ASFP
www.asfp.org.uk

BLUE BOOK

British Standard version

Fire resisting ductwork

tested to BS476 Part 24

3rd Edition

(Volume 3 of 3 – rules for assessments)

FIRE AND YOUR LEGAL LIABILITY

Fire kills around 300 people and damage claims exceed £1 billion every year in the UK. That's why we must all play our part.

Why is this of relevance to me?

If you are involved in the provision of fire protection, at any level, then you share liability for its usefulness and its operation when it's needed in a fire, and that liability will still be there in the event of a court case.

I place the order; it is not my responsibility to install the works

If it is your responsibility to specify the materials and/or appoint the installation contractor it is also your responsibility to ensure that they can prove competency for the fire protection materials used, or the works to be carried out. It's no longer simply a duty of care or voluntary – it's a legal obligation under sections 5.3 and 5.4 of the Regulatory Reform (Fire Safety) Order 2005. Similar provisions also exist in equivalent legislation in Scotland and Ireland.

If you knowingly ignore advice that leads to a failure in the fire performance of any element of installed fire protection within a building, then you are likely to be found to be just as culpable as the deficient installer.

You also share liability for the provision of information required under Building Regulation 38 (formerly 16B) that tells the user of the building about the fire prevention measures provided in the building. The user needs this to make an effective risk assessment under the Regulatory Reform (Fire Safety) Order 2005 and national equivalents in Scotland and Ireland.

I'm only installing what I'm contracted to do

If you are installing fire protection, then as with those specifying the materials and/or the contractor, you also have a legal obligation to ensure that the materials you install are adequate under sections 5.3 and 5.4 of the Regulatory Reform (Fire Safety) Order 2005 and national equivalents in Scotland and Ireland.

What is expected of me?

In the event of fire, and deaths, a court will want to know how every fire protection system was designed and specified; the basis for selection of the installer; whether adequate time was provided for its installation; and whether there was adequate liaison between the different parties to ensure it was installed correctly. No ifs, no buts – it's all contained in the Construction, Design and Management Regulations 2015.

The CDM 2015 Regulations, enforced by Health and Safety Executive, concentrate on managing the risk, and the health and safety of all those who design, specify and build, those that use the building, those who maintain it and those that demolish it – cradle to grave.

Be aware – the time to consider the above is before the event, not after it!

Association for Specialist Fire Protection (ASFP)

The Association was formed in 1976, and currently represents UK manufacturers and contractors of specialist passive fire protection products, with associate members representing regulatory, certification, testing and consulting bodies. It seeks to increase awareness and understanding of the nature of fire and the various forms, functions and benefits provided by passive fire protection. It is willing to make available its specialist knowledge on all aspects of fire protection and can assist specifiers and main contractors in identifying products suitable for specific requirements, both in the UK and related overseas markets. The Association encourages experimental work related to passive fire protection and promotes consideration and discussion of all issues affecting the fire protection of buildings

Kingsley House, Ganders Business Park, Kingsley, Bordon, Hampshire GU35 9LU, UK
Tel: 01420 471610 Fax: 01420 471611 www.asfp.org.uk

Building and Engineering Services Association

BESA is the UK's leading trade association for building engineering services contractors – representing the interests of firms active in the design, installation, commissioning, maintenance, control and management of engineering systems and services in buildings. Founded in 1904, it adds value to members' businesses by providing quality services, promoting excellence and shaping the commercial environment through representation and leadership.

137-143 Hammersmith Road London W14 0QL
Tel: 020 7313 4900 www.thebesa.com

National Association of Air Duct-Cleaners UK (NAADUK)

National Association of Air Duct cleaners UK is the UK's trade association representing contractors who provide cleaning services for HVAC ducts and other equipment. All NAADUK operators have agreed to meet stringent criteria to become a member and are trained, qualified and certified equivalent to TR/19 and BSEN 15780 standards.

Naaduk 12A Flightway, Dunkeswell, Honiton, Devon EX14 4RD
Tel: 01404 891539 www.naaduk.co.uk

The Fire Test Study Group (UK) Ltd (FTSG)

FTSG is a forum for technical discussions and liaisons between consulting fire test laboratories involved in producing test and assessment information for the purposes of building control.

The member laboratories are all UKAS Accredited for testing and the primary objective of the group is to ensure common technical interpretations of the fire test standards and a common approach to technical appraisals or assessments of products which may be made by the members within the terms of Approved Document B and national equivalents in Scotland and Ireland.

FTSG members support the publication of this edition of the “Blue Book” as it provides specifiers and regulatory bodies with an independently validated comprehensive and concise guide to the performance of fire resisting ducts when tested against British Standards.

Fire Test Study Group (UK) Ltd, Holmesfield Road, Warrington, Cheshire, WA1 2DS
Tel: 01925 655116 www.ftsg.co.uk

Acknowledgements

The publishers wish to express their appreciation of the work undertaken by the ASFP Technical Committee and Task Group 6 (Fire Resisting Ducts and Dampers) in the drafting of this 3rd edition of the Blue Book BS. Particular appreciation is expressed to the following individuals who served on an editing group from Task Group 6:

Darren Webster	Firesafe Ductwork (TG6 chair)
Paul Hanson	Royal Borough of Kensington & Chelsea
Brian James	Fire Protection Ltd and BESA delegate
Tony Baker	BRE
Norman Macdonald	Firemac
Shayne Wehrle	Swegon Air Management
Niall Rowan	ASFP Technical Officer

Disclaimer

Although care has been taken to ensure, to the best of our knowledge, that all data and information contained in this document is accurate to the extent that it relates to either matters of fact or accepted practice or matters of opinion at the time of publication, neither the Association for Specialist Fire Protection Limited nor the co-publishers will be liable for any technical, editorial, typographical or other errors or omissions in or misinterpretations of the data and information provided in this document. Since this document may be subject to change and updating, it is an uncontrolled document. The data is only correct at the dates of the fire assessment and acceptance into this publication. The latest version of this publication is freely downloadable from the ASFP web site at www.asfp.org.uk/publications. The latest date is indicated at the bottom of each page. The ASFP offers no responsibility for products delivered to the market, or for any aspect of 'withdrawn' products.

Compliance with this ASFP document does not of itself confer immunity from legal obligation.

Amendment sheet

DATE	SECTION	AMENDMENT SUMMARY
31-08-17	All	New volume 3 produced to include all of existing assessment rules which were included in second edition of the Blue Book (BS) but which were omitted from third edition.

Since this document may be subject to change and updating, it is an uncontrolled document. For the latest version of this publication visit the ASFP web site at www.asfp.org.uk/publications as indicated by the dated 'footer' on each page.

Assessments or 'engineering judgments'

1. General to increase scope of a products range

The sheer range of products and sizes and configurations of passive fire protection products means that it is almost impossible to test every single variant. It would also be uneconomic to do so and fire resisting ducts are no exception. Consequently, assessments or 'expert judgments' are used following the generation of fire test evidence to expanding the scope of the applicability of the tested product/system. Assessments are normally the view of a recognised expert in a particular fire test, and the performance of products in that test, that may be used for the purpose of interpreting or applying results in connection with National Regulations.

Assessments have been used in this way, in the UK, for many years and have been accepted as having a similar status to a test report. It is normal for UKAS accredited test laboratories to conduct the assessments although this is by no means mandatory. Some fire consultants and suitably qualified/experienced fire engineers would also be expected to have the appropriate knowledge. ASFP recommends that assessments using these rules are only carried out by UKAS accredited test laboratories or suitably qualified/experienced fire engineers.

ASFP recommends that such assessments are conducted in accordance with the 'PFPF Guide for Assessments In Lieu Of Fire Resistance Tests'. Assessments, which follow the guidance within the PFPF Guide, will provide the end user with confidence that the evaluation has been carried out with the necessary care and expertise and is appropriate to the intended use. The guide can be downloaded from here: http://ftsg.co.uk/pubs.html

2. General to increase scope of a products range

Just as all the combinations of permutations of fire-stopping cannot all be tested, so the total range of end-use (on-site) applications cannot be tested either. Special conditions will arise from site to site which may mean that the manufacturer's instructions and tested installation method cannot be followed. In such circumstances, an evaluation of likely performance needs to be undertaken. This is normally conducted via a site specific 'assessment' or 'expert judgment' report as per 6.1 above. The report should address the on-site condition and the required amendments to the construction and provide justification that the proposed changes are acceptable. Typical areas where site specific assessments may be required are:

a) 'one-off' projects or applications, where the cost of testing would otherwise make the application uneconomic

c) Where, for various reasons (e.g. size or configuration) it is not possible to subject a construction or a product to a fire test.

3. Direct and Indirect application (ducts tested to BS 476: part 24)

The application of data from tests to BS476 Part 24 may be split into two distinct categories viz. direct application i.e. that not requiring the opinion of an independent expert and extended fields of application which requires an assessment

Direct application is derived from information obtained from tests carried out in accordance with BS 476: Part 24 at UKAS accredited laboratories. The test results achieved by a particular design may be directly applied to a limited number of variations (e.g. a reduction in duct size) without recourse to expert advice, providing the design remains substantially as tested – *See Section 11.2*

Extended application is assessed from test evidence to BS 476: Part: 24 which may be supplemented by appropriate test evidence generated from other sources. The assessment considers changes in the tested design beyond the scope of direct application and may also consider variations to the tested design. For example, an increase in duct size which necessitates the inclusion of a joint in the duct walls.

3.1 Direct application (ducts tested to BS 476: part 24)

3.1.1 Introduction

The scope of the current BS test method does not consider the effect, detrimental or not, that variations in the test construction may have on the achieved performance of the duct (i.e. the field of direct application is very limited).

3.1.2 Critical Parameters

The following text conforms to accepted best practice in the UK. Rules for direct application of EN test data are very similar.

Vertical and Horizontal Ducts
A test result for horizontal ducts A and B is applicable to horizontal ducts only.

A test result obtained for vertical ducts A and B is applicable to vertical ducts without a horizontal branch. However, if a test on a horizontal duct A with a branch is also successfully undertaken the vertical ducts may include a horizontal branch.

Sizes of Ducts
A test result obtained for the standard sizes of ducts A and B is applicable to all dimensions up to the size tested together with the following increases

	Rectangular Width (mm)	Rectangular Height (mm)	Circular Diameter (mm)
Duct A	+ 250	+500	+200
Duct B	+250	+750	+370

For ducts tested at smaller sizes than those specified in Clause 6 of BS476 Part 24, no extrapolation of data to larger sizes can be allowed.

The maximum sizes that may be considered under direct application rules are as follows –

	Rectangular Width (mm)	Rectangular Height (mm)	Circular Diameter (mm)
Duct A	1250	1000	1000
Duct B	1250	1000	1000

Pressure Difference
The test results obtained for the standard under-pressure of 300 Pa in duct A is applicable to an under-pressure and an over-pressure up to the same value, viz -300 to +300 Pa, providing that the integrity criteria during Duct B test was satisfied

Height of Vertical Ducts
Ducts supported at each storey

The test results are applicable to any number of storeys provided:

i) the distance between supporting constructions does not exceed 5m.

ii) limitations on buckling are satisfied, as below

- Self-load bearing ducts

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

- Limitations on buckling

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

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

Support systems - Horizontal Ducts

Horizontal ducts are typically supported along their length by a system of frames and fire resisting fixings to the building structure, which generally consist of vertical hangers connected to a horizontal member, or members. The vertical hangers are fixed to the building structure above the duct.

Unprotected hangers made of steel may be sized such that the calculated stresses do not exceed the values given as follows:

Allowable Tensile Stress			
Tensile stress in all vertically oriented components	**Up to 60 minutes**	**Over 60 minutes up to 120 minutes**	**Over 120 minutes up to 240 minutes**
	15 N/mm^2	10 N/mm^2	6 N/mm^2

Note 1: *The elongation in mm of the hangers of the test ducts can be calculated on the basis of temperature increases and stress levels. For unprotected supporting systems, the temperature used will be the maximum furnace temperature. For protected steel hangers, the maximum recorded hanger temperature, if available, shall be used. The value represents the elongation limit for hangers with a greater length than in the test.*

Note 2: *Stress is calculated from supported load only.*

An example for the calculation of tensile stress in vertical hanger members:

W	=	weight of duct assembly per unit length	-	kg/m
W_b	=	weight of bearer per unit length	-	kg/m
W_r	=	weight of drop rod per unit length	-	kg/m
L_h	=	distance between hanger supports	-	m
L_b	=	length of bearer	-	m
h	=	height of drop rod	-	m
A	=	cross section area of drop rod *	-	mm^2

Weight of duct on each hanger support = $(W \times L_h)$ kg

Weight of hanger support = $(W_b \times L_b + 2W_r \times h)$ kg

Therefore tensile strength stress in drop rod (σ)

$$= \frac{(W \times L_h + W_b \times L_b + 2W_r \times h) \times 9.81}{2A} \quad \text{N/mm}^2$$

* If the drop rod is a threaded rod then A is based on the root diameter.

Note 3: *The maximum tested stress may be used if greater than above.*

Note 4: *The largest distance between frames of the support systems used in the test construction must not be exceeded in practice.*

Note 5: *If frames of the support system have been positioned at all joints within the furnace, then these must be located at all joints in practice.*

Note 6: *In cases where the lateral dimension between the outer vertical surface of the duct and the centre line of the vertical hanger rod is less than 50mm, the test result will apply up to 50mm. The lateral dimension must not exceed 50mm unless demonstrated by test. The horizontal load bearing component of the support system shall be sized so that the bending stress does not exceed that applied to the equivalent member in the test.*

Compensators
If compensators providing for expansion have been incorporated in the test, in practice the distance between each compensator must not be more than 10m. Where the duct passes through a wall, the compensator must be located not more than 5m from the wall.

Supporting Construction
For the purpose of this publication the supporting construction is the wall or floor through which the duct passed under test. In practice it may be referred to as a compartment floor or wall or separating element. Consequently a test result obtained for a fire resisting duct passing through a wall or floor made of masonry, concrete or a partition (without any cavity) is applicable to the same type of construction providing its thickness and density is equal to or greater than that used for the test.

Duct leakage value
Provided a duct is selected for test representing a certain leakage value, the test results will apply to those ducts having lower leakage values. (See HVCA publications DW/143 and DW/144.)

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

Penetration Seal
It is important in order to maintain the performance of the duct that the position where it passes through the supporting construction is effectively sealed. **The test method considers this seal to be an integral part of the duct construction. Therefore, for the field of direct application, it must be constructed of the same material and be installed using the same method as tested.** The gap dimension between the inside edge of the supporting construction and the perimeter of the duct and hence the seal 'thickness' must also remain as tested.

3.2 Extended application (ducts tested to BS 476 part 24)

Specialist technical advice should be sought from a competent organisation if desired variations in the tested construction are not included within the field of direct application. Such variations may include the following:

i) Increase in size of duct beyond direct application;

ii) Ducts with 1, 2 or 3 sides;

iii) Variation in supporting method;

iv) Change in duct construction (e.g. alternative materials);

v) Change in duct orientation (e.g. from horizontal to vertical);

vi) Change in duct use (e.g. ventilation to smoke extract);

vii) Change in duct shape;

viii) Variation in jointing method;

ix) Variation in penetration sealing system.

The above list is not exhaustive and acceptable variations are subject to test performance and duct design. It is prudent to consider the intended range of ducts to be offered prior to testing to ensure a large number of tests are avoided.

For the purpose of assessments for the extended field of application, laboratories accredited by UKAS for conducting the relevant tests and some fire consultants might be expected to have the necessary expertise or competent authority /persons appropriate to the complexity of the evaluation undertaken.

<u>The following rules for extended application are designed to provide a uniform approach for the assessment of fire resisting ductwork. The types of ductwork covered in this document are:</u>

i) Mechanical Ventilation Systems – used to extract vitiated or polluted air from a building and to supply replacement fresh or conditioned air.

ii) Smoke Extraction Systems – used to evacuate products of combustion from a building, such as smoke and toxic gases.

iii) Dual Ventilation/Smoke Extraction Systems – used as a conventional ventilation system under normal conditions, but converted to a smoke extraction system in the event of fire.

iv) Pressurisation Systems – used to restrict the penetration of smoke into certain critical areas of a building by maintaining the air within them at pressures higher than those in adjacent areas.

v) Car Park and Kitchen Extract Systems – car parks and non-domestic kitchens are required to have separate and independent extraction systems because of the polluted nature of the extracted air.

All assessment reports must clearly state which types of ductwork are covered by the assessment and which types are not covered.

These rules do not apply to ducts/enclosures containing building services.

3.2.1 Extended application for steel ducts

3.2.1.1 General

a. *Requirements for assessors and for test data* – The requirements for assessors and for the suitability of primary and secondary fire test data should be as described in the Passive Fire Protection Federation document 'Guide to Undertaking Assessments in Lieu of Fire Tests'.

b. *Fire resistance period* – The maximum fire resistance period for duct A (fire outside) should not exceed the maximum period tested on duct A. The maximum fire resistance period for duct B (fire inside) should not exceed the maximum period tested on duct B. In each test the performance criterion for stability must have been satisfied for the required duration. Also the performance criteria for integrity and insulation should have been satisfied for the required duration. However, if a premature failure of integrity or insulation occurs (e.g. integrity failure at the penetration seal through the wall) an assessment may be carried out, giving clear reasons and arguments for the failure and the necessary corrective measures to increase the performance to the required fire resistance period, provided that the test was continued to the required duration to prove the stability performance of the duct.

c. *Ducts A and B* – An assessment should only be carried out for duct A if a duct A has been tested. An assessment should only be carried out for duct B if a duct B has been tested.

d. *Fire resistance* – The fire resistance performance of a duct refers to the three performance criteria of stability, integrity and insulation. Assessments for the same duct construction should not be carried out for the addition of insulation if an uninsulated duct assembly was tested or for an uninsulated duct if an insulated duct assembly was tested.

e. *Material* – Tests on mild steel ducts may be used to assess ducts constructed with stainless steel but not vice versa.

f. *Practicality* – The assessor should try to ensure that the construction of the tested/assessed ductwork system is practical for on-site applications. For example, consideration may have to be given to the design of the penetration seal system for applications where space is restricted between the duct and adjacent walls or floors.

3.2.1.2 Increase in size of duct beyond limits of direct application of test data

The aspects of the duct construction that must be considered for larger ducts are:

a. *DUCT SPECIFICATION* – The design specification for larger and smaller ducts is provided by the manufacturer of the duct. The design must be the same as that of the tested ducts. The specification must be based on the following parameters.

b. *GAUGE OF STEEL SHEET* – The design of the duct, including the gauge of steel sheet used in the construction, must be suitable for the velocity, pressure and structural requirements of the duct. However, in all cases, the minimum thickness of the steel sheet must be the steel thickness of the tested duct.

c. *LONGITUDINAL SEAMS* – Use 'Pittsburgh lock seam' or 'Grooved corner seam' unless another type is tested.

d. *CROSS JOINTS* – The cross joints are one of the main structural components of a duct system and are essential to maintaining the stability and integrity of a fire rated duct. The tested cross joints and fixings should be the minimum fitted. If roll-formed sheet metal profiles are tested then rolled steel angle-flanged joints may be used but not vice versa. The size of the joint members should be increased for larger sizes. The stresses (e.g. bending, compressive) within the joint members should not exceed those within the tested joint members or those given in the following Table, whichever is the greater. ***See 6.2.1.11 for the calculation procedure.***

Fire resistance period – minutes	Up to 60	Over 60 up to 120	Over 120 up to 240
Limiting stress – N/mm^2	15	10	6

e. *PANEL STIFFENING* – If tested ducts include panel stiffening then this must be included on all assessed ducts. If tested ducts were made with plain sheet then panel stiffening may be added.

f. *INTERMEDIATE STIFFENERS* – Intermediate stiffeners may be fitted around the duct, located between the cross joints. The stiffeners may be added to give additional support to the duct walls and therefore reduce the stresses within the cross joint members. If stiffeners are fitted this may allow the spacing between cross joints on larger ducts to be maintained instead of being reduced. If stiffeners were fitted to the tested ducts then the maximum tested spacing between cross joints and stiffeners must not be exceeded.

g. *INTERNAL STIFFENERS* – Tie bars may be fitted that connect the flanges of cross joints. If the tested ducts were fitted with tie bars then they must be fitted in practice. If tie bars were fitted at the penetration seal in the tested ducts then they must be fitted to all ducts at the penetration seals.

h. *DUCT SECTION LENGTH* – The maximum tested section length must not be exceeded.

i. *ASPECT RATIO* - The maximum aspect ratio for a rectangular duct of the longer side dimension to the shorter side dimension is 4:1.

3.2.1.3 Variation in supporting method

The support systems used for fire resisting ductwork must be capable of bearing the load of the ductwork under fire conditions. The support systems generally consist of the hangers and bearers, the fixings and brackets.

The aspects of the support systems that must be considered are:

a. *TYPE OF SUPPORT SYSTEM* – The type of support system used should be the tested system. If an alternative system is proposed, it must be shown to be strong enough, provide equivalent support to the ductwork compared to the tested system and be shown that it will not cause an increase in the deformation of the duct in fire.

b. *STRENGTH OF SUPPORT SYSTEM* – The tensile stress of unprotected hanger (drop rod) members must not exceed $15N/mm^2$ for fire ratings up to 60 minutes, $10N/mm^2$ for fire ratings up to 120 minutes and 6N/mm^2 for fire ratings up to 240 minutes. (A calculation method is provided in section 6.1.2). The shear and bending stresses in the bearers should not exceed those in the tested bearers. The stresses in protected support system members should not exceed the tested values. Stresses within the support components can be reduced by increasing the size of the components or reducing the spacing of the supports. Alternatively fire protection may be fitted around the supports; this will reduce the maximum temperature reached by the support components, allowing higher stresses to be used. Table 1 of BS 5950: Part 8 provides details of the strength reduction factors for grades 43 and 50 steels at elevated temperatures.

c. *SPACING AND POSITION OF SUPPORT SYSTEM* – The spacing between support systems should not exceed the maximum spacing tested. If some of the support systems on the tested ducts were positioned at approximately midway between cross joints or between cross joints and stiffeners then the support systems may be positioned at any point along the duct. If the support systems were positioned adjacent to cross joints or stiffeners on the tested ducts then they must be fitted adjacent to a cross joint or stiffener in practice.

d. *ELEMENT OF BUILDING CONSTRUCTION* – The element of building construction to which the support systems are attached must have a fire resistance of at least that specified for the duct and be able to support the weight of the duct under fire conditions. The fixings and brackets used to connect the support systems to the element of building construction must be all steel fixings, have been proved to be suitable for use on fire rated constructions for the time period required, be strong enough to support the weight of the duct under fire conditions and be fitted in accordance with the manufacturer's instructions. The most common type of fixing into masonry/concrete constructions is an expansion anchor. Chemical anchors and shot-fired fixings are not usually suitable unless they have met the above requirements.

3.2.1.4 Penetration seals at compartment walls & floors

The following general rules are to be followed when considering the method of sealing gaps around ductwork where it penetrates a compartment wall or floor. Further explanatory text is provided in the appendix.

a. *TYPE OF SEAL* – The method of sealing any gaps around the duct, including collars or sleeves, as it passes through a compartment wall or floor should be the same as that tested or assessed in accordance with BS476 Part 24.

b. *GAP SIZE* – The gap between the duct and the reveal of the opening in the wall or floor should be the same as the gap tested ± 10%. For gap sizes greater than this range, the size of the opening must be reduced to a similar size to that tested. The reduction in opening size can be achieved by reinstating the wall or floor with original or equivalent materials. The remaining gap must be sealed as tested with the ductwork system. For gap sizes smaller than this range and for alternative solutions to reducing the gap size of larger openings, the method of sealing the gap must be independently assessed.

c. *DUCT CROSS JOINTS AND STIFFENERS* – If a duct cross joint or stiffener was fitted within, or adjacent to the penetration seal on the tested duct(s) then a cross joint or stiffener must be fitted at penetration seals in practice.

d. *DUCT SUPPORTS* – In practice, the distance between the face of the wall and the first support to horizontal ductwork, on both sides of the wall, must not be exceeded by more than 100mm of the distance employed on the fire side of the *fire* test specimen. The method and location of supporting ductwork in practice must be the same as tested or assessed.

e. *WALL OR FLOOR CONSTRUCTION* –Fire rated ducts may pass through walls / floors that have differing fire resistance requirements. The thickness and type of wall /floor will affect the fire resisting performance. The test data only applies to the thickness and type of wall /floor as used in the duct test. Otherwise independent assessment will be required

f. *SIZE OF DUCT* – The performance of the sealing system when used with ducts that are larger than the tested duct must be independently assessed.

3.2.1.5 Insulation

a. *TYPE OF INSULATION PRODUCT* – Tests on insulated duct assemblies relate only to the specific named insulation product as tested and the fixing method used. Alternative insulation products and fixing methods should not be assessed without additional test data to BS 476: Part 24 or compatible with Part 24.

b. *THICKNESS* – The thickness of the tested insulation product may be reduced for shorter fire resistance periods than those tested but not increased for longer periods than those tested

c. *PROTECTION SYSTEM* – In some cases the insulation/protection system is supported independently from the steel duct. Where this occurs additional support may be needed for the protection system, particularly the top and bottom walls of the system, for larger sizes of duct.

3.2.1.6 Smoke outlet/extraction ducts

Where the steel duct system is to be used as a smoke outlet/extraction duct, the non-mandatory annex to B.S. 476: Part 24: 1987 recommends that an additional criterion of 75% retention of cross-sectional area should apply to the duct system, for both type A and B ducts, in order to maintain adequate extraction. Therefore to be suitable for a smoke outlet/extraction duct, the tested duct system must have retained at least 75% of its cross-sectional area, both inside and outside the furnace, for the required duration.

For ducts larger than those tested it must be ensured that the modifications to the gauge of steel sheet, the size and strength of the cross joints, the size of stiffeners, the maximum spacing between cross joints and stiffeners and the spacing of the hanger support systems are sufficient for the duct system to retain at least 75% of its cross-sectional area.

3.2.1.7 Kitchen extract ducts

Where the steel duct system is to be used as a kitchen extract duct, the non-mandatory annex to B.S. 476: Part 24: 1987 recommends that the ducts are not lined with combustible materials, which are likely to accumulate combustible deposits, and that the temperature rise on the internal duct surface of duct type A should not exceed 140^{o}C mean or 180^{o}C maximum. A steel duct will satisfy the first of these recommendations, as steel is deemed to be non-combustible. The temperature rise on the internal duct surface of duct type A, within the furnace, must be proven in the test on the duct A.

3.2.1.8 Vertical ducts

ORIENTATION – It is permitted to carry out an assessment for vertical ducts on the basis of tests on horizontal ducts but not vice versa.

a. *Support* – Vertical ducts must be supported at each floor level so that the weight of the duct is taken by the floor. This must not compromise the penetration seal. If the distance between the floors is greater than 5m – see 6.1.2 'height of vertical ducts' - then intermediate supports must be fitted, e.g. cantilever bracket from adjacent fire rated wall. Also, to prevent buckling of the duct, the distance between supports should not exceed 8 times the smallest lateral dimension across the outside face of the duct.

b. *Penetration seal* – The design of the penetration seal through a floor is the same as the design of the seal through walls for horizontal ducts.

3.2.1.9 One, two and three sided ducts

a. INDEPENDENT SYSTEMS - These occur where the insulation/protection system for the steel duct is independent from the duct. The 4-sided steel duct is constructed and supported in the usual way and the 1, 2 or 3-sided protection system is fitted independently from the steel duct. The protection system is fastened to the adjacent floor and/or wall via continuous steel angles, or similar. The angles and fixings must be strong enough to take the weight of the protection system when exposed to fire conditions. Steel support systems are sometimes fitted to take the weight of the protection system.

c. For this type of protection system, particularly for larger sizes, the protection system should have been tested to BS 476: Part 22 as a partition assembly and a ceiling membrane assembly to show that it can remain intact and carry out its protective function for the desired exposure period.

b. ATTACHED SYSTEMS – These occur where the steel duct itself is 1, 2 or 3-sided and is fastened to the adjacent floor and/or wall via continuous steel angles, or similar. The angles and fixings must be strong enough to take the weight of the duct and insulation when exposed to fire conditions. Steel support systems are sometimes fitted to take the weight of the duct system.

d. An alternative arrangement for attached systems is a 4-sided steel duct, constructed and supported in the usual way, with the 2 or 3-sided protection system fastened to the steel duct and butting up to the wall and/or floor soffit. The protection system may or may not be fastened to the wall and/or floor. Care must be exercised for both situations as the deflection of the steel duct may compromise the protection system.

e. If the insulation for the duct relied on being 'wrapped around' a 4-sided duct it must be shown that the alternative fixing method for the insulation is suitable.

3.2.1.10 Circular and flat oval ducts

Circular and flat oval straight seamed and spirally wound steel ducts may be assessed on the basis of the tests on rectangular ducts but not vice versa. Details of the construction of circular and flat oval straight seamed steel ducts must be provided by the duct manufacturer, but with the following minimum requirements:

- The minimum thickness of steel sheet used in the construction of the ducts is that used in the construction of the tested rectangular ducts.
- The longitudinal seams and cross joints must be at least equivalent in strength to the seams used on the tested rectangular duct.
- The spiral seam of spirally wound ducts must be at least equivalent to the grooved seam.
- The maximum diameter of circular ducts covered by an assessment is 1250mm.
- The maximum size of flat oval duct covered by an assessment is for ducts with a maximum surface area per metre length of $3.83m^2/m$.
- For flat oval ducts over 500mm wide x 150mm deep, tie rods with a minimum diameter of 12mm, must be fitted between the top and bottom walls of the flat portion of the duct, as follows:
    - for ducts between 500mm wide and 700mm wide, there should be one tie rod located at mid-width of the duct at 1000mm centres along the duct.
    - for ducts between 701mm wide and 900mm wide, there should be one tie rod located at mid-width of the duct at 750mm centres along the duct.
    - for ducts between 901mm wide and 1200mm wide, there should be two tie rods equi-spaced across the duct at 500mm centres along the duct.
    - for ducts between 1201mm wide and 1800mm wide, there should be tie rods at 250mm centres along the duct, alternating between one tie rod centrally located and two tie rods equi-spaced across the duct.
- The design of the penetration seal where the duct passes through fire compartment walls or floors must be equivalent to the system used for rectangular ducts.
- The design of the hanger support systems should be such that the maximum stresses in the hanger components do not exceed the limits described for rectangular ducts.

Generally circular and flat-oval ducts have been accepted due to the increased structural stability of circular and flat-oval ducting over the standard rectangular ducting. This is based on the theory that both these types of duct systems provide greater resistance to collapse of the duct at elevated temperatures compared to rectangular ducts.

3.2.1.11 Calculation procedure for cross joints of steel ducts

The stress in the cross joints is calculated for the top wall of the duct, assuming simply supported ends of the cross joint members.

DATA

Width of duct: d (m)

Section length of duct: L (m)

Steel cross joint member:

W_c = weight (kg/m)

Z_c = section modulus (cm^3)

Steel sheet of duct walls:

t = thickness (mm)

Note: It is assumed that, for duct sections without a stiffening collar at mid length, half the weight of the top duct wall is taken by the cross joint member. For duct sections with a stiffening collar at mid length, it is assumed that a third of the weight of the top duct wall is taken by the cross joint member.

Weight of insulation: W_i (kg/m^2)

Total weight per metre on the cross joint member (w) is:

$W_t = W_c + [(t \times 10^{-3} \times 7850) + W_i] \times L/2 \times 9.81$ (kg/m) without stiffener, or

$W_t = W_c + [(t \times 10^{-3} \times 7850) + W_i] \times L/3 \times 9.81$ (kg/m) with stiffener

Maximum bending moment (M) is:

$M = w \times L^2/8$

Stress in cross joint member (σ) is:

$\sigma = M/Z_c$ (N/mm^2)

3.2.2 Extended application for self-supporting ducts

Self-supporting fire rated ducts are those ducts that are formed with fire protection boards, and possibly framework, without a steel duct. Steel components may be used in the construction, e.g. steel angles at longitudinal corners and cross joints.

3.2.2.1 General

a. *Requirements for assessors and for test data* – The requirements for assessors and for the suitability of primary and secondary fire test data should be as described in the Passive Fire Protection Federation document ‘Guide to Undertaking Assessments in Lieu of Fire Tests’

b. *Fire resistance period* – The maximum fire resistance period for duct A (fire outside) should not exceed the maximum period tested on duct A. The maximum fire resistance period for duct B (fire inside) should not exceed the maximum period tested on duct B. In each test the performance criterion for stability must have been satisfied for the required duration. Also the performance criteria for integrity and insulation should have been satisfied for the required duration. However, if a premature failure of integrity or insulation occurs (e.g. integrity failure at the penetration seal through the wall) an assessment may be carried out, giving clear reasons and arguments for the failure and the necessary corrective measures to increase the performance to the required fire resistance period, provided that the test was continued to the required duration to prove the stability performance of the duct.

c. *Ducts A and B* – An assessment should only be carried out for duct A if a duct A has been tested. An assessment should only be carried out for duct B if a duct B has been tested.

d. *Fire resistance* – The fire resistance performance of a duct refers to the three performance criteria of stability, integrity and insulation. Assessments for the same duct construction should not be carried out for the fitting of an additional insulation product if the duct assembly was tested without additional insulation and vice versa.

e. *Material* – Tests only relate to the materials tested.

f. *Practicality* – The assessor should try to ensure that the construction of the tested/assessed ductwork system is practical for on-site applications. For example, consideration may have to be given to the design of the penetration seal system for applications where space is restricted between the duct and adjacent walls or floors.

3.2.2.2 Increase in size of duct beyond the size limit for direct application

The aspects of the duct construction that must be considered for larger ducts are:

a. *DUCT SPECIFICATION* – The design specification for larger and smaller ducts is provided by the manufacturer of the duct. The design must be the same as that of the tested ducts. The specification must be based on the following parameters.

b. *THICKNESS OF CONSTRUCTION MATERIALS* – The thickness of the materials forming the structure of the duct may be increased but not decreased. The minimum thicknesses of the materials should be the thicknesses used for the tested duct.

c. *LONGITUDINAL CORNER JOINTS* – The minimum specification for the joints should be the system used for the tested ducts. The strength of the tested joint design may be increased but the design of the joint should not be changed. Longitudinal joints must have been included in the tested specimens if they are to be included in the assessed constructions.

d. *CROSS JOINTS* – The cross joints are one of the main structural components of a duct system and are essential to maintaining the stability and integrity of a fire rated duct. The tested cross joints and fixings should be the minimum fitted. The strength of the tested joint design may be increased but the design of the joint should not be changed. If steel cross joints are fitted then the stresses (e.g. bending, compressive) within the joint members should not exceed those within the tested joint members or those given in the following Table, whichever is the greater. ***See 6.2.2.10 for the calculation procedure.***

Fire resistance period – minutes	Up to 60	Over 60 up to 120	Over 120 up to 240
Limiting stress – N/mm^2	15	10	6

e. *INTERMEDIATE STIFFENERS* – Intermediate stiffeners may be fitted around the duct, located between the cross joints. The stiffeners may be added to give additional support to the duct walls. If stiffeners are fitted this may allow the spacing between cross joints on larger ducts to be maintained instead of being reduced. If stiffeners were fitted to the tested ducts then the maximum tested spacing between cross joints and stiffeners must not be exceeded.

f. *INTERNAL STIFFENERS* – Internal stiffeners may be fitted within the duct. If the tested ducts were fitted with internal stiffeners then they must be fitted in practice. If the stiffeners were fitted at the penetration seal in the tested ducts then they must be fitted to all ducts at the penetration seals.

g. *DUCT SECTION/ LENGTH* – The maximum tested section length or distance between joints must not be exceeded.

h. *ASPECT RATIO* - The maximum aspect ratio for a rectangular duct of the longer side dimension to the shorter side dimension is 4:1.

3.2.2.3 Variation in supporting method

The support systems used for fire resisting ductwork must be capable of bearing the load of the ductwork under fire conditions. The support systems generally consist of the hangers and bearers, the fixings and brackets.

The aspects of the support systems that must be considered are:

a. TYPE OF SUPPORT SYSTEM – The type of support system used should be the tested system. If an alternative system is proposed, it must be shown to be strong enough, provide equivalent support to the ductwork compared to the tested system and be shown that it will not cause an increase in the deformation of the duct in fire.

b. STRENGTH OF SUPPORT SYSTEM – The tensile stress of unprotected hanger (drop rod) members must not exceed 15N/mm^2 for fire ratings up to 60 minutes, 10N/mm^2 for fire ratings up to 120 minutes and 6N/mm^2 for fire ratings up to 240 minutes. (A calculation method is provided in 6.1.2 Note 2. The shear and bending stresses in the bearers should not exceed those in the tested bearers. The stresses in protected support system members should not exceed the tested values. Stresses within the support components can be reduced by increasing the size of the components, or reducing the spacing of the supports. Alternatively fire protection may be fitted around the supports; this will reduce the maximum temperature reached by the support components, allowing higher stresses to be used. Table 1 of BS 5950: Part 8 provides details of the strength reduction factors for grades 43 and 50 steels at elevated temperatures.

c. SPACING AND POSITION OF SUPPORT SYSTEM – The spacing between support systems should not exceed the maximum spacing tested. If some of the support systems on the tested ducts were positioned at approximately midway between cross joints or between cross joints and stiffeners then the support systems may be positioned at any point along the duct. If the support systems were positioned adjacent to cross joints or stiffeners on the tested ducts then they must be fitted adjacent to a cross joint or stiffener in practice.

d. ADDITIONAL HANGERS ACROSS WIDTH OF DUCT – For ducts larger than those tested additional hanger members (drop rods) may be fitted across the width of the duct, at each support position, to provide extra support to the top and bottom walls of the duct.

e. The hangers must support the top and the bottom of the duct, including the bearers. Any penetrations of the hangers through the duct walls must be sealed with a fire rated seal system. The additional drop rods across the width of the duct are not required if steel cross joints are fitted that comply with the requirements of Section 6.2.2.2(d) above, and provided that it is considered that this will not affect the performance of the fire resisting board in fire

f. ELEMENT OF BUILDING CONSTRUCTION – The element of building construction to which the support systems are attached must have a fire resistance of at least that specified for the duct and be able to support the weight of the duct under fire conditions. The fixings and brackets used to connect the support systems to the element of building construction must be all steel fixings, have been proved to be suitable for use on fire rated constructions for the time period required, be strong enough to support the weight of the duct under fire conditions and be fitted in accordance with the manufacturer's instructions. The most common type of fixing into masonry/concrete constructions is an expansion anchor. Chemical anchors and shot-fired fixings are not usually suitable unless they have met the above requirements.

3.2.2.4 Penetration seals at compartment walls & floors

The following general rules are to be followed when considering the method of sealing gaps around ductwork where it penetrates a compartment wall or floor. Further explanatory text is provided in the appendix.

a. TYPE OF SEAL – The method of sealing any gaps around the duct, including collars or sleeves, as it passes through a compartment wall or floor should be the same as that tested or assessed in accordance with BS476 Part 24.

b. GAP SIZE – The gap between the duct and the reveal of the opening in the wall or floor should be the same as the gap tested ± 10%. For gap sizes greater than this range, the size of the opening must be reduced to a similar size to that tested. The reduction in opening size can be achieved by reinstating the wall or floor with original or equivalent materials. The remaining gap must be sealed as tested with the ductwork system. For gap sizes smaller than this range and for alternative solutions to reducing the gap size of larger openings, the method of sealing the gap must be independently assessed.

c. *DUCT CROSS JOINTS AND STIFFENERS* – If a duct cross joint or stiffener was fitted within, or adjacent to the penetration seal on the tested duct(s) then a cross joint or stiffener must be fitted at penetration seals in practice.

d. DUCT SUPPORTS – In practice, the distance between the face of the wall and the first support to horizontal ductwork, on both sides of the wall, must not be exceeded by more than 100mm of the distance employed on the fire side of the *fire* test specimen. The method and location of supporting ductwork in practice must be the same as tested or assessed.

e. WALL OR FLOOR CONSTRUCTION – Fire rated ducts may pass through walls / floors that have differing fire resistance requirements. The thickness and type of wall /floor will affect the fire resisting performance. The test data only applies to the type of wall /floor as used in the duct test. Otherwise independent assessment will be required

f. SIZE OF DUCT – The performance of the sealing system when used with ducts that are larger than the tested duct must be independently assessed.

3.2.2.5 Insulation

a. TYPE OF INSULATION PRODUCT – Tests on insulated duct assemblies, where an additional insulation product has been fitted to a self-supporting duct system, relate only to the specific insulation product tested and the fixing method used. Alternative insulation products and fixing methods should not be assessed without additional test data to BS 476: Part 24 or compatible with Part 24.

b. THICKNESS – The thickness of insulation material may be reduced for shorter fire resistance periods than those tested but not increased for longer periods than those tested

c. PROTECTION SYSTEM – In some cases the insulation/protection system is supported independently from the self-supporting duct. Where this occurs addition support may be needed for the protection system, particularly the top and bottom walls of the system, for larger sizes of duct.

3.2.2.6 Smoke outlet/extraction ducts

Where the duct system is to be used as a smoke outlet/extraction duct, the non-mandatory annex to B.S. 476: Part 24: 1987 recommends that an additional criterion of 75% retention of cross-sectional area should apply to the duct system, for both type A and B ducts, in order to maintain adequate extraction. Therefore to be suitable for a smoke outlet/extraction duct, the tested duct system must have retained at least 75% of its cross-sectional area, both inside and outside the furnace, for the required duration.

For ducts larger than those tested it must be ensured that the modifications to the thicknesses of materials used in the construction of the duct, the size and strength of the longitudinal/corner joints and cross joints, the size of stiffeners (if fitted), the spacing of the hanger support systems and the fitting of additional hangers (drop rods) across the width of the duct are sufficient for the duct system to retain at least 75% of its cross-sectional area.

3.2.2.7 Kitchen extract ducts

Where the duct system is to be used as a kitchen extract duct, the non-mandatory annex to B.S. 476: Part 24: 1987 recommends that the ducts are not lined with combustible materials, which are likely to accumulate combustible deposits, and that the temperature rise on the internal duct surface of duct type A should not exceed 140°C mean or 180°C maximum. If the walls of the duct are not made of a non-combustible material then the inside of the duct must be lined with a non-combustible material, e.g. steel sheet. The temperature rise on the internal duct surface of duct type A within the furnace must be proved in the test on the duct A. If an additional non-combustible lining is added, allowance must be made for the additional weight of the duct system and possible changes to the insulation performance of the duct system.

3.2.2.8 Vertical ducts

a. ORIENTATION – It is permitted to carry out an assessment for vertical ducts on the basis of tests on horizontal ducts but not vice versa.

b. SUPPORT– Vertical ducts must be supported at each floor level so that the weight of the duct is taken by the floor. This must not compromise the penetration seal. If the distance between the floors is greater than 5m - see section 6.1.2 - then intermediate supports must be fitted, e.g. cantilever bracket from adjacent fire rated wall. Also, to prevent buckling of the duct, the distance between supports should not exceed 8 times the smallest lateral dimension across the outside face of the duct.

c. PENETRATION SEAL – The design of the penetration seal through a floor is the same as the design of the seal through walls for horizontal ducts.

3.2.2.9 One, two and three sided ducts

These occur where the self-supporting duct itself is 1, 2 or 3-sided and is fastened to the adjacent floor and/or wall via continuous steel angles (or equivalent). The angles and fixings must be strong enough to take the weight of the duct and insulation when exposed to fire conditions. Steel support systems will have to be fitted to larger ducts to take the weight of the bottom wall of the duct system.

For this type of protection system, particularly for larger sizes, the protection system should have been tested to BS 476: Part 22 as a partition assembly and a ceiling membrane assembly to show that it can remain intact for the desired exposure period.

If the insulation for the duct relied on being 'wrapped around' a 4-sided duct it must be shown that the alternative fixing method for the insulation is suitable.

3.2.2.10 Calculation procedure for cross joints of self-supported ducts

The stress in the cross joints is calculated for the top wall of the duct, assuming simply supported ends of the cross joint members.

DATA

Width of duct: d (m)

Section length of duct: L (m)

Steel cross joint member:

W_c = weight (kg/m)

Z_c = section modulus (cm^3)

Board forming duct walls:

W_b = weight (kg/m^2)

Note: It is assumed that, for duct sections without a stiffening collar at mid length, half the weight of the top duct wall is taken by the cross joint member. For duct sections with a stiffening collar at mid length, it is assumed that a third of the weight of the top duct wall is taken by the cross joint member.

Weight of insulation: W_i (kg/m^2)

Total weight per metre on the cross joint member (w) is:

W_t = W_c + [W_b + W_i] x L/2 x 9.81 (kg/m) without stiffener, or

W_t = W_c + [W_b + W_i] x L/3 x 9.81 (kg/m) with stiffener

Maximum bending moment (M) is:

M = w x L^2 /8

Stress in cross joint member (σ) is:

$\sigma = M/Z_c$ (N/mm^2)