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# BRE Global Client Report

## Grenfell Tower Fire Investigation - On-Site Investigation Interim Report, work to 31st January 2018

**Prepared for:** Metropolitan Police Service

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## Executive Summary

This is an interim report, submitted at the request of the Metropolitan Police Service (MPS) to inform the Police-led investigation and other parties as to suggested lines of inquiry to pursue based upon work carried out to date.

This interim report is based on site investigation work at Grenfell Tower carried out between 14th June 2017 and 31st January 2018 by BRE Global.

Any new information or changes to current information and/or assumptions may necessitate review or modification of the findings and/or conclusions of this report.

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# 1 Introduction

1 This is an interim report, submitted at the request of the Metropolitan Police Service (MPS) to inform the Police-led investigation and other parties as to suggested lines of inquiry to pursue based upon work carried out to date.

2 This interim report is based on site investigation work at Grenfell Tower carried out between 14th June 2017 and 31st January 2018 by BRE Global.

3 Site investigation work is expected to continue into March 2018 and the findings detailed in this report may need to be updated in light of the findings of this further work.

4 On 14th June 2017, a fire broke out in Grenfell Tower, Grenfell Road, London, W11 1TG (the Tower). The fire spread extensively, resulting in 71 deaths, 74 confirmed hospitalisations due to injuries (admissions up until midday on 15th June 2017), and many more people being evacuated from their homes both in the Tower and the surrounding area. BRE Global Ltd (hereafter BRE) has been commissioned to provide support to the Metropolitan Police Service (MPS) in relation to the investigation of the fire.

5 MPS has given BRE the following overarching aims:

5.1 To establish the circumstances surrounding all or as many of the deaths resulting from the fire as possible.

5.2 To establish whether there have been any failings of duty of care owed to the victims of the fire (both fatalities and surviving residents).

5.3 To provide expert witness support in relation to any criminal prosecution, public inquiry or inquests arising from the above.

6 In order to address the above aims, it was agreed that BRE's programme of work is to address the following objectives:

6.1 How the fire spread from the item or items first ignited to involve the façade of Grenfell Tower.

6.2 How the external envelope of Grenfell Tower performed in relation to:

6.2.1 spread of fire and smoke and the deaths of the victims;

6.2.2 compliance with Building Regulations [1];

6.2.3 compliance with the Regulatory Reform (Fire Safety) Order 2005 [2]; and

6.2.4 any other fire safety related duty of care owed by duty holders to the victims of the fire.

6.3 How the general construction and fire precautions at Grenfell Tower performed in relation to:

6.3.1 spread of fire and smoke and the deaths of the victims;

6.3.2 compliance with Building Regulations;

6.3.3 compliance with the Regulatory Reform (Fire Safety) Order 2005; and

6.3.4 any other fire safety related duty of care owed by duty holders to the victims of the fire.

7 A programme of work has been developed by BRE and agreed with MPS. It is anticipated that the programme of work will need to evolve as findings from the programme of work are gained; however at present the programme of work includes the following tasks:

7.1 A detailed on-site examination gathering all relevant physical evidence regarding the building and its fire safety systems.

7.2 Standard fire tests and derived experiments to be carried out on relevant fire safety features such that their fire performance can be determined.

7.2.1 Small scale British Standard tests relevant to the regulatory compliance of components of the façade [3][4][5].

7.2.2 Small scale European standard tests relevant to the regulatory compliance of components of the façade [6][7][8][9][10].

7.2.3 Small scale British Standard tests for determination of fire properties of components from across the Tower [11].

7.2.4 Large scale British Standard tests and ad-hoc experiments on the façade system [12].

7.2.5 British Standard fire resistance tests on doors [13][14].

7.2.6 Experimental fridge freezer fires utilising the International Standard fire test room [15], to quantify the size of fire such a fridge freezer could produce in a compartment fire.

7.3 A reconstruction of the fire [16] in the flat of origin, in particular examining spread of the fire to the façade system. The reconstruction rig will be used for two tasks:

7.3.1 A reconstruction of the fire that occurred in the flat of fire origin, examining how the fire spread from items ignited to involve the façade of Grenfell Tower.

7.3.2 A repeat of the above, with the inclusion of a suitable sprinkler system, to examine how such a system might have impacted on fire development and spread.

7.4 A review of building documentation and evidence from the fire to determine design and actual (i.e. as built) construction of the block and level of performance afforded by the fire safety systems that were provided. This includes support to MPS to assist its officers with the process of reviewing all documentation disclosed by all relevant parties and parties under investigation.

7.5 A review of the locations where deceased were found with respect to the flats where these residents lived or were visiting to identify possible movement (if any) through the building immediately prior to death.

7.6 A review of witness statements, 999 call transcripts, and eyewitness photographs and videos to establish spread of fire and smoke and performance of building fire safety systems as witnessed (or recorded and/or obtained posthumously) by people in and around the Tower. This will include support to MPS to assist its officers with the process of taking witness statements and basic interpretation of photographic and video data of the fire.

7.7 Computer modelling of smoke movement and fire spread throughout common parts of the block to establish how the performance of the building and its fire safety systems may have impacted upon:

7.7.1 the ability and willingness of residents to use means of escape, and

7.7.2 the effectiveness of fire and rescue response by London Fire Brigade. (Note, however, BRE will not be commenting upon the effectiveness of fire and rescue response by London Fire Brigade, nor on the performance of any of the emergency services.)

7.8 A review of all of the above work packages (upon their completion) to identify whether there is any need for them to be revisited in light of evidence obtained from previous work packages. There will also be ongoing interaction with the Forensic Examination Review Group (FERG) setup by MPS to provide independent oversight of the entire forensic process in relation to Grenfell Tower.

7.9 Review of all the above points to identify fire spread and fire safety issues relevant to the circumstances of each fatality.

7.10 Review of all the above points in relation to fire safety related duties of care owed by all duty holders in respect of:

7.10.1 initial construction of the block;

7.10.2 refurbishments between construction and 2014;

7.10.3 refurbishment of the block in 2014-2016;

7.10.4 ongoing management of fire safety by the responsible person under the Regulatory Reform (Fire Safety) Order 2005; and

7.10.5 ongoing management of tenants in relation to the Housing Acts [17][18]and the Smoke and Carbon Monoxide Alarm Regulations [19].

7.11 Expert witness support to any criminal prosecutions, inquests and the Public Inquiry as needed.

7.12 General technical support to the public inquiry when requested via the Memorandum of Understanding signed between MPS and the Public Inquiry [20].

8 This report is primarily concerned with findings in relation to the on-site investigation (item 7.1 above).

9 This report is not, in its current format, prepared in accordance with the requirements of Part 19 of the Criminal Procedure Rules [21]. However, work has been carried out in anticipation of such a need arising. To that end, it is confirmed that the contents of this report have been prepared impartially, with honesty and due care. This report makes clear where opinions are being expressed and where any assumptions have had to be made. Opinions are expressed only where BRE staff are competent to render such an opinion. Staff that have carried out work for this report but are not authors of this report are listed at Appendix A. CVs of the authors and peer reviewer are provided at Appendix B.

10 This report is based upon information gathered by BRE staff and other members of the MPS led team involved in investigating the fire that occurred on 14th June 2017. Any new information or changes to current information and/or assumptions may necessitate review or modification of the findings of this report.

## 2 Description of On-Site Investigation

11 BRE has been conducting an on-site investigation at Grenfell Tower since 14th June 2017, and has maintained a permanent presence at the investigation at the Tower from that date until the time of writing of this report. BRE has been working as part of the Grenfell Tower forensic team, led by MPS. Other organisations in the forensic team have been:

11.1 Origin and cause:

11.1.1 London Fire Brigade

11.1.2 Key Forensic Services

11.1.3 Bureau Veritas UK Ltd

11.2 RINA Consulting Ltd – Electrical survey

11.3 CORGI Services Ltd – Gas survey

11.4 WSP – Building Management System

12 The site of Grenfell Tower became potentially extremely hazardous as a result of the fire. Extensive work has been undertaken by numerous organisations to manage the safety of the Tower following the fire to enable a number of activities, including the BRE on-site examination, to occur in as safe a manner as possible. In addition to the forensic team above, BRE wishes to thank the Forensic Team and MPS and the following organisations for their parts in these efforts:

12.1 The Health and Safety Executive

12.2 Harrow Building Control

12.3 Wates Construction

12.4 Deconstruct (UK) Ltd

12.5 Mattison Scaffolding Ltd

12.6 Derisk (UK) Ltd

12.7 Michael Barclay Partnership LLP

12.8 Environtec Ltd

12.9 Plowman Craven Ltd

12.10 Kenyon International Emergency Services Inc

12.11 UK National Disaster Victim Identification Unit

13 The aims and objectives for the BRE on-site investigation are as follows:

13.1 To collect as much physical evidence as possible in relation to

13.1.1 Patterns of fire damage, fire spread and smoke spread at Grenfell Tower (externally and internally)

13.1.2 The fire protection systems at Grenfell Tower

13.1.3 The general construction of Grenfell Tower relevant to fire safety

13.2 To compare the physical evidence of the construction and fire protection of Grenfell Tower with the recommendations of the edition of Approved Document B which was in effect at the time of the last building work to be carried out at Grenfell Tower [22] (see Chapter 4.3 for rationale and impact assessment of previous versions of AD B having been in place). Note that departure from the recommendations of Approved Document B does not necessarily mean a breach or breaches of the Building Regulations; however it will provide lines of enquiry for other tasks and the overall investigation.

14 The methodology for the on-site investigation has developed over the course of the investigation. The overarching principles for the investigation have been developed in line with the Code of Practice for Investigators of Fires and Explosions for the Criminal Justice Systems in the UK [23]. However, there are two priorities which have taken precedence over the forensic examination:

14.1 The health and safety of all personnel working in and around the Tower.

14.2 The recovery of remains of victims of the fire.

15 Given the foregoing, the BRE on-site investigation has progressed as follows:

15.1 A preliminary investigation was carried out from the afternoon of 14th June 2017 until the night of 20th June 2017. This phase of the investigation was urgent, driven by the risk that the Tower might collapse, which would have resulted in the loss of much of the evidence. Entry to the Tower was undertaken whilst the structure was being closely monitored for movement and with measures in place for rapid evacuation of the Tower. Investigators sought to capture an overview of the fire safety features of the Tower in case this became the sole source of evidence available to the investigation.

15.2 Once emergency propping to the Tower was completed and additional safety precautions were put into place, priority shifted to the safe recovery of remains of victims of the fire. This recovery would necessitate large numbers of search officers, anthropologists and archaeologists accessing all of the fire damaged flats to sift debris. However, the preliminary investigation had revealed a need for a detailed examination of the front doors or remains of front doors to all of the flats in the building. The doors on upper floors had been completely destroyed, with only door ironmongery left in the debris on the floor. BRE therefore undertook a fingertip search of all of the front door thresholds, to attempt to find what ironmongery remained and where it had landed on the floor. This would assist identification of what type of door was present at each flat, its condition and whether it was likely to have been in the open or closed position at the time that it burnt through. This phase lasted from 23rd June 2017 to 10th July 2017 and, once the examination of each flat was completed, released the Disaster Victim Identification (DVI) teams to commence their work to identify and recover all of the remains from the Tower.

15.3 From this point on, BRE's work phases overlapped each other but are described here in the order in which they were commenced in the Tower.

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15.4 Plans for full propping to the Tower and scaffolding of the Tower began to be formalised by organisations brought in by MPS to manage the Tower as a construction site (see list above). It was established at this stage that both propping and scaffolding would be most disruptive to flats, but much less so to the lobbies, lift and stair cores. Priority was therefore then given to the examination of flats. All flats were to be examined by BRE and the order in which flats were examined was dictated by the priority that needed to be given to propping in the various parts of the Tower, the objective being wherever possible to retrieve evidence prior to there being a risk of it being disturbed or destroyed by works needed. This work phase lasted from 13th July 2017 to 21st December 2017.

15.5 The scaffolding of the Tower required fixing into a stable structure due to its height. Initial investigations by the contractor team had determined that the core containing the lobbies, lifts and stairs was the preferred structure for the fixing of the scaffolding, as this had suffered the least damage and was a continuous structure down into the basement of the Tower. This approach would necessitate fixing all the way through the flats from the outside of the building into the core. In addition to the need to examine flats detailed above, there was also a need to complete the examination of the smoke control system, as ventilation shafts are fixed to the outside of the shear walls forming the core, and would need to be destroyed to enable fixing. The approach was later modified so that fixing would be into the structural walls between flats, as these are understood by BRE to have been subsequently examined and found to be of sufficient strength to provide this function. Examination of the smoke control system was carried out by the BRE Heating, Ventilation and Air Conditioning (HVAC) team, under instruction from the BRE Fire Investigation team. This work phase lasted from 26th July 2017 to 10th August 2017.

15.6 Construction of scaffolding was needed for a number of reasons, including the need to safely access the surviving façade for its examination and removal as evidence, the need to cover the Tower as understood to be requested by the majority of community groups, and the eventual need for a safe means to demolish the Tower. The construction of the façade and the need to fix the scaffolding into the structure of the Tower meant that it would not be possible to build scaffolding without damaging or destroying evidence. A scaffold construction plan was therefore developed by the construction team in discussion with BRE and MPS regarding the forensic needs of the scaffolding. It was agreed that scaffolding would be built up to the floors for which façade removal was needed, the scaffolding handed over to MPS/BRE so that removal could be carried out, and then scaffolding would be built up to the next floor for handover and removal. Construction of the scaffolding began on 4th September 2017. BRE's work on the scaffold was due to be completed on 31st January 2018. However, lumps of concrete began falling off of the Tower on Monday 18th December 2017, resulting in works being halted for the safety of personnel. At the time of writing, an alternative scaffold plan is being designed and constructed by the construction team to catch any further debris that falls from the fire damaged parts of the external face above where works need to be completed. Completion of the removal of evidence from the façade is therefore currently anticipated to be in March 2018.

15.7 The final phase of the on-site investigation is to examine all aspects of the Tower which have not been affected by the aforementioned issues. These include the lobbies, stairwell, lift shafts, service risers, bin chutes and the dry riser. This final phase commenced in December 2017 and is due to be completed by March 2018.

# 3 Trends

16 The trend data set out in this chapter summarises the key findings in relation to volume fire safety features of the tower, in particular:

16.1 Flat front doors

16.2 Damage to flats

16.3 Presence of fire resisting entrance halls in flats

16.4 Smoke and heat detection in flats

16.5 Fire stopping

16.6 Dampers in smoke control system

17 All data in this chapter is liable to change as quality control of evidence and analysis across all flats is ongoing at the time of writing. In particular, ongoing analysis will seek to reduce the number of unknowns in the tables.

## 3.1 Flat front doors

18 Table 1 provides current data relating to flat front doors (further work is ongoing to attempt to reduce the number of unknowns currently in this table). As shown by Figure 1, 45 percent of flat front doors from Floor 4 to Floor 23 did not have a working door closer installed ("Door closer present but not working" plus "Door closer absent), 38 percent were unknown ("Door closer found but unconfirmed if working" plus "unknown if door closer installed") with 17 percent of flat front doors with working door closers.

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## Table 1 – Summary flat front door findings

| Floor | Flat | Door in-situ? | Door leaf type | Door frame type | Glazing in door? | Door closer present? | Door closer type | Working door closer? | Door open/closed |
|---|---|---|---|---|---|---|---|---|---|
| 4 | Flat 11 | Yes | Composite | Composite | Yes | No | N/a | N/a | Closed |
| | Flat 12 | Yes | Composite | Composite | No | No | N/a | N/a | Closed |
| | Flat 13 | Yes | Composite | Composite | No | Unknown | N/a | Unknown | Closed |
| | Flat 14 | Yes | Composite | Composite | No | Yes | Overhead | Yes | Closed |
| | Flat 15 | Yes | Composite | Composite | No | No | N/a | N/a | Closed |
| | Flat 16 | Yes | Composite | Composite | Yes | No | N/a | N/a | N/A |
| 5 | Flat 21 | Yes | Composite | Composite | No | Yes | Concealed | Yes | Closed |
| | Flat 22 | Yes | Composite | Composite | No | Yes | Concealed | No | Closed |
| | Flat 23 | Yes | Composite | Composite | Yes | Yes | Concealed | Yes | Closed |
| | Flat 24 | Yes | Composite | Composite | No | Yes | Concealed | No | Closed |
| | Flat 25 | Yes | Composite | Composite | No | No | N/a | N/a | Closed |
| | Flat 26 | Yes | Composite | Composite | Unknown | Yes | Concealed | No | Open |
| 6 | Flat 31 | Yes | Composite | Composite | No | Yes | Concealed | No | Closed |
| | Flat 32 | Yes | Composite | Composite | No | No | N/a | N/a | Closed |
| | Flat 33 | Yes | Composite | Composite | Yes | Yes | Overhead | Yes | Closed |
| | Flat 34 | Yes | Composite | Composite | No | Yes | Overhead | Yes | Closed |
| | Flat 35 | Yes | Composite | Composite | No | Yes | Concealed | No | Closed |
| | Flat 36 | Yes | Composite | Composite | No | Yes | Concealed | Unknown | Closed |
| 7 | Flat 41 | Yes | Composite | Composite | No | No | N/a | N/a | Open |
| | Flat 42 | Yes | Composite | Composite | Yes | Yes | Concealed | No | Closed |
| | Flat 43 | Yes | Composite | Composite | No | Yes | Concealed | No | Closed |
| | Flat 44 | No | Composite | Composite | Yes | Yes | Concealed | No | Open |
| | Flat 45 | No | Composite | Composite | Yes | No | N/a | N/a | Open |
| | Flat 46 | Yes | Composite | Composite | Yes | Yes | Concealed | Unknown | Unknown |
| 8 | Flat 51 | Yes | Composite | Composite | Yes | Yes | Concealed | Yes | Closed |
| | Flat 52 | Yes | Composite | Composite | Yes | Yes | Concealed | No | Closed |
| | Flat 53 | Yes | Composite | Composite | No | No | N/a | N/a | Closed |
| | Flat 54 | Yes | Composite | Composite | Unknown | No | N/a | N/a | Closed |
| | Flat 55 | No | Composite | Composite | No | Unknown | Unknown | Unknown | Closed |
| | Flat 56 | Yes | Timber | Timber | No | Yes | Concealed | Unknown | Closed |
| 9 | Flat 61 | No | Timber | Timber | No | Yes | Concealed | Yes | Closed |
| | Flat 62 | Yes | Composite | Composite | No | Yes | Concealed | Yes | Closed |
| | Flat 63 | Yes | Composite | Composite | No | Yes | Concealed | Yes | Closed |
| | Flat 64 | No | Composite | Composite | No | Yes | Concealed | Unknown | Unknown |
| | Flat 65 | No | Composite | Composite | No | Yes | Concealed | Unknown | Closed |
| | Flat 66 | No | Composite | Composite | No | No | N/a | N/a | Open |

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| Floor | Flat | Door in-situ? | Door leaf type | Door frame type | Glazing in door? | Door closer present? | Door closer type | Working door closer? | Door open/closed |
|---|---|---|---|---|---|---|---|---|---|
| 10 | Flat 71 | Yes | Composite | Composite | Yes | No | N/a | N/a | Unknown |
| | Flat 72 | Yes | Composite | Composite | Yes | No | N/a | N/a | Closed |
| | Flat 73 | No | Composite | Composite | Unknown | No | N/a | N/a | Unknown |
| | Flat 74 | No | Composite | Composite | Unknown | Yes | Concealed | No | Closed |
| | Flat 75 | No | Composite | Composite | Unknown | No | N/a | N/a | Unknown |
| | Flat 76 | No | Composite | Composite | Unknown | No | N/a | N/a | Unknown |
| 11 | Flat 81 | No | Composite | Composite | Unknown | Yes | Concealed | Unknown | Closed |
| | Flat 82 | Yes | Composite | Composite | No | No | N/a | N/a | Closed |
| | Flat 83 | Yes | Composite | Composite | Yes | Yes | Concealed | Unknown | Closed |
| | Flat 84 | No | Composite | Composite | Unknown | Yes | Concealed | No | Unknown |
| | Flat 85 | No | Composite | Composite | Unknown | Yes | Concealed | Unknown | Closed |
| | Flat 86 | No | Timber | Timber | Unknown | Yes | Concealed | Unknown | Unknown |
| 12 | Flat 91 | No | Timber | Timber | Unknown | Yes | Concealed | Yes | Closed |
| | Flat 92 | No | Timber | Timber | Unknown | Yes | Concealed | Unknown | Unknown |
| | Flat 93 | Yes | Composite | Composite | No | Yes | Concealed | No | Closed |
| | Flat 94 | No | Composite | Composite | Yes | No | N/a | N/a | Unknown |
| | Flat 95 | No | Composite | Composite | No | No | N/a | N/a | Unknown |
| | Flat 96 | No | Composite | Composite | Unknown | Yes | Concealed | No | Closed |
| 13 | Flat 101 | No | Composite | Composite | No | Yes | Concealed | No | Closed |
| | Flat 102 | No | Composite | Composite | No | Yes | Concealed | No | Unknown |
| | Flat 103 | No | Composite | Composite | Yes | No | N/a | N/a | Closed |
| | Flat 104 | No | Composite | Composite | Yes | Yes | Concealed | Unknown | Closed |
| | Flat 105 | No | Timber | Timber | No | Yes | Concealed | Unknown | Unknown |
| | Flat 106 | No | Composite | Composite | No | No | N/a | N/a | Closed |
| 14 | Flat 111 | No | Composite | Composite | Unknown | Yes | Concealed | No | Closed |
| | Flat 112 | No | Timber | Timber | No | Yes | Overhead | No | Unknown |
| | Flat 113 | No | Composite | Composite | Unknown | Unknown | Unknown | Unknown | Unknown |
| | Flat 114 | No | Composite | Composite | Unknown | Yes | Concealed | Yes | Closed |
| | Flat 115 | No | Composite | Composite | Unknown | Unknown | Unknown | Unknown | Closed |
| | Flat 116 | No | Composite | Composite | Unknown | Unknown | Unknown | Unknown | Unknown |
| 15 | Flat 121 | No | Composite | Composite | Yes | Yes | Concealed | Yes | Closed |
| | Flat 122 | No | Composite | Composite | Yes | No | N/a | N/a | Closed |
| | Flat 123 | No | Composite | Composite | Yes | Yes | Concealed | No | Closed |
| | Flat 124 | No | Composite | Composite | No | Yes | Concealed | Yes | Closed |
| | Flat 125 | No | Composite | Composite | No | Yes | Concealed | Yes | Closed |
| | Flat 126 | No | Composite | Timber | No | No | N/a | N/a | Closed |

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| Floor | Flat | Door in-situ? | Door leaf type | Door frame type | Glazing in door? | Door closer present? | Door closer type | Working door closer? | Door open/closed |
|---|---|---|---|---|---|---|---|---|---|
| 16 | Flat 131 | No | Composite | Composite | No | Unknown | Unknown | Unknown | Closed |
| | Flat 132 | No | Composite | Composite | No | Unknown | Unknown | Unknown | Closed |
| | Flat 133 | No | Composite | Composite | No | Unknown | Unknown | Unknown | Unknown |
| | Flat 134 | No | Composite | Composite | No | Unknown | Unknown | Unknown | Closed |
| | Flat 135 | No | Composite | Composite | Yes | Unknown | Unknown | Unknown | Closed |
| | Flat 136 | No | Composite | Composite | Unknown | Unknown | Unknown | Unknown | Unknown |
| 17 | Flat 141 | No | Composite | Composite | Yes | Yes | Concealed | Unknown | Closed |
| | Flat 142 | No | Timber | Timber | No | Yes | Concealed | Unknown | Closed |
| | Flat 143 | No | Composite | Composite | Yes | Yes | Concealed | Unknown | Closed |
| | Flat 144 | Yes | Composite | Composite | No | No | N/a | N/a | Closed |
| | Flat 145 | No | Composite | Composite | No | Yes | Concealed | Yes | Closed |
| | Flat 146 | No | Composite | Composite | No | No | N/a | N/a | Closed |
| 18 | Flat 151 | No | Composite | Composite | Yes | Yes | Overhead | Yes | Closed |
| | Flat 152 | No | Composite | Composite | Unknown | Unknown | Unknown | Unknown | Unknown |
| | Flat 153 | No | Composite | Composite | No | Yes | Concealed | No | Unknown |
| | Flat 154 | No | Timber | Timber | No | Yes | Concealed | Yes | Closed |
| | Flat 155 | No | Composite | Composite | No | Yes | Concealed | Unknown | Unknown |
| | Flat 156 | No | Timber | Timber | No | Yes | Concealed | Yes | Closed |
| 19 | Flat 161 | No | Composite | Composite | Unknown | Unknown | Unknown | Unknown | Closed |
| | Flat 162 | No | Composite | Composite | Unknown | Unknown | Unknown | Unknown | Closed |
| | Flat 163 | No | Composite | Composite | Unknown | Unknown | Unknown | Unknown | Unknown |
| | Flat 164 | No | Composite | Composite | Unknown | Unknown | Unknown | Unknown | Unknown |
| | Flat 165 | No | Composite | Composite | Unknown | Unknown | Unknown | Unknown | Unknown |
| | Flat 166 | No | Timber | Timber | Unknown | Unknown | Unknown | Unknown | Unknown |
| 20 | Flat 171 | No | Composite | Composite | No | Yes | Concealed | Unknown | Closed |
| | Flat 172 | No | Composite | Composite | No | Yes | Concealed | Unknown | Closed |
| | Flat 173 | No | Composite | Composite | Unknown | Yes | Concealed | Unknown | Unknown |
| | Flat 174 | No | Timber | Timber | No | Yes | Concealed | Unknown | Closed |
| | Flat 175 | No | Composite | Composite | No | Yes | Concealed | Unknown | Unknown |
| | Flat 176 | No | Composite | Composite | No | No | N/a | N/a | Closed |
| 21 | Flat 181 | No | Composite | Composite | Unknown | Yes | Concealed | Yes | Closed |
| | Flat 182 | No | Composite | Composite | Unknown | Yes | Concealed | Unknown | Unknown |
| | Flat 183 | No | Composite | Composite | No | No | N/a | N/a | Closed |
| | Flat 184 | No | Composite | Composite | No | Yes | Concealed | Unknown | Closed |
| | Flat 185 | No | Timber | Timber | No | Yes | Concealed | Unknown | Unknown |
| | Flat 186 | No | Composite | Composite | No | Yes | Concealed | Unknown | Closed |

| Floor | Flat | Door in-situ? | Door leaf type | Door frame type | Glazing in door? | Door closer present? | Door closer type | Working door closer? | Door open/closed |
|---|---|---|---|---|---|---|---|---|---|
| 22 | Flat 191 | No | Composite | Composite | No | Yes | Concealed | Unknown | Closed |
| | Flat 192 | No | Composite | Composite | No | Yes | Concealed | No | Closed |
| | Flat 193 | No | Composite | Composite | No | Yes | Concealed | No | Unknown |
| | Flat 194 | No | Composite | Composite | No | No | N/a | N/a | Open |
| | Flat 195 | No | Timber | Timber | No | Yes | Overhead | No | Unknown |
| | Flat 196 | No | Composite | Composite | Yes | Yes | Concealed | Unknown | Closed |
| 23 | Flat 201 | No | Composite | Composite | No | Yes | Concealed | Yes | Closed |
| | Flat 202 | No | Timber | Timber | No | Yes | Overhead | No | Unknown |
| | Flat 203 | No | Composite | Composite | No | No | N/a | N/a | Closed |
| | Flat 204 | No | Composite | Composite | No | Yes | Concealed | No | Unknown |
| | Flat 205 | No | Composite | Composite | No | No | N/a | N/a | Unknown |
| | Flat 206 | No | Timber | Timber | No | Yes | Concealed | Yes | Closed |

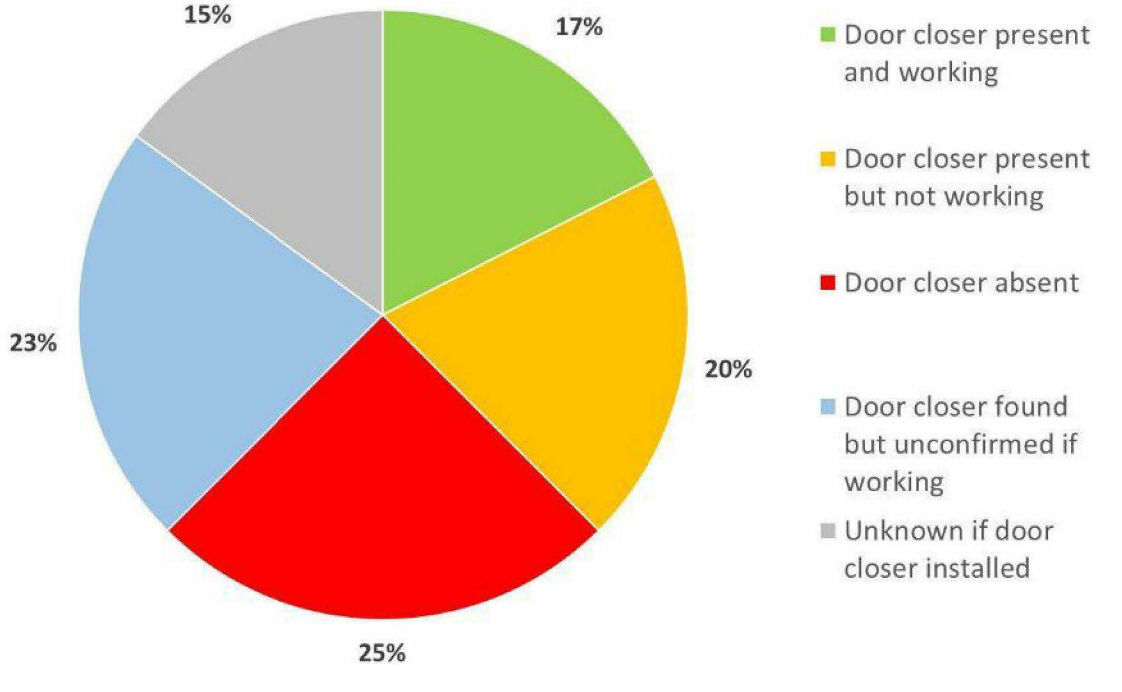


**Figure 1 – Chart showing percentage of working versus non-working door closers from Floor 4 to Floor 23 (120 flats)**

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## 3.2 Flat internal surveys

19 Damage to flats generally increases with height up the Tower; a summary of the extent of damage to each flat is provided at Table 2 and Table 3.

20 The following levels were used to assess non-structural damage within flats:

20.1 0 – No damage

20.2 1 – Smoke and/or fire damage <1m$^2$

20.3 2 – Smoke and/or damage limited to 1 room

20.4 3 – Fire damage to multiple rooms

20.5 4 – Fire damage throughout flat with evidence of partitions remaining

20.6 5 – Flat consumed by fire

**Table 2 – Trends across Tower showing extent of damage to flat fixtures, fittings and contents of flats**

| Floor | Flat 1 | Flat 2 | Flat 3 | Flat 4 | Flat 5 | Flat 6 |
|---|---|---|---|---|---|---|
| 23 | 5 | 5 | 5 | 5 | 5 | 5 |
| 22 | 5 | 5 | 5 | 5 | 5 | 5 |
| 21 | 5 | 5 | 5 | 5 | 5 | 5 |
| 20 | 5 | 5 | 5 | 5 | 5 | 5 |
| 19 | 5 | 5 | 5 | 4 | 5 | 5 |
| 18 | 5 | 5 | 5 | 4 | 5 | 5 |
| 17 | 5 | 4 | 5 | 4 | 5 | 5 |
| 16 | 5 | 5 | 5 | 4 | 5 | 4 |
| 15 | 5 | 5 | 5 | 4 | 5 | 5 |
| 14 | 5 | 5 | 5 | 5 | 5 | 5 |
| 13 | 5 | 5 | 5 | 5 | 5 | 5 |
| 12 | 5 | 5 | 3 | 5 | 5 | 5 |
| 11 | 5 | 3 | 3 | 5 | 5 | 5 |
| 10 | 3 | 1 | 4 | 5 | 5 | 5 |
| 9 | 3 | 1 | 3 | 4 | 5 | 5 |
| 8 | 2 | 0 | 2 | 3 | 5 | 5 |
| 7 | 1 | 1 | 3 | 5 | 4 | 4 |
| 6 | 4 | 1 | 2 | 1 | 3 | 4 |
| 5 | 2 | 0 | 1 | 1 | 3 | 4 |
| 4 | 1 | 0 | 0 | 0 | 3 | 3 |

21 The following levels were used to assess the spalling within flats:

21.1 0 – no spalling (this does not indicate no fire/smoke damage)

21.2 1 – spalling but no exposure of reinforcing steel

21.3 2 – single layer of reinforcing steel exposed

21.4 3 – double layer of reinforcing steel exposed

21.5 4 – double layer of reinforcing steel exposed and/or reinforcing steel has snapped.

**Table 3 – Trends across Tower showing extent of spalling of concrete and whether the floor slab was deflected across flats, from 23rd floor down to 4th floor. The table provides an average of spalling throughout the flat and the worst level of spalling. Deflection is noted where it could be observed by the naked eye**

| Floor | Type | Flat 1 | Flat 2 | Flat 3 | Flat 4 | Flat 5 | Flat 6 |
|---|---|---|---|---|---|---|---|
| 23 | Average | 2 | 2 | 2 | 1 | 2 | 2 |
| | Worst | 2 | 3 | 2 | 2 | 2 | 3 |
| | Deflection | - | - | - | Y | - | Y |
| 22 | Average | 1 | 2 | 1 | 1 | 2 | 2 |
| | Worst | 2 | 4 | 4 | 2 | 3 | 3 |
| | Deflection | Y | Y | Y | Y | Y | Y |
| 21 | Average | 2 | 1 | 2 | 1 | 1 | 1 |
| | Worst | 3 | 3 | 3 | 2 | 3 | 3 |
| | Deflection | Y | Y | Y | - | Y | Y |
| 20 | Average | 1 | 1 | 2 | 1 | 1 | 1 |
| | Worst | 2 | 2 | 2 | 3 | 2 | 2 |
| | Deflection | Y | - | Y | Y | - | - |
| 19 | Average | 1 | 1 | 1 | 0 | 1 | 1 |
| | Worst | 2 | 2 | 3 | 2 | 2 | 2 |
| | Deflection | Y | Y | - | - | Y | Y |
| 18 | Average | 1 | 1 | 1 | 1 | 1 | 1 |
| | Worst | 2 | 2 | 2 | 2 | 2 | 3 |
| | Deflection | Y | Y | Y | - | - | Y |
| 17 | Average | 2 | 1 | 0 | 0 | 1 | 1 |
| | Worst | 2 | 2 | 2 | 2 | 2 | 2 |
| | Deflection | - | - | - | - | - | Y |
| 16 | Average | 1 | 1 | 1 | 0 | 0 | 1 |
| | Worst | 3 | 3 | 4 | 0 | 2 | 2 |
| | Deflection | Y | Y | Y | Y | Y | Y |
| 15 | Average | 1 | 1 | 1 | 1 | 0 | 1 |
| | Worst | 1 | 3 | 3 | 2 | 2 | 2 |
| | Deflection | Y | - | Y | Y | Y | Y |
| 14 | Average | 1 | 1 | 1 | 1 | 1 | 1 |
| | Worst | 1 | 3 | 2 | 2 | 4 | 2 |
| | Deflection | Y | Y | Y | Y | Y | - |

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| Floor | Type | Flat 1 | Flat 2 | Flat 3 | Flat 4 | Flat 5 | Flat 6 |
|---|---|---|---|---|---|---|---|
| 13 | Average | 3 | 1 | 1 | 1 | 2 | 1 |
| | Worst | 4 | 3 | 3 | 2 | 4 | 2 |
| | Deflection | Y | Y | - | Y | Y | Y |
| 12 | Average | 1 | 1 | 0 | 1 | 1 | 1 |
| | Worst | 2 | 2 | 0 | 2 | 2 | 3 |
| | Deflection | - | - | - | - | - | - |
| 11 | Average | 1 | 0 | 0 | 1 | 1 | 2 |
| | Worst | 3 | 0 | 0 | 2 | 3 | 3 |
| | Deflection | - | - | - | - | - | - |
| 10 | Average | 0 | 0 | 1 | 1 | 1 | 1 |
| | Worst | 0 | 0 | 4 | 3 | 3 | 3 |
| | Deflection | - | - | - | - | - | - |
| 9 | Average | 0 | 0 | 0 | 1 | 1 | 1 |
| | Worst | 0 | 0 | 0 | 3 | 2 | 3 |
| | Deflection | - | - | - | - | - | - |
| 8 | Average | 0 | 0 | 0 | 0 | 2 | 1 |
| | Worst | 0 | 0 | 0 | 3 | 3 | 4 |
| | Deflection | - | - | - | - | - | - |
| 7 | Average | 0 | 0 | 0 | 2 | 0 | 1 |
| | Worst | 0 | 0 | 0 | 3 | 2 | 4 |
| | Deflection | - | - | - | - | - | - |
| 6 | Average | 1 | 0 | 0 | 0 | 0 | 0 |
| | Worst | 3 | 0 | 0 | 0 | 0 | 2 |
| | Deflection | - | - | - | - | - | - |
| 5 | Average | 0 | 0 | 0 | 0 | 0 | 1 |
| | Worst | 0 | 0 | 0 | 0 | 0 | 3 |
| | Deflection | - | - | - | - | - | - |
| 4 | Average | 0 | 0 | 0 | 0 | 0 | 1 |
| | Worst | 0 | 0 | 0 | 0 | 0 | 2 |
| | Deflection | - | - | - | - | - | - |

22 Internal lobbies to the individual flats have been examined to determine whether they comply with all of the recommendations for a fire protected entranceway at the time of the original construction of Grenfell. In Table 4 below, a "no" applies both to lobbies which do not comply with these recommendations and to lobbies where it is unclear whether they comply with these recommendations. Non-compliance arising solely from issues of actions or inactions on the part of residents (outside of the control of the landlord) and which might be categorised as maintenance, have not been considered as part of this current review (i.e. a lobby whose construction complies with the recommendations but for which the rising butt hinges no longer provide a self-closing function due to wear and/or lack of lubrication, is still considered compliant), though it may be considered later.

**Table 4 – Trends across flats showing whether or not a compliant fire protected entrance hall has been found to be provided in each of the flats**

| Floor | Flat 1 | Flat 2 | Flat 3 | Flat 4 | Flat 5 | Flat 6 |
|---|---|---|---|---|---|---|
| 23 | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| 22 | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| 21 | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| 20 | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| 19 | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| 18 | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| 17 | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| 16 | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| 15 | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| 14 | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| 13 | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| 12 | Unknown | Unknown | Yes | Unknown | Unknown | Unknown |
| 11 | Unknown | No | Unknown | Unknown | Unknown | Unknown |
| 10 | Yes | No | Unknown | Unknown | Unknown | Unknown |
| 9 | No | Yes | Yes | Unknown | Unknown | Unknown |
| 8 | No | Yes | No | Yes | Unknown | Unknown |
| 7 | Yes | Yes | Yes | No | No | No |
| 6 | No | Yes | Yes | No | Yes | Yes |
| 5 | No | No | Yes | Yes | Yes | No |
| 4 | Yes | Yes | Yes | No | No | Yes |

23 Provision of fire alarms within individual flats has been examined and is summarised at Table 5. Detection is deemed to be compliant where a smoke detector is provided in the flat lobby and a heat detector is provided in the kitchen and both have hardwired power supplies. Similar to internal lobbies, action by residents which hinder the operation of fire alarms have not been considered as part of this current review (i.e. a smoke detector which has been taped over is still considered compliant), though it may be considered later.

**Table 5 – Trends across flats showing whether fire detection is considered compliant (smoke detector in entrance hall and heat detector in kitchen)**

| Floor | Detection | Flat 1 | Flat 2 | Flat 3 | Flat 4 | Flat 5 | Flat 6 |
|---|---|---|---|---|---|---|---|
| 23 | Smoke | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| | Heat | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| 22 | Smoke | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| | Heat | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| 21 | Smoke | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| | Heat | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |

| Floor | Detection | Flat 1 | Flat 2 | Flat 3 | Flat 4 | Flat 5 | Flat 6 |
|---|---|---|---|---|---|---|---|
| 20 | Smoke | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| | Heat | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| 19 | Smoke | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| | Heat | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| 18 | Smoke | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| | Heat | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| 17 | Smoke | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| | Heat | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| 16 | Smoke | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| | Heat | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| 15 | Smoke | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| | Heat | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| 14 | Smoke | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| | Heat | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| 13 | Smoke | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| | Heat | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| 12 | Smoke | Unknown | Unknown | Yes | Unknown | Unknown | Unknown |
| | Heat | Unknown | Unknown | Yes | Unknown | Unknown | Unknown |
| 11 | Smoke | Unknown | Yes | Unknown | Unknown | Unknown | Unknown |
| | Heat | Unknown | No | Unknown | Unknown | Unknown | Unknown |
| 10 | Smoke | Yes | Yes | Unknown | Unknown | Unknown | Unknown |
| | Heat | Yes | Yes | Unknown | Unknown | Unknown | Unknown |
| 9 | Smoke | Unknown | Yes | Yes | Unknown | Unknown | Unknown |
| | Heat | No | Yes | Unknown | Unknown | Unknown | Unknown |
| 8 | Smoke | Yes | Yes | Unknown | Yes | Unknown | Unknown |
| | Heat | Yes | Yes | Yes | Yes | Unknown | Unknown |
| 7 | Smoke | Yes | Yes | No | Unknown | Yes | Yes |
| | Heat | Yes | Yes | Unknown | Unknown | Yes | Yes |
| 6 | Smoke | Yes | Yes | Yes | Yes | Yes | Yes |
| | Heat | Yes | Yes | Yes | Yes | Yes | Yes |
| 5 | Smoke | Yes | Yes | Yes | Yes | Yes | Unknown |
| | Heat | Yes | Yes | Yes | Yes | Yes | Unknown |
| 4 | Smoke | Yes | Yes | Yes | Yes | Yes | Unknown |
| | Heat | Yes | Yes | Yes | Yes | Yes | Unknown |

24 Provision of fire stopping around services entering individual flats has been examined and is summarised in Table 7. Fire stopping is deemed to be compliant where all examined fire stopping has been found to be compliant. Where there is any one example of inadequate fire stopping, then the overall fire stopping to that flat has been deemed to be non-compliant. Note that fire stopping which has not been accessible due to suspected presence of asbestos has been excluded; once inspected this may lead to flats currently considered compliant to become non-compliant.

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**Table 6 – Trends across flats showing whether all inspected fire stopping is considered compliant to each flat**

| Floor | Flat 1 | Flat 2 | Flat 3 | Flat 4 | Flat 5 | Flat 6 |
|---|---|---|---|---|---|---|
| 23 | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| 22 | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| 21 | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| 20 | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| 19 | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| 18 | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| 17 | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| 16 | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| 15 | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| 14 | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| 13 | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| 12 | Yes | Unknown | Yes | Unknown | Unknown | Yes |
| 11 | Yes | Yes | Yes | Yes | Yes | Yes |
| 10 | Yes | No | Unknown | Unknown | Yes | Unknown |
| 9 | Unknown | No | Unknown | Yes | Yes | Unknown |
| 8 | Unknown | No | No | No | Yes | Unknown |
| 7 | Yes | Yes | No | Unknown | Unknown | Unknown |
| 6 | Yes | Yes | Yes | Yes | Yes | Yes |
| 5 | Yes | Yes | Yes | Yes | Yes | Yes |
| 4 | Yes | Yes | Yes | No | Yes | Unknown |

## 3.3 Smoke control dampers

25 A list of lobby smoke dampers is shown in Table 7, including its as-found (by BRE) open/closed position. It is notable that all dampers on Floor 11 were open, and on Floor 18 the south side dampers were open and the north side dampers closed.

**Table 7 – Summary of BRE visual inspection of lobby smoke dampers**

| | Lower (supply) dampers as found status | | Upper (extract) dampers as found status | | BRE observations |
|---|---|---|---|---|---|
| **Floor** | **Left hand side (LHS)** | **Right hand side (RHS)** | **LHS** | **RHS** | |
| Ground | Closed (1 damper in riser ceiling) | | Closed (1 damper in lobby wall) | | Both dampers clean, no smoke residues |
| 1 | Closed (1 damper in lobby wall) | | Closed (1 damper in lobby wall) | | Both dampers clean, no smoke residues |
| 2 | Closed (1 damper in lobby ceiling) | | Closed (1 damper in lobby ceiling) | | Both dampers clean, no smoke residues |
| 3 | Closed (1 damper in lobby wall) | | Closed (1 damper in lobby wall) | | Both dampers clean, no smoke residues |

| | Lower (supply) dampers as found status | | Upper (extract) dampers as found status | | BRE observations |
|---|---|---|---|---|---|
| Floor | Left hand side (LHS) | Right hand side (RHS) | LHS | RHS | |
| 4 | Closed | Closed | Closed | Closed | Water damage to all dampers but smoke residues on supply dampers only. Smoke pattern on extract dampers showed contact points on edge of frames had lower smoke residues |
| 5 | Closed | Closed | Closed | Closed | Water damage and smoke residues on all dampers. Lower levels of smoke residue on damper blade tip contact points |
| 6 | Closed | Closed | Closed | Closed | Water damage on all dampers. No smoke residue on supply dampers and minimal residues on extract dampers. Lower levels of smoke residue on extract damper blade and frame edge contact points |
| 7 | ***Slightly open*** | Closed | Closed | Closed | Extract damper had even coverage of smoke residue except contact points on edges of frames and blade tips which were clean |
| 8 | Closed | Closed | Closed | Closed | All dampers had smoke residues but contact points on frame edge and blade tips were clean |
| 9 | Closed | Closed | Closed | Closed | All dampers had smoke residues but contact points on frame edge and blade tips were clean |
| 10 | Closed | Closed | Closed | Closed | All dampers had smoke residues but contact points on frame edge and blade tips were clean |
| 11 | ***Open*** | ***Open*** | ***Open*** | ***Open*** | All visible damper surfaces had smoke residues |
| 12 | Closed | Closed | Closed | Closed | All dampers had smoke residues but contact points on frame edge and blade tips were clean |
| 13 | Closed | Closed | Closed | Closed | All dampers had smoke residues but contact points on frame edge and blade tips were mostly clean. |
| 14 | Closed | Closed | Closed | Closed | All dampers had smoke residues but contact points on frame edge and blade tips were mostly clean |

| | Lower (supply) dampers as found status | | Upper (extract) dampers as found status | | BRE observations |
|---|---|---|---|---|---|
| Floor | Left hand side (LHS) | Right hand side (RHS) | LHS | RHS | |
| 15 | Closed | Closed | Closed | Closed | All dampers had smoke residues but contact points on frame edge and blade tips were mostly clean |
| 16 | Closed | Closed | Closed | Closed | All dampers had smoke residues but contact points on frame edge and blade tips were mostly clean |
| 17 | Closed | Closed | Closed | Closed | All dampers had smoke residues but contact points on frame edge and blade tips had clean areas |
| 18 | ***Open*** | ***Open*** | Closed | Closed | All dampers had smoke residues but on extract dampers contact points on frame edge and blade tips were mostly clean |
| 19 | Closed | Closed | Closed | Closed | All dampers had smoke residues but contact points on frame edge and blade tips were mostly clean |
| 20 | Closed | Closed | Closed | Closed | All dampers had smoke residues but contact points on frame edge and blade tips had clean areas |
| 21 | Closed | Closed | Closed | Closed | All dampers had smoke residues but contact points on frame edge and blade tips were mostly clean |
| 22 | Closed | Closed | Closed | Closed | All dampers had smoke residues but contact points on frame edge and blade tips were mostly clean |
| 23 | Closed | ***Middle damper blade slightly open*** | Closed | Closed | All dampers had smoke residues but contact points on frame edge and blade tips were mostly clean (except slightly open damper blade) |

Note to above table: Once the smoke extract system had been activated all dampers become extracts.

# 4 Key Findings

## 4.1 Fire spread and damage across Tower

26 BRE understands from London Fire Brigade, Key Forensic and Bureau Veritas that the fire started in a fridge freezer in the kitchen of Flat 4-6 (Flat 16) on the fourth floor.

27 The fridge freezer is understood to have been situated within 1m of the kitchen window in Flat 4-6 and the large casement of the kitchen window (left of the fan light) is understood to have been in the tilt-open position. The position of the smaller casement (under the fan light) is not known at the time of writing this report. A fire involving the fridge freezer would, in BRE's opinion, generate flaming sufficient to impinge upon the construction of the kitchen window. The construction of the window, in BRE's opinion (and based on the evidence presented above), did not provide any substantial barrier to fire taking hold on the façade outside.

28 Given the foregoing, it is BRE's opinion that there are the following options which need to be considered for the path of fire spread to the façade:

28.1 Flames extending to and out of the open window, impinging on the aluminium external skin of the façade, melting the aluminium and igniting the polyethylene core underneath;

28.2 Flames extending to and out of the open window, then igniting the polyethylene core of the aluminium cladding material at one of the cut edges of the Aluminium Composite Material (ACM);

28.3 Flames extending to and out of the open window, then entering the façade cavity via a gap in the ACM panels and igniting the rigid foam insulation facing into the cavity;

28.4 Flames igniting the extractor fan and/or the infill panel it is installed in, then flaming from these impinging on the aluminium external skin of the façade, melting the aluminium and igniting the polyethylene core underneath;

28.5 Flames igniting the extractor fan and/or the infill panel it is installed in, then flaming from these igniting the polyethylene core of the aluminium cladding material at one of the cut edges of the ACM;

28.6 Flames igniting the extractor fan and/or the infill panel it is installed in, then flaming from these entering the façade cavity via a gap in the ACM panels and igniting the rigid insulation facing into the cavity;

28.7 Flames burning and/or deforming the construction around the window (uPVC, insulation and rubberised membrane), igniting the polyethylene core of the aluminium cladding material at one of the cut edges of the ACM;

28.8 Flames burning and/or deforming the construction around the window (uPVC, insulation and rubberised membrane), igniting the rigid insulation facing into the cavity.

29 These hypotheses are not mutually exclusive and will be tested as part of the ongoing programme of work, with the aim of narrowing the number of possible hypotheses.

30 The physical evidence from the examination of the façade indicates (to BRE) a route for fire spread up the column adjacent to the kitchen of Flat 16. This route is provided by the combustible components in the construction and the lack of appropriate subdivision of this fuel to prevent fire involvement of one component involving the next. Spread of fire laterally across the façade of Grenfell Tower appears to have occurred via both columns and spandrel cassettes. As above, the combustible components of the façade provide a potential route for fire spread. Downward fire spread appears to have occurred, primarily as a result of burning droplets of polyethylene falling and igniting combustible materials below.

31 The various deficiencies identified in the construction of the façade could all have contributed to the spread of the fire described above. It is BRE's opinion that all of these would have contributed to some extent, though some will be more significant than others. The ongoing programme of work will seek to assess the relative significance of these.

32 As fire spread across the façade, it encountered windows of flats. It is BRE's opinion that the mechanisms of spread out of the window of Flat 16 to the façade would also allow spread back into flats from the façade. In particular, it is BRE's opinion that there are three principal options regarding the mechanism of fire spread back into flats:

32.1 The fire spreading across the façade led to flames breaking windows and/or extending in through open windows, igniting the contents of the flats;

32.2 The fire spreading across the façade led to flames breaking windows and/or extending in through open windows, igniting the internal linings of the flats;

32.3 The fire spreading across the façade breaching the construction around the windows, introducing flames inside of flats from the façade.

33 Once the fire was in any one flat, fire growth would initially occur within the room first involved, with smoke and fire going on to impact upon other rooms in the flat, depending on whether or not doors within the flat were open (unless fire had already spread to other rooms via the façade). Any single flat, once involved in fire, would be expected to be substantively destroyed as a flat is normally designed to be a single fire compartment. The severity of fire within any one flat would likely become limited by the ventilation provided by the broken windows of the flat and/or the flat front door if the door was open or burned away. The duration of fire within any one flat will be dependent upon the fire load within. This sequence of development and the factors involved would apply to all flats which ignited during the course of the incident.

34 As set out in Chapter 3.2, the severity and duration of the fire within each flat led to spalling and in some cases deflection of the concrete floor slabs within the flats. The patterns of spalling damage vary across flats with at least one flat per floor (from 4$^{th}$ to 23$^{rd}$) having some level of spalling. The spalling survey undertaken by BRE investigators did not focus on measuring the depth of spalling but rather graded the level of spalling visually based upon the level of exposure of the reinforcing bars within the concrete. There was no obvious visible deflection of the floor slab below the 13$^{th}$ floor. Between the 4$^{th}$ floor and 16$^{th}$ floor there are 29 flats where the concrete has not spalled with the number of flats with spalling increasing up the Tower. Using data for the worst level of spalling in a flat (rather than average) the majority of damage is Level 2 or exposure of the first layer of reinforcing bars. There are nine flats where these reinforcing bars have snapped or the extent of the spalling exposed the end of a bar causing it to drop from the ceiling – this was considered the worst level of spalling. There is only very limited consistency in the pattern of spalling when considering the Tower as whole. However, this information may become more significant later in the investigation process once witness evidence and photographic evidence is collated with regards to the duration of fire in each flat.

35 The common parts, in particular the lobbies and stairwell, have patterns of damage which vary considerably across the height of the building; there is not a consistent increase in damage progressing up the building. The protection of one area from another by fire resisting construction is only as good as the weakest point in the fire resisting construction. Whilst the concrete structure has (in BRE's opinion) performed extremely well in terms of its loadbearing capacity and the fire resistance integrity and insulation through the concrete itself, fire and smoke have entered lobbies and stairwells to extents which indicate weaknesses in the compartmentation between flats and the common parts. In particular, there is substantial smoke damage to the lobby on the fifth floor and seventh floor, and fire damage to the lobby on the 10th floor and 11th floor. These floors are significant as they are below the line at which there is total destruction of flats at the 13th floor and this damage may indicate significant impacts on viability of means of escape via the single stairwell.

36 There are two principal factors affecting the extent to which flat front doors have afforded protection between flats and lobbies:

36.1 Whether the doors, as supplied, provided the recommended period of fire resistance; 60 minutes;

36.2 Whether the doors closed as they should do under the action of self-closing devices, such that the doorset (i.e. the door and its frame) could provide some protection between flats and lobbies.

37 Across the upper floors; 9th floor and above, the majority of flat front doors are destroyed. Therefore at some point during the fire each of these doors has "failed", and fire and smoke has spread across the threshold where a barrier to fire spread ought to have been provided. However, given the length of time the fire was burning, it is not currently clear whether this "failure" means:

37.1 The door provided the level of protection expected, held back fire and smoke for a reasonable period of time and, assuming no other failures in compartmentation, protected the means of escape and firefighting access for a reasonable period of time. In this case its failure is solely an outcome of it being exposed to conditions of a severity and/or duration that exceeds that which the door should be able to withstand.

37.2 The door, although closed, did not provide the level of protection expected, allowing fire and smoke to spread more quickly to affect the means of escape and firefighting access than ought to have been the case. In this case its failure is an outcome of the doorset, or one of the components within the doorset, failing sooner than ought to have been case.

37.3 The door was left open and therefore provided no barrier to the spread of fire and smoke. In this case the only component of interest is the closer; whether it was present and working. The fire performance or otherwise of the other aspects of the door are of no use if the door remains open.

38 The doors which burnt through in the open position are:

38.1 Flat 7-4 (Flat 44);

38.2 Flat 7-5 (Flat 45);

38.3 Flat 9-6 (Flat 66); and

38.4 Flat 22-4 (Flat 194).

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39 Note that the doors to Flat 5-6 (Flat 26) and Flat 7-1 (Flat 41) are also considered by BRE to have been in the open position during the fire but these doors remain; the bottom half of the front door to Flat 5-6 remains and the front door to Flat 7-1 is intact (notwithstanding smoke damage).

40 The period of fire resistance provided by flat front doors will need to be determined via test. Once testing is complete, it will be possible to assess whether or not door failure is likely to have occurred at a time which might be considered reasonable against the guidance of Approved Document B and the Building Regulations. It may, subject to the amount of information that can be gathered about the severity of fires in the Tower over the course of the investigation, be possible to assess an approximate time at which doors failed as a result of fire attack.

41 Bin chute doors have performed well across all of the bin chutes up the Tower. Some of these doors have clearly been exposed to severe fire attack and there has been localised failure along the top edge of some of these doors, but the bin chute rooms behind have been largely undamaged throughout the incident.

42 Stairwell doors have been exposed to fire conditions in lobbies from the 10$^{th}$ to 23$^{rd}$ floors. However, the stairwell itself has only been exposed to fire temperatures (indicated via the burning of luminaires) at the 13$^{th}$ and 14$^{th}$ floors, and to significantly elevated temperatures (indicated via the melting of luminaire diffusers) at the 15$^{th}$ and 16$^{th}$ floors. The 17$^{th}$ to 23$^{rd}$ floors have undergone less severe conditions than at the aforementioned lower floors. The stairwell doors appear substantial and may provide 60 minutes fire resistance (to be confirmed via test). It is possible, although unlikely, that the severity and duration of fires at the 13$^{th}$ and 14$^{th}$ floors was significantly greater than those of floors above; this is considered unlikely because London Fire Brigade would normally, in BRE's experience, seek to bring fires under control on one floor before proceeding to the next; this will be confirmed via the witness evidence of firefighters. Assuming that all of the internal fires up the Tower were of a broadly consistent severity and/or duration (and considering the likelihood that extinguishment would have been achieved progressing up the Tower), then the pattern of damage in the stairwell indicates that some other factor needs to be considered. In BRE's opinion there are currently three principal possibilities that need to be considered to account for the localised areas of high damage in the stairwell:

42.1 That some of the stairwell doors were not self-closing, and remained open during the incident;

42.2 That someone or something (an object placed by someone) propped a stairwell door open for a period of time;

42.3 That the doors and/or the flows of smoke and hot gases around the stairwell were impacted by the smoke control system. In particular, given that extraction appears to have occurred at 11$^{th}$ floor level, it is possible that makeup air to the 11$^{th}$ floor was passing down through the stairwell from the permanently open vent at the head of the stair. Influx and passage of fresh air from the roof might have improved conditions in the stairwell. However, it is also possible that makeup air was drawn from the 13$^{th}$ and 14$^{th}$ floors into the stairwell, given their proximity to the 11$^{th}$ floor (pressure differentials would be strongest near the point of extraction) and may have drawn smoke, hot gases and fire from these floors into the stairwell. This possibility will be examined via the computer modelling to be carried out as part of the investigation, which will examine the interaction between the fires in the flats, the pathways generated by doors open, closed (gaps around door leaves) or feathering (door drawn intermittently open by the pressure differential of a smoke control system), the smoke control system and the viability of the means of escape throughout the incident.

## 4.2 Performance of Fire Safety Systems

### 4.2.1 Passive

43 The structure of the Tower has, in BRE's opinion, performed extremely well. Whilst the time at which the fire was deemed by London Fire Brigade to be under control is not yet known to BRE, it appears that the fire was burning at a level of severity which would significantly impact upon the fire resistance of the structure for between 9 and 12 hours. The gradings provided by the Post War Building Studies [24] indicate that the upper half of the structure could provide 6 hours fire resistance against a standard fire resistance furnace, and the lower half of the structure could provide more than this. Given the foregoing, it would (in BRE's opinion) be expected that the structure would have collapsed during the course of the incident. The physical evidence in relation to the structure confirms that there are parts of the structure which are very close to their point of failure.

44 Fire stopping has generally been found to be of a good standard. Some deficient fire stopping has been found but, based on BRE's experience, the proportion of inadequate fire stopping is not inconsistent with that of a typical building where fire stopping is monitored and, where deficiencies are identified, is remedied as part of an ongoing action plan.

45 Fire resisting doors have been found to vary across the Tower.

45.1 On the third floor and below, new doors appear to have been installed as part of the 2014-2016 refurbishment and these appear to be fire resisting doors. Only the front door to Flat 9 has been exposed to significant fire and smoke, and this door appears to have performed well in protecting the third floor lobby from the effects of fire.

45.2 On the fourth floor and above, the stairwell and refuse chute room doors appear to pre-date the 2014-2016 refurbishment. The refuse chute room doors have performed extremely well; all remain in place across the entire height of the building in spite of being exposed to severe fire attack from the lobbies. Some of the stairwell doors, particularly in the upper half of the building, have failed, however this tends to correspond with areas of high fire damage generally. Physical evidence indicates that some of the stairwell doors were open for a significant period when undergoing fire attack, but the reasons for and the timings of this need to be examined further (see above).

45.3 Flat front doors on the fourth floor and above have been found, by BRE, to be predominately composite construction incorporating plastic and metal components. Where these doors have been closed they have provided some level of protection against spread of smoke and fire into the protected lobby. However, their fire resistance rating is unknown as the doors are not marked with this information. In addition, a significant proportion of flat front doors either had no door closer or the door closer was not working which resulted in some doors remaining open when the residents evacuating have not closed doors behind them. Approved Document B recommends door closers are installed because it is accepted that in a fire situation people evacuating may forget to close doors behind them when leaving.

### 4.2.2 Active

46 Some of the smoke and heat detectors within flats have been variously heard beeping during the course of the investigation as a result of the disconnection of electricity supplies to the Tower. However, aside from this, their effectiveness during the course of the incident is not currently known; this will need to be established via witness testimony and 999 transcripts from the incident.

47 The smoke control system appears, based upon the physical evidence gathered, to have been operating. However, smoke control systems are normally only designed to cope with the smoke generated by a single fire in one fire compartment. The smoke control system in the Tower is likely to have been overwhelmed by the number of fires, particularly given that some doors were left open. It is, in BRE's opinion, unlikely that the smoke control system could have been reasonably expected to maintain clear air for evacuation in the means of escape in this incident. However, the smoke control system may have influenced smoke movement in and around the stairwell and as such may have impacted upon the time at which the stairwell became unavailable.

47.1 As would normally be the case, the smoke control system has been designed to extract from only one floor (the fire floor). This floor is determined by smoke detection in the lobbies. If an override switch is activated on another floor, the dampers on the original floor close so that there is always only one floor being extracted.

47.2 The pressure switch incorporated in this system appears to enable the function that fans slow down if the stairwell door is closed since this leads to a pressure differential greater than the value prescribed. However this assumes that all other doors onto the lobby of the fire floor are also closed. If one is open and is open to the outside (i.e. front door to a flat where windows are open), then the pressure differential will never be achieved and fans continue to operate at full speed. If this flat is also on fire then smoke (and possibly flames) will be drawn into the lobby by the system.

47.3 The makeup air for the smoke control system appears to be intended to come from the stairwell and the permanently open vent at the top of the stairwell. As described at Chapter 4.1, the pattern of damage in the stairwell indicates a possibility that the flow of air in the stairwell might have been influenced by the smoke control system. As previously set out, this will need further investigation via the computer modelling to be carried out.

48 The effectiveness of the dry rising main is not yet known and will need to be established via witness testimony from firefighters. It is of interest that the Tower was only provided with a dry rising main. BRE's understanding of the guidance in Approved Document B which recommends wet rising mains for buildings over 50m is that this is because fire engine pumps are not powerful enough to send water at the necessary pressure and flow above 50m. Given this, there are a number of possibilities to consider:

48.1 That pumps on London Fire Brigade appliances are sufficiently powerful to send water at sufficient pressure and flow up to 70m (the approximate height of the Tower – the highest outlet is on the roof);

48.2 That connecting multiple fire engine pumps in series might have generated enough power to send water at sufficient pressure and flow up to 70m. However, given that vehicle access was only for one fire engine, the feasibility of this also needs to be considered;

48.3 That firefighting could not have taken place at the top of the Tower in any event because water flow and pressure would have been insufficient.

49 The absence of a sprinkler system in the Tower is of interest. Whilst no assessment of performance of a sprinkler system can be made as there was none, the potential benefits and limitations of having a sprinkler system need to be considered.

49.1 Sprinklers control fires and significantly reduce the risk of fires spreading. However, in order to do so the sprinkler system must be capable of delivering water onto the items burning. In the specific circumstances of this incident, fire is understood to have taken hold inside a fridge

freezer adjacent to a window and cladding system. Had a sprinkler system been installed, it is BRE's opinion that compliance with BS 9251 [25][26] in respect of sprinkler head positioning would have been achieved via the installation of a single sprinkler head in the middle of the kitchen ceiling. It is therefore possible that the metal chassis of the fridge freezer might have shielded the fire from the sprinkler spray. This possibility will be tested as part of the second reconstruction.

49.2 Sprinkler systems can only be designed to provide a given amount of water (i.e. pumps and pipework will have a maximum flow of water they can provide). Typically in a block of flats, sprinkler systems are only designed to have a maximum of four heads discharging water (BS 9251: 2005 specifies a minimum of four heads for a residential occupancy system), and pumps, tanks, pipes and other components are sized accordingly. Once fire had taken hold across the façade and ignited more than four flats, it is BRE's opinion that the sprinkler system is very unlikely to have made any appreciable difference to the spread of the fire.

49.3 Given the foregoing, it is BRE's opinion that a sprinkler system designed and installed to current standards could only have significantly altered the outcome of the fire if it had prevented the fire from leaving Flat 16 and igniting the cladding.

50 The lift cars were both stopped on the 10th floor of the Tower. It is currently unknown whether the lifts were firefighting lifts or fireman lifts. Fireman lifts are not suitable for use during a fire since they have the functionality to return to the fire service access floor and thereby prevent their use by occupants. However, firefighting lifts can be used by firefighters during an incident and as such move between floors. It is currently unknown when the lifts stopped working and what their performance was prior to stopping. Witness statements and possibly information from the lift management system will inform this later in the investigation.

### 4.3 Approved Document B Comparison

51 Approved Document B (Fire safety) of the Building Regulations provides guidance on how to satisfy the requirements of Part B of Schedule 1 of the Building Regulations. The status of Approved Documents is set out at Sections 6 and 7 of the Building Act 1984 [27], such that Approved Documents are generally considered to be "deemed to satisfy" guidance. This means that if someone doing building work has complied with the guidance in the relevant Approved Document, they are often deemed to have satisfied the requirements of the Building Regulations, although this would ultimately be a decision for Building Control or a court in the case of a dispute. They may choose not to follow the guidance in the relevant Approved Document, but are then responsible for demonstrating compliance with the Building Regulations by some other means. Given this status, Approved Document B has been used at this early stage of the programme of work and investigation to conduct a gap analysis. Where fire safety measures in Grenfell Tower are found to comply with the guidance of Approved Document B, these are unlikely to be of significant further interest with regards to an investigation to identify failure to comply with fire safety legislation. Conversely, where there exists a difference between the guidance and what is present at Grenfell Tower, the programme of work and wider investigation will need to seek to establish whether a valid alternative solution exists which demonstrates compliance with the Building Regulations, or whether there has been a breach of the Building Regulations.

52 The edition of Approved Document B which has been used by BRE in this report is the 2006 edition incorporating 2007, 2010 and 2013 amendments. This appears to BRE to have been the edition in effect at the time plans were drawn up for the refurbishment of 2014-2016, although it is noted that there are nine changes affecting the findings below between this edition and the original unamended 2006 edition [28]. None of these changes alter the technical findings and opinions of BRE.

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52.1 Paragraph 1.5 is updated to reflect BS 5446 [29] Part 1 being superseded by BS EN 14604 [30].

52.2 A new Note 5 to Table 10 makes provision for internal linings in other circulation spaces (including common areas of blocks of flats) to be lined with products which achieve Class C (European Class) provided they are bonded to a Class A2 (European Class) substrate.

52.3 Appendix A, under Fire Resistance, makes reference to the 2007 edition of BS EN 13501 Part 4 [31], where previously it made reference to xxxx edition (a reference to the most recent edition).

52.4 Appendix A, under Reaction to Fire, makes reference to the 2007 edition of BS EN 13501 Part 1 [10], where previously it made reference to the 2002 edition [32].

52.5 Appendix A, under Internal Linings, makes reference to the use of standard substrates under BS EN 13238 [33], where previously it did not.

52.6 Appendix B makes reference to the 2008 edition of BS EN 1634 Part 1 [34], where previously it made reference to the 2000 edition [35].

52.7 Appendix B makes reference to the 2008 edition of BS EN 1634 Part 2 [36], where previously it made reference to the xxxx edition (a reference to the most recent edition).

52.8 Appendix B makes reference to the 2004 edition of BS EN 1634 Part 3 [37], where previously it made reference to the 2001 edition [38].

52.9 Appendix B makes reference to the fire resistance testing of lift landing doors under BS EN 81 Part 58 [39], where previously it did not.

53 Approved Document B Volume 2 deals with all types of building except dwellinghouses (which are covered by Volume 1). The parts of the guidance in Approved Document which are relevant to a building are based upon a number of key factors, in particular:

53.1 The purpose group of the premises

53.2 The height of the building

53.3 The height of the top storey of the building

53.4 The number of storeys above and below ground

53.5 The area and cubic capacity of the building

53.6 The shortest distance between the perimeter of the building and a relevant boundary

54 Grenfell Tower is predominantly a block of flats (Purpose Group 1(a)) but included a number of other uses, in particular a community room and nursery on the ground floor, a community meeting room on the first floor, and a boxing club on the second floor. All of these uses fall within the description of the Assembly and recreation Purpose Group (Purpose Group 5). Given that one of the uses of the Tower is a block of flats, each of the purpose groups in the building needs to be considered in its own right.

55 Grenfell Tower contains 24 storeys above ground, plus the plant room above. The upper surface of the plant room roof is approximately 70m above ground, whereas the top storey (23$^{rd}$ floor) is approximately 63m above ground. The Tower has sides of approximately 22m, with an overall area per floor of approximately 484m$^2$.

56 Table 8 summarises the relevant sections of Approved Document B outlining the guidance provided within and compares the physical evidence found at Grenfell Tower with the guidance in the relevant sections of the guidance. It further provides a list of implications for any future work and for the ongoing investigation.

57 Note that, in any event, all features of the building, once fully investigated, will need to be considered in terms of their contribution to the overall package of fire safety which was afforded by the building. Therefore, even where a feature is indicated in Table 8 as needing no further investigation because it exceeds current recommendations, some further work may be necessary with regards to assessing the overall fire safety package of measures that existed in the Tower.

**Table 8 – Comparison of physical evidence at Grenfell Tower with relevant guidance in Approved Document B [22]**

| Relevant section of Approved Document B | Guidance in Approved Document B | Physical evidence at Grenfell Tower | Implications for future work and ongoing investigation |
|---|---|---|---|
| Section 1 | | | |
| Fire alarm and fire detection systems | Mains powered smoke and heat detectors in accordance with the recommendations of BS 5839 Part 6 to at least a Grade D Category LD3 standard: mains powered smoke detectors (additional heat detectors optional), each with an integral standby power supply, detectors to be provided in all circulation spaces that form part of the escape route from the flat. | Mains powered smoke and heat detectors interlinked within each and every flat.<br><br>Communal automatic fire detection system in lift lobbies, linked to panel at ground floor entrance lobby, linked to smoke control system. | At present no further investigation regarding potential failure to comply recommended. |
| Section 2 | | | |
| Means of escape from flats | All habitable rooms to have direct access to a protected entrance hall within flat. | Original construction of original flats and flats introduced by refurbishment appear to comply. | This feature of the Tower, insofar that it relates to original flats, is one which, in BRE's opinion, would be difficult and expensive to change as part of any refurbishment.<br><br>At present no further investigation regarding |

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| Relevant section of Approved Document B | Guidance in Approved Document B | Physical evidence at Grenfell Tower | Implications for future work and ongoing investigation |
|---|---|---|---|
| | | | potential failure to comply recommended. |
| | Single means of escape in common parts only acceptable if:<br>• the flat is separated from the common stair by a protected lobby or common corridor, and<br>• the protected lobby is protected by a smoke control system, and<br>• the stairwell is ventilated. | Conforms with guidance. | On the basis that smoke control and stairwell ventilation were provided, this layout needs no further investigation. However the adequacy of smoke control and stairwell ventilation needs to be examined in any event. |
| | Stairs which are also firefighting stairs should be at least 1100mm wide. | Stairs in stairwell narrower – 1.02m (~1020mm).<br>Staircase in atrium narrower still – 0.94m (~940mm) | This feature of the Tower, insofar that it relates to original flats, is one which, in BRE's opinion, would be difficult and expensive to change as part of any refurbishment.<br>This feature of the building will need to be considered in conjunction with other fire safety measures as to whether the building as a whole provided sufficient protection. |
| | Protected lobbies and stairs to be enclosed by fire resisting construction. | Based upon Fire Grading of Buildings, walls and floors exceed guidance. | This feature of the building will need to be considered in conjunction with other fire safety measures as |

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| Relevant section of Approved Document B | Guidance in Approved Document B | Physical evidence at Grenfell Tower | Implications for future work and ongoing investigation |
|---|---|---|---|
| | | Door fire performance currently unknown. | to whether the building as a whole provided sufficient protection.<br><br>Doors to be subjected to standard fire resistance tests. |
| | The protected stair should discharge directly to the final exit or by way of a protected exit passageway to a final exit, having at least the same standard of fire resistance and lobby protection as the stairway. | The single stairwell discharges into an atrium, although the atrium appears to be separated from the remainder of the building via suitable fire resisting construction. | Housekeeping of the atrium would be particularly important; this may need to be considered as part of the review of fire risk assessments of the Tower. |
| | Gas service and installation pipes not to be installed in stairways unless in accordance with the requirements for installation and connection set out in Pipelines Safety Regulations 1996 [40] and the Gas Safety (Installation and Use) Regulations 1998 [41]. | Gas installation being inspected by Corgi. | Implications pending findings from Corgi. |
| | Basements should be served by a separate stair. | Conforms with guidance. | At present no further investigation regarding potential failure to comply recommended. |
| | The stairs may serve both flats and other occupancies provided the flat is ancillary to the main use of the building and is provided with an independent alternative escape route, the stair is separated from any other occupancies on | This does not conform as the flats are the main use of the building. | This feature of the Tower, insofar that it relates to original flats, is one which, in BRE's opinion, would be difficult and expensive to change as part of any refurbishment. |

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| Relevant section of Approved Document B | Guidance in Approved Document B | Physical evidence at Grenfell Tower | Implications for future work and ongoing investigation |
|---|---|---|---|
| | lower stories by protected lobbies, any automatic fire detection and alarm system with which the main building is fitted also covers the flat. | | This feature of the building will need to be considered in conjunction with other fire safety measures as to whether the building as a whole provided sufficient protection. |
| Section 5 | | | |
| Fire resistance of enclosures, doors and glazed elements | Fire resistance should be:<br>• 120 minutes for loadbearing walls<br>• 120 minutes around the protected shaft / firefighting shaft<br>• FD60S for all doors enclosing the protected shaft / firefighting shaft and stairwell doors. | Based upon Fire Grading of Buildings, walls and floors exceed guidance.<br>Door fire performance currently unknown. | This will need to be considered in conjunction with other fire safety measures as to whether the building as a whole provided sufficient protection.<br>Doors to be subjected to standard fire resistance tests. |
| Door fastenings | Door fastenings should not impede use in the direction of escape. Locks, whether physical or electronic, should be easily overridden by those making their escape. | Conforms with guidance. | At present no further investigation regarding potential failure to comply recommended. |
| Direction of door opening | Where practicable, doors should open in direction of escape. | Conforms with guidance. | At present no further investigation regarding potential failure to comply recommended. |
| Construction of stairs | Stairs should be constructed of limited combustibility materials. | Conforms with guidance. | At present no further investigation regarding potential failure to comply recommended. |

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| Relevant section of Approved Document B | Guidance in Approved Document B | Physical evidence at Grenfell Tower | Implications for future work and ongoing investigation |
|---|---|---|---|
| Headroom in escape routes | Clear headroom of not less than 2m. | Conforms with guidance. | At present no further investigation regarding potential failure to comply recommended. |
| Floor coverings | Should minimise slipperiness when wet. | The floor coverings in the lobbies appear to have been slip resistant.<br><br>The stairwell floor comprises bare concrete. One member of the BRE team slipped on these stairs on 14th June 2017 when there was firefighting water flowing down the stairs, and the individual was wearing safety footwear at the time. | At present no further investigation regarding potential failure to comply recommended. May need to be considered if there are any indications that residents evacuating also encountered difficulty. |
| Final exits | Should be at least as wide as escape routes and facilitate dispersal of persons away from a building. | Final exit doors are 1m (~1000mm) wide (main entrance) and 0.85m (~850mm (east face entrance).<br><br>This appears not to conform with guidance. | This will need to be reviewed in conjunction with the review of witness statements to establish whether there are any indications that residents evacuating encountered difficulty as a result of narrow escape routes. |
| Lighting of escape routes | Adequate artificial lighting in all common escape routes. Standards according to BS 5266 Part 1 [42] | No lighting measurements carried out as soot staining to luminaire components, walls and ceilings prevents accurate measurement of lighting levels.<br><br>Appears to conform with guidance based on frequency of luminaires with battery backups. | At present no further investigation regarding potential failure to comply recommended. |

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| Relevant section of Approved Document B | Guidance in Approved Document B | Physical evidence at Grenfell Tower | Implications for future work and ongoing investigation |
|---|---|---|---|
| Exit signs | Except within a flat, signage in accordance with the Health and Safety (Safety signs and signals) Regulations 1996 [43] and BS 5499 Part 1 [44] (superseded by BS ISO 3864 Part 1 [45]). | Exit signs are provided on the ground to third floors but not on the fourth floor and floors above. | This will need to be considered in conjunction with the review of witness statements to establish whether there are any indications that residents evacuating encountered wayfinding difficulties. |
| Evacuation lifts | Where provided, these should comply with BS 5588 Part 8 [46] (superseded by BS 9999 [47]).<br><br>Firefighting lifts (see Section 17) may be used for evacuation of disabled people as part of a management plan. | The lift enclosure structure appears to conform with guidance.<br><br>The fire resistance of lift landing doors is not currently known. | Given that the lifts are firemans/firefighting lifts (see below) it is expected that inspection of lift doors and accompanying documents will confirm whether or not fire resisting. If not, then it may become necessary to test the lift landing doors. |
| Lift construction | Lift shaft should be enclosed within fire resisting construction so as to minimise smoke travel between lobbies on different floors. | The lift enclosure structure appears to conform with guidance.<br><br>The fire resistance of lift landing doors is not currently known. | Given that the lifts are firemans/firefighting lifts (see below) it is expected that inspection of lift doors and accompanying document will confirm whether or not fire resisting. If not, then it may become necessary to test the lift landing doors. |
| Lift machine rooms | Lift machine rooms should be sited over the lift well. | Conforms with guidance. | At present no further investigation regarding potential failure to comply recommended. |
| Refuse chutes | Should be constructed in accordance with BS 5906 [48] and be separated from other | Conforms with guidance. | At present no further investigation regarding potential failure to comply recommended. |

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| Relevant section of Approved Document B | Guidance in Approved Document B | Physical evidence at Grenfell Tower | Implications for future work and ongoing investigation |
|---|---|---|---|
| | parts of the building by fire resisting construction, and should not be located within protected stairways or protected lobbies. | | |
| Section 6 | | | |
| Wall and ceiling linings | Wall and ceiling linings of common escape routes should be Class 0. | Not yet known; samples taken. | Samples of paint and substrate from common escape routes have been taken and are due to be tested for their composition. |
| | Wall and ceiling linings within small rooms (no more than $4m^2$) should be Class 3. | Appears to comply, notwithstanding residents' own modifications and items below. | At present no further investigation regarding potential failure to comply recommended. |
| | Wall and ceiling linings of circulation spaces within dwellings should be Class 1. | MDF board has been introduced to box in the water supplies to flats, which is relevant to this. | It is recommended that the MDF board of this construction is tested. |
| | Parts of rooms (less than half the floor area and no more than $20m^2$) may be Class 3. | Both the uPVC around the windows and the PURL board on/near the external walls are relevant to this. | uPVC and PURL board to be tested. |
| Section 7 | | | |
| Fire resistance | Current guidance does not permit unsprinklered buildings above 30m and as such does not provide a minimum period of fire resistance for loadbearing elements in such buildings. However, loadbearing elements in sprinklered buildings | Conforms or exceeds, although noting sprinklers are now a stipulation. | The balance of excessive fire resistance versus a lack of sprinklers in this building will need to be considered in conjunction with other fire safety measures as to whether the building |

| Relevant section of Approved Document B | Guidance in Approved Document B | Physical evidence at Grenfell Tower | Implications for future work and ongoing investigation |
|---|---|---|---|
| | above 30m should provide a minimum of 120 minutes fire resistance. | | as a whole provided sufficient protection. |
| Section 8 | | | |
| Provision of compartment walls and floors | Every wall separating a flat from any other part of the building and every floor should be a compartment wall/floor. | Conforms with guidance. | At present no further investigation regarding potential failure to comply recommended. |
| Sprinklers | Blocks of flats over 30m tall should be fitted with sprinklers inside flats (common areas need not be sprinklered). | Does not conform. | Further investigation of the decision making process at design stage of the refurbishment needed. |
| Construction of compartment walls and floors (generally – not including walls around firefighting shaft) | Should form a complete barrier to fire spread between the compartments they separate and provide 60 minutes fire resistance. | Based upon Fire Grading of Buildings, walls and floors exceed guidance. | This will need to be considered in conjunction with other fire safety measures as to whether the building as a whole provided sufficient protection. |
| Doors | Doors in compartment walls should have the following fire resistance (European equivalent in brackets):<br>• Separating flat from common space – FD30S (E30 $S_a$)<br>• Enclosing a protected shaft forming a stairway situated wholly or partly above the adjoining ground in a building used for Flats etc. – FD30S (E30 $S_a$) | Fire resistance of doors not known. | A sample of doors to be subjected to standard fire resistance tests. |

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| Relevant section of Approved Document B | Guidance in Approved Document B | Physical evidence at Grenfell Tower | Implications for future work and ongoing investigation |
|---|---|---|---|
| | • Any door forming part of the enclosure to a protected entrance hall or protected landing in a flat – FD20 (E20) | | |
| Protected shafts | Current guidance does not permit unsprinklered buildings above 30m and as such does not provide a minimum period of fire resistance for protected shaft enclosures in such buildings. However, protected shafts in sprinklered buildings above 30m should provide a minimum of 120 minutes fire resistance. | Conforms or exceeds, although noting sprinklers are now a stipulation. | The balance of excessive fire resistance versus a lack of sprinklers in this building will need to be considered in conjunction with other fire safety measures as to whether the building as a whole provided sufficient protection. |
| Protected shafts conveying gas | Any pipe containing natural or LPG should be of screwed or welded steel construction, installed in accordance with the Pipelines Safety Regulations 1996 [40] and the Gas Safety (Installation and Use) Regulations 1998 [41]. | Gas installation being inspected by Corgi. | Implications pending findings from Corgi. |
| Ventilation of protected shafts conveying gas | Ventilated direct to outside air by ventilation openings at high and low level in the shaft. | Gas installation being inspected by Corgi. | Implications pending findings from Corgi. |
| Section 9 | | | |
| Provisions of cavity barriers | At the junction of all external cavity walls with compartment walls and floors. | Cavity barriers present but not adequate. | Further investigation to determine whether inadequacies arise from design, supply, |

| Relevant section of Approved Document B | Guidance in Approved Document B | Physical evidence at Grenfell Tower | Implications for future work and ongoing investigation |
|---|---|---|---|
| | | | workmanship or other issues.<br><br>Cavity barrier inadequacies to be repeated in later large scale cladding experiments to assess significance. |
| | Around openings, including windows. | No cavity barriers found. | Further investigation to determine whether inadequacies arise from design, supply, workmanship or other issues.<br><br>Cavity barrier inadequacies to be repeated in later large scale cladding experiments to assess significance. |
| | At intervals no greater than 20m where the lining is Class 1 or Class 0, or no greater than 10m for any other class. | Cavity barriers present but inadequate. | Further investigation to determine whether inadequacies arise from design, supply, workmanship or other issues.<br><br>Cavity barriers inadequacies to be repeated in later large scale cladding experiments to assess significance. |
| Construction and fixings for cavity barriers | Cavity barriers should provide at least 30 minutes fire resistance. | Inappropriate use of fixings. | Further investigation to determine whether inadequacies arise from design, supply, workmanship or other issues.<br><br>Cavity barriers inadequacies to be |

| **Relevant section of Approved Document B** | **Guidance in Approved Document B** | **Physical evidence at Grenfell Tower** | **Implications for future work and ongoing investigation** |
|---|---|---|---|
| | | | repeated in later large scale cladding experiments to assess significance. |
| <u>Section 10</u> | | | |
| Fire stopping of pipes | Pipe stacks should be no more than 160mm diameter, branches 110mm, provided they are non-combustible, lead, aluminium, aluminium alloy, uPVC, or fibre cement construction. Other materials up to 40mm diameter. | Conforms with guidance. | At present no further investigation regarding potential failure to comply recommended. |
| Fire stopping of ventilation ducts | Air handling ducts can be protected in three ways:<br>Method 1 – Protection using fire dampers<br>Method 2 – Protection using fire-resisting enclosures<br>Method 3 – Protection using fire-resisting ductwork | Bathroom extract not yet accessed due to potential presence of asbestos. | Implications pending inspection. |
| Fire stopping generally | May be made of cement mortar, gypsum-based plaster, cement or gypsum based vermiculite/perlite, glass fire, crushed rock, blast furnace slag or ceramic-based products and intumescent mastics. | Varying types of fire-stopping used. Not confirmed at the time of writing if mastics used were intumescent but all internal fire-stopping appeared to perform adequately. | Implications pending inspection. |

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| Relevant section of Approved Document B | Guidance in Approved Document B | Physical evidence at Grenfell Tower | Implications for future work and ongoing investigation |
|---|---|---|---|
| Section 12 | | | |
| External surfaces above 18m | Class 0 or Class B-s3, d2 or better. | Awaiting standard test results. | Awaiting standard test results. |
| External surfaces below 18m | Index (I) or not more than 20 or Class C-s3, d2 or better, or timber. | Awaiting standard test results. | Awaiting standard test results. |
| Insulation materials/products | Any insulation, filler material (not including gaskets, sealants and similar) etc. used in the external wall construction should be limited combustibility. | Awaiting standard test results. | Awaiting standard test results. |
| Cavity barriers | Should be provided as per Section 9. | Cavity barriers present but inadequate. | Further investigation to determine whether inadequacies arise from design, supply, workmanship or other issues.<br>Cavity barriers inadequacies to be repeated in later large scale cladding experiments to assess significance. |
| Alternative approach | If not the above approach, the performance criteria in BR 135 [49] should be met using full scale test data from BS 8414 Part 1 or 2 [12][50]. | BRE understand from MPS that at the time of writing no evidence of a BS 8414 test has been discovered. | Large scale cladding test to be carried out. |
| Section 13 | | | |
| Space separation | Refer to BR 187 [51]. | Appears to conform with guidance, although detailed analysis not yet carried out. | At present no further investigation regarding potential failure to comply recommended. |

| Relevant section of Approved Document B | Guidance in Approved Document B | Physical evidence at Grenfell Tower | Implications for future work and ongoing investigation |
|---|---|---|---|
| | | Building-to-building fire spread did not occur. | |
| Section 14 | | | |
| Roof coverings | Roof to provide 30 minutes fire resistance from below for means of escape from plant room. | Conforms with guidance. | At present no further investigation regarding potential failure to comply recommended. |
| | Roof covering CC or better, subject to distance to relevant boundary. | Appears to conform with guidance. | At present no further investigation regarding potential failure to comply recommended. |
| Section 15 | | | |
| Fire mains | Wet fire main should be provided. | Dry rising fire main provided.<br><br>Does not conform with guidance. | Analysis to be carried out to establish whether sufficient water flow and pressure can be achieved with one or more fire appliance pumps. |
| | Fire main outlets should be within stairwell (as flats open directly onto lobby). | Fire main outlets within lobbies.<br><br>Does not conform with guidance. | Dry rising outlet in lobby not stairwell may have caused problems with firefighting tactics – to be checked against witness statements. |
| | Hydrants should be within 90m of fire main inlet | Distances conform with guidance but some hydrants were found not to conform with guidance concerning marking to assist firefighters to locate them. | Witness statements of firefighters to confirm whether any difficulties locating water supplies. |
| Section 16 | | | |
| Vehicle access | Access for a pumping appliance to within 18m of inlet. | Possible for a single appliance to gain | Witness statements to be checked to ensure route was not blocked. |

| Relevant section of Approved Document B | Guidance in Approved Document B | Physical evidence at Grenfell Tower | Implications for future work and ongoing investigation |
|---|---|---|---|
| | | access within 18m of inlet. | To be considered in conjunction with dry rising main; whether one appliance powerful enough for water to 70m height. |
| | Roadways and hardstandings to be sufficiently wide, high and loadbearing for fire appliances used by the local fire and rescue service. | Conforms with guidance. | At present no further investigation regarding potential failure to comply recommended. |
| Section 17 | | | |
| Provision of firefighting shafts | Provide firefighting shaft with firefighting lifts. | Lifts appear not to conform with standard for firefighting lift. May comply with firemans lift. | Further inspection of lift and findings from BMS retrieval needed. |
| | Firefighting shafts should serve all floors through which they pass. | Conforms with guidance noting that shaft need not serve basement. | At present no further investigation regarding potential failure to comply recommended. |
| | Every part of every storey should be no more than 60m from a fire main in a firefighting shaft. | Conforms with guidance. | At present no further investigation regarding potential failure to comply recommended. |
| Design and construction of firefighting shafts | Firefighting shaft equipped with fire mains with outlet connections and valves at every storey. | Conforms with guidance. | At present no further investigation regarding potential failure to comply recommended. |
| | Firefighting lift shaft should conform with clauses 7 and 8 of BS 5588 Part 5 [52]. | The lift enclosure structure appears to conform with guidance.<br>The fire resistance of lift landing doors is not currently known. | Given that the lifts are firemans/firefighting lifts (see below) it is expected that inspection of lift doors and accompanying document will confirm |

| Relevant section of Approved Document B | Guidance in Approved Document B | Physical evidence at Grenfell Tower | Implications for future work and ongoing investigation |
|---|---|---|---|
| | | | whether or not fire resisting. If not, then it may become necessary to test the lift landing doors. |
| | Firefighting lift installation should conform with BS EN 81 Part 72 [53][54] and BS EN 81 Part 1 [55]. | Inspection of systems ongoing, however a secondary power supply for the lifts has not been located indicating potential non-conformance. | Further inspection of lift and findings from BMS retrieval (WSP) and electrical survey (RINA) needed. |
| | Flats allowed to open directly onto lift lobby provided lift doors no more than 7.5m from firefighting stair. | Conforms with guidance. | At present no further investigation regarding potential failure to comply recommended. |
| Section 18 | | | |
| Provision of smoke outlets | Smoke outlets should be provided. | Conforms with guidance. | At present no further investigation regarding potential failure to comply recommended. |
| | Smoke outlets should be situated at high level. | Conforms with guidance. | At present no further investigation regarding potential failure to comply recommended. |
| | Each compartment should have direct access to venting. | Conforms with guidance. | At present no further investigation regarding potential failure to comply recommended. |
| Natural smoke outlet provisions | Combined clear cross sectional area not less than 1/40$^{th}$ of the floor area. | Although only viewed and not specifically measured, appears to conform with guidance. | At present no further investigation regarding potential failure to comply recommended. |
| Construction of outlet ducts or shafts | Outlet ducts or shafts should be of non-combustible construction. | Conforms with guidance. | At present no further investigation regarding potential failure to comply recommended. |

# 5 Interim Conclusions

58 As set out in Chapter 2, the overarching aims for the BRE on-site investigation are as follows:

58.1 To collect as much physical evidence as possible in relation to

58.1.1 Patterns of fire damage, fire spread and smoke spread at Grenfell Tower (externally and internally)

58.1.2 The fire protection systems at Grenfell Tower

58.1.3 The general construction of Grenfell Tower relevant to fire safety

58.2 To compare the physical evidence of the construction and fire protection of Grenfell Tower with the recommendations of the edition of Approved Document B which was in effect at the time of the last building work to be carried out at Grenfell Tower [22].

59 Grenfell Tower, as originally built, appears to have been designed on the premise of providing very high levels of passive fire protection.

59.1 The structure and compartment walls/floors afforded a much higher degree of fire resistance than would currently be recommended by Approved Document B. Had the modern standard of fire resistance been provided, in BRE's opinion, given the severity of spalling to concrete including exposure of reinforcing steelwork, it is likely that the Tower would have collapsed, whether fully or partially.

59.2 The original façade of Grenfell Tower, comprising exposed concrete and, given its age, likely timber or metal frame windows, would not have provided a medium for fire spread up the external surface.

60 In BRE's opinion, provided compartmentation was completed via suitably fire resisting doors and fire stopping, there would have been little opportunity for a fire in a flat of Grenfell Tower to spread to any neighbouring flats. This principle of design is, in BRE's opinion, what would have allowed for a building of this height to be permitted a single staircase despite there being no suppression system.

61 Evidence collected and recorded during the on-site investigation has indicated that various routes for fire spread appear to have been introduced, whether via the addition of fuel or shortcomings in compartmentation:

61.1 The cladding over the façade appears to have introduced a medium for fire spread up the façade;

61.2 Subdivision of the fuel load presented by the cladding system via cavity barriers appears to have been inadequate;

61.3 The manner in which new windows were connected to the cladding system lacked any barriers to fire spread between flats and the cladding system;

61.4 The lack of door closers on fire doors have introduced weaknesses into the separation between flats and the common parts.

62 The cladding system is of particular concern given the manner in which fire spread up and across it and involved flats as it did so. The multiple potential deficiencies concerning the cladding system reflect its significance with regards to actual fire spread during the fire. The cladding system had the following issues. Note the significance of these is far greater when they are considered in combination as opposed to when they occur in isolation.

62.1 Insulation was combustible. This appears to have provided a medium for fire spread up, across and within sections of the façade.

62.2 Cavity barriers were improperly oriented, were of insufficient size specification to close gaps in the event of fire, and/or gaps were larger than they ought to have been given the cavity barriers used.

62.3 Gaps between insulation and the surface of the building and gaps between insulation and cavity barriers, provided a route for fire spread.

62.4 The aluminium composite material used in the façade has a core which appears to be highly combustible. This material appears to have provided a medium for fire spread up and across the façade.

62.5 Windows appear to have been installed into the façade in a manner which provides a direct route for fire spread from flats into the cavity of the façade, and from the façade back into flats. There do not appear to have been any cavity barriers installed at locations where window openings communicate with the cavity in the façade.

63 Fire doors appear to have provided some degree of protection where these have been provided and closed. In particular, it is worthy of note that the doors onto the waste chute rooms appear to have performed particularly well. The absence of door closers on front doors to flats appears to have resulted in a significant number of doors being left open. Where this has occurred, the fire in each flat appears to have emitted large quantities of smoke (and later fire) directly into the immediate lobby, and these have gone on to affect the lifts and single stairwell.

64 The pattern of fire damage across Grenfell Tower is complex, but there is a general trend of damage increasing further up the Tower. The particular exception to this is in the stairwell, where damage appears to be concentrated around the 13th and 14th floors, with less damage across the upper parts of the stairwell.

65 The means of escape for Grenfell Tower appear at the time of construction to have been broadly compliant with guidance and codes of practice that were in place at the time. Whilst it is acknowledged that it would be difficult to make changes to the single stairwell as part of any refurbishment, assessment will need to be made of the impact of the associated building features, notably the atrium, the lifts and other occupancy types within the Tower, which were introduced/modified as part of the refurbishment.

66 Access and facilities for the fire and rescue service are in BRE's opinion variously deficient or in need of further investigation. A building of Grenfell Tower's height ought to have been fitted with a wet rising main as part of the refurbishment; instead the existing dry rising main was extended and modified. This is particularly significant in conjunction with the limited vehicle access at the Tower as, it is BRE's opinion that it is unlikely that a single fire appliance could provide sufficient pressure and flow of water for firefighting at the top of the Tower. The aforementioned points (paragraph 65) regarding means of escape necessarily affect access for firefighters within the Tower to carry out their various roles.




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67 The gap analysis to Approved Document B (AD B) has highlighted where there are non-conformances or further investigation is required to confirm whether or not there is a non-conformance issue, see Table 9. The gap analysis will be used to inform the ongoing investigation with the aim of meeting the overarching objectives which have been set.

**Table 9 – Summary of subjects from Table 8 for which further investigation is recommended**

| Non-conformance / potential non-conformance subject | Further investigation suggested |
|---|---|
| **Means of escape** | |
| Stairs narrower than recommended | Consider as part of holistic fire safety review |
| Stairwell discharges into atrium | Housekeeping within fire risk assessments |
| Stairs serving other occupancies | Consider as part of holistic fire safety review |
| Floors slippery when wet | Review witness statements |
| Final exits narrow | Review witness statements |
| Exit signs inadequate | Review witness statements |
| **Internal linings** | |
| Wall and ceiling linings in escape routes unknown | Samples taken and tests to be carried out |
| Wall and ceiling linings in flat circulation spaces | Testing recommended |
| Wall and ceiling linings in flats; uPVC and PURL board | Samples taken and tests to be carried out |
| **Compartmentation** | |
| Excessive fire resistance vs no sprinklers | Consider as part of holistic fire safety review |
| Doors fire resistance unknown | Fire resistance tests to be carried out |
| Gas services in protected shaft unknown | Pending report from CORGI |
| Ventilation of protected shafts conveying gas | Pending report from CORGI |
| Inadequate cavity barriers at compartment junctions | Further investigation to determine root cause plus inclusion in large scale tests and reconstruction |
| Inadequate cavity barriers around windows | Further investigation to determine root cause plus inclusion in large scale tests and reconstruction |
| Inadequate cavity barriers at relevant intervals | Further investigation to determine root cause plus inclusion in large scale tests and reconstruction |
| Cavity barriers inappropriately fixed | Further investigation to determine root cause plus inclusion in large scale tests and reconstruction |

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| Non-conformance / potential non-conformance subject | Further investigation suggested |
|---|---|
| Fire stopping of ventilation ducts unknown | Inspection pending asbestos survey |
| Fire stopping generally | Inspection to be completed pending asbestos survey |
| **External fire spread** | |
| External surfaces above 18m unknown fire performance | Small scale standard tests to be carried out |
| External surfaces below 18m unknown fire performance | Small scale standard tests to be carried out |
| Insulation materials and other major façade components unknown fire performance | Small scale standard tests to be carried out |
| Cavity barriers inadequate | Further investigation to determine root cause plus inclusion in large scale tests and reconstruction |
| Alternative cladding test approach unknown | Large scale compliance test to be carried out |
| **Access and facilities for the fire service** | |
| Dry rising main instead of wet rising main | Analysis of whether single fire engine can supply water to 23rd floor and roof to be carried out |
| Dry rising outlets in lobbies not stairwell | Review firefighter witness statements |
| Hydrants not clearly marked | Review firefighter witness statements |
| Vehicle access for one appliance only | To be considered in conjunction with dry rising main for ability to send water to 23rd floor or roof |
| Firefighting lift unknown | Continue survey of lifts and associated documentation. Awaiting reports from RINA and WSP |
| Firefighting lift landing doors unknown | Continue survey of lifts and associated documentation. Awaiting reports from RINA and WSP |

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# Appendix A Acknowledgements

The following individual's efforts are acknowledged as having provided input into this report by conducting on-site surveys and investigations and collating relevant information during the course of our investigation to date. Some individuals named below have since left BRE Global Ltd.

| Name | Role |
|---|---|
| Sharon Hill | Fire Investigation Co-ordinator (Administrative assistance) |
| Sean Taylor | Fire Investigation Consultant (On-site investigation) |
| Meghan Sanders | Fire Investigation Consultant (On-site investigation) |
| Kieran Wood | Fire Investigation Consultant (On-site investigation) |
| Arron Perry | Senior Technician, Environment (Ventilation system) |
| Connor McIntosh* | (On-site investigation) |
| Kaloyan Markov* | (On-site investigation) |

* No longer employed by BRE.

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## Appendix B Curricula Vitae

| | |
|---|---|
| **NAME** | **DAVID CROWDER** |
| **CURRENT POSITION** | Head of Fire investigation and Expert Witness Services, BRE Group |
| **ACADEMIC QUALIFICATIONS** | PhD, BSc (Hons) |
| **PROFESSIONAL QUALIFICATIONS** | CEng, MIFireE |
| **SPECIALISATIONS** | Fire investigation. Fire development and building performance against regulations and guidance. Experimental research and consultancy. |

### CAREER SUMMARY

Since joining BRE in 2006, David has been involved in a wide range of large scale experimental work, testing, consultancy and fire investigations, particularly with respect to new developments in the built environment. David has overall responsibility for the fire investigation team as well as expert witness services across all disciplines in the BRE Group of companies.

He has worked on a wide range of investigations and projects for the UK government, the EU and private concerns. Research projects include: fire spread in car parks, researching the effectiveness of residential sprinklers, evacuating mobility impaired people from hospitals, developing a fire protection strategy for HMS Victory, developing cost effective water misting systems for use in prison cells and a scoping study on the environmental impact of fires. He holds a PhD in the impact of fire chemistry (flammability and toxicity) in fatal fires, examined via the investigation and reconstruction of real fires, and a Bachelor of Science Degree with Honours in Forensic and Investigative Science specialised in Fire Engineering and Fire Investigation.

David specialises in investigating fire development, the performance of fire protection measures and systems during real fire incidents, and the regulatory aspects of performance in these areas. He is a Chartered Engineer registered with the Engineering Council by the Institution of Fire Engineers.

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### FIRE INVESTIGATION EXPERIENCE

The following has been selected with respect to experience as a fire investigator.

1. David holds a PhD in the impact of fire chemistry (flammability and toxicity) in fatal fires, examined via the investigation and reconstruction of real fires, and a Bachelor of Science Degree with Honours in Forensic and Investigative Science specialised in Fire Engineering and Fire Investigation.
2. David has been part of the fire investigation team at BRE since 2006 and has been Business Group Manager for Fire Investigation at BRE since 2011 and Head of Expert Witness Services

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across the BRE Group since 2014. This has included the on-site investigation of numerous major fires including the Cutty Sark fire in 2007, Atherstone-on-Stour in 2007, Royal Marsden Hospital in 2008, Lakanal in 2009, the Peckham and Camberwell timber frame fires in 2009 and 2010 respectively and Shirley Towers in 2010.

3. David attended the Atherstone-on-Stour multi fire-fighter fatality fire in 2007 and worked on teams for both prosecution and defence of cases brought against Warwickshire Fire and Rescue Service and its Officers. He was a member of the BRE team carrying out reconstructions for Warwickshire Police to investigate ignition scenarios and the plausibility of witness statements related to these. He then managed and led an extensive programme of reconstructions and computer modelling for Warwickshire Fire and Rescue Service to develop a timeline of fire development and spread responsible for the events witnessed during the incident. He was not called to give evidence at any of the Court hearings as his written evidence was agreed by both parties prior to the hearings.

4. David attended the Lakanal tower block fire in 2009, managing and undertaking an extensive programme of work for the Metropolitan Police Service, London Fire Brigade and the Department for Communities and Local Government. He led the BRE on-site investigation and managed an extensive programme of testing, reconstruction and computer modelling to establish the sequence of fire development and building performance during the incident. He prepared an extensive expert witness report reviewing all of the evidence collected by the multi-agency investigation, all of the legislation and guidance that applied to the fire safety of the building throughout its 50 year life, the works carried out on the building during that time and whether any parties may have responsibility for the condition of the building and consequent fire spread as a result of this. David presented three days of expert evidence during the inquest into the incident from January to March 2013. David was then retained by the London Fire and Emergency Planning Authority to provide expert witness support in relation to its prosecution of the London Borough of Southwark (LBS) under the Regulatory Reform (Fire Safety) Order 2005. LBS pleaded guilty to all the offences charged in February 2017.

5. David has provided expert witness services on a number of legal cases where there was extensive or unusual fire spread as well as numerous cases where there are disputes concerning the design and construction of premises which impact on fire safety. He has been involved in both prosecution and defence of cases under the Regulatory Reform (Fire Safety) Order 2005 as well as murder, manslaughter, arson with intent and reckless arson cases. He has also provided assistance in matters relating to both liability and quantum for damages in civil disputes as well as identifying opportunities for recovery. David's experience in civil proceedings includes giving evidence at the High Court and as part of Mediation and Arbitration proceedings.

6. David carried out computer modelling of the Penhallow Hotel fire of 2007 to investigate the way in which the layout and contents of the building contributed to the fire spread during the incident. This formed part of BRE's work supporting the Cornwall Fire and Rescue Service investigation into whether there were any failings under the Regulatory Reform (Fire Safety) Order 2005.

7. David has carried out many laboratory fire experiments and fire reconstructions on structures and components to test hypotheses or assess possible fire performance in support of investigations following major incidents, including the fires at the Hard Rock Cafe in 2005, the Royal Marsden Hospital in 2008, the multi-fatality house fire involving a freezer in Neasden in 2011 and a fire in a power station. He has also worked on research to investigate the feasibility of retrieving DNA from blood exposed to fire.

8. David has been involved in two fire investigations led by the UK's Marine Accident Investigation Branch; the Commodore Clipper fire of June 2010 and the Yeoman Bontrup fire of July 2011. His involvement in both investigations concerned the contribution of materials to the development and spread of the fires on the vessels.
9. David investigated track fires on the London Underground on behalf of Balfour Beatty. The investigation and supporting laboratory experiments led to the development of safer systems of work for Balfour Beatty and Track Alliance staff working on the London underground network.
10. David chairs the Institution of Fire Engineers Fire Investigation Special Interest Group.
11. David represents BRE on the UK Fire Investigation Strategic Steering Group of the Chief Fire Officers' Association.
12. David is one of the authors of the Code of Practice for Investigators of Fire and Explosions for the Criminal Justice Systems in the UK, which is jointly endorsed by the Chief Fire Officers' Association, the Institution of Fire Engineers and the UK Association of Fire Investigators.
13. David is a regular guest lecturer on the Fire and Explosions Investigation course at Leeds University, lecturing on the correct use of fire modelling in support of fire investigation.

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## OTHER RELEVANT EXPERIENCE

- Managed and led the programme of work for the Chief Fire Officers' Association drafting the new suite of National Operational Guidance on Fires in the Built Environment. This guidance will be used by the UK Fire and Rescue Service by CFOA to provide a common understanding and common language for firefighters to understand the behaviour of buildings and structures during fires.
- Member of the team carrying out research for the Department for Communities and Local Government on fire spread in car parks. Managed the programme of 11 large scale experiments that were carried out during the overall programme of research.
- Managed and led BRE involvement in the EU TRANSFEU project; a project to develop fire safety hazard analysis of railway rolling stock. Involved in the setting up and development activity on coupling the existing BS EN ISO 5859 smoke box to gas phase FTIR for detection and measurement of toxic gases; the method to be incorporated into EN 45545 Part 2.
- Managed and carried out programme of experimental research for the Fédération Internationale de l'Automobile (FIA) investigating fires in motor sport vehicles and feasibility of on-board and hand-held suppression systems used by marshals for dealing with these fires.
- Drafting of Government Guidance documents, including HTM 05-03 Part J (for the Department of Health) and parts of BB100 (for the Department for Children Schools and Families, now Department for Education).
- Member of the team carrying out research for the Ministry of Justice on fire safety in prison cells. Managed a full scale burnout of a prison cell to be used as benchmark data for the programme of research.

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- Member of the team carrying out fire risk assessment of HMS Victory for the Ministry of Defence. Responsible for design of test rig to replicate HMS Victory so that fire tests could be carried out to provide source data for design of suppression system for HMS Victory. Carried out investigation of Cutty Sark fire to gather supporting data for this process.
- Managed and carried out research for Transport for London into potential vulnerability of Cycle Hire terminals to arson attack.
- Carried out computational fluid dynamics modelling using JASMINE in support of ATKINS (now AECOM) design team for Dubai Metro Danube Station (previously named Jebel Ali Industrial station).
- Member of the team carrying out scoping study for the Department for Communities and Local Government on sustainability and fire. Has extensive experience on the fire performance of buildings incorporating innovative construction products and techniques (also known as modern methods of construction) based on incident experience and experimental research.

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10. Crowder D. ‘Fire investigation and research involving innovative construction products and techniques’ Hertfordshire branch of Institution of Fire Engineers Annual General Meeting, 27th April 2010.

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13. Crowder D. 'Fire investigation on behalf of Communities and Local Government: Learning lessons on how buildings and their occupants respond to fire' International Association of Arson Investigators Annual Training Conference, 25th January 2011.

14. Crowder D. 'Fire investigation as a feedback mechanism for the fire community' University of Edinburgh and Lloyds Register Educational Trust Technical Leadership seminar in Fire Safety Engineering, 2nd June 2011.

15. Crowder D. 'DCLG Research Project: Fire Spread in Car Parks' Fire Safety in Residential Care Premises and Fires in Multi-Storey Car Parks IFE East Sussex Group CPD Training Day, 21st July 2011.

16. Crowder D. 'Fire Safety Update' Building Research Housing Group Seminar 76: Safety Matters, 17th November 2011.

17. Crowder D. 'The Lakanal Fire, London – Findings from the Inquest' Various, April 2013 to June 2014.

18. Crowder D. 'Potential Perils of modern methods of Construction' Association of Insurance Surveyors CPD seminar, 25th June 2012.

19. Crowder D. 'Fire and Safety' Building Research Housing Group Seminar 77: Does Safety Matter, 13th September 2012.

20. Crowder D. 'Renewable Energy Risks and Modern Methods of Construction Losses' Zurich Risk Engineering Forum, 10th October 2012.

21. Crowder D. 'Monitoring the fire risks of sustainable technologies' Fireforum Congress 2012 "Fire and Sustainability" Brussels, 18th October 2012.

22. Crowder D and Charters D. 'Evacuating Vulnerable and Dependant People from Buildings in an Emergency' FB52. IHS BRE Press 2013.

23. Crowder D. 'The Fire Risks of Renewable Energy Generation' Allianz Regional Risk Control training day, 12th March 2013.

24. Crowder D. 'Fire Protection in Social Housing – The Lessons to be Learnt' Firex 2013, 14th May 2013.

25. Crowder D. 'Lessons from Real Fires in Timber Construction' Wood2Build, 6th June 2013.

26. Shipp, M, Crowder, D, Holland, C et al. (2013) Fire safety and solar electric/photovoltaic systems. International Fire Professional, October 2013; 6, pp. 12-17.

27. Crowder D and Westlake J. 'Prevention of Arson in Schools' Education Estates Conference, 26th November 2013.

28. Crowder D. 'Do You Understand the Structure of Your Building?' All Party Parliamentary Fire Safety and Rescue Group, 4th December 2013

29. Foster A and Crowder D. ‘Proximate Cause and Subrogation’ Chartered Institute of Loss Adjustors Future Focus Conference, 2nd May 2014.

30. Crowder D. ‘Fire safety in student accommodation – Lessons from related real incidents’ University Safety and Health Association Fire Seminar, 4th June 2014.

31. Crowder D. ‘Fire safety issues in social housing – real fire experience’ Firex 2014, 17th June 2014.

32. Shipp, M, Holland, C, Crowder, D and Lennon, T. (2015) ‘Gone to blazes; Tackling fire spread in roof voids’. RIBA Journal. Available online February 2015.

33. Crowder, D. ‘Lessons from Major Fire Disasters’ Fire Toxicity 2016, 21st March 2016.

34. Holland, C, Crowder, D and Shipp, M. (2016) External fire spread: New research Part 1. Building Engineer April 2016.

35. Holland, C, Crowder, D, Shipp, M and Cole, N. (2016) External fire spread Part 2: New experiments on façade systems. Building Engineer May 2016.

36. Holland, C, Crowder, D and Shipp, M. (2016) Fire safety issues with balconies. Building Engineer July 2016.

37. Holland, C, Crowder, D and Shipp, M. (2017) Life safety and Regulation 7. Building Engineer January 2017.

| | |
|---|---|
| **NAME** | **CIARA HOLLAND** |
| **CURRENT POSITION** | Senior Fire Investigation Consultant |
| **ACADEMIC QUALIFICATIONS** | MSc Forensic Science<br>BSc (Hons) Forensic Chemistry |
| **PROFESSIONAL QUALIFICATIONS** | AIFireE, MCSFS |
| **SPECIALISATIONS** | Fire investigation, Fire development and building performance against building regulations and guidance, Experimental research and consultancy |

## CAREER SUMMARY

Ciara is a Senior Fire Investigation Consultant within the BRE Fire Investigation team. She specialises in the investigation of fire safety deficiencies and how these deficiencies contribute to disproportionate damage. As part of this work, Ciara regularly assesses how fire safety deficiencies relate to legislative, contractual and professional duties of those responsible for the provision of fire safety designs and fire protection systems.

Since joining BRE in 2012, Ciara has worked on a variety of research projects for UK Government and private concerns. Projects include: assessing the effect of fire on various electrical cable supports, the effect of fire on consumer units, reviewing performance of compartmentation in roof voids in past fires, large scale reconstructions and experiments following fires involving hotels and development of guidance on fires in the built environment for the National Operational Guidance programme for the UK Fire and Rescue Service.

Prior to BRE, Ciara lectured on Forensic Science, with a focus on Forensic Toxicology and Quality Assurance, at the University of Strathclyde as a Teaching Associate. She was responsible for the delivery of the fire science input on the Scottish National Fire Investigators Courses 2011/2012. Further responsibility within these courses involved assisting with the setup and data recording at ~18 live burns. She was further employed as a Research Associate at Strathclyde University to investigate an analytical method of analysis for brominated flame retardants.

Ciara holds an undergraduate degree in Forensic Chemistry and an MSc in Forensic Science. Ciara is a Member of the Chartered Society of Forensic Sciences, an Associate Member of the Institution of Fire Engineers, a member of the International Association of Arson Investigators (IAAI) and the UK Association of Fire Investigators (UK Chapter of IAAI). Ciara represents BRE Global on the UK's National Arson Prevention Forum and is a visiting lecturer on Fire Science and Fire Investigation at the University of Strathclyde.

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## EXPERIENCE

The following has been selected with respect to experience as a fire investigator.

- Ciara attended the scene at Oldham Street, Manchester in July 2013 following a firefighter fatality to investigate the fire on behalf of DCLG. Subsequently, Ciara provided an expert report to the

Coroner of the inquest held in May 2016 specifically addressing issues related to the fire loading in the premises at the time of the fire.

- Ciara is Deputy Project Manager for the Investigation of Real Fires project which BRE undertakes on behalf of DCLG. As part of this project Ciara has investigated issues with building performance at a number of fire scenes or following a fire at a premises including: Oldham Street, Manchester, July 2013 (firefighter fatality), Nottingham University, September 2014 (timber frame under-construction), Camden Market, May 2014 (market stalls) and Langley Mill, Derby, June 2015 (multi-fatal fire).
- Ciara has managed and led a number of large-scale experimental research projects looking at various aspects of fire safety performance of buildings including:
  - A programme of work which looked at the effect of fire on electrical cable supports and fixings following the deaths of a number of firefighters; the findings of this research were used to inform the latest amendment to BS 7671 – the wiring regulations.
  - A series of fire experiments investigating the performance of domestic consumer units in fires; the findings of this research were also used to inform an amendment to the wiring regulations (BS 7671).
  - A series of large-scale experiments assessing the performance of different external building façades including non-fire rated double glazing when exposed to a fire from below.
  - A series of experiments investigating fire spread along soffits in buildings to determine whether it provides a route for by-passing compartmentation.
  - Large-scale fire experiments to assess the fire development characteristics of photovoltaic lithium-ion battery storage units during a fire.
- Ciara has also carried out many laboratory fire experiments and fire reconstructions on structures and components to test hypotheses or assess possible fire performance in support of investigations following incidents. These experiments range from bench-scale analysis of toxic species evolved from burning electrical equipment in trains to large-scale reconstructions or partial reconstructions of incidents. Most notably a large-scale reconstruction and subsequent experimental programme to investigate fire safety solutions in relation to a series of fires at timber-frame hotels.
- Ciara has provided expert opinion on a number of legal cases. She has been involved in the defence of criminal cases including murder and arson with intent and reckless arson cases.
- Ciara has also provided assistance in a number of civil disputes where there was extensive or unusual fire spread as well as cases where there are disputes concerning the design and construction of premises which impact on fire safety. This includes matters concerning liabilities for damage post-fire and disputes over passive fire protection defects in various building types. Ciara has provided expert advice at mediation.
- Ciara was a key member of the team on a programme of work for the Chief Fire Officers' Association drafting the new suite of National Operational Guidance on Fires in the Built Environment. This guidance will be used by the UK Fire and Rescue Service by CFOA to provide a common understanding and common language for firefighters to understand the behaviour of buildings and structures during fires.
- Ciara is a member of the team conducting research into fire incidents involving photovoltaic/solar panel systems on behalf of the Department for Business, Energy and Industrial Strategy.

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Findings from the research will be used to monitor and improve the safe-use of these systems and inform guidance provided to Fire & Rescue Services when fighting fires involving these systems.

- Ciara is also proficient in the application and use of various analytical techniques including GC-MS, GC-FID, HPLC, FT-IR and UV for forensic investigations.

**PUBLICATIONS**

1. Holland, C, et al. (2012) Elemental analysis of paper using Laser Induced Breakdown Spectroscopy. Poster presentation at European Academy of Forensic Science Triennial Conference, August 2012.
2. Shipp, M, Crowder, D, Holland, C et al. (2013) Fire safety and solar electric/photovoltaic systems. International Fire Professional, October 2013; 6, pp. 12-17.
3. NicDaeid, N, Savage, K, Ramsay, D, Holland, C et al. (2014) Development of gas chromatography-mass spectrometry (GC-MS) and other rapid screening methods for the analysis of 16 'legal high' cathinone derivatives. Science & Justice, January 2014; 54 (1) pp. 22-31.
4. Holland, C. Understanding additional risks through the introduction of photovoltaics. Presentation at FIREX International 2014, Expertise & Guidance Theatre, ExCel London, June 2014.
5. Holland, C. Fire Investigation: An Intelligence Led Approach. Presentation at CFOA Conference: A View from the Top Floor at FIREX International 2014 ExCel London, June 2014.
6. Holland, C and Bulbrook, D. National Operational Guidance – Fires in the Built Environment. Presentation at the Institution of Fire Engineers AGM, Stratford-upon-Avon, June 2014.
7. Holland, C. Fires in educational premises – Is there a problem? Presentation at the Institution of Fire Engineers South East Branch Seminar on Fire Safety in Educational Premises and Compartmentation, Siemens HQ, Frimley, September 2014.
8. Holland, C. A series of experiments to assess the effect of fire on a selection of electrical cable supports. Presentation at the Institution of Fire Engineers RE14 conference, Fire Service College, Moreton-on-Marsh, November 2014.
9. Holland C. 3rd party certification and fire protection fakes. Presentation at the UK Association of Fire Investigators Annual Training Conference, University of London Union, January 2015.
10. Shipp, M, Holland, C, Crowder, D and Lennon, T. (2015) Gone to blazes; Tackling fire spread in roof voids. RIBA Journal. Available online February 2015.
11. Holland, C. (2015) Fire safety of cable installations in buildings. Building Engineer September 2015.
12. Holland, C. (2015) Process mapping deliberate fire investigation and prosecution - BRE perspective on provision of expert witness services. Arson Prevention Forum Conference, Emergency Services Show, September 2015.
13. Holland, C. (2016) Life safety and the UK Building Codes. Fire Toxicity 2016 Conference, University of Central Lancashire, Preston, March 2016.

14. Holland, C, Crowder, D and Shipp, M. (2016) External fire spread: New research Part 1. Building Engineer April 2016.

15. Holland, C, Crowder, D, Shipp, M and Cole, N. (2016) External fire spread (Part 2): New experiments on façade systems. Building Engineer May 2016.

16. Holland, C, Crowder, D and Shipp, M. (2016) Fire safety issues with balconies. Building Engineer July 2016.

17. Holland, C, Crowder, D and Shipp, M. (2016) Life safety and Regulation 7. Building Engineer January 2017.

18. Holland, C. Fire experiments with emerging technology. Presentation at the IFE South Wales Branch seminar, South Wales Fire & Rescue Service HQ, Llantrisant, April 2017.

19. Holland, C. Fire incidents in care homes and sheltered accommodation post-Rose Park Inquiry. Presentation at Fire Safety in Healthcare Services Conference 2017, Dublin, April 2017.

| NAME | DAVID BUTLER |
|---|---|
| CURRENT POSITION | Associate Director, HVAC Engineering and Building Diagnostics |
| ACADEMIC QUALIFICATIONS | MSc, BTech |
| PROFESSIONAL QUALIFICATIONS | Fellow of Institute of Refrigeration |
| SPECIALISATIONS | Physical mock-up testing, building diagnostics, site investigations and consultancy related to building services including heating, ventilation and air conditioning. |

## CAREER SUMMARY

Over 30 years' experience of designing and undertaking of physical mock-up tests, laboratory testing and site investigations and consultancy on the performance of building conditioning systems. This has included conventional HVAC systems and low energy and passive systems and heat pumps. Experience over the last 10 years of building investigations relating to building physics including overheating, condensation and the operation and performance of HVAC systems in houses, commercial and other buildings. Undertaken policy related work under DEFRA's MTP and for the Carbon Trust related to air conditioning.

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## EXPERT WITNESS RELATED

**2016 –** Investigation into dampness at Aberystwyth University for Balfour Beatty Investments.

**2016 –** Review of air conditioning at Linwood Community Leisure Centre for Renfrewshire Council.

**2013-2016 –** Expert opinion on overheating at Flat 164, 25 Barge Walk.

**2014 - 2016 –** Site investigation of dampness in thatched roof at Farthingale for Cunningham Lindsey.

**2015 –** Report on heat pump at Commongate Cottage Re: Mark Noble vs Finn Geotherm (referred by IDRS, International Dispute Resolution Centre).

**2015 –** Investigation into failure of computer centre cooling system failure at Surrey University for Clyde & Co.

**2015 –** Expert opinion on high humidity at Cedar Cottage, Blackheath for Eversheds LLP on behalf of Morden College.

**2015 –** Review of thermostatic mixing valve (TMV) failures at Elizabeth House, Thurrock for Devonshires Solicitors on behalf of Hanover Housing Association.

**2014 –** Reassessment of soffit insulation and condensation in flats for Paradigm Housing Group.

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**2014 –** Review of M&E Specification, Employers Requirements and contract documents of a large residential housing scheme for Rydon Construction.

**2014 –** Site investigation and review of underfloor heating system for Cunningham Lindsey.

**2014 –** Investigation into heating systems at Longtown for Riverside Housing Association.

**2014 –** Advice on ductwork insulation at Orford Park Leisure Hub for Warrington Borough Council.

**2013 –** Advice on overheating of hospital ward pantries for Lewisham Healthcare NHS Trust.

**2013 –** Review and expert opinion report for Accent Nene regarding defective air source heat pump installations in 101 dwellings.

**2011 to 2012 –** Detailed site investigations and monitoring of air to water heat pumps at a new housing development to determine cause of occupant complaints for the developer.

**2010 –** Detailed investigation into an electrically heated flat for Accent Nene.

**2006 to 2007 –** Expert Opinion on chilled beam performance at Bristol Harbourside for Kier Build. Briefing Kier Build and their solicitors and Barrister on technical aspects relating to chilled beams (and provision of technical testing services).

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**OTHER RELEVANT EXPERIENCE**

Full-scale physical mock-up testing of internal environments, including air movement, ventilation, heating/cooling performance and thermal comfort.

Laboratory testing of HVAC components including heat pumps.

Building diagnostics, consultancy and expert opinion on overheating, air quality, building health, control and energy efficiency related to building conditioning systems (mechanical and passive ventilation and cooling and heat pumps).

Client advice and design guidance on passive and low energy cooling and air conditioning systems.

Monitoring of building services systems and equipment in the field to assess system performance and building environmental parameters and to investigate overheating and condensation.

Development and review of testing methodologies to assess the thermal performance of buildings using the co-heating test method.

Technical Expert and Consultant to the Carbon Trust for various refrigeration related technologies including chillers, and new technology studies.

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**PAPERS AND PUBLICATIONS**

Over 80 published papers and technical articles including:

**Abela A, DJG Butler**. BRE Information Paper on Heat Metering. December 2016

**Butler DJG and A Dengel**. Review of co-heating test methodologies. NHBC Foundation 2013.

**Butler DJG.** Seminar presentation on Targeting packaged ac efficiency, RAC 2009, Birmingham NEC, 2009.

**Butler DJG.** Refrigeration for air conditioning buildings. Refrigeration: Optimising refrigeration systems for building services engineers, CIBSE, London 2008.

**Butler DJG, MJ Swainson**. The role of physical mock-up testing to predict air conditioning performance. CIBSE National Conference, 30 September 2004, London.

**Butler DJG (contract author)** CIBSE Guide B4. Refrigeration and heat rejection. The Chartered Institution of Building Services Engineers, September 2003.

| NAME | MARTIN SHIPP |
|---|---|
| CURRENT POSITION | Technical Development Director; Fire Safety, BRE Fire Safety Group |
| ACADEMIC QUALIFICATIONS | BSc (Hons) Physics |
| PROFESSIONAL QUALIFICATIONS | CEng FIFireE CPhys MInstP |
| SPECIALISATIONS | Research management, Fire investigation, Fire safety engineering, Fire safety management, Fire safety risk assessment , Expert witness, fire consultancy |

### CAREER SUMMARY

Martin Shipp currently has responsibility for fire safety engineering, fire investigation, fire safety management and projects related to all aspects of transport fire safety. He has over forty years' experience at BRE involving applied research, testing, risk assessment, fire investigation, project management, drafting of guidance documents and fire safety engineering consultancy.

Martin is a Chartered fire safety engineer, and has expertise in experimental research, consultancy, laboratory testing and fire safety management. He specialises in risk assessment and hazard analysis, building examination, on-site fire investigation and failure examination, design reviews, large-scale experimental research, vehicle and tunnel fire safety, and is an experienced expert witness. He has carried out investigations for many major UK fires in recent years.

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### FIRE INVESTIGATION EXPERIENCE

The following has been selected with respect to experience as a fire investigator.

1. Martin is a Chartered (fire) Engineer with the UK Engineering Council, and a Fellow of the Institution of Fire Engineers. He is a Chartered Physicist and a Member of the Institute of Physics. He is a member of the Board (Trustee) of the Institution of Fire Engineers and IFE International President 2017/2018.
2. Martin joined the BRE fire division (then, the Fire Research Station; FRS) in 1974, and has carried out fire safety research (primarily experimental and primarily for government clients) since then.
3. In 1988 Martin was called upon to assist the Department of Energy in its inquiry into the Piper Alpha disaster, and then to contribute to the Cullen enquiry by leading the BRE team that carried out an on-site investigation of the ERQ module from Piper Alpha, that had been recovered from the sea bed.
4. From 1988 to 2011 Martin has been head of the BRE team carrying out investigations of real fires, primarily for central government (building regulations). This has included the investigation

of numerous major fires including Windsor Castle 1992, and assisting Bedfordshire Police with the investigation into the Yarl's Wood Detention Centre fire in 2002[1].

5. Martin attended the Rosepark Care Home fire in 2004 and managed an extensive programme of laboratory research for the Scottish Executive and Procurator Fiscal in connection with the incident. He gave evidence to the Fatal Accident Inquiry for 3½ days in 2010.

6. Martin has carried out many laboratory fire experiments and fire reconstructions on structures and components to test hypotheses or assess possible fire performance following major incidents. See, for example, his Chapter "The use of laboratory reconstruction in fire investigations" which is Chapter 4 in the book "Fire Investigation" edited by Niamh Nic Daeid[2].

7. As a fire safety scientist, Martin has provided expert advice, and appeared in Court, on a number of criminal and civil legal cases, including the multi-fatality Falklands Hospital arson case (at the Old Bailey) 1984, the Yarl's Wood detention centre fire (at Harrow Crown Court) 2002, the multi-fatality Aviemore "Four Seasons" hotel fire (at Inverness Sheriff's Court) 1995, and a multi-fatality domestic fire in Dumfries (at Dumfries Sheriff's Court).

8. Martin has provided expert fire engineering advice to solicitors and barristers on a number of civil cases where there was extensive or unusual fire spread. This has included fires involving a large supermarket, a block of flats, a London hotel, and a large white goods warehouse. (None of these cases have come to Court.)

9. Martin was a member of the management committee of the Forum of Arson Investigators (now subsumed by the UK-AFI). He has been a guest member of the European Network of Forensic Science Institutes (ENFSI) Fire and Explosion Investigation Working Group. Martin has represented BRE on the UK's National Arson Control Forum.

10. From 1987 Martin was the BRE lead consultant to the UK/French Channel Tunnel Safety Authority (CTSA), advising on all aspects of fire safety (tunnel and rolling stock). Following the fire in the Tunnel in November 1996 he was appointed by the Safety Authority Inquiry Team to take the lead in the on-site investigation of the fire. His report on fire development was incorporated into the CTSA report into the incident[3,4].

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[1] The Ombudsman's report. Yarl's Wood 2002: Inquiry into a disturbance and fire. http://www.ppo.gov.uk/special-investigations/yarls-wood-02.html

[2] "Fire Investigation" edited by Niamh Nic Daeid. CRC Press Forensic Science Series, 2004. ISBN 9780415248914.

[3] "*Inquiry into the fire* on the *Heavy Goods Vehicle Shuttle 7539* on 18 November 1996". The Stationery Office, 1997, ISBN 9780115519314.

[4] Shipp M. (Contributor). `The Handbook of Tunnel Fire Safety`; Chapter 2, `Tunnel fire investigation I: The Channel Tunnel fire, 18 November 1996`. Edited by Alan Beard and Richard Carvel, Thomas Telford, 2005.

11. Martin was a member of the BRE team that assisted with the investigation into the Paddington (Ladbroke Grove) railway fire on behalf of Railtrack in 1999. Findings were incorporated in the Inquiry Report[5].

12. Martin provided assistance to Cornwall Fire and Rescue Service as part of the Penhallow Hotel fire investigation in 2007, and gave evidence (including computer modelling carried out by specialist colleagues) at the Coroner's Court for that incident.

13. Martin provided assistance to North Yorkshire Police as part of the investigation into the fatal fire which occurred in September 2009 in Buckrose Court, Norton, Malton, North Yorkshire, and gave evidence in Leeds Crown Court during the trial.

14. Martin provided assistance to Warwickshire Police as part of the Atherstone-on-Stour fire investigation in 2007, and has carried out laboratory reconstructions for that inquiry.

15. Martin was a member of the Metropolitan Police Service/ London Fire Brigade team investigating the fire at Lakanal House, Camberwell, July 2009.

16. During 2004/05 Martin led the BRE team drafting a number of the new guidance documents on fire safety risk assessment to support the Regulatory Reform (Fire Safety) Order (FSO) (for ODPM – now Department for Communities and Local Government (DCLG)).

17. Martin has carried out, or managed the carrying out of, fire safety risk assessments for a number of clients, including carrying out the fire safety risk assessment of HMS Victory for the Ministry of Defence (MOD) Navy at Portsmouth.

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**OTHER RELEVANT EXPERIENCE**

Managed and executed research, consultancy, risk assessment and drafting of guidance documents in the following areas:

- Fire safety in Tunnels and consultancy to Channel Tunnel Safety Authority. Development of key performance indicators for Fire Safety Engineering.
- Drafting of BS5599 Part 12 Managing fire safety (and management of parts of BS9999) for British Standards Institute (BSI).
- Drafting of CIBSE (Chartered Institution of Building Services Engineers) Guide E (Fire safety engineering) Chapter 14 Fire safety management.
- Drafting of Government Guidance documents, including parts of AD B (for DCLG), eight FSO Guides (for DCLG) and BB100 (for the Department for Children Schools and Families, now Department for Education).
- In 1992 Martin was asked by the European Space Agency (ESA) to review the fire safety provisions for the European module of the International Space Station, and this included being

[5] "The Ladbroke Grove Rail Inquiry ", Parts 1 and 2. The Rt Hon Lord Cullen. Health and Safety Commission, 2001. ISBN 0717620565.

project manager for a joint FRS/ESA experimental study of fires in space by carrying out fire experiments in micro-gravity during parabolic flights.

- Professional posts include: member of the BS committee FSH/14 to develop BS 9999:2008, drafting the section on the Management of Fire Safety (became BS 5588 Part 12). He was a member of drafting committee for CIBCE Guide E (Fire Engineering) (management section), member of the management committee of the Forum of Arson Investigators and guest member of the ENFSI Fire and Explosion Investigation Working Group. Member of the UK Association of Fire Investigators (the UK Chapter of the International Association of Arson Investigators (IAAI). Member of the CFOA Fire Investigation Strategic Steering Group. Member of the editorial board of Fire Safety Engineering magazine. BRE representative to the National Arson Control Forum. Elected member of the Board (Trustee) of the Institution of Fire Engineers and International President 2017/2018. Martin is on the executive board of the Fire Sector Federation and workstream chair for Fire Investigation.
- Member of the BRE team reviewing the fire strategy for Gatwick Airport on behalf of BAA (now Gatwick Airport Ltd). Led the BRE team in carrying out the fire safety risk assessment for HMS Victory on behalf of MOD. Acted as independent reviewer of the risk assessments from Penhallow hotel on behalf of Cornwall Fire and Rescue Service. Led the BRE team who carried out a laboratory reconstruction to assist in resolving a FSO dispute on behalf of Essex Fire and Rescue Service, and computer modelling to assist in resolving a FSO dispute on behalf of Edinburgh City Council.

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**PAPERS & PUBLICATIONS**

Martin has published and lectured extensively and is sole or joint author in over 200 publications and national or international conference papers. A selection of his most recent relevant outputs follows:

1. Williams C. and Shipp M. `Fire safety management`, CIBSE Guide E: Fire engineering guide launch, London, Friday 6th February 2004.
2. Shipp M. (Contributor). `Fire Investigation`; Chapter 4, `The use of laboratory reconstruction in fire investigations`. Edited by Niamh Nic Daeid, CRC Press Forensic Science Series, 2004.
3. Shipp M. (Contributor). `The Handbook of Tunnel Fire Safety`; Chapter 2, `Tunnel fire investigation I: The Channel Tunnel fire, 18th November 1996`. Edited by Alan Beard and Richard Carvel, Thomas Telford, 2005.
4. Shipp M and Harrison R. `Government advice`. Fire Prevention/Fire Engineers Journal Fire Industry Confederation Supplement "Fire Safety Order; your responsibilities explained", April 2006.
5. Shipp M. `Is fire safety management too difficult?`. Paper given at Building Better Schools - designing to maximise safety and minimise risk, BRE, Watford, 14th November 2006.
6. Shipp M. `School fires`. Paper given at "The Shape of Things to Come: Fire safety in our schools", the All-Party Parliamentary Fire Safety and Rescue Group meeting, House of Commons, Monday 4th December 2006.

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7. Shipp M. `Fire safety design solutions`. Paper given at "The Regulatory Reform (Fire Safety) Order 2005: Risk assessment and design implications", CIBSE Engineering Centre, Tuesday 30th January 2007

8. Martin B and Shipp M. `Recent changes to Approved Document B`. Fire Safety Professional, Issue 23, Spring 2007.

9. Fraser-Mitchell J, Shipp M, and others. `Building Bulletin 100: Design for fire safety in schools` (BB 100). Department for children, schools and families. RIBA Bookshops. 2007. http://www.teachernet.gov.uk/_doc/12199/BuildingBulletin100_onlineversion.pdf

10. Shipp M. `Fire Safety Regulatory Reform Order`. Presentation to AXA Insurance visit to BRE, 27th November 2007.

11. Shipp M. `The Guides`. Presentation at the IFE South Western Branch Seminar: "Fire Safety Order – suitable and sufficient?", Sandy Park, Exeter. 15th May 2008.

12. Shipp M. `Fire investigation as a Component of Community Risk Reduction`, IFE AGM and Conference 2008 "Innovation in Community Risk Reduction", Blackpool, 2nd and 3rd July 2008.

13. Shipp M. ` Managing fire safety and managing occupied buildings`. Presentation at the BSI launch "Fire Safety in Buildings BS 9999:2008", 15 Hatfields, London, Thursday 13th November 2008.

14. Shipp M. `An introduction to the FSO and the day` and ` What else? where next?`. Presentations at the BRE Conference "The Fire Safety Order – Practical Problems for Practitioners", 8th April 2009, BRE, Watford.

15. Shipp M and Smith V. ` What to do when there is no guide`. Presentation at the BRE Conference "The Fire Safety Order – Practical Problems for Practitioners", BRE, Watford, 8th April 2009.

16. Shipp M. (Contributor). `Fire Safety Management`. CIBSE Guide E: Fire Engineering, 3rd Edition. The Chartered Institution of Building Services Engineers. 2010.

17. Shipp M. `Fire Safety Management`. Presentation at the CIBSE Guide E: Fire Engineering Conference, CIBSE Engineering Centre, Balham. 17th May 2010.

18. Shipp M. `The Fire Safety Order - Challenges for the Risk Assessor`. Presentation at International Firex 2011, NEC Birmingham, Tuesday 17th May 2011.

19. Shipp M. `The role of sprinklers for fire safety in care homes: lessons learned from Rosepark`. Paper given at "Sprinklers save lives, property, money, jobs, communities, the environment, the evidence is compelling isn't it?", the All-Party Parliamentary Fire Safety and Rescue Group meeting, House of Commons and House of Lords, Westminster, Monday 6th February 2012.

20. Shipp M. ` Fire Development and Building Research Establishment` and ` Fire Safety Enforcement (and Building Research Establishment)`. Presentation at "The Penhallow Hotel Fire": Cornwall Fire & Rescue Service National Seminar, 28th March 2012.

21. Holland C, Shipp M and Crowder D. `A series of experiments to assess the effect of fire on a selection of electrical cable supports and fixings`. Wiring Matters - Autumn Issue 2015.

22. Shipp M. `Understanding the built environment and modern methods of construction`. Presentation at the Congress on the Future of Firefighter Safety, Caledonian Club, London, 9th October 2015.

23. Holland C, Crowder D and Shipp M. `External fire spread: New research Part 1`. Building Engineer. April 2016.

24. Holland C, Crowder D, Shipp M and Cole N. `External fire spread (Part 2): New experiments on façade systems`. Building Engineer. May 2016.

25. Holland C, Crowder D and Shipp M. `Fire safety issues with balconies`. Building Engineer. June 2016.

26. Shipp M. ` New fire safety knowledge from experimental research and investigations – a personal experience`. Presentation at the IFE 2016 International Conference "Fire Engineering Contributions to World Cities", the Guildhall, London. 27th and 28th July 2016.

27. Holland C, Crowder D and Shipp M. `Fire probes uncover cost of poor workmanship`. CIOB Construction Manager. 25th May 2017.

28. Shipp M. `Improving fire safety by research`. Presentation at the IFE 2017 International Conference "Learning lessons, sharing knowledge, saving lives, reducing losses". Greater Manchester Fire and Rescue Service Training Centre, Manchester. 11th -12th July 2017.

29. Shipp M. `Learning from Incidents, an International Perspective`. Presentation at the IFE Mid-Western Branch event "Fire-fighter Safety in Buildings Part 10 – 'New' Perspectives". Severn Park Training Centre, Avonmouth. 21st August 2017.





Report Ends