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

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

Phase 1 Report – Master file
incorporating Section 1, 2,3 and 4
&
Summary, Conclusions and Next Steps

REPORT OF

Dr Barbara Lane FREng CEng

Fire Safety Engineering

12th April 2018

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

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CONTENTS

1 Introduction

1.1 Formal Details

1.1.1 I am Dr Barbara Lane. I am a Director of Arup, and a member of the UK Middle East and Africa Board, within our Global Group structure. I am Group leader, an operational role, of the Advanced Technology and Applied Innovation Group in the UK. Arup is an independent company of designers, planners, engineers, consultants and technical specialists offering a broad range of professional services in the Built Environment. Arup is located at 13 Fitzroy Street, London, W1T 4BQ.

1.1.2 I am a Chartered Fire Engineer. I was made a Fellow of Arup in 2012 - a life-long, honorary title awarded to exceptional individuals in the firm considered role models with world-class vision and initiative. I specialise in fire safety engineering in the Built Environment. This includes during the design, construction and operational stages. My experience over the last 21 years incorporates specific experience on matters such as the consideration of regulatory compliant fire safety design and construction solutions, the performance and testing of construction materials in fire, and the handover process including cause and effect testing of fire safety systems, management duties, and handover documentation.

1.1.3 I was made a Fellow of the Royal Academy of Engineering in September 2016. The citation prepared by the selection committee states: "*..for crystallising fire safety engineering as a profession by immersing it in the field of building design and construction...[and integrating] it with other disciplines by incorporating structural engineering into fire analysis, and driving competence, education, regulation and stakeholder relationships.*" They additionally stated how I was also one of the first to: "*study, develop and bring to practice the explicit coupled analysis*[1] *of structures and fire - generating methods that migrated from science to the mainstream...*"

1.1.4 In Appendix A, I have provided my CV, which contains further details of my experience, qualifications, appointments and specialist fields.

1.1.5 I was assisted in preparing my report by my colleagues at Arup, Dr Susan Deeny, Dr Peter Woodburn, Dr Graeme Flint, Mr Tom Parker, Ms Danielle Antonellis, and Mr Alfred Chapman. Their CVs are provided in Appendix A.

1.1.6 I was assisted in my investigations on site by these colleagues too but additionally, Mr Joe Wade, Mr Conor Hoey, Mr Roy Little, Mr Marc Pawson, Mr Angus Elliott, and Mr Albert Voet.

1.1.7 However, this report, and the analysis and views expressed in this report, are my own.

[1] An advanced numerical model of the impact of heat from a fire, on complex structural stability systems.

1.2 Synopsis

1.2.1 The Government has set up an independent public inquiry into the fire which occurred on the 14th June 2017 at Grenfell Tower.

1.2.2 The Inquiry will examine the circumstances leading up to and surrounding the fire at Grenfell Tower on 14 June 2017. It will establish the facts and will make recommendations as to the action needed to prevent a similar tragedy happening again.

1.2.3 The Inquiry will be independent.

1.2.4 The Inquiry's Terms of Reference are:

1. To examine the circumstances surrounding the fire at Grenfell Tower on 14 June 2017, including:

   a) the immediate cause or causes of the fire and the means by which it spread to the whole of the building;

   b) the design and construction of the building and the decisions relating to its modification, refurbishment and management;

   c) the scope and adequacy of building regulations, fire regulations and other legislation, guidance and industry practice relating to the design, construction, equipping and management of high-rise residential buildings;

   d) whether such regulations, legislation, guidance and industry practice were complied with in the case of Grenfell Tower and the fire safety measures adopted in relation to it;

   e) the arrangements made by the local authority or other responsible bodies for receiving and acting upon information either obtained from local residents or available from other sources (including information derived from fires in other buildings) relating to the risk of fire at Grenfell Tower, and the action taken in response to such information;

   f) the fire prevention and fire safety measures in place at Grenfell Tower on 14 June 2017;

   g) the response of the London Fire Brigade to the fire; and

   h) the response of central and local government in the days immediately following the fire; and

2. To report its findings to the Prime Minister as soon as possible and to make recommendations.

1.2.5 As part of the call for evidence for this Public Inquiry, expert witnesses have been instructed to assist the Inquiry.

1.2.6 The expert witnesses are to provide a range of technical advice and expert reports to assist the work of the Inquiry in delivering against its Terms of Reference.

1.2.7 On the 16th November 2017 I was instructed as an Expert Witness to the Public Inquiry.

1.3 Disclosure of Interests

1.3.1 I have over the course of my 21-year career as a fire safety engineer at Arup, had various technical reasons on my projects, projects for other employees of Arup, and through my own research work, to interact with personnel from DCLG (now MHCLG), Kingspan, Celotex, NHBC, RBKC, LFB, Max Fordham, Siderise, SiG, BRE, Exova Warringtonfire, Professor Bisby, Professor Torero, Professor Galea. All of these organisations are referred to herein.

1.3.2 I have worked on projects or reviewed projects where the building envelope contained combustible materials, in that 21-year period.

1.3.3 I have since 2014, in public, expressed concerns regarding combustible insulating materials used in building envelopes. I have previously shared those concerns with the BRE, the DCLG, NHBC and Kingspan, and also via various public speaking engagements.

1.3.4 Other Arup staff have also given presentations on the subject of fire safe facades, and entered into discussions as a result, explaining those views, with companies such as Booth Muirie, one of the producers of ACP panels in this country. Booth Muirie, are wholly owned by Kingspan Group Ltd.

1.3.5 At the request of London Fire Brigade, I spent a few hours around the Grenfell Tower site (not in the building) late afternoon/evening on Wednesday the 14th June providing technical guidance to London Fire Brigade in their Command Unit, regarding potential structural fire collapse scenarios.

1.3.6 On the 16th June 2017, Arup was appointed by the Royal Borough of Chelsea and Kensington (RKBC), to provide technical support to James King of Harrow Building Control. This consisted of advice regarding the post-fire structural stability of Grenfell Tower, during body recovery only. Our involvement is now complete.

1.3.7 I spent the entire day of Friday the 16th June around the site, outside the building only, again providing advice regarding post-fire structural stability. On that day I was in the company of Mr John Allen, Building Control officer, from RKBC. Various firefighters from London Fire Brigade, members of the Metropolitan Police Service, and a representative of the HSE, were also in my presence at times throughout that day also, as were two other members of Arup staff.

1.3.8 Arup was also appointed by RKBC, immediately after the Grenfell Tower fire, to carry out an audit of the compliance status of the Kensington Row high rise residential building. Our involvement is now completed.

1.3.9 I am a post-graduate of Edinburgh University were I studied under the supervision of Professor Dougal Drysdale.

1.3.10 I was a Visiting Professor at the University of Edinburgh for over five years. I resigned when I was made aware that academic staff at the University were interacting with the BRE on Grenfell-related fire safety matters. These staff work at the *The BRE Centre for Fire Safety Engineering* at the University of Edinburgh. My own work at the University involved the supervision of Arup funded PhD students, an annual research planning meeting regarding research for Arup projects, the occasional undergraduate lecture for recruitment to Arup, and the funding of an Arup Professor of Structural Fire Engineering.

1.3.11 In my investigation of the facts and in expressing my opinion herein, I don't consider these interactions to have caused any actual or potential conflict of interest.

1.3.12 Regarding my assistants, I describe their interests as follows.

1.3.13 Dr Deeny, completed her PhD (2006-2010) within the *The BRE Centre for Fire Safety Engineering* at the University of Edinburgh.

1.3.14 In the course of her 8-year professional career as a fire safety engineer she has had various technical reasons on her projects and through Arup's external research activities to interact with personnel from *The BRE Centre for Fire Safety Engineering:* Professor Luke Bisby (Expert to the Inquiry), Professor Jose Torero (Expert to the Inquiry) and Dr Rory Hadden (MPS Forensic Expert Review Group (FERG). Professor Torero no longer works from the University of Edinburgh.

1.3.15 Dr Flint is a graduate of the University of Edinburgh. In addition, he has over the course of his 11-year career as a fire safety engineer at Arup had various technical reasons on his projects, projects for other employees of Arup, and through his own research work, to interact with personnel from Kingspan, Celotex, RBKC, NHBC, LFB, Max Fordham, Siderise, BRE, Exova Warringtonfire, Professor Bisby, Professor Torero. All of these organisations are referred to herein.

1.3.16 During his time as a professional engineer he has worked on projects or reviewed projects where the building envelope contained combustible materials.

1.3.17 As part of his graduate training at Arup he undertook a 10-week placement with the London Fire Brigade Fire Engineering Group.

1.3.18 He assisted me when advising RBKC on the 14th June 2017 and over the following weeks, regarding the structural stability of Grenfell Tower in the aftermath of the fire.

1.3.19 Dr Peter Woodburn has been involved in Fire Engineering and Fire Science since 1990. He was professionally employed by Atkins, Halcrow (CH2M Hill) and since April 2015 by Arup as a fire safety engineer.

1.3.20 He was employed by the Civil Engineering Department, University of Edinburgh as a Research Associate in fire engineering over the period 1995-1996.

1.3.21 In his professional career he has interacted with London Fire Brigade on several projects.

1.3.22 During his employment at Arup he has undertaken liaison with University of Edinburgh on research at the University funded by Arup, including Arup-funded PhD students.

1.3.23 Dr Woodburn assisted me when advising RBKC on the 14th June 2017 and over the following weeks, regarding the structural stability of Grenfell Tower in the aftermath of the fire.

1.3.24 Mr Tom Parker is a graduate of the University of Edinburgh and was taught by Professor Bisby, and Professor Torero. In addition, he has over the course of his 3-year career as a fire safety engineer at Arup had various technical reasons on his projects, and projects for other employees of Arup, to interact with personnel from Kingspan, Celotex, Siderise, BRE, Exova Warringtonfire. All of these organisations are referred to herein.

1.3.25 During his time as a professional engineer he has worked on projects or reviewed projects where the building envelope contained combustible materials.

1.3.26 In my investigation of the facts and in expressing my opinion herein, I don't consider these interactions to have caused any actual or potential conflict of interest.

1.3.27 Mrs Danielle Antonellis is a graduate of Worcester Polytechnic Institute. She was professionally employed by Tyco Fire Protection Products (now Johnson Controls) and since May 2014 by Arup as a fire safety engineer. Danielle was previously based at Arup's Boston (USA) office and Arup's Hong Kong SAR office. She has been based at Arup's London office since February 2018. She has not currently worked with any of the parties identified in the Public Inquiry.

1.3.28 Mr Alfie Chapman graduated from the University of Edinburgh in 2016, he was taught by, and the second reader of his MEng thesis was, Professor Luke Bisby. He joined Arup in Edinburgh in September 2016 and has since returned to the University of Edinburgh to give recruitment talks. He has not worked with any other parties identified in the Public Inquiry.

1.4 Disclaimer

1.4.1 I understand that this report will be made available to the Core Participants in these Public Inquiry proceedings, the Core Participants' legal advisers', the Judge and his assessors, and this report has been prepared to that end.

1.4.2 In all other respects, this report is confidential and may not be used, reproduced or circulated for any other purpose (whether in whole or in part) without my prior written consent.

1.4.3 Neither I nor Arup accepts any responsibility to third parties for the unauthorised use of this report.

2 Issues

2.1 Instructions

2.1.1 On the 16th November 2017 I was instructed as an Expert Witness and to do the following.

2.1.2 To provide reports, for the purposes of Phases 1 & 2 of the Inquiry, which address the following issues:

1. Design and construction of the building and decisions relating to modification and refurbishment;
2. Fire prevention and fire safety measures in place at Grenfell Tower on 14th June 2017
3. Whether regulations, legislation, guidance and industry practice were complied with in the case of Grenfell Tower and the fire safety measures adopted in relation to Grenfell Tower;
4. Recommendations about what, if any changes could be made to the regulatory regime and industry practice to prevent a similar incident from happening in the future.

2.1.3 Specifically, for this Phase 1, I am instructed to provide a preliminary report on the identification of the active and passive fire protection measures within Grenfell Tower on 14th June 2017, including preliminary conclusions (where possible) as to the extent to which they:

a) failed to control the spread of fire and smoke; and

b) contributed to the speed at which the fire spread.

2.1.4 In Phase 2, I am instructed to provide a report on:

a) The design and construction of Grenfell Tower and the decisions relating to its modification, refurbishment and management (so far as is relevant to the events on the night of 14 June 2017);

b) whether such regulations, legislation, guidance and industry practice were complied with in the case of Grenfell Tower and the fire safety measures adopted in relation to fire and

c) final conclusions on the active and passive fire protection measures within Grenfell Tower on 14th June 2017 and the extent to which they: (1) failed to control the spread of fire and smoke and (2) Contributed to the speed at which the fire spread.

d) Recommendations about what, if any changes could be made to the regulatory regime and industry practice to prevent a similar incident from happening in the future.

2.1.5 I am therefore, to make the necessary technical investigations and to express my opinion with full reasons on each of these issues.

2.2 Statements considered

2.2.1 I have been provided with witness statements given by the London Fire Brigade (LFB) to the Metropolitan Police Services (MPS). Where I have referred to the content of these witness statements, I have referenced the witness statement accordingly. I am aware that the process of taking firefighter witness statements is ongoing and that the Inquiry is receiving rolling disclosure of firefighter witness statements.

2.2.2 When I am provided with any additional firefighter witness statements I will review these, and update my report as necessary.

2.2.3 I am aware that those who escaped Grenfell Tower on the night of the fire are yet to provide witness statements to the Inquiry. Once these are available, where necessary, I will update my analysis in this Report to take into account their evidence.

2.2.4 I have been provided with witness statements given by some of the residents in Grenfell Tower to the Metropolitan Police Services (MPS). At this stage I have been told that I am unable to refer to those police statements in this report. I have not relied on those statements in giving the opinions I express in this report.

2.2.5 Please note I have not listened to any of the 999 calls at this stage. This will be the subject of expert evidence by others, and particularly Professor Ed Galea.

2.3 Documents considered in forming my opinion

2.3.1 The Inquiry is using an online document management platform called Relativity. I have been provided with access to my own workspace on Relativity, which contains documents provided to me by the Inquiry. Additional documentation has been provided to me by the Inquiry as and when it has been disclosed by document providers. From time to time, I have also made my own requests to the Inquiry for specific documents and, where available, these documents have been provided to me.

2.3.2 I have reviewed an extensive number of relevant documents relevant to the Issues forming the basis of this report. Where I have relied on documents that are material to my opinions, I have referenced them specifically in the body of this report.

2.3.3 I am aware that disclosure to the Inquiry is ongoing and that further documents, witness statements or information may become available in the future. Further, in some places in this report I say that certain documents have not been disclosed. This means that, at the time of writing my report, I have not seen such a document. If I need to revise the views expressed in this Report in light of further disclosure, I will inform the Inquiry.

2.4 Site investigations

2.4.1 In preparing this Phase 1 report I have carried out a series of post-fire site inspections at Grenfell Tower. The purpose of my site inspections was to identify the active and passive fire protection measures, as were present within Grenfell Tower on 14th June 2017.

2.4.2 I also recorded post-fire damage, and explored as built construction detailing. These investigations are summarised in Appendix C.

2.4.3 All my photographic evidence has been uploaded into Relativity.

2.4.4 I provide photos throughout my Report and its Appendices, and I make clear where they are Arup photos, and so taken by me or a member of the Arup team, who attended site with me.

2.4.5 I intend to return to Grenfell Tower, if possible, to carry out some additional fire door inspections, and analyse the interfaces with the detection system, to cross check final measurements, and make any other final observations.

2.4.6 I explain the methodology I applied on site in Section 6, and I explain the role of each member of my team when we were on site.

2.5 Outstanding information

2.5.1 There is still information I would like to be provided to me, as part of my work for the Public Inquiry. This information is documented in full and has been disclosed to the Public Inquiry team.

2.5.2 I will update my report when evidence is provided to me that requires me to change any of my assumptions, analysis or conclusions. I have all the substantial documents I needed to rely on, in writing this Phase 1 report.

2.5.3 It is important I make clear that the following information has not been provided to me, and this information is particularly relevant to finalising my opinion on the active fire protection systems, and the interfaces provided at Grenfell Tower:

a) Copy of the application programme for Smoke Control System Programmable Controller.

b) Fire alarm log showing Activations, Disablements, and Faults.

c) Fire alarm cause and effect programme.

d) Copy of the BMS (Building Management System) application programme.

2.6 Issues addressed in my report

2.6.1 This is my Phase 1 report. I have investigated the following issues, insofar as the evidence is available to me:

1. the design and construction of the building and decisions relating to modification and refurbishment since 2011;
2. the fire prevention and fire safety measures in place at Grenfell Tower on 14th June 2017; and
3. whether regulations, legislation, and guidance were complied with in the case of Grenfell Tower and the fire safety measures adopted in relation to Grenfell Tower.

2.6.2 The remainder of my report is split into eighteen technical sections, and addresses the following issues:

Section 3 Building description including fire safety requirements

Section 4 Description of the refurbishment works

Section 5 The observed events of 14th June 2017

Section 6 Investigating how this happened – the physical evidence at Grenfell Tower

Section 7 Where the fire started

Section 8 The Building Envelope – materials and construction

Section 9 Resulting routes for fire spread out and in through the window openings

Section 10 Resulting routes for vertical and horizontal fire spread throughout the Building Envelope

Section 11 Construction of the external walls – the provisions made at Grenfell Tower to comply with Building Regulations

Section 12 The significance of the building envelope fire

Section 13 Critical times during the fire event

Section 14 The performance of the protected stair and lobbies

Section 15 Construction of the common lobbies – the provisions made at Grenfell Tower to comply with Building Regulations

Section 16 Construction of the single protected stair – the provisions made at Grenfell Tower to comply with Building Regulations

Section 17 External firefighting – the provisions available at Grenfell Tower

Section 18 Communicating with residents in an emergency

Section 19 How the protected stair and lobbies failed for firefighters and for residents

Section 20 The consequences of the failures in Grenfell Tower

Section 21 Experts Declaration

2.6.3 I have provided additional supporting information in the following series of Appendices:

Appendix A: Experience, Qualifications, Appointments, Speciality of the Expert and of those who have assisted in the preparation of the report

Appendix B: Texts and published material referred to

Appendix C: Excerpts from Site inspection records from Grenfell Tower

Appendix D: Legislation, Regulations and Guidance relevant to Grenfell Tower

Appendix E: Compliance Assessment - External Fire Spread Regulation B4

Appendix F: Reaction to fire tests and classifications

Appendix G: Compliance Assessment means of warning and escape Regulation B1

Appendix H: Compliance Assessment - access and facilities for the Fire and Rescue Services Regulation B5

Appendix I: Flat Entrance fire doors and Stair fire doors – requirements and provisions

Appendix J: Smoke extract – requirements and provisions

Appendix K: Gas supply – fire safety requirements and provisions

Summary

2.6.4 In this Summary section of my Phase 1 report I have:

(1) provided a summary of my key factual findings (see paragraphs 2.7 – 2.16); and

(2) set out my conclusions on the matters I was asked to address in this Phase 1 report (see paragraphs Conclusions 2.17 – 2.23); and

(3) I provide some proposed Next Steps in paragraphs 2.24 to 2.32.

2.7 Overview of my approach

2.7.1 Using my site observations, and based on the documentation available to me, I have analysed how the fire spread from Flat 16, how it spread around each elevation of the building, and the timings of this fire spread (Section 5, 13).

2.7.2 I analysed the evacuation times of all residents who left the Tower (Section 14). I analysed the movement within the Tower of those residents who did not get the opportunity to evacuate, and died at the Tower (Section 20).

2.7.3 I analysed the London Fire Brigade (LFB) response with respect to critical times only, as I explain in Section 5, 12, 17 and 20. Their chain of command and critical decision making and processes are the subject of expert evidence by others in this Public Inquiry.

2.7.4 I carried out an assessment of compliance with the Building Regulations, by reference to *British Standard Code of Practice CP3: Chapter IV Part 1 Flats and Maisonettes (in blocks over two storeys), 1971* (referred to as CP3 herein), - the guidance that applied at the time of construction, and by reference to *Approved Document B Fire Safety Volume 2 – Buildings other than Dwelling Houses 2006, incorporating 2013 amendments* (referred to as ADB 2013 herein) - the statutory guidance which applied at the time of the main refurbishment works from 2012-2016 (Section 11, 15, and 16).

2.7.5 In my Conclusions section (Section 2.17 -2.23) I provide my preliminary conclusions as to the extent to which the active and passive fire protection measures within Grenfell Tower on 14th June 2017:

(a) failed to control the spread of fire and smoke; and

(b) contributed to the speed at which the fire spread.

2.7.6 I am aware of a range of opinion as to ways of complying with Building Regulation B4 External Fire Spread, specifically regarding the application of the words *Filler material* to Aluminium Composite Panels (ACP), and regarding the appropriate reaction to fire tests relevant to the fire performance of External Surfaces and relevant to the fire performance of Insulation (as relevant to Section 12 in ADB 2013).

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2.7.7 I have set out herein, and in detail in my Report, my analysis of this subject (carried out since the Grenfell fire). I have also included my own conclusions regarding whether the cladding system installed at Grenfell Tower complied with the Building Regulations.

2.7.8 In due course I intend to produce an additional detailed report on this subject, and also on the overall culture of compliance regarding the B4 requirement. This will include industry guidance – I have not incorporated industry guidance in this Phase 1 report.

2.7.9 In preparing this report, it has also been necessary for me to analyse the performance of the active and passive systems prior to and after LFB made the formal decision to end the Stay Put strategy.

2.7.10 I have therefore provided my opinion and a preliminary conclusion on the subject of the timing of the change to the Stay Put strategy and what this meant for the life safety of the residents.

2.7.11 As I explain below, because Stay Put relies, in part, on early firefighting and an assumption of early suppression of one internal fire event, I have also incorporated a review of firefighting access and facilities in this report and set out preliminary conclusions on this subject.

2.8 Building Description and the key fire safety requirements

2.8.1 Grenfell Tower was a twenty-five storey residential block built in the early 1970's, located in the Lancaster West Estate in North Kensington, London. This Estate is located in the Royal Borough of Kensington and Chelsea (RBKC). The 67.30-metre (220 ft 10 in) tall building originally contained 120 one- and two-bedroom flats (six dwellings per floor on twenty of the twenty-five storeys) with Ground, Level 1, 2 and 3 assigned to non-residential purposes. These non-residential purposes were altered to provide an additional 9 flats during the 2012-2016 refurbishment program.

2.8.2 Grenfell Tower was subject to a number of refurbishment activities between construction and the fire of 14th June 2017. Of these, the most significant were the fire door replacement program of 2011-2012, the main refurbishment of 2012-16 which included the installation of a new external rainscreen cladding system, and the gas supply refurbishment works 2016-17 (still in progress at the time of the fire). I will describe these works further below.

2.8.3 On the 14th June 2017, a fire started in the kitchen of Flat16, on Level 4 of the Tower.

2.8.4 The first call to London Fire Brigade is recorded at 00:54. By 01:14, the internal kitchen fire broke out of the top portion of the kitchen window, around the kitchen extract fan, with flames protruding beside a column forming part of the overall stability system of the Tower. This column was overclad with a new rainscreen cladding system. This system had been installed over the existing building external wall, during a refurbishment programme that took place in 2012-2016.

2.8.5 These flames started an external fire in the rainscreen cladding system. By 01:29, the external fire had spread to the top of Level 23, on the East elevation of the Tower, directly above Flat 16. By 01:42, 02:25, and 02:51, the North, South, and West elevations respectively, had become involved in the external fire. I have provided a description of the observed events in Section 5 of this report. I have explained the location of the first fire in Section 7 of this report.

2.8.6 A total of 71 people died because of the fire on 14th June 2017, with a further resident losing her life on 29th January 2018.

2.8.7 A single means of escape was provided in the Tower, and the evacuation strategy was one termed Stay Put. In my Report, where I refer to **Stay Put**, I mean an evacuation strategy where occupants, other than in the flat of fire origin, are deemed safe to remain in place whilst the fire in the flat of fire origin is dealt with by the fire and rescue services.

2.8.8 As I explain in Section 3 of this report, fire safety is achieved through the provision of multiple forms of fire safety measures, both active and passive. The 'layered approach' or 'defence in depth' should achieve a high level of safety through the provision of multiple forms of fire safety measures. This is the underlying approach of many safety frameworks, not just fire safety.

2.8.9 Individual layers are not necessarily required to be sophisticated or of a very high reliability. Instead, a high level of safety is achieved through aggregating each layer. Therefore, in theory, lapses and weaknesses in one defence layer should not allow a substantial risk to materialize, since other defences also exist to prevent a catastrophic failure in safety.

2.8.10 However, loss of several layers of safety can greatly increase the likelihood of a catastrophic incident. This is important because it means the provision of all the required layers of safety (not some) form an essential part of the design and construction process.

2.8.11 Provision of layers of safety relies, in its final form, on the maintenance of those provisions by the fire safety management regime in an occupied building. This regime must therefore be cognisant of all the layers of safety and must take steps to maintain all the required layers of safety.

2.8.12 It is a system that should, from design and construction, and then through to handover and occupation of a building, place strong importance and value on the clear understanding and delivery of the layers of safety.

2.8.13 This requires understanding and clear communication from all those involved in the system, to produce a safe building. This understanding must include therefore, how those layers have been provided, and upon what they rely for maintenance, and what is required to ensure safe operation of those layers, in the event of a fire. I will investigate the details surrounding these matters as they are relevant to Grenfell Tower, in my Phase 2 report.

2.8.14 At the time of construction of the Tower, the relevant fire safety design guidance for Grenfell Tower was *British Standard Code of Practice CP3: chapter IV Precautions against Fire, Part 1. Flats and maisonettes (in blocks over 2 storeys) 1971* (CP3), which was intended to provide a means of compliance with the London Building Acts (Amendment) Act 1939.

2.8.15 At the time of the refurbishment works, the "full plans" building control application was made in September 2014 and so Approved Document B 2013 (ADB 2013), was the statutory guidance relevant for compliance with the Building Regulations 2010.

2.8.16 As I have explained in Section 3 of this report, current guidance is explicit in its reliance on compartmentation and the fire resisting construction of common parts in order to support a Stay Put strategy.

2.8.17 The assumption forming the basis of the layers of safety in a high-rise residential building is that the most likely fire scenario is a single dwelling fire or a minor fire in a common lobby.

2.8.18 The layers of safety are not intended to mitigate the consequences of a multi storey building envelope fire. Nor are they intended to mitigate a whole series of internal flat fires occurring on multiple storeys, resulting from an external fire event.

2.8.19 Such events are not considered as relevant fire events by the current Regulations and published guidance.

2.8.20 The statutory regime also assumes that water will be applied early in a fire by the fire brigade, and that the fire brigade will extinguish a fire early. This critical role of the fire brigade has been a theme in the statutory regime since the 1962 edition of CP3. This is my definition of **"Defend in Place"** firefighting tactics. (Please refer to Section 3 for additional information).

2.8.21 The active and passive fire protection measures are provided to support this form of firefighting. This includes the high degree of compartmentation and the smoke ventilation in the lobby. Should a fire not be extinguished early (and even if smoke reaches the lobby outside the dwelling), the intention is that the stairway remains protected for use for occupants above the fire floor. In this scenario ADB 2013 considers '*that simultaneous evacuation of the building is unlikely to be necessary.*'

2.8.22 Since the publication of CP3 and retained in the most recent statutory guidance document ADB 2013 (as well as the most recent non-statutory guidance document for residential buildings, BS9991 2015), the layers of safety forming the basis of fire safety guidance in high rise residential buildings are:

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

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

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

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

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

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

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

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

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

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

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

2.8.23 Since 2006, the statutory and non-statutory guidance has also included a requirement to install sprinklers in new high-rise blocks of flats, i.e. buildings greater than 30m in height. However, there has not been a requirement to retrofit sprinklers in high rise blocks of flats constructed before 2006.

2.8.24 This results in a package of fire protection measures that includes a combination of construction, systems, early firefighting intervention, and fire safety management actions. All elements of this combination are required to support a Stay Put strategy.

2.8.25 A **Stay Put** strategy relies on the early suppression by the fire and rescue services, of an internal fire event i.e. **Defend in Place** firefighting. An internal fire event is defined within the published guidance documents, as a fire within a flat, or a limited fire in the common areas outside a flat.

2.9 Relevant refurbishment works

2.9.1 Grenfell Tower is owned by the Local Authority – the Royal Borough of Kensington and Chelsea. Grenfell Tower was part of their provision of social housing in the borough. The management of social housing in the borough was devolved to the Kensington and Chelsea Tenant Management Organisation (KCTMO), a tenant management organisation, in 1996.

2.9.2 The architect for the 2012-2016 refurbishment works was Studio E, and the principal contractor for the works was Rydon. The fire engineer for the project was Exova Warringtonfire. The client for the refurbishment works was KCTMO. The refurbishment works were funded by RBKC and the funds were released in May 2012. The Department of Building Control at the RBKC acted as building control authority.

2.9.3 The refurbishment in 2012 – 2016 was substantial. It incorporated the over cladding of every storey of the existing building with a rainscreen cladding system. The cladding subcontractor was Harley Facades (formerly Harley Curtain Wall). Additionally, there was a full refurbishment internally of Ground Level to Level 3 inclusive, including structural works. There were building services works within every floor and every flat in the Tower. The services engineer was Max Fordham. The services contractor was J S Wright.

2.9.4 The external wall construction of Grenfell Tower was originally of concrete construction. The refurbishment of the building envelope consisted of the addition of a drained and ventilated rainscreen cladding system.

2.9.5 There is a useful definition of the purpose of a rainscreen in the (BS 8298-4) *Code of practice for the design and installation of natural stone cladding and lining, rainscreen and stone on metal frame cladding systems.* It defines the key elements creating a ventilated rainscreen cladding system as:

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

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

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

2.9.6 From Level 4 – 23 at Grenfell Tower, the rainscreen outer layer was manufactured by Arconic Inc. and fabricated for use at Grenfell Tower by CEP Architectural Facades. The rainscreen cladding was a Reynobond 55 PE cassette system. In particular, it consisted of:

(a) Reynobond 55 PE 4mm Smoke Silver Metallic E9107S DG 5000 Washcoat – the Arconic order acknowledgements and associated CEP purchase orders confirm the total area of this product purchased for Grenfell Tower was 6586 m^2 (note this product was supplied in five different lengths and three different widths); and

(b) Reynobond 55 PE 4mm Pure White A9110S DG 5000 Washcoat- the Arconic order acknowledgement and associated CEP purchase order confirms the total area of this product purchased for Grenfell Tower was 180m^2.

2.9.7 At Grenfell Tower cladding panels were hooked onto bolts attached to a continuous cladding rail. Whereas in the standard Arconic Inc. system the bolt is fixed into individual brackets which are then attached to a cladding rail.

2.9.8 As the dimensions of the panels shape and fixing method observed onsite deviate from the standard Arconic Inc. details, I consider it is likely that a bespoke system (using Reynobond 55 PE panels but not in accordance with the standard Arconic systems) was installed at Grenfell Tower.

2.9.9 At this stage it is my opinion CEP fabricators received the ACP panels from Arconic Inc. then formed them into a bespoke cassette shape with a bespoke fixing detail. I require evidence from CEP to explain their process and procedures, and I will address this in my Phase 2 report.

2.9.10 The cavity was approximately 140mm in depth over columns and approximately 155mm deep over spandrels (spandrels are horizontal sections running above and below the windows, and connecting each column).

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

2.9.12 New windows were installed on every floor. The new windows were Metal Technologies 5-20 HI thermally broken windows. These windows were able to open fully inward to allow summertime heat purging. Between each window new infill panels were provided. These were the product Aluglaze, formed of an insulating core of 25mm of Styrofoam (expanded polystyrene) and sandwiched between 1.5mm thick aluminium panels.

2.9.13 Additionally, for the new windows in any kitchen, and specifically where the kitchen extract vent was to be located, an aluminium insulating core panel formed of 1.5mm aluminium layers sandwiching 25mm thick Kingspan TP10 polyisocyuranate (PIR) foam, was to be provided. I have found instead, that these also appear to have been made with Aluglaze, from my investigations on site.

2.9.14 The cavity created by the new and old infill panels was enclosed with either Kingspan Thermapitch TP10 or Celotex TB4000. The window reveals, on all four sides, were insulated with either Kingpsan Thermapitch TP10 or Celotex TB4000, and faced with uPVC.

2.9.15 The refurbishment also included internal works such as the extension of the existing dry riser in the building, as well as the implementation of a new smoke ventilation system for every lobby to the single stair. A new heating system was provided to the building to supply every flat, resulting in works in the residential lobby to the single stair on each floor and within each flat on each floor.

2.9.16 There are two other refurbishment works projects, separate to the 2012-2016 refurbishment, that I have concluded as being directly relevant to my investigation of the active and passive systems that existed in Grenfell Tower the night of the fire. These works are:

(a) The flat entrance door fire door replacement works which took place in 2011 from Levels 4 – 23 inclusive, as carried out by Manse Masterdor Limited, for the KCTMO; and

(b) The gas supply works which took place between October 2016 and June 2017. These works were still in progress at the time of the fire. These works were being carried out by tRIIO (Principal Designer) and several subcontractors namely, Holland Gas Engineers Ltd and Express Building Contractors Limited, for Cadent. As the owner and operator of the gas pipework distributed to the emergency control valve in each flat, Cadent was the initiator of the works and the company paying for these gas works.

2.9.17 I explain those works in Section 4 of my report, and the resulting active and passive fire protection measures in place in Grenfell Tower on the night of the fire on 14th June 2017 (please refer also to Section 15 and 16 of my report).

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

2.10.1 I have provided a detailed explanation of the statutory guidance in my Appendices.

2.10.2 Based on that statutory framework, I have identified in the Table A below the active and passive fire protection measures which are relevant to Grenfell Tower.

2.10.3 This list of active and passive fire protection measures assumes a high degree of compartmentation. This is necessary to support the Stay Put strategy. The high degree of compartmentation also supports the firefighting tactic Defend in Place.

2.10.4 A high degree of compartmentation also relies on compliance with Regulation B4 for External Fire Spread - *The external walls of the building shall adequately resist the spread of fire over the walls ..., having regard to the height, use and position of the building*. That is necessary to prevent the type of fire spread observed at Grenfell Tower – an external fire spreading and breaching the internal compartmentation, and so entering multiple separate flats.

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

2.10.6 They provide the means for early internal firefighting. They provide the means to limit fire and smoke spread from a dwelling fire, or from a small common lobby fire. They ultimately create the "high degree of compartmentation" to support the Stay Put strategy in a high rise residential building.

Table A: Active and Passive fire safety systems relevant to Grenfell Tower.

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

2.11 The external fire spread and the increasing involvement of flats other than Flat 16

2.11.1 A fire started in Flat 16 on Level 4 of Grenfell Tower on 14th June 2017, and subsequently started to spread up the building's East envelope by 01:14. In Section 7 of my report I explain my understanding of where the fire started and how it exited Flat 16 on the 4th floor of Grenfell Tower.

2.11.2 In Section 8, 9 and 10 of my report I explain the materials forming the rainscreen cladding system installed on Grenfell Tower, and how their arrangement supported the spread of fire out through the kitchen window of Flat 16. I also explain how those materials and their arrangement, supported the spread of fire through the rainscreen cladding system, in multiple pathways. This ultimately created a fire event that spread around all 4 elevations on 14th June 2017.

2.11.3 The vertical fire spread was primarily along column lines.

2.11.4 The horizontal fire spread was primarily (a) along the rainscreen cladding system above and below windows, and (b)as well as through the infill panels between windows (insulating core panels); both routes aided by the insulation materials surrounding the new window openings, the insulation materials surrounding the cavity formed between the new and old infill panels, and either the lack of fire resisting cavity barriers, or the presence of defective cavity barriers. I explain this in detail in Section 9 and Section 10 of my report.

2.11.5 In Section 5 of my report, I present a chronological analysis of the external fire spread around Grenfell Tower through a series of photographs. I provide a summary of the two main flame fronts below, the timing of which are compared with the evacuation rate, in Figure B below.

2.11.6 Once the fire spread to the building envelope adjacent to column B5 (the column directly outside the kitchen window of Flat 16), it spread in two horizontal directions around the building – towards the North elevation and towards the South elevation of the building. The fire eventually spread to the building envelope on all four elevations, fully enveloping the building perimeter at approximately 04:03.

2.11.7 Regarding the sequence of events during this fire spread, the first London Fire Brigade call to the incident was at 00:54.

2.11.8 Fire spread out of the window on Level 4 to column B5 on the East elevation of the building envelope. The first image of fire taking hold outside Flat 16 was at approximately 01:14.

2.11.9 The fire spread vertically along the line of column B5, reaching approximately Level 13 (37m above Ground Level) by 01:22, and reaching Level 23 along column B5, by 01:26. Therefore, in approximately 12 minutes, the fire spread up 19 storeys on the East elevation of the building.

2.11.10 Significant burning debris started to fall off the building by this time. Falling debris was a significant hazard for those occupants who decided to evacuate the building, and who did not Stay Put. It was also a significant hazard for emergency responders (Fire Brigade, Ambulance, and Police) throughout the fire.

2.11.11 By 01:36 the fire spread was in two horizontal and opposite directions on the East elevation of the building envelope. The fire spread from column B5 towards the Northeast corner of the building, and from column B5 towards the Southeast corner of the building.

2.11.12 The North elevation of the building was involved by 01:42, and the fire continued to spread horizontally on the North elevation of the building envelope, reaching the Northwest corner by 02:10. Therefore, at this time, both the East and North building envelopes of the building were involved in external fire, and multiple internal fires were also observed. London Fire Brigade declared the fire a "major incident" at 02:06.

2.11.13 In the other direction – moving along the East elevation towards the South elevation - the fire reached the Southeast corner by 02:22, involving the South elevation by 02:25. There were therefore, by 02:27, two distinct flame spread routes at Grenfell Tower.

2.11.14 At 02:47, AC Roe (LFB Incident Commander) recorded the decision to change the Fire Safety Guidance advice given by control staff to Residents of Grenfell Tower, from a Stay Put strategy to "*advise people to make efforts to leave the building*".

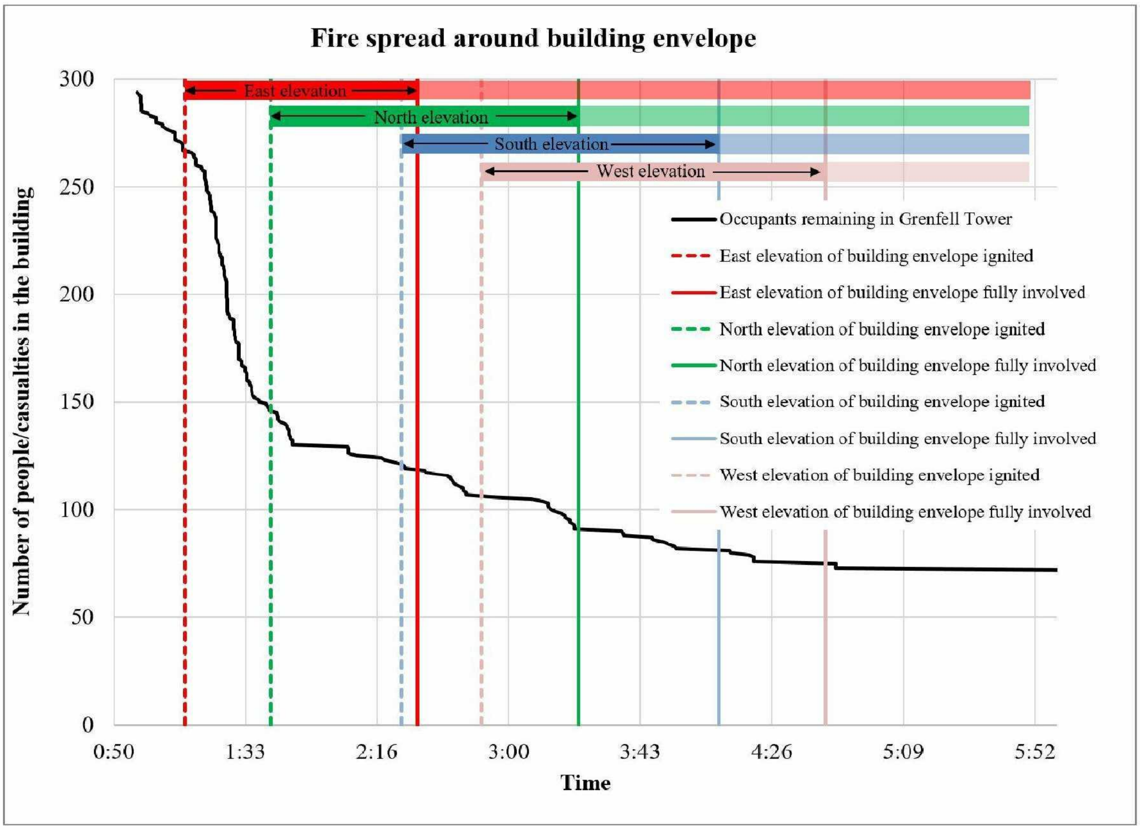
2.11.15 At this time, the East, North, and South elevations of the building envelope were involved in fire.

2.11.16 Less than 10 minutes later, the fire spread from the North elevation to the final elevation - the West elevation - at 02:51. The fire continued to spread horizontally on the West elevation towards the Southwest corner of the building.

2.11.17 At the same time the fire spread on the South elevation of the building also travelled towards the West elevation, and reached the Southwest corner by 03:56.

2.11.18 By 04:03, the two flame fronts appear to effectively converge on Level 22 and Level 23, near the Southeast corner of the building.

Figure B: Fire spread around the building envelope, and the number of occupants remaining in the Tower, presented as they change with time



2.11.19 I have analysed photographs taken by others, outside Grenfell Tower during the fire, to calculate which flats were affected by the external flame fronts I have described above.

2.11.20 Within minutes of the fire spreading to the external building envelope outside Flat 16, it spread across multiple levels on the exterior East elevation - all the flats directly above Flat 16. The affected flats were then at high risk of internal fires.

2.11.21 There is evidence of multiple internal fires burning by 01:49 (refer to Section 12 of my main report), if not as early as 01:36 (see Figure 12.2 of this report).

2.11.22 Therefore, both internal and external firefighting became necessary from an early stage of the fire. I address firefighting in Section 13 and Section 17 of this report.

2.11.23 Table C below shows the cumulative number of flats affected by external fire, based on my analysis of photographs. There was a total of 129 flats in Grenfell Tower.

Table C: Cumulative number of flats affected by flame fronts

Time	Cumulative number of flats affected by flame fronts
01:14	1
01:21	8
01:26	20
01:36	20
01:52	26
02:10	34
02:23	53
02:34	56
02:53	61
03:09	70
03:21	73
03:43	92
04:03	98
04:31	103
04:44	106

2.11.24 This information allows me to conclude that the principles of the Stay Put regime can be considered to have started to fail by 01:15 (time fire spread to Level 5), and to have substantially failed by 01:26 (fire had spread to Level 23).

2.11.25 The fire had broken out of Flat 16 into the rainscreen cladding system by 01:14 (and potentially by 01:12) and the fire had spread to Level 5 above by 01:15.

2.11.26 By 01:21, the fire had reached the exterior of flat 86 directly above Flat 16 but at Level 11, and therefore the external fire was now impacting a total of 8 flats.

2.11.27 The fire continued to spread and had reached Level 23 on the East elevation by 01:26 resulting in 20 flats impacted by the external flame front.

2.11.28 The internal fires were also continuing to spread – with a significant number of internal fires on the East elevation of the building between 02:22 and 02:53. The Stay Put strategy was formally ended at 02:47.

2.11.29 The scale of involvement of the flats, as well as the involvement overall of the rainscreen cladding system, allows me to conclude the following.

2.11.30 The fire did occur within a flat, as is the assumed basis for the Stay Put strategy i.e. a one-compartment fire. However Flat 16 could not maintain the required high degree of compartmentation due to the failure of the building envelope to adequately resist the spread of fire. Therefore, occupants in all flats, other than Flat 16 where the fire started, were not safe to remain, as they were increasingly being directly affected by heat and smoke due to the external fire.

2.11.31 Despite the flats being provided with internal compartmentation, it was not the case there was a low probability of fire spread beyond the flat of origin, because the fire was spreading through the rainscreen cladding system itself, which was connected to every flat in the Tower. This also created a means for fire spread back into multiple flats in the Tower.

2.11.32 This meant that it was not the case that a simultaneous evacuation of the Tower was *unlikely to be necessary* – as the guidance suggests. Instead the increasing internal fires, and the smoke being produced by the rainscreen cladding fire (as well as posing a direct risk to occupants), were placing substantial pressure on the active and passive fire protection systems within the Tower, in a scenario for which they were not designed.

2.11.33 The underlying assumptions of the building design (to ensure that a fire is contained within the flat of origin and that common escape routes and stairways remain relatively free from smoke and heat in the event of a fire within a dwelling), were now undermined by the spreading external fire, and the resulting internal spread of fire and smoke.

2.11.34 This meant that there was a total failure of the principles of Stay Put.

2.11.35 Therefore, the primary consequence of the rainscreen cladding fire starting at Level 4, and spreading seven storeys storeys within 7 minutes, and 19 storeys within 12 minutes, was that it rendered the Stay Put strategy unfit for purpose before 01:26.

2.12 Analysis of early firefighting activity

2.12.1 As I explain in Section 3 of my Report, in high rise residential buildings, provisions are made for internal firefighting only: by means of a firefighting shaft, with a water main, and firefighting lift.

2.12.2 Occupants are expected to leave their flat, with the fire door shut behind them and to call 999 to inform the fire brigade. Smoke control is provided in the lobby in the event the door is left open for some reason and to clear any smoke which may enter the lobby from the fire flat.

2.12.3 The fire brigade is expected to arrive in standard pump vehicles and park near the building entrance and the riser provided. A water supply is secured from a hydrant outside the building, and a connection made to the fire main within the building via the fire brigade's pump vehicle.

2.12.4 The Incident Commander appraises the situation and defines operational objectives.

2.12.5 Two crews use the firefighting lift to go to the firefighting lobby two floors below the fire. A Bridgehead is established in what should be a safe air environment.

2.12.6 One crew is tasked with approaching the dwelling containing the fire and this crew dons breathing apparatus in the Bridgehead. This first crew uses the firefighting stair to walk up to the firefighting lobby on the floor below the fire and connects a hose to the rising main outlet there. The first crew moves to the fire floor with a charged hose using the firefighting stair and is tasked with fighting the fire.

2.12.7 A second crew dons breathing apparatus in the Bridgehead and travels to the fire floor to connect into the rising main there and is tasked with protecting the first team who are in the dwelling.

2.12.8 The fire in the dwelling should then be extinguished. In the event the fire and smoke spread internally, additional firefighting and rescue would be carried out in those localised areas only.

2.12.9 For a high rise building with firefighting lifts and rising main there is no provision for external attack of the fire and so no perimeter access is provided. However, despite the fact that the roads, access ways and hard standings were not designed to enable an external attack on a fire involving the cladding, or to provide access for high reach appliances, LFB managed to set up 4 aerial appliances and put 4 external hoses on the Tower. I summarise the measures employed below. But to be clear, this was additional to what would had been a 'standard' firefighting approach if the cladding had not become involved in the fire

2.12.10 External firefighting requires a different form of fire vehicle, with wider access routes, substantial direct access around the perimeter of the building, as well as different pumping facilities. The water is applied from the outside, and so the fire must be within reach of the hoses from those vehicles in order to be effective.

2.12.11 That is why buildings with a storey more than 18m above ground level, require internal firefighting facilities – this is because they are too high to be dealt with effectively on all storeys, by external firefighting equipment. The primary means of firefighting must be from within the building from the protected firefighting shaft.

2.12.12 For Grenfell Tower, a compliant fire service vehicle access route was provided via Grenfell Road, and I observed 4 hydrants (three more than required) in close proximity to Grenfell Tower; three within the required 90m from the fire main inlet, and the fourth within 95m.

2.12.13 This was sufficient for the provisions made in the statutory guidance for internal firefighting - from within the single internal protected stair, with protected lobbies containing the dry rising main and fire lift, as were provided at Grenfell Tower.

2.12.14 Regarding the 14th June 2017, at 00:55:14 LFB assigned three pump appliances to the incident. At 00:59:12 a fourth pump appliance was assigned when the incident was confirmed as a high rise.

2.12.15 The first firefighting crew entered Flat 16 by approximately 01:08 and applied a firefighting jet to the fire in the kitchen by approximately 01:14.

2.12.16 By this time, the fire had already spread to the external building envelope. A firefighter, on foot, outside the building applied an external jet to the exterior of Grenfell Tower below Level 4, using a handheld hose from ground level. This has a lower reach than an aerial appliance – such appliances had not yet arrived on site.

2.12.17 Level 4 was within reach of a hose from a standard pump, as is evidenced from my analysis in Section 5 and Section 17. However, water was not placed on Level 4 in the short time frame of 01.14 – 01:16 when the fire exceeded Level 5.

2.12.18 Firefighter Hippel (MET000083300) observed the Bridgehead instruct firefighters not to apply the external jet onto the 4th floor window sometime between 01:05 when he arrived and 01:10 when they went to Flat 16. He states this was because no one was sure if anyone was present in Flat 16, including LFB personnel.

2.12.19 I have not able to determine from the photographic evidence if the decision to not spray water on the window was reversed. If it was, I do not know the time it was reversed and by whom at this stage of my investigation. I did not observe a firefighting jet being applied at or above the Flat 16 kitchen window in my review of photographs and videos in the first 30 minutes of the fire. I intend to update my analysis and carry out further investigation into early firefighting if additional evidence becomes available to me.

2.12.20 Once the fire passed Level 5-7, it appears however to have spread out of reach of that hand held hose.

2.12.21 An aerial appliance was first requested at 01:14. That request was increased to 2 aerial appliances at 01:28. At that stage the fire had reached Level 23 on the East elevation, directly above Flat 16.

2.12.22 At 02:05 the LFB message log records 2 aerial appliances are present at site.

2.12.23 I do not know, based on the evidence currently available to me, at precisely what time the aerial appliances arrived at site. I also do not know what the height capabilities are for the aerial appliances requested. A statement in AC Roe's decision log at 06:42 indicates that the aerial appliance was present on site had a reach of 30m.

2.12.24 Once the aerial appliances arrived on site, the fire service were only able to position one aerial appliance next to the East elevation due to space restrictions. I have identified the space restrictions in Section 17. The access to the East elevation was also restricted for high reach appliances as the hardstanding was too narrow and not clear of overhead obstructions.

2.12.25 However, this is not a failing of the design, the type of fire presented was not one that is provided for by means of the statutory guidance, and therefore had not been considered in the road layout and design.

2.12.26 I do not know how much time passed between the aerial appliance arriving on site, being manoeuvred into position on the East elevation and the commencement of firefighting using that appliance.

2.12.27 It is therefore not possible for me to say when the high reach appliance was able to put water on the East elevation.

2.12.28 The time period of interest is the time from first application of water on the East elevation by a hand held hose, and the time an aerial appliance arrived at the East elevation.

2.12.29 It is my opinion that understanding what external firefighting actions, if any, could have been sufficient to suppress the fire once it spread externally upwards beyond Flat 16 window line between approximately 01:14 and 01:20, is of considerable importance.

2.12.30 I intend to update my analysis and carry out further investigation into these issues once more evidence becomes available.

2.12.31 However, what is of significance, is that the next consequence of the rainscreen cladding system fire, was that external firefighting become the required primary firefighting need. This need appears to have occurred simultaneously to the time the crews were applying water internally to Flat 16.

2.12.32 I estimate the fire had spread approximately 32m to Level 11 by 01:21 and by 01:26 it had reached Level 23 around 65m above ground. Both appear to be in excess of the aerial ladder platform (ALP) present on site which had a reach of 30m.

2.12.33 Regarding the other building elevations, as I explain in Section 17 of my report, there were no provisions required to be made for vehicle access, to the North and West elevations. LFB did manage to get an appliance to the North elevation very late in the fire (by 17:47).

2.12.34 On both the East and South elevations overhead obstructions were present, therefore reducing the ability or preventing the fire service from being able to use appliances next to these elevations.

2.12.35 External space restrictions therefore restricted the ability of the fire service to use high reach appliances in the external firefighting operations at Grenfell Tower.

2.12.36 However, LFB improvised to create a means of firefighting on each elevation. This shows that water reach was achieved to approximately the following floors of Grenfell Tower by 04:44:

East elevation – Level 14 (as achieved by high reach vehicle appliance; refer to Figure 17.13)

South elevation – Level 10 (as achieved from potentially a ground monitor positioned on the Lancaster Estate raised walkway; refer to Figure 17.21).

North elevation – Level 9 (as achieved from a handheld hose from the roof of the school building; refer to Figure 17.19).

West elevation – Level 7 (as achieved from a handheld hose from the playground at ground level; refer to Figure 17.20)"

2.12.37 There is a correlation between the levels to which external water was applied and the lack of external fire damage on these levels.

2.12.38 The rainscreen cladding system fire meant that LFB had to mobilise and attempt to suppress a fire that is not anticipated by the relevant regulatory regime i.e. an external fire with the ability to spread over a high rise residential building.

2.12.39 I have found no evidence that London Fire Brigade were ever informed of the combustible nature of the rainscreen cladding system installed at Grenfell Tower, and so no evidence that they understood the need to change their standard pump response for an intended internal high rise residential fire. I note also that, in any event, a substantial amount of the building always remained out of reach of any high reach appliance.

2.12.40 A full timeline has been provided in Table 13.3.

2.13 The active and passive fire protection measures as the fire spread

2.13.1 Because the Stay Put strategy was rendered ineffective before 01:26, this created serious consequences regarding the resulting needs for evacuation, and the management of the evacuation.

2.13.2 The spreading external fire and the spreading internal fire, also created serious consequences regarding what was now required of internal firefighting, and also what was required of LFB regarding rescue.

2.13.3 Both of these issues are clear in hindsight. It is necessary therefore to understand what protection measures were available to the residents as these events unfolded, and what protection measures were available to the Fire Brigade at Grenfell Tower to deal with the unfolding events.

2.13.4 I have therefore investigated:

(a) the internal firefighting required for the fire scenario created and what provisions were available at Grenfell Tower;

(b) the external firefighting possible for the external fire scenario created at Grenfell Tower and what provisions were available at Grenfell Tower;

(c) the provisions available at Grenfell Tower, during this external and internal fire event, for self-evacuation for the residents;

(d) the provisions available for rescue by LFB; and

(e) the provisions available for communicating when and how to evacuate to all the residents.

2.13.5 It is important to make clear that the only way to access Grenfell Tower to undertake fire suppression or rescue, was through the single protected escape stair and through the lobby on every level. These are intended to provide a safe working area for the fire and rescue services.

2.13.6 Similarly, the only way to leave the Tower was for each resident to exit through the lobby outside their own flat and then travel down the single protected escape stair.

2.13.7 Therefore, the performance of the lobbies and the stair became the most critical protection measure, once the fire spread beyond Flat 16 within the rainscreen cladding system.

2.13.8 The single stair and lobbies, and the fire safety provisions therein, were not designed to create a safe escape route or safe working environment, for a multi-storey fire. The design approach for high rise residential buildings is based on inhibiting that scenario from occurring.

2.13.9 However, because of the rainscreen cladding system fire, a multi-storey building fire occurred, and caused the single escape stairs and its lobbies, to become the single most important life safety feature.

2.13.10 I have considerable concern as to the standards of fire safety provision in the lobbies and in the stair (please refer to Section 15, Section 16 and their associated appendices), whilst acknowledging the extreme risk the cladding presented.

2.13.11 In order to explore the performance of the protected stair and the lobbies, I derived a set of critical times during the fire event – this is presented in Section 13.

2.13.12 I then analysed in detail based on my own site work, and the London Fire Brigade witness statements, the performance of the protected stair and lobbies over time, during this multi storey external fire – this is presented in Section 14 of my report.

2.13.13 The fire in the building impacted the stairs on all levels between 4 to the top Level 23. There is substantial evidence of early smoke spread in multiple lobbies at Levels 05 & 06, 15 & 16 before 01:18 and subsequently lobbies deteriorated on upper levels after this time.

2.13.14 Based on the available witness statements, it appears that between 01:40 and 01:58 the conditions worsened within the stair and lobbies. Thick smoke with low to zero visibility is described as filling the stair. It is described as becoming increasingly hot below Level 20. Additionally, lobbies on levels 6-10, 14, 19 and 20 are all described as being smoke filled. Lobbies on Levels 6-10 are described as containing smoke hotter than the stair.

2.13.15 Between 01:59 and 02:58 some lobbies, in particular at Level 10, are described in the witness statements as *'incredibly hot'*. The stair at Level 10 is also described as *'boiling hot'* at this level with thick heavy smoke between Levels 7 to 12.

2.13.16 After 03:00, I have only limited evidence regarding the conditions within the stair. The fire service ceased committing crews above Level 04 at 03:39.

2.13.17 However, I have concluded that there is physical evidence of a hot spot occurring within the stair, a zone including Level 13 to Level 16 inclusive.

2.13.18 Using evacuation data, it appears most likely this hot spot occurred after the formal end of the Stay Put strategy, and in the period after 03:56. Prior to this time, residents did manage to evacuate from within Levels 13 -16 and above, albeit at a much reduced rated and total number, compared to before 01:40. However, after 03:55 there were no successful evacuations from above Level 12, the base of the hot spot zone.

2.13.19 In general, from 0:55 to 01:30 the stairs appear to have been free of smoke and therefore tenable for escape.

2.13.20 I have calculated the timing of the evacuation of the residents, and the significance therefore of this timing with respect to the corresponding timing of decision making and actions by LFB.

2.13.21 It is important to note here that this evidence was not available to decision makers or residents on the night.

2.13.22 It is my opinion that the witness evidence about the conditions in the stair and the lobbies is deeply disturbing, and for many appeared life threatening from early in the fire event.

2.14 Analysis of the evacuation of residents from the Tower

2.14.1 I have relied on the MPS record of exit times taken from CCTV footage of Grenfell Tower (MET000080463).

2.14.2 Table D shows evacuation during 7 distinct periods of time during the fire that I have chosen as follows. The first 3 time periods correspond to evacuation in the first hour, broken into 3 equal periods of 20 minutes. The next 3 entries are periods of approximately 1 hour each, while the final entry is the remainder of the time after 04:47 until the final resident escapes at 08:07. Against each of these times is noted the number of people escaping and which floors they escaped from.

2.14.3 There are some significant pieces of information to be derived from this data.

2.14.4 34 residents left the building before 01:20 - occupants were escaping from all floors up to Level 13.

2.14.5 Between 01:19 and 01:38, the largest number of evacuations occurred (110). From my investigation, the fire service witness statements describe the stairs as being free of smoke at this time. Residents of every floor escaped during this time, except Levels 4, 22 and 23.

2.14.6 It is at around 01:40 that my review of witness statements, presented in Section 14 of my report, has identified that significant smoke logging occurred in the stair.

2.14.7 At 01:40 there were still 151 residents inside the building. At this time the fire was spreading in two separate flame fronts along the East elevation and had also reached and involved the North elevation. A total of 144 persons had evacuated the building by 01:38, that is 40 minutes after the initial fire.

2.14.8 Between 01:39 and 01:58 the evacuation rate slowed significantly from 5.5 people/minute to 1 person/minute. In this time period, 01:39 and 01:58, some LFB crews accessing the tower were still advising residents to stay in their flats or in another flat on that floor, consistent with the Stay Put policy. Only 20 people escaped. The highest floor escaped from in that time period was Level 20. 18 residents that escaped in this time period were from Level 11 or below.

2.14.9 Between 01:59 and 02:58 the rate of evacuation slowed even further, a total of 24 people which is 0.4 persons/min: this is now only 10% of the flow rate in the first 40 minutes of the fire event. At this time, some lobbies, in particular Level 10 are described as *'incredibly hot'*. The stair at Level 10 is also described as *'boiling hot'* at this level with thick heavy smoke between Levels 7 to 12. The people who were able to evacuate, and importantly willing to evacuate in such conditions, came from multiple floors, from Level 3 to 23. In that hour the same numbers of people escaped from above or in the hot zone (12 people), as did from below the hot zone, a total of 24 people.

Table D: Evidence of evacuation from the upper floors at the start and the end of the evacuation phase

Time period	Residents evacuated in time period	Levels from which residents escaped in time period (no. of occupants from each level in brackets)
00:58 – 01:18	34	3(2), 4(12), 5(2), 6(1), 8(4), 12(1), 13(10) and Unknown (1)
01:19 – 01:38	110	1(6), 2(3), 3(2), 5(10), 6(2), 7(11), 8(8), 9(13), 10(3), 11(7), 12(3), 13(7), 14(3), 15(6), 16(6), 17(9), 18(2), 19(3), 20(2), 21(1) and Unknown (3)
01:39 – 01:58	20	1(2), 4(3), 6(6), 7(3), 10(1), 11(2), 20(2) and Unknown (1)
01:59 – 02:58	24	3(4), 5(2), 9(2), 11(1), 12(3), 14(4), 15(1), 19(3), 20(1) and 23(2)
02:59 – 03:55	24	12(5), 15(1), 16(2), 18(8), 21(6) and 22(2)
03:56 – 04:47	9	10(6) and 11(3)
04:48 – 08:07	2	10(1) and 11(1)

2.14.10 At 02:47, AC Roe changed the evacuation strategy from Stay Put to "all out". A total of 187 persons had already escaped from the building. A total of 107 then remained of which 36 would ultimately be able to evacuate. I have provided my analysis of the remaining 71 persons and their movements, in Section 20 of my report.

2.14.11 Between 02:59 and 03:55, 6 people escaped from below the hot spot zone in the stairs, and 18 people escaped from above it.

2.14.12 At 03:39 fire fighters were not being committed above Level 4. After this time, residents are recorded as escaping from Level 15, 16 and 21, these levels were either in or above the hot spot zone.

2.14.13 After 03:56, all 11 residents who evacuated originated from a flat below the bottom of the hot spot zone at Level 13.

2.14.14 After approximately 04:00, no residents escaped from above Level 11, indicating that the hot zone in the stair may have prevented its use by residents to escape unaided via the stair. However this is also the time the two flame fronts met on the West elevation, on Levels 22 and 23.

2.14.15 I note that the decision log of AC Roe identifies that there are no active fire survival guidance calls as of 04:22.

2.14.16 By 04:20 a change occurred again, in that fire fighters had reached Level 10. Between 03:56 and 04:47 residents escaped from Level 10 in two distinct groups, the first (flat 74) leaving at 04:12 and the second (flat 73) leaving around 04:20. Additionally, 3 people escaped from Level 11 - a single family group - all leaving at 04:47.

2.14.17 After 04:47 there were 2 individuals evacuated: from Level 10 at 06:05 and Level 11 at 08:07, both below the hot spot zone.

2.14.18 Between 03:08 – 06:31 the Bridgehead was located at ground level indicating that the whole height of the stair was deemed to be not safe without Breathing Apparatus during this period by LFB. Despite these conditions, 35 residents were able to escape from floors as high as Level 22, from 03:08.

2.14.19 At this time, I do not know which residents, either before or after the formal end of Stay Put, were rescued and which self-evacuated. It is important that this is investigated in the next phase of the Public Inquiry.

2.14.20 Further, I am aware the 999 calls are being reviewed by other experts. I would expect that my analysis here and further analysis by others can be combined in the near future.

2.14.21 I am aware residents on many floors did not feel they were able to escape downwards as they considered the conditions too severe in the lobby outside the flat within which they were located.

2.14.22 The impact of fire generally but in particular, smoke and other products of combustion, on the welfare of adults and children who did manage to enter the stair, also requires substantial analysis. This should provide further information regarding the toxicity of conditions in the stair.

2.15 Performance of the active and passive fire protection measures

2.15.1 Once the fire broke into the rainscreen cladding system, the active and passive fire protection measures within the Tower were then required to mitigate an extraordinary event – a multi storey fire. The high degree of compartmentation had suffered its primary failure, caused by the fire spreading through the rainscreen cladding system. The Stay Put strategy was already in jeopardy by 01:26.

2.15.2 The remaining active and passive fire protection measures within the Tower were therefore required to mitigate the effects of the resulting fire and smoke spread from that rainscreen cladding system fire, and on multiple floors.

2.15.3 I have identified in Sections 14-18 what those active and passive fire protection measures were and their compliance with the relevant standards. Those included: fire doors – flat entrance doors and stair doors; the smoke control system in the lobbies; the fire lift and dry risers in the lobbies; as well as a process of communication with the residents, in particular, once the formal end of Stay Put occurred.

2.15.4 I have identified in Sections 14-18, and in the supporting Appendices G, H, I and J, a number of deficiencies with many of the active and passive measures provided in Grenfell Tower. It is important to acknowledge that some of these deficiencies may not have played a significant role in terms of the spread of smoke and fire, given that there was a fire of this magnitude. For other protection measures the failure to resist smoke or fire played a role on the night of the fire.

2.15.5 The majority of the fire protection measures were intended to protect the lobbies and so protect the stair. The fire lift and dry risers were there to enable early internal firefighting and support the Defend in Place firefighting tactic.

2.15.6 I have considered carefully how the protected stair and lobbies performed on the night of the fire and have concluded that overall they failed (Section 14 and Section 19). The lobbies were compromised by smoke and heat. The stairs appear to have been compromised by smoke, and eventually by heat. The stairs and the lobbies appear therefore to have created particularly challenging conditions for firefighters and for anyone seeking to evacuate from floors, particularly above Level 13. Further work will be required once all the witness statements are available to me, in understanding any further detailed effects on firefighting and evacuation.

2.15.7 For the purposes of this Summary only, I make the following specific points. The full details are presented in Section 19.

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2.15.8 Protected Lobbies

2.15.9 Fire and smoke spread to and throughout every Lobby above Level 10 in Grenfell Tower. On Levels 04 -10 fire and smoke also spread, however post fire damage indicates the spread was more severe on the North side of the lobby and less severe on the South side of the lobby.

2.15.10 The heat, toxicity and reduced visibility caused by this fire and smoke spread appears to have slowed the rate of evacuation of people through the lobbies. People may have been unable to enter the lobbies or possibly unwilling to enter the lobby outside their flat entrance door, due to the immediate physical and psychological effects of entering the smoke and heat filled lobbies. There is evidence of residents being impaired and suffering from the effects of toxicity in their journey down the stair.

2.15.11 The heat and smoke within the lobbies prevented their use as a Bridgehead by the fire service, and so the fire service were never able to move the Bridgehead higher up in the building.

2.15.12 This low location for the Bridgehead, reduced the time available to conduct rescue operations at higher levels whilst wearing breathing apparatus.

2.15.13 Above the Bridgehead the heat and smoke within the lobbies either prevented or reduced access to the fire main and the ability to find and locate occupants.

2.15.14 The current evidence regarding the passive and active fire protection systems in the lobbies indicates the following.

2.15.15 Lobby enclosure - The flat entrance doors appear to be the primary route of fire and smoke spread to the protected lobbies. I found no evidence of other breaches in the construction separating the flats from the lobbies. The non-compliances I have identified with the composite fire doors installed in 2011-2012 refurbishment, could have contributed substantially to the failure of the fire doors to control the spread of fire and smoke, particularly during stages of the fire when the fire doors would have been expected to be effective in maintaining the compartmentation lines. Failure of the self-close function of the doors, (particulars of which are currently unknown), could have also contributed - for example due to the open and close action as people evacuated.

2.15.16 Travel distance within the lobby – The maximum travel distance within the lobbies was 3m further than that recommended in the statutory guidance. However, this would not have contributed to the failure to control fire spread. It may have affected the visibility of the stair exit door and taken occupants longer to reach the exit. However, given the conditions described within the lobbies, a 3m reduction in travel distance would not have mitigated the loss in tenability (visibility, heat and toxicity) experienced in the lobbies.

2.15.17 Fire main – Had a wet riser been provided as per the provisions made in the statutory guidance, the initial firefighting response to Flat 16 may have been faster, however, I have found no evidence that the type of water main made a material difference to the fire spread to the external wall, in these circumstances of a substantial multi-storey fire.

2.15.18 However, a wet riser would have provided greater water pressure and flow at high levels than the installed dry fire main where no more than 2 hoses were in operation. The demand for fire water on multiple levels which caused a failure in the dry riser system, would also have caused a failure in the wet riser system, based on current design standards.

2.15.19 This is because for a wet rising main the pumps and water supplies would not have been designed for multiple hose streams on multiple levels either. The only equipment to boost the supply would have been the standard fire pumps.

2.15.20 However, I conclude the failure of the internal fire main reduced the ability of the fire service to cool the lobbies and so limit the spread of fire and smoke to the lobbies and to the stair.

2.15.21 Fire lift – The lower standard of fire lift provided, failed to operate for the fire service. I explain the difference in performance of a *fire lift*, and the modern standard *firefighting lift* in Section 16 of my main report. Further evidence is required to assess the function of the manual override switch installed for the fire lift at ground floor, and second floor. This failure is not directly linked to a failure to control the spread of fire. It indirectly contributed in that it affected the operations of the fire service, who rely on fire-fighting lifts to transport equipment, personnel and exercise rescue.

2.15.22 Fire detection and alarm – A fire detection system was provided to activate the smoke control system. I did observe failings in the operation of this system, and I am concerned the system may not have operated when smoke entered the detection system provided. This is discussed further below.

2.15.23 General provisions – I did not observe any failings with regard to headroom, flooring and refuse chutes in the lobby which contributed to or failed to control the spread of fire and smoke.

2.15.24 External firefighting – The external fire caused the fire service to need to improvise and use external firefighting measures. There appears to be a correlation between the application of firefighting water up to Level 10 on the South elevation and the reduced level of damage in the South side of the lobbies on Level 9 and below. The external firefighting may have provided indirect protection to the lobbies by limiting fire spread to the flats on Level 04 -10 on the South elevations.

2.15.25 **Protected Stair**

2.15.26 Smoke spread to the stair on Levels 3 – 23 of Grenfell Tower - the post-fire damage to the stair indicates particularly hot smoke entered the stair between Levels 13 -16. This smoke was hot enough to melt the plastic lights located within the stairs at these levels. It currently appears this occurred later in the fire from 03:55 onwards.

2.15.27 Stair enclosure – the stair doors may have failed to prevent the spread of smoke to the protected single stair due to:

a) Non-compliances in the construction of the door against current statutory guidance for 60 minutes integrity fire resistance and cold smoke leakage (noting that the LGA guidance permits 30 minutes integrity fire resistance). From my survey the performance may actually have been as low as 20 minutes integrity fire resistance. Further evidence is required regarding the fire resistance performance of the stair doors.

b) Doors being held open by the presence of firefighting hoses and in one reported case a fatality. Further investigation is required to determine the number and location of hoses and how long they were in place.

c) I was not able to determine whether any stair door self-closers failed to operate, however, I did not find any evidence of this in fire fighter witness statements. Evidence from the 2016 risk assessment described two stair doors as failing to self-close fully. I currently have no evidence these defects were ever dealt with.

2.15.28 Further evidence and investigation is required to determine the contribution the stair doors made to the spread of smoke and heat to the single stair.

2.15.29 Stair enclosure – failure to prevent the spread of hot smoke to the hot zone: having reviewed all the passive and active systems required to provide protection to the stair, I cannot find at this time a direct link between any of their failings and the particular failure at Levels 13 – 16 which allowed very hot smoke to enter the stair. Contributing factors which require further investigation include how many stair doors and on what levels were left open due to obstructions, such as firefighting hoses and debris.

2.15.30 Analysis of the internal conditions using data from the 999 call records is the subject of separate expert assessment. I intend to revisit this issue once that work has been completed.

2.15.31 Stair width – The width of stair was non-compliant with the statutory guidance. I have found evidence the stair was congested on the 14 June 2017 with ascending fire service and escaping occupants, including the fire service descending with casualties and equipment. However, the principal cause of the congestion was the failure of compartmentation, requiring mass evacuation on multiple levels, and firefighting on multiple levels with the low location of the Bridgehead and failure of the fire lift. A compliant stair width (an extra 60mm width) would not have mitigated these effects (please refer to Section 19 for further information).

2.15.32 Smoke ventilation – the system as designed and installed was non-compliant with the statutory guidance. Additionally, it appears the system failed to operate as intended on the night of the fire. This had no effect on the initial fire event, as smoke does not appear to have spread to the Level 04 lobby at this time. Had the system operated, it could have been used, under the control of the fire service, to systematically vent smoke from other lobbies during the fire event. Further investigation is required to assess how effective the installed system could have been and whether the override function was provided and operational, and therefore available for the fire service. The coupling of a fire lift with an operational smoke ventilation system, could possibly have had an impact on the ability to execute rescue.

2.15.33 General provisions – I have not observed at this time any failings associated with headroom or construction of flights and landings, which contributed directly or indirectly to the failure to control the spread of fire and smoke in Grenfell Tower.

2.16 Consequences: failure of Stay Put and failure of Defend in Place

2.16.1 The events at Grenfell Tower meant, rather than a fire within one internal compartment, a major fire in the building envelope occurred and this itself was on multiple storeys and across multiple compartments. Additionally, there were many post-flashover fires internally, in multiple compartments, on multiple storeys.

2.16.2 The building envelope created an intolerable risk on the night of the fire, resulting in extreme harm. It did not adequately resist the spread of fire over the walls having regard to the height, and use of the building. The active and passive fire protection measures within the Tower were then required to mitigate an extraordinary event, and as a result, the consequences were catastrophic.

2.16.3 I have explained that it is my opinion that the Stay Put strategy had substantially failed by 01:26, with conditions on the lobbies already a challenge before 01:20 on some floors, and the conditions in the stair and many of the lobbies undergoing significant deterioration after 01:40.

2.16.4 The poor visibility present in the lobbies and stair would have reduced the speed at which people could travel, therefore increasing the time required to make an escape and increasing the duration of exposure to the products of fire (smoke and heat). This is in addition to the way-finding difficulties presented by reductions in visibility.

2.16.5 These factors on their own, or in combination, appear to have discouraged residents from evacuating independently. This is of particular concern to me, when considering the significant reduction in evacuation rates after 01:40, as compared with the first 40 minutes of the fire.

2.16.6 The effect of heat - where temperatures exceeded 150°C - can be tolerated for only very short periods of time. They would cause immediate pain to any exposed skin. Based on the current evidence these temperatures appear to have occurred in the stair over Levels 13 -16, potentially after 04:00.

2.16.7 |If that was the case, the immediate physical pain caused by these temperatures would have prevented some individuals from attempting to enter the stair between Level 13 – 16, or descend below Level 16 where one was already in the stair, at that time.

2.16.8 The impact of toxicity from the smoke which filled the lobbies and stair, was a significant issue during the fire. Smoke contains a number of toxic asphyxiate gases in potentially lethal concentrations and smoke also contains sensory irritants. The asphyxiate gases could cause a slowing of escape by reduced awareness or could cause incapacitation or death. The sensory irritants, which cause symptoms to humans on exposure, could slow evacuation by impairing vision, causing a burning pain or reducing breathing rates, as well as pulmonary oedema (a build-up of fluid in the lungs).

2.16.9 The combination of poor visibility and sensory irritants when residents opened their flat entrance doors to try to enter lobbies, would have been a significant deterrent to escape. This is particularly the case when the guidance being issued from the 999 calls was to Stay Put - the lobby conditions would have emphasised to some that this was indeed the safer option.

2.16.10 Once the Stay Put guidance changed, the conditions at the time, with poor visibility and sensory irritants, would have been a substantial deterrent for the remaining residents, especially if no form or assistance was available to guide them through the lobbies, or to guide them down through the stairs.

2.16.11 For the internal fire-fighting operations, the firefighting stair and lifts are required to provide a safe air environment in order to reach the Bridgehead, which is typically located in the lobby two floors below the fire floor.

2.16.12 The lobbies below the fire floor are required to provide a safe air environment to act as the Bridgehead.

2.16.13 The stair above the Bridgehead, which is only accessed by crew in breathing apparatus, is required to provide tenability for crews to work. Tasks include finding and connecting hoses to fire mains and the carry down of any occupants rescued.

2.16.14 Therefore, for firefighting, how smoke and heat was able to enter the lobbies, as far down as Level 4, and for some hours forced LFB to set up the Bridgehead at Ground level, is relevant to the failure of the stairs and lobbies, as a safe air working environment for a Bridgehead.

2.16.15 The position of the Bridgehead was never above Level 04 until after 07:30.

2.16.16 Once the Bridgehead has been secured, firefighting and rescue activities can commence. These tactics have the following stated benefits in fighting fires in high rise buildings:

(a) Minimises use of breathing apparatus air supply to access the fire sector; and

(b) Reduces difficulty in manoeuvring charged hoses around corners in stairs by minimising the number of stair flights being traversed.

2.16.17 This was not possible to achieve at Grenfell Tower due to the low level the Bridgehead had to be located.

2.16.18 This location also extended the time required for the fire service to reach the upper levels of Grenfell Tower throughout the fire with breathing apparatus, thus reducing the time available for fire-fighting and search and rescue, on all levels. I have found no evidence yet that LFB ever reached above Level 20 until the very late afternoon on the 14th June 2017.

2.16.19 Fire and Rescue Authorities must also have effective arrangements in place to handle fire survival guidance calls from residents and others when they believe they are unable to leave the building due to disability, poor mobility, illness or the effects of fire and smoke. The Bridgehead location and lobby sector location forms an important role for this activity, as it is in these locations that all such advice and resulting actions are co-ordinated.

2.16.20 The scale of fire survival guidance calls at Grenfell Tower (recorded at 200 at its peak) rendered this process exceptionally complex.

2.16.21 According to *Generic risk assessment 3.2: fighting fires in high rise buildings* ('GRA 3.2') 2014, fire survival guidance call arrangements made by the fire brigade, should include:

a) "details of how calls will be passed to and recorded at the incident

b) their impact on resources and mobilising

c) a re-evaluation process to ensure the balance of risk to the public is reviewed if circumstances change (which may result in a change to the advice previously given)

d) how information will be exchanged between callers, Fire Control and commanders at the incident."

2.16.22 The Incident Command manual also provides guidance on how tall buildings should be broken into operational sectors:

(1) the fire sector – *this is an operational sector and would be the main area of firefighting and rescue operations, consisting of the floor/s directly involved in fire, plus one level above and one level below.*

(2) the search sector – *this is an operational sector and would be the area of operations in a high rise, above the 'fire sector' where search and rescue, venting and other operations are taking place.*

(3) the Lobby Sector – *this is a support sector and would cover the area of operations from the ground floor lobby to the Bridgehead, which is normally two floors below the fire floor.*

2.16.23 The fire sector was considered to be on every floor from Level 4 above by LFB and it was reported as from Ground level at 03:08, 04:28, 06:31.

2.16.24 I consider the multiple internal fires, and the extensive smoke spread throughout the Tower, to have caused a total failure of Defend in Place firefighting; one of the core fire protection measures to support the Stay Put strategy. It was not possible for LFB to suppress all the products of combustion from the external rainscreen cladding system fire.

2.16.25 Above the location of the Bridgehead, how smoke and heat was able to enter the lobbies on multiple floors as well as the stair, is also relevant to the failure to provide a safe place of work for the fire service to undertake search and rescue operations on those upper levels. It also severely limits the potential to undertake firefighting on those levels.

2.16.26 The reduction in visibility caused by smoke would have limited the ability of the fire service to find the fire main within the lobbies, as well as limit the ability to access flats easily. As the brigade became so reliant on breathing apparatus (again due to the presence of smoke so extensively throughout the single protected stair), any additional time lost on tasks was time lost for rescue.

2.16.27 The reduction in visibility would also have slowed the speed at which LFB could ascend the stair. From the fire service witness statements reviewed (see Section 14) poor visibility also appears to have caused confusion and specific issues regarding orientation within the Grenfell Tower. This would have affected the ability to conduct time effective search and rescue operations, as well as impacting on LFB's ability to communicate rescue needs and conditions accurately to the Bridgehead.

2.16.28 The heat experienced within the stair and some of the lobbies, prevented LFB from reaching the fire main to undertake firefighting. It would also have added to the physical stress experienced by having to ascend up to 18 storeys above the Bridgehead in breathing apparatus.

2.16.29 Although the toxicity of smoke should not have affected the fire service directly, due to their breathing apparatus, it would have limited their time available for rescue due to their high reliance on breathing apparatus, which has a fixed quantity of available air.

2.16.30 This therefore impacted their available time for rescue in another way - with respect to their safe exit time from the building when assisting or carrying rescued residents. The toxic smoke increased the need for LFB personnel to physically support and even carry down residents given the toxic smoke which impaired residents' movement in the stairs.

2.16.31 The ultimate consequence was a disproportionately high loss of life. This was a kitchen fire escalating to an almost all-building fire, compromising the fundamental basis of the Stay Put strategy. I address the delay in the change of evacuation advice to the residents and the communication with them, in my Conclusions.

2.16.32 I have analysed the location and movement of the 71 residents who lost their life in Tower, in Section 20 of my report, and as summarised below.

2.16.33 For residents of Grenfell Tower below Level 18, the majority of the deceased were recovered on the floor where they resided. The total number of deceased found below Level 18 was 16 people. Three of these residents were recovered outside Grenfell Tower.

2.16.34 Thirteen of the fatalities, who were residents on Levels 11 -17, were also recovered on the floor on which they were believed to be residing on 14 June 2017. One person was recovered within the stair on the level they were residing (Level 17). Therefore, twelve people were unable or were unwilling to leave their flats; they were recovered in the same flat it is believed they were resident in.

2.16.35 When I use the word unwilling, it is important to understand by that I mean they perceived a serious risk to their own life by exiting their flat. The conditions in the lobby outside their flat, would probably have created that perception, and caused grave consequences for many residents.

2.16.36 For residents of flats on levels above Level 18 significant numbers of the deceased had moved from their floor of origin.

2.16.37 On Levels 18 - 23 a total of 28 people remained within their flats, either unable or unwilling to attempt to escape via the protected lobbies and stair of the tower. The total number of deceased found on Level 18 and above was 47. So it would appear that people moved upwards because of the spread of smoke and fire.

2.16.38 There were two distinctions in location of the deceased (who were residing on Level 18 and above - which was a total of 54 persons), compared with those deceased residents who originated from flats on Level 17 and below (a total of 16 persons):

(a) A high number of people from Levels 18 - 22 moved upwards to Level 23 (a total of 15 persons).

(b) None of the deceased from Level 11 -17 were found on floors higher than where they were originally located.

(c) A limited number of people attempting to escape from Levels 18 - 22 were recovered as fatalities within the stairs and lobbies.

(d) Only 1 person, from Level 17 or below, was recovered as a fatality after attempting to escape from their flat and they were recovered at Level 17.

2.16.39 On three floors only, Level 14, 22 and 23, people moved from their flat to another flat on the same floor - I am unclear if this was under the direction of LFB or not.

2.16.40 In all cases those people moved from the North and East side of Grenfell Tower (Flat 6, 5 or 1) to the Flat 3, which was diagonally opposite, on the South and West elevations. The position of Flat 3 also meant it was the last flat on every level which the external fire spread to (as I have shown in Section 12).

2.16.41 On every level of the Grenfell Tower people escaped away from Flat 6, which was the flat directly above the Flat 16 on Level 4 and the location of the initial fire event. No fatalities were recovered from Flat 6 on any floor.

2.16.42 The majority of residents of Flat 6 on every floor evacuated the building before 01:32am. Two people evacuated at 03:52 (I believe they most likely moved to another part of the building before escaping). Those who did not evacuate moved to Level 23 where they eventually lost their life, a total of eight persons from Flat 6 on Levels 19, 20 and 22.

2.16.43 Three persons from Flat 6 were recovered outside Grenfell Tower (Levels 11, 19 and 23).

2.16.44 Therefore, it appears that the initial external fire spread from Flat 16 upwards (the Flat 6 on the East elevation on every floor above Level 4) and its subsequent spread on the North and East elevations (Flats 5, Flat 2 and 1), caused people to leave their flats, and potentially to do so early in the fire.

2.16.45 This also coincides with the time, currently recorded, at which the stair and lobbies became logged with thick hot smoke. People who moved from Flats 1, 2, 5 and 6 on Levels 18 - 22 appear to have been unable or unwilling to escape downwards, probably due to their perception of the severity of conditions in the protected stair. These people therefore moved up to the top floor of the building to Level 22 and Level 23.

2.16.46 I am not aware that those people (at Level 22 and Level 23), were provided with any assistance from LFB during the fire.

2.16.47 The engulfing of Level 23 by the external fire, began between 01:29 when it first reached Flat 6 on the East elevation. By 03:43 it reached Flat 3 on the South West corner.

2.16.48 At 03:39 fire fighters were not being committed above Level 4. After this time, residents are recorded as escaping from Level 15, 16 and 21 only.

2.16.49 After 03:43, the fire began to spread from the exterior to the interior of the flats at Level 23. The persons already residing in the flats in Level 23 (13 persons) and those who moved there (a further 15 persons) no longer had a safe refuge.

2.16.50 After approximately 04:00, no resident escaped from above Level 11. This is also the time (04:03) the two flame fronts met on the West elevation, on Level 22 and 23.

2.16.51 A total of 53 people died and were recovered on Level 17 - 23; a total of 17 people died on Levels 11 - 16. Two people died in hospital after evacuating Grenfell Tower.

2.16.52 No one died from any of the Flats on Levels 10 and below.

Conclusions

2.17 Instructions

2.17.1 I now provide my preliminary conclusions as to the extent to which the active and passive fire protection measures within Grenfell Tower

(a) failed to control the spread of fire and smoke; and

(b) contributed to the speed at which the fire spread.

2.17.2 In doing this work, it has been necessary for me to analyse the timing of the formal end of the Stay Put strategy, when considering the extent to which the relative performance of the active and passive systems was relevant, and when considering the consequences of any failures of the active and passive fire protection measures.

2.17.3 Because Stay Put relies in part on early firefighting and the assumption of suppression of an internal fire event only, I have also incorporated my review of firefighting activities in my report and have provided some preliminary conclusions on this subject.

2.17.4 I have also considered the methods for communicating with residents regarding evacuation, as part of my review of the active fire protection measures and have provided a preliminary conclusion on this subject.

2.18 The failure of the Rainscreen cladding system

2.18.1 In Section 8 and 11, I have identified the materials forming the rainscreen cladding system, and assessed their compliance with the relevant statutory requirements.

2.18.2 Based on the relevant test evidence submitted to the Public Inquiry, the construction materials forming the rainscreen cladding system, either individually or when assessed as an assembly, did not comply with the recommended fire performance set out in the statutory guidance of ADB 2013for a building of that height.

2.18.3 Additionally, I conclude the entire system could not adequately resist the spread of fire over the walls having regard to height, use and position of the building. Specifically, the assembly failed adequately to resist the spread of fire to an extent that supported the required Stay Put strategy for this high-rise residential building.

2.18.4 There were multiple catastrophic fire-spread routes created by the construction form and construction detailing.

2.18.5 In addition, as I have explained in Section 9, the detailing created around the old and new windows meant that the materials and the arrangement of those materials, increased the likelihood of a fire breaking out of the flat and increased the likelihood of that fire breaking into the large cavities contained within the cladding system. Those cavities contained combustible materials.

2.18.6 Attempts had been made to subdivide the column cavities and provide vertical and horizontal fire stopping at key compartment lines. However, both the horizontal and vertical fire stopping were installed incorrectly, and no evidence has been provided that they were ever tested for performance in an ACP based rainscreen cladding system of the type installed at Grenfell Tower.

2.18.7 The windows were not provided with fire resisting cavity barriers. These unprotected openings themselves were surrounded by combustible material.

2.18.8 Additional combustible construction materials were located in the room on the ceiling beside the window.

2.18.9 Therefore, in the event of any fire starting near a window, there was a disproportionately high probability of fire spread into the rainscreen cladding system.

2.18.10 This was also true in the event of a fire remote from the window, unless the fire brigade extinguished it or the fire did not grow into a fire that could cause the heating of any of the unprotected openings from the flat to the building envelope.

2.18.11 The interface between the kitchen window and (a) the column rainscreen cladding system and (b) the above window horizontal rainscreen cladding system, was the primary cause of the early stages of fire spread.

2.18.12 The type of materials and how they were arranged around the window provided no means to control the spread of fire and smoke, from the small kitchen fire which was the source of the fire. In addition, the type of materials and how they were arranged around the windows in the kitchen, contributed to the speed at which the fire spread from the flat of fire origin to a multi storey external fire.

2.18.13 Once the fire entered the rainscreen cladding system outside Flat 16 on the East elevation, the Reynobond 55PE rainscreen cladding layer coupled with the ventilation cavity backed by the Celotex insulation or Kingspan K15 insulation, incorporating defective vertical and horizontal cavity barriers, failed to control the spread of fire and smoke.

2.18.14 The Reynobond 55PE contributed to the most rapid of the observed external fire spread.

2.18.15 There were also Aluglaze polystyrene core insulating panels installed between every window, in front of the existing window infill panels. Polystyrene produces large quantities of black toxic smoke; and supports rapid fire spread as evidenced during the fire.

2.18.16 The assembly - taken together with the insulation material on the existing external wall, the missing and defective cavity barriers - became part of a successful combustion process. This process generated substantial fire spread over 5 distinct pathways. A full geometric grid was created by means of the construction materials, which connected (in the event of an internal fire, cavity fire or external fire) every flat on a storey; and every storey from ground to roof level. These pathways also supported the spread of fire back into the building.

2.18.17 The consequence of this was that any individual flat of fire origin was no longer in a separate fire rated box i.e. the compartmentation required in the building was breached by the ability of the fire to spread on the external wall to that compartmented flat. I conclude that a Stay Put strategy was not a realistic basis for fire safety design in this building, as a result of the rainscreen cladding system.

2.18.18 The arrangement and type of construction materials in the rainscreen cladding system caused:

(a) multiple internal fires, many of which underwent a flashover fire (this in general occurred were external firefighting was not possible by LFB);

(b) multiple fires impacting flat entrance fire doors;

(c) generation of large quantities of polymeric based smoke which entered many flats;

(d) smoke egress through flat entrance doors out to multiple lobbies;

(e) the need for smoke control on multiple lobbies simultaneously (which was never the intention of the relevant guidance or regulations);

(f) the need for suppression by LFB on multiple floors simultaneously (which was again never the intention of the relevant guidance or regulations);

(g) the very early and simultaneous requirement for external firefighting, which again, was not provided for;

(h) the need to change the evacuation strategy, for which no communication systems were provided for within the building;

(i) the need for all mobility impaired persons to self-evacuate, for which no facilities were provided for within the building

2.18.19 The rainscreen cladding system, installed during the refurbishment in 2012-2016, was therefore non-compliant with the functional requirement of the Building Regulations.

2.18.20 In my Phase 2 report I will investigate how this state of affairs came to exist at Grenfell Tower.

2.19 The consequences for the early firefighting activity

2.19.1 I do not consider it reasonable that in the event of the installation of a combustible rainscreen cladding system on a high rise residential building, the fire brigade should be expected to fully mitigate any resulting fire event. That is particularly so in circumstances where the fire brigade had never been informed that a combustible rainscreen cladding system had been installed in the first place. Further, there are so many combinations of events, that could fall entirely outside the reach of external firefighting activity. This is important when only internal firefighting arrangements are made for high-rise residential buildings by Regulation at this time.

2.19.2 I have found no evidence yet that any member of the design team or the construction team ascertained the fire performance of the rainscreen cladding system materials, nor understood how the assembly performed in fire. I have found no evidence that Building Control were either informed or understood how the assembly would perform in a fire. Further I have found no evidence that the TMO risk assessment recorded the fire performance of the rainscreen cladding system, nor have I found evidence that the LFB risk assessment recorded the fire performance of the rainscreen cladding system. I await further evidence on these matters, which I will explore in my Phase 2 report.

2.19.3 I have considered the early firefighting activity which took place, in this report.

2.19.4 The fire and rescue services arrived at Flat 16 and successfully dealt with the internal flat fire – they controlled the internal flat fire using the internal firefighting equipment provided to them.

2.19.5 It is important to note that, on arrival at Grenfell Tower, they were unable to control the fireman's lift which appears to have caused a short delay arriving at Flat 16. It also meant that they could not use the lift any further during the fire.

2.19.6 Despite that delay the fire in Flat 16 was successfully dealt with.

2.19.7 However, the pre-flashover fire in Flat 16 spread easily into the rainscreen cladding system. This meant that LFB was quickly put in a position where there was an additional fire to suppress – the external fire in the cladding system beside the Flat 16 kitchen window. This seems to have occurred at the same time as LFB started to suppress the fire in the kitchen of Flat 16. The first call for an aerial appliance, which can provide a water supply from about 30m above ground level, occurred at 01:14, according to the evidence available to me at this time. I have not been able to establish what time this appliance arrived at the Tower.

2.19.8 I do not consider it to have been feasible, without prior warning, to implement effective external firefighting to Level 4 in the very early stages of the fire. As to what was possible after those early stages, this too requires investigation by the appropriate Experts.

2.19.9 I consider the performance of the rainscreen cladding system to have been the primary cause of the failure of the required external firefighting at Grenfell Tower.

2.19.10 There is no provision made for external firefighting as the primary source of firefighting in high rise residential buildings. The primary source of firefighting is internal firefighting by means of a protected shaft with water mains, firefighting lift, and smoke extract from the lobby to the stairs.

2.20 Changing the Stay Put protocol – timing and management

2.20.1 I consider the Stay Put strategy to have effectively failed by 01:26.

2.20.2 I have calculated that the stair became smoke-logged from 01:40 onwards and there is evidence of multiple lobbies containing thick black smoke by 01:20.

2.20.3 There was therefore an early need for a total evacuation of Grenfell Tower. I have the benefit of all the post-fire data and my analysis of the stairs, lobbies, and evacuation flow rates, when reaching this conclusion. I do not wish to imply this was an easy decision to make during the unfolding and complex events that occurred during the Grenfell Tower fire.

2.20.4 However, the DCLG publish the Fire and Rescue Authorities Operational Guidance: Generic Risk Assessment GRA3.2 *Fighting fires in high rise buildings*. It advises contingency plans for "particular premises" including:

(a) fire spread beyond the compartment of origin and the potential for multiple rescues;

(b) an operational evacuation plan being required in the event the Stay Put strategy becomes untenable,

2.20.5 It is important to understand what "*particular premises*" are and how they relate to Grenfell Tower – I expect this will be dealt with through firefighter evidence and expert work by others in Phase 2.

2.20.6 At present I am unclear about the basis for delaying the formal end of the Stay Put strategy between 01:40 and 02:47. I am particularly concerned by the delay from 02:06 when a major incident was declared, to 02:47.

2.20.7 However, any change in Stay Put is not easily dealt with in the UK, where there is no statutory requirement to provide an automatic detection and alarm system in high-rise residential buildings for the purposes of warning all occupants that an all building evacuation is required.

2.20.8 There was no fire alarm panel provided with controls for LFB or responsible persons, to raise an all-out alarm within Grenfell Tower.

2.20.9 In Section 18 of my report I have identified the current forms of communication available for residents and firefighters when (a) there is no automatic communication provision in a building and (b) the Stay Put strategy needs to change.

2.20.10 In my opinion, it is important to understand how the fire service could communicate with residents and the extent to which limitations on communications affected rescue operations. I recommend that the Inquiry investigates these issues further.

2.20.11 However, at this stage, I note the following key matters:

(a) The current approach in the statutory guidance is that blocks of flats are not provided with an automatic or manual means of raising an alarm sounder or providing voice alarm announcements. Where there is a large fire in a high-rise block of flats, such as at Grenfell Tower, it is not possible to easily communicate changes in advice (e.g. from Stay Put to "all out").

(b) Where there is no central alarm system to alert residents to the need to evacuate, firefighters are dependent on loudhailers, 999 calls, Fire Survival Guidance calls (FSG) and directed evacuation of every flat individually by fire fighters knocking on doors. These methods have significant limitations, especially in a major multi storey fire, such as that at Grenfell Tower.

(c) The limitations on communication would have caused difficulty on 14th June 2017, especially when the Stay Put guidance was formally changed. It is not clear at this stage how the "all out" message was communicated to residents who were still in the Tower.

(d) In light of the number of other residential buildings in the UK with a building envelope formed of similar materials to Grenfell Tower, serious and urgent consideration should be given to changing the current approach.

(e) I am also concerned about how the above limitations on communications affect those who require assistance to evacuate from high-rise residential buildings.

2.20.12 I also wish to rise the matter of <u>the type of guidance</u> required for the residents of Grenfell Tower, once the formal end of Say Put occurred. In the time frame after the Stay Put guidance changed, it is important that the Public Inquiry analyses what guidance was given to the residents remaining in the Tower after 02:47. That would include if that guidance was relevant to helping those residents understand the conditions in the stairs and lobbies, if it was relevant to help them overcome any fear of entering such conditions without rescue assistance, and if the guidance provided location-specific information on how to reach a place of ultimate safety outside the Tower.

2.21 Failure of the fire doors

2.21.1 Overview of compliance status

2.21.2 In 2011, the TMO carried out a flat entrance fire door replacement programme following consultation with LFB. This resulted in the fitting of 106 replacement flat entrance fire doors to tenanted apartments by the company Masterdor. No work was undertaken to 12 Leaseholder flats and 2 of the tenanted flats. Please refer to Appendix I for the detailed information regarding fire doors at Grenfell Tower.

2.21.3 I have calculated that the following types of flat entrance fire doors were installed on the 120 flats from Levels 04-23 the night of the fire:

a) 14 doors that were not replaced in 2011 (12 leaseholders, 2 tenanted flats);

b) 58 unglazed Masterdor Suredors installed in 2011; and

c) 48 glazed Masterdor Suredors installed in 2011.

2.21.4 I am aware that MPS are creating a tally of door types found on site, and I will update my numbers should relevant evidence make that necessary.

2.21.5 With respect to the relevant fire test evidence I found significant differences regarding all the fire doors.

2.21.6 The installed doors contained different locks, hinges, letter plates and self-closers. These metal fittings, which are embedded into the door can significantly affect the performance of the door by reducing the time to burn through the door.

2.21.7 Some of the installed doors contained glazing not included in the disclosed fire door relevant test evidence. This glazing would fail prematurely allowing fire and smoke to vent directly through the door.

2.21.8 The installed doors contained different intumescent seals, which are intended to seal the gaps between the door leaf and its frame to prevent passage of smoke and flame. This was in addition to the lack of relevant test evidence for cold smoke leakage performance.

2.21.9 For 14 flats (12 leaseholders and 2 tenanted) on Levels 8, 9, 11 – 14, 17 – 23, it is believed the original fire doors were retained. The performance of these doors is unknown. All of these doors were destroyed during the fire, therefore it was not possible for me to survey their construction.

2.21.10 Based on the evidence currently available to me I am not able to assess the condition and operability of the self-closing devices to flat entrance fire doors. If self-closing devices were not installed or not maintained this may have resulted in flat doors not closing behind escaping occupants. Where doors failed to close, such doors would provide no barrier to the spread of fire and smoke.

2.21.11 However, based on my current understanding of door types as installed on site: with the combination of 14 doors not replaced in 2011, the 48 glazed doors from the 2011 door replacement, and all doors in the 2011 door replacement with differences in ironmongery etc, I conclude that all the flat entrance fire doors (from Level 4 – 23) were non-compliant with the fire test evidence relied upon at the time of the installation.

2.21.12 Regarding the fire doors to the stair, these doors do not appear to have been upgraded or replaced since the original installation in 1972. The original requirement was for the doors to the protected stair enclosure was to provide 30 minutes stability and 30 minutes integrity to the standard at the time BS 476-1:1953. This is a lower performance than the current benchmark standard of 60 minutes integrity and cold smoke leakage performance to ADB 2013 (as the stair would be required to be a firefighting stair).

2.21.13 The current LGA guidance on existing blocks of flats makes no recommendation that stair doors achieve the ADB 2013 standard which is 60 minutes integrity fire resistance with protection against cold smoke leakage. It instead refers to doors requiring a performance of 30 minutes fire resistance. It does state there is no expectation that an existing building should meet the current 60 minute standard for fire doors in firefighting shafts.

2.21.14 No documents have been disclosed which provides a design specification for the original doors to the protected stair enclosure.

2.21.15 There are a total of twenty stair fire doors on Levels 04-23.

2.21.16 At this stage I cannot confirm any of these doors provided the 60 minutes integrity and insulation to comply with current guidance in ADB 2013, nor can I confirm their performance to the original 30 minutes stability and integrity required to comply with the relevant guidance (CP3 Part 4 1971) during their installation in 1972.

2.21.17 **Performance of the flat entrance fire doors during the fire**

2.21.18 During my site inspection I did find that the flat entrance fire doors which in general were of composite form (filled with a polymeric foam), were destroyed or partially destroyed where an internal flat fire had occurred. I also observed heavy spalling to the surface of the concrete ceiling directly in front of these doors, on the flat side.

2.21.19 I have assessed the Masterdor Suredor composite door flat entrance doors installed to 106 flats on Level 04 -23 in 2011-2012 (MAS00000003) as non-compliant with the current statutory guidance (Section 15.5 and Appendix I).

2.21.20 This non-compliance would have contributed to the failure to prevent the spread of fire and hot smoke from the flat to the lobby.

2.21.21 Therefore, I consider the evidence demonstrates that it is most likely that the flat entrance doors in Grenfell Tower failed to control the spread of fire and smoke to the lobby as follows:

(a) Failure to prevent the spread of smoke and flame by leakage through gaps between the door leaf and door frame. This could occur early in the development of fire within the flat. But also early in the smoke spread development from the external wall fire, prior to any flat fire.

(b) Failure of the fire door to resist the spread of fire and smoke from a flashover fire within an apartment due to the presence of multiple untested components within the doors. This applies to all 106 doors.

(c) Failure of the fire door to resist the spread of fire and smoke from a flashover fire within the apartment due to the presence of glazing in the fire door which would be expected to cause failure early in the development of a fire within the flat. 48 doors were specified with glazing by Masterdor out of 106 doors. The BRE have advised me that they observed 29 doors with glazing and it was unknown whether a further 19 doors had glazing or not.

(d) Failure of an unknown number of doors to self-close after an occupant escape. Fire and smoke spread to the lobby would then be immediate from the flat to the lobby. In Section 20 I show how many occupants left early, and their location, and any failure of those fire doors at that time would have had serious consequential effects on the lobbies.

2.21.22 Whilst it is noted that the fire performance of the flat entrance doors is not intended to provide indefinite and therefore complete protection to the lobbies (ADB 2013 Section B1.viii), they are intended to provide protection from flames, smoke and gases (ADB 2013 Section B1.ix) i.e. growing fires and flashover fires within the flats.

2.21.23 The non-compliances I have found on site, relative to the test evidence provided, means I must conclude that those doors could not function as they were required to do in accordance with ADB 2013.

2.21.24 Further, I consider the evidence of sufficient quality to allow me to conclude that the fire doors and their lack of performance contributed significantly to the spread of smoke and fire to the lobbies. This failure would have materially affected the ability or willingness of occupants to escape independently through this space to the stair.

(a) As I have explained in Section 19 smoke containing sensory irritants would have caused immediate effects for anyone entering a smoke filled lobby.

(b) Where substantial heat was able to enter the lobby, this would have caused immediate pain to exposed skin. Substantial heat within the lobbies could also have prevented the fire service from reaching the fire main, which was located directly outside a flat entrance door (Flat 3).

(c) Poor visibility due to the presence of thick black smoke, which obscured the stair door several metres from the flat entrance doors, may have prevented occupants from attempting to escape through the lobbies to the stair. The failure of the flat entrance fire doors to control the spread of fire and smoke from flats to the lobbies also materially affected the operations of the fire service as follows:

(i) As I have explained in Section 19 this meant these lobbies could not be used as a safe air environment for the fire service Bridgehead and so forced the Bridgehead to remain at or below Level 04 until 07:30am. This greatly reduced the time available using breathing apparatus, and so the time available for rescue on upper floors, and particularly above Level 15.

(ii) Above the Bridgehead it affected the ability of the fire service to conduct search and rescue operations in the poor visibility of the lobbies. It also materially affected the fire services' ability to locate and operate the fire main which they could have used to cool the lobbies.

2.21.25 **Performance of the stair fire doors during the fire**

2.21.26 I can conclude that the non-compliances I have identified did not contribute to the failure to prevent the spread of fire and smoke during the initial fire event in Flat 16. At this time the protected stair was reported as being clear of smoke (Section 14).

2.21.27 However, once the fire spread externally and ignited multiple internal fires, this spread hot smoke to the lobbies. As I have described in Section 14 severe fire damage occurred in the lobbies on Levels 10 and above and on the North side of the lobbies only on Levels 5, 7-9.

2.21.28 From the evidence available it does not appear that there was a substantial quantity of combustible materials within the lobbies to cause the level of fire damage observed and the fire conditions described by the fire service.

2.21.29 The patterns of damage within the lobbies, (as evidenced by damaged or destroyed partitions, destroyed ceiling and wall linings, and spalling of the concrete structure) indicate intense fire and smoke venting from the flats into the lobbies, and particularly into the corridor arrangement, immediately outside the flat entrance doors. This direct heating into the lobby, is one method for an integrity failure of the stair door (also in the lobby), allowing smoke spread to the stair.

2.21.30 However, at the time of my post-fire site inspections, the stair door which separates the lobbies from the stair, was missing or fire damaged on Levels 10 – 23, with the exception of Levels 11, 12, 15 and 17.

2.21.31 Therefore, the strongest evidence of the cause of the luminaire damage in the stair on Levels 13-16 (the hot spot zone), is smoke and heat entering the stair from open doors to the lobby.

2.21.32 I have identified the fact that the firefighting operations in response to the multi-storey fire may have contributed to the failure of the stair fire doors to prevent fire and smoke spread. Current evidence indicates some of the stair doors were ajar as firefighting hoses were running from the stair into the lobby. However, I currently do not know the number of doors involved, nor, which specific doors, nor for how long this opening may have occurred. I cannot yet conclude whether this made a significant contribution.

2.21.33 Therefore, the stair doors may have failed to prevent the spread of smoke to the protected single stair due to:

(a) Non-compliances in the construction of the door against current statutory guidance for 60 minutes integrity fire resistance and cold smoke leakage (noting that the LGA guide *Fire safety in purpose-built flats* permits 30 minutes integrity fire resistance). Based on the dimensions found during my survey, the performance may actually have been as low as 20 minutes integrity fire resistance. Further evidence is required regarding the fire resistance performance of the stair doors.

(b) Doors being held open by the presence of firefighting hoses and, in one reported case, a fatality. Further investigation is required to determine the number and location of hoses and how long they were in place.

(c) I was not able to determine whether any stair door self-closers failed to operate, however, I did not find any evidence of this in fire service witness statements. Evidence from the 2016 risk assessment provided by the TMO, described two stair doors as failing to self-close fully. I currently have no evidence that these defects were ever dealt with.

2.21.34 Further evidence and investigation is required, in particular to ascertain why very hot smoke was able to spread from the lobbies to the stair on Levels 13 - 16.

2.22 Failure of the lobby ventilation

2.22.1 Overall compliance status

2.22.2 As I explain in Appendix J the purpose of lobby smoke ventilation under the statutory guidance is:

"*There should therefore be some means of ventilating the common corridors/lobbies to control smoke and so protect the common stairs. This offers additional protection to that provided by the fire doors to the stair. (The ventilation also affords some protection to the corridors/lobbies).*"

2.22.3 From my investigations into the currently available evidence, the smoke ventilation system installed in Grenfell Tower appears to have been a refurbishment of the original smoke ventilation system from the time of its construction.

2.22.4 During a fire the system was intended to extract smoke using mechanical fans from the fire floor lobby through two smoke shafts (North and South) on a single floor only.

2.22.5 The smoke ventilation shared common automatically opening vents (AOVs) and ventilation shafts with the environmental system. When operating in environmental mode the AOVs on all floors could have been open.

2.22.6 Smoke detectors positioned in the lobby were intended to automatically activate the smoke system, shutting down and isolating the environmental ventilation, isolating all lobbies except for the fire floor by shutting AOVs on all other floors and activating the extract fans serving the North and South shafts.

2.22.7 In smoke mode, as air and smoke was extracted from the lobby it would draw air into the lobby from the stair, which had a permanently open vent at roof level. The flow of fresh air from the stair to the lobby was therefore intended to prevent smoke from entering the stair.

2.22.8 I have explained in Appendix J that this system was not in accordance with the recommendations of CP3 nor in accordance with the current statutory guidance; it was a bespoke system design which was not compliant with provisions made in ADB 2013.

2.22.9 During my site investigation I have found evidence that the system did not operate as intended. The installed system was provided with an override facility which could have allowed fire fighters to change the floor on which the smoke ventilation system was operating. There is evidence the fire service attempted to take control of the system but were unable to successfully do so.

2.22.10 The system was designed to extract smoke from one lobby at a time only. Therefore, in Grenfell Tower, where all lobbies from Level 4 to Level 23 become smoke logged, even if it had functioned, a compliant system would not have been able to provide smoke control to all lobbies. It would not have been capable of preventing the spread of smoke to the stair from lobbies on other levels, had it operated as intended. Therefore, it could not have provided complete protection to the protected stair during the fire event that occurred in Grenfell Tower.

2.22.11 However, the system was intended to be capable of being switched off and restarted on a different floor. Therefore, had the smoke control system operated correctly and the fire service been able to take control, they might have used the system to sequentially vent smoke from the lobbies on each floor of Grenfell Tower.

2.22.12 I consider that this system under the control of the fire service could have provided some assistance to improving conditions for means of escape and firefighting within the lobbies and therefore the stair.

2.22.13 Whilst it appears the smoke control system failed to operate as intended, this had no effect on the initial fire event, as smoke does not appear to have spread to the Level 04 lobby at this time.

2.22.14 Further investigation is required to assess how effective the installed system could have been and whether the override function was provided and operational and therefore available for the fire service.

2.22.15 The coupling of a fire lift with an operational smoke ventilation system, could, if operating, have been of benefit to firefighting operations and occupants making their escape.

2.22.16 **Failure of the fire lift**

2.22.17 Based on the documentation assessed (see Appendix H) the lifts within Grenfell Tower were not designed in accordance with the requirements for a fire-fighting lift as described in ADB 2013 (the most recent refurbishment works to the lifts were conducted in 2012-2016).

2.22.18 The lifts do appear to have been provided with the features consistent with a *fire lift* as described in CP3, which was the original design guidance available at the time of construction.

2.22.19 This is a lower standard of performance, which lacks a secondary power supply, water ingress protection or FD60 performance for the lift landing doors. It does provide a fireman's switch, which automatically grounds the lift and stops it from being called to other floors by building occupants.

2.22.20 On the 14 June 2017, however, the fire service contemporaneous notes (MET00005384) describe the failure of the fireman's switch to recall the lift or alter its control to firefighting mode during the initial response to the Flat 16 fire on Level 4. The significant findings from the 2016 risk assessment (TMO00017691) note that the fireman's switch was that time located at Level 2 and was required to be moved to Ground level. I observed the switch at Ground level and at Level 2, but have not been able to verify that the switches were correctly interfaced with the lift controls.

2.22.21 Due to this failure to operate under the fire service control, the firefighting lift failed:

(a) To provide equipment transport to the initial fire Bridgehead location at Level 2 delaying to the time of fire fighter entry to Flat 16.

(b) To provide equipment transport thereafter as the fire spread up the building and as the fire service tried to move the Bridgehead up the building.

(c) To provide an available form of transport for rescued occupants from the Bridgehead back down to ground during the night, and particularly as needed by mobility impaired persons.

(d) To prevent occupants being able to use the lift during the fire and so created unnecessary risk to residents during the fire.

2.22.22 All operations by the fire service within the 23 storeys were therefore required to be by means of walking up and down the stair only. This would have increased the time required by the fire fighters wearing breathing apparatus to reach the upper levels and reduce the time available to them to undertake rescue operations.

2.22.23 On 14th June 2017 the lower standard fire lift which was provided, failed to operate during the fire. I want to investigate further how this failure occurred and I await the data I require to do this.

2.22.24 In conjunction with additional fire fighter evidence, I want to investigate further how the lift being in operation could have helped, particularly with rescue.

2.22.25 The lift itself does not appear to have created the spread of fire and smoke; nor is it intended to control the spread of fire and smoke. However, it was a mitigation measure, when dealing with the consequences of the spread of fire and smoke.

2.22.26 For example, a compliant lift could have enabled a faster initial response time to the fire in Flat 16 (firefighters could not take control of the lift as is required, and eventually had to call the lift in the normal passenger service mode (not emergency controls) and wait for it to arrive at the ground floor). This might have increased the chances of extinguishing the fire before it spread externally. However, it cannot be asserted that it would have absolutely achieved this. But this is a significant enough concern to investigate in more depth. I intend to do this once further relevant evidence is made available to me.

2.22.27 **Failure of the water supply**

2.22.28 A dry fire main was provided at Grenfell Tower instead of a wet fire main. This was non-compliant with the design guidance in force at the time of original construction, and is also non-compliant with current standards.

2.22.29 The fire main was located within the lobby and not within the stair. This was compliant with the design guidance available at the time of construction only. Later guidance would call for the main to be provided in the stair rather than the lobby.

2.22.30 There were no difficulties associated with the dry fire main position in the lobby during the fire service response to the initial fire in Flat 16, Level 04.

2.22.31 However, following the ignition of multiple internal flat fires by the external wall construction fire, the operation of the dry fire main failed in two ways:

(a) The fire service was unable to get adequate water for fire-fighting from the dry main on the upper levels due to the lower capacity of the dry main system compared to a wet main system. This failure is relevant to the non-compliant installation of a dry fire main instead of a wet fire main; and

(b) The requirement for the fire service to connect multiple hoses to fight the multiple internal fires meant the demand for water outstripped the capacity of the system. However, this failure is not relevant to the non-compliant installation of a dry fire main. Wet fire mains are also only designed to supply up to 2 hoses operating simultaneously.

2.22.32 In a wet riser the system is already charged with a pump connected when the fire service arrives. There are no operations required for the fire service to find hydrants, connect to their pumping appliance and connect to the riser inlet. Therefore, the provision of a dry main would have contributed to an increase in the time taken by the fire service to get water to the initial fire event in Flat 16.

2.22.33 A wet fire main, could have enabled a faster initial response time to the fire in Flat 16 which might have increased the chances of extinguishing the fire before it spread externally. However, it cannot be asserted that it would have absolutely achieved this.

2.22.34 A wet fire main, could have enabled greater water pressure for fire-fighting on the upper floors of Grenfell Tower, which may have allowed the fire service to use water to cool the lobbies and stair and therefore provide more assistance to people trying to escape.

2.22.35 Whilst the dry fire main failed for the fire service, in controlling fire and smoke spread in the lobbies and stair and particularly on the upper levels, the wet fire main could also have failed to provide sufficient water and pressure to control fire and smoke spread once more than 2 hoses were in operation.

2.22.36 The multi-floor fire required the fire service to operate multiple hoses in Grenfell Tower. Internal water mains are not currently designed to provide this level of supply.

2.23 The remaining non-compliant active and passive systems

2.23.1 In Section 15 and 16 of my report and throughout their associated Appendices, I provide my preliminary opinion on the compliance status of the active and passive systems installed in Grenfell Tower on the night of the fire.

2.23.2 I have not identified them all here in my Conclusions, as I consider those referenced above only, at this stage, to have been relevant to the events in Grenfell Tower.

2.23.3 This was an internal fire, for which current statutory design guidance provides fire safety guidance. It then became a major fire, of a scale that falls outside the remit of current statutory design guidance.

2.23.4 However, the number of non-compliances signify a culture of non-compliance at Grenfell Tower. I am particularly concerned about the maintenance regime of the active and passive fire protection measures. I note that multiple automatic systems such as the control of the fire lift and the smoke ventilation system, appear not to have operated as required.

2.23.5 I will address question of whether there was a culture of non-compliance at Grenfell Tower in my Phase 2 report.

2.23.6 I am aware that alternative methods to comply are permitted under Section 0.21 of the Approved Document B 2013. I will investigate what, if any, alternative compliance approaches were proposed by any stakeholder, to deal with the non-compliances (as I have currently defined them).

2.23.7 I intend to explain the significance of all the non-compliances I have found, with regard to the concept of Material Alteration, under Regulation 3 of the Building Regulations. Therefore, I will investigate if some, or all of the non-compliances, were such that overall they resulted in the building being less satisfactory than it was before the refurbishment work was carried out in 2012-2016.

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

Next Steps

2.24 Phase 2 report

2.24.1 This report contains my preliminary conclusions on the matters raised in my Phase 1 instructions (see Section 1). In Phase 2, I am instructed to provide a report on:

(a) The design and construction of Grenfell Tower and the decisions relating to its modification, refurbishment and management (so far as is relevant to the events on the night of 14 June 2017);

(b) Whether such regulations, legislation, guidance and industry practice were complied with in the case of Grenfell Tower and the fire safety measures adopted in relation to fire; and

(c) Final conclusions on the active and passive fire protection measures within Grenfell Tower on 14th June 2017 and the extent to which they: (i) failed to control the spread of fire and smoke and (ii) contributed to the speed at which the fire spread.

(d) Recommendations about what, if any changes could be made to the regulatory regime and industry practice to prevent a similar incident from happening in the future.

2.24.2 Prior to preparing my Phase 2 Report, I would like to highlight a number of particularly concerning matters which arise as a result of my Phase 1 work.

2.25 Persons requiring assistance during evacuation.

2.25.1 Section 2 *Means of escape from flats* in ADB 2013 makes no provision for occupants that require assistance to escape.

2.25.2 However, the functional requirement for means of escape is clear. It requires:

"*…appropriate means of escape in case of fire from the building to a place of safety outside the building…*".

In addition, Section Bi.v states:

"*Note: Some people, for example those who use wheelchairs, may not be able to use stairways without assistance. For them evacuation involving the use of refuges on escape routes and either assistance down (or up) stairways or the use of suitable lifts will be necessary.*"

2.25.3 There is evidence of the lack of assistance for such persons in Grenfell Tower.

2.25.4 In the next stage of my work, I intend to explore the provisions made by the relevant parties at Grenfell Tower, for occupants that required assistance to escape at Grenfell Tower.

2.25.5 I also intend to explore how this information was communicated to relevant residents and the fire service before the night of the fire.

2.25.6 It is also important that the Inquiry investigates how many residents in Grenfell Tower required assistance to evacuate, whether they were known to LFB and the steps taken to rescue them.

2.25.7 In my opinion, the lack of guidance for buildings containing flats in ADB 2013 should attract immediate attention.

2.25.8 I note that in the LGA Guide, Section 79.9 which deals with preparing for emergencies, it advises:

"In 'general needs' blocks of flats, it can equally be expected that a resident's physical and mental ability will vary. It is usually unrealistic to expect landlords and other responsible persons to plan for this or to have in place special arrangements, such as 'personal emergency evacuation plans'. Such plans rely on the presence of staff or others available to assist the person to escape in a fire."

2.25.9 Further it provides in 79.10 to 79.11:

"Even in sheltered housing schemes, there will be reliance ultimately on rescue by the fire and rescue service in the event that residents cannot escape by themselves. However, in sheltered housing schemes, it is commonplace to hold information relating to any resident with particular mobility or other issues affecting their ability to escape. This can be made available to the fire and rescue service on arrival at the premises (e.g. by keeping it in a 'premises information box', which can only be unlocked by the fire and rescue service, at the main entrance).

It is not realistic to expect such an approach to be adopted where there are disabled people and others requiring assistance in a 'general needs' block. Any attempts to keep information of this kind must be updated regularly as inaccurate information could potentially be more harmful than no information."

2.25.10 I consider that the lack of provision for persons requiring assistance in a high rise residential building is unacceptable, and results in a substantial breach of the functional requirement for means of escape under the Building Regulations. In my view, the LGA guidance should be updated to adequately deal with persons requiring assistance from "general needs" blocks.

2.25.11 It is also my opinion that a failure to provide adequate means of escape for persons requiring assistance also causes a breach under the RR(FS)O 2005, which I will address in my Phase 2 report.

2.26 Mitigating existing rainscreen cladding systems formed with polymeric materials

2.26.1 In my opinion, it is not acceptable to expect the fire brigade to mitigate for combustible external wall construction in high rise residential buildings, as there are so many reasons why that is not feasible, as I have explained throughout my report, but particularly in Section 17.

2.26.2 Therefore, where there are other buildings of similar construction to Grenfell Tower, I would urge relevant parties to communicate with one another now and consider whether Stay Put is a viable strategy.

2.26.3 Such an exercise should incorporate specific consideration of (a) evacuation of those who require assistance to evacuate (see Section 18); (b) communication methods with residents of high rise buildings in the event of fire (See Section 18); and (c) availability of facilities for fighting external multi storey fires in these buildings (see Section 17), especially firefighting strategies for when internal compartmentation is overcome by an external fire. There is a resulting bespoke set of provisions and access needs for external firefighting in those circumstances.

2.26.4 There is also, in my view, an urgent need to consider how to communicate with residents in a high rise residential building, in the event of fire.

2.26.5 For residential buildings with a Stay Put strategy, I remain concerned that some materials of limited combustibility may not be adequate for the external surface of a rainscreen cladding system, in a high rise residential building.

2.26.6 In my opinion, full scale testing of rainscreen cladding systems ought to be carried out, including window openings and other relevant fixtures and fittings, rather than in strict compliance with the current arrangements in BS8414.

2.26.7 This testing would assist in establishing whether materials of "limited combustibility" remain suitable, or whether a higher performance requirement for the external surface when comprised of a rainscreen composite panel, should be specified i.e. that materials may in fact need to be "non-combustible" and Class A1, for high rise residential buildings with a Stay Put strategy.

2.26.8 The absence of a body of relevant fire test evidence for rainscreen cladding systems, and the components of rainscreen cladding systems, based on the current submissions to the Public Inquiry, shows a serious failing in the testing and classification regime. A body of publicly available and relevant fire test evidence is urgently required to support common construction forms.

2.27 Fire Doors

2.27.1 On the 15th March 2018, the government issued a press release on the topic of non-compliant fire doors, it states:

"*Independent experts have advised that the risks to public safety remain low, and that evidence from investigations to date does not change this assessment*".

It further advises:

"*The risk to public safety remains low and there is currently nothing to suggest this is a widespread issue*".

2.27.2 I note the current Masterdor Suredor website states that its doors are:

"*Specially designed for social housing specification projects, Masterdor Suredor is a thermally efficient high performance GRP door range that replicates the styling of traditional timber doors providing a cost effective tried and tested solution for your project.*"

2.27.3 BS9991 2015 advises:

"*Fire doors: Doors in fire-separating elements are one of the most important features of a fire protection strategy, and it is important to select a fire door that is suitable for its intended purpose. They should normally be self-closing* …"

2.27.4 Fire doors which contain glazing pose a serious failure risk unless expressly constructed and tested to prove their viability. Fire doors containing multiple additional fixtures and fittings, unless expressly constructed and fire tested to prove their viability, also pose a serious risk of failure.

2.27.5 It is particularly the case that in single stair high-rise residential buildings such failures cannot be tolerated, due to the Stay Put strategy.

2.27.6 In my professional opinion, fire doors that do not provide the necessary fire performance do pose a risk to life, and should be replaced in existing buildings.

2.28 Industry awareness of fire performance – relevant test evidence

2.28.1 I have found no evidence so far that there was any understanding by any member of the design team or construction team, nor by the approving authority, that the rainscreen cladding system was either combustible or in breach of the Building Regulations.

2.28.2 I have provided my definition of relevant test evidence in Section 3 of my report.

2.28.3 I have reviewed all of the fire test evidence provided to the Public Inquiry at this stage, and in general found it not to be relevant test evidence for Grenfell Tower. i.e. None of it supports the relevant material or product at Grenfell Tower, to be in accordance with a specification or design which has been shown by test to be capable of meeting the required performance.

2.28.4 This is particularly with respect to the rainscreen cladding system installed at Grenfell Tower but also regarding the fire doors.

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

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

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

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

2.28.8 Further ADB 2013 states "*Small differences in detail (such as glazing apertures, intumescent strips, door frames and ironmongery etc) may significantly affect the rating.*"

2.28.9 I have found no relevant test evidence has been provided at this stage, for the rainscreen cladding assembly, nor its component parts.

2.28.10 I have found that the flat entrance fire doors which were installed, were not in compliance with the relevant test evidence provided.

2.28.11 I have found no evidence that this was understood by relevant professionals, prior to handover of the fire safety system, nor was it understood by the fire safety management regime.

2.28.12 In my view it is essential that there is renewed and proper understanding of relevant test evidence, and how it relates to performance, as already emphasised in ADB 2013.

2.28.13 This is a critical change which is needed throughout the design and construction industry.

2.29 The issue of "*Filler material*" and its application to products used as External Surfaces

2.29.1 The external surface, the insulation and the cavity barriers, are addressed in turn in Section 12 of ADB 2013 (12.6, 12.7, and 12.8), and together form the External Wall construction. I have always considered those three elements in turn, as the external wall construction in my professional experience also.

2.29.2 The introduction of ACP rainscreen cladding panels into the construction industry market, created the industry wide use of *composite external surfaces*. This required and still requires attention.

2.29.3 The suite of National and European reaction to fire tests is complex and confusing, as I have illustrated in my Appendix F. No guidance is provided on which regime takes precedence when differing classifications are obtained for the same material or product. This has become a critical problem.

2.29.4 The test standards BS 467-6 and BS 476-7 would not expose the core of composite materials directly to heat. Its exposure is indirect by heat transfer through the outer aluminium layer.

2.29.5 The national Test Standards BS 476 – 4 and BS 476 – 11, both expose the core of composite material directly to heat, as the full depth of the composite material is placed inside a furnace and heated from all sides.

2.29.6 The European test standards BS EN ISO 1182, BS EN 1716, and BS EN ISO 11925-2 all expose the core directly to heat. In BS EN ISO 1182 the full depth of the composite material is placed inside a furnace and heated from all sides. In BS EN 1716 the core is ground to a powder then ignited. In BS EN ISO 11925-2 a gas flame is impinged directly onto the exposed edge of the sample if the edge is exposed in end use (as occurs in ACM panels).

2.29.7 The European test standard BS EN 13823 does not directly expose the core of ACM panels to heat. However, it cannot be used in isolation to demonstrate Class A2, B or C and must always be used in conjunction with a European test that exposes the core directly.

2.29.8 This difference is critical in products where the combustible core of the product is exposed in practice, and also by very means of its thickness within a composite. Particularly in ACM material is used in panel forms, which are approximately 3-4mm in thickness. It is very difficult to demonstrate that the core in such a slender composite would not be exposed to heat in practice – either via an exposed edge or via conduction through the aluminium sheet.

2.29.9 Therefore, as I have explained in Appendix F, there are two aspects of ADB 2013 that, in my opinion, require urgent review and change.

2.29.10 First, the absence of definitions of "external surface" and "filler" as they apply to the rainscreen cladding outer layer when formed using ACP with a combustible core.

2.29.11 Secondly, Diagram 40 in Approved Document B contains contradictory requirements. A material can fail to meet all applicable European performance requirements (Class B or Class A2 as is allowed by means of Diagram 40 and Section 13a of the ADB), but nonetheless be compliant with the National Class 0 (when classified by means of a Class 1 material which has a fire propagation index (I) of not more than 12 and sub-index (i1) less than 6), defined by testing to British standards (Clause 13b of Appendix B of ADB 2013).

2.29.12 I consider that an urgent change to Section 12 of ADB 2013 is required and specifically with reference to Diagram 40. I suggest that the performance standard for an external surface, should be European performance classification A2 (in this context of high rise residential buildings). For the European testing regime, the composite system must be tested, and this would remove any room for doubt on this subject.

2.29.13 The Class B performance and the Index I performance should be removed for high rise residential buildings.

2.29.14 I consider both changes should certainly be extended to hospitals, where a Stay Put strategy is adopted.

2.29.15 I have been unable to find any conclusive evidence that the context of "*filler material (not including gaskets, sealants and similar) etc.*" as written in Insulation Materials/Products Section 12.7, was intended to incorporate the core of an External Surface, and specifically an ACM.

2.29.16 I consider the evidence tends more towards the definition of filler material as it relates to Buildings, where filler is clearly defined as a joint or a surface filler (BS EN ISO 6707-).

2.29.17 I note the use of the word "core" throughout BR 135, which does not mention the words Filler material at all. And I note throughout Appendix F in Approved Document B 2013, as it relates to another form of composite panel, it too uses the word core, and not filler material.

2.29.18 I am aware that there is a range of opinion, since the Grenfell Tower fire, on this issue and as a result others consider that the core in an ACP is now *filler material* and therefore is dealt with by the provisions made for Insulation under Section 12.7 of the ADB 2013. I have been unable to find the technical basis for this body of opinion.

2.29.19 For the reasons I have set out in detail in Appendix F, I disagree with this view.

2.29.20 However, there is a more fundamental issue here regarding the fire performance of the core in composite external surfaces, such as those found in rainscreen cladding systems formed with ACP.

2.29.21 I have concluded in Appendix D of my report, that the legal requirement is to demonstrate compliance with the functional requirement of the Building Regulations 2010.

2.29.22 It is my opinion, having carried out this detailed review of the suite of test standards in Section F of my report, that in order to comply with the Building Regulations, I must consider the whole of the product which forms the external surface of the rain screen cladding panel system – i.e. the two layers of aluminium and the core (typically approx. 4mm thick in total). Otherwise the performance of the core is entirely omitted when considering the construction of the external walls.

2.29.23 For the avoidance of doubt, I do not consider it possible to comply with the functional requirements of the Building Regulations B4 (1) if the relevant test evidence omits the core in an ACP rain screen cladding system, or the relevant test evidence is based on a test that does not expose the edges of the ACP to direct heat.

2.29.24 That is why I consider that an urgent change to Section 12 of ADB 2013 is needed.

2.29.25 My opinion on *filler material*, has had no material impact on my compliance assessment of Grenfell Tower, because no relevant fire test evidence was provided to support the use of these products.

2.29.26 It also appears that no such test evidence existed in the first place (please refer to my Appendix E).

2.30 Polymeric materials and toxicity

2.30.1 In all my analyses presented here, the presence of smoke delayed or prevented residents from entering the lobby outside their flat, and also from entering the single escape stair.

2.30.2 I observed the composite fire doors used at Grenfell Tower produce large quantities of smoke and other products of combustion themselves, when heated, during a recent test at the BRE on 17th March 2018.

2.30.3 These materials, along with the polymeric materials used throughout the rainscreen cladding system, the infill panels between the windows, and the insulation used around the window surrounds, require expert review. This is with regard to the process of and products of combustion of such materials, which pose a direct threat to life. These can include thermal radiation, temperature of smoke, soot (the impairment of movement), acute toxicants, irritants and asphyxiants (incapacitation), toxic gases; chronic toxicants and carcinogens (with the potential to increase the likelihood of developing cancer).

2.30.4 I therefore recommend that the Inquiry considers appointing a toxicologist expert with specific reference to fire chemistry and with an understanding of the effect of heat on the body.

2.31 The gas installation at Grenfell Tower

2.31.1 A key area for further investigation is the gas installations at Grenfell Tower, both in terms of whether it complied with the relevant regulatory regime and whether it could be isolated within a reasonable time on the night of the fire. I have prepared a briefing note for the newly appointed Gas Services Expert in Appendix K of this report. In particular, it will be important for the Inquiry to investigate the role, if any, that the gas services played on the night including with reference to the hot zone that I have identified in the stair, as discussed in Section 14.

2.32 Suppression systems in existing high-rise residential buildings

2.32.1 I am aware of a body of professional opinion that considers that a suppression system may have prevented the fire events at Grenfell Tower.

2.32.2 Suppression systems can be a substantial mitigation measure in many internal fire events.

2.32.3 Regarding the specific complex fire scenario here – i.e. an external cladding system fire, caused by an internal fire event breaking through the construction detailing in and around a window opening – I am of the opinion there is a useful body of research work needed here to resolve this matter.

2.32.4 There is the need for very specific detailing of an effective suppression system in this event, and I am not aware such a system exists in the market at this time.

2.32.5 In particular, a number of matters would require detailed technical investigation including: the system arrangements on and near the window, the obstructions that could prevent effective fire control, the necessary water flow and the timing of the operation of such a system in order to suppress and control a fire before ignition of the various combustible cladding materials of the type found at Grenfell. All these matters require a detailed technical understanding and require new data, to create a basis for design that can be relied upon.

2.32.6 I am not aware of any body of work with this focus as yet, and do recommend that it is carried out.

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

3.1 Building description

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

3.1.2 The Lancaster West Estate is located in the Royal Borough of Chelsea and Kensington. The Lancaster West Estate scheme was designed by Clifford Wearden & Associate in the late 1960s, Phase 1 was approved in 1970 and construction of Grenfell Tower, by contractors A.E. Symes, of Leyton, London, commenced in 1972, with the building completed in 1974.

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

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

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

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

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

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

3.1.9 The client for the refurbishment works was the TMO.

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

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

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

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

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

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

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

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

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

3.1.19 The external wall construction of Grenfell Tower was originally a solid concrete construction. As noted above, precast biscuits were used as permanent formwork and facing of the columns. Solid precast spandrel beams were used to connect between columns around the perimeter of the building. Non-structural precast panels were provided as in-fill in the facade between windows.

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

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

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

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

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

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

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

3.1.24 A ventilated rain screen cladding system is either pressure-equalised or drained and ventilated. The ventilated rain screen system installed at Grenfell Tower was a drained and ventilated system.

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

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

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

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

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

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

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

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

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

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

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

3.1.35 The Refurbishment also included internal works such as the extension of the existing dry riser in the building, as well as the implementation of a new smoke ventilation system for every lobby to the single stair.

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

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

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

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

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

3.2 Over view of fire safety measures required for high rise residential buildings

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3.2.13 Then in Section 7 Fire Brigade Facilities it states:

> **SECTION SEVEN: FIRE BRIGADE FACILITIES**
>
> **701. General.** In high blocks of flats it is essential that provision should be made to assist the fire service in applying water to a fire as early as possible. This entails the installation of fire lifts and internal fire mains or ' risers '. The location of fire main, fire lift and main staircase must be inter-related so that if a fire lift opens into an area on an upper floor that might become smoke-logged, ready access to the fire main can be had from another floor.

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

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

(3) The third method, using smoke dispersal in Stage II, is to achieve cross-ventilation in the communicating spaces leading to main stairways by means of manually operated ventilators together with either permanent openings or ventilators automatically controlled by smoke detectors.

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

3.2.16 The issue of applying water early in a fire, and the fire being extinguished early are therefore required of the fire brigade. This is my definition of **"Defend in Place"**.

3.2.17 The active and passive fire protection measures are provided to support this form of firefighting. This includes the high degree of compartmentation and the smoke vent in the lobby. Should a fire not be extinguished early (and even if smoke reaches the lobby outside the dwelling), the intention in CP3 is that the stairway remains protected for use for occupants above the fire floor.

3.2.18 This combination of construction, systems, and early firefighting intervention, supports a Stay Put strategy. This is a layered safety approach.

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

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

b) fire resisting construction around any escape stair;

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

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

e) a very specific emphasis on the requirement for fire doors in flats, between flats and lobbies, and between lobbies and stairs (See Figure 3.1 below);

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

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

4.3 FIRE RESISTING DOORS

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

Figure 3.1: Fire doors - Excerpt from CP3 1971

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

a) lobby ventilation (see the specific requirements for single stair buildings in Figure 3.2below);

b) stair ventilation (see the specific requirements for single stair buildings in Figure 3.2 below);

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

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

e) fire lift for firefighters;

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

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

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

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

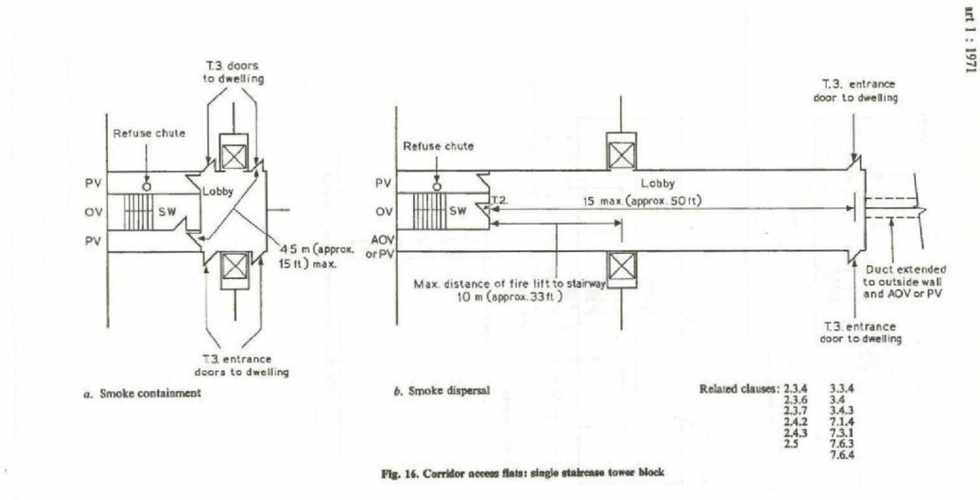


Figure 3.2: Corridor access flats - Single stair: CP3 1971

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

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

b) maintenance of active and passive fire protection systems;

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

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

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

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

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

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

3.2.27 **Current Guidance**

3.2.28 The most recent publication referring to the Stay Put strategy, is the British Standard BS 9991 *Fire safety in the design, management and use of residential buildings – Code of practice.* BS 9991 provides guidance for building designers on fire safety measures in residential buildings, including high-rise buildings, in order to comply with the Building Regulations 2010.

3.2.29 The latest version of this standard was published in 2015.

3.2.30 BS 9991:2015 defines the Stay Put strategy on Page 18, as follows:

"3.58 stay put strategy

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

3.2.31 This is a departure from CP3 1971 which had clearly stated that there is no reliance on the fire and rescue services for evacuation.

3.2.32 Both ADB 2013 (Section 2.3) which is statutory guidance, and BS 9991 2015 (Section 0.2.1), state that the basis of the provisions for means of escape for flats is:

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

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

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

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

3.2.33 Therefore, current guidance is explicit in its reliance on compartmentation and the fire resisting construction of common parts to permit the Stay Put strategy to be implemented.

3.2.34 It is also useful to note that BS9991 2015 makes the following statement in Section 0.2.1:

"In purpose-built blocks of flats, special provisions are made to ensure that a fire is contained within the flat of origin and that common escape routes and stairways remain relatively free from smoke and heat in the event of a fire within a dwelling. For this reason, the general fire strategy is a stay put strategy (see 3.58 and A.1).

NOTE It is important that information is given to residents regarding the meaning of the stay put strategy and the arrangements for means of escape available to them if a fire affects their flat.

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

3.2.35 This clearly introduces the concept that, as well as their role to suppress the fire early, any change from the Stay Put strategy relies on the fire and rescue services to direct every occupant to evacuate.

3.2.36 There are however no means to communicate such a change provided anywhere in BS9991 2015. I discuss this in specific detail in Section 18 of my Expert Report.

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

3.3 Fire development outside the dwelling

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

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

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

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

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

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

3.2.39 In BS9991 2015 it states regarding fire doors:

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

3.2.40 The fire and rescue services operational guidance (GRA 3.2 2014) recognises that there will need to be reliance on the fire and rescue service for changing from a Stay Put strategy. This operational guidance states that fire and rescue service Incident Commanders should be prepared to change that strategy during a fire event, as I have reproduced in Figure 3.3.

Contingency plans for particular premises should cover:

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

Figure 3.3: GRA 3.2 fighting fires in high-rise buildings. Excerpt from Page 17.

3.2.41 Other than these references to the fire and rescue service changing the stay put strategy, the statutory framework is still underpinned by the Stay Put and Defend in Place strategies. I have not identified any active and passive fire protection features in the current guidance which would assist in supporting a change from the Stay Put strategy, or from a "defend in place" firefighting strategy.

3.2.42 I consider therefore that the Stay Put strategy and the Defend in Place firefighting tactic have remained as the foundation for the statutory requirements regarding high rise residential buildings since 1971.

3.2.43 **Changes to active and passive fire protection measures since 1971**

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

3.2.45 The most significant change in fire protection measures was in 2006 when sprinkler systems were recommended for **new** residential buildings only, where they are more than 30m above ground level. These systems should be specified using BS 9251:2005 *Sprinkler systems for residential and domestic occupancies*, the Code of practice and BS DD 252 *Components for residential sprinkler systems* and in accordance with specification and test methods for residential sprinklers.

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

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

3.3.2 Appendix D: Legislation, Regulations and Guidance

3.3.3 Appendix E: Compliance assessment for External Fire Spread Regulation B4

3.3.4 Appendix F: Reaction to fire tests and classifications

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

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

3.3.7 Appendix I: Flat Entrance fire doors and Stair fire doors – requirements and provisions

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

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

Table 3.1 **Passive and Active fire safety systems**

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

3.3.10 The presence of these active and passive fire protection measures are intended to create a layered safety approach. They provide the means for early internal firefighting. They provide the means to limit fire and smoke spread from a dwelling fire. They create the "high degree of compartmentation" to support Stay Put strategy in a high rise residential building. There are multiple layers of safety, not a single layer of safety, which I explain in more detail below.

3.4 How the fire safety measures are intended to protect life

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

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

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

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

3.4.5 No alarm will sound anywhere else in the building.

3.4.6 Occupants of the fire flat or nearby are expected to call 999 to inform the fire and rescue service, and leave their flat, with the fire door shut behind them.

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

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

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

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

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

3.4.12 Two crews use the firefighting lift to go to the firefighting lobby two floors below the fire.

3.4.13 A Bridgehead is established in the lobby two floors below the fire in a safe air environment.

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

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

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

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

3.4.18 The fire in the dwelling is extinguished.

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

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

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

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

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

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

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

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

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

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

3.4.26 **Layers of safety**

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

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

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

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

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

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

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

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

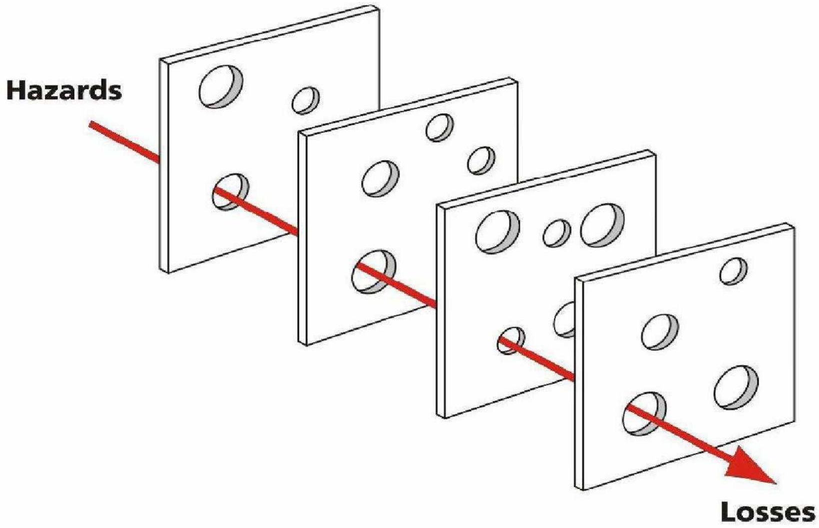


Figure 3.4 Swiss cheese model of acident causation

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3.5 Statements of compliance

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

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

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

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

3.5.5 This guide states:

"it is intended for buildings which have been constructed as purpose-built blocks of flats. It applies to existing blocks only." It goes on to state *"Fire safety design in new blocks of flats is governed by the Building Regulations 2010, but, once a block is occupied, this guide is applicable"* . It confirms that *"This document is intended to assist responsible persons to comply with the FSO and the Housing Act 2004. Accordingly, it is expected that enforcing authorities will have regard to this guide."*

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

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

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

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

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

3.5.11 In my Phase 2 report I will investigate how these non-compliances were understood and considered by the relevant members of the design and construction team, as well as the Royal Borough and Chelsea and Kensington, the TMO, their fire risk assessor for Grenfell Tower, Carl Stokes; as well as the London Fire Brigade (LFB) during their Regulatory Reform (Fire Safety) Order 2005 (RR(FS)O) inspections at Grenfell Tower.

3.5.12 I will also investigate how any non-compliances I have found impacted any of the relevant duties under the RR(FS)O (the legislation that applies once buildings are occupied).

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

3.5.14 I am using these documents to make statements of compliance only, at this stage.

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

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

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

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

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

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

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

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

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

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

3.6 Key definitions

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3.6.23 **PCS (Pouvoir Calorifique Supérieur)**: The gross heat of combustion which is the heat of combustion of a substance when the combustion is complete and any produced water is entirely condensed under specified conditions (EN ISO 13943). (BS EN 13501-1:2007+A1:2009, Fire classification of construction products and building elements – Part 1: Classification using data from reaction to fire tests)

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

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

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

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

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

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

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

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

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

3.7 Understanding how materials react to fire

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3.8 Definition of relevant test evidence

3.8.1 Reaction to fire tests

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

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

In such cases the material, product or structure should:

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

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

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

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

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

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

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

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

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

3.8.4.3 **BS 8414 and BR135**

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

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

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

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

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

3.8.5 **Fire resistance of Fire Doors**

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

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

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

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

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

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

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

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

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

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

4 Overview of building works at Grenfell Tower, including recent refurbishment 2012-2016

4.1.1 This section provides an overview of the refurbishment works completed after the construction of Grenfell Tower in 1972. It is based on documentation provided to me in Relativity.

4.1.2 The review includes a description of the original design and construction of the building and provides a timeline of refurbishment works derived from documentation, since 1985 including a description of the programmes of work.

4.1.3 The main focus is the Refurbishment works in 2012 to 2016 – this is specifically to understand what parts of Grenfell Tower were altered during this latest refurbishment project and more importantly to ascertain the scale of works carried out.

4.1.4 However, the TMO tenant flat entrance door replacement from 2011, and the new tenant gas supply works in 2016 and 2017 have also become relevant to my work for this Public Inquiry.

4.1.5 Note, where it has been possible to confirm the involvement of specific companies in any of these aspects of works, an organogram has been provided.

4.1.6 The flat numbers for residential levels 1 – 23 in Grenfell Tower are shown for reference in Figure 4.1 through Figure 4.6 inclusive and Table 4.1. This is to help with orientation when reading the contents of my report.

4.1.7 Note, the residential flats on typical levels 4 – 23 are numbered '1' through '6'. The specific number for each individual flat is based on its location in plan (reference) and the level it is on (sequential from 1 – 20, starting at level 4). For example, the flat in the Northeast corner of level 4 is flat 16, as shown in Figure 4.6.

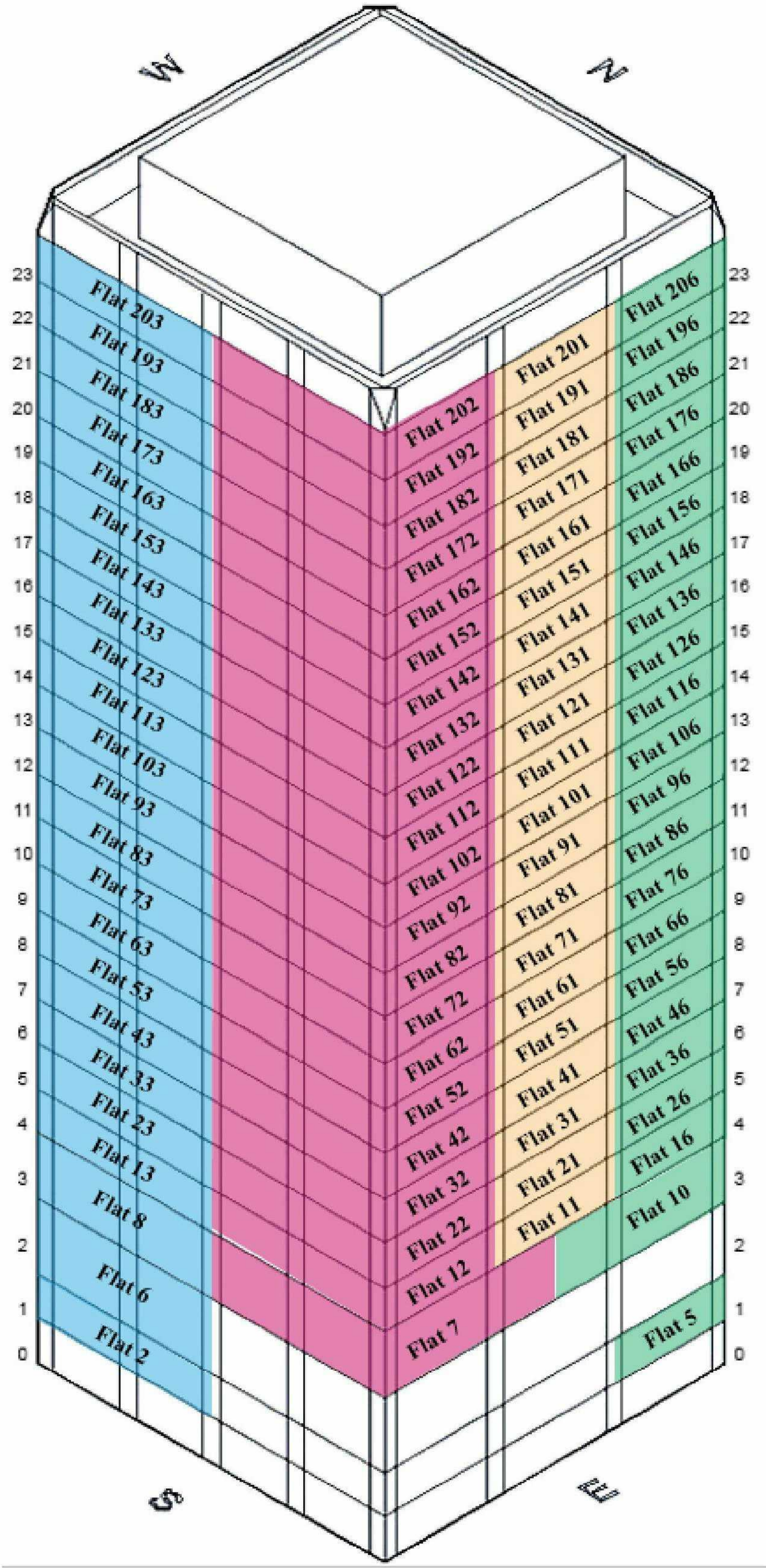


Figure 4.1: Residential flat numbers for South and East building elevations

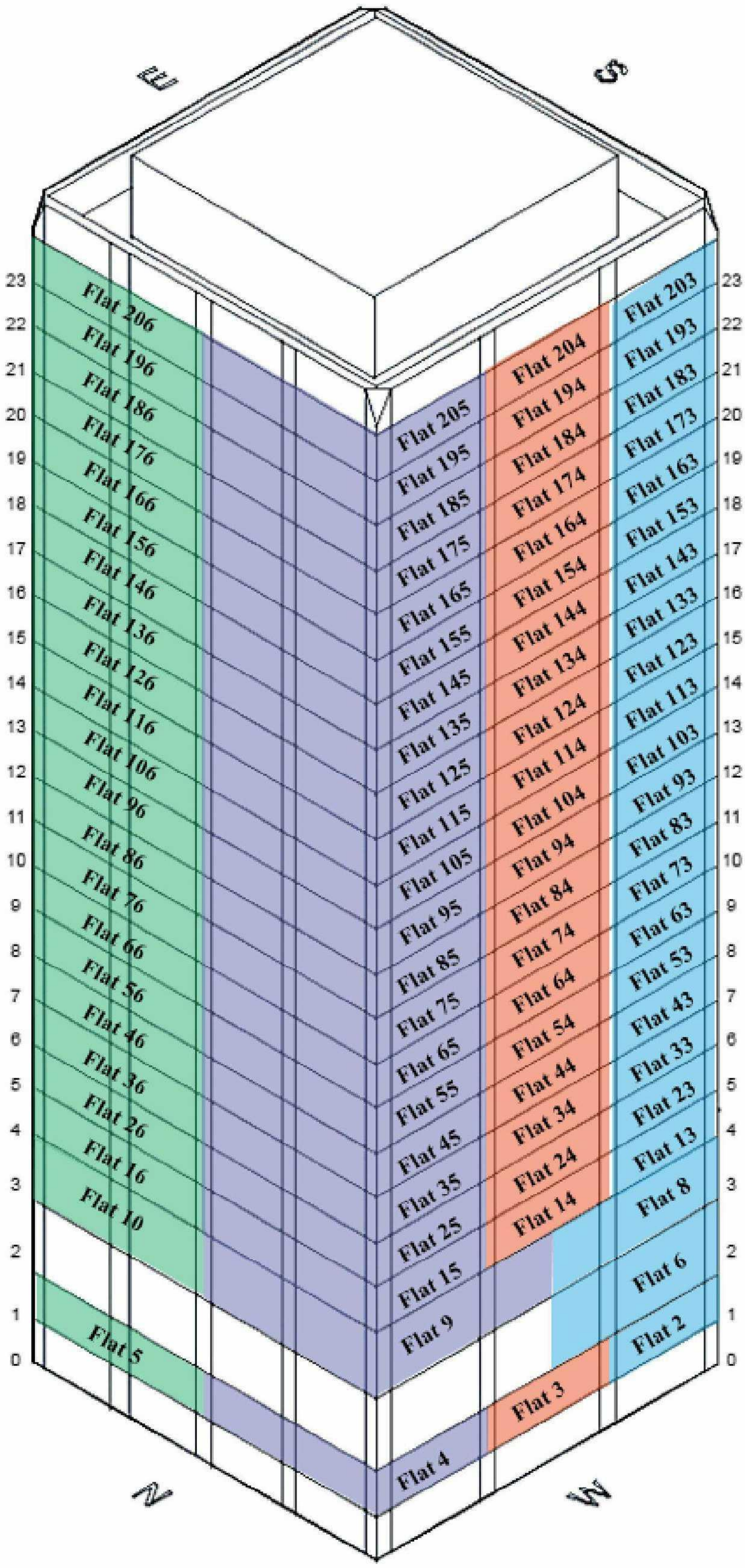


Figure 4.2: Residential flat numbers for North and West building elevations

Table 4.1: Residential flat numbers in Grenfell Tower, by level

Level	Flats
1	2, 3, 4, 5
2	6
3	7, 8, 9, 10
4	11, 12, 13, 14, 15, 16
5	21, 22, 23, 24, 25, 26
6	31, 32, 33, 34, 35, 36
7	41, 42, 43, 44, 45, 46
8	51, 52, 53, 54, 55, 56
9	61, 62, 63, 64, 65, 66
10	71, 72, 73, 74, 75, 76
11	81, 82, 83, 84, 85, 86
12	91, 92, 93, 94, 95, 96
13	101, 102, 103, 104, 105, 106
14	111, 112, 113, 114, 115, 116
15	121, 122, 123, 124, 125, 126
16	131, 132, 133, 134, 135, 136
17	141, 142, 143, 144, 145, 146
18	151, 152, 153, 154, 155, 156
19	161, 162, 163, 164, 165, 166
20	171, 172, 173, 174, 175, 176
21	181, 182, 183, 184, 185, 186
22	191, 192, 193, 194, 195, 196
23	201, 202, 203, 204, 205, 206

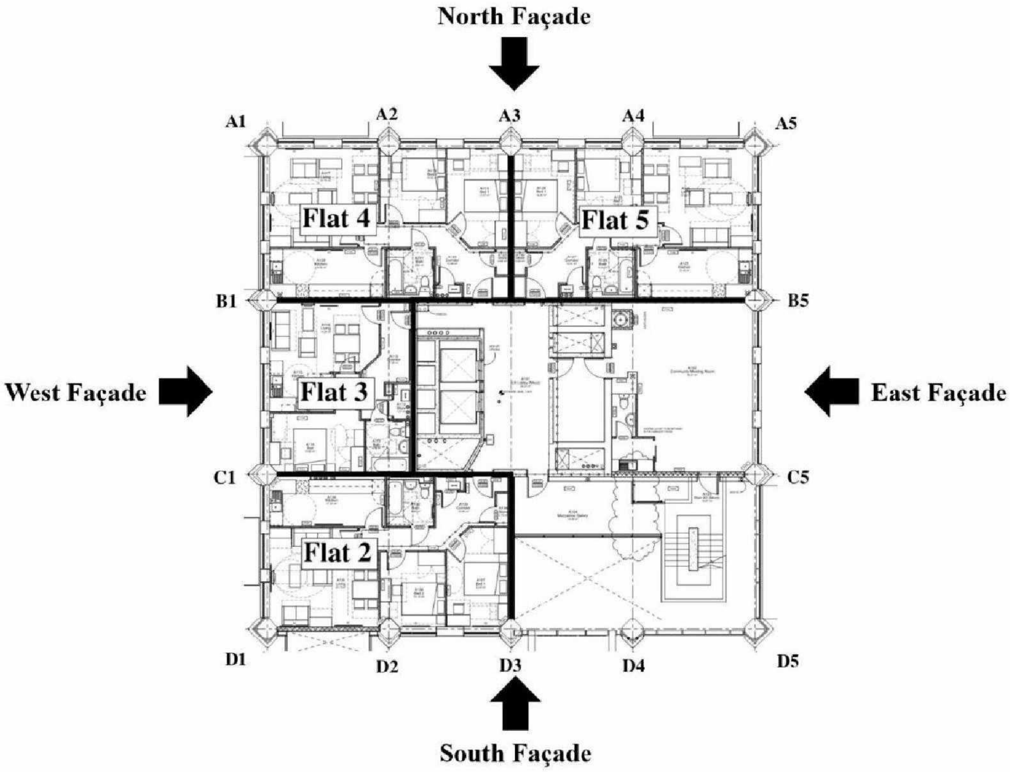


Figure 4.3: Residential flats 2 – 5 on level 1 (SEA00003231)

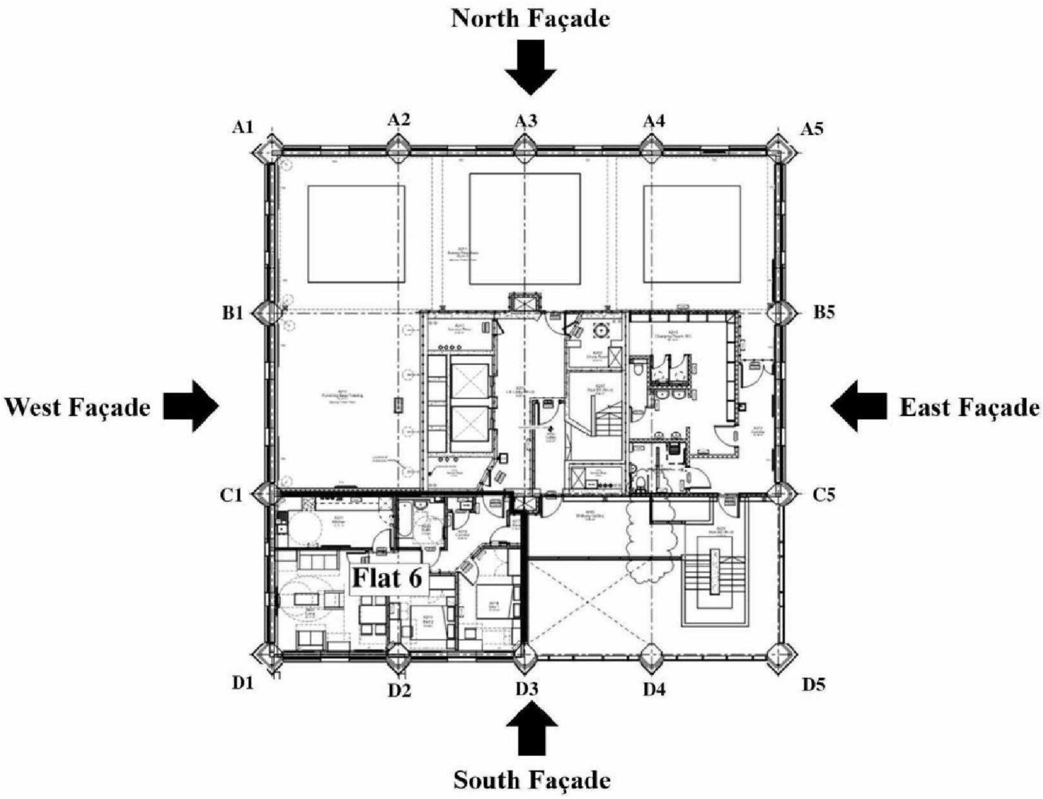


Figure 4.4: Residential flat 6 on level 2 (SEA00003149)

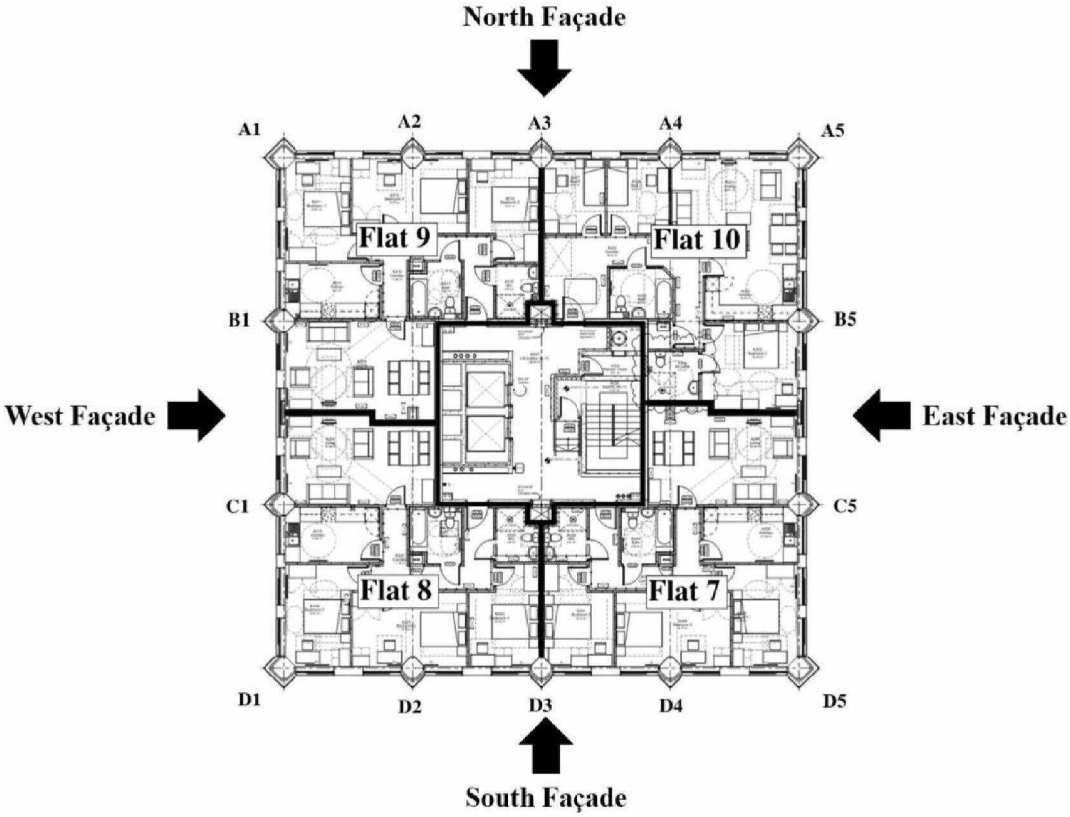


Figure 4.5: Residential flats 7-10 on level 3 (SEA00003229)

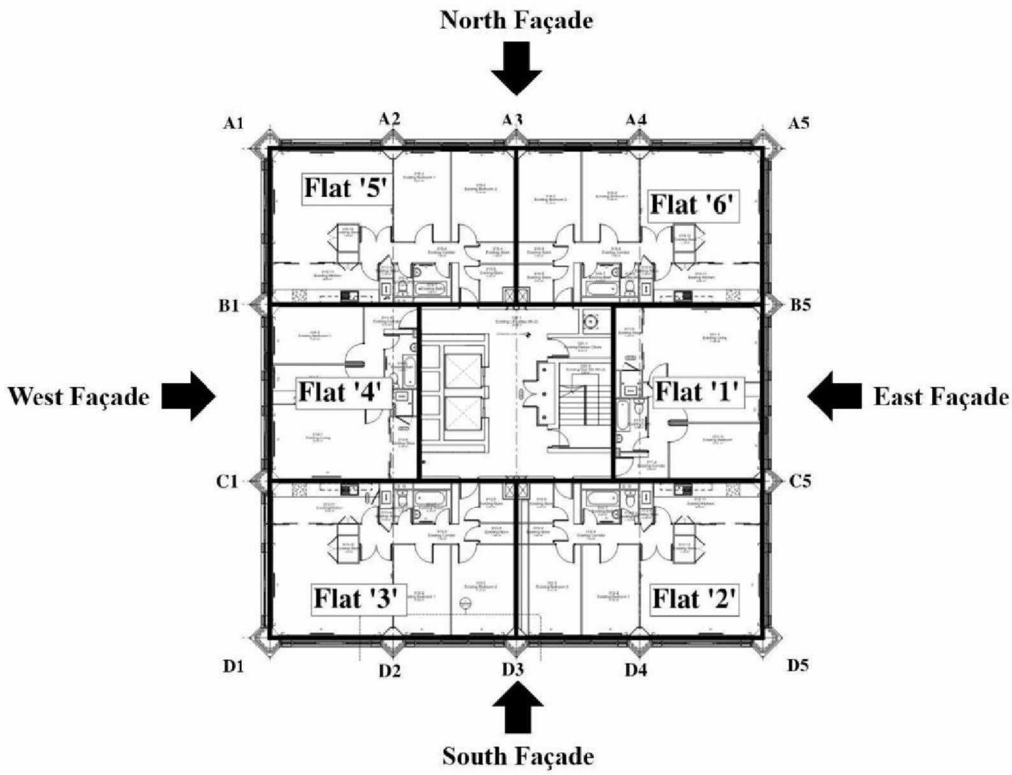


Figure 4.6: Residential flats on typical levels 4 – 23 (SEA00010474)

4.2 Original design and construction of the building

4.2.1 As I have explained in Section 3, Grenfell Tower was built between 1972 and 1974. The building is 65.49m in height (measured to the top level, which is the plant level) and 22.4m by 22.4m on plan. There is a central reinforced concrete (RC) core with perimeter RC columns.

4.2.2 The original building floor plans for the basement level – level 23 are shown for reference in Figure 4.7 through Figure 4.12 inclusive.

4.2.3 The original building elevations are shown for reference in Figure 4.13.

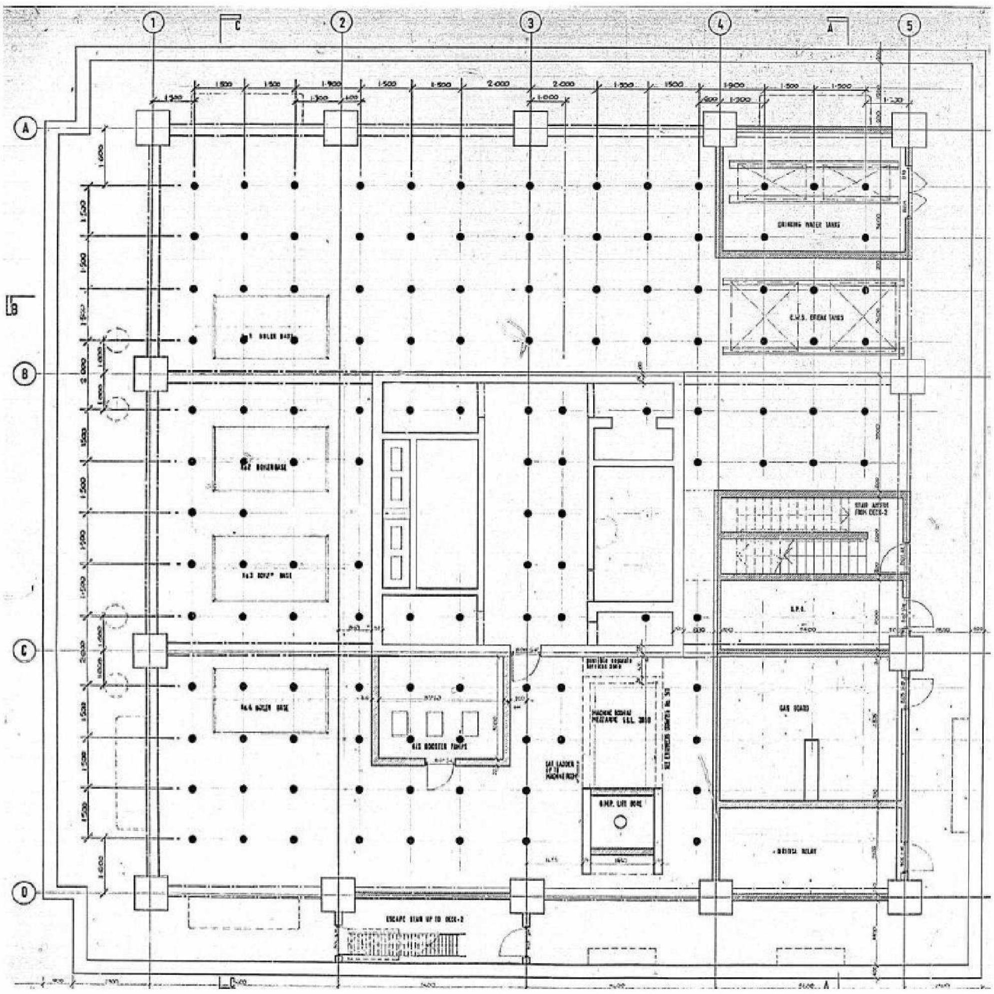


Figure 4.7: Original basement plan. (RBK00018843)

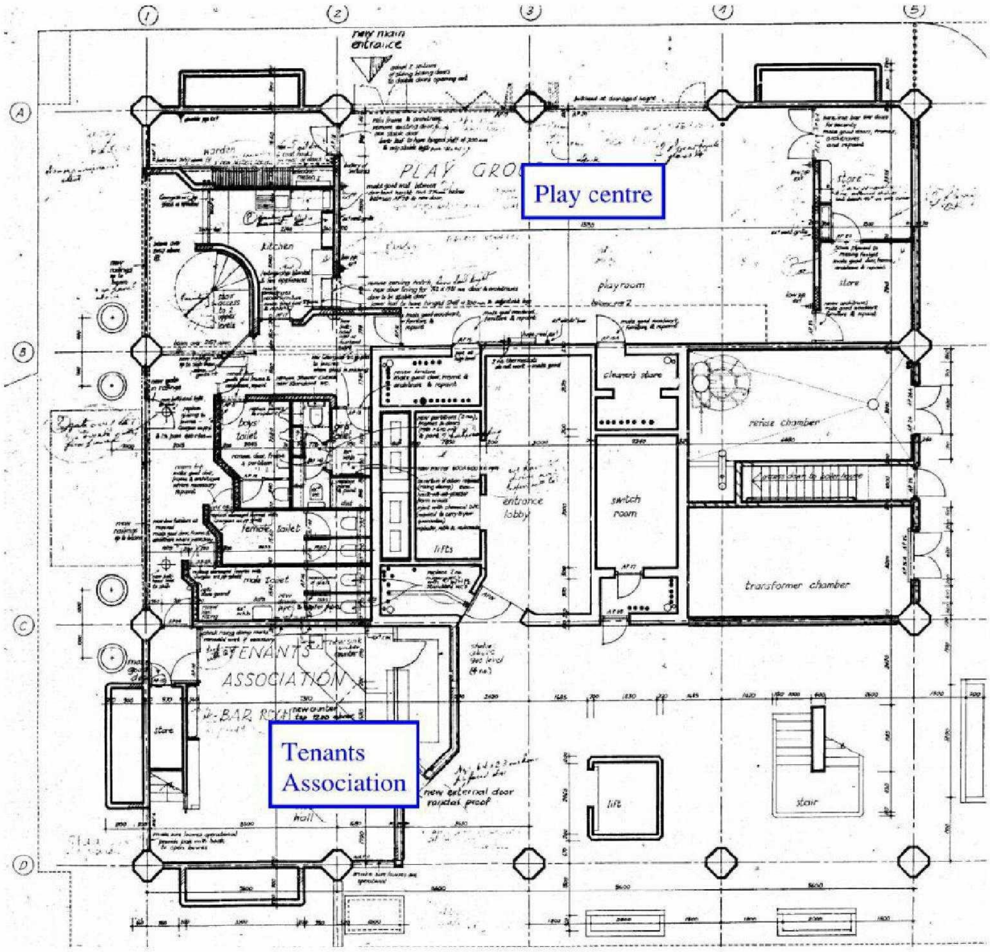


Figure 4.8: Original ground floor plan. (RBK00018861)

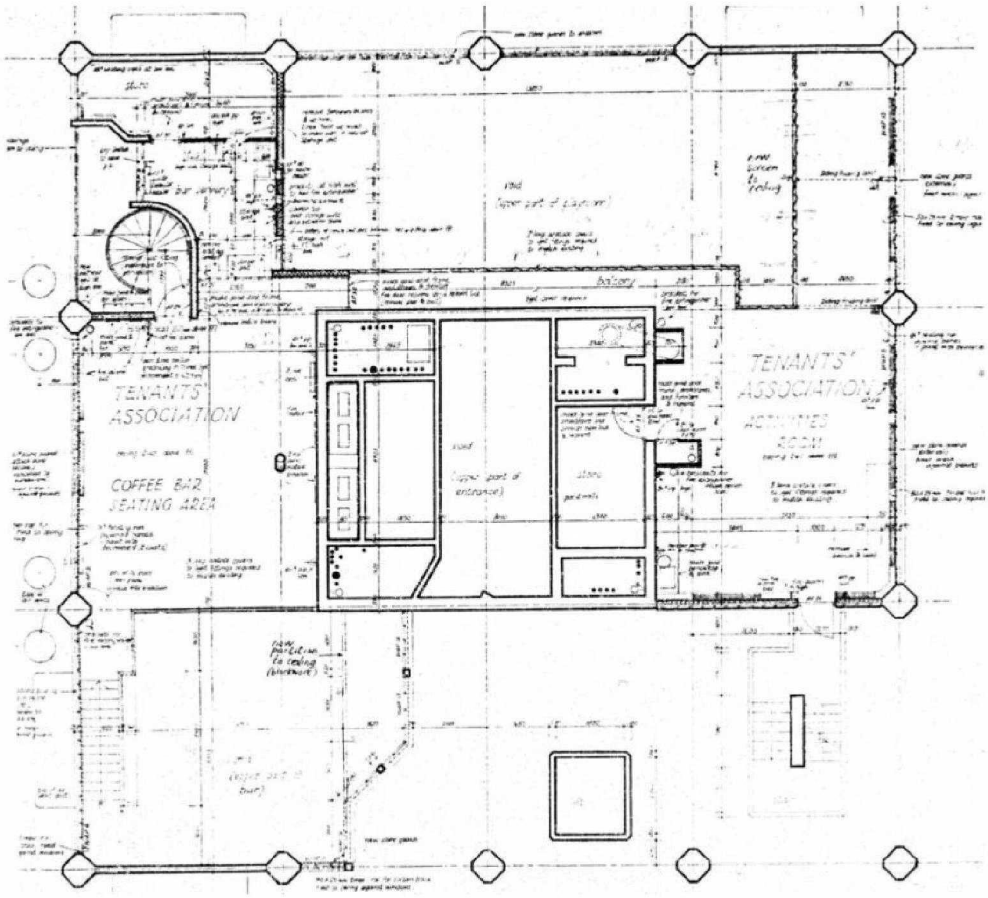


Figure 4.9: Original level 1 floor plan. (RBK00018862)

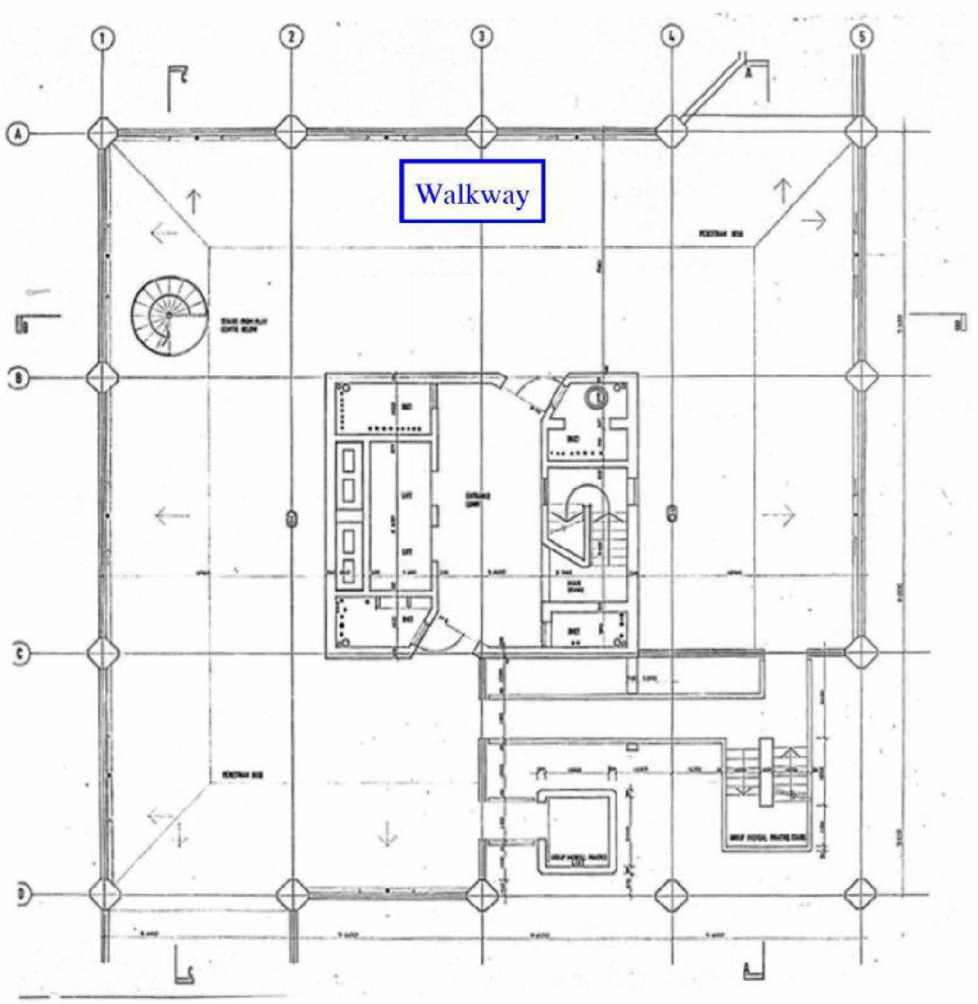


Figure 4.10: Original level 2 floor plan. (RBK00018833)

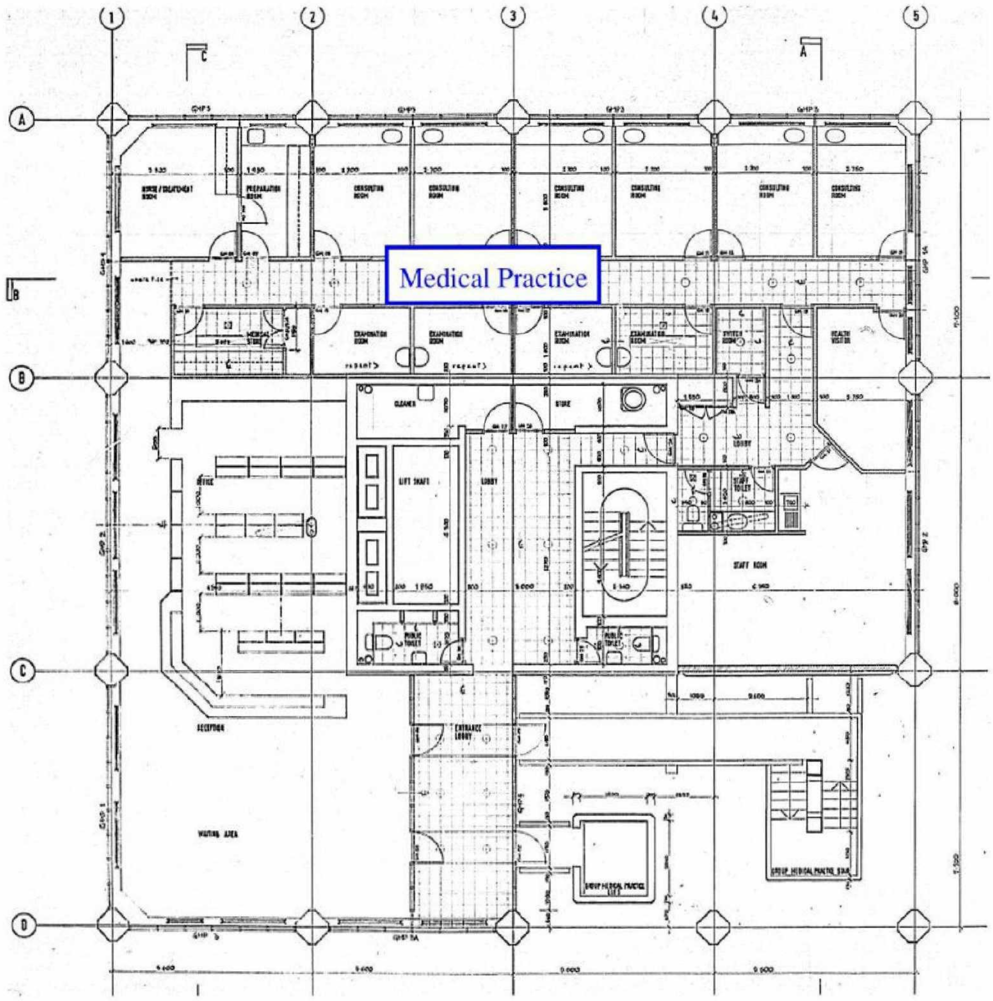


Figure 4.11: Original level 3 floor plan. (RBK00018834)

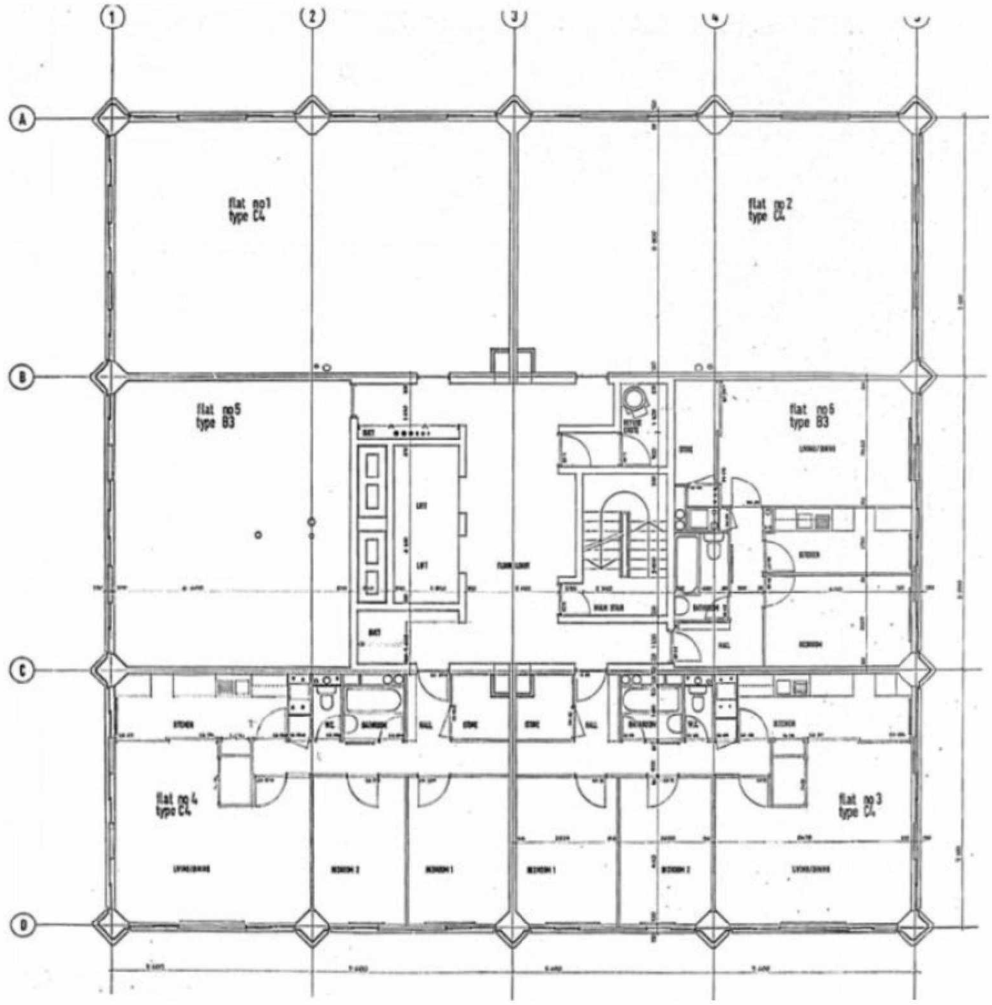


Figure 4.12: Original floor plan for residential levels 4 – 23. (RBK00018836)

Figure 4.13: Original construction of Grenfell Tower – building elevations (CCL00000028)

4.3 Timeline of building works

4.3.1 Table 4.2 below shows the major works that occurred in Grenfell Tower from 1985.

4.3.2 I have derived this from the information contained in a chronology of works submitted by RBKC (RBK00000275) and through inspection of documents submitted by Carl Stokes (CST00000384), KCTMO (TMO10048276) and Curtins Consulting Limited (CCL00000028), and as explained in detail in Appendix E.

4.3.3 I discuss the works summarised in in more detail in the following sections. Each section also identifies the works discussed on mark-ups overlaid on the Studio E As-Built drawings. This is in order to quantify what areas and to what scale the works altered Grenfell Tower, and where.

4.3.4 I describe the 2012-2016 refurbishment project in more detail from Section 4.7.

Table 4.2: Summary works for Grenfell Tower

Building works	Date	Description of Works	Extent of Works
Refitting of flat front doors	1985	Provision of new self-closing fire resisting flat entrance doors.	Unknown
Lift replacement	2005	Replacement of two electric passenger lifts and installation of one hydraulic passenger lift inclusive of all builders, electrical, structural and other attended works.	Lift shaft spanning from ground floor to level 23, but did not serve Levels 1 or 3 Lift motor room at Roof level.
TMO tenant flat entrance door replacement	2011	Programme of replacing 106 No. flat front entrance doors of dwellings occupied by RBKC tenants to comply with fire safety standards. The replacement doors were intended to achieve FD30S ratings, self-closing.	Flat entrance doors on Levels 4 to level 23
Refurbishment works	2012 - 2016	Over cladding of the façade.	Entire external envelope of building at all levels up to the crown of the roof edge balustrade. Did not include any works to the existing rooftop plantroom enclosure or the roof surface membranes.
		Reconfiguration of Walkway levels (Levels 1 to 3) to provide additional residential accommodation (9 no. new flats)	Levels 1 – 3

Building works	Date	Description of Works	Extent of Works
		and reconfigured non-residential accommodation. Installation of new flat entrance doors to nine new flats on those levels. Modification of the communal lobby to the stair on Level 2. Six new fire doors to the modified protected stair enclosures.	
		Refurbishment and relocation of the nursery from Level 1 to Ground level.	Ground level
		Relocation and refurbishment of the boxing club from Ground and Level 1 to Level 2.	Level 2
		Provision of new community room, replacing part of the relocated nursery.	Level 1
		Modification to the open stair between Ground and Level 3 to enclose it and create a new entrance lobby spanning 3 storeys.	Ground level – level 2
		Open doorways into the existing lift shafts to serve two new floors being served. Previously the lifts did not serve Levels 1 and 3 (previously called Mezzanine and Walkway+1).	Level 1 & 3
		New heating system was provided New central boiler plant located in basement, connecting to this heating system. Each flat, the nursery, boxing studio and the community use room at Ground are served by individual HIU (heat interface unit), providing space heating and instantaneous hot water.	All areas inside flats on every storey, all non-domestic accommodation at levels Ground to 3 and all common lobbies from Level 3 to Level 23.
		New boosted cold water distribution system was provided.	All areas inside flats on every storey, all non-domestic accommodation at levels Ground to 3 and all common lobbies from Level 3 to Level 23.
		Refurbishment and extension of the smoke/environmental ventilation systems.	Walkway plant (at high level above stair on Level 2) Roof top plant room areas Automatic opening ventilators (AOV) in

Building works	Date	Description of Works	Extent of Works
			lobbies on all floors from Level 2 to 23
		New branches and landing valves from the existing dry riser system to serve lobbies at Level 1, 2 and 3, and to provide a new inlet at Ground level.	Basement – level 3
		New gas connection from the existing Landlord gas system in the basement to serve the new boiler plant in the basement.	Basement level
New tenant gas supply	2016 – 2017	A new tenant gas supply, replacing one of the existing risers, was installed in Grenfell Tower to serve residential flats. This work was undertaken to rectify a gas leak discovered in 2016.	Basement level to roof Distribution pipe in lobbies on Levels 4-6, 8, 9, 11-14, 16, 17 and 21 Installation of new gas meters and associated pipework to 13 residential flats between levels 4 and 21.

4.4 Main flat entrance fire door replacement 1985

4.4.1 A Building Regulations application (AR/BR/2/150917) for the provision of new self-closing fire resisting flat entrance doors was made in 1985 (RBK00000275). No information has been provided as part of the disclosure of the number of flat entrance doors replaced.

4.4.2 It is unknown if any works were undertaken to the stair doors at this time.

4.5 Lift replacement works 2005

4.5.1 Description of works

4.5.2 The original construction of Grenfell Tower (1972) consisted of two lifts in the central core area. As described in Section 15, these lifts would have been required by the relevant design guidance to be installed as “Fireman’s lifts”. Unlike modern “firefighting lift” installations, this simply required a specific control method for the lifts, to be activated by a fireman’s switch.

4.5.3 I have reviewed the Health and Safety file (CST00000384) and it appears that that Apex Lift & Escalator Engineers Ltd were appointed as main contractors for the works:

“Refurbishment of two electric passenger lifts and installation of one hydraulic passenger lift inclusive of all builders, electrical, structural and other attended works.”

4.5.4 The lift replacement was undertaken as a “like for like” replacement. The lifts were not installed as full firefighting lifts in accordance with the relevant guidance in 2005, i.e. they were not provided with alternative power supplies and with water protection to their control systems. Please refer to Section 15 for additional details.

4.5.5 I have highlighted the 2005 lift replacement works in Figure 4.15 and Figure 4.16, with a side by side comparison of the original plan and existing plan (2012) of the typical residential levels (4 – 23) and the plant room (no original drawing available at this time).

4.5.6 The programme of works listed in the Health and Safety file states the works are to occur between 14/01/2005 to 08/07/2005.

4.5.7 Figure 4.14 presents an organogram I have created of the companies that have currently been identified as contributing to the lift replacement works.

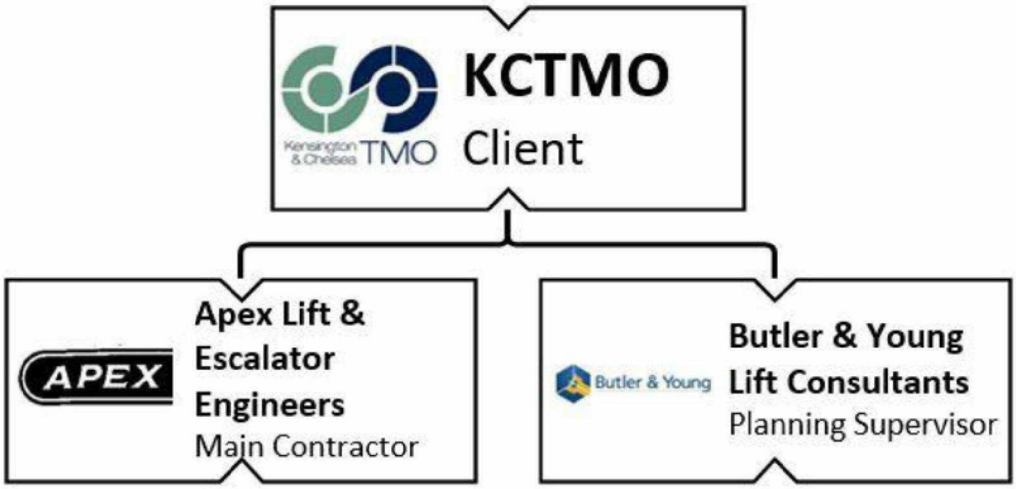


Figure 4.14: Organogram for 2005 lift works

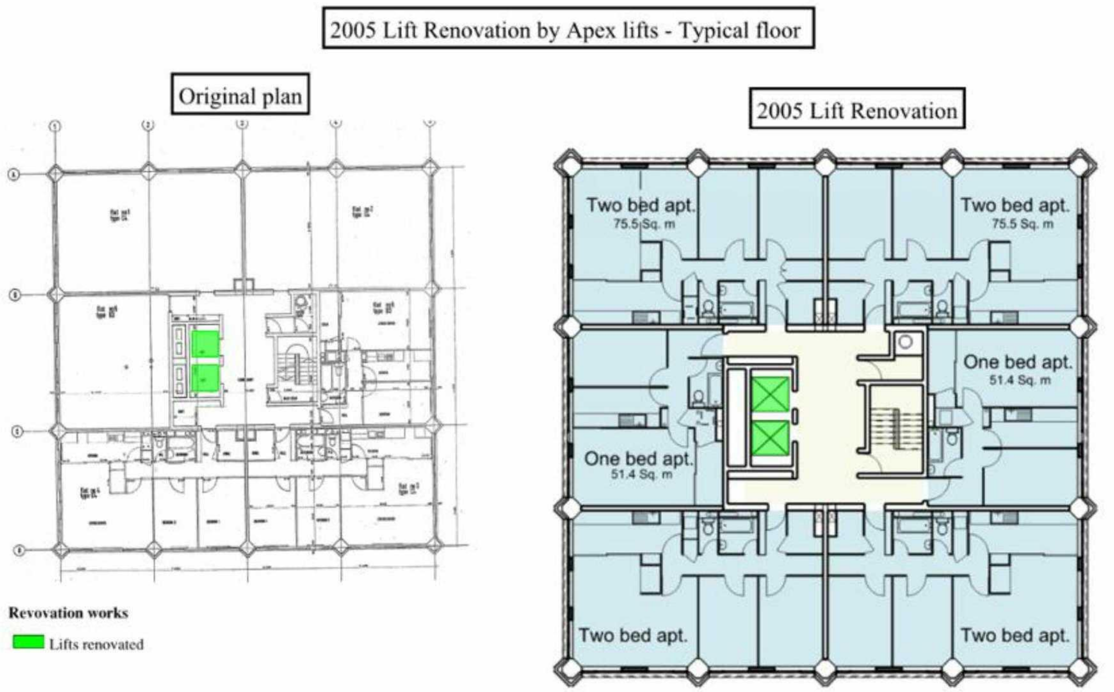
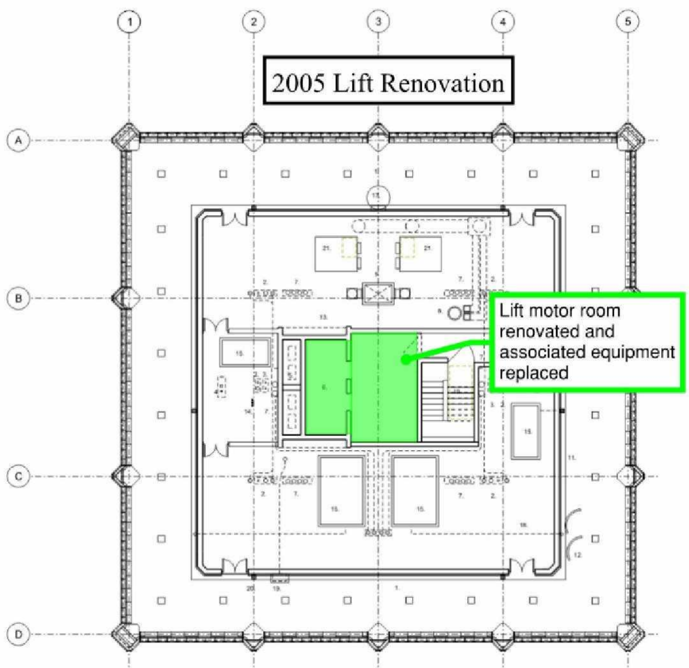


Figure 4.15: 2005 lift replacement on typical residential levels 4 – 23. (RBK00018837, CCL00000028)

2005 Lift Renovation by Apex lifts - Rooftop lift motor room

Original plan

No plan available



Lifts renovated

Figure 4.16: 2005 lift replacement on plant level. (CCL00000028)

4.6 TMO tenant flat entrance door replacement – 2011

4.6.1 Description of works

4.6.2 In May/June 2011, the TMO carried out a programme of replacing doors on dwellings occupied by RBKC tenants to comply with fire safety standards (see email TMO10037908).

4.6.3 Of the 120 No. original flats between levels 4 and 23; 14 were leasehold flats and 106 were tenanted flats as established from the list issued by Kennedys Law on 19/01/2017 on behalf of TMO.

4.6.4 A tenanted flat is one where the occupier rents the flat from the Royal Borough of Kensington and Chelsea (RBKC) Council. In this case the Council is responsible for demonstrating the compliance of the main flat fire doors with the required fire performance.

4.6.5 A leasehold flat is where the occupier owns the flat but not the land it sits on. The leaseholder rents the flat for a period of time from the free holder.

4.6.6 From the TMO's perspective (TMO10037573), the Leaseholder was responsible for demonstrating the compliance of the main flat fire doors with the required fire performance.

4.6.7 109 No. Main flat entrance fire doors are listed on the 2011 door replacement specification spreadsheet written by Masterdor (MAS00000003). Three of the doors listed are duplicates (Flats 106, 114, 202). The reasons why there are duplicate doors on the list is unknown.

4.6.8 Discounting the duplicate doors, 106 No. fire doors appear therefore to have been supplied and installed by Manse Masterdor Ltd to replace main flat entrance fire doors in Grenfell Tower in May/June 2011. From the flat doors listed by Manse Masterdor the door replacement included 104 tenanted flat doors and 2 leaseholder flat doors.

4.6.9 The remaining 14 flat entrance doors, not listed for replacement in 2011 by the Masterdor specification spreadsheet were the doors for flats 56, 61, 86, 92, 105, 112, 142, 154, 156, 165, 166, 185, 195, and 206. Of these flats, 12 flats were at the time leasehold flats and 2 were at the time tenanted flats (flats 154 and 166). (MAS00000003)

4.6.10 These works did not appear to have involved the stair doors.

4.6.11 Figure 4.18 shows the location of the main flat doors, which were specified to be replaced.

4.6.12 Figure 4.17 presents an organogram I have created of the companies that have currently been identified as contributing to those door replacement works.

4.6.13 Where any physical evidence is provided regarding the type of door installed for specific flats in Grenfell Tower I may be required to revise my report.

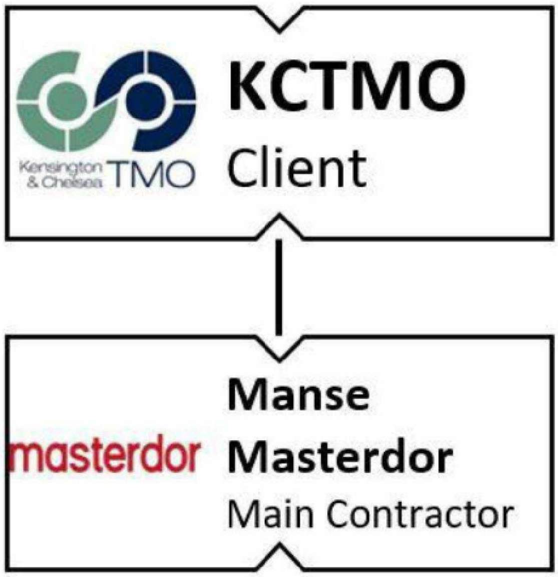


Figure 4.17: Organogram for 2011 door replacement works

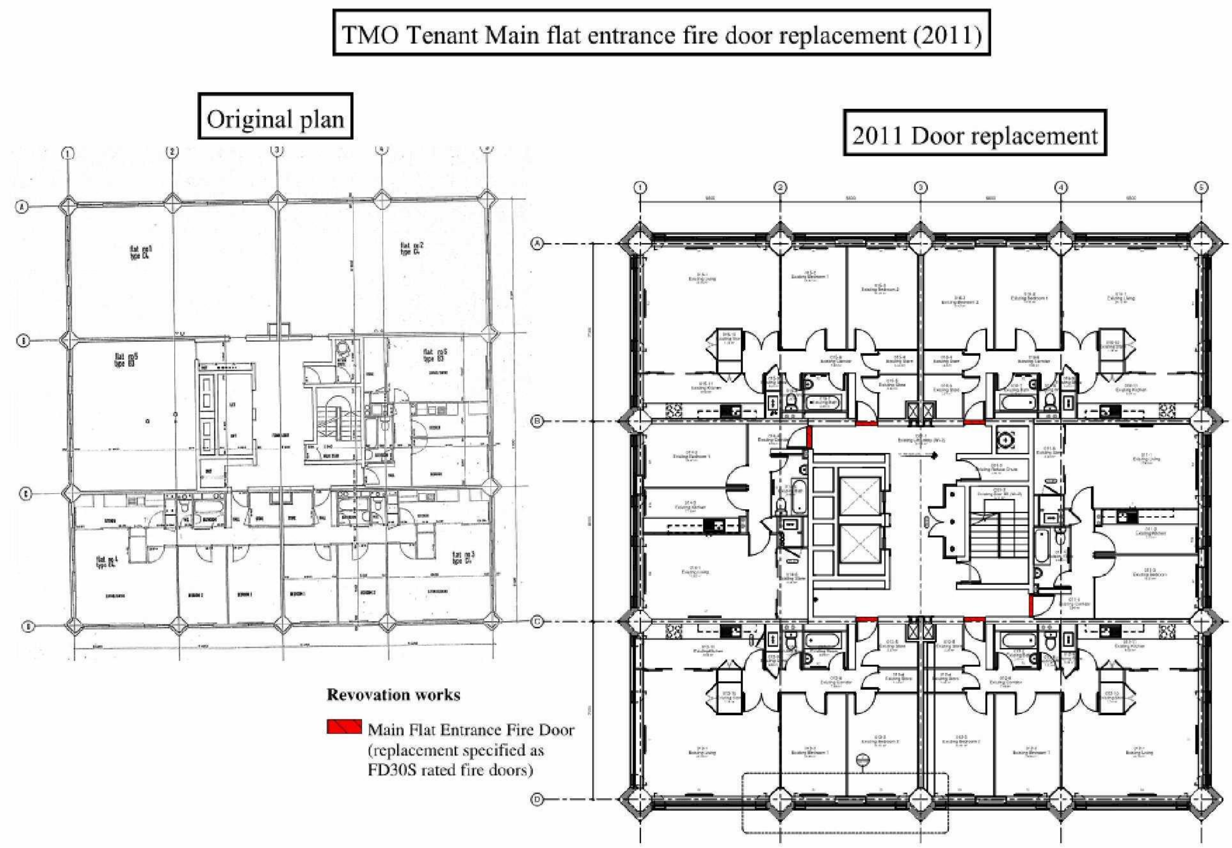


Figure 4.18: 2011 TMO tenant main flat entrance fire door replacement on levels 4 – 23. (RBK00018837; SEA00010474)

4.7 Refurbishment works: 2012-2016

4.7.1 Overview of works

4.7.2 The Rydon Building Manual for Grenfell Tower (RYD00000002) describes the refurbishment works that were undertaken at Grenfell Tower from 201 – 2016 as follows:

"The Works consist of the Design, Construction, Completion and Defects Rectification of the proposed re-cladding of Grenfell Tower and remodelling of its lower floors to provide improved accommodation for a nursery, boxing club, and 9 new residential flats and mechanical and electrical Installation to the entire tower with soft and hard landscaping works surrounding the tower.

The building is an existing tower block with 23 storeys and a ground floor

The general scope of the project is:

- *Adaption of 2 lifts to include 2 x new doors*
- *Recladding of the façade*
- *Reconfiguration of the podium levels to provide additional residential accommodation (9 no. new flats)*
- *Relocation and refurbishment of the nursery*
- *Relocation and refurbishment of the boxing club*
- *Provision of new community room*
- *Decorations to the existing lobbies*
- *Construction of a new entrance lobby (previously an undercroft)*
- *Modifications to the MEP systems as follows:*
- *New heating system to all areas*
- *New boosted cold water distribution system to all areas*
- *Refurbishment and extension of the smoke/environmental ventilation systems*
- *Alterations to the dry riser system*
- *Alterations to the door entry system*
- *External hard & soft landscaping"*

4.7.3 These works are discussed in more detail in the following sections. The items of work that were undertaken, and not included on this list, are the provision of services cupboards and new suspended ceilings in each of the existing residential levels (Levels 4 to 23), and the reconfiguration of the existing stairs as part of the construction of the new entrance lobby. (SEA00002540) These works are also discussed below.

4.7.4 **Over cladding of the façade**

4.7.5 As I have described in detail in Section 8, the refurbishment works intended to create a new external wall of a ventilated rainscreen cladding form. The cladding was installed on every level from Ground to level 23.

4.7.6 The key components installed were:

a) Aluminium windows supplied by Metal Technology Ltd;

b) Insulating core panels as infill between windows, formed of combustible Styrofoam supplied by Panel Systems Ltd;

c) Window fan inserts specified as the combustible Kingspan TP10 insulation;

d) 100mm thick Celotex RS5100 combustible PIR insulation board applied to columns;

e) 80mm thick Celotex RS5080 combustible PIR insulation board (two layers) applied to the spandrels between floors;

f) Kingspan K15 combustible phenolic foam insulation (two layers) applied to the spandrels between floors;

g) Arconic Reynobond 55 PE Cassette system (smoked silver metallic);

h) Arconic Reynobond 55 PE Cassette system (pure white);

i) EPDM damp proof course between the new windows and the existing concrete structure;

j) Vertical cavity barriers on the columns;

k) Horizontal cavity barriers;

4.7.7 Figure 4.19 presents an organogram I created of the companies that have been identified to have contributed to the recladding works.

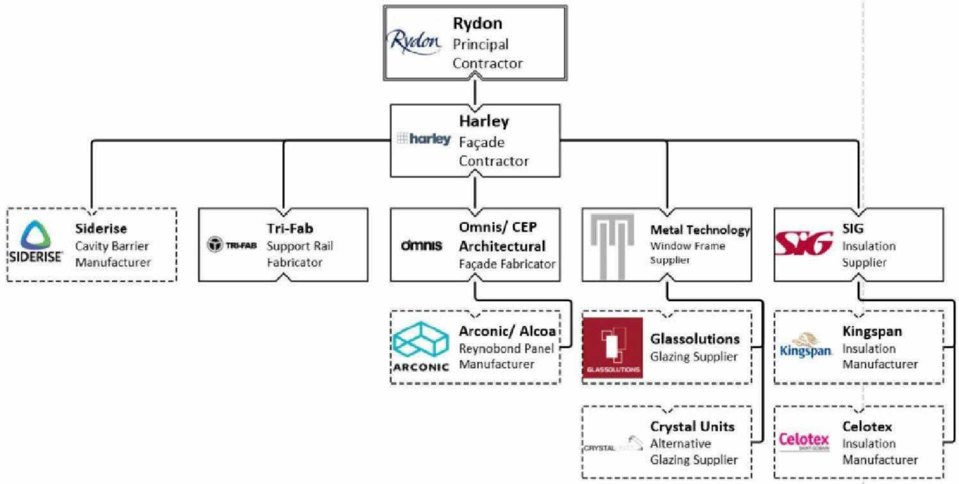


Figure 4.19: Organogram for facade works 2012-2016

4.7.8 Reconfiguration of the Walkway levels (Levels 1 to 3)

4.7.9 Ground floor:

4.7.10 I have reviewed the Studio E Stage D report, dated August 2013. Per the RIBA (Royal Institute of British Architects) Outline of Work 2007 (amended 2008), Stage D is the *Design Development* stage, is described as follows:

"Development of concept design to include structural and building services systems, updated outline specifications and cost plan. Completion of Project Brief. Application for detailed planning permission."

4.7.11 The Studio E Stage D report described the refurbishment works planned for the ground floor as follows:

a) *"Enlarged entrance foyer, new stair and Part M compliant lift*

b) *Concierge / reception desk with view of main entrance, new lift and stair and the entrance to the main lift core. [Ultimately not provided]*

c) *A new enlarged meeting room and facilities for the Estate Office. This suite of offices is accessed by a new stair [Ultimately not provided]*

d) *New office for the EMB (Estates Management Board). This office is transferred from its existing location on the north-east corner of Barandon Walk. [Ultimately not provided]*

e) *Relocated nursery in an L-shaped configuration with the new entrance in roughly the same position as the existing.*

f) *A new fire* escape stair [Ultimately not provided]" (CCL00000028)

4.7.12 Not all of these works were undertaken. The meeting room and office for the Estates Management Board were removed from the works. The areas identified for the Estates Management Board were instead allocated to the new residential entrance, refurbished nursery and community room at Ground level.

4.7.13 It is important to note that the works at Ground level also included a new dry riser inlet to serve the existing fire main in the core. Please refer to Appendix H for further description of the dry riser works.

4.7.14 These changes also involved the installation of new services and connections for hot and cold water and for heating. These works are described by system in the following sections.

4.7.15 There is evidence from the 2016 fire risk assessment significant findings (TMO00017691) that the firefighter was noted by the assessor as being present at Level 2 and was required to be moved to Ground Level. I observed a switch in both the Level 2 and Ground floor lobbies.

4.7.16 I have seen no evidence as to whether the work to activate the Ground floor switch had been undertaken. Therefore, while I observed a switch in the Ground floor lift lobby (see Section 15 and Appendix H) there is no evidence that it was correctly connected or programmed to function as intended.

4.7.17 **Level 1:**

4.7.18 Studio E Stage D report (i.e. Scheme Design report), dated August 2013, described the refurbishment works planned for Level 1 as follows:

"This level is not currently served by the two central lifts and it is proposed that a new lobby slab and lift openings be created at Mezzanine level. The existing floor to ceiling dimension is low – as little as 2050mm – and Planning felt that this was not suitable for large family dwellings so 1 and 2 bed units only are proposed. A community meeting room (pink above) is proposed above the existing bins and transformer room." (CCL00000028)

4.7.19 These changes are reflected in the Studio E As-Built drawings as indicated in Figure 4.41.

4.7.20 These changes also involved the installation of new services and connections for hot and cold water and for heating.

4.7.21 New openings were cut in the existing lift shafts for the lifts to serve this level.

4.7.22 As part of the enclosure of the existing stair connecting to Ground, a bridge connection was made to serve this level. Originally access to Level 1 was via dedicated stairs in the play centre and the office areas.

4.7.23 The works at Level 1 also included a new section of pipe extending from the existing rising fire main to a new dry riser outlet in the common lobby. Please refer to Section 4.7.130 for further description of the dry riser works.

4.7.24 The original smoke ventilation shafts were also extended down to serve this level.

4.7.25 **Level 2:**

4.7.26 Originally, this level was an open walkway connecting to the walkways connecting the various buildings in the Lancaster West Estate. Access to this level was either via lift from Ground, or via the open stair that was enclosed as part of the 2012-2016 works.

4.7.27 The Studio E Stage D report, dated August 2013, described the refurbishment works planned for Level 2 as follows:

"The boxing club occupies the majority of the available floor plate. Access is via the new escape stair with disabled access via the main lift core. The existing fire escape stair in the core discharges into the lift lobby and the route is continued down to ground via the new stair." (CCL00000028)

4.7.28 Additionally, after Stage D the extent of the Boxing Club was reduced, and an additional residential unit inserted into the Southwest corner of the building. These changes are reflected in the Studio E As-Built drawings as indicated in Section 4.7.157.

4.7.29 Originally, the stairs from Ground passed through this level to Level 3. The refurbishment works terminated the stairs at this level and created a new access path into the stairs in the core.

4.7.30 The works at Level 2 also included a new section of pipe extending from the existing rising fire main to a new dry riser outlet in the common lobby. Please refer to Section 4.7.130 for further description of the dry riser works.

4.7.31 The original smoke ventilation shafts were also extended down to serve this level.

4.7.32 These changes also involved the installation of new services and connections for hot and cold water and for heating.

4.7.33 **Level 3:**

4.7.34 Studio E Stage D report, dated August 2013, described the refurbishment works planned for Level 3 as follows:

"A new "shell and core" arrangement similar to the 20 floors above is proposed with some structural changes: new floor slab, new lift door openings, new connection to the refuse chute and a new connection to the escape stair. Four new units are arranged in each quadrant: 3no 4 Bed and 1 no 3 Bed Wheelchair accessible unit. The structural module has a strong influence on the layout: the bedrooms are situated on the north and south elevations and the living spaces face east and west where the structural module is wider. The kitchens are stacked directly below the kitchens to the two-bed units on the floor above, which is important to maintain a vertical continuity of services such as gas and water." (CCL00000028)

4.7.35 The stairs that originally served this level from Ground were removed, and the space in the Southeast corner of the building enclosed, with a new area of floor, to include a new residential unit.

4.7.36 These changes are reflected in the Studio E As-Built drawings as indicated in Section 4.7.157.

4.7.37 These changes also involved the installation of new services and connections for hot and cold water and for heating.

4.7.38 New openings were cut in the existing lift shafts for the lifts to serve this level, as described in section 4.7.41.

4.7.39 The works at Level 3 also included a new section of pipe extending from the existing rising fire main to a new dry riser outlet in the common lobby. Please refer to Section 4.7.130 for further description of the dry riser works.

4.7.40 The original smoke ventilation shafts were also extended down to serve this level.

4.7.41 **Adaption of lifts to include new doors**

4.7.42 The specific works related to lifts to be undertaken by the principal contractor Rydon are stated in the note GRENFELL LIFT ACTIONS. Resulting from meeting between TMO/ Rydon of 11 Feb 2015 as:

"In order to create the lift access to the 2 new floors, Rydon have to cut openings, install new doors and new panels/call signs and re-programme the 2 lifts at Grenfell." (ART00003801)

4.7.43 These changes are reflected in the Studio E As-Built drawings as indicated in Section 4.7.157.

4.7.44 **New heating system**

4.7.45 A new heating system for all areas of Grenfell Tower was created during the 2012 – 2016 refurbishment works also. This system is described in the Description of Services document prepared by J S Wright & Co Ltd (RYD00000577) as follows:

"The building has been provided with heat for space heating and instantaneous domestic hot water by means of a central gas-fired condensing boiler installation, delivering LTHW (low temperature hot water) heating to the various areas...

Each flat, the nursery, boxing studio and the office area is served by individual HIU (heat interface unit) as indicated on the drawings, providing space heating and instantaneous hot water. The HIUs hydraulically separate the central plant installation from the local installation in each area."

4.7.46 A new central gas-fired boiler plant was provided in the basement which consisted of 3 no. gas-fired condensing boilers (duty and standby boilers provided for space heating and hot water supply), as shown in Figure 4.20.

The existing main boiler plant continued to serve the 'Finger Block' flats, which are in separate buildings from Grenfell Tower. (RYD00000577)

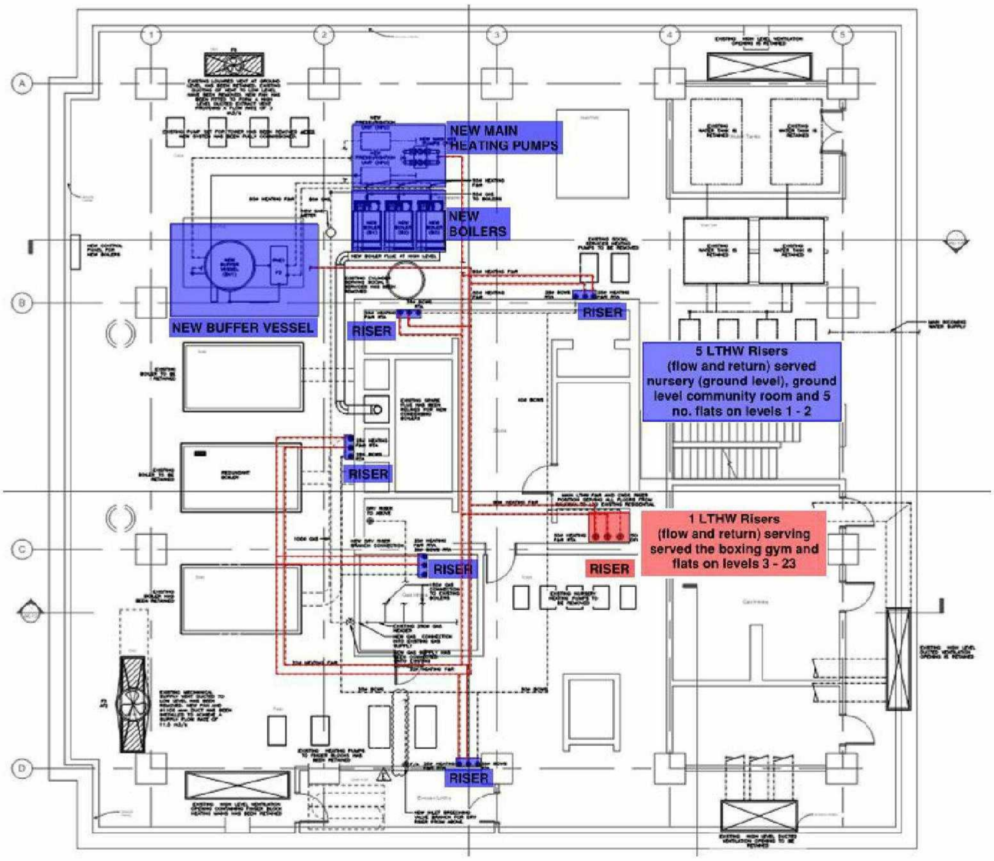


Figure 4.20: New central boiler plant and LTHW piping distribution on basement level (RYD00000577)

4.7.47 Based on my review of the J S Wright & Co Ltd 'As Installed' mechanical drawings (August 2014), the new Low Temperature Hot Water heating system (LTHW) flow and return piping was then distributed from these new boilers in the basement to every level above through 6 no. existing risers, as shown in Figure 4.20.

4.7.48 The nursery (ground level), ground level community room and 5 no. flats on levels 1 – 2 were served by 5 no. of the 6 LTHW risers, as shown in Figure 4.20. The remaining LTHW riser served the boxing gym and flats on levels 3 – 23 (RYD00000577).

4.7.49 As indicated in Figure 4.20, the pipes serving Levels 3 to 23 enter the existing Southeast riser in the core on the basement level. On Level 3, the LTHW flow and return pipes leave the Southeast riser (south of protected stairway), run laterally through the common lobby, and enter the protected stairway, as shown in Figure 4.21. These pipes rise to level 4, where a new service cupboard was created as part of the refurbishment works. A new service cupboard was created in the same place in the lobbies on each level from level

4 – 23 as part of the 2012 – 2016 refurbishment works. The LTHW pipes rise through these cupboards to level 23. (RYD00000577)

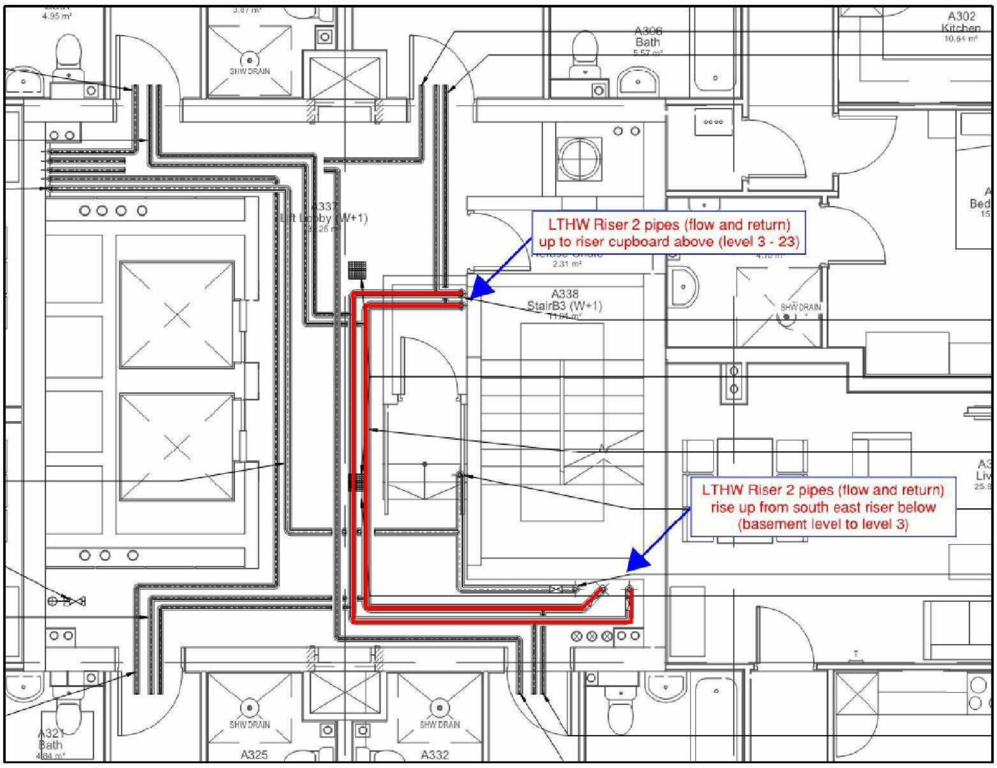


Figure 4.21: Lateral LTHW lateral piping through level 3 common lobby (RYD00000577)

4.7.50 The pipes appear to have been fire stopped at each floor level. The service riser does not appear to form a protected shaft. The new riser cupboard is not shown on the fire strategy drawings by Studio E (SEA00003112). The new cupboards are not described in the Exova fire strategy report (EXO00000582).

4.7.51 On the Studio E Employers Requirements and As-Built drawings the new cupboards were not identified as requiring to be made of fire resisting construction, in contrast to the new partitions being introduced on Levels 1, 2 and 3. Therefore, there is no evidence that the cupboards on levels 4 – 23 were specified to be made of fire resisting construction.

4.7.52 On each level from level 4 – 23, the LTHW pipes leave the riser cupboard and distribute laterally through the common lobby to each flat. As shown in Figure 4.22, a flow and return pipe enters each flat above the flat entrance door (RYD00000577).

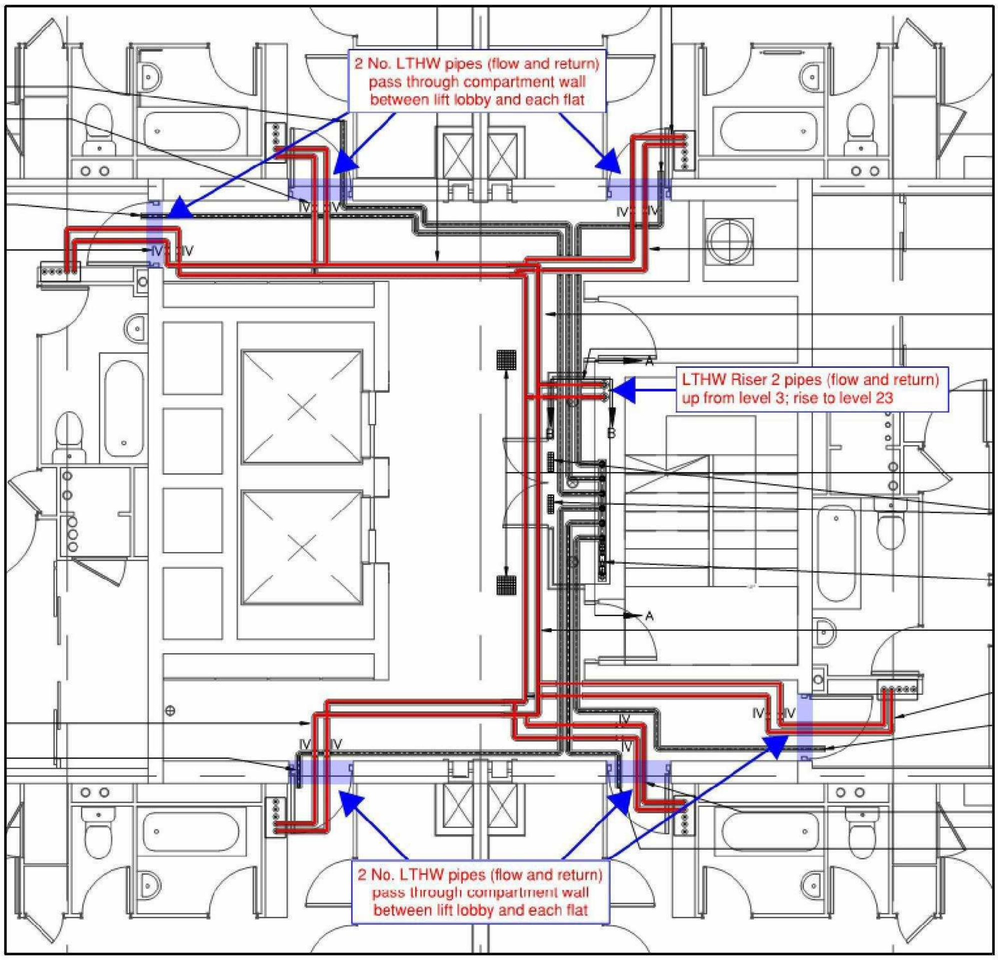


Figure 4.22: LTHW lateral distribution piping through typical residential level common lobby (RYD00000577)

4.7.53 These changes are reflected in the Studio E As-Built drawings as indicated in this section.

4.7.54 The pipe distribution works in the lobby were then concealed above a new suspended plasterboard ceiling, described in Section 4.7.140.

4.7.55 Based on the Studio E Grenfell Tower Regeneration Project Room Data Sheets, Employer Requirements, dated 20-11-2013, holes were core drilled through the concrete wall above each flat front door for new water and heating pipes to each flat on every level (SEA00002540). This means that 18 holes were drilled on each floor, and 360 holes over all levels. Please see Figure 4.23 for an example of this distribution taken during my post fire inspection of the building.

Figure 4.23: New pipework fitted in ceiling of Level 4 common lobby

4.7.56 The core drilling works were communicated to residents by a TMO notice, dated October 2014 (excerpt below):

"We will be carrying out work to your property from Wednesday on the 19th November 2014. The work will involve drilling three core holes above your front door this is to enable us to run the new pipework into your property." (MAX00001704)

4.7.57 Each existing residential flat on levels 4 – 23 was served by an individual HIU, which allowed residents to control their flat's heating and hot water. According to the building fire risk assessor, The HIUs are electrically powered/operated with a fused spur. (RYD00094168) Figure 4.24 is an image of the HIU installed in every flat as part of the heating system works.

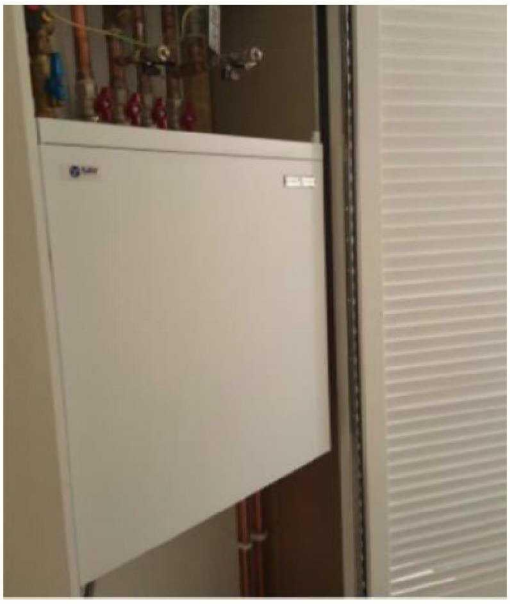


Figure 4.24: Heat interface unit (HIU) (RYD00000577)

4.7.58 As described in the Studio E Stage D report,

"Builder's work and making good associated with M&E works: replacement of radiators and new heating pipework. Existing finishes to be protected throughout. New window sill/surround required to making good around replacement windows."

4.7.59 New pipework was to be installed in each flat to serve the HIU's, domestic plumbing and radiators. I have not determined the exact run of each set of pipes in each flat.

4.7.60 A total of 440 new radiators were installed, with 3 radiators (local heat emitters as referenced in RYD00000577) fitted to 1 bedroom flats and 4 radiators fitted to 2 bedroom flats on each level.

4.7.61 **New boosted cold water distribution system**

4.7.62 A new boosted cold water distribution system was installed as part of the 2012 – 2016 refurbishment works. This system is described in the Description of Services document prepared by J S Wright & Co Ltd, which states:

"New potable cold water pipework has been run from the roof storage tanks to serve sanitary appliances in all areas of the building. The pipework on the upper residential floors has been installed in a vertical duct located in the lift lobbies outside the flats. At podium level, the pipework generally runs concealed in ceiling voids or in services riser ducts.

An additional pump set has been installed for a number of flats on the upper floors as the static pressure alone from the storage tanks will not be sufficient to ensure a reasonable pressure or flow of water through the heat interface unit. This additional pump set is located in the roof plant room...

New hot and cold water pipework has been installed to serve the new apartments, the nursery, boxing club and offices." (RYD00000577)

4.7.63 As shown in Figure 4.25, the new Boosted Cold Water Service (BCWS) pump serves the roof plant level and residential levels 14 – 23, whereas ground floor – level 13 are served by the static pressure from the existing storage tanks. (RYD00000577)

4.7.64 Based on my review of the J S Wright & Co Ltd 'As Installed' mechanical drawings (August 2014), the new BCWS piping is distributed from the roof plant level through level 4 via the new riser cupboard that was created in the common lobby on every level, as shown in Figure 4.26 (RYD00000577).

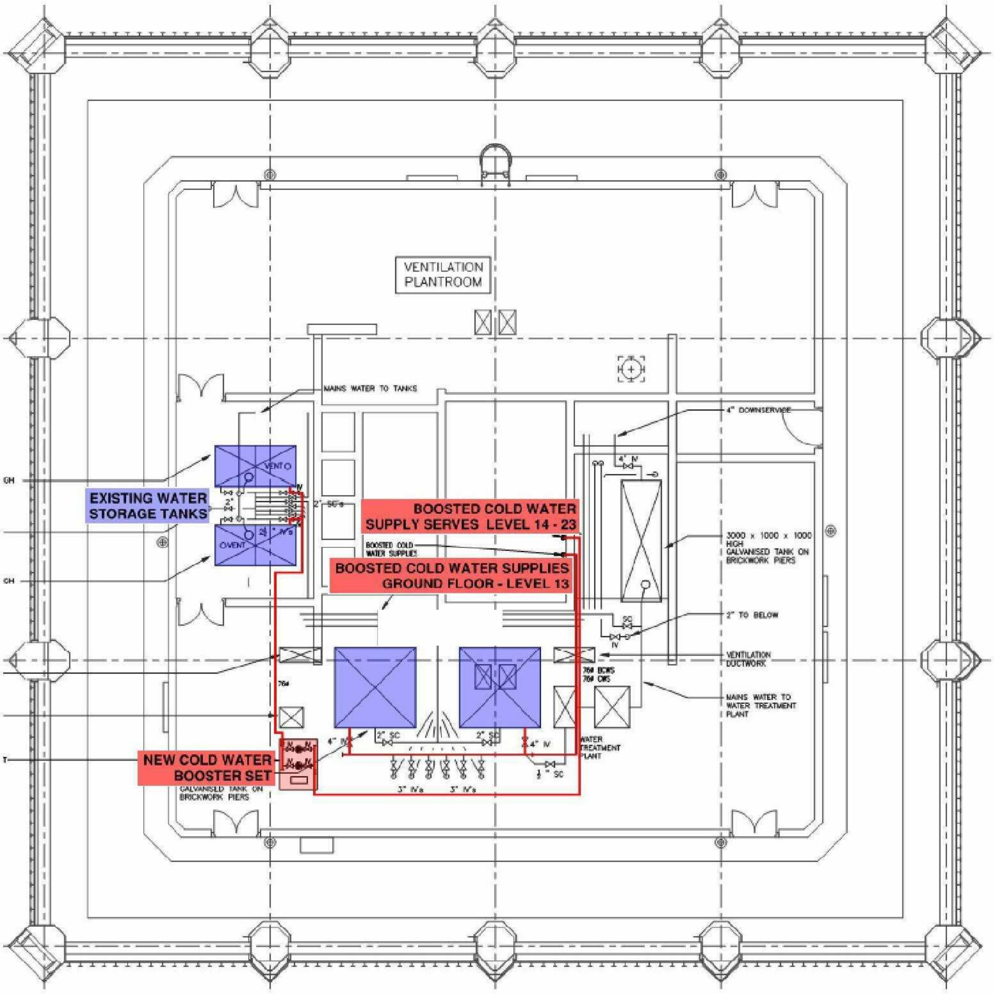


Figure 4.25: Refurbishment works to boosted cold water distribution system on Roof Plant Room. (RYD00000577)

4.7.65 On each level from level 4 – 23, the BCWS piping leaves the riser cupboard and distributes laterally through the common lobby to each flat, as shown in Figure 4.26.

4.7.66 The pipe distribution works in the lobby were then concealed above a new suspended plasterboard ceiling, described in Section 4.7.140.

4.7.67 As described in section 4.7.44 and shown in Figure 4.26, each Existing Common lobby on levels 4 – 23 was required to have three cores through concrete walls for new water and heating pipes to each flat. (SEA00002540) A TMO notice was provided to residents in October 2014 in preparation for this works to be completed (MAX00001704).

4.7.68 A single BCWS pipe enters each flat above the flat entrance door (RYD00000577), via one of the 3 holes described in section 4.7.44, as shown in Figure 4.26.

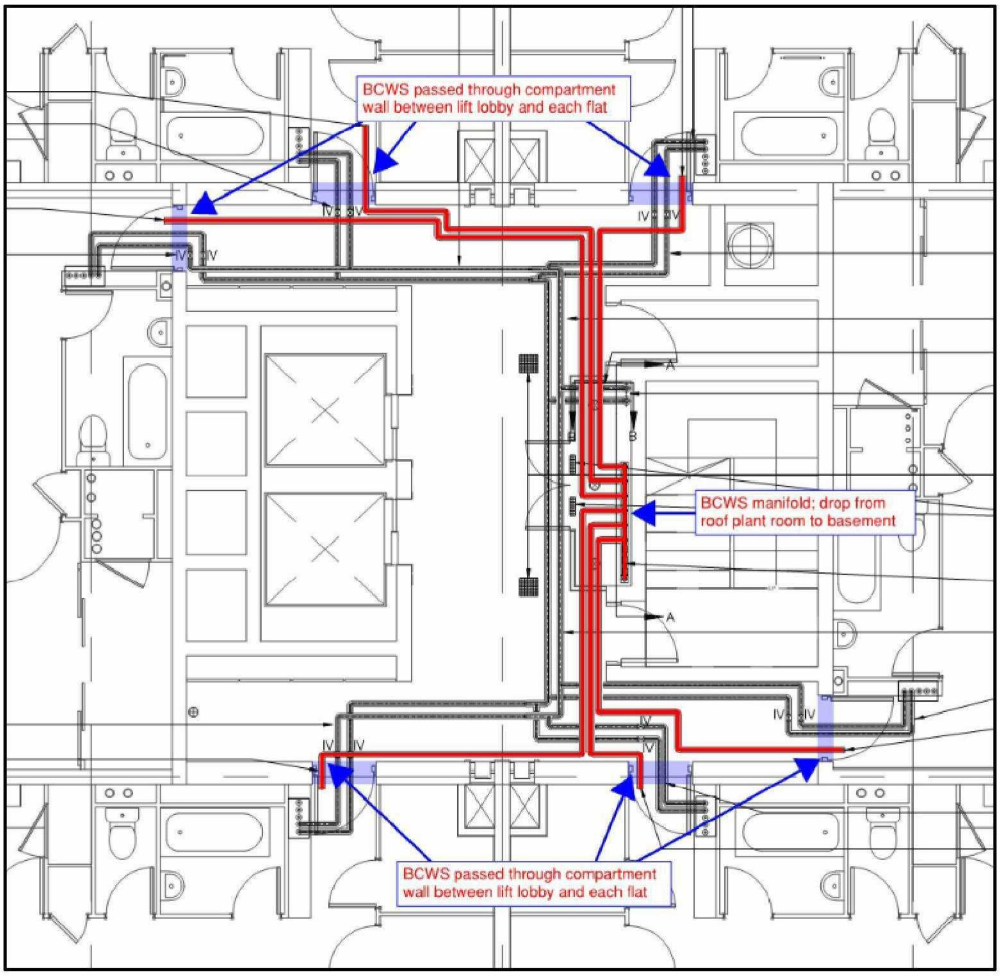


Figure 4.26: BCWS lateral distribution piping through typical residential level common lobby (RYD00000577)

4.7.69 The BCWS pipe leaves the riser cupboard on level 4 and enters the protected stairway on level 3, as shown in Figure 4.27. The BCWS then leaves the protected stairway and distributes laterally to the Southeast corner of the level 3 common lobby.

4.7.70 The BCWS pipe then drops into the Southeast riser from level 2 to the basement level; it serves the boxing gym on level 2. At the basement level, the piping is distributed to 5 no. other risers, as shown in Figure 4.28. These 5 no. other risers supply the nursery, community room, and flats on level 2 and 3.

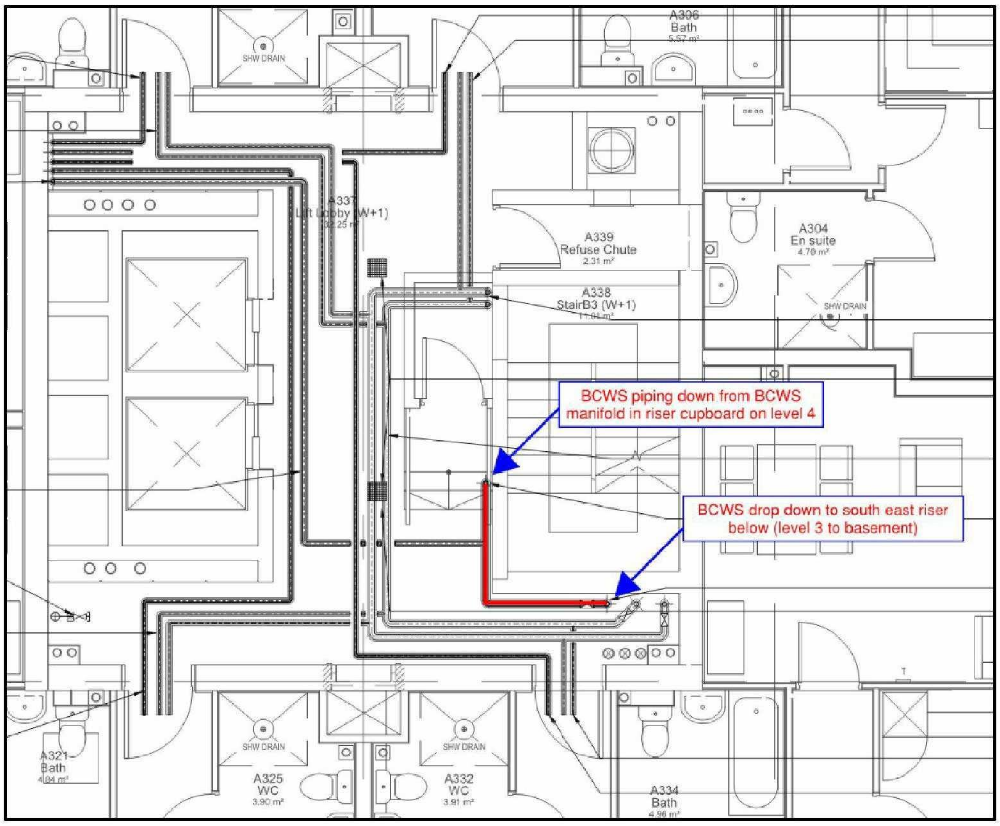


Figure 4.27: BCWS lateral distribution piping through level 3 common lobby (RYD00000577)

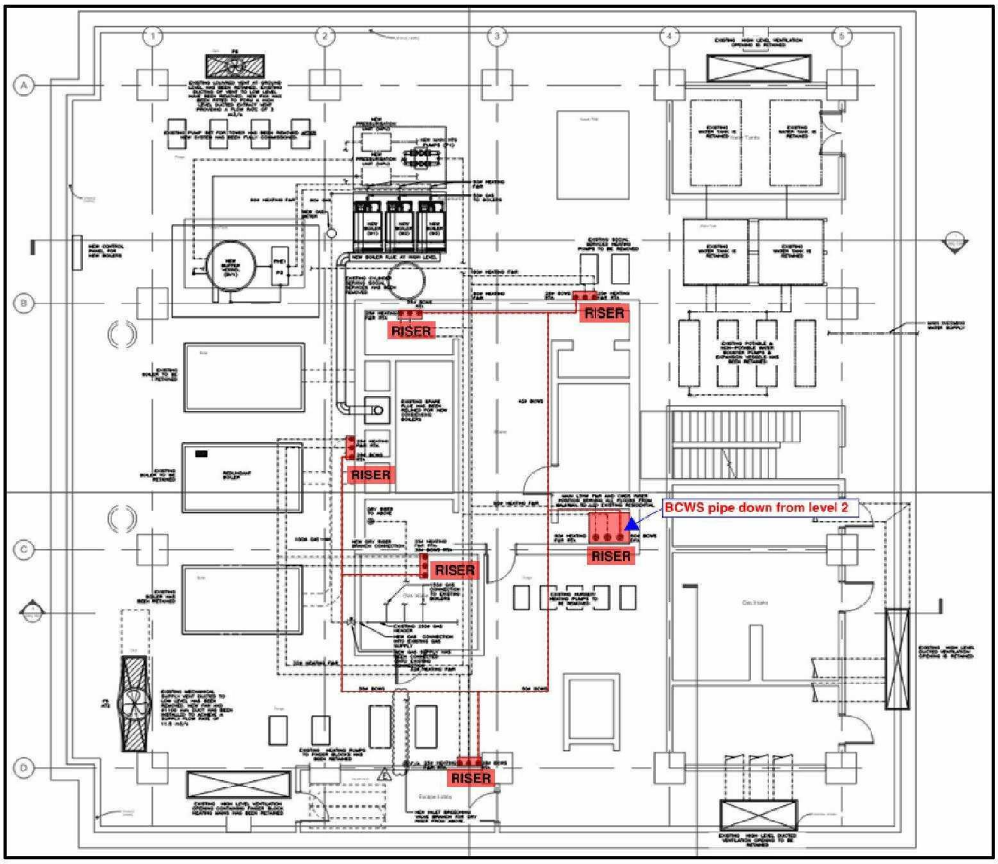


Figure 4.28: BCWS risers on basement level. (RYD00000577)

4.7.71 Refurbishment and extension of the smoke/environmental ventilation systems

4.7.72 I have reviewed the details of the smoke ventilation system as recorded in the PSB technical submissions for the smoke ventilation system. This information is included within the Rydon O&M information (RYD00000577).

4.7.73 The latest recorded version of the PSB technical submission which I have reviewed is Revision 6 dated 15/03/2016 (PSB00000214).

4.7.74 The version of the technical submission included within RYD00000577 is revision 1 dated 1/12/2014 which was an earlier version.

4.7.75 I have assumed at this stage that revision 6 of the PSB technical submission (PSB00000214) represents the as-built condition.

4.7.76 Refurbishment works 2012 - 2016

4.7.77 During the refurbishment works 2012 - 16, the existing pairs of smoke shafts serving the north and south sides of each of the lobbies on Levels 4 to 23 were retained for use in the refurbished smoke / environmental ventilation system.

4.7.78 The pairs of shafts serving the north and south sides of the lobbies were extended (as single shafts) to serve levels 1 – 3.

4.7.79 New AOVs, fans, power supplies and controls were provided for the refurbished smoke / environmental ventilation system.

4.7.80 **Refurbished environmental system**

4.7.81 The refurbished environmental system was provided in Grenfell Tower to maintain comfortable temperatures in the lobbies on all Levels 1 - 23.

4.7.82 The environmental system utilised the same shafts and AOVs as the smoke ventilation system.

4.7.83 Warm air was exhausted from lobbies by a pair of new North AOVs located at high level on the north side of each lobby.

4.7.84 The new north AOVs were served by the original pair of smoke shafts leading to one new fan set (one run and one standby fan) used for both smoke and environmental exhaust which discharged at roof level.

4.7.85 Fresh air was supplied to lobbies, for the environmental system, by a pair of new south AOVs located at low level on the south side of each lobby.

4.7.86 A new environmental supply fan was also provided at Level 2 and served the south smoke shafts and new south AOVs in each lobby. The environmental fan on Level 2 drew fresh air from outside via louvres on level 2.

4.7.87 This supply environmental fan was installed in parallel with the new smoke fan sets (run and standby fans) for the south shaft located on Level 2 – see below. Bypass smoke dampers were installed to isolate the smoke fans from the environmental fan, in the event of a fire activation caused by detection of smoke in any one lobby.

4.7.88 Max Fordham (MAX00006475) noted that shared shafts between environmental and smoke systems is unusual:

4.7.89 Normally, comfort ventilation would be kept separate from smoke ventilation. However, for this project where the lobbies are landlocked, the only reasonably viable option is to use the smoke vent shafts.

4.7.90 **Operation of the environmental system – environmental mode**

4.7.91 In operation in environmental mode the AOVs on all floors were to be open.

4.7.92 The bypass damper assembly at Level 2 was to be set to connect the environmental supply fan to the south shafts and to isolate the south shafts smoke fan set from the environmental system.

4.7.93 The environmental supply fan located on Level 2 was to be operated in order to direct fresh air into the lobbies via the south shafts through the south shaft AOVs. The fresh air inlet to support this action were the additional dedicated louvres located on the façade, at Level 2.

4.7.94 Warm air was to be exhausted from the lobbies via the North AOVs and North shafts by the combined smoke / environmental fan at roof level, and the warm air discharged at roof level.

4.7.95 Therefore, immediately prior to any fire, all AOVs could be open for the purposes of environmental control.

4.7.96 **Operation of the environmental system – smoke mode**

4.7.97 In the event of a fire, the environmental fan was to be shut down and electrically isolated.

4.7.98 The environmental fan was to be closed from the shafts system by the bypass smoke dampers.

4.7.99 The AOVs on the fire floor only were to open.

4.7.100 The AOVs on all other floors were to be closed and locked out.

4.7.101 **Components of the refurbished smoke ventilation system**

4.7.102 The components of the smoke ventilation system were as follows:

4.7.103 A smoke detector was installed in each of the lobbies, linked to the smoke ventilation system only.

4.7.104 Smoke exhaust was provided by the AOVs located at high level on the north side of each lobby, served by the original pair of smoke shafts leading to smoke / environmental exhaust fans and outlet on the roof.

4.7.105 Smoke exhaust was also provided by the AOVs located at low level on the south side of each lobby, served by the original pair of smoke shafts leading to smoke exhaust fans and outlet on at Level 2.

4.7.106 A master control panel and a Human Machine Interface (HMI) panel were both located at Ground Floor level. The master control panel was located in the hub room A010.

4.7.107 The HMI panel was located within the Ground floor lobby.

4.7.108 The control panels were intended to allow the operator to access system configuration, maintenance and testing functions. The HMI also provided the Fireman's override facilities. A description of the override facilities is provided in Section 4.7.121

4.7.109 New associated controls and power supplies were provided.

4.7.110 There was an existing permanently open vent at the head of the stair which was retained. In the refurbished system operating in smoke mode the purpose of this open vent was to provide inlet air to the fire lobby via the stair and the stair door on the fire floor.

4.7.111 **Operation of the refurbished smoke ventilation system – smoke mode**

4.7.112 Upon detection of smoke in one of the lobbies, the AOVs serving that floor should open and the AOVs serving all other floors should close and be locked out.

4.7.113 The smoke exhaust fan sets at roof level (serving the North shaft) and at Level 2 (serving the south shaft) were to operate to exhaust smoke from the lobby on the fire floor only.

4.7.114 The smoke exhaust fans at roof level were to exhaust smoke from the AOVs located at high level on the north side of the lobby into the North vent shafts to discharge at roof level.

4.7.115 The smoke exhaust fans at Level 2 level were to exhaust smoke from the AOVs located at low level on the South side of the lobby into the south vent shafts to discharge to outside at Level 2.

4.7.116 Fresh air was to be drawn into the lobby from the stair via the permanently open vent at the head of the stair.

4.7.117 If the stair door was open, the flow of air into the lobby from the stair would prevent smoke present within the lobby from flowing into the stair.

4.7.118 If the stair door was closed, fresh air was to be drawn through the gaps around the edges of the stair fire door by depressurisation of the lobby. This would prevent smoke ingress through the gaps around the door.

4.7.119 A pressure sensor in each lobby was provided to allow control of the exhaust rate to maintain the pressure difference between the lobby and the stair at a level which (a) prevents smoke ingress into the stair, but (b) still allows the stair door to be opened for evacuation or firefighting.

4.7.120 The operation of the smoke ventilation system on the fire floor is shown schematically in Figure 4.29.

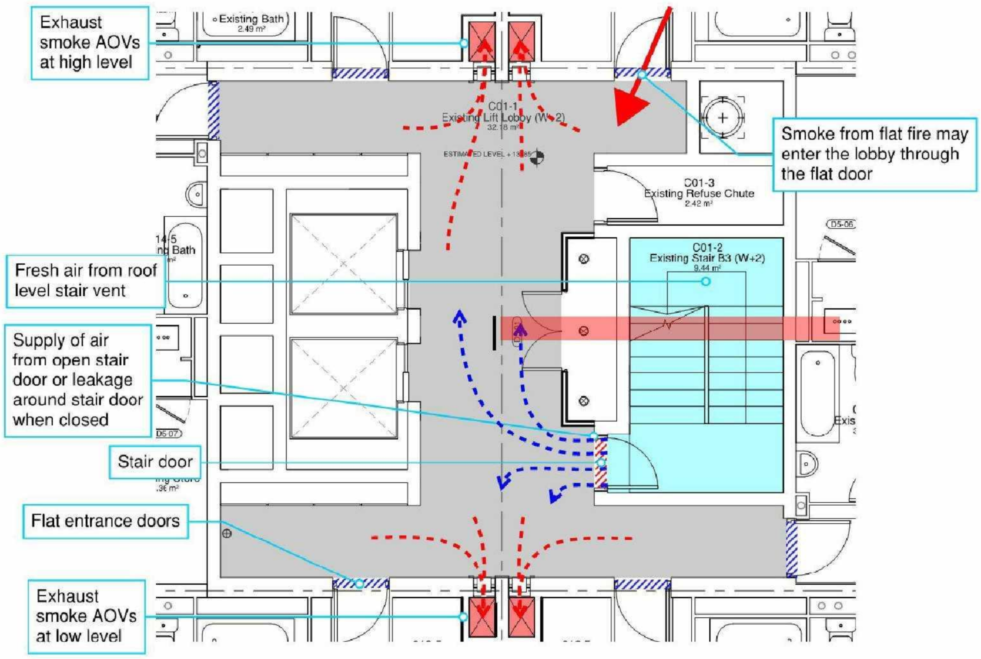


Figure 4.29: Operation of the refurbished smoke ventilation system on the fire floor. SEA00010474

4.7.121 **Override facility**

4.7.122 PSB0000214 states that an override facility was provided to enable fire fighters to change the floor on which the smoke ventilation system was operating. The description of this system is provided in the excerpt from PSB0000214 shown in Figure 4.30.

- If the HMI override is activated i.e. shut system down all open dampers will close. The dampers on any given floor can be then opened using the local key override switch. Once a single switch has been turned to open all other switches, on the other floors, will be locked out.
- The above sequence shall also be executed if the manual overrides are operated on any level or by the master control panel.

4.7.123 Figure 4.30: Excerpt from PSB0000214 detailing the override controls available to firefighters.

4.7.124 The smoke ventilation system could therefore have been operated by fire fighters to clear smoke and support evacuation and firefighting on floors other than the fire floor. But this required first of all activating the override on the HMI, switching off the system on the floor it had operated on, and then either using the key to the switch on the required floor, or using the controls at the HMI (if available) to operate the system on the required floor.

4.7.125 It is unclear from PSB0000214 whether fire fighters would have to physically access each floor to operate key switches in order to change the floor on which the system is operating, or whether this could be achieved from the HMI in all cases.

4.7.126 The override system would close and lock out the AOVs to all floors other than the floor of operation once a floor had been selected, so could only ever address the effects of fire and smoke on a single floor at any one time.

4.7.127 I have not currently found any evidence which suggests that fire fighters successfully operated the override facility provided to the smoke ventilation system.

4.7.128 **Organisations contributing to the refurbishment works**

presents the organisations that have currently been identified as contributing to the refurbishment of the smoke ventilation system.

4.7.129 These changes are reflected in the Studio E As-Built drawings.

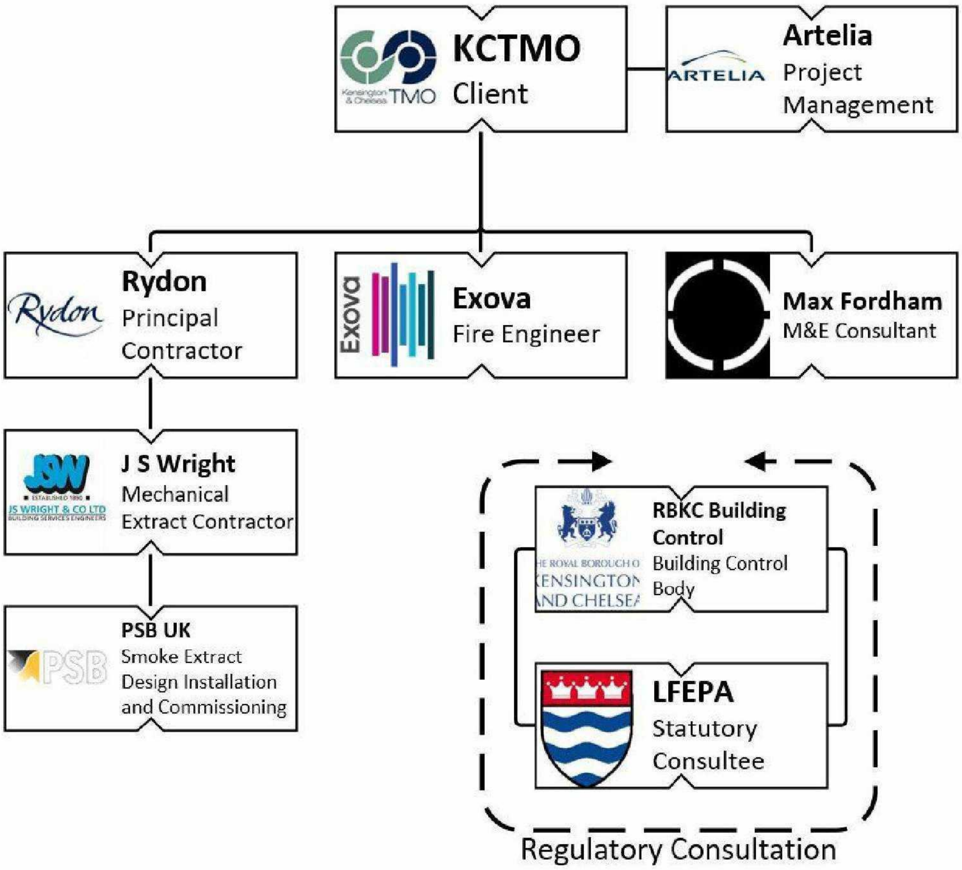


Figure 4.31: Organogram for smoke control refurbishment

4.7.130 **Alterations to the dry riser system**

4.7.131 The information in the original building design drawings identifies that the dry rising fire main was originally provided with an inlet valve at Ground Level, adjacent to the core entrance. This fire main served all levels between Level 4 and Level 23. The original fire main did not serve Levels 1, 2 or 3. It is not currently known how those levels were provided with firefighting hose coverage as part of the original design.

4.7.132 The Description of Services document prepared by J S Wright & Co Ltd describes the alterations to the dry riser as follows:

"The existing dry riser system has been modified to suit the new areas at podium level. The inlet valve has been relocated to the front of the building near the main entrance. Refer to drawings for locations of new landing valves."

4.7.133 Based on my review of the J S Wright & Co Ltd 'As Installed' mechanical drawings (August 2014), the following modifications were made to the dry riser as part of the 2012 – 2016 refurbishment works (please refer to Figure 4.33):

a) A new landing valve (dry riser outlet) was provided in the Southeast corner of the common lobbies on levels 1 & 2;

b) New branches connecting the rising fire main to the new outlets on levels 1 & 2 were provided;

c) A new landing valve was provided on level 3, connected directly to the existing rising fire main;

d) A new inlet breaching valve on south façade at ground level;

e) A new drain at basement level;

f) A new run of pipe connecting the new inlet valve to the existing dry rising fire main at ground level (this pipe was run through the basement to connect to the new drain at basement level).

4.7.134 A schematic of these modifications is shown in Figure 4.33 (RYD00000577). The revised outlet location on Level 2 is indicated in Figure 4.34, with a photograph of it from my post fire inspection provided in Figure 4.32.

4.7.135 These changes are reflected in the Studio E As-Built drawings, as indicated in this section.

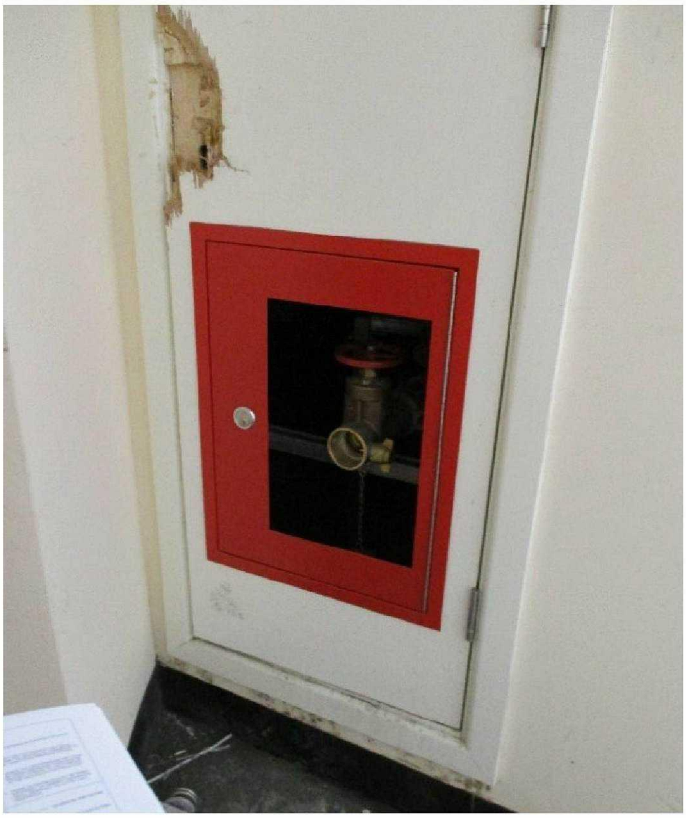


Figure 4.32: Example new dry rising fire main outlet at Level 2

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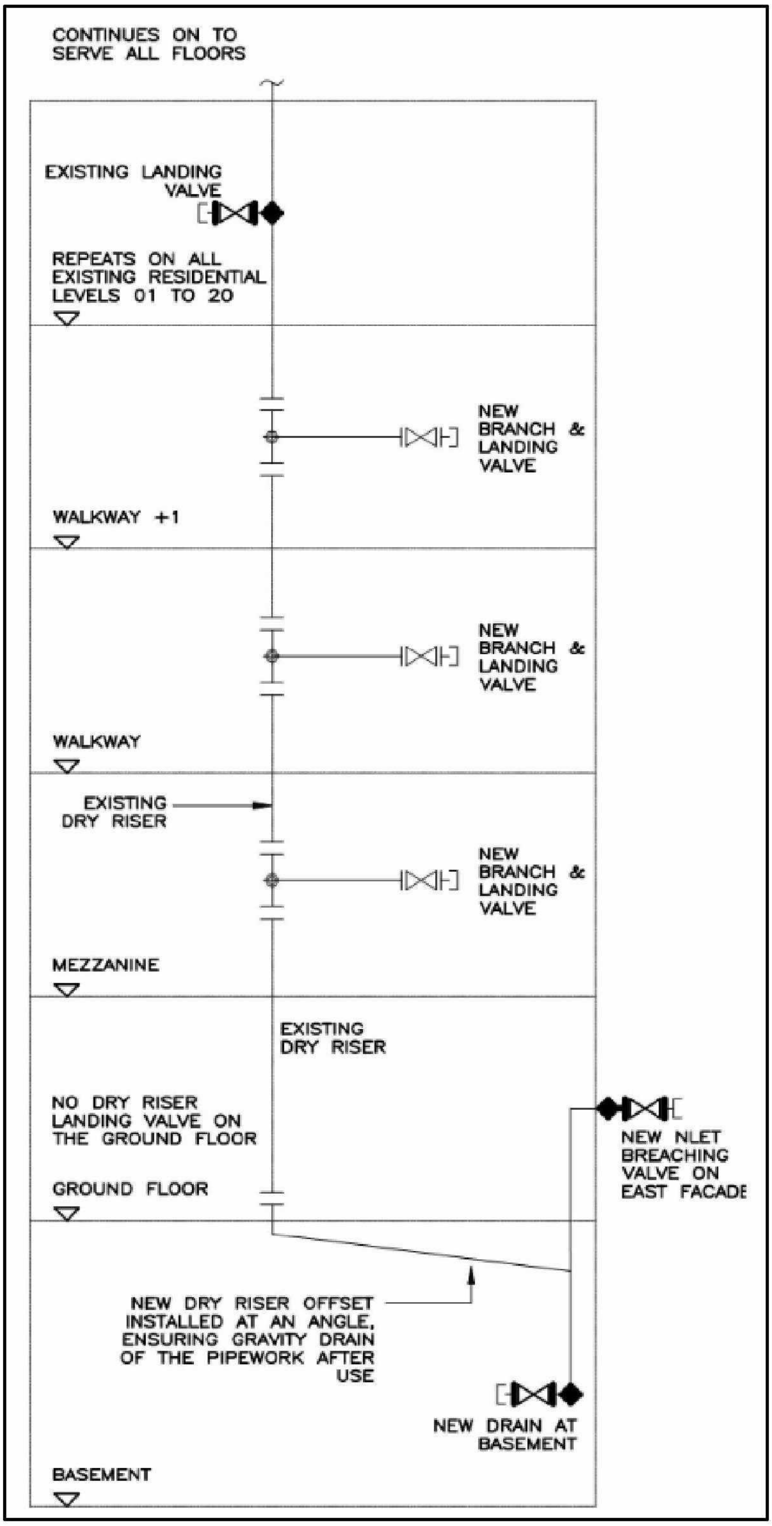

Figure 4.33: Dry riser schematic (RYD00000577)

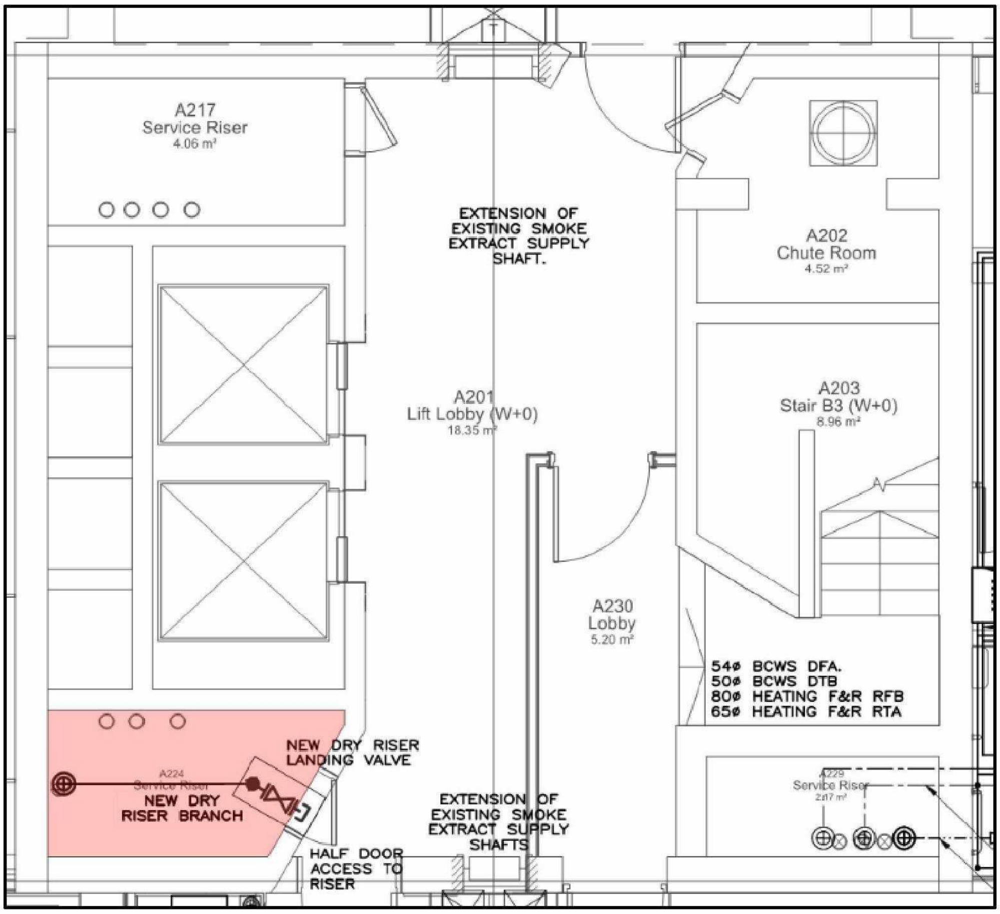

Figure 4.34: New dry riser on level 2 (RYD00000577)

4.7.136 **New Landlord gas connection to serve the new boiler plant**

4.7.137 As described in section 4.7.44, a new boiler was installed in the basement level of Grenfell Tower during the 2012 – 2016 refurbishment works.

4.7.138 A new connection from the existing gas system, referenced as the 'Landlord Gas Supply' in Appendix K, was also provided during the refurbishment works to serve the new boiler. This pipe connection is shown in red in Figure 4.35.

4.7.139 This conclusion is based on my review of the Max Fordham Employer's Requirements for MEP Services (dated 28/11/13) and my site inspection of the gas supply systems (MAX00006475).

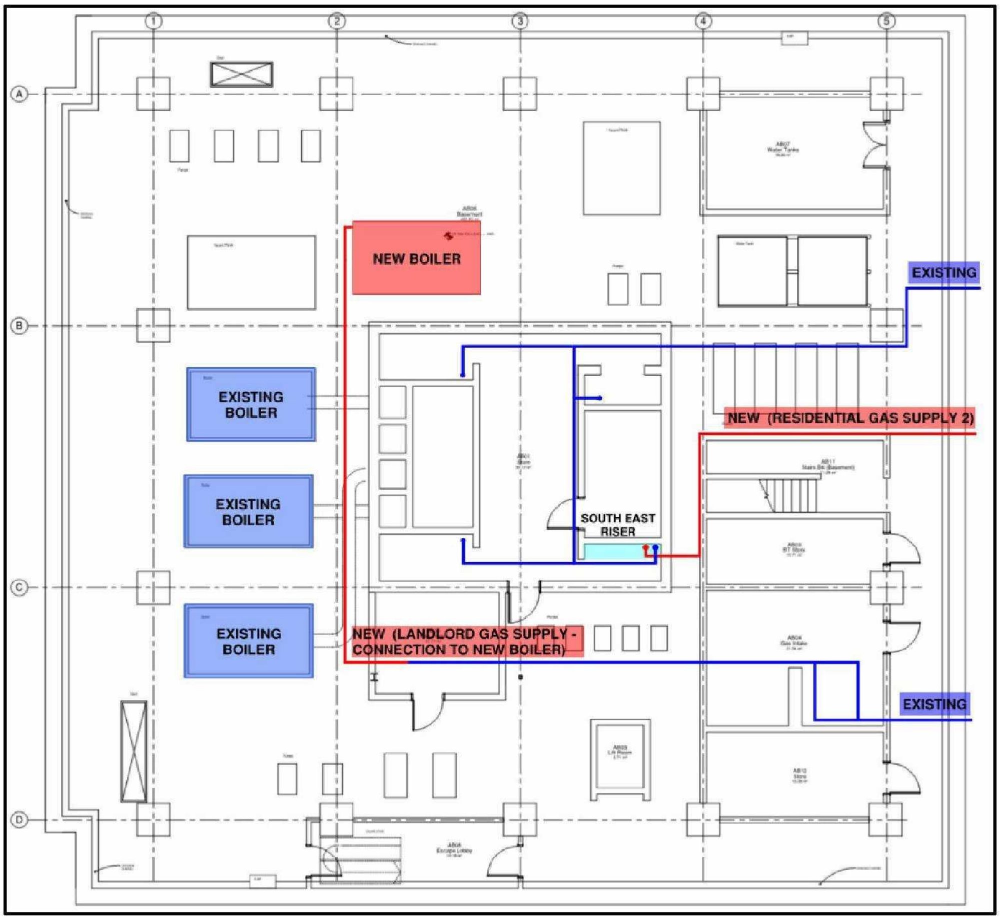

Figure 4.35: Gas works in basement (based on HAR00007951)

4.7.140 Ceilings in lift lobbies

4.7.141 Based on the Studio E Grenfell Tower Regeneration Project Room Data Sheets, Employer Requirements, dated 20-11-2013 (SEA00002540), each Existing Common lobby on levels 4 – 23 was required to have a new ceiling throughout.

4.7.142 A letter from Carl Stokes, Grenfell Tower Fire Risk Assessor, to the KCTMO describes his findings from his site visit to Grenfell Tower on 9 April 2015. This includes the following observations:

"New ceilings are being installed on the flat/lift lobby areas along with a boxed in area where the valves and pipes of the new heating system will be located, below are photographs taken on the 14th floor level where the new ceilings and cupboards have been partly constructed. The ceilings and the cupboards are fire rating and to the specification as stated in the construction documentation as issued by the TMO, I am told.

The construction of the ceilings and the cupboards is of plasterboard on a timber frame with the doors of the cupboards being 30 minute fire rated doors fitted with cold smoke seals and intumescent strips. The doors will have locks on them.

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I was told that where the ceiling abut up to the walls the access panels of the risers are being cut at the new ceiling height so access to the electrical cable risers is maintained." (CST00000170)

4.7.143 Pre-fire photographs of the Level 14 new ceiling installations are shown in Figure 4.36 and Figure 4.37.

4.7.144 Carl Stokes' correspondence indicates that he believed that the ceiling and new cupboards were of fire resisting construction. There is no evidence in the refurbishment design information reviewed to date to support this.

4.7.145 During my site inspections I did observe the new ceiling cupboard enclosure. The ceiling construction was mounted on metal stud framing and not timber as stated by Mr Stokes. Please refer to Appendix C and Section 14.

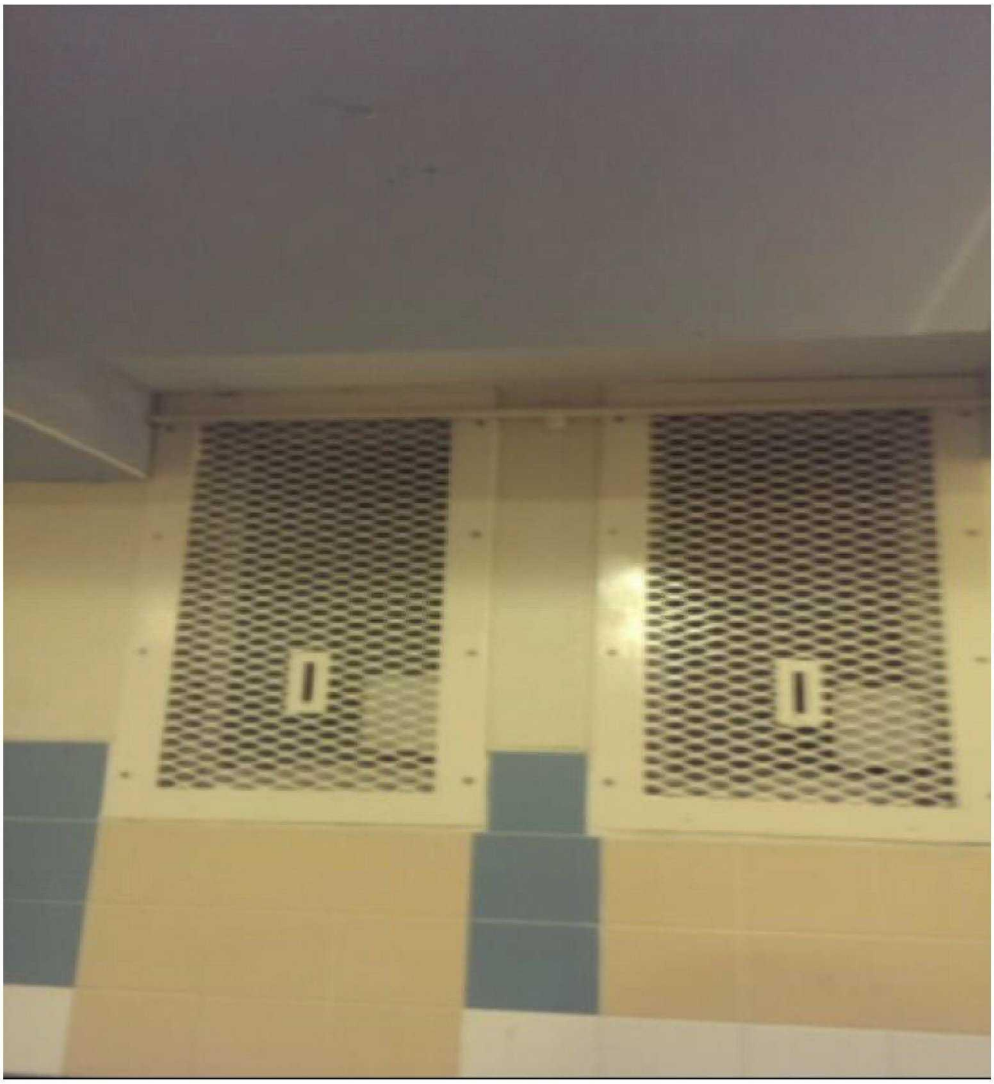

Figure 4.36: New ceiling around vents on Level 14 (CST00000170)

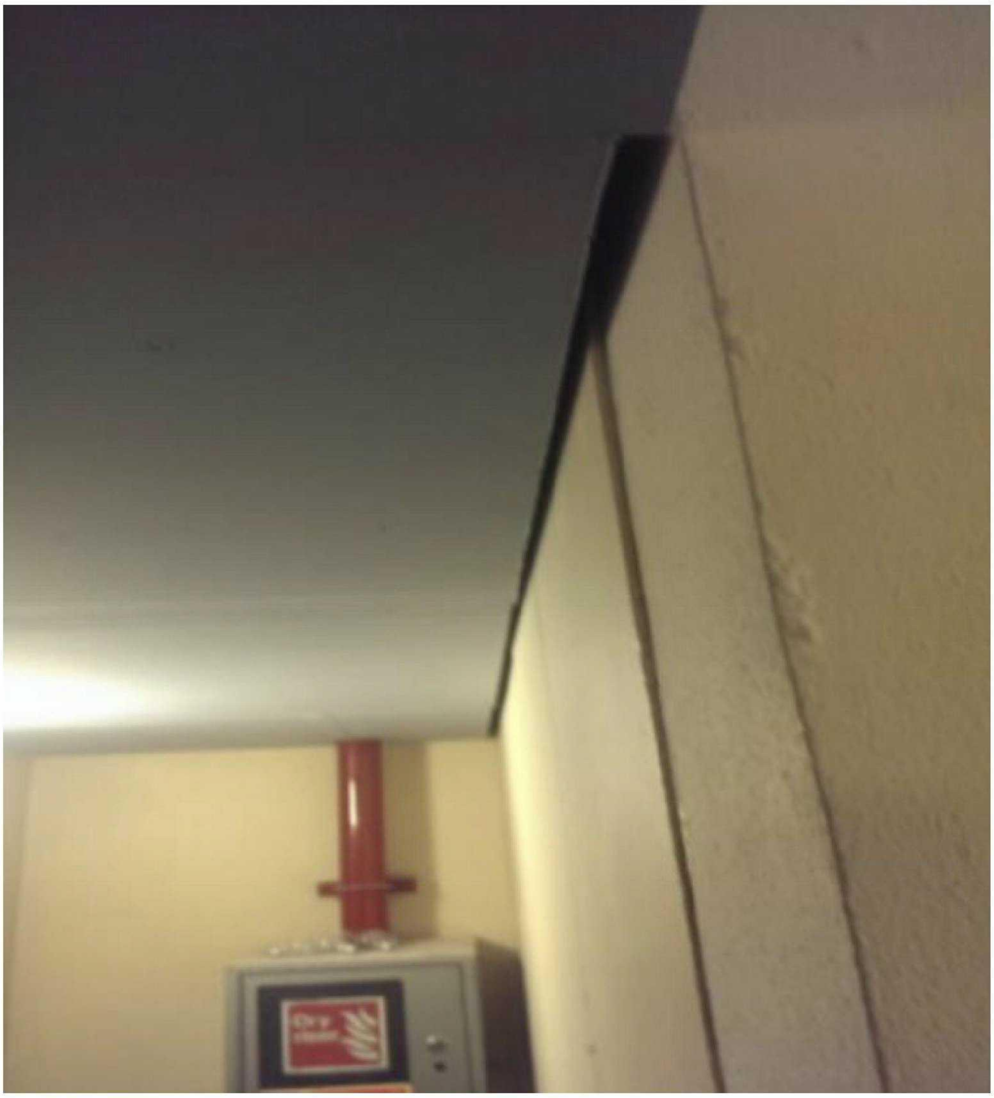

Figure 4.37: Wall access panels to be cut at new ceiling height so access to the electrical cable risers can be maintained (CST00000170)

4.7.146 **New fire doors installation 2016**

4.7.147 As part of these works, nine new flats were created at level 1 - 3, each with an associated main flat entrance fire door, specified to be FD60S fire rated. (RYD00000435)

4.7.148 Additionally, eight new fire doors to the escape stair/firefighting stair were installed as follows: 2 no. FD60S at Ground, 2 no. FD30S at Level 1, 3 no. FD30S at Level 2 and 1 no. FD60 at Level 3. Please refer to the sketches in Appendix I for the locations of these new fire doors and for full details regarding current evidence of their fire performance.

4.7.149 **New tenant gas supply, 2016 – 2017**

4.7.150 A new tenant gas supply, referred to here as Residential Gas Supply 2 in Appendix K, was provided between October 2016 and June 2017 to serve flat '2' on Levels 4, 5, 6, 8, 9, 10, 11, 12, 13, 14, 16, 17 and 21.

4.7.151 This new tenant gas supply was required because of corrosion within one of the existing gas risers (Riser 2, serving flat 2 on each level) which led to a small gas leak. The survey and discovery of the leak was completed on 30th September 2016, after which Riser 2 was isolated (1 October 2016) (Stephen Mason statement CAD00000004).

4.7.152 I traced this new gas supply pipe during my Tower inspection. It enters the building on the east side of the basement level and enters the Southeast riser in the core of the building. It rises vertically to Level 2, where the gas pipe leaves the riser, enters the Community Meeting Room and then turns and enters the protected stairway; see Appendix K.

4.7.153 This gas supply system is then routed through the protected stairway from Level 2 to Level 23.

4.7.154 At the abovementioned levels, a lateral gas pipe passes out through the stair wall across the lobby at ceiling level and enters flat '2' at the right-hand side of the flat entrance, as shown in Figure 4.38. This pipe is also shown in outside Flat 12.

4.7.155 Within the stair the riser was enclosed in construction that was complete from levels 4 to 22 at the time of the fire on 14 June 2017, but was not fully enclosed to the roof vent. The construction separating the lateral distribution pipes on each of the floors (where provided) was not installed at the time of the fire. As described in Appendix K, the fire resistance performance of the enclosing construction is currently unknown.

4.7.156 The arrangements for ventilation of the enclosure to the riser within the protected stair were not complete at the time of the fire on 14 June 2017.

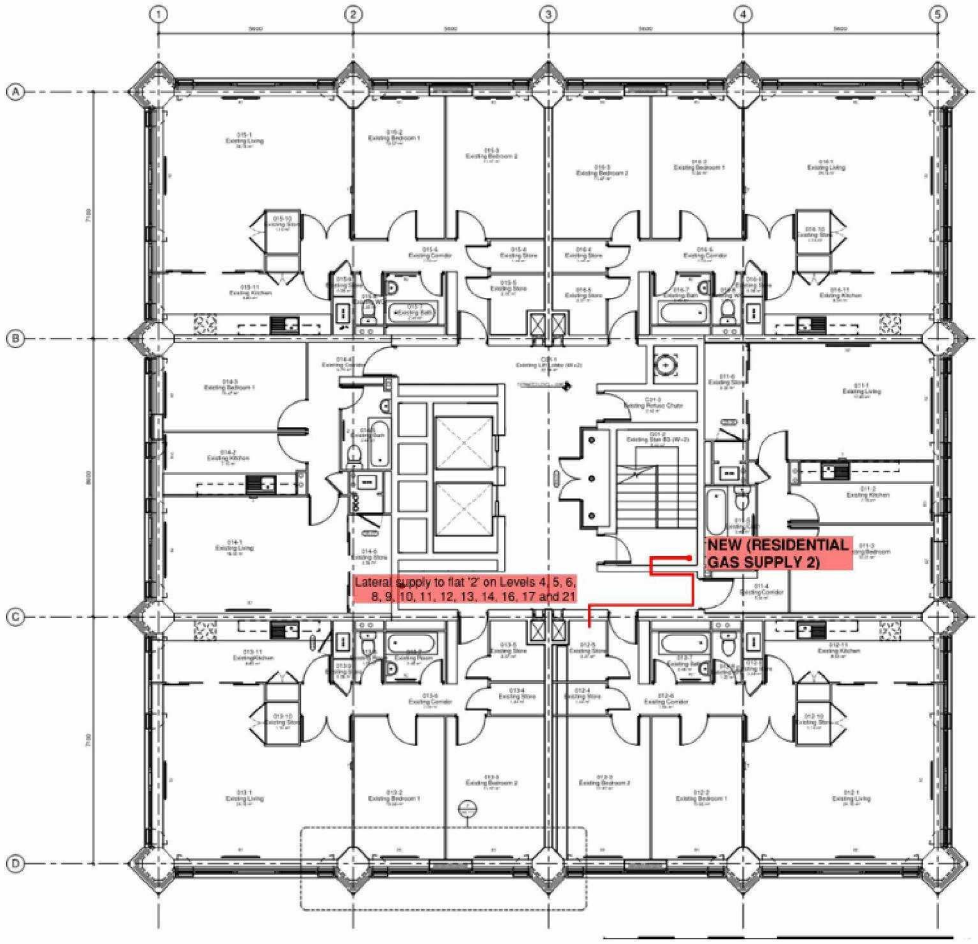

Figure 4.38: Gas works on typical residential level (SEA00010474)

4.7.157 **Location of refurbishment works, 2012 – 2016**

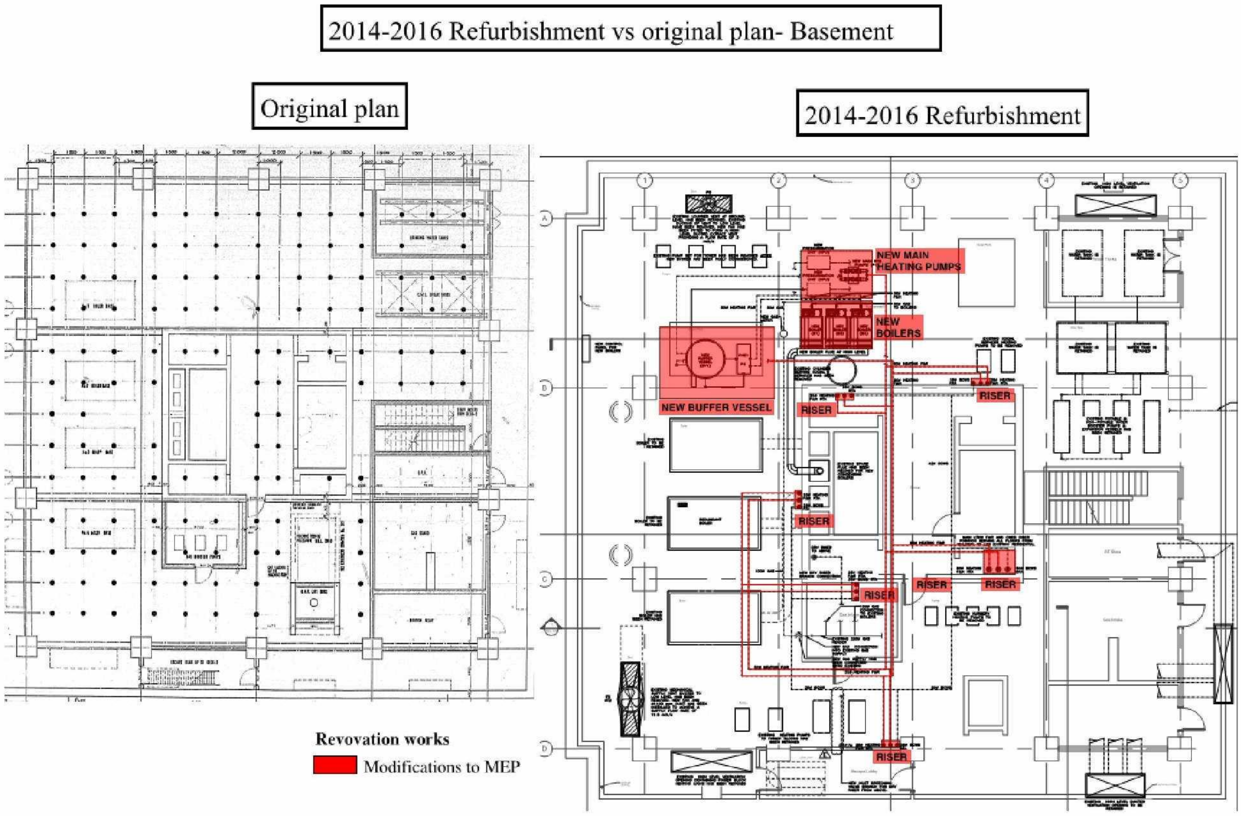

Figure 4.39: Basement level – refurbishment plan and original basement plan (RBK00018843, RYD00000577)

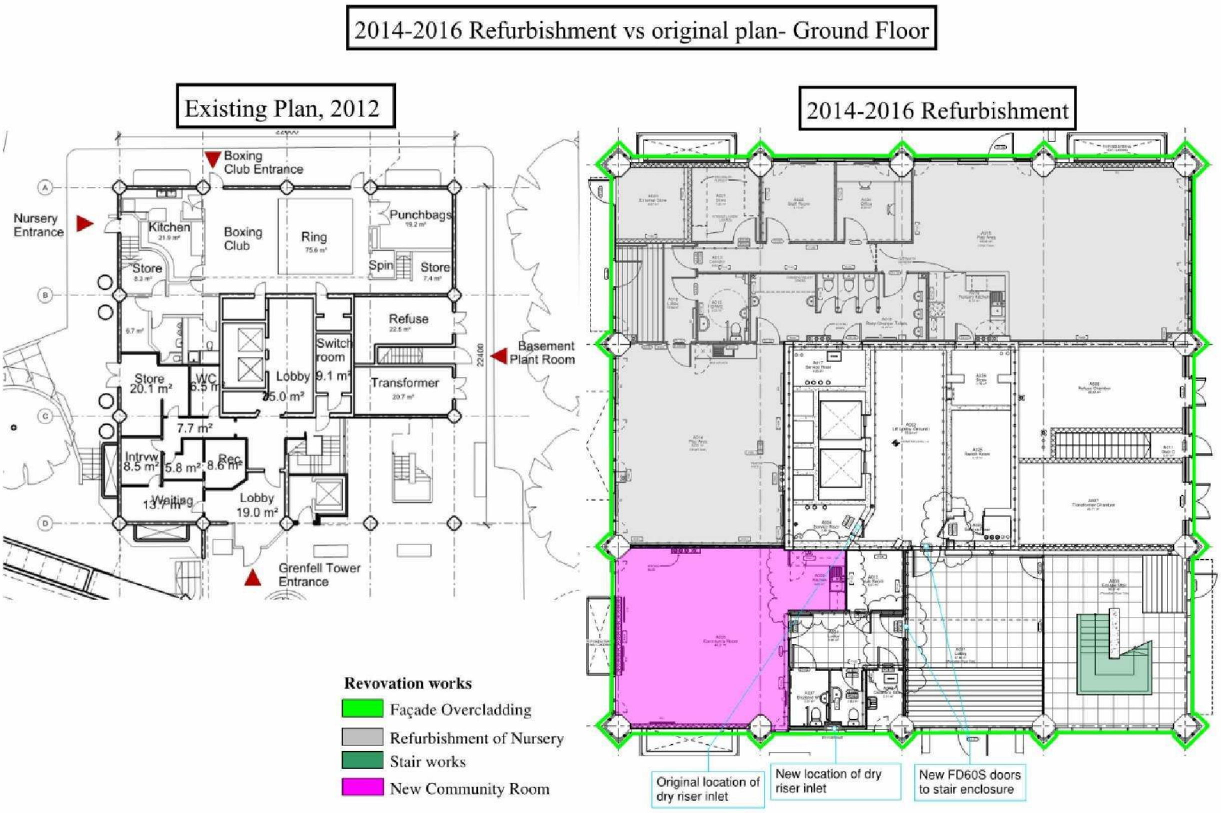

Figure 4.40: Ground level – refurbishment plan and existing 2012 plan (MAX00000879, SEA00003232)

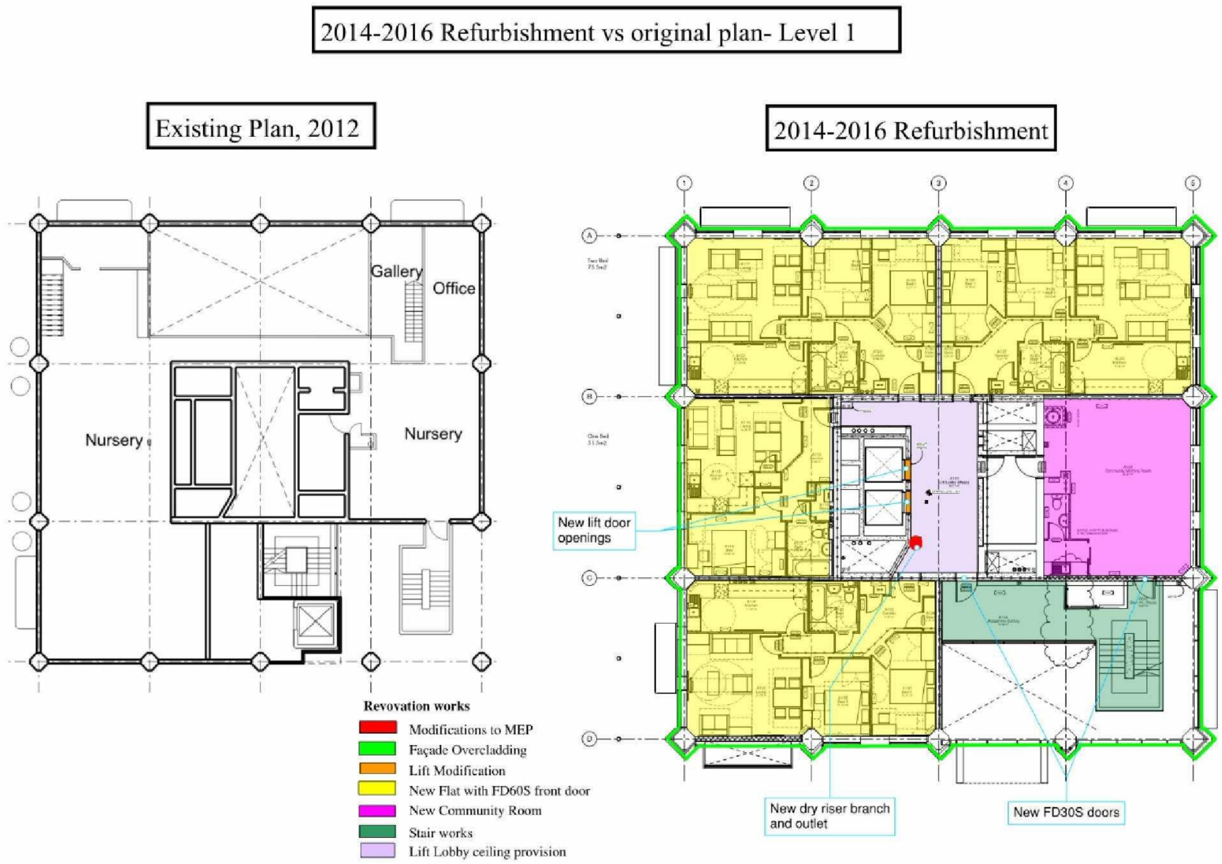

Figure 4.41: Level 1 – refurbishment plan and existing 2012 plan (MAX00000879, SEA00003231)

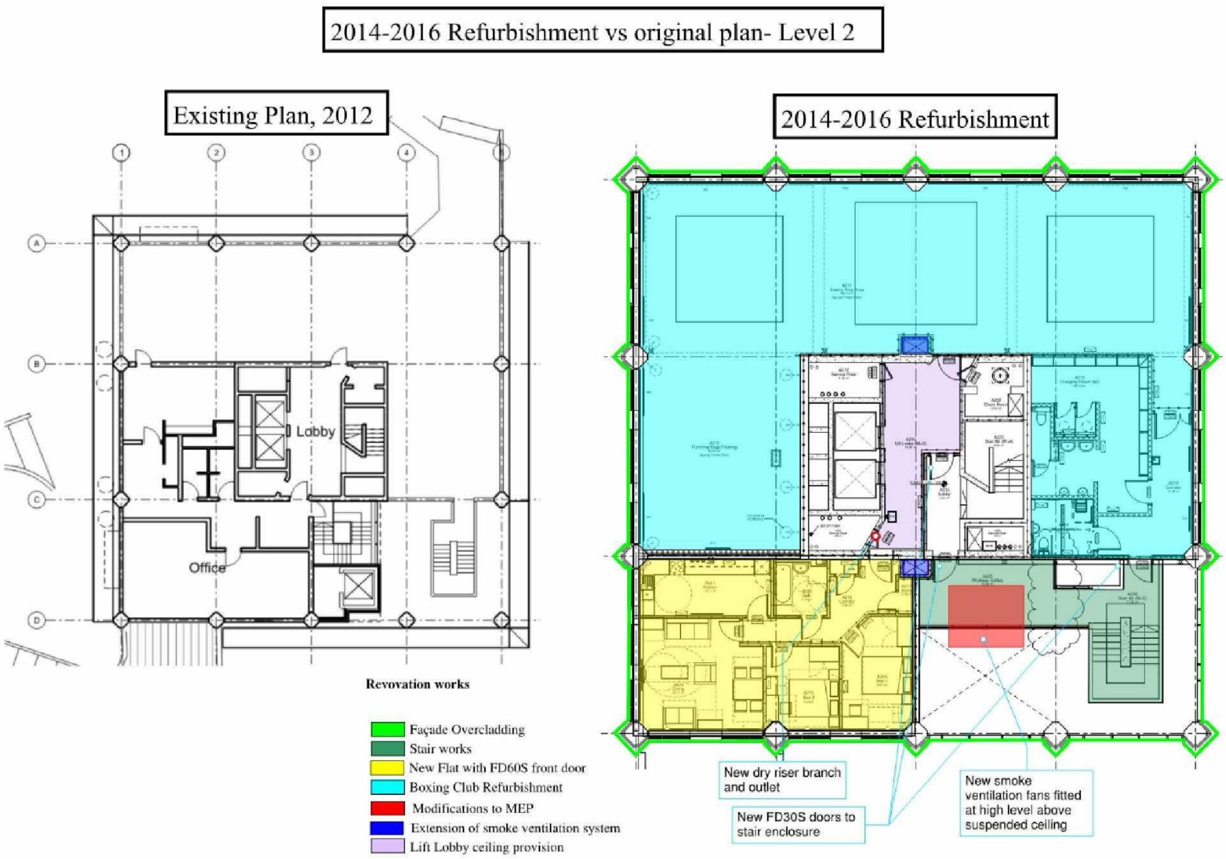

Figure 4.42: Level 2 – refurbishment plan and existing 2012 plan (MAX00000879, SEA00003149)

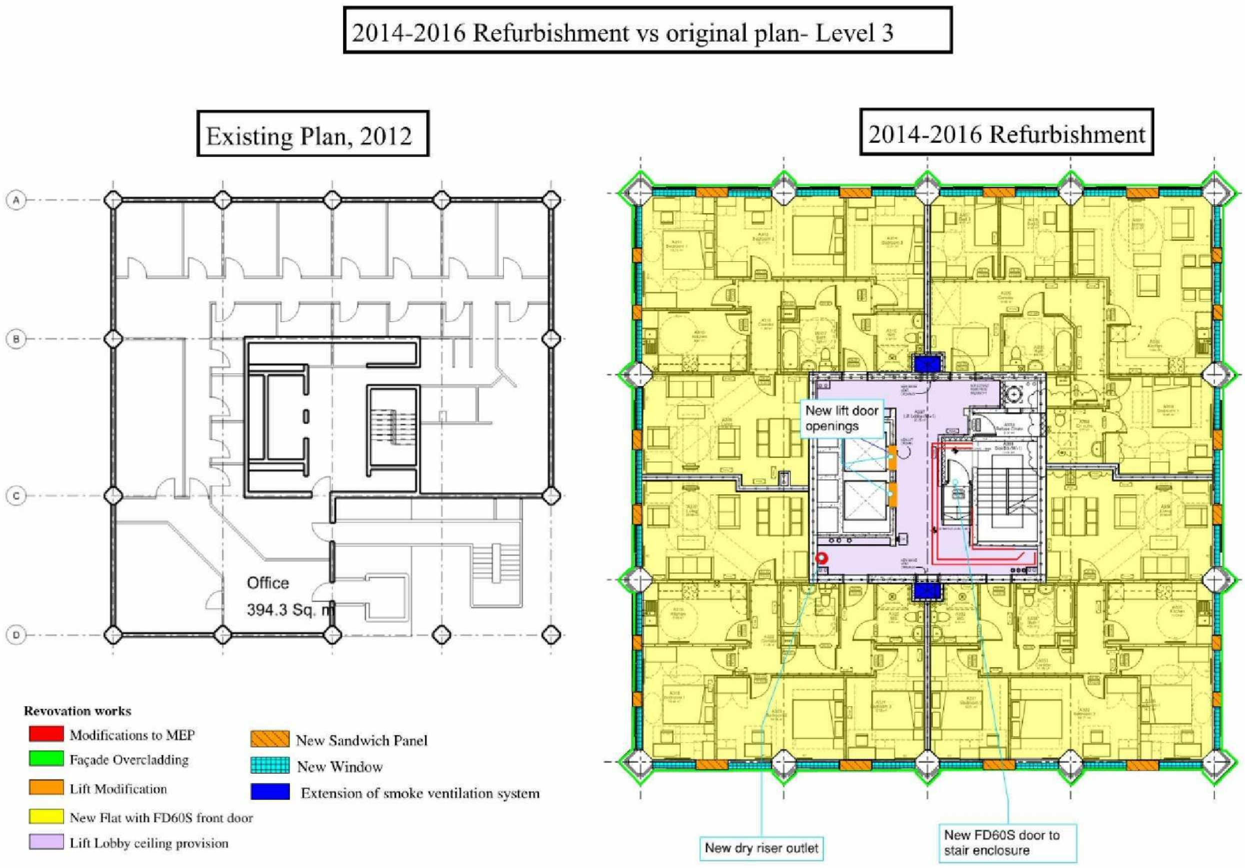

Figure 4.43: Level 3 – refurbishment plan and existing plan (MAX00000879, SEA00003229)

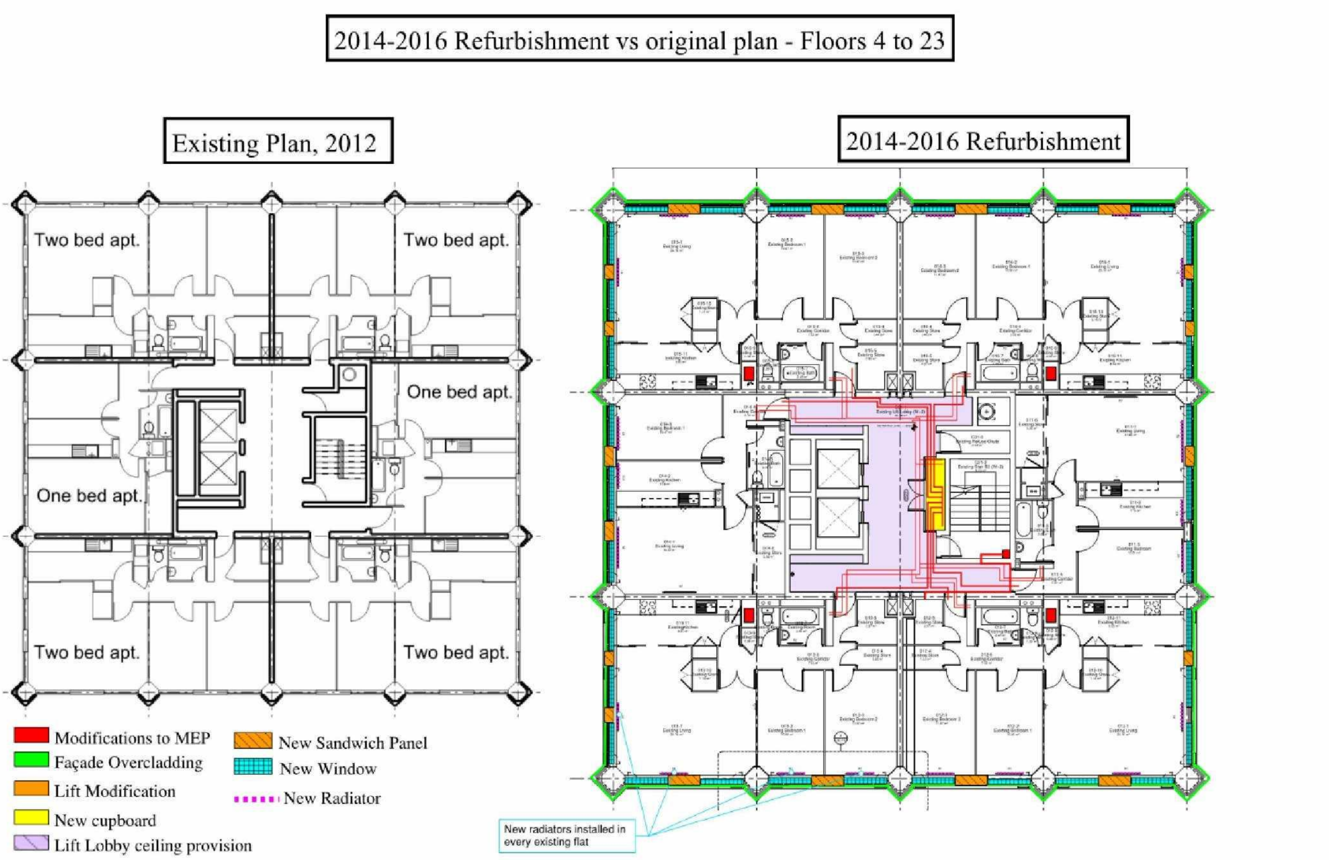

Figure 4.44: Level 4 – 23 typical residential level – refurbishment plan and existing 2012 basement plan (SEA00010474, RYD00000577)

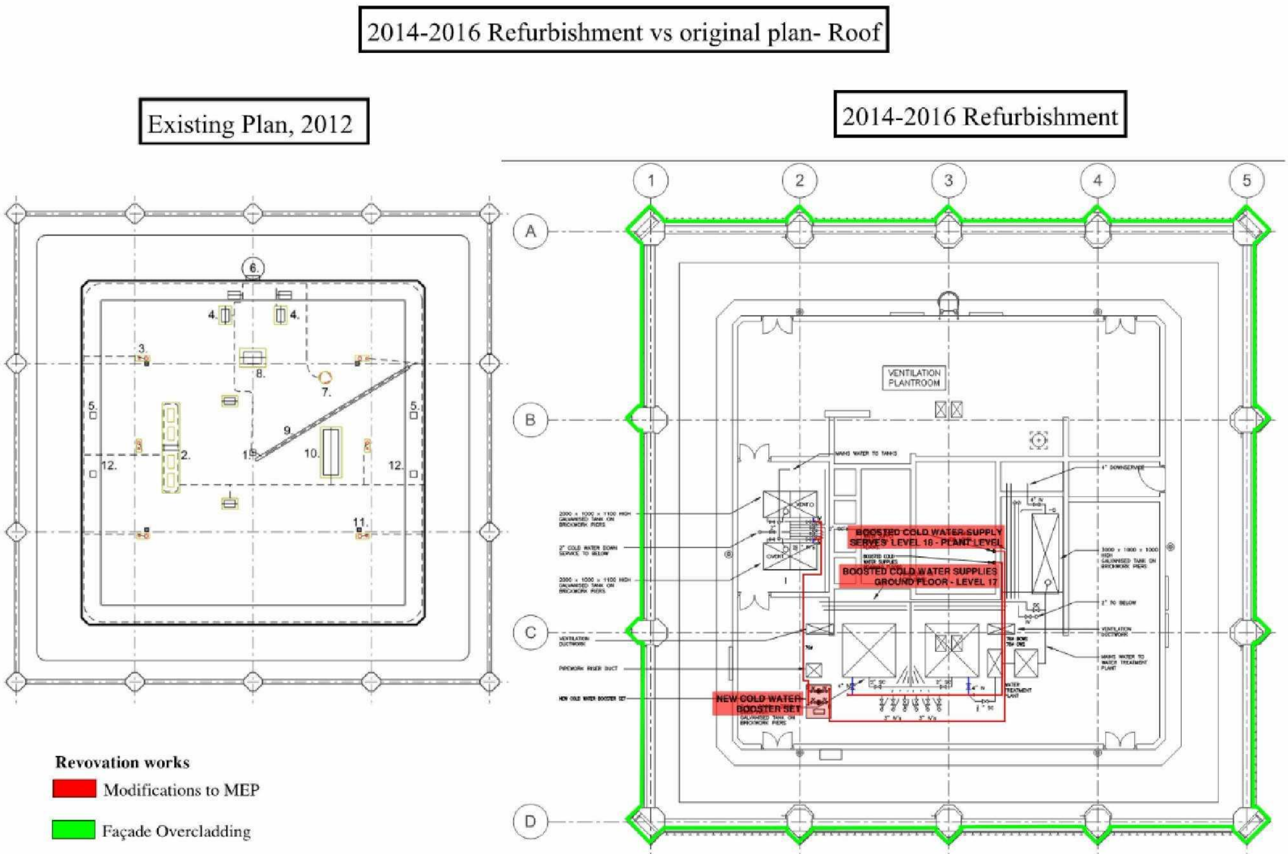

Figure 4.45: Roof level – refurbishment plan and existing 2012 roof plan (MAX00000879, RYD00000577)

4.8 Conclusions

4.8.1 In this section I have explained my findings from my review of the evidence provided to me regarding key refurbishment projects at Grenfell Tower.

4.8.2 I consider these to be substantial works on all levels inside Grenfell Tower, as well as the more obvious external works to the building envelope. These internal and external works took place during the most recent works from 2012-2016, as well as the fire doors work preceding this time period, and the gas works which were underway at the time of the fire.

4.8.3 Substantial works have been undertaken in all parts of the building over this time period, including the inside and outside of all individual flats and substantially throughout all of the communal spaces including all protected lobbies and the full extent of the stair core (by means of the gas works).

4.8.4 In Appendix D, I present a summary of the relevant legislation, regulations and guidance that was relevant to the works described in this section.

4.8.5 In the next phase of my work, I will determine which of the works described herein would have required specific approval under the Building Act 1984 and the Building Regulations relevant to 2012-2016.

5 The observed events of 14th June 2017

Please refer to separate document

6 Investigating how this happened – the physical evidence at Grenfell Tower

Please refer to separate document

7 Where the fire started

Please refer to separate document.

8 The Building Envelope – materials and construction

Please refer to separate document

9 Resulting routes for fire spread out and in through the window openings

Please refer to separate document

10 Resulting routes for vertical and horizontal fire spread through the building envelope

Please refer to separate document

11 Construction of the external walls – the provisions made at Grenfell Tower to comply with the Building Regulations

Please refer to separate document

12 The significance of the building envelope fire

Please refer to separate document

13 Critical times during the fire event

Please refer to separate document

14 The performance of the protected stairs and lobbies

Please refer to separate document

15 Construction of the common lobbies – the provisions made at Grenfell Tower to comply with Building Regulations

Please refer to separate document

16 Construction of the single protected stair – the provisions made at Grenfell Tower to comply with Building Regulations

Please refer to separate document

17 External access for the fire and rescue services - the provisions available at Grenfell Tower

Please refer to separate document

18 Communicating with residents in an emergency

Please refer to separate document

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19 How the protected stair and lobbies failed for fire fighters and for residents

Please refer to separate document

20 The consequences of the failures in Grenfell Tower

Please refer to separate document

BLA BLAR00000001/179

21 Experts Declaration

I Barbara Lane declare that:

1. I understand that my duty in providing written reports and giving evidence is to help the Court, and that this duty overrides any obligation to the party by whom I am engaged or the person who has paid or is liable to pay me. I confirm that I have complied and will continue to comply with my duty.
2. I confirm that I have not entered into any arrangement where the amount or payment of my fees is in any way dependent on the outcome of the case.
3. I know of no conflict of interest of any kind, other than any which I have disclosed in my report.
4. I do not consider that any interest which I have disclosed affects my suitability as an expert witness on any issues on which I have given evidence.
5. I will advise the party by whom I am instructed if, between the date of my report and the trial, there is any change in circumstances which affect my answers to points 3 and 4 above.
6. I have shown the sources of all information I have used.
7. I have exercised reasonable care and skill in order to be accurate and complete in preparing this report.
8. I have endeavored to include in my report those matters, of which I have knowledge or of which I have been made aware, that might adversely affect the validity of my opinion. I have clearly stated any qualifications to my opinion.
9. I have not, without forming an independent view, included or excluded anything which has been suggested to me by others, including my instructing lawyers.
10. I will notify those instructing me immediately and confirm in writing if, for any reason, my existing report requires any correction or qualification.
11. I understand that;
    a. my report will form the evidence to be given under oath or affirmation;
    b. questions may be put to me in writing for the purposes of clarifying my report and that my answers swill be treated as part of my report and covered by my statement of truth;
    c. the court may at any stage direct a discussion to take place between experts for the purpose of identifying and discussing the expert issues in the proceedings, where possible reaching an agreed opinion on those issues and identifying what action, if any, may be taken to resolve any of the outstanding issues between the parties;
    d. the court may direct that following a discussion between the experts that a statement should be prepared showing those issues which are agreed, and those issues which are not agreed, together with a summary of the reasons for disagreeing;
    e. I may be required to attend court to be cross-examined on my report by a cross-examiner assisted by an expert;
    f. I am likely to be the subject of public adverse criticism by the judge if the Court concludes that I have not taken reasonable care in trying to meet the standards set out above.

12. I have read Part 35 of the Civil Procedure Rules, the accompanying practice direction and the Guidance for the instruction of experts in civil claims and I have complied with their requirements.
13. I am aware of the practice direction on pre-action conduct. I have acted in accordance with the Code of Practice for Experts.

STATEMENT OF TRUTH

I confirm that I have made clear which facts and matters referred to in this report are within my own knowledge and which are not. Those that are within my own knowledge I confirm to be true. The opinions I have expressed represent my true and complete professional opinions on the matters to which they refer.

Signature Date 12th April 2018

Barbara Lane.

Name in full Dr Barbara Ann Lane FREng CEng

Appendix A: Experience, Qualifications, Appointments, Speciality of the Expert and of those who have assisted in the preparation of the report

Appendix B: Texts and published documents referred to

Appendix C: Excerpts from site inspection records from Grenfell Tower

Appendix D: Legislation, Regulations and Guidance relevant to Grenfell Tower

Appendix E: Compliance assessment - External Fire Spread Regulation B4

Appendix F: Reaction to fire tests and classifications

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

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

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

Appendix J: Smoke extract – fire safety requirements and provisions

Appendix K: Gas supply – fire safety requirements and provisions

All the Appendices are each a separate file.