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Lakanal Fire Investigation - Questions Posed by the Crown Prosecution Service

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Protecting People, Property and the Planet

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Executive Summary

On the 3rd July 2009, a fire broke out in Lakanal, Camberwell, London. The fire spread extensively throughout the building and claimed the lives of six people.

Further to a meeting between the Crown Prosecution Service, Metropolitan Police Service and BRE on the 10th February 2012, I have been asked to consider a number of questions posed by the Crown Prosecution Service and to undertake review of a number of additional documents held by the Metropolitan Police Service in relation to Lakanal. Responses to the questions that have been posed by the Crown Prosecution Service are presented in this report. The review of the additional documents will be reported in full in an amended version of the Lakanal Fire Investigation – Expert Witness Report that I have prepared in relation to the fire.

My interpretation and analysis has necessarily involved a substantial element of expert opinion. This report makes clear where I am giving opinion. This report has been prepared using a large number of documents from which quotes and excerpts have been taken where they are of relevance to this piece of work. Where quotes and excerpts have been taken, every effort has been made to try to avoid them being presented out of context; however the reader is advised to consult original documents where there is any doubt in this regard.

This report is based upon information provided to me by the Metropolitan Police Service. Any new information or changes to current information and/or assumptions may necessitate review or modification of the findings of this report.

Contents

1 Introduction

1 On the 3rd July 2009, a fire broke out in Lakanal, Camberwell, London. The fire spread extensively throughout the building and claimed the lives of six people. BRE became closely involved in the investigation of the incident through its contract with the Department for Communities and Local Government (DCLG): Investigation of Real Fires. BRE provided some support to the Metropolitan Police Service investigation into this incident as part of its work on behalf of DCLG. It is understood that DCLG provided the Metropolitan Police Service with a copy of the Fires of Special Interest report prepared by BRE (FSIS Ref. No. 14/08-09, dated 10th August 2009). One of the principal concerns of the investigation with regards to the lives that were lost is the means by which the fire and smoke spread through the building.

2 BRE provided direct assistance to the Metropolitan Police Service (MPS) and London Fire Brigade (LFB) by investigating how the fire developed and spread to affect the various parts of Lakanal on the 3rd July. The assistance took the form of computer modelling supported by a partial full-scale fire reconstruction. The findings from this work are detailed in BRE report number 259441; Lakanal Fire Investigation – Computer modelling and reconstruction fire, dated 17th December 2010.

3 As a follow up to this, DCLG commissioned a further computer modelling study to investigate the movement of smoke throughout the communal parts of the building, in particular the main stairwell of the building. This work is to be used to examine the appropriateness of the current Generic Risk Assessment issued by the Office of the Chief Fire and Rescue Advisor and used by Fire and Rescue Services throughout the UK for tackling fires in high rise blocks of flats. The work has been made available to the Metropolitan Police Service as part of the multi-agency investigation. The findings from this work are detailed in BRE report number 266862v2; Lakanal - Computer Modelling to Investigate Smoke Ingress into, and Movement within, the Common Access Stairway, dated 21st April 2011.

4 The Metropolitan Police Service then requested further assistance from myself to collate and amalgamate all the expert evidence and other relevant information that has been produced and/or collected by the various agencies involved in the investigation. I presented the findings from a review of a number of documents provided to me by MPS in a document wherein the implications of the conclusions of each piece of work and their relationship to one another could be readily identified and understood. The findings from this work are detailed in BRE report number 271805; Lakanal Fire Investigation – Expert Witness Report, dated 29th September 2011.

5 Further to a meeting between the Crown Prosecution Service, MPS and BRE on the 10th February 2012, I have now been asked to consider a number of questions posed by the Crown Prosecution Service (CPS) and to undertake review of a number of additional documents held by MPS in relation to Lakanal (BRE proposal number 130981, dated 29th February 2012, accepted by MPS on the 26th March 2012). The review of the additional documents will be reported in full in an amended version of BRE report number 271805 (see paragraph 4 above).

6 My interpretation and analysis has necessarily involved a substantial element of expert opinion. This report makes clear where I am giving opinion. This report has been prepared using a large number of documents from which quotes and excerpts have been taken where they are of relevance to this piece of work. Where quotes and excerpts have been taken, every effort has been made to try to avoid them being presented out

of context; however the reader is advised to consult original documents where there is any doubt in this regard.

7 This report is based upon information provided to me by the Metropolitan Police Service. Any new information or changes to current information and/or assumptions may necessitate review or modification of the findings of this report.

8 This report is related to previous reports prepared in relation to the fire at Lakanal and needs to be read in conjunction with those reports. In particular:

8.1 BRE report number 259441; Lakanal Fire Investigation – Computer modelling and reconstruction fire [1],

8.2 BRE report number 266862v2; Lakanal - Computer Modelling to Investigate Smoke Ingress into, and Movement within, the Common Access Stairway [2], and

8.3 BRE report number 271805; Lakanal Fire Investigation – Expert Witness Report [3].

2 Description of the project

9 The following questions have been received by me from the Crown Prosecution Service in relation to Lakanal.

10 [Q1] *"In the BRE report dated 27 July 2011 it is indicated that "the severity of the fires in flat 65 and flat 79 as well as the spread from the former to the latter was partly attributable to the performance of the window panels installed during the 2006/7 refurbishment. The window framed sets and composite panels installed increased the susceptibility of the building to allow vertical fire spread from floor to floor. This is partly evidenced by the difference between this incident and the 1997 fire".*

10.1 [a] *What other factors contributed to the spread from flat 65 to flat 79?*

10.2 [b] *If window panels of the correct fire resistance (under Approved Document* [B] *2000) had been installed in 2006/7, how would this have affected the fire spread from flat 65 to flat 79 which occurred?*

11 [Q2] *In the BRE report dated 27 July 2011 it is indicated that "the way in which the fire developed in flat 79 was affected by the removal of the partition walls and the modifications to the staircase in the flat"*

11.1 *In what way was the development of the fire affected by the removal of these walls?*

12 [Q3] *Under the terms of the refurbishment contract Apollo was obliged to report any defects in the existing construction especially where their own work would cover up or hinder access to a defective construction.*

12.1 *Was Apollo placed under contractual obligation to undertake any remedial work to put right any such construction defects?*

13 [Q4] *On the basis of the existing evidence and leaving aside questions of inspections & responsibility for risk assessment, can confirmation be given of which organization or company had responsibility for the condition of the following structures within the block of flats.*

13.1 *Front doors; LBS?*

13.2 *Escape doors; LBS?*

13.3 *Balcony doors; Apollo?*

13.4 *Panels above the front door flats; Drake & Skull?*

13.5 *Boxing in under the stairs; Drake & Skull?*

13.6 *Fire resistance of the Corridor walls; Drake & Skull?*

13.7 *Suspended ceiling in the corridor?*

13.8 *Cross ventilation scheme; LBS?"*

3 Q1a – Factors affecting fire spread from Flat 65 to Flat 79

14 Factors that are likely to have affected the spread of fire, which occurred externally, from Flat 65 to Flat 79 are as follows:

14.1 Building shape and relative positions of flats

14.2 Flat contents

14.2.1 Quantity

14.2.2 Layout

14.3 Ventilation

14.4 Wind direction and speed

14.5 The panels in the window sets

14.6 The glazing within the window sets

14.7 Whether windows were open or closed

15 I have prepared this chapter on the assumption that the fire was able to develop to a size where external fire spread would become a plausible possibility. I have therefore excluded human behaviour that might have extinguished the fire, such as first aid fire fighting using a fire extinguisher or closing doors and windows of bedroom 1 in Flat 65, starving the fire of oxygen. I have also not considered the impact that an automatic fire suppression system might have had on the fire.

3.1 Building shape and relative positions of flats

16 The shape of the external surface of a building can affect the way flames spread from the flat of origin. Rising flames next to a vertical surface will adhere ("stick") to the vertical surface. The flame is where unburnt gases (from the hot fuel) is mixing with oxygen (from the air) and burning. Because flames next to a vertical surface can only mix with air on only one side they are longer than unadhered flames which can mix on all sides.

17 In the case of Lakanal, the flames that were emitted from the windows of the upper floor of Flat 65 spread upwards and came into contact with the underside of the floor slab above the escape balcony (beneath the bedrooms of Flat 79). Once they had spread around this over-hang they then continued to rise and adhere to the vertical surface of the building

3.2 Flat contents

18 In general, normal furniture and furnishings within a flat will be combustible. The contents of both Flat 65 and Flat 79 would have had an affect on fire spread. In principle, the quantity of contents in Flat 65 could have been so low as to limit the size of fire that could have developed there and therefore the length of flames that could have extended out and up to Flat 79. Equally, large quantities of flammable materials

could have been stored in Flat 65 and maximised the size of the fire that could have developed there and therefore the length of flames that could have extended out and up to Flat 79. However, the fire size would have been limited by the available ventilation to the flat (unless an alternative source of oxygen was available in the flat), although this would be extreme and highly unlikely in a typical block of flats.

19 The layout of contents within Flat 79 would have had an impact upon the susceptibility of the contents to ignite once the barrier provided by the glazing and panels of the window sets had failed. If combustible contents had been sited away from the window sets, then it is possible that the flames from Flat 65 would not have been able to ignite any contents within Flat 79 despite the window sets having broken, burnt and fallen away. Note, however, that it would be unreasonably onerous to expect anyone in a flat to keep combustible materials away from windows in case of external fire spread.

3.3 Ventilation

20 The ventilation to Flat 65 would have affected the lengths of the flames produced by the fire in the flat. In particular, any through-draft could have allowed the fire to entrain all of its air through one route and to expel fire gases entirely through another route, increasing the efficiency of the fire and potentially producing a jet fire, as occurred in the 11th floor corridor.

21 The total available area of ventilation openings will have an impact upon the maximum burning rate (fire size) that can be achieved; the greater the ventilation, the larger the fire. However, increasing the ventilation area can also shorten flame lengths emitting from a compartment. This is because the increased ventilation allows more air to get into the fire and therefore allows combustion to complete more quickly, thereby shortening the flame.

22 During the incident, prior to the front door of Flat 65 failing, the lower floor of Flat 65 was effectively only ventilated via the opening left after the windows and window panels burnt and fell away. The upper floor of Flat 65 was ventilated through the windows and doors on the upper floor, and may also have entrained air up through the staircase of Flat 65 (the lower floor of Flat 65 being ventilated by the missing panels and windows in bedroom 1, where the fire started) due to the general upward movement of gases due to buoyancy in fire.

3.4 Wind direction and speed

23 The wind on the day of the incident had an impact on both the way in which the fire developed and spread inside of Lakanal (as fire was forced or blown along the 11th floor corridor) and the way in which flames extended up the side of the building.

24 The prevailing wind on the day of the incident was arriving from a Westerly direction, so it was approximately perpendicular to the West face of the building. This was the side of the building on which the bedrooms of Flat 65 and Flat 79 were located; the side of the building where the external fire spread occurred.

25 The computer modelling of the incident carried out by BRE indicated that, due to the buildings located upwind of Lakanal, there would have been an overall downward movement of air across the face of Lakanal. However the wind is known to have been gusting on the day of the fire. Depending on the exact direction in which wind was interacting with the fire, it may have caused lengthening or shortening of flames. In certain conditions they would have been shortened by the additional ventilation offered by wind, whilst in others the wind may have drawn out the lengths of flames. However, the gusting would have

caused this to occur in all directions, not just up towards Flat 79, so some of the energy from the fire in Flat 65 may have been carried away elsewhere.

3.5 The panels in the window sets

26 The panels in the window sets have already been demonstrated within the computer modelling and reconstruction report as having had a significant impact upon the way in which the fire spread. The panels affected this both in terms of their spread of flame properties (i.e. whether the surface will burn and/or provide a medium for fire spread) and their fire resistance properties (i.e. the time required for fire to pass from one side of the panel to the other).

27 Further information on both of these properties is given in the computer modelling and reconstruction report and in the expert report.

3.6 The glazing within the window sets

28 The performance of the glazing within the window sets could have affected the amount of time during which external flaming might have been prevented from directly impinging upon the contents of Flat 79. Single and double glazing are known to provide different periods of protection, although neither are normally intended to provide any fire protection.

29 Fire resisting glazing is available and can be installed in buildings depending on the requirement, although it would not, in my experience, be normal practice to use fire resisting glazing for the external fenestration of a block of flats.

3.7 Whether windows were open or closed

30 Subject to the performance of the glazing, see above, whether windows were open or closed would have had an impact upon whether there was any barrier to external flaming impinging upon and igniting the contents of Flat 79.

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4 Q1b – Effect of window panels of correct fire resistance

31 The computer modelling and reconstruction report [1] has addressed the means by which the fire spread from Flat 65 to Flat 79 during the actual incident. This was achieved using computer modelling of the fire and the partial reconstruction of the incident, which used in combination allowed all of the issues discussed in chapter 3 to be addressed. I have now been asked to address the potential implications of one of these issues. Given the timescales available for this work to be completed, it has been necessary to carry out this assessment using engineering calculations and judgement rather than computer modelling. The engineering calculations that are available to do this are capable of providing some quantification of the effect of changing the panels in idealised conditions (i.e. it will provide an indication of whether flames get longer or shorter with different panels). However these calculations cannot take account of all of the aforementioned issues and therefore are a simplification of the problem.

32 PD 7974 Parts 1 [4] and 3 [5] provide formulae that define the relationships between some of these factors and can be used to estimate how different panels might have affected the spread of fire from Flat 65 to Flat 79 during the incident.

33 Given the presence of the partition wall in Flat 65 which, at some point, is known to have burnt through, it is necessary to consider the conditions both prior to and after the partition wall burnt through. This will provide some indication of whether burning rate and flame length are sensitive to the involvement of the staircase in Flat 65.

4.1 Effect of ventilation on mass burning rate

34 The size of the openings on Flat 65 can be the limiting factor in determining the size of the fire that can occur within a compartment. As such, the presence of window panels of the correct fire resistance (under Approved Document B 2000) and a fire resisting door between the kitchen and escape balcony, would have altered the ventilation conditions, and consequently the mass burning rate of the fires within Flat 65. PD 7974 Part 1 [4] presents the mass burning rate in an enclosure ventilation controlled conditions as:

$$m_f = 0.02\sqrt{A_T\left(\frac{w_c}{d_c}\right)A_w h^{1/2}}$$

Where:

m_f = ventilation controlled rate of burning by mass (kg/s)
A_w = area of ventilation openings (m^2)
$A_T = A_t - A_w$, where A_t is the total surface area of the enclosure (m^2)
w_c = width of wall containing ventilation openings (m)
d_c = distance front-to-back of the enclosure (m)
h = height of ventilation openings (m)

35 The mass burning rate therefore needs to be calculated for both the upper and lower floors, with ventilation conditions as they were during the incident and as they might have been had the panels of the correct fire resistance been installed.

4.1.1 Upper floor – panels as installed during 2006-2007 refurbishment

36 The area of ventilation openings, A_w, is taken to be equal to the complete area of the kitchen and the living room window and door sets (each set taken to be (0.6 + 1.3 + 0.6) x 1.4 + (0.8 x 2.5) = 5.5m^2, so the total ventilation area is 2 x 5.5 = 11m^2).

37 The surface area of the enclosure, A_t, is assumed to comprise solely the floor, ceiling and four surrounding walls. The dimensions of the room are taken as 3.5m x 10.3m x 2.5m high.

38 The width of the wall containing ventilation openings, w_c, is 7m (both external walls).

39 The distance front-to-back of the enclosure, d_c, is 10.3m.

40 The height of the opening, h, is taken to be the average of the heights of the openings, corrected by the proportion of the overall opening width occupied by each height; ((0.6 + 1.3 + 0.6) x 1.4 + 0.8 x 2.5) ÷ (0.6 + 0.8 + 1.3 + 0.6) = 1.67m.

4.1.2 Upper floor – panels of correct fire resistance

41 The area of ventilation openings, A_w, had the correct fire resistance panels been used, is reduced to only the glass components of the façade. This corresponds to an area of 8.1m^2. The dimensions used can be found in Figure 1.

42 The surface area of the enclosure, A_t, is again assumed to comprise solely the floor, ceiling and four surrounding walls. The dimensions of the room are taken as 2.5m x 3.5m x 10.3m.

43 The width of the wall containing ventilation openings, w_c, is 3.5 m of the living room wall and 2.7 m of kitchen wall (totalling 6.2m).

44 The distance front-to-back of the enclosure, d_c, is again 10.3m.

45 The height of the openings, h, is taken to be the average of the heights of the openings, corrected by the proportion of the overall opening width occupied by each height; ((0.6 + 1.3 + 0.6) x 1.4 + 0.8 x 2.5 + 0.6 x 0.9 + 1.3 x 1.4 + 0.8 x 0.3) ÷ (0.6 + 0.8 + 1.3 + 0.6 + 0.8 + 1.3 + 0.6) = 1.35m.

Figure 1 – Ventilation openings in upper floor of Flat 65. The ventilation openings shown in blue are those which remain when spandrel panels are fire resisting and a fire resisting door is installed between the kitchen and escape balcony. Dimensions are in metres

	Panels 2006/7 Refurbishment	Panels of Correct Fire Resistance
A_t (m^2)	141.1	141.1
A_w (m^2)	11.0	8.1
A_T (m^2)	130.1	133.0
w_c (m)	7.0	6.2
d_c (m)	10.3	10.3
h (m)	1.67	1.35
m_f (kg/s)	0.71	0.55

Table 1 – Values used for input parameters and calculated ventilation controlled mass burning rate on upper floor of Flat 65

4.1.3 Lower floor, bedroom 1 – panels as installed during 2006-2007 refurbishment

46 The area of ventilation openings, A_w is taken to be equal to the complete area of the external bedroom façade (2.5 x 3.5 = 8.75m^2).

47 The surface area of the enclosure, A_t, is assumed to comprise solely the floor, ceiling and four surrounding walls. The dimensions of the room are taken as 2.5m x 3.5m x 4m.

48 The width of the wall containing ventilation openings, w_c, is 3.5m.

49 The distance front-to-back of the enclosure, d_c, is 4m.

50 The height of the opening, h, is 2.5m.

4.1.4 Lower floor, bedroom 1 – panels of correct fire resistance

51 The area of ventilation openings A_w, had the correct fire resistance panels been used, is reduced to only the glass components of the façade. This corresponds to an area of 5.3 m^2. The dimensions used can be found in Figure 2.

52 The surface area of the enclosure, A_t, is again assumed to comprise solely the floor, ceiling and four surrounding walls. The dimensions of the room are taken as 3.5m x 4m x 2.5m high.

53 The width of the wall containing ventilation openings, w_c, is 3.5m.

54 The distance front-to-back of the enclosure, d_c, is again 4m.

55 The height of the openings, h, is taken to be 1.6m.

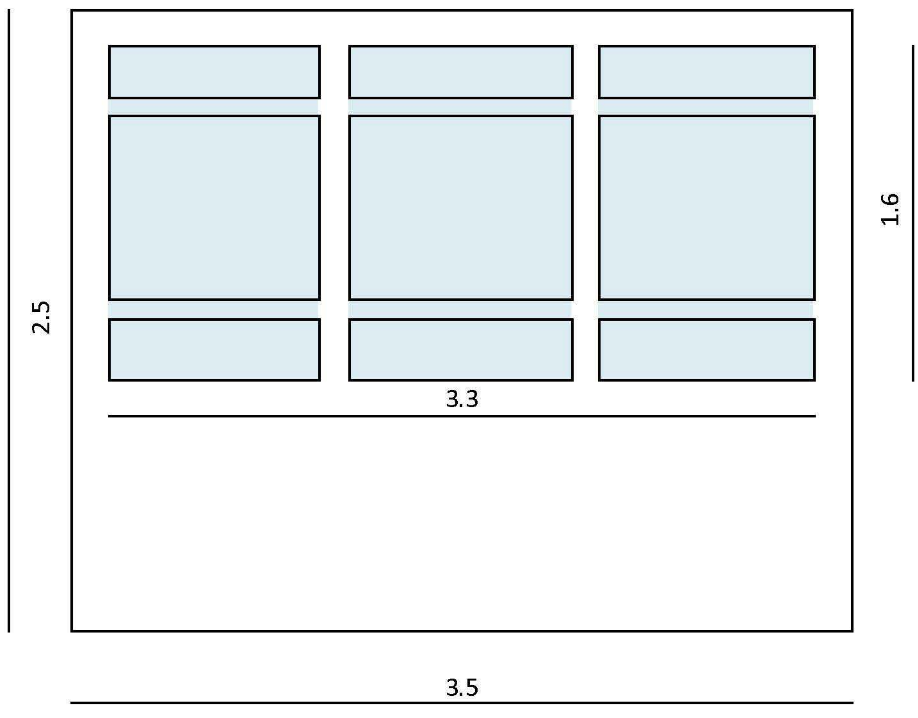

Figure 2 – Ventilation openings in bedroom 1 of Flat 65. Dimensions are in metres

	Panels 2006/7 Refurbishment	Panels of Correct Fire Resistance
A_t (m)	65.5	65.5
A_w (m^2)	8.8	5.3
A_T (m^2)	56.8	60.2
w_c (m)	3.5	3.5
d_c (m)	4.0	4.0
h (m)	2.5	1.6
m_f (kg/s)	0.52	0.38

Table 2 – Values used for input parameters and calculated ventilation controlled mass burning rate in bedroom 1 of Flat 65 without involvement of stairs

4.1.5 Lower floor, bedroom 1 and stairs involved

56 The majority of the dimensions assumed for the calculation of mass burning rate for the area comprising bedroom 1 and the stairs are the same as those used when considering bedroom 1 only. The exceptions are:

56.1 The surface area of the enclosure, A_t, which corresponds to a room with dimensions of 3.5m x 5m x 2.5m high.

56.2 The distance front-to-back, d_c, is 5m.

	Panels 2006/7 Refurbishment	Panels of Correct Fire Resistance
A_t (m)	77.5	77.5
A_w (m^2)	8.8	5.3
A_T (m^2)	68.8	72.2
w_c (m)	3.5	3.5
d_c (m)	5.0	5.0
h (m)	2.5	1.6
m_f (kg/s)	0.52	0.37

Table 3 – Values used for input parameters and calculated ventilation controlled mass burning rate in bedroom 1 with involvement of stairs

4.2 Vertical projection of flame from an opening

57 The flame envelope is defined in PD 7974 Part 3 [5] as the area of emerging gases at temperatures of 540°C and higher.

58 The vertical extension of a flame above the top of an opening can be defined in the absence and presence of a through draft.

59 In the absence of through draft:

$$Z = 12.8\left(\frac{R}{w}\right)^{2/3} - h_w$$

60 In the presence of a through draft:

$$Z = 23.9\left(\frac{1}{u}\right)^{0.43} - h_w$$

Where:

Z = flame height above opening (m)
R = burning rate (kg/s)
w = width of opening (m)
h_w= height of opening (m)
u = wind speed (m/s)

4.2.1 Upper floor – panels as installed during 2006-2007 refurbishment

61 Here, we are interested in the characteristics of the flames protruding from the openings in the kitchen wall.

62 The width of the opening, w, is taken to be 3.5m.

63 The height of the opening, h_w, is taken to be 1.67m (see paragraph 40).

64 The burning rate, R, is taken to be the rate of burning by mass, m_f = 0.71kg/s, as calculated in Table 1.

65 The wind speed at the top floor of Flat 65 is again 2m/s, taken from the Lakanal computer modelling and reconstruction report [1].

4.2.2 Upper floor – panels of correct fire resistance

66 The width of the opening, w, is taken to be 0.8 + 1.3 + 0.6 = 2.7m.

67 The height of the opening, h_w, is taken to be the average height of the openings. This is found to be (0.8 x 0.3 + 1.3 x 1.4 + 0.6 x 0.9) ÷ 2.7 = 1.0m (from Figure 1).

68 The burning rate, R, is taken to be the rate of burning by mass, m_f = 0.55kg/s, as calculated in Table 1.

69 The wind speed at the top floor of Flat 65 is again 2m/s, taken from the Lakanal computer modelling and reconstruction report [1].

	Panels 2006/7 Refurbishment	Panels of Correct Fire Resistance
Vertical flame extension in absence of through draft (m)	2.7	3.5
Vertical flame extension in presence of through draft (m)	16.1	16.8

Table 4 – Calculated flame extension above top of opening of upper floor of Flat 65

70 The large extension of flaming indicated by the presence of a through draft does not correspond to the simulations undertaken in Lakanal computer modelling and reconstruction report [1]. It is therefore more likely, in this situation, that the fire behaviour and flame extension is behaving as though it is in the absence of a through draft.

4.2.3 Lower floor, bedroom 1 – panels as installed during 2006-2007 refurbishment

71 There is no through draft present in the bottom floor, thus this case is not considered.

72 The width of the opening, w, is taken to be 3.5m.

73 The height of the opening, h_w, is taken to be 2.5m.

74 The burning rate, R, is taken to be the rate of burning by mass, m_f = 0.52kg/s, as calculated in Table 2.

4.2.4 Lower floor, bedroom 1 – panels of correct fire resistance

75 The width of the opening, w, is taken to be 3.3 m (taken from Figure 2).

76 The height of the opening, h_w, is taken to be 1.6 m (taken from Figure 2).

77 The burning rate, R, is taken to be the rate of burning by mass, m_f = 0.38kg/s, as calculated in Table 2.

	Panels 2006/7 Refurbishment	Panels of Correct Fire Resistance
Vertical flame extension in absence of through draft (m)	1.1	1.4

Table 5 – Calculated flame extension above top of opening of bedroom 1 in lower floor of Flat 65 without the involvement of the stairs

4.2.5 Lower floor, bedroom 1 and stairs involved

4.2.5.1 Panels 2006/7 Refurbishment

78 The width of the opening, w, is taken to be 3.5m.

79 The height of the opening, h_w, is taken to be 2.5m.

80 The burning rate, R, is taken to be the rate of burning by mass, m_f = 0.52kg/s, as calculated in Table 3.

4.2.5.2 Panels of Correct Fire Resistance

81 The width of the opening, w, is taken to be 3.3m.

82 The height of the opening, h_w, is taken to be 1.6m.

83 The burning rate, R, is taken to be the rate of burning by mass, m_f = 0.37kg/s, as calculated in Table 3.

	Panels 2006/7 Refurbishment	Panels of Correct Fire Resistance
Vertical flame extension in absence of through draft (m)	1.1	1.4

Table 6 – Calculated flame extension above top of opening of bedroom 1 in lower floor of Flat 65 with the involvement of the stairs

4.3 Horizontal projection of flame from an opening

84 The horizontal projection of the flame away from the opening is defined in PD 7974 Part 3 [5] as:

$$x = \frac{h_w}{3}$$

On the condition that $h_w < 1.25w$ (which is the case for all openings in Lakanal)

Where:

h_w=height of opening (m)
w = width of opening (m)

4.3.1 Upper floor – panels as installed during 2006-2007 refurbishment

85 The width of the opening, w, is taken to be 3.5m.

86 The height of the opening, h_w, is taken to be 1.67m (see paragraph 40).

4.3.2 Upper floor – panels of correct fire resistance

87 The width of the opening, w, is taken to be 2.7m.

88 The height of the opening, h_w, is taken to be the average height of the openings. This is found to be 1.0m (see paragraph 67).

	Panels 2006/7 Refurbishment	Panels of Correct Fire Resistance
Horizontal flame projection (m)	0.6	0.3

Table 7 – Calculated horizontal flame extension out from top of opening of upper floor of Flat 65

4.3.3 Lower floor, bedroom 1 – panels as installed during 2006-2007 refurbishment

89 The width of the opening, w, is taken to be 3.5m.

90 The height of the opening, h_w, is taken to be 2.5m.

4.3.4 Lower floor, bedroom 1 – panels of correct fire resistance

91 The width of the opening, w, is taken to be 3.3m.

92 The height of the opening, h_w, is taken to be 1.6m.

	Panels 2006/7 Refurbishment	Panels of Correct Fire Resistance
Horizontal flame projection (m)	0.8	0.5

Table 8 – Calculated horizontal flame extension out from top of opening of bedroom 1 in lower floor of Flat 65

4.3.5 Lower floor, bedroom 1 and stairs involved

93 As the horizontal projection of the flame is only dependent on the size of the opening, for a wide opening, the projection of the flame will be equal to that shown in Table 8.

4.4 Summary of results

4.4.1 2006/2007 Refurbishment

	Upper Floor	Lower Floor	
		Bedroom 1 only	Bedroom 1 and stairs
Mass Rate of Burning, m_f (kg/s)	0.71	0.52	0.52
Presence of through draft vertical extension of flames, Z (m)	16.1	Not applicable	Not applicable
Absence of through draft vertical extension of flames, Z (m)	2.7	1.1	1.1
Horizontal projection of flames, x (m)	0.6	0.8	0.8

Table 9 – Collated values for burning rate and flame extension from Flat 65 given the panels and doors that were installed during the 2006-2007 refurbishment

4.4.2 Correct fire resistance panel

	Upper Floor	Lower Floor	
		Bedroom 1 only	Bedroom 1 and stairs
Mass Rate of Burning, m_f (kg/s)	0.55	0.38	0.37
Presence of through draft vertical extension of flames, Z (m)	16.8	Not applicable	Not applicable
Absence of through draft vertical extension of flames, Z (m)	3.5	1.4	1.4
Horizontal projection of flames, x (m)	0.3	0.5	0.5

Table 10 – Collated values for burning rate and flame extension from Flat 65 given panels and doors of the correct fire resistance

94 The results indicate that despite the reduction in burning rate, there is no reduction in flame length as a result of installing panels of the correct fire resistance. The reduced ventilation causes a lengthening of the flames which is actually more significant than the reduction that might be expected as a result of the reduced burning rate. This leads to an overall lengthening of flames when panels of the correct fire resistance are installed.

95 In both situations, the flame lengths are sufficient to cause direct flame impingement on the panels of Flat 79, so the determining factor regarding whether the fire spreads from Flat 65 to Flat 79 becomes the susceptibility of the Flat 79 panels to ignite or burn through as a result of the direct flame impingement.

96 During the reconstruction and modelling, it was demonstrated that under direct flame impingement the panels in the window sets of Flat 79 that were installed during the 2006-2007 refurbishment could have burnt through and allowed the fire to enter the flat within five minutes. Following the fire at Lakanal in 1997, the window frames and panels were still in situ despite severe damage having been sustained by the flat. Whilst information regarding the 1997 incident is scant, damage on photographs in my opinion indicate that it is highly likely that these panels were able to survive a fully flashed over fire for some time; possibly 30 minutes or more.

97 Note that a reduced burning rate, as might have been caused by the restriction of ventilation associated with the window panels not burning and falling away, would lead to the fire burning for an extended duration.

5 Q2 – Effect of removal of partition wall in Flat 79

98 The partition wall separating bedroom 1 of Flat 79 from the internal staircase had been removed by the time of the fire on the 3rd July 2009.

99 The removal of the wall altered the way in which the fire developed overall inside of Flat 79. The removal of the wall may have allowed temperatures throughout the flat to increase more gradually than would otherwise have been the case.

100 In the incident as it occurred, the fire developed in bedroom 1 of Flat 79. As the fire developed there was a gradual increase in temperatures throughout the flat. A gradual increase in temperatures, as opposed to a sudden increase in temperatures, would allow time for temperatures to settle across the cross section of the windows.

100.1 During a fire in a room, the temperature inside of the room will necessarily become far greater than the temperatures on the outside of the room. In this instance, the materials separating the room from the outside (i.e. walls, windows and doors) will be hotter on their surfaces facing the inside of the room than on their surfaces facing the space outside of the room. Through the material between the surfaces, there will be a temperature gradient from the hot interior surface to the cold exterior surface. Any change in the internal room temperature will naturally have an immediate impact on the temperature of the internal surface of the wall, but will also affect the temperature gradient and therefore the temperatures throughout the material.

100.2 Glass is susceptible to break when it undergoes sudden changes in temperature. This is due to a combination of the non-uniform expansion/contraction of glass under heating/cooling, and the relative brittleness of glass. This can be observed when suddenly submerging a cold glass in boiling water. (Modern glassware used for cooking is often made of Pyrex™ in order to combat this problem.)

101 A gradual rise in temperatures in Flat 79 would have allowed a more gradual and more uniform rise in temperatures through the glass of the window. This is likely to have been responsible for the glass in the upper floor of Flat 79 surviving the fire until it was broken by the actions of London Fire Brigade after the fire had been largely dealt with.

102 As such, the removal of the partition wall may have contributed to the windows on the upper floor of Flat 79 not breaking. This may then also have promoted the venting of the fire in Flat 79 along the length of the 11th floor corridor rather than into the upper floor of Flat 79, then out of the windows and possibly up to the 13th floor.

103 If the wall had been in situ, the fire would have grown within bedroom 1 of Flat 79 until the wall burnt through. At the point of the wall burning through there would have been a sudden temperature increase throughout the remainder of the flat, in particular on the upper floor. Such a sudden temperature rise would, in my opinion, be likely to have caused breaking of the windows of the upper floor of Flat 79 due to the thermal shock to the windows. This, in my opinion, would probably have led to the fire venting through the upper floor of Flat 79 and out of the upper floor windows, possibly then also involving Flat 93 on the 13th

floor directly above. However, prior to the partition wall burning through, it would have improved the conditions throughout the remainder of the flat, since it would have contained the fire for a short period of time.

104 Both the removal of the partition wall and the modifications to the staircase (i.e. the removal of the risers) affected the level of fire separation within Flat 79 and the relative level of safety afforded to the means of escape (i.e. the internal stairs, originally separated by the partition wall) from the flat.

6 Q3 – Contractual obligations of Apollo regarding remedial works

105 Apollo was contractually obliged to notify the Construction Project Manager (CPM) of any defects in existing construction.

106 Apollo was then contractually obliged to obtain instructions (no specification as to the form of these instructions is given) from the CPM before proceeding with any work which might cover up the defects, or any work which might be rendered abortive by the remedial works required to rectify the defects in the existing construction.

107 In my opinion, Apollo was therefore obliged to make such a notification and await instructions, possibly where this might have delayed work, either as a result of time required to carry out remedial work or as a result of waiting for a decision from the CPM. However this would then have invoked their contractual obligation to notify the CPM of any reasons or potential reasons for delay to the progress of the work. Apollo was not obliged to commence any work outside of the scope of the original contract, without obtaining instructions from the CPM to do so, and presumably a concurrent commitment from Southwark Council to pay for the cost of these works.

108 I have not found any text within the refurbishment contract to indicate that Apollo was placed under contractual obligation to put right defects in the existing construction.

7 Q4 – Responsibility for condition of features

109 In all cases below, as requested, I have left aside any questions of inspections and responsibility for risk assessment.

7.1 Front doors

110 At least four different types of front door are known to have been installed throughout the building at the time of the fire. Some front doors are mentioned as having required replacing during the refurbishment works. The contract for the refurbishment works required, among other things, that all works complied with the relevant legislation, including Building Regulations. The specification of works included with the contract for the refurbishment went further and specifically detailed a set of performance criteria for fire resisting doors to be installed during the refurbishment works.

111 I have not seen any record of an approach other than the use of the Approved Documents regarding achieving compliance with the Building Regulations. As such, according to Section 7 of the Building Act 1984, the recommendations contained within the Approved Documents become the standard means of measuring tendency towards compliance or non-compliance with the requirements of the Building Regulations.

112 Responsibility for the as-built condition of front doors to flats that were replaced during the refurbishment appears, in my opinion, to rest with Apollo.

113 However, I have not seen any record of which front doors were replaced during the refurbishment, or indeed at any previous time, so it is not possible to assess who might have responsibility for each of the individual front doors within Lakanal. It is likely, in my opinion, that various front doors have been changed at various times since Lakanal was originally constructed. Some of these changes may have been programmed into works such as the 2006-2007 refurbishment, whilst others may have been changed as part of remedial maintenance work carried out by Southwark Council. As such, it is likely that a number of individuals or organisations have responsibility for the as-built condition of various individual or sets of doors throughout Lakanal, but I have not seen any information capable of confirming who might hold responsibility in relation to each door.

7.2 Escape doors

114 I have not seen any information to suggest that any of the escape doors in Lakanal have been replaced since it was constructed. Leaving aside any questions of inspections and responsibility for risk assessment, there is no requirement under Building Regulations (or any regulations that I am familiar with, other than the Regulatory Reform (Fire Safety) Order 2005), for these doors to have been upgraded. Leaving aside any questions of inspections and responsibility for risk assessment, their condition is deemed to be acceptable by virtue of the original construction of Lakanal having been deemed to be acceptable by then Metropolitan Borough of Camberwell.

115 If any of the escape doors were changed since the construction of Lakanal, then responsibility for their as-built condition would be attributed similarly to the situation with the front doors, although the same caveats regarding records to identify who had responsibility for each door also apply.

7.3 Balcony doors

116 There are two aspects to the responsibility for the condition of the balcony doors; one of compliance with the Building Regulations on the part of Apollo, the other of carrying out the duty to enforce the Building Regulations on the part of Southwark Council. I will deal with each separately as I am of the opinion that there is responsibility on the part of both Apollo and Southwark Council with respect to the as-built condition of the balcony doors.

7.3.1 Apollo

117 Apollo were required by the terms of the refurbishment contract to ensure that, among other things, all works complied with the relevant legislation, including Building Regulations. Within the specifications for the 2006-2007 refurbishment there was reference made to replacing fire doors with equivalent fire doors (this was the case for the replacement of front doors to flats). However the specification that was specifically concerned with the doors separating the flats from the escape balconies (specifically the kitchens and escape balconies) did not appear to specify what type of door should be installed here, as detailed in the expert report [3]. In this situation, under the terms of the 2006-2007 refurbishment contract, it would normally have been the responsibility of Apollo to produce finished designs for a replacement fire resisting door.

118 Any material alteration to Lakanal during the 2006-2007 refurbishment should have invoked the Building Regulations. I have not seen any record of an approach other than the use of the Approved Documents regarding achieving compliance with the Building Regulations. As such, according to Section 7 of the Building Act 1984, the recommendations contained within the Approved Documents become the standard means of measuring compliance with the requirements of the Building Regulations. The definition of material alteration within the Building Regulations would therefore have included any decision to replace the fire resisting doors, separating the kitchens from the escape balconies, with a non-fire resisting door.

119 Given that the Approved Documents are to be used to measure compliance, in my opinion, the replacement of the fire resisting balcony doors (separating the kitchens from the balconies) with non-fire-resisting doors did not comply with the Building Regulations.

7.3.2 Southwark Council

120 Southwark Council have a duty under Section 91 of the Building Act 1984 to carry the Act into execution in their areas. This includes enforcement of the Building Regulations made under the Act.

121 Southwark Council prepared a specification for the 2006-2007 refurbishment that made reference to replacing fire doors with equivalent fire doors (this was the case for the replacement of front doors to flats). However the specification that was specifically concerned with the doors separating the flats from the escape balconies (specifically the kitchens and escape balconies) did not appear to specify what type of door should be installed here, as detailed in the expert report [3]. In this situation, under the terms of the 2006-2007 refurbishment contract, it would normally have been the responsibility of Apollo to produce finished designs for a replacement fire resisting door.

122 During a meeting on the 3rd May 2006 involving Southwark Council, witness statements indicate that it was realised that it would not be possible to install an aluminium fire door to match the remainder of the window sets. It appears from witness statements as though the decision was made at this meeting to abandon a fire door in favour of a glazed and composite panel door. Meeting minutes from the subsequent progress meeting held on the 16th May 2006 state that SBDS were going to do *'everything they could to assist Apollo in speeding up the process'*. Annabel SYDNEY states in her witness statement that she recalls Southwark

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Council's Building Control team being consulted regarding this change, but she does not mention any involvement from London Fire Brigade. This raises the following issues:

122.1 Changing a fire door for a non-fire-resisting door constitutes a material alteration and should have led to formal Building Control Approval being sought.

122.2 Given that this was a change concerning the fire precautions in Lakanal, London Fire Brigade should have been consulted regarding the change.

122.3 Given that there does not appear to have been an approach other than the use of the Approved Documents put forward to achieve compliance with the Building Regulations, the Approved Documents become the measure of compliance. Against this measure, in my opinion, the replacement of the fire resisting balcony doors (separating the kitchens from the balconies) with non-fire-resisting doors did not comply with the Building Regulations.

122.4 Southwark Building Design Services appear to have used their contacts with Southwark Council to informally consult with Southwark Building Control. This informal consultation has then been reported to Apollo as some form of approval being issued by Southwark Building Control. In my opinion, such an assertion that approval had effectively been granted by local authority building control would have led Apollo to consider that it may not need to obtain Building Control approval in its own right. Whilst this may not fully detract from the obligations in the contract for the 2006-2007 refurbishment, in my opinion, it constitutes an active attempt on the part of Southwark Council to short-circuit the application and enforcement of the Building Regulations.

7.4 Panels above front doors to flats

123 Leaving aside all questions of inspections and responsibility for risk assessment at any time, then the company that would have responsibility for the as-built condition of the panels above the front doors to the flats would be Drake and Skull; the company that originally installed the suspended at the position where it was installed at the time of the fire (albeit with panels different to those in place at the time of the fire). In installing the suspended ceiling, Drake and Skull created a concealed void and they were therefore responsible for ensuring that the flats were suitably fire separated from the void.

124 This work appears to have been carried out under the London Building Acts (i.e. prior to the enactment of the Building (Inner London) Regulations 1985) so the requirements for the work being carried out would ultimately have been at the discretion of Southwark Council, although I would have expected it to make use of the guidance available at the time. Assuming that Southwark Council prescribed a suitable standard of work to be carried out in the installation of the suspended ceiling (in particular, that there was a suitable degree of fire separation between the flats and the void above the suspended ceiling), any shortfall in the standard of work completed by Drake and Skull would be the responsibility of Drake and Skull.

125 However, if Southwark Council's specification included the panels above the front doors being in the state that they were in at the time of the fire, and Southwark Council subsequently approved the works, then responsibility for the condition of the panels upon completion of the installation of the suspended ceiling could to some extent rest with Southwark Council.

126 An approval issued around the time of this work being carried out (the approval in connection with the installation of the security doors across the corridors) appears to have specified all of the relevant fire protection measures that were typical at the time (i.e. non-combustible surfaces, appropriate free ventilation area). As such, in my opinion, it is reasonable to assume that at this time Southwark Council were making

their best endeavours to ensure that suitable levels of fire safety were maintained within Lakanal. Therefore, in the absence of any information to indicate otherwise, it is my opinion that it is most likely that responsibility for the condition of the panels above the front doors to the flats does in fact rest with Drake and Skull.

7.5 Boxing in under stairs

127 Leaving aside all questions of inspections and responsibility for risk assessment at any time, responsibility for the condition of the boxing in under the stairs is apportioned in the same way as the responsibility for the panels above the front doors to the flats (see above).

128 The attempts made at installing some form of boxing in around where the timber flat staircases cut into the corridor indicates that there was at least some recognition of the issues that needed to be dealt with regards to this feature (i.e. ensuring that there was a suitable degree of fire separation between the flats and the void above the suspended ceiling). I have not seen any evidence to indicate whether this recognition was made by Southwark Council or by Drake and Skull although, as above, I note the approval issued around this time in relation to the installation of the security doors.

129 Therefore, in my opinion, it is most likely that responsibility for the condition of the boxing in under the stairs rests with Drake and Skull.

7.6 Fire resistance of the corridor walls

130 Leaving aside all questions of inspections and responsibility for risk assessment at any time, responsibility for the fire resistance of the corridor walls (in particular fire stopping where pipes passed through the corridor walls) is apportioned in the same way as the responsibility for the panels above the front doors to the flats (see above).

131 In addition, Drake and Skull would have been responsible for penetrating the corridor walls to install the new heating system to the block, so would have been responsible for reinstating the fire resistance of the wall following the completion of these works using correct fire stopping.

132 Therefore, in my opinion, it is most likely that responsibility for the fire resistance of the corridor walls rests with Drake and Skull.

7.7 Suspended ceiling in corridor

133 Leaving aside all questions of inspections and responsibility for risk assessment at any time, responsibility for the condition of the suspended ceiling in the corridor could be divided between three parties.

7.7.1 Drake and Skull

134 The original installation of the suspended ceiling appears to have been carried out by Drake and Skull in conjunction with the installation of the central heating system. This appears to have involved the construction of a timber frame supporting structure for the suspended ceiling, the creation of an extended concealed void, and fixing some sort of panelling system to form the surface of the ceiling itself.

7.7.2 Donald James

135 Donald James Chartered Surveyors were commissioned by Southwark Council to carry out improvement works to the communal corridor areas of both Lakanal and Marie Curie.

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136 Leaving aside all questions of inspections and responsibility for risk assessment at any time, Donald James would only be responsible for the work detailed in its letter to Southwark District Surveyors, dated 2nd December 1986. That work comprised:

136.1 Replacement of existing chipboard panels on the suspended ceiling with fire resistant boarding.

136.2 Replacement of existing plywood and chipboard access panels to service ducts with ½ hour fire boarding and intumescent fire seals.

136.3 Fire stopping within vertical service ducts.

136.4 Replacement of defective with working ½ hour fire doors between communal corridors and the staircase area.

136.5 Provision of intumescent grilles within the ventilation ducts connecting the ventilated lobby to internal bathroom area.

137 The extent to which Donald James took on responsibility for the condition of the suspended ceiling (and the other features associated with the suspended ceiling) depends upon the wording of the contract under which their work was carried out. This may have specified whether, and to what extent, Donald James were responsible for identifying defects in the existing construction and putting them right.

7.7.3 Southwark Council

138 Southwark Council appears to have recognised some of the shortcomings in the work completed by Drake and Skull. This led to further work being commissioned to replace the panels of the suspended ceiling with panels that offered some sort of fire performance. However, Southwark Council did not commission any work to improve the condition of the timber frame onto which the ceiling panels were fixed (nor did it deal with the issues of the panels above the front doors to the flats, the boxing in under the stairs, or the penetrations through the corridor walls).

139 The extent to which responsibility for the condition of the suspended ceiling can be attributed to individuals, companies or organisation will depend upon the contractual arrangements that were made between Southwark Council, Drake and Skull and Donald James at the various times that works were undertaken.

140 Even in leaving aside all questions of inspections and responsibility for risk assessment at any time, the scope of works which Drake and Skull and Donald James were each instructed to undertake may have involved no design input from their part whatsoever (i.e. a full set of design drawings provided by Southwark Council which the contractor would be able to follow to the letter) or a simple instruction from Southwark Council to deal with the installation of the central heating system and/or suspended ceiling whilst ensuring that all relevant legal requirements were complied with. These are two extreme ends of a wide range of possibilities of the arrangements that might have been put into place. In practice it is unlikely that either of the examples I have provided would have been adopted and that some arrangement falling in between these two would have occurred. The extent to which design responsibility was delegated to the contractor was delegated in each will determine what is the extent of responsibility.

7.8 Cross ventilation scheme

141 The cross ventilation scheme was an original design feature of Lakanal. It was an accepted means of smoke control at the time of Lakanal's construction (mentioned in guidance documents of the time) and was approved by the then Metropolitan Borough of Camberwell under the London Building Acts.

142 On the 21st December 1984 an approval was issued by the Greater London Council Department of Architecture and Civic Design for the installation of security doors and screens with a door entry phone system. The approval had a number of conditions associated with it; one of which was that there was to be a permanently open ventilation area of not less than $0.5m^2$, plus an additional $1m^2$ of openable ventilation area. This approval indicates that some assessment has been made of the minimum free ventilation area that is required for the cross ventilation scheme to work effectively. At the time of the fire the free ventilation area was only $0.3m^2$ with no additional openable area.

143 I have not seen any information to confirm who took the decision to deviate from the approval. In issuing the approval with such a specific set of conditions, the Local Authority (Southwark Council and the Greater London Council) have demonstrated a level of diligence in ensuring that the changes to Lakanal at this time would not adversely affect the overall performance of the building in relation to fire. Therefore, leaving aside all questions of inspections and responsibility for risk assessment at any time, responsibility for the condition and effectiveness of the cross ventilation system rests with the person or persons that reduced the ventilation below that which was specified in the approval.

8 Conclusions

144 At each stage that construction work was carried out at Lakanal, those with design responsibility for the works being completed had a responsibility to ensure that they understood whether their works would affect the overall fire performance of the block and if so, how.

145 The wording of the Building Regulations is designed to ensure that only work that will not adversely affect the overall fire performance of a building can be carried out without the Building Regulations being invoked.

146 It is therefore the responsibility of designers to ensure that where any aspect of the work they are carrying out on a building will adversely affect the fire performance of any feature of that building, they fully understand how that change in performance will affect the whole building.

147 Note that I have not drawn into question the issue of any lack of involvement on the part of Southwark Council with regards to the approval of works. Whilst Local Authority Building Control have a duty to enforce the Building Regulations, it is in my experience widely accepted within the fire safety community that Local Authority Building Control does not enforce fire safety issues as sternly as it should do. However, this is associated with issues of resources that are provided to Local Authorities for them to carry out this function and it may be that it would be unreasonably onerous to expect Southwark Council to be operating at some level well in advance of other local authorities. However, I have raised concerns and apportioned responsibility where Building Control activity has been involved and this involvement appears to have led to a worsening of standards in relation to fire safety.

9 References

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