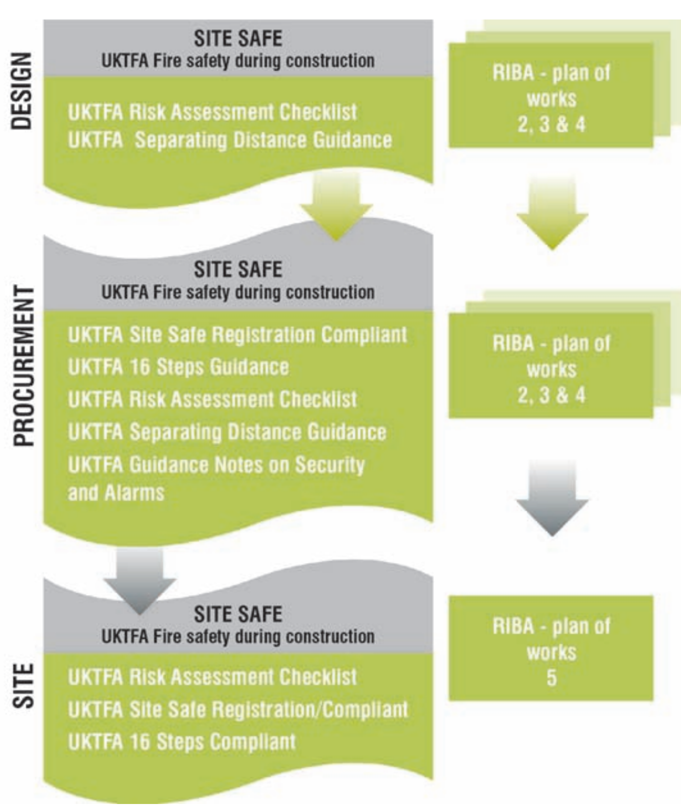
Timber Engineering Notebook series

No. 6: Timber frame structures – separating distances during construction for fire safety

This series is authored by the UKTFA

The UK Timber Frame Association (UKTFA) represents over 85% of the UK's timber structural frame supply industry and is a trade organisation that provides business and technical support to the industry. The Association provides peer reviewed outputs on subjects related to the timber industry such as health and safety, fabric and technical performance, fire safety, promotion and training. These documents and other information are available at www.uktfa.com

Figure 1
UKTFA Site Safe suite of guidance to mitigate risk of fire on construction sites



Introduction

Fire safety is an essential building regulation design requirement for any completed building. It covers aspects such as fire resistance, means of escape, fire spread and space separation. The latter determines the minimum distance of the completed building from a notional boundary such as a centre line of a road. The notional boundary concept applies to every new building, and in doing so, creates a minimum separation distance between completed buildings. For the purposes of this Notebook, this is called 'space separation in-service'.

In a completed building, the timber components are protected from the effects of fire by internal linings and external claddings. During construction however, the temporary exposed timber frame structure may present a risk of fire spread across the site, creating a safety risk to people and property beyond the site boundaries. For buildings under construction there are no codes or standards that provide technical guidance to determine what the safe fire space separation should be to existing buildings outside of the site boundary. Within the site, the contractor has the ability to control works and escape routes for the site labour, for which there are training and guidance available.

The UKTFA working with the Fire and Rescue Service, Association of British Insurers (ABI), The Fire Protection Association (FPA), Health and Safety Executive (HSE) and Fire Engineers has developed guidance, together with supporting documents, to address this gap in good practice information. The guidance relates to safe separating distances during construction for timber frame buildings with a total floor area >600m^2. The work undertaken by these organisations is the focus of this Timber Engineering Notebook.

Methods of achieving the in-service fire resistance of completed timber frame structures will be addressed in a subsequent article.

Background documents

The Construction (Design and Management) Regulations 2007[1] require the designer to consider safety in their choice of materials and how they are assembled in the building process and to ensure that inherent risks are designed out wherever possible.

The HSE published a revision of HSG 168[2] which is aimed at all methods of construction, but which includes a section specifically for timber frame buildings. This document reinforces the requirements of CDM for good fire safety on site and introduces the need, on large sites, for consideration to the risk of fire spreading off the site to adjacent buildings.

Figure 2
UKTFA categories of timber frame

Standard timber frame	Reduced fire spread timber frame	Fire spread resistant timber frame
Category A	Category B	Category C
Standard radiant heat emissions	Reduction in radiant heat emissions	
Standard ignition	Reduction potential for ignition of the frame	
Standard growth of fire	Slower growth of fire spread through compartments	Limited fire growth from seat of fire

The FPA publish guidance entitled *Fire Prevention on Construction Sites*[3]. This publication is targeted at main contractors and has a section that lists recommended approaches to prevent fire spread on large timber frame projects. The guidance references the UKTFA's own guidance as a source of information for contractors. Insurance companies expect all contractors on projects above £2M to comply with this FPA guidance.

The UKTFA has, as a mandatory requirement of membership, a Site Safe Policy that addresses the approach needed to mitigate fire risks on construction sites; the policy covers a comprehensive set of guidance papers (www.uktfa.com). Figure 1 provides the scope of the UKTFA Site Safe Policy and relevant documents matched to the RIBA plan of works. Included in the Site Safe Policy is the *UKTFA Design Guide to Separating Distances During Construction*[4]. The guidance is aimed at timber frame structures with a total floor area of >600m^2. The building types covered by the guidance are: classrooms, terraced houses, care homes, hospitals, hotels and multi storey accommodation buildings. For smaller developments (<600m^2) the guidance can be used, but will be too onerous for single houses and overly conservative for maisonettes and other dwellings of 3-4 units.

The guidance is intended for new build developments in all normal environments; urban, suburban and rural and where the new construction is to be built in close proximity to properties where people sleep, or areas of public gathering such as schools, colleges, restaurants, offices, commercial properties and factories.

The purpose of the design guide is to reduce radiant heat emissions to acceptable levels by the selection of appropriate timber frame material specifications via timber frame categories.

The document (freely available at: www.uktfa.com) provides simple tables from which to select separation distances based on the emitter building dimensions. There are several tables providing three different categories of timber frame (Figure 2). Each category is determined by the materials used (Figure 3). The tables presented in the guidance, give the safe separation distance for each type of category of timber frame. Figure 4 provides an example of the different separation distances for different categories of timber frame.

From the guide, a designer can select an emitter length (eL) which is suitable for the category of timber frame being considered (Figure 5). For a Category A frame this is the length of the timber frame construction which faces the neighbouring building (receiver).

Technical background to the UKTFA guidance on separating distances

The science of the development and behaviour of fire is extremely

Figure 3
Material differences in the categories of timber frame

Category A
Standard timber frame

Category B
Key changes from category A:

Flame retardant materials and insulation materials

There are three subdivisions; B1, B2 and B3 (B1 being lowest performance and B3 being highest)

Category C
Key changes from category A:

Limited or non-combustible sheathing

Figure 4 Example of separation distances

Example

4 storey with 15m emitter face (building greater than 600m²)

Category A - 18.5m

Category B2 - 12.75m

Category C - 7.00m

Number of timber frame storeys	EMITTER LENGTH (eL)						
	≤5m	≤10m	≤15m	≤20m	≤25m	≤40m	>40m
1	5.5	7.25	8.25	8.75	9.5	10.25	10.5
2	7.5	10.5	12.75	14.25	15.5	18	20.25
3	9	13	16	18	20	23.25	28.5
4	10	15	18.5	21.25	23.5	28.5	35.75
5	11	16.5	20.5	23.75	26.5	32.5	41.75
6	11.5	18	22.5	26	29	36	47.25
7	12.25	19	24	28	31.5	39.25	52.5

Number of timber frame storeys	EMITTER LENGTH (eL) - B2 FRAME			
	≤5m	≤10m	≤15m	≤20m
1	5	5	5.25	5.5
2	5.25	7.25	8.5	9.5
3	6	9	10.75	12.25
4	6.75	10.25	12.75	14.5
5	7	11.25	14	16.25
6	7.25	12	15.25	17.75
7	7.5	12.75	16.25	19.25

Number of timber frame storeys	EMITTER LENGTH - C1 FRAME		
	≤5m	≤10m	≤15m
1	5	5	5
2	5	5	5
3	5	5	5.75
4	5	5.5	7
5	5	6	7.75
6	5	6.25	8.25
7	5	6.5	8.25

Figure 5 Emitter lengths used in calculation of separating distances for Category A

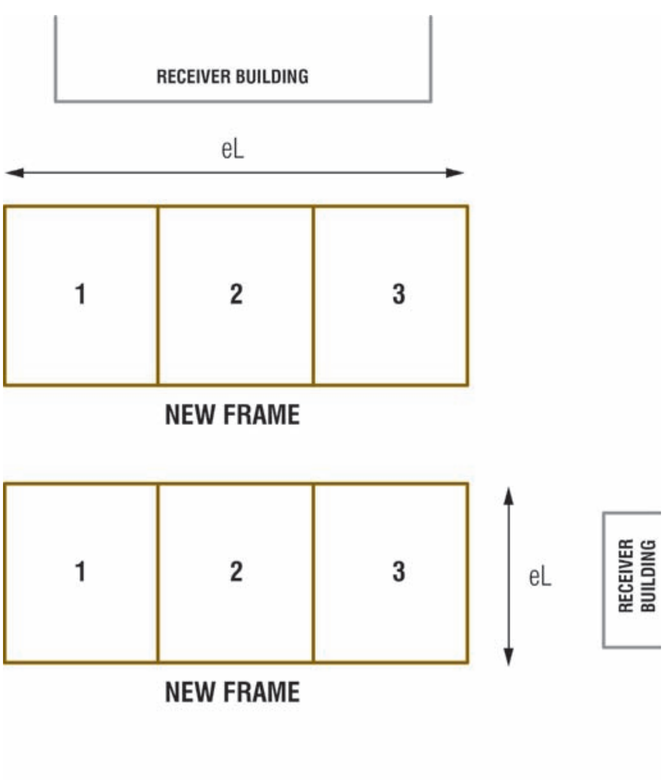


Figure 6 Flowchart for decision process

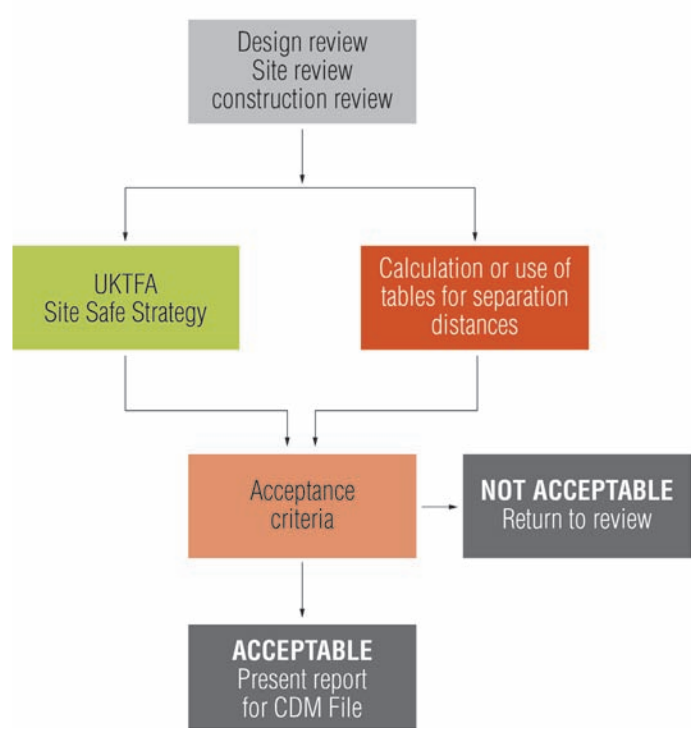
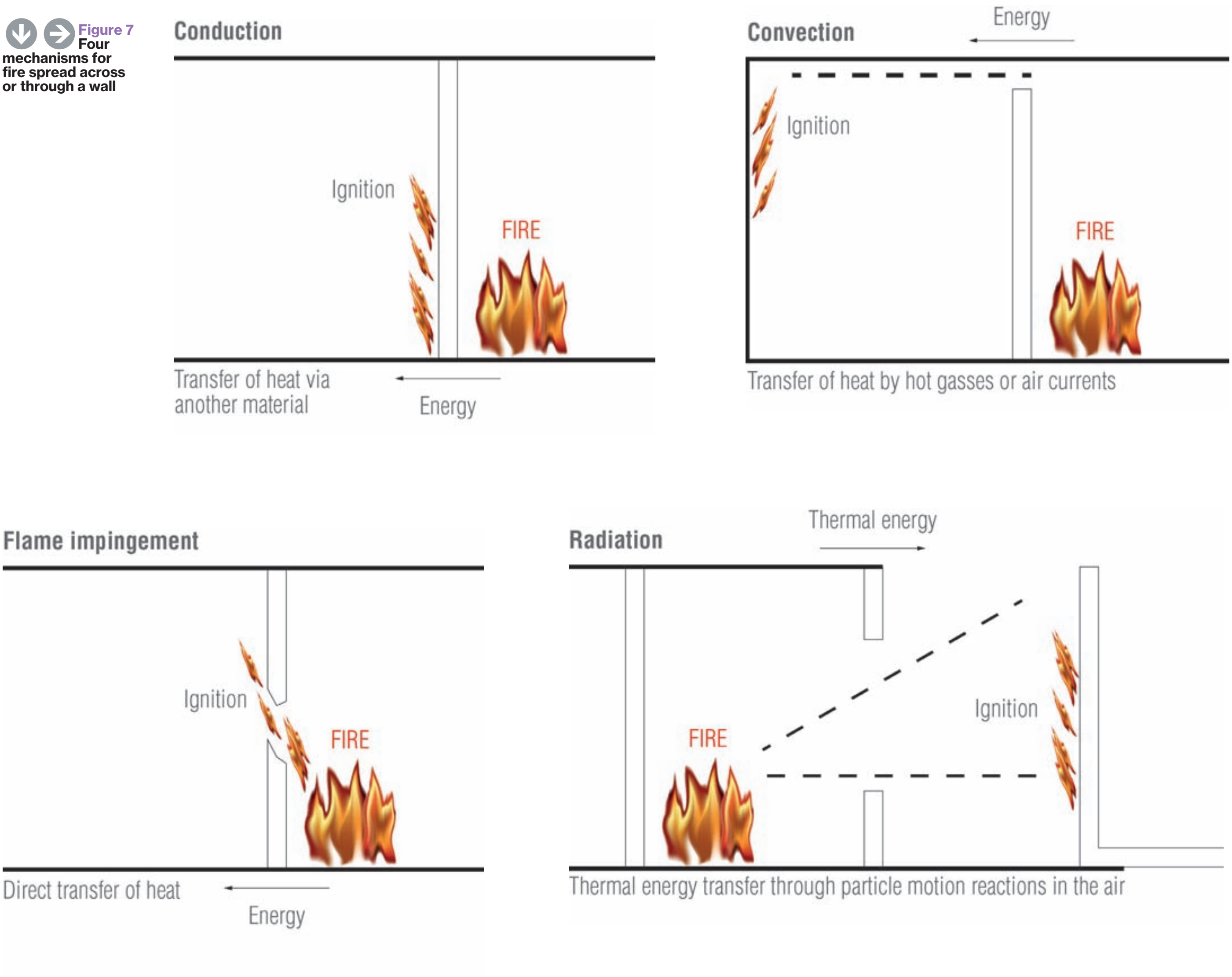


Figure 7 Four mechanisms for fire spread across or through a wall



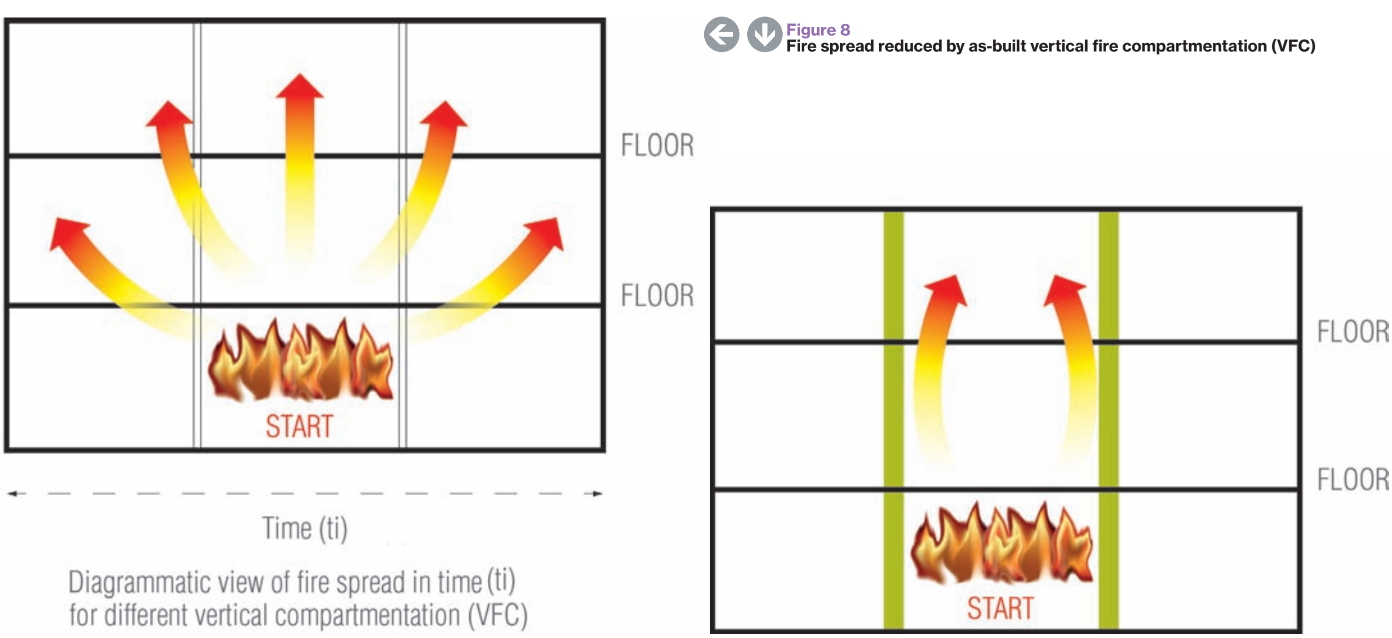


Figure 8 Fire spread reduced by as-built vertical fire compartmentation (VFC)

complicated and the subject of much mathematical debate and development. There are so many variables that simplification is essential to produce guidance that can be used efficiently by design teams. Fortunately there is a Fire Engineering code[5] together with a suite of supporting documents[6], which provide a framework from which, guidance on the behaviour of timber frame structures during the construction process was developed (Figure 6).

In determining the likely scenario of the impact of fire, it was important to consider the four mechanisms by which fire can spread across a building on a construction site and out beyond the site boundary (Figure 7).

The principle cause of fire spread from timber frame to buildings (both beyond and within a site boundary) is radiation. Radiation can cause heat energy to be transferred across significant distances. The term radiant heat flux (RHF) is used as the measure to qualify how much heat radiation is emitted from a fire source (the emitter) and how much of that RHF is transferred to the building either outside or inside the site boundary (the receiver). The RHF unit of measurement is kW/m^2.

Reference 6 provides an expression for the emitter radiated heat rate as:

$$q_{rad} = \varepsilon_g O' T_g^4 A_{rad}$$

Where:
q_{rad} is the radiant heat at the emitter of area A_{rad}
ε_g is the emissivity of the fire
O' is the Stefan-Boltzmann constant
T_g is the flame temperature

It can be seen from this equation that emitted radiant heat is significantly influenced by temperature which is raised to the power 4. Data on frame temperatures for timber frame buildings was not available, so the UKTFA had to undertake research and tests on different constructions to determine the range of temperatures arising from different frame assemblies and material types. It was from this research that three categories of timber frame were derived.

The amount of radiant heat that is calculated to be at a receiver is given by:

$$q_{rec} = \varphi q_{rad}$$

where φ is the view factor (an expresion to deterime how much of the the radiated heat is received at the distance being considered).

The view factors used in the UKTFA guidance were based on known design formula used across both the PD 7974 documents and other fire engineering texts. A review of each method was undertaken and results were both compared to tests and peer reviewed by fire engineering experts.

Within the UK Building Regulations, to derive space separation in service, designers refer to BRE Report 187[7]. The accepted level of RHF on a receiver building, from a fire in the emitter building given in the report, is 12.6kW/m^2 over a ten minute period. It was logical therefore to adopt the same value for the UKTFA guidance on acceptable separation distances between a timber frame building under construction, and that of an adjacent building which may be either completed or also under construction. The duration of the fire is a function of the available fire source, which is referred to as fire load per m^2.

During the construction of a timber framed building, the most vulnerable stage with regard to fire is when the structural shell is complete but with no secondary components to provide fire protection, for which the calorific value for combustion (the fire load) is at a maximum value. The UKTFA guidance provides the user with a choice of length of building (emitter length) based on the as-built vertical fire barriers which are referred to in the guidance as vertical fire compartmentation (VFC); for which the smaller the length between VFCs, the smaller the fire load available and hence a reduced radiant heat (Figure 8).

The VFC must not to be confused with the fire resistance compartmentation used in the Building Regulations for completed buildings. A building regulation wall requires the compartmentation to be continuous from wall to wall and ceiling to fulfil its function. The purpose of VFC, during the construction process, is to delay the fire spread and reduce the emitter length. For Category A frames the use of VFC cannot be relied upon to provide a reduction of fire spread, as the fire may simply spread round the sides of a single wall (Figure 9). In Category B and C the fire intensity is reduced, together

Figure 9
Fire intensity may spread around a VFC (Category A frame)

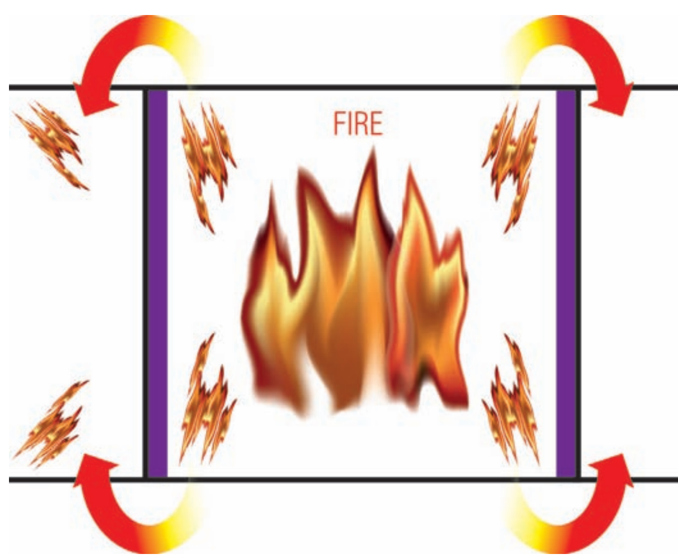


Figure 10
VFC in Category B and C

with less vulnerability on the other side of the VFC to induce simultaneous fire spread (Figure 10).

To reduce the emitter length of a Category A frame the VFC shall be designed with returns to stop flame impingement, conduction and ignition through holes in the structure. Category C frame adjacent to an A frame will provide a sufficient fire break providing it is stable and of sufficient depth to slow or stop the progress of a Category A fire spread. This is a case by case design and the UKTFA guidance recommends that a competent person is engaged to undertake any designs of emitter length reduction in Category A frames.

For Category B and C frames, VFC can comprise of the following:

- Approved flame retardant sheathing and timber frame party walls with full fill UKTFA fire tested insulation in the party wall cavity
- Non-combustible boards fixed to the party wall cavity face
- A non-combustible board on both faces to provide a continuous barrier
- For compartment walls, the continuity of fire spread resistance approach is to follow across floor levels and up to the top of the roof pitch level, so that there is no breach of fire spread compartmentation

Note: Openings for services in any VFC are to be closed off with non-combustible board material or mineral wool, to maintain the fire compartment resistance to fire spread. Simple fire doors (of similar construction as the walls to which they are attached) should be used for access routes through a VFC.

Fire behaviour assumed with each category of timber structure

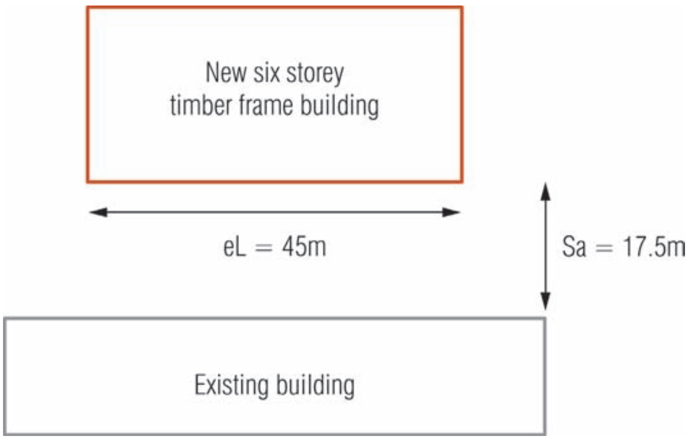
Each category of timber frame has a different mathematical fire behaviour model from which separation distances, based on the height and length of the emitter, are derived. A Category A frame is assumed to have rapid flame spread and the entire building contributes to the RHF. Category B frames are modelled as full vertical height fires but the emitter length is reduced by the introduction of VFC walls. Category C frames limit the fire spread between VFC and up to two floor levels only. Sensitivity analysis of the results was undertaken where a comparison of tests against theoretical models, and experience from real fires, was found to be sufficiently representative of real site performance to enable the results from these to be used in the guidance.

Worked example

A six storey residential building comprises five storeys of timber frame construction on a single storey concrete podium. The proposed building has an elevation length (emitter length eL) of 45m which faces an existing building (the receiver) 17.5m away. What category of timber frame construction should be adopted for the building?

For simplicity, only one elevation of the proposed building will be considered. However, the same approach should be carried out for all elevations of a proposed timber frame building where neighbouring buildings occur.

Note the height of the receiver building is not required for the calculations.



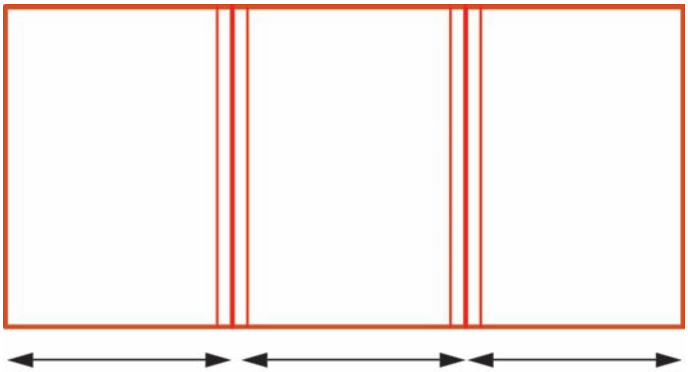
Step 1: Consider standard timber frame construction – Category A:
From Table 1, the required separating distance for a Category A timber frame Sr (=41.75m) > Sa (=17.50m) therefore a construction process risk mitigation is required for the Category A frame.

Step 2: Consider Category B or C timber frame structures to reduce the required separating distance:
From Table 2, the required separating distance for a Category B2 timber frame with vertical fire compartmentation at 20m intervals, Sr (=16.25m)< Sa (=17.50m) therefore this is an acceptable solution. To divide the building into maximum 20m long sections between vertical fire compartment walls, a minimum of 2No vertical fire compartment walls will be required, extending across the full depth of the building and full height over five storeys.

Step 3: Consider alternative strategies:
As an alternative solution, from Table 3, the required separating distance for a Category B1 timber frame with vertical fire compartmentation at 15m intervals, Sr (=16.00m)< Sa (=17.50m) therefore this is also an acceptable solution. To divide the building into maximum 15m long sections between vertical fire compartment walls, a minimum of 2No vertical fire compartment walls will be required, extending across the full depth of the building and full height over five storeys.

Therefore, for a 45m long building, 2No vertical fire compartment walls will be required to divide the building and the frame can be specified as Category B1 timber frame construction.

Step 4: Timber frame solution:
Adopt a Category B1 timber frame structure (see Fig. 3 for acceptable materials and compositions).



Vertical fire compartment at maximum 15m intervals

Table 1: (for Category A) Timber frame separating distance Sr (m)

Number of timber frame storeys	Emitter length (eL)						
	≤5m	≤10m	≤15m	≤20m	≤25m	≤40m	>40m
1	5.5	7.25	8.25	8.75	9.5	10.25	10.5
2	7.5	10.5	12.75	14.25	15.5	18	20.25
3	9	13	16	18	20	23.25	28.5
4	10	15	18.5	21.25	23.5	28.5	35.75
5	11	16.5	20.5	23.75	26.5	32.5	41.75
6	11.5	18	22.5	26	29	36	47.25
7	12.25	19	24	28	31.5	39.25	52.5

Table 2: (for Category B2) Timber frame separating distance Sr (m)

Number of timber frame storeys	Emitter length (eL) - B2 frame			
	≤5m	≤10m	≤15m	≤20m
1	5	5	5.25	5.5
2	5.25	7.25	8.5	9.5
3	6	9	10.75	12.25
4	6.75	10.25	12.75	14.5
5	7	11.25	14	16.25
6	7.25	12	15.25	17.75
7	7.5	12.75	16.25	19.25

Table 3: (for Category B1) Timber frame separating distance Sr (m)

Number of timber frame storeys	Emitter length (eL) - B1 frame			
	≤5m	≤10m	≤15m	≤20m
1	5	5.5	6.25	6.5
2	6	8.25	10	11
3	7	10.25	12.5	14.25
4	7.5	11.75	14.5	16.75
5	8.25	13	16	18.75
6	8.75	14	18.75	20.25
7	9	14.75	18.75	22

Definitions

Emitter – The length of an elevation of the timber frame building being constructed facing the receiver building. Used to calculate the safe separating distance.

Non-combustible boards and boards of limited combustibility – Boards that can be classified as Euroclass A1 and A2 based on testing to EN standards that are typically applied as wall sheathing materials or structural subdeck materials in an enhanced fire resistance timber frame construction type (Category B or C frames).

Receiver – Any surface of a structure, element or part of a building that can be subject to radiant heat flux.

Vertical Fire Compartmentation (VFC) – In the context of the building during construction, fire compartmentation takes the form of vertical walls (and temporary fire doors) or horizontal floors installed as the building is erected and constructed, such that they act as a barrier to the spread of fire.

References and further reading

1) HM Government (2007) The Construction (Design and Management) Regulations [Online] Available at: www.legislation.gov.uk/uksi/2007/320/contents/made (Accessed: July 2013) London: HMSO

2) Health and Safety Executive (2010) *HSG 168: Fire Safety in Construction* London: HSE

3) Fire Protection Association (2012) *Fire Prevention on Construction Sites* (8th ed.) Moreton in Marsh, Glos.: FPA

4) UKTFA (2012) *Design guide to separation distances during construction for timber frame buildings above 600m^2 total floor area together with supporting documents* [Online] Available at: www.uktfa.com (Accessed: July 2013)

5) British Standards Institution (2001) *BS 7974: Application of fire safety engineering principles to the design of buildings* London: BSI

6) British Standards Institution (2011) *PD 7974 -2011 Part 3: Structural response and fire spread beyond the enclosure of origin* London: BSI

7) Building Research Establishment (1991) *BR187: External fire spread: building separation and boundary distances* Watford: BRE

Further reading

The UKTFA has published Technical Papers 1-3 to provide information on the tests and the frame categories. Supporting papers on product compliance (Product Papers 1-3) outline the required product specification to be used in compliant timber frame construction. The UKTFA has established a test and approval protocol for systems and product assemblies that has undergone the methodology described in Technical Paper 3. In addition, for the building designer, Product Paper 4 provides combinations of timber frame assemblies that comply with the categories of timber frame.