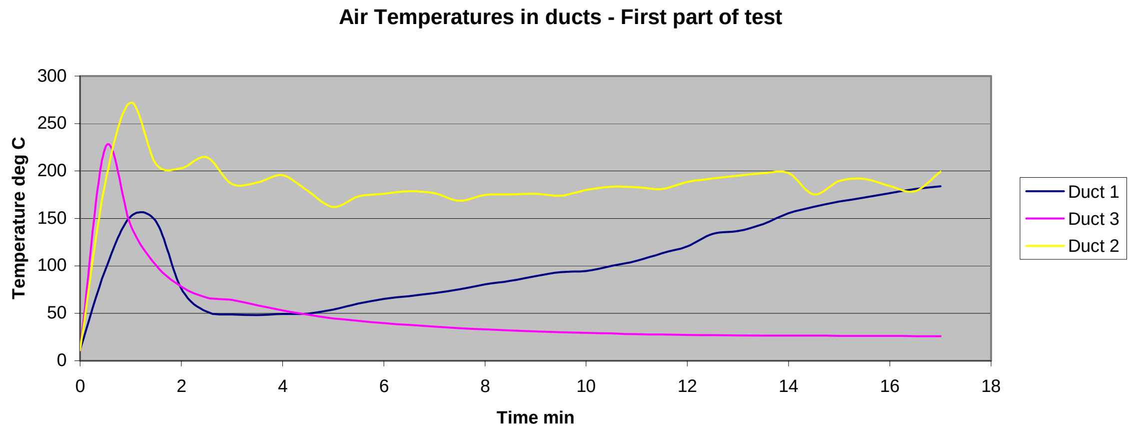


**Figure 13. Temperatures 500mm from damper in first 17 minutes of test**

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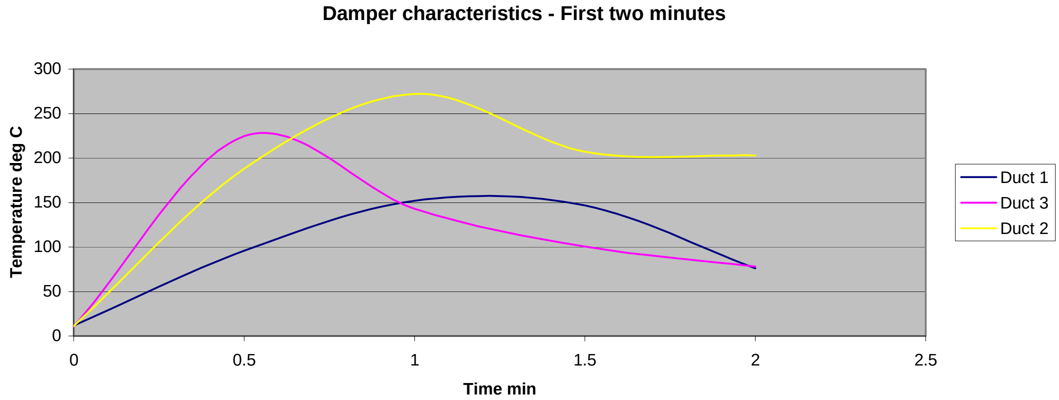


**Figure 14. Temperatures 500mm from damper in first two minutes of test**

The internal air temperature along the length of each duct at 60 minutes is shown in figure 15. It should be noted that the data for the multi-blade damper corresponds to the fan on situation. The data for the other two damper arrangements correspond to fan off situations.

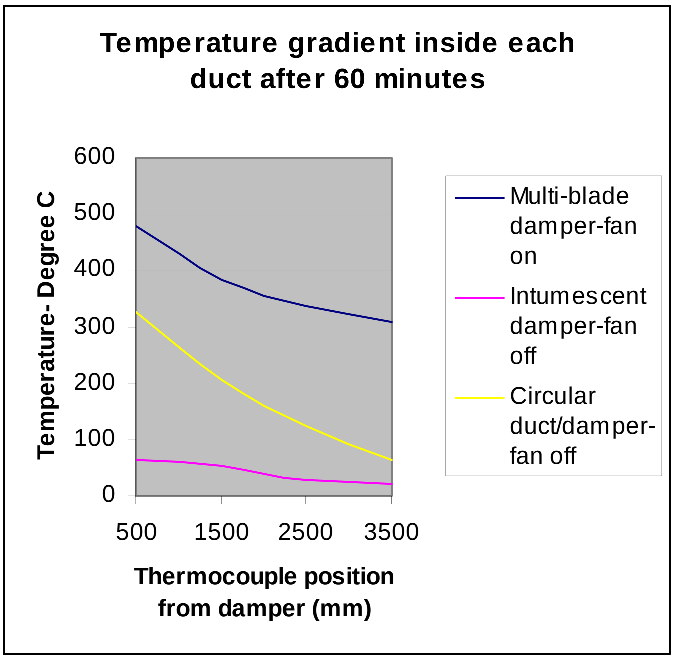


**Figure 15. Temperature gradient inside each duct at 60 minutes**

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### 5.3.4 Validity of results

The test was designed to generate some data relevant to the interaction between ducts, their fixings and supports, dampers and the compartment barrier/wall.

It is important to remember that only one specimen of each damper type was tested, therefore, the results cannot be assumed to be typical of all generically similar products.

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# 6 Discussion

## 6.1 Literature search

A number of issues were identified from the literature review and are discussed below:

- During our investigations it has become clear that dampers known widely as fire and smoke combination dampers are not necessarily leakage rated and might therefore not meet the ES classification in accordance with prEN 13501-3. This needs to be clearly understood by the Industry, including regulators, specifiers and designers. The comment in clause 6.3.1.1 of BS 5588 part 9 that fire dampers are not generally regarded as being effective in resisting the penetration of smoke would be more applicable to dampers classified as E than ES.
- With respect to the more specialist standards such as BS 5908 - Code of practice for fire precautions in the chemical and allied industries, BS 5422 – Method for specifying thermal insulation materials for pipes, tanks, vessels, ductwork and equipment operating within the temperature range -40ºC to +700ºC and BS 5970 – Thermal insulation of pipe work and equipment, it would be very useful if, either by cross referencing or inclusion of text from these standards, guidance on ducts and dampers could be covered in one document, e.g. BS 5588:Part 9. In addition, it appears that better guidance is needed to indicate when fire and smoke rated dampers (Classified ES in accordance with prEN 13501-3) compared with E rated dampers should be specified. This comment is equally valid to the HVCA key document DW/144 – Specification for sheet metal ductwork.
- The data obtained in the review suggest that fires in kitchen extract ducts appear to be a particular problem, especially in terms of property loss. This is due to the build up of combustible residues that adhere to the internal surfaces of ducts which in turn may adversely affect the performance of a damper. Some additional guidance relating to the management and maintenance of ducts in such applications may be appropriate. Further, some consideration of other applications in which combustible residues build up on the internal surfaces of ducts was outside the scope of this project but may also be worthwhile.
- The recommendation in CIBSE Guide B2 – Ventilation and air conditioning, that fire dampers are desirable in kitchens in dwellings including high rise appears to be contradictory to the guidance provided in BS 5588 part 9. CIBSE Guide B2 does not appear to make any reference to the potential for preventing/reducing smoke migration using fire dampers, in particular fire and smoke combination dampers.

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- There appears to be a lack of any guidance on the use of HVAC systems in hazardous environments. This could be addressed in the main British Standard code dealing with fire protection of HVAC systems, BS 5588:Part 9.
- With respect to protected shafts, it should be recognised that historical tests to BS 476 will not necessarily provide an adequate test method for such a three dimensional system. Whether the service duct test of BS EN 1366-5:2003 is more appropriate requires consideration within BS 5588 part 9.
- With respect to HVCA DW/144, there is a need for the document to be updated as it still recommends that fire and smoke combination dampers are tested to BS 476: Parts 20/22. This test method does not cover dampers and as stated in section 3.2.1 of this report, does not allow for an adequate basis to determine leakage. Only EN 1366-2 (ISO 10294-1) appears to provide a suitable method for this application.
- Within the context of the higher incidence of fires in kitchen extract systems reaching into the extract duct, where significant amounts of oil/grease collect, the philosophy of using such ducts to extract smoke in the event of a fire elsewhere in the compartment, may require review within HVCA DW/171.
- It was found that all of the current documents that support the regulations and Approved Document B, including British Standards and Industry based guidance, tend only to refer to BS 476 part 8 and 20 in relation to fire performance testing of ducts and dampers. This situation is clearly unsustainable due to the legal demands of the Construction Products Directive (CPD) and as such, all of these documents will need to be revised to accommodate the new European fire test method (BS EN 1366–2) and in the future, the classification document (prEN 13501-3).

## 6.2 Fire loss reports

Only about 10-15% of fires appear to spread from the room of origin (which is not necessarily the same as the compartment of origin defined in AD B), based on UK and US data. This would tend to suggest that a damper would only be required to function in about 10% of fires. The importance of regular checking of satisfactory operation of fire dampers was highlighted in some reported cases and this should clearly be part of an ongoing fire safety management regime.

The use of return-air plenums in corridor situations has been questioned. Certainly current test methods do not give sufficient information on how effective ceilings would be for such use.

Both UK and USA fire data showed that restaurants are a major potential hazard with respect to fire spread into HVAC systems. FPA data also highlights the potential for

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increase in fire spread when combustible industrial residue becomes attached to the inner surface of HVAC ducts in Industrial occupancies.

The actual fire data analysis carried out as part of this project does tend to show a reasonably high incidence of fires involving plastic extract equipment in domestic premises which resulted in property loss.

## 6.3 Experimental programme

### 6.3.1 Damper Activation

#### 6.3.1.1 Fan on

All but one mechanical damper operated during the tests. An intumescent damper had started to intumesce but did not seal completely. Some variations in the times for dampers to close were noted and these were probably due to different designs of damper. In particular, some variations were possibly due to the different location of the fusible links in the dampers and the variation in temperatures across the duct. There were some observations made of biased flow due to the inlet openings being positioned on one side only. However, such a situation could well happen in actual HVAC installations. The damper that failed to close in both thermal exposures (tests 31 and 32) was an insulated single blade damper. It is suggested that this damper had a greater thermal mass which may have influenced the temperature of the release. Also, it was noted that the fusible link was mounted fairly low down and may therefore have been exposed to a lower temperature in the duct flow. Whilst the insulated damper failed to operate, not all proprietary dampers were tested, and it is possible that this result might occur in an uninsulated damper if hot gases do not flow over the fusible link. This might tend to raise the question on whether the test described in ISO 10294-4: 2001 where the fusible link is tested in isolation from the damper is appropriate. The results from this project tend to suggest that the design of the damper, especially in terms of the location of the fusible link, will be a key factor in its performance in a fire and current test methods do not include the complete damper exposed to a developing fire situation.

#### 6.3.1.2 Fan shut off

Some concern is expressed that no damper closed during the fan-off stage of the programme where the air vents had been baffled to give an air flow of 2m/sec through the vent, particularly as most tests were carried out with the fire directly below the opening nearest the damper. Examination of the gas temperature at the damper fusible link positions show that the temperatures did not exceed 63ºC at the time that the fan was shut off. With the fan off, flow rates were too low to measure, which probably indicates little potential for smoke movement. A maximum temperature of 68.8 ºC after

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19.34 minutes was recorded in test 24, which is just below the operating threshold of fusible links.

It should be noted that the baffles used in this work were constructed from a suitable steel disc. A proprietary device (for example, see plate 4) was not used. The influence of such devices on the performance of the system could usefully be studied further as it is possible that they could be designed to make a positive contribution to the overall performance of the system in reducing fire spread in the early stages of a fire.

#### 6.3.1.3 Vent open

This was included to represent a failure of the air velocity control device, which are typically made of plastic or aluminium (for example, see plate 4). In the situation where failure of the air velocity control device was simulated at 2 minutes, the temperature at the damper position reached peak values in the range 130 ºC to 210 ºC. All of the dampers used in this scenario closed.

**Plate 4 Air velocity control device**

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### 6.3.1.4 Activation test

The results of this work have shown that there may be a need to develop an activation test that is a closer representation of realistic scenarios in addition to the furnace test described in BS EN 1366-2. The results summarised in figure 16 are compared with the slow heating curve of BS EN 1363-2. These data clearly show that the slow heating curve still represents a significantly more rapid temperature-time increase than achieved within the more realistic experiments carried out in this project. As such, any activation test would need to consider a slower temperature-time increase to be representative of realistic fire situations. Such a curve (slower) may differentiate between different types of damper. Further, it appears from the data that the slow heating curve of BS EN 1363-2 does not represent a worst case for testing of dampers. If the slow heating curve described in BS EN 1363-2 were adopted, this would still be exposing the link to a more rapid temperature rise than shown in our experiments. This is illustrated below where the curve is compared with all temperatures measured in the activation tests near the fusible link position.

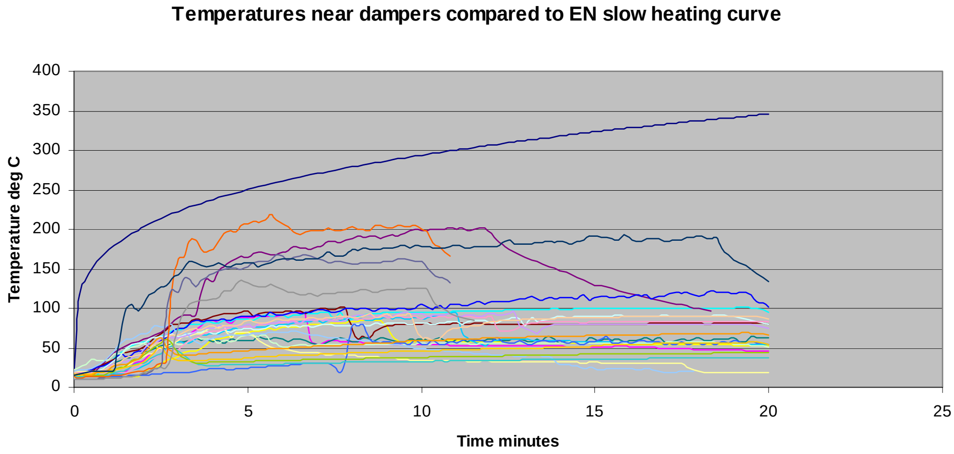


**Figure 16. Comparison between temperatures recorded during activation tests and slow heating curve of EN 1363-2.**

### 6.3.2 Fire resistance test result

#### 6.3.2.1 General

Overall, the performance of the duct/damper/compartment wall was satisfactory and compartmentation was maintained for the targeted 60 minute period. Although we learnt valuable lessons regarding the interaction between ducts, dampers and compartment walls, there appears to be no indication that the principle of the test procedure described in BS EN 1366-2 needs review.

#### 6.3.2.2 Damper activation

All dampers activated. It should be noted that the actual response time of a damper in end use would typically be longer than when tested to the standard method of test described in EN 1366-2, as in that test they are directly exposed to the furnace conditions. In the furnace test carried out for this project, hot gases had to pass through each duct before reaching the dampers. Both the fan on and off situations were examined.

The results showed that both the mechanical dampers (multi-blade fire resistant and pivoting blade circular) activated before the intumescent damper had fully activated. However, the intumescent damper provided a valuable insulation contribution which would reduce the hazard if combustible materials were in contact with the duct.

Plates 5, 6 and 7 are photographs of the three dampers after the furnace test.

**Plate 5. Pivoting blade circular damper**

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**Plate 6. Intumescent fire damper**

**Plate 7. Multi-blade fire resistant damper**

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#### 6.3.2.3 Collapse of ducts in furnace

It is considered that the early collapse of the larger rectangular duct prevented the possibility of an early integrity failure at the position where it penetrated the partition. Aluminium cased steel mandrel rivets, which were used in this test and which we understand from our industry advisors are commonly used to fix ducts onto the damper spigots, probably contributed to the early collapse. In addition, it is also possible that locating the hangers at the maximum spacing recommended in DW/144 also contributed to the collapse. It is therefore possible that a worse result in terms of a shorter time to integrity failure might have been achieved if steel rivets had been used and a hanger located closer to the penetration point.

#### 6.3.2.4 Leakage measurements through damper 1

It was noted by the damper manufacturer who supplied the multi-blade damper for the test that the leakage measured in the fan-on situation was higher than that achieved during the standard EN 1366-2 test. Our view is that this may be partly due to the fact that in the standard test the duct is part of the test equipment and is well sealed. The duct used in this project was a standard HVAC duct and may therefore have contributed to the leakage. As such, systems installed in practise are more likely to achieve a worse performance than in the standard BS EN 1366-2 test. If this is likely to present a problem in practise, then consideration could be given to requiring low leakage characteristics for ducts that pass through compartment walls/barriers.

#### 6.3.2.5 Spigot dimension

During the installation of the product for test, it was noted that the design of dampers did not provide adequate depth of spigot for dry-lining constructions once the plasterboard was in place (see plate 8). However, this will not be a problem if dampers and ducts are installed before the construction of the partition.

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**Plate 8. Multi-blade damper mounted in Dry-lined partition**

### 6.3.2.6 Operating devices for dampers

It was noted during the preparation for the fire resistance test that when designing and installing mechanical dampers, allowance should be made for accommodating the operating device when it is external to the damper body (see for example, plate 9).

**Plate 9. Provision made to accommodate operating device**

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#### 6.3.2.7 Summary

The results and observations from the fire resistance test have highlighted a number of variables that will influence the fire performance of a duct and damper system in a test. It is intended that the information will be made available to the relevant BS and CEN Standardisation committees and appropriate Trade Associations for incorporation into future guidance.

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# 7 Conclusions

The primary source of advice on the fire protection of ducted air distribution systems within the UK is BS 5588 part 9, code of practice for ventilation and air conditioning ductwork. From the literature review and discussions with Industry, it is clear that more specialist publications also rely on this standard. The general view was that BS 5588 part 9 needs further development to produce a stand-alone definitive guide on the use of ventilation and air conditioning ductwork in relation to fire safety and fire protection. Further, any proposals to incorporate BS 5588 part 9 into BS 9999 should be avoided.

Data from both the London Fire Brigade and the USA give some indication of fires that go beyond room of origin. However, it should be noted that the room of origin may not be the compartment in terms of the Building Regulations. Only about 10-15% of fires appear to go beyond the room of origin. Fire tends to spread through a building in a number of ways, including through the HVAC system.

Further, examination of fire loss reports has tended to indicate that kitchen extract systems pose a significant risk primarily in terms of property loss. This is probably due to the build-up of grease inside the duct. Due to the these findings, it is suggested that more guidance on issues associated with management and maintenance of kitchen extract ducts would be useful..

The results of this work showed that dampers vary in terms of their activation characteristics. In the early stages of a developing fire, this project has indicated that dampers relying only on fusible links may not shut in a fan-off situation because the gas temperatures recorded at the fusible link at the damper position may be below the operating temperature of the fusible links (70ºC).

In some cases, it has also been shown that dampers may not close in the fan-on situation and this is partly dependent on the position of the fusible link within the duct. If the fusible link is low down in the duct , it will be exposed to lower gas temperatures and may not reach its activation temperature. It is also to be noted that intumescent dampers in general, are designed to activate at higher temperatures than fusible links.

In some applications, it is therefore considered that fire and smoke combination dampers intended to prevent the spread of smoke and fire that are activated only by fusible links may not be suitable.

The multi-blade, circular single blade and intumescent fire dampers functioned extremely well in the fire resistance test which was designed to replicate three typical damper/duct/wall installations. All dampers closed/sealed and were able to provide the required fire resistance. Therefore, in a post-flashover fire situation, as represented by the fire resistance test, our work has shown that dampers can close and contribute to the maintenance of compartmentation.

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The current practice of supporting ducts at 3m centres appears to be adequate for damper protected applications. The results indicate that the common practice of using aluminium cased steel mandrel rivets appear to have a positive effect by allowing for collapse of the duct in the fire compartment, minimising the potential of causing a premature integrity failure at the compartment boundary. The results of the work also showed that dampers vary in terms of their times to activation. The current test methods that exist within the European fire test system are not generally representative of what has been observed during this project and has therefore highlighted the possible need to develop a damper activation test additional to BS EN 1366-2 where dampers only rely on a fusible link to actuate the operating mechanism.

The results from the fire resistance test has highlighted the importance of the issues associated with the installation of systems. There are a number of significant variables that have been shown to influence the fire performance of the duct and damper system in a test and from this work, these have been shown to include:

- Type of fixings i.e. Aluminium fasteners or steel rivets
- Duct hanger spacings
- Type of ductwork and cross-section
- Use of damper mounting frame
- Type of damper and method of activation
- Combination of duct, damper and cavity barrier or partition.

It is intended that the information relating to the variables from this project will be made available to the relevant BS and CEN Standardisation committees and appropriate trade associations for incorporating into future guidance.

It should be noted that there may be other significant variables that were not studied in this project. The variables listed above did influence performance in the experimental work and therefore will almost certainly influence the performance of ducts, dampers and cavity barriers or partitions in a range of real applications. It is therefore important to ensure, as far as reasonably practicable, that fire test data used to support products in the market place are relevant to the intended end use application.

Since the publication of the new European fire test methods and performance criteria, it is very apparent that it is necessary to clarify the terminology and re-define specifically the terms “fire damper”, “smoke damper”, “fire and smoke damper”. These definitions should then be utilised within all the appropriate standards and guidance documents. It is therefore suggested that these definitions would be best placed in BS 5588 part 9. Additionally, direct reference to EN 1366-2 should be included and the limitations of the ad-hoc test methods used in the UK over a number of years should be explained.

Guidance is required as to when it is required to use the different types of damper i.e. E (integrity) dampers, ES (integrity and smoke leakage) dampers and EI (integrity and insulation) dampers. These different types of damper have different characteristics which

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could be beneficial in different scenarios depending upon risk. The term smoke damper may be confusing as this might be taken to be a smoke extraction damper or an ES damper. This is an issue that would probably be best addressed in BS 5588 part 9.

Further, currently, the insulation issue is not typically addressed in the UK probably because there is not normally a fire load either side of the damper. However, the furnace test did show that a damper providing insulation can significantly reduce the air temperature in the duct. It is conceivable that insulating dampers could be used in situations where there is a requirement for an insulated duct. The use of an insulating damper may open up the possibility for reducing the insulation along the duct. This particular issue requires further work to quantify the benefits of reducing air and surface temperatures on ducts and establish that such duct/damper systems would work properly. It is also possible that the use of two uninsulated dampers close together but separated by an air gap could be beneficial, but this is currently unquantified.

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# 8 References

## 8.1 Regulations

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Technical Booklet E (Northern Ireland), 1994

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## 8.2 Test methods

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BS 476: Part 20. Fire tests on building materials and structures. Part 20. Method for determination of the fire resistance of elements of construction (general principles)

BS 476: Part 24. Fire tests on building materials and structures, Part 24. Method for determination of the fire resistance of ventilation ducts, 1987

BS EN 1366-1, Fire resistance tests for service installations – Part 1 Ducts

BS EN 1366-2, Fire resistance tests for service installations, Part 2: Fire dampers

ISO 6944:1985 Fire resistance tests-Ventilation ducts

ISO 10294-1, Fire resistance tests-Fire dampers for air distribution systems-Part 1 test method

ISO 10294-2, Fire resistance tests-Fire dampers for air distribution systems-Part 2: Classification, criteria and field of application of test results

ISO 10294-3, Fire resistance tests-Fire dampers for air distribution systems- Part 3: Guidance on the test method

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ISO 10294-4: 2001, Fire resistance tests - Fire dampers for air distribution systems – Part 4: Method of test for thermal release mechanism

ISO DIS 10294-5, Fire resistance tests- Fire dampers, Part 5, Intumescent dampers

prEN 13501-3, Classification using data from fire resistance tests. Part 3. Components of normal building service installations

UL 555 Fire dampers

UL 555C Ceiling dampers

UL 555S Smoke dampers

## 8.3 Relevant codes and guidance documents

ASFP, Fire rated and smoke outlet ductwork, and industry guide to design and installation, June 2003

ASFP, Fire Stopping and penetration seals for the construction industry, 1993

BS 5422, Method for specifying thermal insulating materials for pipes, tanks, vessels, ductwork and equipment operating within the temperature range - 40ºC to + 700ºC

BS 5588-9, Fire precautions in the design, construction and use of buildings-Part 9: Code of Practice for ventilation and air conditioning ductwork

BS 5720., Code of Practice for Mechanical ventilation and air conditioning in buildings, 1979

BS 5908, Code of practice for fire precautions in the chemical and allied industries

BS 5970:1992, Thermal insulation of pipe work and equipment (in the temperature range -100 ºC to +870ºC)

BSRIA, TN6/94, Fire Dampers

CIBSE,Guide B2 Ventilation and air conditioning

DW/144, Specification for sheet metal ductwork, Heating and Ventilating Contractors Association (HVCA)

DW/154, Specification for Plastics Ductwork, Heating and Ventilating Contractors Association (HVCA)

DW/171, Standard for Kitchen Ventilation Systems, Heating and Ventilating Contractors Association (HVCA)

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HEVAC, specification for an installation frame for fire dampers, April 2002

NFPA 90A, Standard for the Installation of Air-Conditioning and Ventilation Systems 2002 Edition

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## Appendix A – Project Steering Group

| | |
|---|---|
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| Mr Graham Ellicott | ASFP |
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| Mr Peter Jackman | International Fire Consultants |
| Mr Brian James | HVCA |
| Mr Alan Weir | ADCAS |
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# Appendix B  Details of Activation test

## B1 Test rig

The test rig comprised four main elements.

A test chamber assembly

A duct support assembly

Two duct extension assemblies.

The test chamber assembly, measuring 5m x 3m x 2.5m high, comprised a steel framework in which a ceiling clad with insulated non-combustible board was installed. The non-combustible board, fixed over a substrate of plasterboard, was also used to form a canopy extending downwards by 1.2m around the perimeter of the ceiling thereby forming a hood to retain a hot layer beneath the ceiling.

The duct support assembly comprised an open steel framework mounted over the top of the test chamber assembly to support the ductwork and its instrumentation.

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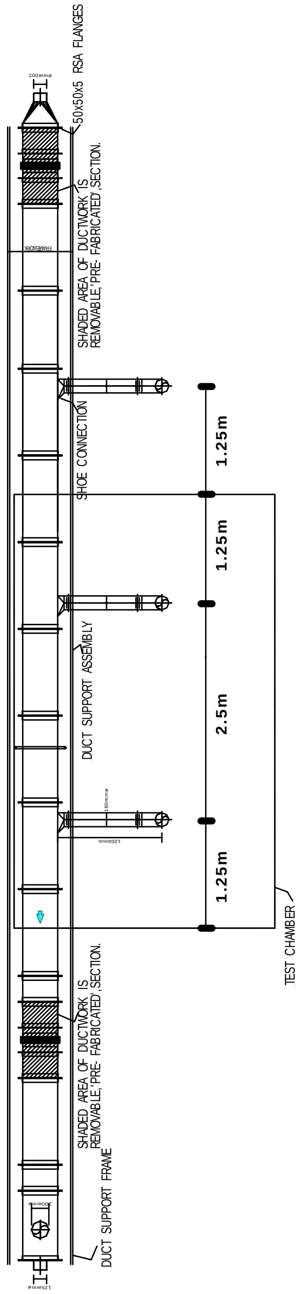
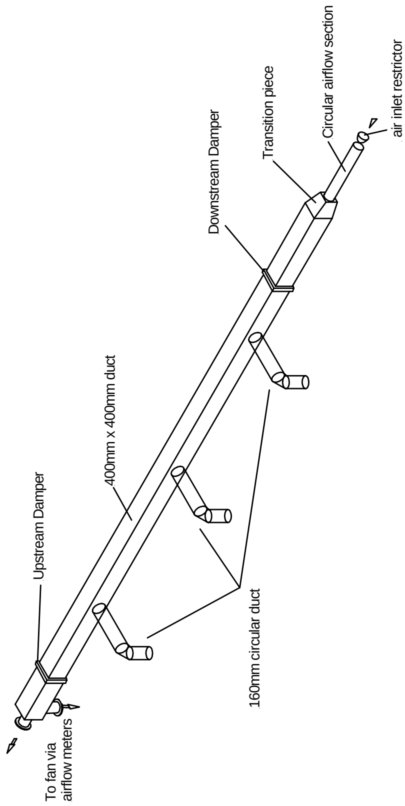
Damper and Duct project

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The two duct extension assemblies, each comprised a section of open steel framework mounted atop a wheeled scaffold tower. The assemblies, positioned at ether end of the test chamber assembly, served to extend to the ductwork beyond the ceiling of the test chamber. As well as supporting the ductwork, the frames also supported the dampers and instrumentation for flow, smoke and temperature measurements. The open frame design of the duct support system made the apparatus flexible in both installing and supporting different damper designs and sizes.

## B2 Test configuration

The configuration employed for each test was a permutation of both the burner position and which of the side branch inlet vents was opened. The burner was located under either Vent1 or Vent2 in the ceiling of the test chamber. Each test had two of the three vents opened and the remaining vent sealed.

## B3 Heat input

Two levels of maximum heat input were selected, each rising to its set point following the $t^2$ curve for a medium rate of fire growth as specified in BS 794: Part1:2003. Values of 300kW and 500kW were selected as the maximum heat input levels and the burner controlled to follow the $t^2$ curve to the selected level and then maintain that setting for the duration of the test.

## B4 Airflow

For most of the tests the airflow passing through the 400mm x 400mm duct was set at 4m/s (0.64m$^3$/s) as this corresponds to that most commonly encountered in practice. The high temperature fan drawing air through the duct was controlled by an inverter drive. By adjusting the fan and noting the pressure differential measured across the orifice plates in the 210mm and 125mm pipes, a total flow of 0.64m$^3$/s was established through the pipes drawing air through the 400mm x 400mm duct. A few tests were conducted with a flow of 2m/s or 3m/s passing through the duct, flows for these were established in a similar manner.

The airflow entrained through each of the vents into the 160mm diameter side branches was set at 2m/s, corresponding to that most commonly encountered in practice. By adjusting the rotating plate under each vent and noting the pressure differential measured by the McCaffrey probe installed in the associated side branch the required flow rate was established.

In all cases the airflow was established prior to the commencement of the test and the fan then left unadjusted for the duration of the test or until the downstream damper closes, the fan then being controlled to maintain a constant underpressure in the duct downstream of the damper.

For the preliminary tests, conducted without a damper, the 125mm diameter tube was sealed and all flow passed through the 210mm diameter tube. For the tests conducted

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with dampers installed, the initial flow was drawn through both tubes. In the event of the damper closing, the sliding valve arrangement connecting the 210mm diameter system to the duct was closed and all flow passed through the 125mm diameter tube. For "Fan 0ff" situations the fan was switched off 2min after the ignition of the burner.

In five of the tests, the rotating disc controlling the flow through the vents into the side branches was replaced by a section of non-combustible board which was adjusted against the inlet flange of the side branch to give the required flow. In these tests the board was pulled away from the vent 2minutes after the ignition of the burner to simulate the effect of a ceiling fitting melting and falling away. Two of these tests were conducted for a "Fan 0ff" situation, the fan being switched off 1min:45s after the ignition of the burner.

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