Grenfell Tower – fire safety investigation: The fire protection measures in place on the night of the fire, and conclusions as to:

the extent to which they failed to control the spread of fire and smoke; the extent to which they contributed to the speed at which the fire spread.

Phase 1 Report – Section 3

Building description and fire safety requirements; key definitions including relevant test evidence

REPORT OF

Dr Barbara Lane FREng FRSE CEng

Fire Safety Engineering

24th October 2018

Specialist Field	:	Fire Safety Engineering
Assisted by	:	Dr Susan Deeny, Dr Peter Woodburn, Dr Graeme Flint, Mr Tom Parker, Mrs Danielle Antonellis, Mr Alfie Chapman
On behalf of	:	Grenfell Tower Inquiry
On instructions of	:	Cathy Kennedy, Solicitor, Grenfell Tower Inquiry
Subject Matter		To examine the circumstances surrounding the fire at Grenfell Tower on 14th June 2017
Inspection Date(s)	:	6th October, 1st November, 7-9th November 2017

Dr Barbara Lane
Ove Arup & Partners Limited
13 Fitzroy Street
London W1T 4BQ

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3 Building description and fire safety requirements; key definitions including relevant test evidence

3.1 Building description

3.1.1 Grenfell Tower is a twenty-five storey with a basement (Ground to Level 23, plus a plant floor at Roof level) residential block built in the early 1970s and is located in the Lancaster West Estate in North Kensington, London.

3.1.2 The Lancaster West Estate is located in the Royal Borough of Chelsea and Kensington. The Lancaster West Estate scheme was designed by Clifford Wearden & Associate in the late 1960s, Phase 1 was approved in 1970 and consisted of Grenfell Tower and three low rise (3-4 storey) residential blocks called finger blocks: Testerton Walk, Hurstway Walk and Barandon Walk.

3.1.3 The construction of Grenfell Tower, by contractors A.E. Symes, of Leyton, London, commenced in 1972, with the building completed in 1974.

3.1.4 The 67.30-metre (220 ft 10 in) tall building contained 120 one- and two-bedroom flats (six dwellings per floor on twenty of the twenty-four storeys, with the other four being used for non-residential purposes), housing up to 600 people.

3.1.5 Grenfell Tower is owned by the Local Authority - Kensington and Chelsea London Borough Council. Grenfell Tower was part of their provision of social housing in the borough.

3.1.6 The management of social housing in the borough was devolved to the Kensington and Chelsea TMO (KCTMO), a tenant management organisation in 1996.

3.1.7 The Royal Borough of Kensington and Chelsea (RBKC) is an inner London borough of royal status. It is the smallest borough in London and the second smallest district in England, it is one of the most densely populated in the United Kingdom.

3.1.8 In 2012 the first submission for the last refurbishment of the Grenfell Tower commenced. The Building Certificate for completion of these works was signed by RBKC on the 7th July 2016. I have no evidence at this stage regarding the formal date of handover of the completed works to KCTMO.

3.1.9 The architect for the refurbishment works was Studio E, and the principal contractor for the works was Rydon. Where I have been able to identify relevant members of the design and construction team, I have identified them in Section 4 of my report.

3.1.10 The client for the refurbishment works was the KCTMO.

3.1.11 The refurbishment works were funded by RBKC and the funds were released in May 2012.

3.1.12 Grenfell Tower has a plan floor area of approximately 22m by 22m, with a single central reinforced concrete core, reinforced concrete floors, and with perimeter reinforced concrete columns. The reinforced concrete columns incorporate a pre-cast fair faced “biscuit” on their outer surface, that was used as permanent formwork when the building was originally constructed.

3.1.13 The precast biscuit is visible today as ridged facing on the building exterior and was permanently connected to the columns through the provision of metal wires embedded in the concrete of the columns.

3.1.14 There were reinforced concrete cross walls separating each flat from level 4 to level 23. These did not extend to the basement level, nor existed at ground to level 3 (inclusive) either.

3.1.15 Instead, levels ground, 1 and 3, were more flexible open spaces which were created for the inclusion of a nursery, offices and a community health centre. Level 2 was left entirely open as a continuation of the walkway connecting to the adjacent blocks of the Lancaster West Estate.

3.1.16 The basement was created as one large, open plan, 5.3m high space extending over the whole footprint of the building, it also has 5 small blockwork inner rooms and a central concrete core area.

3.1.17 Each storey in Grenfell Tower is 2.6m high (floor to floor), except for Level 2, which is 4.3m high, and Level 3, which is a height of 3.9m.

3.1.18 The structural stability mechanism for Grenfell Tower, is that of a conventional concrete building with a lateral stability core in the middle of the building, and concrete columns around the perimeter supporting gravity loads. The floor is a flat reinforced concrete slab transferring floor loading directly to the core. At the outside of the building, loads are transferred into the columns directly by the floor, and via the precast perimeter spandrel beams. Additional support to the floor is provided by the concrete cross walls between flats.

3.1.19 The refurbishment from 2012 – 2016, was a substantial refurbishment. It incorporated the over cladding of every storey of the existing building with a rain screen cladding system.

3.1.20 Additionally, there was a full refurbishment internally of level ground to level 3 inclusive, including structural works. There were also building services works within every floor of Grenfell Tower. Please refer to Section 4 of my main report for a description of the refurbishment works and when they occurred.

3.1.21 The external wall construction of Grenfell Tower was originally a solid concrete construction. As noted above, precast biscuits were used as permanent formwork and facing of the columns. Solid precast spandrel beams were used to connect between columns around the perimeter of the building.

3.1.22 Non-structural precast panels were provided as in-fill in the facade between windows. The specific material of the in-fill panels is currently unknown but I understand it to consist of asbestos-bearing cementitious materials.

3.1.23 The windows fully filled the space vertically between the top of one perimeter beam and the underside of the next beam. Horizontally, the metal window frames were fixed directly to the concrete structure on 3 sides, and to the infill panel on the 4th side.

3.1.24 The external wall was a single system. As I understand it, this meant there was no void or space, concealed within that external wall. I will refer to such spaces - these concealed spaces – as cavities, in my Expert Report. Cavities are spaces enclosed by elements of a building or contained within an element of the building.

3.1.25 Regarding the construction form of the new rainscreen cladding system in the recent refurbishment, please refer to the detailed information I have set out in Section 8 and Section 11 of this report.

3.1.26 The refurbishment of the building envelope consisted of the addition of a rain screen cladding system.

3.1.27 There is a useful definition of the purpose of a rain screen in the (BS 8298-4) *Code of practice for the design and installation of natural stone cladding and lining, rainscreen and stone on metal frame cladding systems.*

3.1.28 A ventilated rain screen should have the following key elements:

a) An outer layer (the rain screen), intended to shelter the building from the majority of direct rainfall. Some joints between panels or at the edges of the rain screen should be left open.

b) A cavity, which can include insulation, intended to collect any water which passes through the joints in the rain screen layer, and to permit such water to flow down to a point where it is collected and drained from the cavity. The insulation layer should not completely fill the cavity.

c) A backing wall, intended to provide a barrier to air infiltration and water ingress into the building

3.1.29 A ventilated rain screen cladding system is either pressure-equalised or drained and ventilated. The ventilated rain screen system installed at Grenfell Tower was a drained and ventilated system. I refer to this system as the External Wall throughout my report.

3.1.30 I have provided detailed information in Section 8 of my Expert Report on the materials I found on site at Grenfell Tower. From Level 4 – 23 at Grenfell Tower, the rain screen outer layer (which I refer to in this report as the External Surface) was a Reynobond 55 PE Aluminium Composite Panels installed as a bespoke cassette system. The panel is a 3mm thick core of solid polyethylene, bonded between two 0.5mm thick pieces of aluminium.

3.1.31 A different form of rain screen was provided at level G, 1 and 2, based on Glassfibre reinforced concrete, and wall plank. The type and manufacturer have yet to be confirmed. However, these materials do not currently have any relevance to my work presented in this Report.

3.1.32 The cavity was approximately 140mm in depth over columns and approximately 156mm deep over spandrels (spandrels are horizontal sections running above and below the windows, and connecting each column).

3.1.33 The inner layer of thermal insulation, was attached directly to the original external concrete surface, and was between 100-160mm (depending on location) and formed with either Celotex RS5000 (Polyisocyuranate, PIR) or Kingspan K15 (phenolic) (depending on location).

3.1.34 New windows were installed on every floor. The new windows were Metal Technology's 5-20 HI thermally broken windows.

3.1.35 Insulating core panels were also provided in the refurbishment between the windows, formed of Aluglaze which is a 25mm core of Styrofoam, sandwiched between 1.5mm thick aluminium panels.

3.1.36 In the new windows for any kitchen, and specifically where the kitchen vent was to be located, an aluminium insulating core panel formed of 1.5mm aluminium layers sandwiching 25mm thick Kingspan TP10 polyisocyuranate (PIR) foam, was specified, instead of a piece of glazing. The kitchen vent was to be located in this panel. I have not found evidence of this system in that location on site, instead it appears to be formed of Aluglaze Styrofoam cored panel also.

3.1.37 The cavity created by the new and old infill panels was enclosed at the sides with either Kingspan Thermapitch TP10 or Celotex TB4000.

3.1.38 The window reveals, on all four sides, appear to have been insulated with either Kingspan Thermapitch TP10 or Celotex TB4000, and faced with uPVC however final confirmation of this is required.

3.1.39 Improving the insulation levels of the walls, roof and windows was:

"*the top priority of this refurbishment. Improving the insulation levels on a solid wall construction is always best done from the outside of the wall. This solves several issues with thermal bridging and interstitial condensation. Thermal bridging will be kept to a minimum by insulated window reveals and using thermal breaks on all fixings that link the new rain screen cladding to the existing concrete structure. The chosen strategy is to wrap the building in a thick layer of insulation and then over-clad with a rain screen to protect the insulation from the weather and from physical damage.*" (Max Fordham Sustainability and Energy Statement 2013 – MAX00001501).

3.1.40 The refurbishment also included internal works such as the extension of the existing dry rising fire main in the building, as well as the implementation of a new combined environmental and smoke ventilation system for every lobby to the single stair.

3.1.41 A new heating system was provided to the building to supply every flat, resulting in works in the residential lobby to the single stair on each floor and within each flat on each floor.

3.1.42 However, there are three other pieces of refurbishment works, separate to the 2014 refurbishment, that I have concluded as being directly relevant to my investigation of the active and passive systems that existed in Grenfell Tower the night of the fire. These works are:

a) The lift replacement works which took place in 2005.

b) The flat entrance door fire door replacement works which took place in 2011 from levels 4 – 23 inclusive; and

c) The gas supply works which took place between October 2016 and June 2017. These works were still in progress at the time of the fire.

3.1.43 I explain those works, and the resulting active and passive fire protection measures in Grenfell Tower on the night of the fire on 14th June 2017, in this Phase 1 Expert Report.

3.2 Overview of fire safety measures required for high rise residential buildings

3.2.1 I have presented my review of the applicable legislation, regulations, statutory and non-statutory guidance in Appendix D of my report. I rely on that in explaining the facts of the fire safety measures required for high rise residential buildings.

3.2.2 Figure 3.1 summarises the legislation, regulation guidance in London and nationally for high rise buildings at the time of the construction of Grenfell Tower.

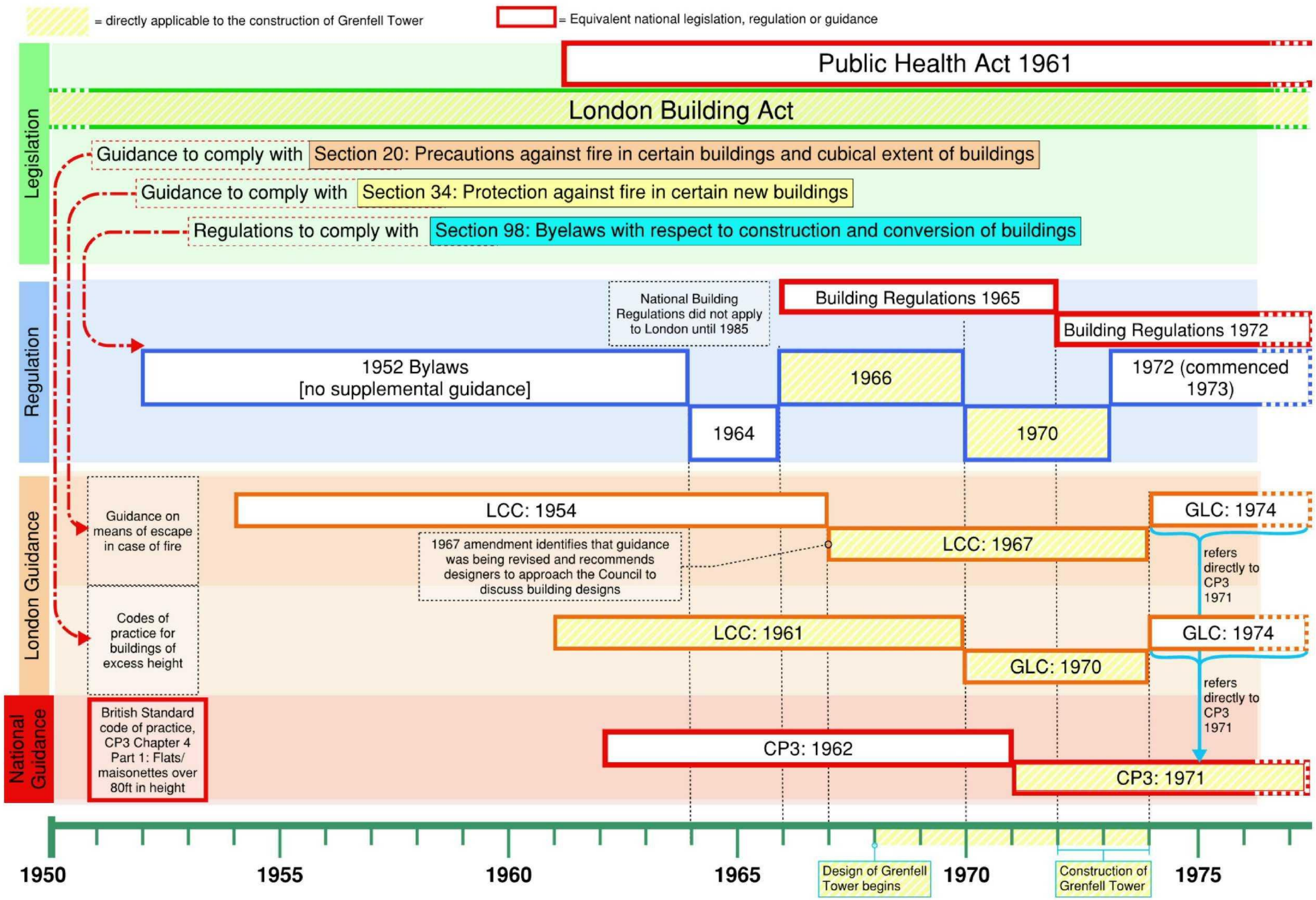

Figure 3.1 Legislation, regulations and guidance applicable in London 1950-1975 (references with yellow fill identify the legislation, regulations and guidance in forceat the time of the design and construction of Grenfell Tower)

3.2.3 Table 3.1 below presents the London and national legislation, regulation and industry guidance applicable at the time of the design and construction of Grenfell Tower (1967 -1974).

Table 3.1 Relevant legislation, regulation and guidance for the design and construction of Grenfell Tower

	London	National
Applicable Legislation at time of construction	London Building Acts (Amendment) Act 1939 Relevant to fire safety design and construction: Section 20, 34 and 98	Public Health Act 1939 & 1961
Applicable Regulations at time of construction	London Building Constructional Amending Bylaws 1952 (as amended 1964, 1966 and 1970) to address Section 98 requirements of the Act	Building Regulations 1965 and 1972 (commenced 1st June 1972)
Applicable Approved Guidance at time of construction	LCC Guide *Means of escape in case of fire* (1967); to address Section 34 requirements of the Act GLC *Code of practice for buildings of excess height* (1970); to address Section 20 requirements of the Act	British Standard CP3: Chapter IV: Precautions against fire: Part 1. Fire precautions in flats and maisonettes over 80ft (1962) British Standard CP3: Chapter IV: Precautions against fire: Part 1. Flats and maisonettes (in blocks over two storeys) (1971)

3.2.1 Regarding Section 34 of the London Building Act, I have reviewed the means of escape guidance from the three guidance documents available during this period (LCC 1967, CP3 1962 and CP3 1971). I have compared the prescribed means of escape solutions within each of those guidance documents with the means of escape as installed in the original construction of Grenfell Tower.

3.2.2 As I explain further in Section 4 of my Expert Report, only the fire safety solutions in CP3 1971 are consistent with the original design and construction of the stair and lobbies in Grenfell Tower.

3.2.3 In particular, the presence of a single stair (which is not adjacent to an external wall), the provision of a specific arrangement of a ventilated corridor to this internal stair case and the ventilation solution for the staircase all indicate that the building was designed to CP3 1971.

3.2.4 This layout is consistent only with the design principles of a CP3 1971 Section 3.4.3.1 solution number (4).

3.2.5 These design principles require ventilation in the corridor from the flat to the staircase, by means of the solution presented in Fig 16b "corridor access flats: single stair case tower block - *smoke dispersal"*. This solution also relies on a specific standard of fire door a Type 3 door to the flats opening onto the corridor, and a Type 2 door to the stair. These doors and the smoke dispersal system are provided to protect the single staircase.

3.2.6 It is on this basis that I have concluded CP3 1971 was the basis of design for the means of escape from Grenfell Tower – see section 4.2 for further details, and so the route to compliance with Section 34 of the London Building Act.

3.2.7 I explain in Appendix D where this guidance intersects with the other applicable London Building Act requirements (Section 20 and Section 98). I explain where it is necessary to rely on other guidance to comply with these requirements of the London Building Act, in conjunction with the guidance in CP3 1971.

3.2.8 It is important to understand the purpose of Section 20 as provided in the foreword to the guidance

"*Basically the principles incorporated in this Code seek to contain an outbreak of fire, to prevent the rapid spread of fire throughout a building or to adjoining buildings, to ensure the safety of the structure against fire, to provide such fire-fighting facilities as would enable the fire brigade to tackle the seat of a fire with the utmost speed and, in conjunction with the Council's Code of Practice for Means of Escape in Case of Fire, to safeguard the occupants of buildings.*"

3.2.9 Ultimately, as it applied to Grenfell Tower at the time, this meant the provision of a 1 hour building with a 2 hour single staircase enclosure, with fire lift, to comply with Section 20, and a ventilated lobby condition designed to CP3 1971, to locate the stair internally and to protect it in that condition. I show in detail how the lobby design rules contained in Section 20 were not implemented at Grenfell Tower – See Appendix H and J of my report.

3.2.10 **The historic basis for the fire safety approach to residential high rise building**

3.2.11 Since 1962, as recorded in the British Standard Code of Practice 3 Chapter IV Precautions Against Fire Part 1 Fire precautions in flats and maisonettes over 80 feet, it was advised that:

> The assumption should no longer be made that buildings must be evacuated if a fire occurs and high residential buildings should, therefore, be designed so that the occupants of floors above a dwelling which is on fire may, if they choose, remain safely on their own floor. It may be necessary to evacuate the floor on which the fire occurs, and in some circumstances those floors which are in the immediate vicinity of the fire, but the occupants of these floors should be free to reach safety in any other part of the building via the staircase.

3.2.12 In British Standard Code of Practice CP3: Chapter IV Part 1 Flats and Maisonettes (in blocks over two storeys), 1971, this principal was again reiterated "*the occupants should be safe if they remain where they are*", based on a "*high degree of compartmentation provided in dwellings in modern blocks*":

> This Code supersedes CP 3, ' Code of basic data for the design of buildings ', Chapter IV, ' Precautions against fire ', Part 1, ' Fire precautions in flats and maisonettes over 80 ft in height '.
>
> It has become apparent, and generally agreed, that external rescue by the Fire Service may not always be possible from blocks of flats and maisonettes, even when the dwellings are within reach of escape ladders. Modern traffic conditions and congestion, as well as parking around blocks, may delay the attendance of the fire brigade; furthermore, reliance on such appliances as manipulative types of escapes or mobile ladders is considered to be unsatisfactory. Also, the assumption should no longer be made that entire buildings, whole floors, or even adjoining dwellings need to be evacuated if a fire occurs. Owing to the high degree of compartmentation provided in dwellings in modern blocks, the spread of fire and smoke from one dwelling to another and the need to evacuate the occupants of adjoining dwellings are unusual. The occupants should be safe if they remain where they are. Nevertheless, the possibility that individuals may seek to leave the building cannot be overlooked and provision should therefore be made for the occupant of any dwelling to do so by his own unaided efforts, using adequately protected escape routes within the building without outside assistance.
>
> Once the principle of rescue by the fire brigade is discounted, it becomes apparent that there is no reason for a substantially different Code of Practice applying to buildings below 24 m (approximately 80 ft) in height, compared with those above 24 m (approximately 80 ft) in height; hence the publication of this ' combined ' Code of Practice, which it is intended will apply to all flats and maisonettes above the first floor in blocks of any height. (One and two storey dwellings entered at ground level from outside a block, that is, not through a main stairway or shared circulation space, are excluded.) One problem in drafting this Code has been the widely varying requirements that have been applied to buildings of different heights in the past. The committee has therefore attempted to achieve a balance between those many standards, bearing in mind the latest developments in methods of achieving life safety.

3.2.13 The concept of occupants in dwellings adjoining the dwelling on fire, being safe if they "*remain where they are*" is described as a "stay put" strategy, throughout the remainder of this report. **This is my definition of "Stay Put".**

3.2.14 It is useful to understand the original basis for this Stay Put strategy, particularly in light of the events at Grenfell Tower.

3.2.15 CP3 made clear, this safety condition was a building safety condition which relied on active and passive fire protection measures.

3.2.16 In CP3, the risk to occupants in a high rise building containing flats, with a Stay Put strategy was described in three distinct stages:

3.2.17 Stage I, the risk is to the occupants of the dwelling in which the fire originates;

3.2.18 Stage II, the risk is to the occupants of adjoining dwellings if smoke or fire should penetrate to the horizontal escape route (the common corridor, or balcony or approach to a subsidiary stairway); and

3.2.19 Stage III, the risk is mainly to the occupants of dwellings on floors above the floor of outbreak if smoke or hot gases should penetrate to the vertical escape route (the common stairway) or to the horizontal escape route from the foot of the stairway to the open air.

3.2.20 The active and passive fire protection measures to support these three Stages of risk form the basis of the design guidance in CP3, and I will explain these later in this Section.

3.2.21 There is also however a critical role set out for the fire and rescue services (referred to in CP3 as fire brigades). In the 1962 edition of CP3 the Introduction states:

> The guiding principle in the recommendations which follow is safety of life. In securing this, means of escape, construction and fire fighting all play a part. This part of the Code deals with all three subjects, but recommendations on construction have not been fully developed as many aspects are already subject to building control.

3.2.22 Then in Section 7 Fire Brigade Facilities it states:

> **SECTION SEVEN: FIRE BRIGADE FACILITIES**
>
> **701. General.** In high blocks of flats it is essential that provision should be made to assist the fire service in applying water to a fire as early as possible. This

> entails the installation of fire lifts and internal fire mains or 'risers'. The location of fire main, fire lift and main staircase must be inter-related so that if a fire lift opens into an area on an upper floor that might become smoke-logged, ready access to the fire main can be had from another floor.

3.2.23 There is reference in the later CP3 1971, to the issue of a fire should it *"not be extinguished early"* and this is attributed to then causing smoke entering the lobby, which is deemed to pose a Stage III risk:

> (2) The second and more effective method where smoke containment is adopted is to enter the stairway from a lobby which is permanently ventilated to the open air and which is itself entered only from the internal communicating space through a smoke-stop door. In this case the stairway will have the protection of two smoke-stop doors and a ventilated lobby. This arrangement is so safe that, provided the stairway enclosure has no weakness, a building with a single stairway so arranged can be regarded as having safe means of escape in the third stage. Fig. 21*a* illustrates such an arrangement. It will be noted that there is no requirement in Stage II for the lobby (see Fig. 21*a*) to have permanent ventilation, since this lobby cannot be attacked by smoke or heat in this stage and thus form a trap for those wishing to escape from the flat. Should a fire not be extinguished early, however, smoke might eventually reach the lobby and the permanent ventilation is a necessity to ensure the dissipation of smoke and heat in Stage III, as a protection to the stairway.
>
> (3) The third method, using smoke dispersal in Stage II, is to achieve cross-ventilation in the communicating spaces leading to main stairways by means of manually operated ventilators together with either

3.2.24 This Stage III risk is to the occupants of dwellings on floors above the floor of outbreak, if smoke or hot gases should penetrate to the vertical escape route (the common stairway) or to the horizontal escape route from the foot of the stairway to the open air.

3.2.25 CP3 therefore expects that water will be applied early in a fire and that the fire brigade will extinguish the fire early. **This is my definition of "Defend in Place"**.

3.2.26 The active and passive fire protection measures are also provided to support this form of firefighting. This includes the high degree of compartmentation and the smoke vent in the lobby also. Should a fire not be extinguished early (and even if smoke reaches the lobby outside the dwelling), the intention in

CP3 is that the stairway remains protected for use for occupants above the fire floor.

3.2.27 This combination of construction, systems, and early firefighting intervention, supports a Stay Put strategy. This is a layered safety approach. For a single safety condition – occupants in adjoining dwellings safe to remain where they are; conditions provided to allow the fire brigade to access water and extinguish the fire early.

3.2.28 The specific **passive fire protection measures** made part of the British Standard Code of Practice 3 Chapter IV, were for the purpose of protecting the occupants during the three Stages of risk. I have provided my summary of these measures as follows:

a) fire resisting construction around each flat – floors and walls;

b) fire resisting construction around any escape stair;

c) fire resisting construction around any lobby between a flat and an escape stair;

d) fire resisting construction around any other riser including refuse chutes, lifts;

e) a very specific emphasis on the requirement for fire doors in flats, between flats and lobbies, and between lobbies and stairs (See Figure 3.2 below);

f) specific limits on travel distances to aid escape – achieved through fire resisting construction and the provision of fire doors;

g) The cables supplying current to the lift motor (for the fire lift) should pass through routes of negligible fire risk.

4.3 FIRE RESISTING DOORS

4.3.1 General. Fire resisting doors are one of the most important links in the chain of fire safety precautions and care in their selection, to ensure that they are adequate for their purpose, cannot be over emphasized. Doors used for fire protection purposes should be self-closing and should, except for entrance doors to dwellings and doors within them, be marked with a warning notice that they are provided for fire safety and should be kept closed. Self-closing devices should be of a type which cannot readily be disconnected or immobilized and should not embody a check retaining action at 90°, and it is essential that a self-closing device of any kind should override any latches fitted to the door or doors. Self-closing devices are particularly important in both double and single swing doors, as the efficiency of doors as a barrier to fire can be negated if the device does not retain the door positively in the closed position.

Figure 3.2: Fire doors - Excerpt from CP3 1971

3.2.29 Specific **active fire protection** measures were also made part of the British Standard Code of Practice 3 Chapter IV, which can be summarised as follows:

a) lobby ventilation (see the specific requirements for single stair buildings in Figure 3.3below);

b) stair ventilation (see the specific requirements for single stair buildings in Figure 3.3 below);

c) smoke detectors to open smoke vents in the lobby (where permanently open vents not provided);

d) dry or wet risers, as a function of building height;

e) fire lift for firefighters;

f) The electric supply to any fire lift provided by a sub-main circuit exclusive to the lift;

g) one public telephone within the block or a call box at no greater distance away than 300 m (approximately 960 ft);

h) lighting in stair cases supplied by "protected circuits";

i) lighting in corridors/lobbies supplied by "protected circuits".

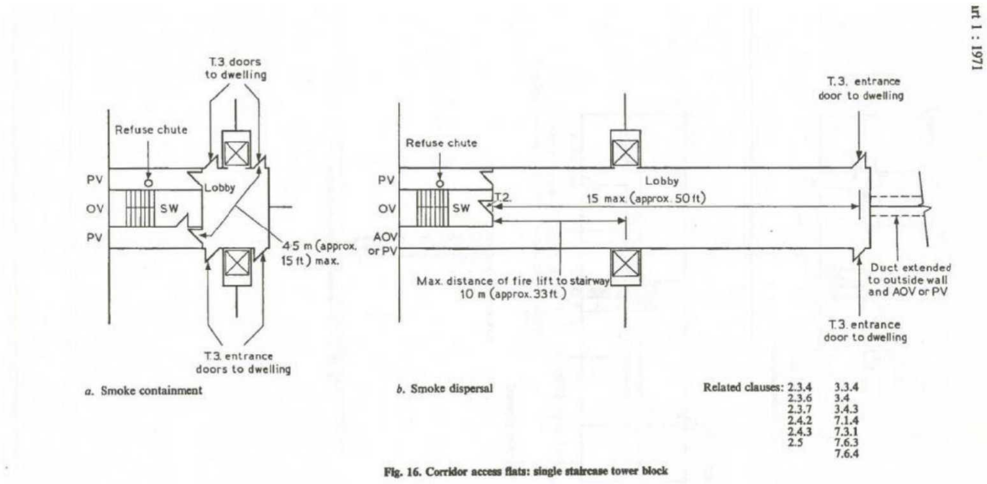

Fig. 16. Corridor access flats: single staircase tower block

Figure 3.3: Corridor access flats - Single stair: CP3 1971 Figure 16 (a) smoke containment solution; and (b) smoke dispersal solution

3.2.30 And finally, from CP3, ***Other fire protection*** measures were also part of the package of measures required for high rise residential buildings, as summarised as follows:

a) fire prevention actions by the building owner in conjunction with residents;

b) maintenance of active and passive fire protection systems;

c) fire brigade information: A notice or map should be located at the entrance to each fire appliance access road to an estate, clearly indicating the location of individual blocks of dwellings, and a notice should also be provided at the entrance to each block indicating the sequence of numbering and the layout of dwellings at each floor.

3.2.31 This results in a combination of construction, systems, early firefighting intervention, <u>and</u> fire safety management actions. These fire safety management actions are another layer of required safety activity. All parts of this combination are required to support a Stay Put strategy.

3.2.32 It is very important to note that, as stated in Section 2.1 of CP3, there is no intention to rely on the fire brigade during evacuation: "*It is no longer assumed that when a fire occurs in a block it is necessary to evacuate the whole block, whole floors or even dwellings adjacent to the fire. In an emergency, however, the occupants of dwellings would generally first try to escape from a fire by the most obvious route in order to reach safety before being cut off by smoke and hot gases. Where escape routes are adequately protected, safety may be reached within the building, or in the open air clear of the building, by the occupants'* ***own unaided efforts and without reliance on rescue by the fire service***."

3.2.33 The active and passive measures which are recommended are intended to protect escape routes to enable escape before being cut off by smoke and hot gases. This is intended to be coupled with early fire suppression by the fire and rescue services.

3.2.34 Fire doors are given particular emphasis regarding their role in residential buildings as stated in section 4.3 of CP3 – *"Fire resisting doors are one of the most important links in the chain of fire safety precautions and care in their selection, to ensure that they are adequate for their purpose, cannot be over emphasised."*

3.2.35 It is on this basis that the building safety condition Stay Put formed the basis of high rise residential building fire safety guidance in the UK, from 1971.

3.2.36 **Current Guidance**

3.2.37 The term 'stay put' is not used anywhere in the statutory guidance Approved Document Part B 2013.

3.2.38 It states in Section 2.3:

> **2.3** The provisions for means of escape for flats are based on the assumption that:
>
> a. the fire is generally in a flat;
>
> b. there is no reliance on external rescue (e.g. by a portable ladder);
>
> c. measures in Section 8 (B3) provide a high degree of compartmentation and therefore a low probability of fire spread beyond the flat of origin, so that simultaneous evacuation of the building is unlikely to be necessary; and
>
> d. although fires may occur in the common parts of the building, the materials and construction used there should prevent the fabric from being involved beyond the immediate vicinity (although in some cases communal facilities exist which require additional measures to be taken).

3.2.39 It further states the following assumptions relevant to compliance with Regulation B1:

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B1.i These provisions relate to building work and material changes of use which are subject to the functional requirement B1 and they may therefore affect new or existing buildings. They are concerned with the measures necessary to ensure reasonable facilities for means of escape in case of fire. They are only concerned with structural fire precautions where these are necessary to safeguard escape routes.

They assume that, in the design of the building, reliance should not be placed on external rescue by the Fire and Rescue Service nor should it be based on a presumption that the Fire and Rescue Service will attend an incident within a given time. This Approved Document has been prepared on the basis that, in an emergency, the occupants of any part of a building should be able to escape safely without any external assistance.

3.2.40 Approved Document Part B 2013 refers to British Standard BS 5588 Part 1 1990. "*Fire precautions in the design, construction and use of buildings. Code of practice for residential buildings*" for means of escape from flats.

3.2.41 British Standard BS 5588 Part 1 1990 is no longer current. It was superseded by British Standard BS9991:2011 *"Fire safety in the design management and use of residential buildings*". BS9991:2011 makes four specific references to a stay put strategy.

3.2.42 Firstly, BS 9991:2011 provides an identical description of the general principles of means of escape from flats as that in Approved Document Part B 2013:

0.2 Flats and maisonettes

0.2.1 General principles

The means of escape from a flat or a maisonette of limited height is relatively simple. With increasing height more complex provisions are needed because emergency egress through upper windows becomes increasingly hazardous.

The provisions for means of escape for flats or maisonettes are based on the assumptions that:

a) fire will occur within the flat or maisonette (e.g. not in a stairwell);

b) there can be no reliance on external rescue (e.g. a portable ladder);

c) the flat or maisonette will have a high degree of compartmentation and therefore there will be a low probability of fire spread beyond the flat or maisonette of origin, so simultaneous evacuation of the building is unlikely to be necessary; and

d) where fires do occur in the common parts of the building, the materials and construction used in such areas will prevent the fire from spreading beyond the immediate vicinity (although in some cases communal facilities exist which require additional measures to be taken).

3.2.43 Secondly, BS9991 refers to the need for additional protection to the staircase by the provision of smoke control, for the stay put strategy.

26.1.1 General

In residential buildings designed with a stay put strategy (see **E.1**), additional protection to the staircase should be provided in the form of a smoke control system.

3.2.44 Thirdly, BS9991 advises that an increase in fire resistance periods for structure may be necessary where occupants of other dwellings are to remain in place:

27 Fire resistance

*COMMENTARY ON CLAUSE **27***

*For the purposes of complying with the recommendations for means of escape in case of fire, a 30 min period of fire resistance is generally considered adequate. However, increased periods of fire resistance might be necessary: firstly to allow a fire in a dwelling to burn out while occupants of other dwellings remain in place (see **E.1** regarding stay-put strategy), and secondly to provide adequate safety for fire-fighting.*

3.2.45 And finally it specifically references the stay put strategy regarding the fire performance of the external face of a building.

29.2 External fire spread over the external faces of buildings

External walls should be constructed using a material that does not support fire spread and therefore endanger people in or around the building.

Flame spread over or within an external wall construction should be controlled to avoid creating a route for rapid fire spread bypassing compartment floors or walls.

This is particularly important where a stay put strategy (see **E.1**) is in place. Combustible materials should not be used in cladding systems and extensive cavities.

External wall surfaces near other buildings should not be readily ignitable, to avoid fire spread between buildings.

3.2.46 With regard to the stay put strategy, BS9991:2011 goes further than Approved Document Part B 2013 and in paragraph 0.2.1 refers to occasions where operational conditions are such that the fire and rescue service decide to evacuate the building

Whilst a simultaneous evacuation is normally unnecessary (see **E.1** regarding stay put strategy), there will be some occasions where operational conditions are such that the fire and rescue service decide to evacuate the building. In these situations the occupants of the building will need to use the common stair, sometimes whilst fire-fighting is in progress. As such, the measures in this British Standard for the protection of common stairs are designed to ensure they remain available for use over an extended period.

3.2.47 This is the only reference to this concept within the standard. The standard does not make any specific provision for communication of this change, nor the management of this change with regard to active or passive fire protection measures within the building. I discuss this in specific detail in Section 18 of my Expert Report.

3.2.48 The latest version of this standard was published in 2015. BS 9991:2015 defines the Stay Put strategy on Page 18, as follows:

"3.58 stay put strategy

strategy normally adopted in blocks of flats and maisonettes whereby, when a fire occurs in a flat or maisonette, the occupants of that dwelling evacuate, but occupants of all other dwellings can safely remain in their dwellings unless directly affected by heat and smoke or directed to leave by the fire and rescue service."

3.2.49 This information in BS9991 2011 and 2015 is a departure from CP3 1971 which had clearly stated that there is no reliance on the fire and rescue services for evacuation.

3.2.50 I have not identified any active and passive fire protection features in the current guidance which would assist in supporting a change from the Stay Put strategy, or from a "defend in place" firefighting strategy.

3.2.51 In light of the above, high rise residential buildings are handed over for occupation on the basis of a stay put/defend in place strategy and without active or passive protection measures to support a change in that strategy. As a result, this is how the fire brigade encounter these buildings in the event of a fire.

3.2.52 The fire brigade operational response therefore reflects this safety condition, see Section 3.2.53.

3.2.53 Fire-fighting operational response for stay-put evacuation strategies

3.2.54 In the above sections I have described the basis of stay put evacuation strategies for high rise residential in historic and current design guidance and their reliance on the operational response of the fire service to suppress the fire (Defend in place – Section 3.2.25).

3.2.55 The operational response of the fire and resc ue service is set out in national guidelines and brigade specific policy documents. I have reviewed these documents for evidence of the fire and rescue operational response to buildings with a "stay -put" evacuation strategy.

3.2.56 LFB policy 539 'Emergency call management, which was first published on 14/11/2007 and reviewed as current on 28/03/2014 (LFB00000737), provides specific guidance regarding the Brigade's responsibility to make arrangements for dealing with emergency calls:

> 1.1 The Authority has a responsibility to make arrangements for dealing with emergency calls for the assistance of the Brigade and making an appropriate response under the provisions of the Fire and Rescue Services Act (2004).

3.2.57 Appendix 3 of this document, 'Fire Survival Guidance', gives the following specific advice to callers from high rise domestic buildings:

Appendix 3 - Fire survival guidance

The London Fire Brigade define a Fire Survival Guidance call as being a call to Brigade Control where the caller believes that they are unable to leave their premises due to the effects of fire, and where the Control Room Officer remains on the line providing appropriate advice until either the caller is able to leave by their own means, is rescued by the Fire brigade or the line is cleared.

There is specific guidance for control room officers to follow when taking calls to fire situations in domestic accommodation, where callers have indicated they are unable to leave their premises. This guidance follows Fire Service Circular 10/93 Fire survival guidance and employs the principles of Escape, Assist, Protect and Rescue.

Brigade Control advise callers to 'Get out and Stay out', however if a call is received from a High rise building where Fire, Heat and Smoke are not affecting the caller, LFB would advise that:

You are usually safest to remain in your premises unless affected by fire, heat or smoke. If the situation changes, you should leave your premises and dial 999, if you need further assistance.'

3.2.58 Therefore, in the event of a fire within a high rise domestic building, LFB emergency call management policy advises persons to remain in their premises unless they are affected by fire, heat or smoke.

3.2.59 The nationwide fire and rescue services operational guidance (GRA 3.2 2014) recognises that there will need to be reliance on the fire and rescue service for changing from a Stay Put strategy. This operational guidance states that fire and rescue service Incident Commanders should be prepared to change that strategy during a fire event, as I have reproduced in Figure 3.4.

Contingency plans for particular premises should cover:

- fire spread beyond the compartment of origin and the potential for multiple rescues
- an operational evacuation plan being required in the event the "Stay Put" policy becomes untenable

Figure 3.4: GRA 3.2 fighting fires in high-rise buildings. Excerpt from Page 17.

3.2.60 LFB produce their own "High Rise fire fighting" policy No 633, which was issued on 26/11/2008 and reviewed on 01/06/2015 (LFB00001256). The guidance contained within this document on operational procedure during a high rise fire is consistent with GRA 3.2 with regard to the potential necessity to change "stay put" evacuation strategies:

Evacuation

7.45 The IC should consider following the evacuation plan devised as part of the occupier's fire risk assessment, unless the fire situation dictates otherwise.

7.46 It may be necessary to undertake a partial or full evacuation in a residential building where a "Stay put" policy is normally in place.

7.47 Firefighting operations can be adversely affected by the type of evacuation being undertaken, the progress of the evacuation and the number and type of people being evacuated. Evacuation can be made more resource intensive if the occupants have an impaired ability to make their own way to safety; for example, disabled persons or those under the affect of alcohol or drugs may need greater assistance. The IC should consider:

(a) the effect of firefighting tactics on evacuation (and vice versa),

(b) the resources required to support the evacuation or "Stay put" policy,

(c) where it is safe to do so, using other emergency service personnel to assist with evacuation; and that widespread evacuation may divert teams from the task(s) they were briefed to undertake which may require additional resources,

(d) the need to establish, if appropriate, separate attack and evacuation stairwells.

3.2.61 **This operational response I refer to as Stay Put policy** in my Expert Report.

3.2.62 From my review of design guidance and the corresponding fire and rescue service operational response policies, I consider therefore that the Stay Put strategy and the Defend in Place firefighting tactic have remained as the foundation for the statutory requirements regarding the design and construction of high rise residential buildings since 1971.

3.2.63 The Stay Put policy of London fire brigade relies on this building design condition.

3.3 Changes to active and passive fire protection measures since 1971

3.3.1 There have been minor alterations in terms of performance of fire protection measures (for example fire doors to stairs cases for firefighters). There has also been the introduction of mains powered smoke detection within flats – although I would emphasise that, to this day, the purpose of such a system has only been to raise an alarm in the flat of fire origin, and nowhere else. Please refer to the detailed analysis of legislation in Appendix D for further information.

3.3.2 However, I have set out below an excerpt from BS 5588 -1:1990 which is the more immediate successor to CP3 1971 . Here two important risks are highlighted (1) how the failure to extinguish the fire poses a risk to persons who rely on the common stair and (2) how either leaving the flat entrance door open, or the flat entrance door failing when the fire is not supressed, pose a risk to persons relying on the common stair to evacuate the building.

3.3 Fire development outside the dwelling

The risks to occupants of other dwellings from a fire in another dwelling are parallel to, but much less direct than, the risks to the occupants of the dwelling of origin. The corresponding situations are as follows.

a) In the case of semi-detached or terraced houses, the risk to occupants of an adjoining house will only arise if the fire spreads through the separating walls, or across the face of the building from one window to another or by radiated heat from a fire in adjacent premises.

b) A fire in an occupied flat or maisonette is discovered by the occupants, who make their way out and leave the door closed, presumably then giving the alarm. The fire should present little or no risk to the occupants of other dwellings if they remain within their own dwelling as it will not break out of the dwelling of origin for some considerable time (during which, no doubt, the fire service will deal with the fire).

If extinction of the fire is delayed, there will be a direct risk to persons using any common access, through smoke and heat affecting the route, and the fire may begin to penetrate to other dwellings. If the dwelling entrance door is left open after the occupants' departure, any access corridor will be quickly filled with the products of combustion, and other occupants trying to use the corridor will be in serious difficulty.

c) A fire may start (or be started) in an unoccupied dwelling, there will be no one to give the alarm, and the fire may develop fully within the dwelling before other occupants are aware of it. After a time the dwelling entrance door will be penetrated, as in item b), and with the same consequences. If the dwelling entrance door gives on to an open balcony rather than an internal corridor, smoke would be of little consequence but, at a later stage, there could be difficulty in passing the door.

3.3.3 Unfortunately, the identification of these risks was not retained in the more recent BS9991 2015, but I will refer to those risks later on in my analysis of the fire events in Grenfell Tower.

3.3.4 However, BS9991 2015 does address the importance of fire doors:

"Doors in fire-separating elements are one of the most important features of a fire protection strategy, and it is important to select a fire door that is suitable for its intended purpose. They are normally self-closing unless they give access to cupboards or service risers, in which case they should be kept locked. The reliability of a fire door, especially in heavily-trafficked places, can be improved by hold-open devices that release the door automatically in response to a fire. Fire doors have at least one of two functions: a) to protect escape routes from the effects of fire so that occupants can reach a final exit; b) to protect occupants, fire-fighters and the contents and/or structure of a building by limiting the spread of fire."

3.3.5 This is of considerable importance when considering the conditions experienced within Grenfell Tower during the fire.

3.3.6 Finally, the most significant change in fire protection measures took place in 2006 when sprinkler systems were recommended for **new** residential buildings that are over 30m from ground level.

3.3.7 These systems should be specified using BS 9251:2005 *Sprinkler systems for residential and domestic occupancies*, the Code of practice and BS DD 252 *Components for residential sprinkler systems* and in accordance with specification and test methods for residential sprinklers.

3.4 The resulting active and passive fire protection measures required in Grenfell Tower

3.4.1 I have provided a detailed explanation of the statutory guidance in my Appendices:

3.4.2 Appendix D: Legislation, Regulations and Guidance

3.4.3 Appendix E: Compliance assessment: External Fire Spread Regulation B4

3.4.4 Appendix F: Reaction to fire tests and classifications

3.4.5 Appendix G: Compliance assessment for means of warning and escape Regulation B1

3.4.6 Appendix H: Compliance assessment for access and facilities for the Fire and Rescue Services Regulation B5

3.4.7 Appendix I: Flat entrance and stair fire doors – requirements and provisions

3.4.8 Appendix J – Lobby smoke control – fire safety requirements and provisions

3.4.9 Appendix K – Gas supply – fire safety requirements and provisions

3.4.10 Appendix L – Lift installations – fire safety requirements and provisions

3.4.11 Appendix M – Applicable historic guidance on fire door design, specification and testing

3.4.12 Appendix N – Collated evidence relevant to conditions in the stairs and lobbies

3.4.13 Appendix O – Review of the BBA certification for Reynobond Architecture Wall Cladding Panels

3.4.14 Based on that statutory framework, I have identified in the table below a number of active and passive fire protection measures which are relevant to Grenfell Tower.

3.4.15 This list of active and passive fire protection measures assumes a high degree of compartmentation. This is necessary to support the Stay Put strategy. This relies on compliance with Regulation B4 for External Fire Spread - *The external walls of the building shall adequately resist the spread of fire over the walls ..., having regard to the height, use and position of the building.* I explain why this is relevant particularly in Section 12 of this report.

Table 3.1 Passive and Active fire safety systems

Passive Systems	**Active Systems**
Fire rated stair case of a specific width and head height	Fire alarm for individual flats
Fire rated lobbies of a specific travel distance	Interface between fire detection and fire alarm systems and other systems
Fire doors	Smoke control in the lobby
Fire protected gas service and installation pipes	Emergency lighting
Flights and landings constructed of materials of limited combustibility	Permanent vent for refuse chute lobby
Protection to critical electrical circuits	Fire main
Refuse chute separated from the lobby by fire resisting construction	Firefighting lift [fire man's lift] Including lift controls
Protected stair way with nothing other than lift well or electricity meter within	Minimum of one hydrant
Vehicle access to fire main	Environmental fan auto off in the event of fire
Fire protection to any riser in the common lobby	Vent at the head of the stair
The external walls of the building shall adequately resist the spread of fire over the walls having regard to the height, use of the building.	Emergency lighting and signage
The roof of the building shall adequately resist the spread of fire over the roof and from one building to another, having regard to the use and position of the building.	
The loadbearing elements of structure of the building are capable of withstanding the effects of fire for an appropriate period without loss of stability; Structural Stability	
The building is sub-divided by elements of fire-resisting construction into compartments; Compartmentation	
Any openings in fire-separating elements (see Appendix E) are suitably protected in order to maintain the integrity of the element (i.e. the continuity of the fire separation); Fire stopping	
Any hidden voids in the construction are sealed and sub-divided to inhibit the unseen spread of fire and products of combustion, in order to reduce the risk of structural failure and the spread of fire, in so far as they pose a threat to the safety of people in and around the building. Cavity barriers	Open state cavity barriers which intumesce in the event of fire

3.4.16 The presence of these active and passive fire protection measures are intended to create a layered safety approach.

3.4.17 They provide the means for early internal firefighting.

3.4.18 They provide the means to limit fire and smoke spread from a dwelling fire.

3.4.19 They create the "high degree of compartmentation" to support Stay Put strategy in a high rise residential building.

3.4.20 There are multiple layers of safety, not a single layer of safety, which I explain in more detail below.

3.5 How the fire safety measures are intended to protect life

3.5.1 **During evacuation of the occupants of the flat of fire origin**

3.5.2 Each flat is a fire resisting "box" with all internal openings sealed to limit fire and smoke spread between flats and out to the common lobby.

3.5.3 The fire resisting box consists of the five internal fire resisting walls/floors only. The sixth side, the external wall, is subject to a different standard of fire performance to the internal walls and floor.

3.5.4 The fire resisting box is based on a single fire within the flat only.

3.5.5 In the event of a fire in a flat, a fire detection and alarm system should be present in that flat, and raise the alarm for occupants in that flat only.

3.5.6 No alarm will sound anywhere else in the building. The fire brigade will not be alerted automatically.

3.5.7 To support this first stage of evacuation from within the flat itself, a protected entrance hall is required within the flat.

Occupants of the fire flat or nearby are then expected to leave their flat, with the flat entrance fire door shut behind them.

3.5.8 In a single stair building, the person from within the flat on fire must first escape through the common lobby over to the stair entrance. A range of fire protection measures are provided to protect the occupants when travelling through the lobby.

3.5.9 Smoke control is provided in the lobby in the event the door is left open for some reason. And to clear any smoke which may enter the lobby from the fire flat.

3.5.10 Fire resisting walls around the flat of fire origin as well as fire resisting walls around the lobby delay the spread of fire and smoke to other flats and the common means of escape. Fire doors are installed within these partitions to allow passage whilst retaining protection.

3.5.11 In the event of smoke in the lobby, a detection system there should trigger the smoke control system. No alarm will be sounded in that lobby. No neighbouring flats on that floor will be notified of a fire.

3.5.12 Furthermore, controls on materials in the common lobby should prevent rapid fire spread through this part of the escape route, in the event fire breaks out of the flat compartment.

3.5.13 People in adjoining dwellings and/or dwellings on the same floor do not automatically evacuate – they have not received any alarm or signal to evacuate.

3.5.14 The design is therefore focused on containing a fire within the flat of fire origin; creating a single flat fire event. This is provided through the fire resisting walls and floors in that flat.

3.5.15 The final side of the fire resisting box is the external wall. In accordance with the Building Regulations, the construction of the external walls is required to adequately resist the spread of fire. Therefore, people in adjoining flats on the same floor who rely on the same horizontal escape route through the lobby, are protected

3.5.16 The required external wall fire performance, based on adequately resisting the spread of fire, is intended to prevent an external fire scenario beyond the single flat on fire.

3.5.17 Equally those on the floors above the floor where the flat fire has started, are also to be protected from the single flat fire below them.

3.5.18 Once occupants of a high rise residential building have made their way through the lobby; the final stage of their evacuation is down the stairs.

3.5.19 The provision of fire resisting construction, including the stair door, is intended to prevent the penetration of smoke and fire into the stair enclosure.

3.5.20 Equally, the fire resisting lobby provides protection in the form of an additional degree of separation between the fire flat and the stair. The smoke ventilation system within the lobby then provides extraction of any smoke that reaches the lobby from the affected flat. This ultimately is intended to prevent the spread of fire and smoke blocking use of the protected stair for any residents above the fire floor. After travelling down the stairs and exiting the building they should then phone 999 and alert the fire brigade to the fire.

3.5.21 **During firefighting operations**

3.5.22 The code of practice for fire safety in flats, CP3 1971 states: "*Reliance on such appliances as manipulative types of escape or mobile ladders is considered unsatisfactory*".

3.5.23 High rise residential buildings must therefore be designed on the basis that firefighting does not occur from outside. This concept has also been carried over into modern design codes, where the regulations require provisions only for internal firefighting in high rise residential buildings.

3.5.24 Therefore, the Building Regulations require adequate access to buildings for fire fighters and their vehicles only at their entry point to the building and at no other location around the building.

3.5.25 The protection measures in the lobby and the stairs described in 3.5.1 to 3.5.20 are also provided to create a safe working environment for the fire brigade.

3.5.26 The fire and rescue service is expected to arrive in standard pump vehicles, park near the building entrance and the riser provided. They prepare for internal firefighting. No external firefighting provisions are made available for high rise residential buildings.

3.5.27 On arrival the Incident Commander appraises the situation and defines operational objectives.

3.5.28 A water supply is secured from a hydrant outside the building, and a connection made to the fire main within the building via the fire and rescue service's pumping appliance.

3.5.29 The firefighters can take the firefighting lift under their direct control. The lift is then used by fire crews to carry their equipment, such as hoses, tools and breathing apparatus, to the Bridgehead, which by policy is the lobby two floors below the fire.

3.5.30 A Bridgehead is typically established in the lobby two floors below the fire, and is used as an area to muster firefighters and their equipment. The lobby is designed to protect the fire fighters from fire and smoke on the fire floor above, and maintain a "safe air environment", i.e. the air is safe to breathe without the protection of breathing apparatus.

3.5.31 A crew is tasked with approaching the dwelling containing the fire and this crew dons breathing apparatus in the Bridgehead.

3.5.32 The first crew uses the firefighting stair to walk up to the firefighting lobby on the floor below the fire and connects a hose to the rising main outlet there.

3.5.33 The first crew moves to the fire floor with a charged hose using the firefighting stair and is tasked with fighting the fire.

3.5.34 A second crew dons breathing apparatus in the Bridgehead and heads to the fire floor to connect into the rising main there and is tasked with protecting the first team.

3.5.35 The fire fighters are now operating within what they term the fire sector. One example of this is a fire sector which includes the fire floor, the floor above and below (see Figure 3.5).

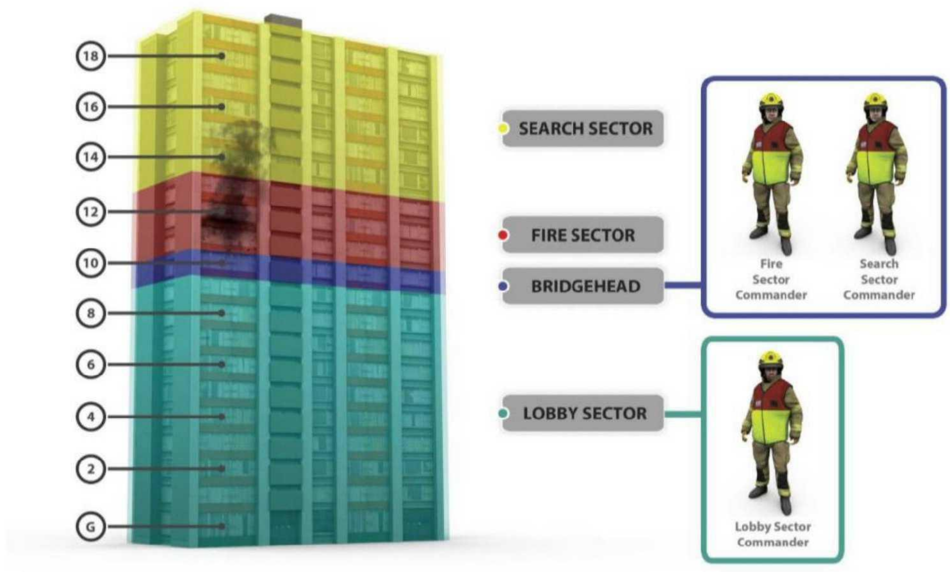

Figure 3.5: Firefighting sectors (Image: ukfrs.com)

3.5.36 The active and passive fire protection measures are required to prevent a fire from spreading significantly beyond a single flat. This underlines the importance of compartmentation in the operational firefighting, in particular:

a) To operate within search sectors above a fire sector they rely on the protected stairs and lobbies to move safely to any required search sector.

b) To operate within lobby sectors used for co-ordination of all their required logistics they again rely on the protected stairs and lobbies to move safely up and down to the lobby sector.

3.5.37 The fire in the dwelling is extinguished.

3.5.38 In the event the fire and rescue services determines that other occupants on that floor should evacuate, they should do this by knocking on the flat doors and requesting that people leave.

3.5.39 If any person in the fire flat or adjacent flats requires assistance to evacuate, they would have to inform the fire and rescue services, as there is no current statutory provision in residential buildings to have that status pre-warned to the relevant fire and rescue service authority.

3.5.40 In the event the fire and smoke spread internally, additional firefighting and rescue would be carried out in those localised areas only.

3.5.41 The Incident Command Manual (p27) sets out how the building is sectorised to reflect the fire and rescue services operations in each area:

"Fire Sector – this is an operational sector and would be the main area of firefighting and rescue operations, consisting of the floor/s directly involved in fire, plus one level above and one level below. If crews involved in this exceed acceptable spans of control, consideration should be given to activating a Search Sector.

Search Sector – this is an operational sector and would be the area of operations in a high rise, above the 'fire sector' where search and rescue, venting and other operations are taking place. In a basement scenario the Search Sector could extend from fresh air to the lowest level. If the distance from the ground floor lobby to the bridgehead is more than two or three floors and spans of control require it, consideration should be given to activating a Lobby Sector.

Lobby Sector – this is a support sector and would cover the area of operations from the ground floor lobby to the bridgehead, which is normally two floors below the fire floor, The Lobby Sector Commander will act as co-ordinator of all the logistics needs of the fire and search sector Commanders, who will, on most occasions, need to be located at the bridgehead directing operations via radio and liaising with the BAECO [breathing apparatus entry control officers]. The Lobby Sector Commander would also co-ordinate all operations beneath the bridgehead level, including salvage and ventilation, liaising with fellow Sector commanders in the usual way."

3.5.42 The fire sector represents the highest risk to fire fighters as they are in direct contact with the fire, and the associated smoke and hot gasses. They rely on a water supply to reduce the associated smoke and hot gasses. They rely on breathing apparatus to carry out their duties in this sector.

3.5.43 The lobby sector represents the lowest risk to fire fighters as it is implemented below the fire sector, with the lowest risk of fire and smoke spread. And is intended to be a safe air environment for crews working without breathing apparatus.

3.5.44 This is how the lives of occupants in high rise residential buildings are intended to be protected. And how the lives of the fire fighters are also intended to be protected.

3.5.45 **Layers of safety**

3.5.46 Fire safety is therefore achieved through the provision of multiple layers of safety.

3.5.47 The 'layered approach' or 'defence in depth' achieves a high level of safety through the provision of multiple forms of fire safety measure.

3.5.48 This is the underlying approach of many safety frameworks, not just fire safety.

3.5.49 Individual layers are not necessarily required to be sophisticated or of a very high reliability, instead a high level of safety is achieved through aggregating each layer.

3.5.50 Therefore, in theory, lapses and weaknesses in one defence should not allow a risk to materialise, since other defences also exist, to prevent a single point of weakness.

3.5.51 Loss of several layers can greatly increase the likelihood of a major incident.

3.5.52 This is important because these layers of safety form an essential outcome of all design decisions, and of all construction decisions, and of all fire safety management decisions.

3.5.53 Once a design is complete, it is necessary to ensure that all the layers of safety have been provided. Once the construction is complete, again it is necessary to confirm all the layers of safety have been provided. And once the building is occupied and under operational fire safety management control, again the maintenance of all the layers of safety become the governing parameter. I will investigate how these activities were dealt with at Grenfell Tower in my Phase 2 report.

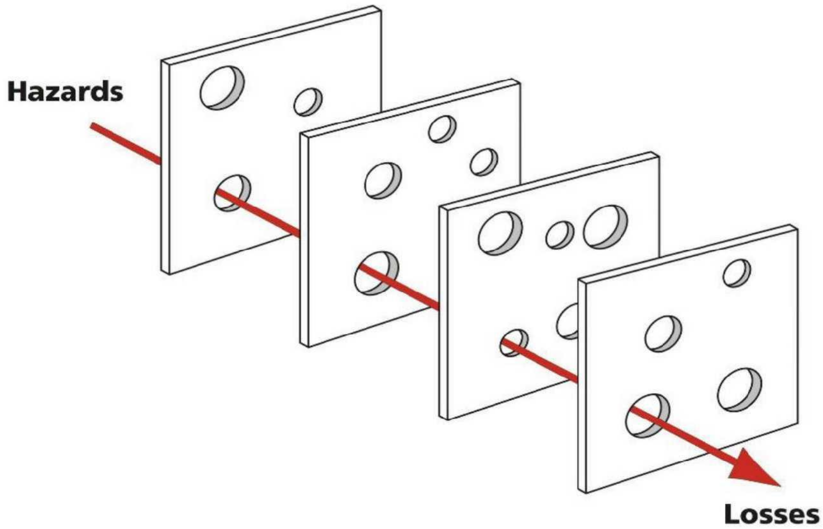

Figure 3.6 Swiss cheese model of acident causation

3.5.54 For the avoidance of any doubt, since the publication of CP3 in 1971, the layers of safety forming the basis of fire safety guidance in high rise residential buildings are:

a) the high degree of compartmentation – around each flat, enclosing every service riser, enclosing the stairs, enclosing the lobbies

b) providing internal firefighting equipment to enable early suppression of the fire – such that this compartmentation may not even be needed

c) the provision of fire doors – greatly emphasised – to protect the openings in the compartmentation.

d) coupled with the provision of smoke control from the lobby. This is to compensate for the loss of a fire door – either because it is left open or the dwelling fire is not extinguished early. And so to reduce the risk of smoke spread to the staircase.

e) the provision of ventilation from the stair – in case of failure of smoke control from the lobby, coupled with the fire doors to the staircase.

f) the provision of limited travel distances within dwellings, and outside the dwelling in the common lobbies – to aid escape to the protected escape stair; as well as emergency lighting and exit signs.

g) the provision of construction and materials that limit fire spread within lobbies, in the event a fire does exit a flat and enter the lobby.

h) the provision of construction and materials that adequately resist fire spread in the external wall construction

i) detection and alarm within individual flats to enable occupants of the fire flat to evacuate

j) Fire prevention actions by the building owner in conjunction with residents;

k) The maintenance of active and passive fire protection systems.

3.5.55 Those layers of safety are intended to prevent reliance on the fire and rescue services for safe evacuation.

3.5.56 The terms of reference for those layers of safety are to deal with a fire in a single dwelling. Or a minor fire in a common lobby.

3.5.57 Those layers of safety are not intended for a multi storey building envelope fire, nor a set of internal dwelling fires occurring on multiple storeys simultaneously. Such events are not considered as relevant fire events, in the current terms of reference for these layers of safety.

3.6 Statements of compliance

3.6.1 In respect of all the fire safety measures I have investigated I have explained my understanding of what was required by the Regulations and the relevant statutory guidance at the time of construction of Grenfell Tower. I have also then explained what is required under the current Building Regulations and its statutory guidance.

3.6.2 I have referred to British Standards, where relevant, in those time frames also.

3.6.3 These are explained and listed in full in Appendix D of my expert report.

3.6.4 I have also referred to the publication by the Local Government Association " *Fire Safety in purpose built blocks of flats*", published in 2011.

3.6.5 This guide states:

"*it is intended for buildings which have been constructed as purpose-built blocks of flats. It applies to existing blocks only*." It goes on to state "*Fire safety design in new blocks of flats is governed by the Building Regulations 2010, but, once a block is occupied, this guide is applicable*". It confirms that "*This document is intended to assist responsible persons to comply with the*

FSO and the Housing Act 2004. Accordingly, it is expected that enforcing authorities will have regard to this guide."

3.6.6 I have referred to HM Government fire safety risk assessment – sleeping accommodation, published in 2006.

3.6.7 Where I refer to or rely on a guidance document I make the reference in the appropriate section of my Report.

3.6.8 I have not considered any other non-statutory guidance at this stage of my work.

3.6.9 Where there is a difference in recommendation I have made that clear, and identified which provision was present in Grenfell Tower the night of the fire.

3.6.10 I have also made clear where I found a safety measure to be entirely different to standards at either time frame - where I have been able to conclude as such, with the evidence available to me at this time.

3.6.11 At this stage I am providing my assessment of each system under the two statutory regimes only (Section 3.6.1 above).

3.6.12 In Phase 2 I will give my overall opinion about the compliance of the systems at Grenfell Tower, in full, when I have completed my analysis of the Phase 2 disclosure including the design, construction, and operational stage documentation and once I have had the opportunity to consider the associated decision making, by all relevant parties.

3.6.13 Further, in my Phase 2 report, I will investigate how any non-compliances were understood and considered by the relevant members of the design and construction team, as well as the Royal Borough and Chelsea and Kensington, the TMO, and their fire risk assessor for Grenfell Tower, Carl Stokes..

3.6.14 I will also investigate how any non-compliances I have found impacted any of the relevant duties under the RR(FS)O (the legislation that applies once buildings are occupied). And again, how any non-compliances were understood and considered by the relevant members of the design and construction team, as well as the Royal Borough and Chelsea and Kensington, the TMO, their fire risk assessor for Grenfell Tower, Carl Stokes and the London Fire Brigade (LFB) during their Regulatory Reform (Fire Safety) Order 2005 (RR(FS)O) inspections at Grenfell Tower.

3.6.15 In referring to those statutory guidance documents, relevant British Standards LGA and HM guides, in carrying out my compliance assessment, this is in no way intended to imply I agree in full with their contents.

3.6.16 I am aware that alternative methods to comply are permitted under Section 0.21 of the Approved Document B 2013:

"…there may well be alternative ways of achieving compliance with the requirements. If other codes or guides are adopted, the relevant

recommendations concerning fire safety in the particular publication should be followed, rather than a mixture of the publication and provisions in the relevant sections of this Approved Document. However, there may be circumstances where it is necessary to use one publication to supplement another. Guidance documents intended specifically for assessing fire safety in existing buildings will often include provisions which are less onerous than those set out on this Approved Document or other standards applicable to new buildings. As such, these documents are unlikely to be appropriate for use where building work, controlled by the Regulations, is proposed."

3.6.17 I will investigate what, if any, alternative compliance approaches were proposed by any stakeholder, to deal with the non-compliances (as I have currently defined them).

3.6.18 I intend to explain the significance of all the non-compliances I have found, with regard to the concept of Material Alteration, under Regulation 3 of the Building Regulations.

3.6.19 The term "material alteration"is defined by reference to a list of "relevant requirements" of Schedule 1 to the Building Regulations. That list includes the requirements of Parts B1, B3, B4 and B5. This means that an alteration which, at any stage of the work, results in a building being less satisfactory than it was before in relation to compliance with the requirements of Parts B1, B3, B4 or B5 is a material alteration, and is therefore controlled by Regulation 4 as it is classed as "building work".

3.6.20 Regulation 4(1) requires that any building work carried out in relation to a material alteration:

"complies with the applicable requirements of Schedule 1 to the Regulations, while Regulation 4(3) requires that once that building work has been completed, the building as a whole must comply with the relevant requirements of Schedule 1 or, where it did not comply before, must be no more unsatisfactory than it was before the work was carried out". (see ADB at 0.20 on page 11)

3.6.21 I will investigate if some, or all of the non-compliances, were such that overall they resulted in the building being less satisfactory than it was before the work was carried out.

3.6.22 I will investigate if the non-compliances as I have found them directly contributed to the spread of fire and smoke in my Phase 2 report. I have provided preliminary opinion here only in my Phase 1 report.

3.6.23 I have not considered industry practice in my Phase 1 report.

3.7 Key definitions

3.7.1 There are many definitions used when discussing fire safety and the behaviour of fire and smoke. In particular, there are many definitions and variations regarding the word "combustible". When explaining the performance of materials particularly in the rain screen cladding system, the words combustible, non-combustible, limited combustibility, are referred to frequently.

3.7.2 In order to assist the reader, I provide the following definitions, to assist in understanding my Report.

3.7.3 The definitions provided are taken from BS 4422:2005 *Fire Vocabulary* which is reproduced in Appendix B. Where definitions are not taken from BS 4422:2005, the alternative reference document is provided.

3.7.4 **Burning**: Continuous combustion including smouldering. The process of self-perpetuating combustion, with or without an open flame. Smouldering is burning. (NFPA Glossary of terms, 2013 edition)

3.7.5 **Combustible**: A material that will ignite and burn when sufficient heat is applied and when an appropriate oxidiser is present. (Dehann, 2007).

3.7.6 **Combustion process**: A chemical process of oxidation that occurs at a rate fast enough to produce heat and usually light in the form of either a glow or flame. (NFPA 101, 2012)

3.7.7 **Combustion (Glowing)**: The rapid oxidisation of a solid fuel directly with atmospheric oxygen creating light and heat in the absence of flames. (Kirk's Fire Investigation, Sixth Edition, John D. Dehann, 2007)

3.7.8 **Combustion (Smouldering)**: The slow, low temperature, flameless combustion of a solid. (Principles of fire behaviour and combustion, Gann and Friedman, 2015)

3.7.9 **Expanded Polystyrene (EPS)**: Expanded polystyrene is a thermoplastic polymer and is created by the addition of catalysts and Pentane as an expanding agent to a styrene monomer which is derived from crude oil by a combination of ethylene and benzene. Expanded polystyrene bead is then created by a process known as 'prefoaming' which forms thousands of tiny cells within each bead which ultimately entrap air. (IACSC Design, Construction, Specification and Fire Management of Insulated Envelopes for Temperature Controlled Environments, Second Edition, 2008).

3.7.10 **Extruded Polystyrene Foam (XPS)**: Although based on the same raw materials as Expanded Polystyrene, it is instead manufactured by a continuous extrusion process in which blowing agents are added to produce a rigid, closed cell homogeneous material. The extruded board has a natural high-density surface skin that is planed off when the material is used as a core insulant in insulated composite panels (IACSC Design, Construction, Specification and Fire Management of Insulated Envelopes for Temperature Controlled Environments, Second Edition, 2008).

3.7.11 **Thermoplastic** means that when heated EPS and XPS will soften and melt, and so will modify its behaviour under fire conditions. Fire spread may be enhanced by falling droplets or the spread of a burning pool of molten polymer. (Dougal Drysdale, 'An Introduction to Fire Dynamics', Wiley, 1998)

3.7.12 **Fire**: 1) Process of combustion characterized by the emission of heat and effluent accompanied by smoke, and/or flame and/or glowing; 2) rapid combustion spreading uncontrolled in time and space.

3.7.13 **Fire Resistance**: Ability of an item to fulfil for a stated period of time the required fire stability and/or integrity and/or thermal insulation, and/or other expected duty specified in a standard fire resistance test.

3.7.14 **Flame**: Aa body or stream of gaseous material involved in the combustion process and emitting radiant energy at specific wavelength bands determined by the combustion chemistry of the fuel. In most cases, some portion of the emitted radiant energy is visible to the human eye (NFPA 72, 2013)

3.7.15 **Flaming Combustion**: Undergoing combustion in the gaseous phase with the emission of light and heat.

3.7.16 **Ignition**: The onset of combustion (Principles of fire behaviour and combustion, Gann and Friedman, 2015)

3.7.17 **Ignition, pilot**: Ignition, by a separate pilot ignition source, of flammable vapours emitted from the pyrolysis of a heated material

3.7.18 **Ignition, self**: Spontaneous ignition due to self-heating

3.7.19 **Ignition, spontaneous**: Ignition of a heated material without any separate pilot ignition source

3.7.20 **Insulating core panels**: A form of insulating composite panel which consists of an inner core sandwiched between and bonded to facings of galvanised steel, often with a PVC facing for hygiene purposes. The panels are then formed into a structure by jointing systems, usually designed to provide an insulating and hygienic performance (taken from Appendix F of Approved Document B) 2013.

3.7.21 **Limited combustibility** – As defined in Table A7 of the Approved Document B 2013 and explained in detail in Appendix F of my expert report.

3.7.22 **Non-combustible**: Not capable of undergoing combustion under specified conditions.

3.7.23 **PCS (Pouvoir Calorifique Supérieur)**: The gross heat of combustion which is the heat of combustion of a substance when the combustion is complete and any produced water is entirely condensed under specified conditions (EN ISO

13943). (BS EN 13501-1:2007+A1:2009, Fire classification of construction products and building elements – Part 1: Classification using data from reaction to fire tests)

3.7.24 **Polymers**: Materials of high molecular weight, whose individual molecules consist of long 'chains' of repeated units which in turn are derived from simple molecules known as monomers. There are two basic types of polymer - addition and condensation. The addition polymer is the simpler in that it is formed by direct addition of monomer units to the end of a growing polymer chain. The condensation polymer involves the loss of a small molecular species (normally H_2O) whenever two monomer units link together (Dougal Drysdale, 1998).

3.7.25 **Polymeric Foam**: A foam, in liquid or solidified form, formed from natural sources defined as polymers. Polymeric foam constitutes of large beads and microscopic cells used for a variety of applications (Polymeric Foams, Khemani)

3.7.26 **Polyurethane (PUR)**: PUR is a polymeric foam, and is formed from a reaction involving isocyanates and reactive hydrogen-bearing materials, such as polyethers, castor oils, amines, carboxylic acid, and water. By varying the number of branchings, it is possible to make polyurethanes that are thermoplastic or thermosetting. (Fire protection handbook NFPA, Volume 1, 20th edition, 2008)

3.7.27 **Polyisocyanurate Foam (PIR)**: PIR is a thermosetting polymeric foam and is formed from a reaction involving a mixture of two principle liquid components and a number of additives to produce highly cross linked polymers with a closed cell structure (IACSC Design, Construction, Specification and Fire Management of Insulated Envelopes for Temperature Controlled Environments, Second Edition, 2008).

3.7.28 **Thermosetting polymers**: Cross-linked structures which will not melt when heated. Instead, at a sufficiently high temperature, many decompose to give volatiles directly from the solid, leaving behind a carbonaceous residue. (Dougal Drysdale, 1998)

3.7.29 **Products of combustion**: Solid, liquid and gaseous materials resulting from combustion. The products of combustion can include fire effluent, ash, char, clinker and/or soot.

3.7.30 **Pyrolysis**: The anaerobic decomposition of a gas, liquid or solid into other molecules when heated (Principles of fire behaviour and combustion, Gann and Friedman, 2015). For solid fuels, it is a chemical decomposition reaction where solid fuels vaporise under heat. At sufficiently high temperatures the pyrolysis rate dramatically increases. Over time, concentration gradients of fuel and air form over the condensed fuel surface. There is a region above the surface where both gaseous fuel and air coexist within the flammability limits. Below this region the mixture is too rich to ignite. Above this region the mixture is too lean to ignite. Therefore, once the pyrolysis gases are formed, they must mix to form a flammable mixture. A combustion reaction can then be ignited if a spark or pilot were to exit in the flammable region above the surface of the solid. It is for this reason the solid fuel ignition time is generally estimated by the gasification (pyrolysis) time. Products of pyrolysis also include char. (Fundamentals of combustion processes, Sara McAllister, Jyh-Yuan Chen, A. Carlos Fernandez-Pello, 2011)

3.7.31 **Self-sustaining** (with regards to the combustion process): The process of burning gasses which feedback sufficient heat to a material to continue the production of gaseous fuel vapours or volatiles. (SFPE Handbook 1-110)

3.7.32 **Sustained flaming**: Existence of flame on or over a surface for a minimum period of time. (The period of time required will vary across different standards, but it is usually of the order of 10s.). (BS EN 13501-1:2007+A1:2009, Fire classification of construction products and building elements – Part 1: Classification using data from reaction to fire tests)

3.8 Understanding how materials react to fire

3.8.1 As a solid is heated, pyrolysis occurs (chemical decomposition) which yields gaseous fuel (volatiles) at the surface of the solid. Whether or not this is preceded by melting depends on the nature of the solid material.

3.8.2 If a material is a Thermoplastic, melting does occur first, then chemical decomposition, followed by the evaporation of low molecular weight products. An example of a thermoplastic is polystyrene.

3.8.3 If a material is a thermosetting polymer, these produce volatiles directly from the solid, when heated, leaving behind carbonaceous residue. These materials do not melt when heated. Examples of thermosetting materials relevant to Grenfell Tower are phenolic foam and polyisocyanurate foam (PIR).

3.8.4 The significance of the volatiles produced, is that they then either auto ignite to form a flame (mix of volatiles and air such that it can sustain flaming), or undergo pilot ignition to form a flame (spark/ember/other flame ignites the volatiles directly).

3.8.5 The volatiles that are generated in the heating process determine how easily a flame may stabilise at the surface of the solid and also how much soot may be produced by the flame.

3.8.6 During the fire (burning of the solid), the toxicity of the resulting combustion products is affected by the nature of the volatiles produced during the heating phase (e.g. hydrogen cyanide from polyurethane).

3.8.7 The toxicity yield is dependent on the condition of burning, i.e. how hot the fire is and whether it comes into direct flame contact, and the availability of air.

3.8.8 The most commonly used insulating foams are (SFPE Handbook):

a) Polystyrene (in the form of either XPS or EPS) is resistant to short term temperatures of 90°C and long term temperatures of 80°C. Above these temperatures it will soften, until at 150°C it shrinks and returns to its original density as a solid polystyrene. Continued heating will melt the polystyrene to a liquid and then gases form above 200°C. These gases can be ignited at temperatures between 360 and 380°C and self-ignition occurs at approximately 500°C.

b) Rigid polyurethane foam (PU) is resistant to temperatures up to 120°C, and it degrades from 200°C, volatiles can be ignited from 300°C, and these self-ignite at 400°C.

c) Polyisocyanurate (PIR) is temperature resistant by 20-50°C more than PU, and produces smaller quantities of volatiles when compared with PU. It extinguishes when away from an ignition source, forming a char.

d) Phenolic foam (PF) is resistant to temperatures of 130°C with short exposure up to 250°C possible. At 270°C small quantities of volatile gases are produced. Above 400°C PF glows, but does not flame or self-ignite. Once the ignition source is removed PF foam smoulders and the char remains.

3.8.9 At Grenfell Tower, as I have explained in Section 8 of my expert report, I found evidence of extruded polystyrene foam (XPS) as the core to the infill panels between the windows, and surrounding the kitchen extract fans. I found evidence of phenolic foam and PIR foam attached to the original concrete external wall.

3.8.10 In summary all these foams emit volatiles when heated, and these volatiles can be toxic. In my opinion, it is important an Expert in Toxicology carries out analysis of the construction products used at Grenfell Tower.

3.8.11 The current reaction to fire testing regime is explained in detail and assessed in detail in Appendix F of my expert report.

3.9 Definition of relevant test evidence

3.9.1 Reaction to fire tests

3.9.1.1 Regarding the required fire performance of materials and products, much of the guidance provided in Section 12 External Fire Spread of ADB 2013 is, as it states in Appendix A of ADB 2013:

"given in terms of performance in relation to British or European Standards for products or methods of test or design or in terms of European Technical Approvals.

In such cases the material, product or structure should:

***a.** be in accordance with a specification or design which has been shown by test to be capable of meeting that performance; or*

***b**. have been assessed from test evidence against appropriate standards, or by using relevant design guides, as meeting that performance; or*

***c**. where tables of notional performance are included in this document, conform with an appropriate specification given in these tables*"

3.9.1.2 Further as stated in BS 476 – Part 10: 2009 Section 5.3 "*Within the field of reaction to fire, direct field of application is the application of the test results for a material or product in accordance with the details of how they were tested. Specifically, this means that when compared with the field of application, the mounting and fixing arrangement used in the test method is applied directly to the use of the material or product in real end use conditions*."

3.9.2 I have considered the end use application at Grenfell Tower when assessing relevant reaction to fire test evidence.

3.9.3 All the relevant fire tests are listed in full in my Appendix F of this report.

3.9.4 I have considered any variations in test evidence when they have been determined through a carefully designed test programme or, by an assessment or expert judgement by an expert, as described in BS 476 – Part 10: 2009.

3.9.4.1 Otherwise I conclude where *the mounting and fixing arrangement used in the test method* is not applied directly to the use of the material or product at Grenfell Tower, this is not relevant test evidence

3.9.4.2 I consider the absence of relevant test evidence to be non-compliant with the provisions made in Appendix A of the ADB 2013 for reaction to fire tests.

3.9.4.3 **BS 8414 and BR135**

3.9.4.4 Regarding the tests referenced specifically in Section 12.5 of the ADB 2013 by means of BRE Report *Fire performance of external thermal insulation for walls of multi storey buildings* (BR 135) *for cladding systems using full scale test data* from BS 8414-1:2002 or BS 8414-2:2005, it states:

"*The classification applies only to the system as tested and detailed in the classification report. The classification report can only cover the details of the system as tested.*"

3.9.4.5 Therefore, any fundamental difference between the tested construction and the inspected as built construction on Grenfell Tower, would result in the classification no longer being applicable to the installed system.

3.9.4.6 For this reason, I conclude that any difference between the Grenfell Tower rainscreen cladding system, and the relevant supporting fire test evidence, when classified with BR135, means that test evidence cannot be relied upon to demonstrate compliance with the provisions made in Section 12 of the ADB 2013, and particularly if no other supporting evidence provided.

3.9.4.7 I consider this to be non-compliant with the provisions made in Section 12.5 of the ADB 2013.

3.9.5 Fire resistance of Fire Doors

3.9.6 As per Appendix B of ADB 2013, I have considered the following test data.

3.9.7 Performance under test to BS 476-22. A suffix (S) is added for doors where restricted smoke leakage at ambient temperatures is needed where S is demonstrated using BS 476-31.1; or

3.9.8 Classification in accordance with BS EN 13501-2: 2003, "Fire classification of construction products and building elements" when tested to:

a) BS EN 1634-1:2008 Fire resistance tests for doors, shutters and openable windows;

b) BS EN 1634-2: 2008 Fire resistance characterisation test for elements of building hardware;

c) BS EN 1634-3:2004 Fire resistance and smoke control tests for door and shutter assemblies, openable windows and elements of building hardware.

3.9.9 The requirement (in either case) is for test exposure from each side of the door separately, except in the case of lift doors which are tested from the landing side only.

3.9.10 Any test evidence used to substantiate the fire resistance rating of a door will, as stated in Appendix B of ADB 2013, "*be carefully checked to ensure that it adequately demonstrates compliance and is applicable to the adequately complete installed assembly*".

3.9.11 As stated in Appendix B of ADB 2013 "*Small differences in detail (such as glazing apertures, intumescent strips, door frames and ironmongery etc) may significantly affect the rating.*"

3.9.12 I conclude that for any fire door where there were such differences in detail, when compared with the relevant test evidence, the fire door is non-compliant with the performance requirements made in Appendix A and Appendix B of the ADB 2013.