Grenfell Tower – fire safety investigation: Module 3

The active and passive fire protection measures within Grenfell Tower on 14th June 2017 and the extent to which they: (1) complied with relevant regulations, legislation, guidance and industry practice, (2) failed to control the spread of fire and smoke, and (3) contributed to the speed at which the fire spread.

The lobby smoke control system at Grenfell Tower

REPORT OF

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Fire Safety Engineering

21st May 2021

Specialist Field	:	Fire Safety Engineering
Assisted by	:	Dr Susan Deeny, Farah Binte Mohd Faudzi, Tom Parker, Daniel Thomson, David Yates, Dr Graeme Flint
Specialist assistance	:	Joe Wade, Darren Wright, Dr Peter Woodburn
On behalf of	:	Grenfell Tower Inquiry
On instructions of	:	Cathy Kennedy, Solicitor, Grenfell Tower Inquiry
Subject Matter		To examine the circumstances surrounding the fire at Grenfell Tower on 14th June 2017
Inspection Date(s)	:	6th October, 1st November, 7-9th November 2017

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1 Introduction

1.1.1 **Report arrangement**

1.1.2 This report is in response to my Phase 2 instructions from the Grenfell Tower Inquiry:

Your final conclusions on the active and passive fire protection measures within Grenfell Tower on 14th June 2017 and the extent to which they: (1) complied with relevant regulations, legislation, guidance and industry practice, (2) failed to control the spread of fire and smoke, and (3) contributed to the speed at which the fire spread.

This Report should incorporate your opinion (where relevant) on:

Your final conclusions on the active and passive fire protection measures within Grenfell Tower on 14th June 2017 and the extent to which they: (1) complied with relevant regulations, legislation, guidance and industry practice, (2) failed to control the spread of fire and smoke, and (3) contributed to the speed at which the fire spread.

In providing that opinion you are asked to provide a supplemental report which highlights the extent to which further information and analysis has led you to modify your views or enabled you to reach a final conclusion where you were unable to do so in your Phase 1 report.

1.1.3 It is a supplemental report to Appendix J of my Phase 1 report, in which I presented my analysis of the requirements and provisions of the lobby smoke control system at Grenfell Tower {BLAS0000031}.

1.1.4 That analysis was based on evidence available to me at the time and I concluded my report by setting out (at Section J11) a list of ten investigations which I intended to conduct in Phase 2.

1.1.5 This Module 3 report retains the results of my Phase 1 investigations but incorporates the findings I have made as a result of additional evidence available to me, and my work in response to the investigations identified in my Phase 1 report.

1.1.6 This report has the same heading structure as Appendix J to my Phase 1 report {BLAS0000031} but also incorporates several new headings, as explained in Table 1-1 below.

1.1.7 I explain at the start of each retained Section, the primary changes made.

Table 1-1 Comparison of headings

Phase 1 report	Module 3 report	Section number of this report
Purpose of Appendix J	N/A	
Introduction	Introduction	Section 1
Purpose of a lobby smoke control system in a residential building	Lobby smoke control systems in high rise residential buildings- the functional requirements	Section 2
Recommended Provisions for the smoke control system at Grenfell Tower at the time of original construction	Recommended Provisions for the smoke control system at Grenfell Tower at the time of original construction	Section 3
Recommended Provisions for the smoke control system at Grenfell Tower at the time of the primary refurbishment	Developing a performance specification	Section 4
Description of the refurbishment smoke control system	Description of the design approach taken to the refurbishment smoke control system.	Section 5
Physical evidence of the installed Refurbishment works	Evidence of the performance of the as installed refurbished smoke control system.	Section 6
n/a	Controls and the resulting operation of the smoke control system	Section 7
Evidence of commissioning	Evidence of the commissioning process and outcomes.	Section 8
n/a	Changes made to the system post commissioning (pre-handover of the building)	Section 9
Preliminary findings from my review of the smoke control system software	Now set out in full in Section 7.	N/A
Compliance of the refurbished system with ADB	Compliance of the refurbished system with the functional requirements of the Building Regulations	Section 10
Operation of the Smoke ventilation on 14 June 2017	Operational condition of the smoke control system prior to the 14th June 2017	Section 11
Classification of Dampers in accordance with ADB and UK testing requirements	Now set out in full in Section 4	N/A
n/a	Analysis of the lobby smoke control system performance the night of the fire	Section 12
n/a	Analysis of the smoke control system installation as a protected shaft the night of the fire	Section 13
n/a	Conclusions	N/A
n/a	Expert Declaration	Section 14

1.1.8 For the avoidance of doubt, where I have retained any original text from Appendix J, I have incorporated the Phase 1 Corrections and Addenda {BLAS0000037} into that text so that it appears as corrected.

1.1.9 In preparing this report, I have reviewed all additional witness statements provided to the Inquiry relevant to the design, building control approval, installation, commissioning, and maintenance of the refurbishment smoke control system.

1.1.10 The most substantial of these is from Mr Mahoney (PSB) {PSB00001373} in which he now says that the depressurisation system he designed, *"a mechanical extract 'depressurisation' system"*, should not be confused with the pressure differential systems *"described"* in BS EN 12101-6:2005 (paragraphs 36-40).

1.1.11 Whilst Mr Mahoney says that the system is *"referred to within industry as a 'depressurisation' system"* (paragraph 41), he also says that there is "no comprehensive guidance available as to generic performance criteria for systems of this type" (paragraph 62).

1.1.12 As I understand it, Mr Mahoney's position is that a pressure differential formed the basis of his design, but that some pressure differential systems are designed to comply with BS EN 12101-6:2005 while other such systems, in common use, are expressly *not* so designed, and it was the latter type of system he chose for Grenfell Tower, on behalf of PSB.

1.1.13 I have also carried out further analysis of the available evidence of both testing and certification for the smoke control equipment, AOVs, fans, dampers, and smoke extract ductwork.

1.1.14 I have received no new commissioning information, but I have provided my opinion on the recent (second) witness statement from Mr Partlow of PSB and whether the tasks to which he refers affect my original commissioning analysis. I have conducted a fresh analysis of the commissioning process, now that PSB have confirmed the basis for their design {PSB00001373}.

1.1.15 I have carried out further analysis of evidence regarding the known condition of the smoke control system after the completion certificate was issued on 3rd May 2016 {PSB00001258}, focusing on evidence of changes made to the smoke control system post-commissioning and evidence of unresolved reported defects between 3rd May 2016 and the night of the fire.

1.1.16 I have provided further analysis of the planned maintenance carried out by KCTMO on the smoke control system between 3rd May 2016 and the night of the fire. This supplements my general investigation in my Module 3 report for the inquiry *"The Management and Maintenance of Grenfell Tower - Chapter 7 - KCTMO's duty to provide a suitable system of maintenance for fire protection measures"* {BLARP20000033}.

1.1.17 I have relied on this information to conclude my investigation regarding the intended operation of the refurbishment smoke control system in Grenfell Tower and the compliance of the resulting intended operation with the functional requirements of the *Building Regulations 2010*.

1.1.18 I have also concluded my investigation into the available evidence regarding the operation of the smoke control system on the 14th June 2017. At Sections 12 and 13 of the report, I have explored specific scenarios based on the evidence.

1.1.19 I have explored these scenarios in order to ascertain:

a) whether there is sufficient evidence to conclude that the refurbishment lobby smoke control system operated as intended at Level 4 of Grenfell Tower, or that it operated in a different way; and

b) whether the lobby smoke control system contributed to the spread of fire and smoke in Grenfell Tower.

1.1.20 I have set out alternative operation scenarios that may have occurred the night of the fire, where the evidence allows me to do so.

1.1.21 I have also reviewed Appendix J of my Phase 1 report {BLAS0000031} against the factual findings in the Chairman's Phase 1 Report; I have therefore amended specific timings of events on the night of 14th June 2017 to align with the Inquiry's findings.

1.1.22 **Specialist assistance in formulating the meaning of the available evidence**

1.1.23 In conducting my investigations, I have relied on expert assistance from the following colleagues at Arup: Dr Peter Woodburn (Chartered Mechanical Engineer), Mr Joe Wade (Commissioning engineer) and Mr Darren Wright (Director of Building Performance and Systems).

1.1.24 This was specifically for assistance in ascertaining relevant information from the software and controls system for both the smoke control system and the Building Management System.

1.1.25 This is just as I would do in my normal professional activities when working on major projects with responsibility for the design, commissioning, and compliance review of active fire safety systems, including smoke control systems.

1.1.26 I have provided all relevant CVs to the Inquiry.

1.1.27 **Dampers and Automatically Openable Vents [AOVs]**

1.1.28 In this report I rely on the use of the word damper, for the devices installed within the builders work shafts in Grenfell Tower. This is based on the following definition provided in BS 4422:2005 *Fire Vocabulary*:

3.96

damper, fire

moveable closure, within a duct, which is operated automatically or manually and is designed to prevent the passage of fire

3.97

damper, smoke

moveable closure within a duct which is operated automatically or manually and is designed to prevent the passage of smoke

1.1.29 This is as distinct from an automatically openable vent [AOV] such as those provided in the external walls of Grenfell Tower, which directly vented to fresh air. This is based on the following definition provided in BS 4422:2005 *Fire Vocabulary*: 3.707

smoke vent

opening in the enclosing walls or roof of a building, intended to release heat and smoke in the event of fire, automatically and/or manually opened

2 Lobby smoke control systems in high rise residential buildings - the functional requirements

2.1 Overview

2.1.1 Lobby smoke control systems form part of the package of measures relied upon for means of escape, and for firefighting, in high-rise residential buildings.

2.1.2 They are one of the (active) fire safety measures described within the Approved Document B 2013 (ADB 2013), relevant to various functional requirements (including B1 Means of warning and escape and B5 Access and facilities for the fire service) of the Building Regulations.

2.1.3 Where smoke control systems are comprised of shafts and/or ductwork penetrating internal compartmentation, their construction is also subject to the functional requirements of B3 Internal fire spread (structure) of the Building Regulations.

2.1.4 Each part of ADB 2013 is set out in a particular hierarchy: first the functional requirement, secondly the Secretary of State's view about the performance standards that enable compliance with that functional requirement, and thirdly a series of provisions which are intended to provide a compliance solution to the functional requirement, as addressed in that part.

2.1.5 ADB 2013 makes clear that there is no obligation to adopt any particular solution to meet the functional requirements under 'Use of Guidance' page 5 paragraphs 3-4:

The Approved Documents are intended to provide guidance for some of the more common building situations. However, there may well be alternative ways of achieving compliance with the requirements.

Thus there is no obligation to adopt any particular solution contained in an Approved Document if you prefer to meet the relevant requirement in some other way.

2.1.6 In this Section I set out (relevant to the decision to rely on a lobby smoke control system only, and using the hierarchy relied upon within the ADB 2013) the relevant functional requirements, the associated performance as described by the Secretary of State, and the subsequent provisions made in the ADB 2013.

2.1.7 In my opinion, any alternative solution to the provisions set out in ADB 2013 must consider the performance standards described by the Secretary of State.

2.1.8 The final solution, and the final performance standard derived, should then be set out for review and consideration by the approving authority, with an explanation as to how it meets the relevant functional requirement.

2.1.9 I have already set out in detail in Section 3 of my Phase 1 report {BLAS0000003} the full package of measures to support means of escape and firefighting in a building with a Stay Put strategy and do not repeat it here.

2.2 Requirement B1 *Means of warning and escape*

2.2.1 **The functional requirement**

2.2.2 Regulation B1 of the *Building Regulations 2010* states (bold by me):

The building shall be designed and constructed so that there are appropriate provisions for the early warning of fire, and appropriate means of escape in case of fire from the building ***capable of being safely and effectively used at all material times***

2.2.3 **Performance**

2.2.4 ADB 2013 sets out the Secretary of State's view that Requirement B1 will be met if (bold by me):

a. there are routes of sufficient number and capacity, which are suitably located to enable persons to escape to a place of safety in the event of fire;

b. the routes are sufficiently protected from the effects of fire where necessary;

c. the routes are adequately lit;

d. the exits are suitably signed; and

e. there are appropriate facilities to either limit the ingress of smoke to the escape route(s) or to restrict the fire and remove smoke;

f. all to an extent necessary that is dependent on the use of the building, its size and height; and

g. there is sufficient means for giving early warning of fire for persons in the building.

2.2.5 Later at B1.ii to B1.iv, ADB 2013 provides some further *"analysis of the problem"*, from which I have extracted the following relevant points (bold by me):

B1.iiii Fires do not normally start in two different places in a building at the same time"

B1.iv The primary danger associated with fire in its early stages is not flame but the smoke and noxious gases produced by the fire. They cause most of the casualties and may also obscure the way to escape routes and exits. Measures designed to provide safe means of escape must therefore provide appropriate arrangements to ***limit the rapid spread of smoke and fumes.***

2.2.6 Additionally, at paragraph 2.3 of ADB 2013 it is stated:

The provisions for means of escape for flats are based on the assumption that:

...

c. measures in Section 8 (B3) provide a high degree of compartmentation and therefore a ***low probability of fire spread beyond the flat of origin****, so that simultaneous evacuation of the building is unlikely to be necessary*

2.2.7 Of importance too are the criteria for means of escape, as described at B1.v (bold by me):

B1.v The basic principles for the design of means of escape are:

a. that there should be alternative means of escape from most situations; and

*b. where direct escape to a place of safety is not possible, it should be possible to reach a place of relative safety, **such as a protected stairway, which is on a route to an exit, within a reasonable travel distance.** In such cases the means of escape will consist of two parts, the first being unprotected in accommodation and circulation areas and the second in protected stairways (and in some circumstances protected corridors).*

2.2.8 **Provisions made in ADB 2013 – Protected stairways**

2.2.9 A protected stairway is defined in Appendix E of the ADB 2013 as:

A stair discharging through a final exit to a place of safety (including any exit passageway between the foot of the stair and the final exit) that is adequately enclosed with fire-resisting construction.

2.2.10 Further at B1.ix of ADB 2013 it states (bold by me):

*B1.ix Protected stairways are designed to provide virtually 'fire sterile' areas which lead to places of safety outside the building. Once inside a protected stairway, a person can be considered to be safe from immediate danger from flame and smoke. **They can then proceed to a place of safety at their own pace. To enable this to be done, flames, smoke and gases must be excluded from these escape routes, as far as is reasonably possible, by fire-resisting structures or by an appropriate smoke control system, or by a combination of both these methods.***

2.2.11 Consequently, ADB 2013 contains guidance about controlling the use of space within protected stairways at paragraph 2.40, including addressing the question of gas service and installation pipes at paragraph 2.42.

2.2.12 But, importantly for present purposes, it also attributes a protection role to the common corridor/lobby.

2.2.13 It states at paragraph 2.24 *Protection of common escape routes* of ADB 2013:

To reduce the risk of a fire in a flat affecting the means of escape from other flats and common parts of the building, the common corridors should be protected corridors. The wall between each flat and the corridor should be a compartment wall (see Section 8).

2.2.14 ADB 2013 then introduces the need for smoke control to the common lobby at paragraph 2.25 "***Smoke control of common escape routes***":

Despite the provisions described in this Approved Document, it is probable that some smoke will get into a common corridor or lobby from a fire in a flat, if only because the entrance door will be opened when the occupants escape.

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).

This can be achieved by either natural means in accordance with paragraph 2.26 or by means of mechanical ventilation as described in paragraph 2.27

2.2.15 Taken together, all of the above results in the following performance conditions:

a) The fire is in a single location and it is located within a flat.

b) The protected stair is within a reasonable travel distance from the flat entrance door.

c) The flames, smoke and gases are then to be excluded from the protected stairs.

d) The flames are to be excluded by means of fire resisting construction between the flat and the stair.

e) The smoke and gases are to be excluded by means of (1) fire doors to the stair, and (2) smoke control in the lobby.

f) The flat entrance door, where the fire has occurred, is assumed open when occupants escape only.

g) The lobby door to the stair, on the fire floor, is assumed open as escaping occupants enter the protected stairway, and then proceed to a place of safety at their own pace.

2.2.16 ADB 2013 then makes provisions on this basis and, regarding the smoke control in the lobby, two solutions are described – natural ventilation and mechanical ventilation.

2.2.17 <u>Protection by means of natural ventilation</u>

2.2.18 Natural ventilation smoke systems provide the means for hot smoke to ventilate from a space driven by its own buoyancy only.

2.2.19 ADB 2013 at paragraph 2.26 describes two forms of natural ventilation system.

2.2.20 The first option relies on smoke vents located on an external wall in each of the common lobbies, coupled with a smoke vent at the top storey of the stairway. In single stair buildings these smoke vents should be actuated by means of smoke detectors in the common lobby.

2.2.21 The second option relies on discharging smoke from a vent in the common lobby to a vertical smoke shaft open to the atmosphere at the top, thereby acting as a chimney. Smoke detection should be provided to open the relevant lobby smoke vent, and the vent at the top of the smoke shaft, but keep all other lobby smoke vents closed. These vents should have a fire/smoke resistance performance of at least that of 30 minutes integrity and achieve cold smoke leakage performance (termed $E30S_a$) and be capable of automatically opening and closing.

2.2.22 <u>Protection by means of mechanical ventilation</u>

2.2.23 ADB 2013 describes mechanical ventilation as an alternative to the natural ventilation options I have summarised above.

2.2.24 It states at paragraph 2.27 (bold by me):

As an alternative to the natural ventilation provisions in paragraph 2.26, ***mechanical ventilation to the stair and/or corridor/lobby may be provided to protect the stair(s) from smoke.*** *Guidance on the design of smoke control systems using pressure differentials is available in BS EN 12101-6:2005.*

2.2.25 ADB 2013 does not provide any further definition of a mechanical ventilation solution or any further description of different types of mechanical ventilation.

2.2.26 It is necessary to refer to BS EN 12101-6:2005, as recommended by ADB 2013, for further information on mechanical ventilation solutions.

2.2.27 BS EN 12101-6:2005 provides the following definition of smoke control methods, including mechanical based methods:

0.3 Smoke control methods

The effect of the air movement forces described above is to create pressure differentials across the partitions, walls and floors which can add together and can cause smoke to spread to areas removed from the fire source. The techniques most commonly used to limit the degree of smoke spread, or to control its effects, are:

a) smoke containment using a system of physical barriers to inhibit the spread of smoky gases from the fire affected space to other parts of the building, e.g. walls and doors;

b) smoke clearance, using any method of assisting the fire service in removing smoky gases from a building when smoke is no longer being produced, i.e. post extinction;

c) smoke dilution, deliberately mixing the smoky gases with sufficient clean air to reduce the hazard potential;

d) smoke (and heat) exhaust ventilation, achieving a stable separation between the warm smoky gases forming a layer under the ceiling, and those lower parts of the same space requiring protection from the effects of smoke for evacuation of occupants and firefighting operations. This normally requires the continuous exhaust of smoke using either natural or powered ventilators, and the introduction of clean replacement air into the fire affected space beneath the smoke layer;

e) pressurization, see 3.1.27;

f) depressurization, see 3.1.10.

This document provides guidance and information on smoke control using ***pressure differentials****, i.e. only the techniques given in items e) and f).*

2.2.28 *Pressurisation* and *depressurisation* are defined as follows in BS EN 12101-6:2005:

3.1.10 depressurization

smoke control using pressure differentials where the air pressure in the fire zone or adjacent spaces is reduced below that in the protected space

3.1.27 pressurization

smoke control using pressure differentials, where the air pressure in the spaces being protected is raised above that in the fire zone

2.2.29 Note in this report I use the speeling pressurisation and depressurisation.

2.2.30 To summarise, *pressure differential systems* are one form of mechanical smoke control.

2.2.31 A pressure differential system can be a *depressurisation* system, which means the air pressure in the fire zone or adjacent spaces is reduced below that in the protected space and therefore limits the flow of smoke/hot gases from the fire zone into the protected space as it is a relatively higher-pressure zone.

2.2.32 Alternatively, a pressure differential system can be a *pressurisation* system which means the air pressure in the spaces being protected is raised above that in the fire zone and adjacent places, and therefore reduces the ability for hot gases from the relatively lower pressure fire zone to flow into the protected space.

2.2.33 I have provided a diagrammatic example of a pressurisation and a depressurisation system in Figure 2-1 and Figure 2-2 as described in BS EN 12101-6:2005.

2.2.34 In the diagrams, the protected zone is the protected stair and the lobby, as both are protected in the approach described in Clause 4 of BS EN 12101-6:2005 where the system is provided for means of escape and firefighting purposes.

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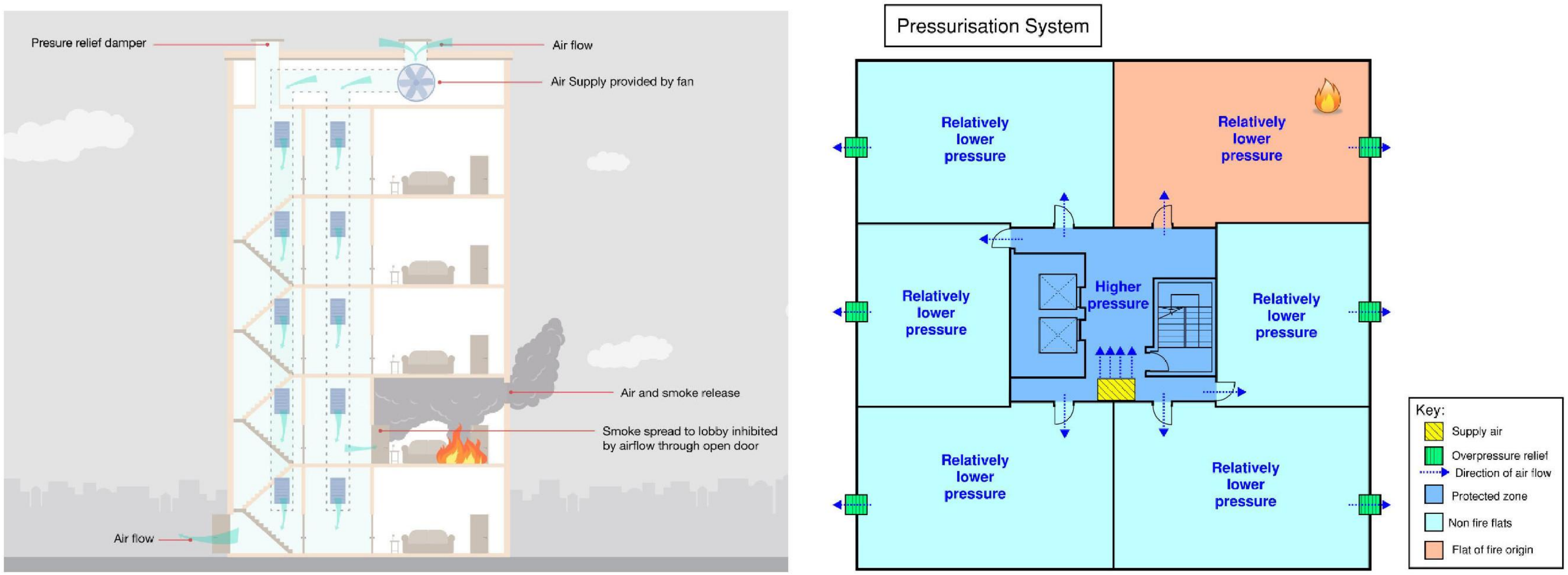


Figure 2-1: Diagrammatic example of a pressurisation system in accordance with BS EN 12101-6:2005

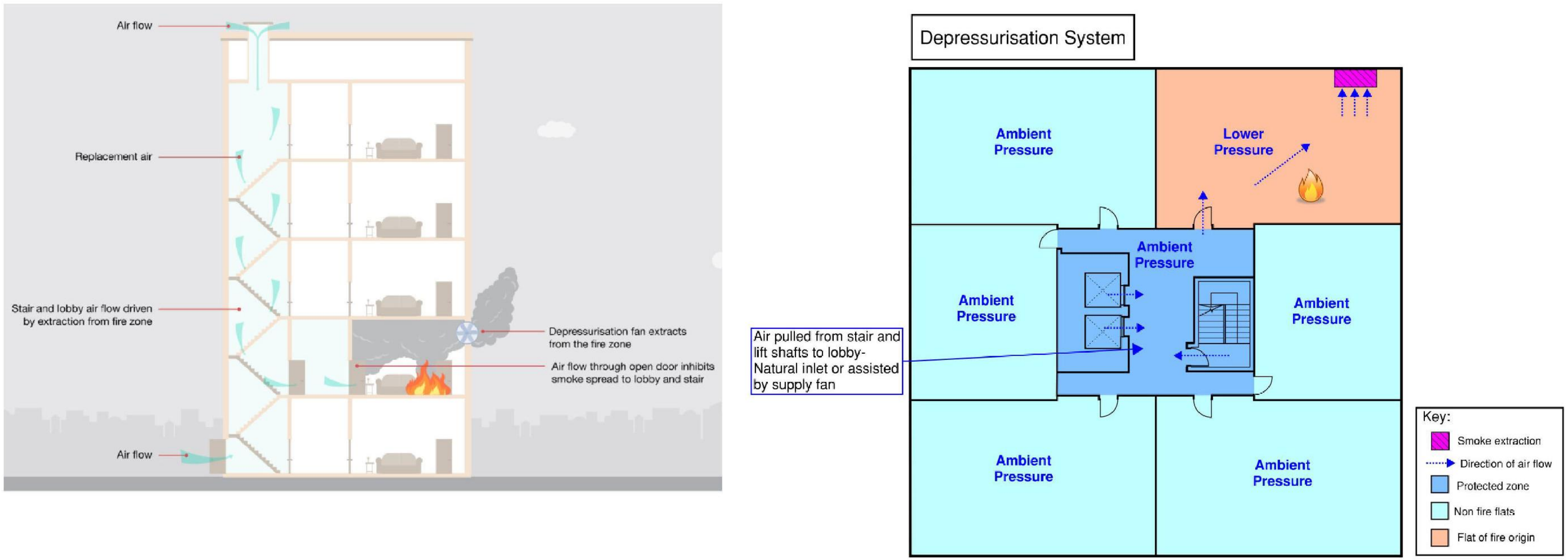


Figure 2-2: Diagrammatic example of a depressurisation system in accordance with BS EN 12101-6:2005:

2.2.35 I provide a summary explanation of the performance requirements for pressure differential systems, as described within BS EN 12101-6:2005, in Section 4.3 below.

2.2.36 Where the lobby is not considered as, nor required to be, a protected zone, this will need to be incorporated into the pressurisation or depressurisation performance requirements.

2.2.37 Travel distance to the protected stairway

2.2.38 B1.v *Criteria for means of escape* of ADB 2013 states (bold by me):

where direct escape to a place of safety is not possible, it should be possible to reach a place of relative safety, such as a protected stairway, which is on a route to an exit, ***within a reasonable travel distance****.*

2.2.39 Reasonable travel distance is therefore a performance requirement to comply with Regulation B1.

2.2.40 Paragraph 2.23 of ADB 2013 states:

Planning of common escape routes

2.23 Escape routes in the common areas should comply with the ***limitations on travel distance*** *in Table 1. However, there may be circumstances where some increase on these maximum figures will be reasonable.*

2.2.41 Table 1 of ADB 2013 is excerpted in Figure 2-3::

Table 1 Limitations on distance of travel in common areas of blocks of flats (see paragraph 2.23)

Maximum distance of travel (m) from flat entrance door to common stair, or to stair lobby [4]	
Escape in one direction only	Escape in more than one direction
7.5m [1][2]	30m [2][3]

Notes:

1 Reduced to 4.5m in the case shown in Diagram 9.

2 Where all flats on a storey have independent alternative means of escape, the maximum distance of travel does not apply. However, see paragraph 16.3 (B5) which specifies Fire and Rescue Service access requirements.

3 For sheltered housing, see paragraph 0.29.

4 Where travel distance is measured to a stair lobby, the lobby must not provide direct access to any storage room, flat or other space containing a potential fire hazard.

Figure 2-3: Table 1 from ADB 2013

2.2.42 It is therefore acknowledged in ADB 2013 that there are circumstances where an extended travel distance may be reasonable.

2.2.43 ADB 2013 provides no further guidance regarding the circumstances in which extended travel distances may be reasonable.

2.2.44 I have found guidance in BS 9991:2011 and in the *SCA Guide* (both 2012 and 2015 editions) regarding the functional objectives of a smoke control system where it is relied upon due to extended travel distances within a common corridor/lobby.

2.2.45 <u>BS 9991:2011 Fire Safety management in the design, management and use of residential buildings – code of practice</u>

2.2.46 This British Standard is a code of practice, which confirms on Page v "*It has been assumed in the preparation of this British Standard that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.*"

2.2.47 It is neither statutory guidance nor an approved code of practice (See Appendix D of my Phase 1 report {BLAS0000025}).

2.2.48 Clause 0.2.3 Smoke control in common parts of BS 9991:2011 states (bold by me):

Smoke can be controlled in the common areas through fitted ventilation systems which are either natural or mechanical. These ventilation systems have two main purposes: the first of which is to provide some protection to the stair core and the second of which is to aid fire-fighters when tackling a fire. ***Ventilation systems can also be used to compensate for extended travel distances within the common corridor leading to the stairs and thereby help occupants to escape safely. Where smoke control is used to provide compensation for extended travel distances, it is the responsibility of the designers to demonstrate that the ventilation system can provide tenable conditions (see Annex E) for the occupants using the route with extended travel distances***

2.2.49 Clause 4.2 Variation of recommendations of BS 9991:2011 states (bold be my):

The guidance on means of escape in Section 2 permits variations to be made to travel distances on the basis that the level of risk can be reduced by the provision of additional fire protection measures. Such measures include:

• *the provision of an active fire-fighting system (e.g. sprinklers);*

• *the provision of an* ***enhanced smoke management system;***

• *the provision of an additional level of automatic fire detection*

2.2.50 Clause 7.4 in relation to escape routes from flats and maisonettes with corridor or lobby approach states:

Where travel distances from the furthest dwelling entrance door to the means of escape staircase cannot be met then consideration may be given to the provision of a mechanical smoke ventilation system and the use of sprinkler systems, see 26.1.3 and Clause 23.

2.2.51 The travel distance for lobby access flats in buildings greater than 11m in height in height, from Figure 6 of BS 9991:2011 is **7.5m**.

2.2.52 Clause 26.1 *Smoke Control for means of escape* of BS 9991:2011 states (bold by me):

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

COMMENTARY ON 26.1.1 Whilst the primary aim of smoke control in residential buildings is to protect the staircase enclosure it can also provide some protection to the adjacent protected corridor or lobby.

In extended corridors, the primary objective of the smoke control system is to protect both the common corridor and the staircase enclosure for means of escape.

There are three main methods of smoke control; natural smoke ventilation, mechanical smoke ventilation and pressurization. Further information on these may be found in Annex E and in BS EN 12101-6.

2.2.53 Clause 26.1.3, *Buildings with a single stair above 11m in height*, of BS 9991:2011 states:

Where travel distances are in excess of those recommended in Figure 6, a mechanical smoke ventilation system may be considered (see E.5).

2.2.54 Annex E.1 General of BS 9991:2011 states:

The primary objective of smoke control in residential buildings is to protect the staircase enclosure; however, the adjacent protected corridor or lobby might also gain some protection.

For extended corridor scenarios, the primary objective of the smoke control system is to protect both the common corridor and the staircase enclosure ***for means of escape.***

2.2.55 BS 9991-2011 does not specifically refer to an objective to keep smoke from entering the stair during firefighting operations.

2.2.56 Annex E.5 *Extended corridors*, states (where MSVS is Mechanical Smoke Ventilation Systems):

Where the design of a block is such that travel distances exceed those shown in Figure 6 and Figure 7, a fire-engineered MSVS may be provided to compensate for the extended travel distance.

The primary objective for this type of system is to maintain tenable conditions within the extended corridor and the associated staircase enclosure for means of escape purposes*. Information regarding tenability criteria (such as temperature and visibility) for assessing the performance of the MSVS can be found in PD 7974-6.*

It is important to ensure that the location of the inlet air in relation to the point of extract does not create dead spots in the protected zone.

2.2.57 Further, in Annex E.6 *Considerations for the selection of an MSVS* of BS 9991:2011 states:

When the sole purpose of an MSVS is to protect the means of escape, it is important that the following aspects are taken into account with regard to their effect on the ability of the system to meet its performance criteria.

a) Different fire locations (both close to and far from the point of extract).

b) Pressure differences across a flat front door with a variety of extraction rates.

c) A negative wind coefficient at the stair head vent.

d) Fire pressure and increasing fire growth.

When the purpose of an MSVS is also to aid fire-fighting operations, it is important that the following aspects are taken into account with regard to their effect on the ability of the system to meet its performance criteria, in addition to those aspects given in a) to d).

1) A variety of door opening sizes for the stair or corridor door (when closed, partially open and fully open).

2) Increased ventilation to a fire due to a broken window.

3) Low-level ventilation to the stair.

2.2.58 Therefore, in circumstances where there is an extended travel distance from the flat entrance door to the protected stair, BS 9991:2011 recommends a higher performance requirement for the mechanical smoke ventilation system than protection of the stair only. This is to maintain tenable conditions within the lobby and stair for means of escape.

2.2.59 In this scenario the lobby is therefore part of the protected zone.

2.2.60 It raises the issue of the change in scenario caused by firefighting operations also.

2.2.61 In Section E.6, Considerations for selection of an MSVS [Mechanical Smoke Ventilation System], BS 9991:2011 it refers to guidance published by the Smoke Control Association:

NOTE There are numerous different types of fan assisted system including a mechanical extract /natural inlet and a mechanical extract/mechanical inlet system. Further information on these can be found in the Smoke Control Association publication, "Guidance on smoke control to common escape routes in apartment buildings (flats and maisonettes)" [32]. This document also includes information regarding system controls (control panels, indication/ status panels, manual control points, etc.), which can be important considerations when selecting an MSVS.

2.2.62 <u>Smoke Control Association Guides</u>

2.2.63 Four revisions of the Smoke Control Association's *Guidance on smoke control to common escape routes in apartment buildings (flats and maisonettes)* have been published in 2010, 2012, 2015 and 2020.

2.2.64 In this report I have referred to the guidance in the 2012 and 2015 publications which were current at the time of the 2012-2016 primary refurbishment (hereinafter the *SCA Guide 2012* and the *SCA Guide 2015* respectively).

2.2.65 The *SCA Guide* is an industry guidance document. It is not statutory guidance, nor an approved code of practice nor a British Standard.

2.2.66 As I have shown above it is referred to from Section E.6 of BS 9991:2011.

2.2.67 The *SCA Guide 2012* and *SCA Guide 2015* provide guidance on design objectives and performance criteria for lobby smoke control systems, the different types of system to consider, performance requirements for equipment forming the system, as well as information regarding commissioning and maintenance.

2.2.68 As stated in the introduction to Section 6.1 '*Commentary*' of the *SCA Guide 2012*:

Mechanical systems, as described in 6.4, may be designed to allow extended travel distances subject to agreement from the approving authorities.

2.2.69 And Section 6.1 '*Commentary*' of the *SCA Guide 2015*:

Mechanical systems may be designed to allow extended travel distances subject to agreement from the approving authorities.

2.2.70 Section 6.4 '*Mechanical (Powered) smoke ventilation* 6.4.1 *General principles*' of both the *SCA Guide 2012* and *SCA Guide 2015* states (bold by me):

*Basic mechanical systems are commonly provided simply as an equivalent to the natural ventilation systems described in Approved Document B It is possible to design systems providing a higher performance that may then be used to allow extended travel distances in corridors ...... **In this case the system objectives and performance should follow the guidance in section 5.***

2.2.71 Section 5 of the SCA Guide 2012 and 2015 then provide a methodology for a designer to demonstrate that their alternative solution meets the functional requirements of the Building Regulations.

2.2.72 I present my review of this methodology in full in Section 4.5 and Section 5.5.

2.3 Performance requirement B3 *Internal fire spread (structure)*

2.3.1 The functional requirement

2.3.2 Regulation B3(3) of the Building Regulations 2010 states:

(3) Where reasonably necessary to inhibit the spread of fire within the building, measures shall be taken, to an extent appropriate to the size and intended use of the building, comprising either or both of the following –

(a) sub-division of the building with fire-resisting construction;

2.3.3 Performance

2.3.4 ADB 2013 sets out the Secretary of State's view that the Requirement of B3 will be met in the following circumstances (bold by me):

a. if the loadbearing elements of structure of the building are capable of withstanding the effects of fire for an appropriate period without loss of stability;

b. if the building is sub-divided by elements of fire-resisting construction into compartments;

c. if 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); *and*

d. if 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.

2.3.5 In any type of natural or mechanical smoke control system, dampers on the fire floor are automatically opened and dampers on all other floors are automatically closed, in order to allow the full capacity of the smoke control system to be directed to a single fire floor only.

2.3.6 Smoke control systems rely on a smoke detection system to identify the correct fire floor and cause the control system to open the dampers on that floor and to ensure that the dampers on all other floors remain shut.

2.3.7 However, there are other performance requirements for these dampers.

2.3.8 They must be of a form which ensures compartmentation is maintained between the fire floor and all other floors.

2.3.9 A high degree of compartmentation is one of the fundamental assumptions forming the means of escape provisions for high rise residential building.

2.3.10 Paragraph 2.3 of ADB 2013 states (bold by me):

The provisions for means of escape for flats are based on the assumption that:

a. the fire is generally in a flat;

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

c. ***measures in Section 8 (B3) provide a high degree of compartmentation*** *and therefore a low probability of fire spread beyond the flat of origin, so that simultaneous evacuation of the building is unlikely to be necessary; and*

d. although fires may occur in the common parts of the building, the materials and construction used there should prevent the fabric from being involved beyond the immediate vicinity (although in some cases communal facilities exist which require additional measures to be taken).

2.3.11 ADB 2013 explains that fire resistance, in addition to being required to achieve compartmentation, can also be required to meet functional requirements other than B3:

Guidance elsewhere in the Approved Document concerning fire resistance

B3.iv There is guidance in Sections 2 to 5 concerning the use of fire-resisting construction to protect means of escape. ...

2.3.12 Therefore, both the provisions relevant to B1 and those relevant to B3 must be read to determine the complete provisions relevant to the protection of ventilation shafts for compartmentation and means of escape.

2.3.13 **Provisions made in ADB 2013**

2.3.14 Section 8 *Compartmentation* of ADB 2013 is *"is concerned with the sub-division of a building into compartments"*. It provides specific guidance on the provisions for protected shafts. Paragraph 8.7 of ADB 2013 states (Bold by me):

Protected shafts

8.7 Spaces that connect compartments, such as stairways and service shafts, ***need to be protected to restrict fire spread between the compartments and they are termed protected shafts****. Any walls or floors bounding a protected shaft* ***are considered to be compartment walls or floors*** *for the purpose of this Approved Document*

2.3.15 *Protected shaft* is defined in Appendix E of ADB 2013 as:

A shaft which enables persons, air or objects to pass from one compartment to another and which is enclosed with fire-resisting construction.

2.3.16 Paragraph 8.20 of ADB 2013 states (bold by me):

8.20 ***Every compartment wall and compartment floor*** *should:*

a. form a complete barrier to fire between the compartments they separate;

2.3.17 Section 5 *General provisions* of ADB 2013 includes *"guidance on matters common to all parts of the means of escape"*. It provides specific guidance regarding the protection of escape routes from the spread of fire and smoke from mechanical ventilation systems.

2.3.18 At paragraph 5.46 it states (bold by me) [note I explain the meaning of ES classified dampers in Section 2.3.24 - 2.3.27 below]:

5.46 Any system of mechanical ventilation should be designed to ensure that, ***in a fire, the ductwork does not assist in transferring fire and smoke through the building and put at risk the protected means of escape from the accommodation areas.***

Any exhaust points should be sited so as not to further jeopardize the building, i.e. away from final exits, combustible building cladding or roofing materials and openings into the building.

5.47 Ventilation ducts supplying or extracting air directly to or from a protected escape route, should not also serve other areas. A separate ventilation system should be provided for each protected stairway. Guidance on ventilation systems that circulate air only within an individual flat is given in paragraph 2.18.

Where the ductwork system serves more than one part of a sub-divided (see paragraph 3.26) escape route, ***a fire damper should be provided where ductwork enters each section of the escape route*** *operated by a smoke detector or suitable*

fire detection system (see also Section 10). The ***fire dampers should close when smoke is detected.***

5.48 Ducts passing through the enclosure of a protected escape route should be fire-resisting, i.e. the ductwork should be constructed in accordance with Method 2 or Method 3, (see paragraph 10.9).

Note: ***Fire dampers activated only by fusible links are not suitable for protecting escape routes. However, an ES classified fire and smoke damper which is activated by a suitable fire detection system may be used.*** *See paragraph 10.15.*

2.3.19 Therefore, the smoke ventilation shafts and ventilation openings provided in the common lobby as part of a smoke control system, must be capable of forming a complete barrier to fire between the compartments they separate.

2.3.20 Furthermore, they must not assist in transferring fire and smoke from the accommodation to the protected means of escape.

2.3.21 In addition to setting out the required fire resistance of the shafts, paragraph 10.9 of ADB 2013 states:

Where air handling ducts pass through fire separating elements the integrity of those elements should be maintained.

2.3.22 Paragraph 10.9 of ADB 2013 sets out three methods of doing this:

There are three basic methods and these are:

Method 1 Protection using fire dampers;

Method 2 Protection using fire-resisting enclosures;

Method 3 Protection using fire-resisting ductwork.

2.3.23 Because the damper must be able to both automatically open and close, in the event of a fire, Methods 2 and 3 are not appropriate so *"Method 1 protection using fire dampers"* applies.

2.3.24 ADB 2013 provides definitions for two types of damper in Appendix E:

Fire damper *Mechanical or intumescent device within a duct or ventilation opening which is operated automatically and is designed to prevent the passage of fire and which is capable of achieving an integrity E classification and/or an ES classification to BS EN13501-3:2005 when tested to BS EN1366-2:1999. Intumescent fire dampers may be tested to ISO 10294-5.*

Fire and smoke damper *Fire damper which when tested in accordance with BS EN 1366-2:1999 meets the ES classification requirements defined in EN 13501-3:2005 and achieves the same fire resistance in relation to integrity, as the element of the building construction through which the duct passes. Intumescent fire dampers may be tested to ISO 10294-2.*

2.3.25 Therefore, a fire damper may achieve an 'E'-integrity-only classification, or an 'ES' integrity and smoke leakage classification.

2.3.26 A fire and smoke damper is required to achieve an 'ES' i.e. integrity and smoke leakage classification.

2.3.27 Section 5 *General provisions* paragraph 5.48 of ADB 2013, states that an ES-classified fire and smoke damper may be used for protecting escape routes.

2.3.28 This is re-iterated in paragraph 10.13:

10.13 Where the use of the building involves a sleeping risk, such as an hotel or residential care home, fire dampers should be actuated by smoke detector-controlled automatic release mechanisms, in addition to being actuated by thermally actuated devices....

Note: Fire dampers actuated only by fusible links are not suitable for protecting escape routes. However an ES classified fire and smoke damper which is activated by a suitable fire detection system may be used. See paragraph 10.15.

2.3.29 Less smoke is allowed to leak through a fire and smoke damper in the relevant classification standard BS EN 13501-4; which is why they are specifically described for use when protecting means of escape.

2.3.30 Therefore, to maintain the integrity of the fire resisting enclosure of the lobby:

a) ES-classified fire and smoke dampers are required to protect means of escape,
b) Actuation is required by smoke detectors.

2.3.31 Dampers can automatically open, by means of a control system linked to a smoke detection system, and so allow smoke to vent from the fire floor; but dampers must also remain automatically shut on any other floor.

2.3.32 Therefore, the damper type and the overall sequence of operation of all the dampers, must in the event of a fire fulfil both the means of escape and compartmentation performance requirements.

2.4 Regulation B5 Access and facilities for the fire service

2.4.1 The functional requirement

2.4.2 Regulation B5(1) of the *Building Regulations 2010* states:

The building shall be designed and constructed so as to provide reasonable facilities to assist firefighters in the protection of life

2.4.3 Performance

2.4.4 ADB 2013 explains that it is the Secretary of State's view that the Requirements of B5 will be met:

a. if there is sufficient means of external access to enable fire appliances to be brought near to the building for effective use;

b. if there is sufficient means of access into and within, the building for firefighting personnel to effect search and rescue and fight fire;

c. if the building is provided with sufficient internal fire mains and other facilities to assist firefighters in their tasks; and

d. if the building is provided with adequate means for venting heat and smoke from a fire in a basement.

2.4.5 **Provisions made in ADB 2013**

2.4.6 Components of the resulting firefighting shaft for high rise buildings are described in Diagram 52 shown in Figure 2-4:.

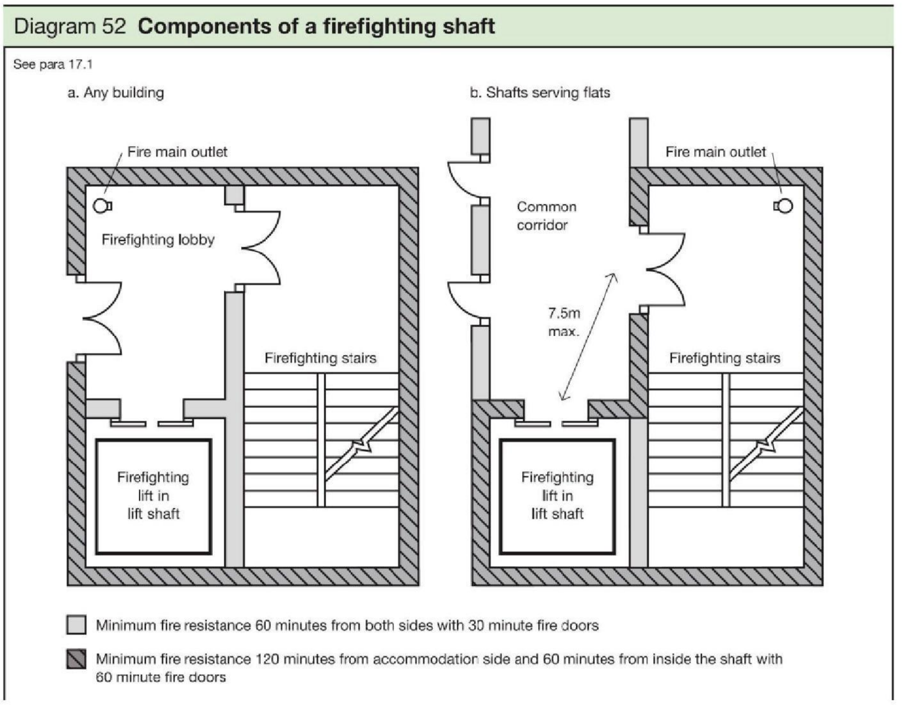


Figure 2-4: Excerpt of Diagram 52 form ADB 2013

2.4.7 However, Approved Document B clarifies at paragraph 17.14 that there are "Variations for block of flats":

Where the design of means of escape in case of fire and compartmentation in blocks of flats has followed the guidance in Sections 3 and 9, the addition of a firefighting lobby between the firefighting stair(s) and the protected corridor or lobby provided for means of escape purposes is not necessary. Similarly, the firefighting lift can open directly into such protected corridor or lobby, but the firefighting lift landing doors should not be more than 7.5m from the door to the firefighting stair.

2.4.8 The relevant smoke control provisions, as described in Diagram 52, are therefore as follows:

2. Smoke control should be provided in accordance with BS 5588-5:2004 or, where the shaft only serves flats, the provisions for smoke control given in paragraph 2.25 may be followed instead.

2.4.9 In terms of the performance of smoke ventilation for firefighting purposes, Section 13.1 of BS 5588-5:2004 states:

The build-up of smoke and heat as a result of a fire can seriously inhibit the ability of the fire service to carry out rescue and fire-fighting operations within a building.

Effective means should be provided to ventilate the fire-fighting shaft of smoke in such a way as to minimize the possibility of serious contamination of the fire-fighting stairwell

2.4.10 ADB 2013 does not address directly the reasonably foreseeable scenario that both the stair and accommodation doors to the protected lobby will be open as part of typical firefighting operations.

2.4.11 However, Paragraph 17.10 goes on to set out provisions for limiting the distance between a fire main outlet located with the protected stair and every part of the storey for laying a hose:

17.10 If the building is not fitted with sprinklers then every part of every storey that is more than 18m above fire and rescue service vehicle access level (or above 7.5m where covered by paragraph 17.3), should be no more than 45m from a fire main outlet ***contained in a protected stairway*** *and 60m from a fire main* ***in a firefighting shaft****, measured on a route suitable for laying hose.*

2.4.12 In Section 3 of my Phase 1 report {BLAS0000003} I set out the operational procedures for firefighting in residential buildings with a stay-put evacuation strategy.

2.4.13 Once a water supply is secured from an external hydrant to the building dry fire main and a bridgehead is established two floors below the fire floor with two firefighting crews in breathing apparatus:

a) The first of the two crews connect a hose to the fire main outlet within the protected stair one level below the fire floor.

b) The first crew advance to the fire floor, carrying the charged hose and is tasked with fighting the fire in the dwelling.

c) The second crew advance to the fire floor, connect and charge a hose within the protected stair at that level. The second crew is tasked with protecting the first crew.

2.4.14 I have illustrated this using Diagram 52 from ADB 2013 in Figure 2-5: whereby the fire and rescue service connect their hose to the fire main outlet in the stair on the floor below the fire floor.

2.4.15 The hose is then run through the open door to the protected stair on the fire floor.

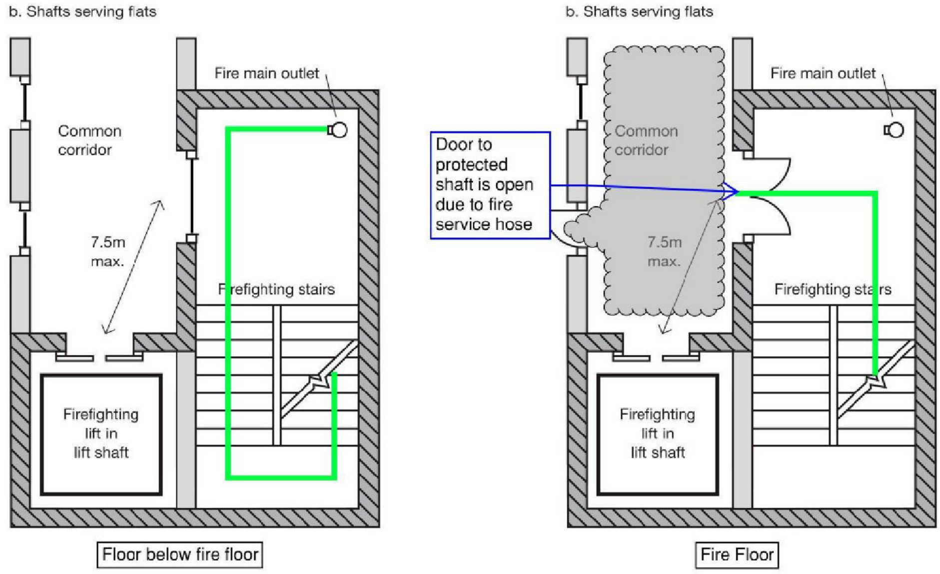


Figure 2-5: Firefighting stair enclosure as depicted in Diagram 52 of ADB 2013and overmarked by me (fire and rescue service hose indicated with green line)

2.4.16 It is also important to note the underlying assumption in Diagram 52 of ADB 2013 that facilities for firefighting are located inside the protected stair. This enables the firefighter to work in a safe air environment below the fire sector.

2.4.17 The provisions made in ADB 2013 therefore assume that a stair door to the lobby of the fire floor will open in a fire as firefighters advance within the protected stairway from the riser on the level below.

2.4.18 Therefore, the lobby smoke control system, as well as being designed to allow for the flat door opening during escape, and the stair door opening during means of escape, must then also allow for the stair door to open during firefighting in the flat also.

2.4.19 However, by definition this means the flat door is open during firefighting also.

2.4.20 This is aligned too with the guidance provided in Section 5 of the SCA Guide as set out in Section 4.5 of this report; and BS 9991:2011.

2.4.21 **Summary of performance and provisions**

2.4.22 In Figure 2-6 I have illustrated the provisions recommended within ADB 2013 to meet the performance described by the Secretary of State and therefore satisfy the functional requirements of the Building Regulations.

2.4.23 In the following section (i.e. Section 2.5) I go on to explain the minimum provisions which any an alternative approach to the provisions set out in ADB 2013 needs to address.

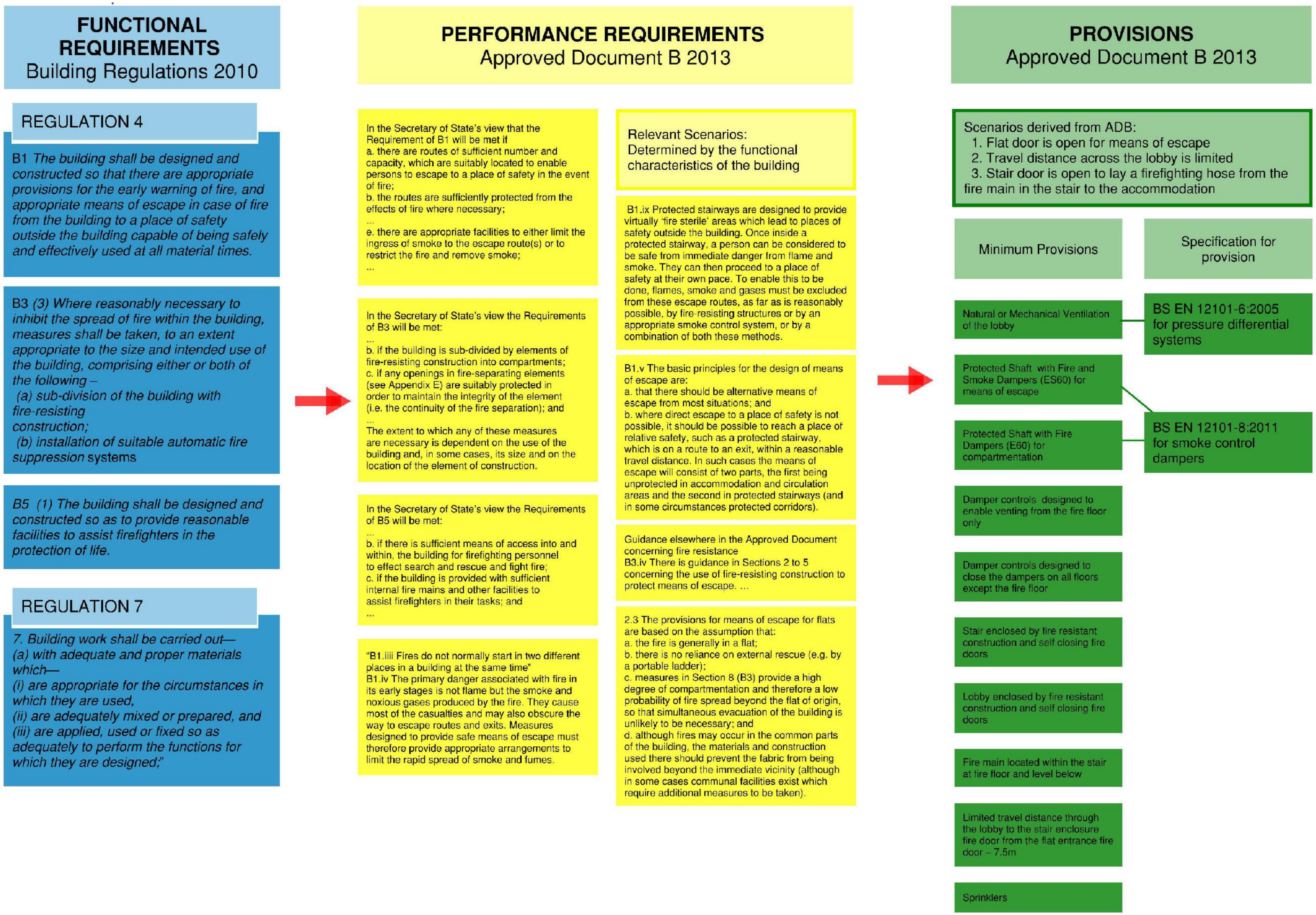


Figure 2-6: ADB 2013 provisions meeting the functional requirements for protected stair with lobby

2.5 Designing an alternative solution based on a mechanical lobby smoke control system

2.5.1 Proposing an alternative solution to the provisions made in ADB 2013, such that it meets the functional requirements, is termed 'an alternative approach'.

2.5.2 As I have stated above, the final alternative solution, and the final performance standard as derived, should then be set out for review and consideration by the approving authority, with an explanation as to how it meets the relevant functional requirements.

2.5.3 The relevant design basis must be derived from building-specific characteristics. This principle applied to Grenfell Tower as much as to any other building.

2.5.4 Certain relevant characteristics of Grenfell Tower were pre-existing and did not follow the guidance within ADB 2013. In particular:

a) the position of the dry fire main, which was in the lobby and not in the stair,

b) the travel distance in the lobby was 10.5m and therefore extended beyond the limit in ADB 2013 of 7.5m .

2.5.5 These two key characteristics are of central importance when choosing the form of lobby smoke control.

2.5.6 The relevant scenarios for means of escape, and for firefighting, as applicable to Grenfell Tower, then need to be considered and incorporated within any alternative approach.

2.5.7 The primary design considerations emanating from the physical characteristics of Grenfell Tower and its existing safety measures were:

a) The flat entrance door open for escape allowing smoke to enter the existing lobby;

a) The lobby door to the stair, on the fire floor, assumed open as occupants enter the protected stair, and proceed to a place of safety at their own pace;

b) The lobby door to the stair open for firefighting;

c) The stair door to the lobby below the fire zone also open, as the dry riser in Grenfell Tower was to be retained in its existing position in the lobby;

d) The door open to the fire flat, for the purposes of firefighting;

e) The proposed system should protect the staircase enclosure, for the means of escape scenario and fire-fighting scenario;

f) The travel distance in the lobby in Grenfell Tower was extended – the proposed system should therefore protect the lobby, as a minimum, for means of escape.

2.5.8 The fundamental purpose of the design of any mechanical smoke ventilation system for Grenfell Tower was therefore to maintain tenable conditions for means

of escape in the extended travel lobby and tenable conditions for means of escape and firefighting in the stair.

2.5.9 Both these protective purposes must be regarded as '*primary objectives*' of the smoke control system as described in BS 9991:2011 (refer to 2.2.52) and as *"Objectives"* described in the SCA Guide 2012 and 2015 (refer to Section 4.5).

2.5.10 In Figure 2-7, I have illustrated the *door open* conditions for means of escape and firefighting.

2.5.11 As shown in the figure on the left, during means of escape the flat entrance door, where the fire has occurred, is assumed open when occupants escape. This will then shut behind them due to the self closer attached to the door. The lobby door to the stair, on the fire floor, is assumed open as occupants enter the protected stairway, the door then shuts behind them due to the self closer attached to the door. The occupants proceed to a place of safety at their own pace.

2.5.12 During firefighting, as shown in the figure on the right, the flat entrance door and the door from the stair into the lobby on the floor of fire origin will be open as well as the door to the stair on the floor below, to allow the passage of a firefighting hose attached to the dry riser.

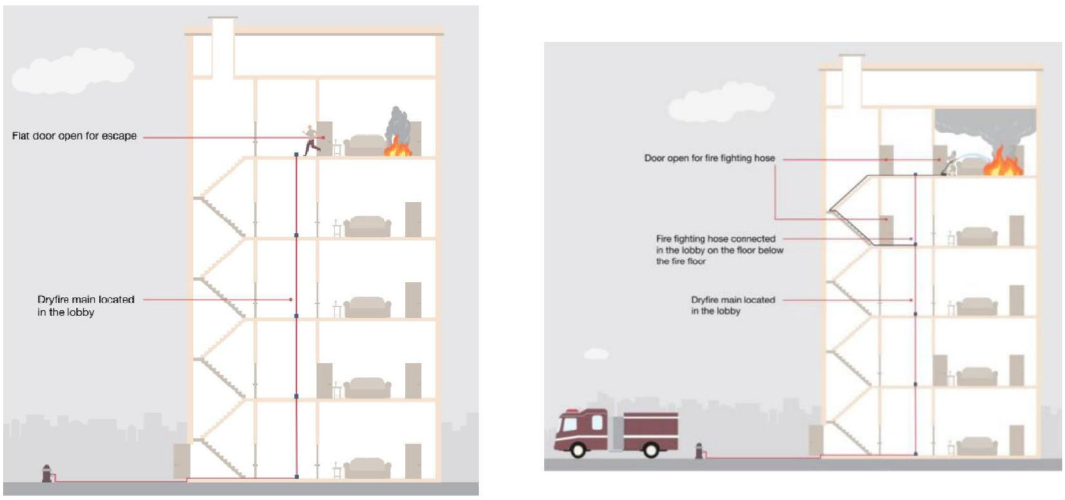


Figure 2-7 Door open conditions for means of escape (left) and firefighting (right)

2.5.13 BS 9991:2011 and the *SCA Guide 2012* and the *SCA guide 2015* all provide recommendations regarding the need to consider open doors when designing a mechanical smoke ventilation system.

2.5.14 This is because any such system needs to address the foreseeable scenarios which will occur when the system is operating.

2.5.15 BS 9991:2011 requires – *"A variety of door opening sizes for the stair or corridor door (when closed, partially open and fully open)"* where a mechanical smoke ventilation system is required to aid fire-fighting operations.

2.5.16 The *SCA Guide 2012* and *SCA Guide 2015* requires the designer to define their 'design conditions'. The indicative examples of 'design conditions' provided include consideration of the stair and flat entrance doors opening at different

times and duration, during escape and firefighting, respectively. I have set out the detailed recommendations for each design condition in Section 1 of this report.

2.5.17 It is useful to note from SCA Guide 2015 at 5.2.1:

Any system should, however, be designed to promote tenable conditions for travel through the ventilated corridors/lobbies during the escape period. It should be noted that this may only be possible during periods when the apartment door is closed and the flow of smoke from the apartment into the corridor is substantially reduced by the passive fire protection provided by the door.

2.5.18 In Figure 2-8, I have illustrated the minimum provisions, as I have derived them, required by any alternative approach to meet the functional requirements of the Building Regulations.

2.5.19 This will form the basis of my assessment of the design of the Grenfell Tower smoke control system, which was such an alternative approach.

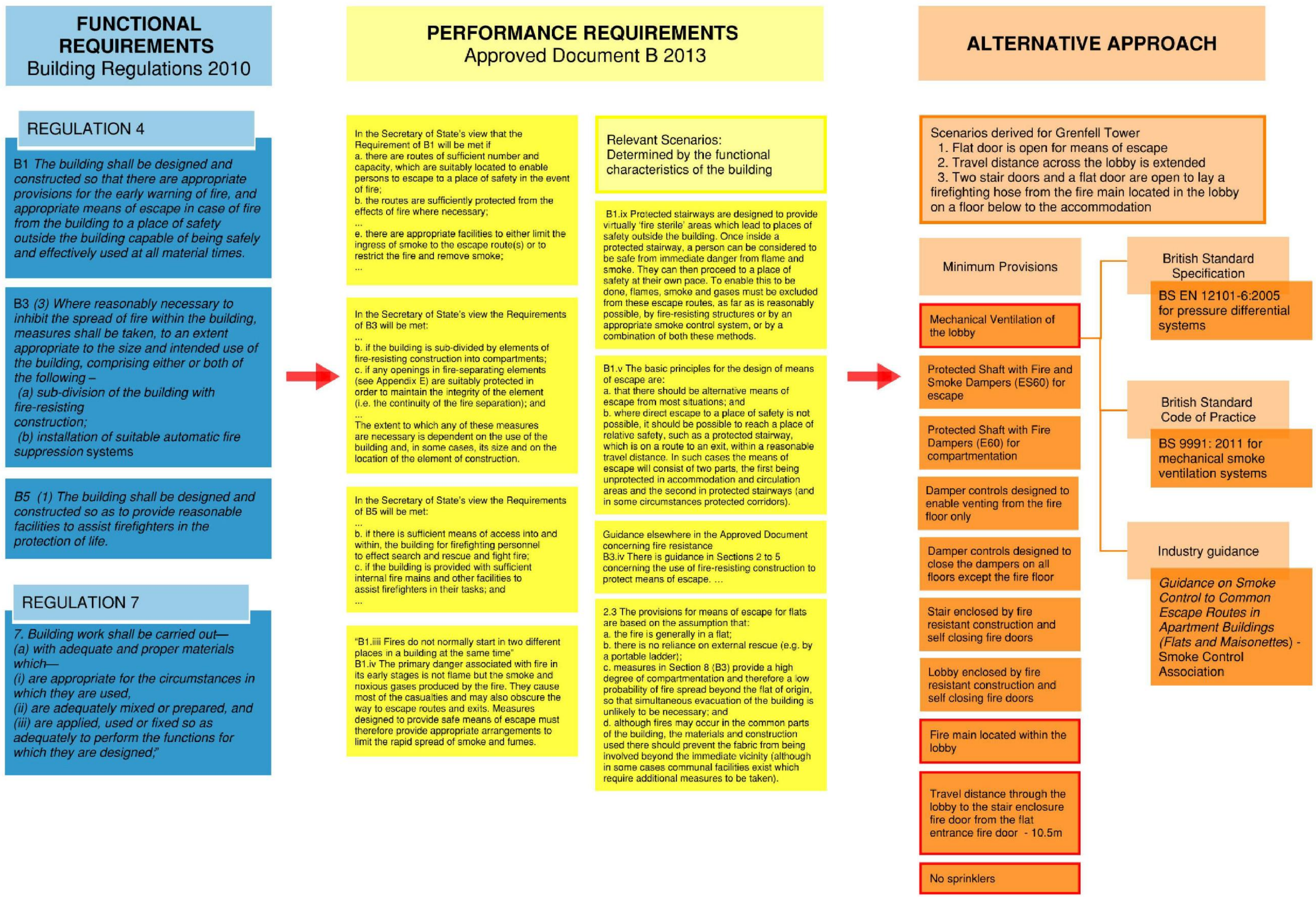


Figure 2-8: Derivation of an alternative approach to comply with the functional requirements

3 Recommended provisions for the smoke control system at Grenfell Tower at the time of original construction

3.1 Changes to this section

3.1.1 In Section J4.1.5 of my Phase 1 report {BLAS0000031}, I presented the ventilation requirements required for lobbies and stairs to comply with the GLC Section 20 Code of Practice 1970.

3.1.2 This description is now provided at paragraph 3.2.5 (b) below where it has been amended to describe the opening to the base of the original stair in Grenfell Tower.

3.1.3 In Section 3.3 below, corrections from my Phase 1 report *Corrections and Addenda* {BLAS0000037} have been incorporated, which expanded my technical explanation of the requirements of CP3 1971.

3.1.4 No other substantial technical assumptions have been amended but I have made minor edits to improve descriptions in a small number of instances.

3.2 GLC Section 20 Code of Practice 1970

3.2.1 The Greater London Council (GLC) Section 20 Code of practice 1970 required buildings with a storey height of 24.384m or more to be provided with what is termed a *fire-fighting lobby approach staircase*.

3.2.2 For a fire-fighting lobby approach staircase not located beside an external wall, which is the case for Grenfell Tower, there were two options for ventilation of the stairs and lobbies:

a) A2.02(1) where the staircase and its lobbies ventilate into a common open well (i.e. an enclosed space open only to the sky); or

b) A2.02(2) where the staircase and lobbies ventilate into independent vertical shafts.

3.2.3 The lobbies and staircase in Grenfell Tower were not ventilated using either of these methods. There is no common well open to the sky, as required for A2.02(1) into which the both the lobbies and staircase are ventilated. There are not two separate shafts provided either, as required in A2.02(2) to ventilate each of the lobby and stair.

3.2.4 A third option was available for a single staircase block of flats and this is described in Part A2.03 in the GLC Section 20 Code of Practice 1970. This permitted either a single or double lobby between the flats and the staircase. Grenfell Tower contained a single lobby between the flats and the staircase.

3.2.5 In Figure 3-1 I have set out the requirements of part A2.03 for the single lobby option, and compared those with the provisions at Grenfell Tower:

a) For the lobbies, cross ventilation by permanent vents to outside totalling in net area 25% of the vertical cross section of the lobby was required. In

Grenfell Tower the required permanent opening was therefore 4.94m^2 [25% of the North-South vertical cross section in the centre of the lobby]. No permanent vents from the lobby to outside were provided at Grenfell Tower, where the lobby is located internally.

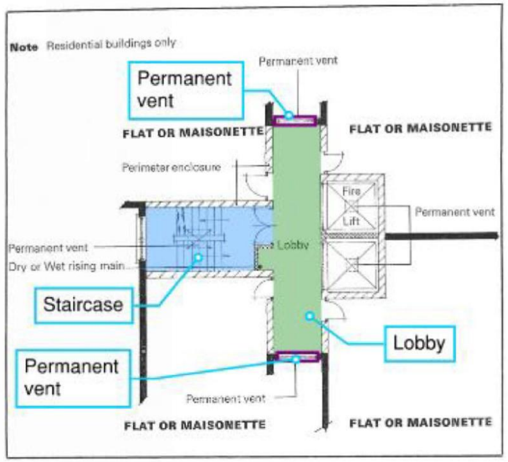
b) Separately, for the staircase, either ventilation by a shaft or by permanent openings to the open air at the top and the bottom of not less than 0.9m^2 was required. As I have explained above, no shaft was provided to ventilate the staircase of Grenfell Tower. A permanent opening of 1m^2 was provided at the head of the staircase, while the base of the stair opened directly to outside at Level 2 walkway {RBK00018833}.

3.2.6 Therefore, the ventilation provision made in the staircase and lobby in Grenfell Tower was not in accordance with any part of the GLC Section 20 Code of practice 1970 (and noting that the 1970 guidance for Section 20 does not include any options for mechanical ventilation to fire-fighting shafts).

Typical cross-ventilated fire-fighting lobby approach staircase - A2.03(1)

Section 20 Requirements

4 **Typical cross-ventilated fire-fighting lobby approach staircase**



A2.03 Fire-fighting lobby-approach staircase in a single staircase block of flats and/or maisonettes

Where in a block of flats and/or maisonettes a single staircase is permitted the requirements contained in the Council's Code of Practice for Means of Escape in Case of Fire relating to the ventilation of the staircase and lobby or lobbies would normally be acceptable to the Council for the purpose of this Code which are as follows:

1 Single lobby schemes

a the lobby of the staircase should be cross ventilated by means of permanent openings totalling in net area not less than 25 per cent. of the vertical cross section of the lobby or 30 square feet (2·8 m²) whichever is the greater, or

b the total amount of possible ventilation should be not less than 30 square feet (2·8 m²) divided into at least two areas so located as to provide good cross ventilation. One-third of this amount should be in the form of permanent vents but the remainder may be in the form of windows. The permanent vents should extend horizontally across not less than one-half of the effective width of the lobby and downwards to about 6 feet (1·800 m) from the level of the floor but not lower, and the top of each permanent vent should be at or near to the ceiling of the lobby.

The permanent vents should be in the form of widely spaced louvres and, where protected from the weather, the louvres should slope upwards from the lobby to the outer air.

The windows should be capable of being opened without the aid of a key but in special circumstances consideration will be given to such windows being fitted with budget locks as described in A Part I – item **A1.07** of this Appendix. (See Diagram **4**.)

3 Ventilation of internal staircase

Where access to the staircase is through a single or double lobby as described in (**1**) and (**2**) above, the staircase may be internal provided it is ventilated:

a into a vertical shaft as described in item **A2.02 2** of this Appendix. A casement window, opening outwards into the shaft and capable of being opened without the aid of a key (see also A Part I – item **A1.07** of this Appendix) should be provided at each floor or landing level having an openable area equal to 15 per cent. of the internal area of the staircase enclosure or 15 square feet (1·4 m²) whichever be the greater. In addition a permanent vent should be provided at the top of the staircase equal in area to 5 per cent. of the internal area of the staircase; or

b by a permanent opening to the open air at the bottom and top each opening having an unobstructed area of not less than 10 square feet (0·9 m²).

Note
The enclosures of a shaft provided to comply with the foregoing should have a standard of fire-resistance at least equal to that required under Part XI of the London Building (Constructional) Amending By-laws (No. 1) 1964 for the separations between tenancies in the building.

1. Minimum required permanent opening cross-ventilation area for lobby

Grenfell Tower lobby vertical cross-section area = 2.6m x 7.6m = 19.76m²

Therefore, required required permanent opening = 0.25 x 19.76m² = 4.94m²;

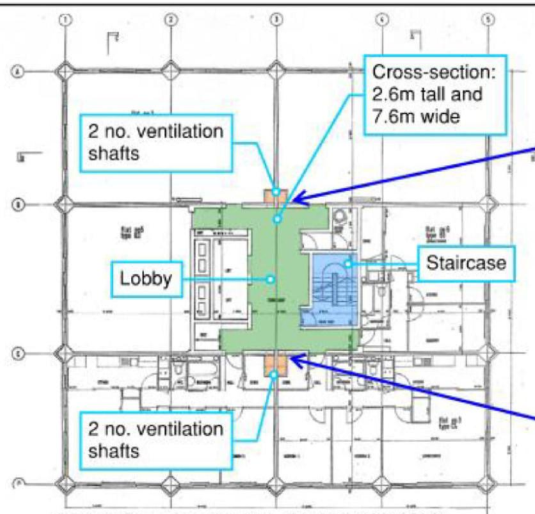
or

Per A2.03(1b) adjacent - 2.8m² divided into at least two areas on opposing elevations to outside, so as to provide good cross-ventilation.

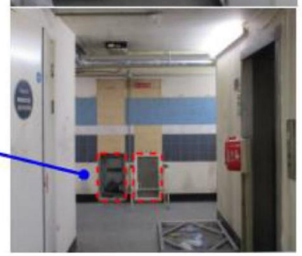
2. Required ventilation of internal staircase

The stair at Grenfell Tower was internal, therefore, the requirements for a stair ventilation shaft as outlined in A2.02(2) would be required, **or** 0.9m² permanent opening at the bottom and top of the stair provided.

Grenfell Tower Provisions



Original floor plan - levels 4 - 23 (RBK00018836)



Lobby openings containing damper

High level

Two 0.14m² (0.22 x 0.65m) openings were provided at high level, each into a separate ventilation shaft of 0.24m².

The ventilation shafts were not open to atmosphere at roof level.

A damper was located in each opening.

Low level

Two 0.14m² (0.26 x 0.55m) openings were provided at low level, each into a separate ventilation shaft of 0.24m².

The ventilation shafts were not open to atmosphere at roof level.

A damper was located in each opening.

1. Provided permanent opening cross-ventilation area for lobby - No

The lobby is landlocked and does not have any external elevations. Therefore, permanent openings to outside could not be provided.

2. Provided ventilation to internal staircase - No

The internal staircase was not provided with a ventilation shaft or openable windows to said shaft.

A 1m² permanent opening was provided at the head of the stair. A permanent opening was not provided at the bottom of the stair. Therefore, neither of staircase ventilation options outlined in Section 20 were satisfied.

The ventilation provisions did not satisfy the requirements of Section 20.

Figure 3-1: Assessment of the requirements of A2.03(1) GLC Section 20 Code of Practice 1970 for staircase and lobby ventilation against the provisions in Grenfell Tower

3.3 British Standard Code of Practice CP3 1971

3.3.1 As I have explained in Appendix D {BLAS0000025}, and in Section 4 {BLAS0000004} of my Phase 1 report, I have concluded that CP3 1971 was used as the basis of the design for the smoke control to the lobbies, in order to protect the single staircase in Grenfell Tower.

3.3.2 Figure 16b of CP3 1971 "*Corridor access Flats; single staircase tower block*" was applicable, as referenced in clause 3.3.4.3.3 "Stage II common access corridors serving dwellings should be cross ventilated."

3.3.3 Figure 16b is reproduced below in Figure 3-3.

3.3.4 CP3 1971 stipulated the following provisions for smoke ventilation for Stage II escape routes from flats to main stairways:

a) Clause 3.3.4.3.1 provides when only one direction of travel is available to a main stairway, "*the* [flat entrance] *door should not be more than 15m from a door in the enclosing wall of a main stairway*".

b) Clause 3.4.6 provides for a main stairway enclosure not situated against an external wall nor with opening windows, that it should have a permanent vent at the top of 1.0m^2.

c) Clause 3.4.3.1 (4) provides for single stairway conditions - requiring cross ventilation in the common access corridor by means of an opening of free area not less 1.5m^2, which may open automatically provided there is an overriding manual control (Clause 3.3.4.3.3).

d) An alternative approach is also provided for in Clause 3.3.4.3.3 by means of 1m^2 openable by hand and 0.5m^2 permanently open or automatically openable.

e) In all cases where dwellings are approached through a corridor and are not provided with an independent alternative escape route to a main stairway, dwelling entrance doors and stair entrance doors should contain no glazing (Clause 3.3.4.4).

3.3.5 For Stage III protection to a single means of escape stair (Figure 16b), cross ventilation is also referred to but with manual controls to be provided for the fire brigade, such that they can operate the system on a floor, to protect the stair.

3.3.6 A mechanical performance is not set out in Figure 16b.

3.3.7 However, Clause 2.3.4.1(3) of CP3 1971 highlights the potential for providing smoke control to dwellings with a corridor approach, by the use of "*A new method of smoke control by which smoke is repelled by mechanical ventilation from pressurised area.*"

3.3.8 Furthermore, Clause 2.5.1 (2) of CP3 1971 states *"Full development of this method, however, lies in the future."* Therefore, while mechanical ventilation was referred to as a potential method of smoke control in CP3, no guidance was provided as to how it should be achieved.

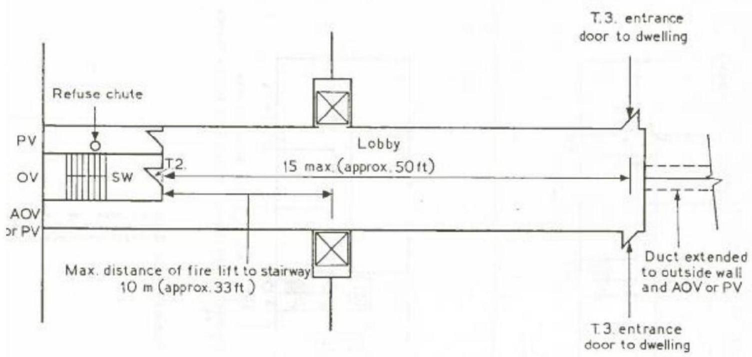
3.3.9 It is also to be noted that Clause 2.5.3 of CP3 made clear that ventilation could be provided by alternative means to either permanent or automatically opening systems, but would then be *"for the use of the fire service and is not directly related to safety during early escape"*:

2.5.3 The provision of means of ventilation, as distinct from permanent or automatically controlled ventilation, may contribute to personal safety in a more general way. It will assist the fire service and will thereby reduce the risk that smoke will spread within the building. This Code therefore contains recommendations for a measure of ventilation to corridors but, as this provision is for the use of the fire service and is not directly related to safety during early escape, it is not necessarily provided in the form of permanent openings. Windows or doors that can be opened when desired will suffice (see Fig. 24*a*). The permanent openings to lobbies serve a different purpose since their function is to be effective at the time of escape. These openings, together with the doors that separate the lobbies from the corridor, may be used for venting the latter (see Figs. 15*a*, 18*a* and 23).

Figure 3-2: Clause 2.5.3 of CP3 1971

3.3.10 The cross-ventilation arrangement recommended by Figure 16b in CP3 1971 is reproduced in Figure 3-3 below. In particular, the requirement for two remotely sited Automatically Opening Vents [AOVs] providing fresh air ventilation to the lobby is shown. The use of duct extended to the outside wall to achieve this is also set out in Figure 16b.

3.3.11 The system also required doors of a particular fire resistance: Type 3 for dwellings and Type 2 to the staircase.



b. Smoke dispersal

Related clauses: 2.3.4, 2.3.6, 2.3.7, 2.4.2, 2.4.3, 2.5, 3.3.4, 3.4, 3.4.3, 7.1.4, 7.3.1, 7.6.3, 7.6.4

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

Figure 3-3: Excerpt from CP3 1971 showing the recommended provisions for escape and smoke control in a single stair tower block.

3.3.12 The system that existed in Grenfell Tower before the refurbishment works is described in the Max Fordham 'Employer's Requirements for MEP Services' dated 28 November 2013 {MAX00006475}, excerpted below:

The system comprises a fresh air shaft and a smoke extract shaft serving all of the lift lobbies on the residential levels of the building. The system is designed to work as a natural ventilation system, but supply and extract fans are also installed to enable the Fire Brigade to provide additional mechanical ventilation if they consider that to be advantageous in dispersing smoke.

Each lift lobby has a fresh air inlet at low level on one side of the lobby and a smoke exhaust vent on the opposite wall of the lobby at high level. The vents connect directly into the fresh air shaft and the smoke extract shaft respectively.

Each vent has a motorised damper which is normally closed.

There is a smoke detector in each lobby. In the event of a fire in any of the lobbies, the smoke vent dampers and the fresh air dampers serving that particular lobby open. The dampers on all other levels remain closed.

A fireman's switch at ground level gives the Fire Brigade the choice of using mechanical ventilation.

3.3.13 Max Fordham further described the original system in {MAX00002335}, excerpted in Figure 3-4:

2 Existing System

The existing smoke extract system in Grenfell Tower consists of the following elements:

- 2x natural ventilation supply shafts of 0.24 m^2 area each, with 2x low level smoke dampers of 0.18 m2 area each. These serve floors 1-20 (residential floors only). Inlet at Walkway +1 level.
- 2x natural ventilation extract shafts of 0.24 m^2 area each, with 2x high level smoke dampers of 0.18 m2 area each. These serve floors 1-20 (residential floors only). Outlet at roof level.
- Manual fireman's override switch located in dry riser inlet cupboard on ground floor allowing control of mechanical supply and extract run and standby fans. Supply fans located at Walkway +1 level, extract fans located in roof top plant room.

The existing system operates in the following manner on detection of smoke within a communal lobby:

- Actuators open supply and extract dampers on fire floor upon receiving signal from smoke detector outstation. All dampers on other floors remain in closed position.
- Smoke is cleared by the stack effect in the extract shaft caused by the pressure differential arising from the temperature difference between the hot smoke and cooler external air temperature.
- Make-up air is drawn through the low level supply shaft.
- The supply and extract fans do not operate unless the manual override switch is operated by the fire brigade upon their arrival. This switch opens smoke dampers local to both fan sets and activates the fans to enable mechanical ventilation to aid smoke removal. This switch is located on the ground floor adjacent to the dry riser inlet breaching valve and controls the fans only.

Figure 3-4: Excerpt from {MAX00002335} describing the original smoke ventilation system and its operation during a fire.

3.3.14 The operation of the original system in smoke ventilation mode (either in natural or mechanical mode) is visualised for the fire floor in Figure 3-5, below.

3.3.15 The blue dashed arrows indicate fresh air inlet provided at low level from the south dampers.

3.3.16 The red dashed arrows indicate the movement of smoke and hot gases out of the lobby through the high level dampers on the north side of the lobby.

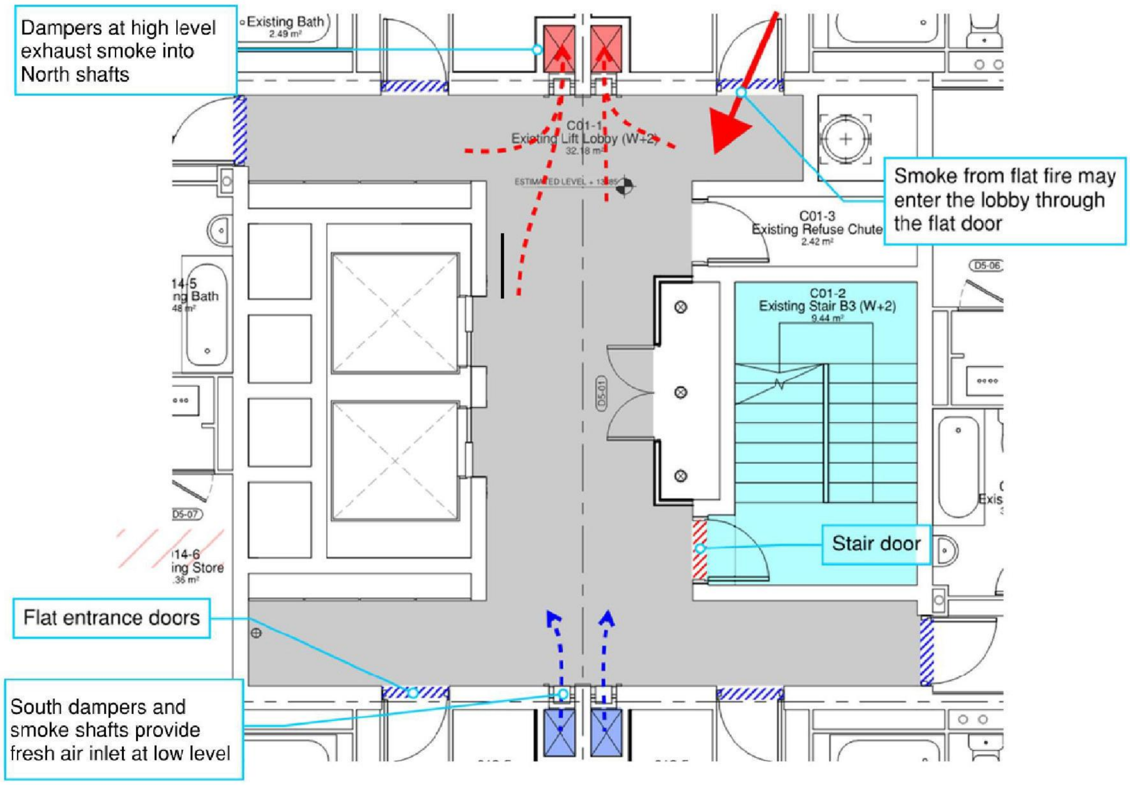


Figure 3-5: Operation of the original smoke ventilation system (either in natural or mechanical mode) on the fire floor, overlaid on an excerpt from {SEA00010474}.

3.3.17 **Components of the original system**

3.3.18 As shown in Figure 3-4, Max Fordham's report {MAX00002335} described the original ventilation system as having the following elements:

a) Smoke exhaust was provided by a pair of dampers located at high level on the north side of each lobby from Levels 4 to 23. These dampers were served by a pair of smoke shafts (the total free area within the 2 North builders' work shafts of $0.48m^2$) outlet on the roof.

b) Fresh air inlet was provided by a pair of dampers located at low level on the south side of each lobby from Levels 4 to 23. These dampers were served by a pair of smoke shafts (the total free area within the 2 South builders work shafts of $0.48m^2$) inlet on at Walkway + 1 level.

c) A manual "fireman's" override located in the dry riser inlet cupboard at Ground Level.

d) Supply and extract fans that can be operated by the fire and rescue service (noting that the location of these fans is not stated in the Max Fordham report {MAX00002335}).

3.3.19 The Max Fordham report {MAX00002335} does not specifically reference the associated controls and power supplies or the performance of these components of the existing system.

3.3.20 **Original system – Operation for smoke**

3.3.21 The system operated in two modes:

a) An automatic natural ventilation mode, operated on detection of smoke in one of the lobbies;

b) A mechanical mode instigated by manual operation by firefighters.

3.3.22 In both modes, dampers are opened automatically on the fire floor and all other dampers on all other floors, which are normally shut, remain closed.

3.3.23 The default smoke mode is natural ventilation, in which smoke is exhausted via the north smoke shafts (high level dampers) driven by the buoyancy of the smoke (the 'chimney effect').

3.3.24 Fresh air enters the lobby via the south smoke shafts (low level dampers) by natural means. Therefore, the south smoke shafts were intended to provide the inlet air to replace the smoke exhausted through the north smoke shafts.

3.3.25 A manual override facility was provided to enable firefighters to provide additional mechanical ventilation if they required. If the mechanical ventilation mode was selected by firefighters using the manual override controls at Ground Level, then smoke was to be exhausted via the north smoke shafts (high level dampers) driven by the exhaust fan.

3.3.26 Fresh inlet air was to enter the lobby on the fire floor, via the South smoke shafts (with low level dampers) driven by the supply fan.

3.3.27 Therefore, the direction of air flow within both north and south smoke shafts remained the same as when the system was in the natural ventilation mode.

3.3.28 **Compliance of the original system**

3.3.29 In natural ventilation mode, the aggregate area of the smoke shafts on each side of the lobby was $0.48m^2$.

3.3.30 The aggregate area of the dampers on each side of the lobby was $0.28m^2$.

3.3.31 These values are both significantly lower than the equivalent free area recommended by CP3 1971 of $1.5m^2$ (see Section 3.3.4, above) when automatically opening.

3.3.32 This area is required at each end of the *common access corridor* as set out in Clause 3.3.4.3.3 of CP3 1971.

3.3.33 No part of the system was designed to be opened by hand, and so the method set out in Clause 3.3.4.3.3 is not applicable.

3.3.34 Therefore, the system did not comply with the requirements of CP3 1971 due to the aggregate area of the dampers being lower than the equivalent free area recommended by CP3 1971 of $1.5m^2$ when automatically opening.

3.3.35 Grenfell Tower had a mechanical mode and this mode was to be operated by the fire service by means of controls in the dry riser cupboard at Ground floor.

3.3.36 This was an additional provision not required by CP3 1971.

4 Developing a performance specification

4.1 Introduction

4.1.1 In this section, I set out the more detailed design principles and standards necessary to develop a performance specification for a lobby smoke control system, with particular reference to the performance standards required at Grenfell Tower at the time of the primary refurbishment.

4.2 Changes to this section

4.2.1 In Section J5 Appendix J of my Phase 1 report {BLAS0000031} I described the recommended provisions in ADB 2013 for smoke control systems, and the performance requirements for pressure differential systems as described in BS EN 12101-6:2005.

4.2.2 These formed the basis for my assessment of compliance of the PSB smoke control system with ADB 2013.

4.2.3 Mr Mahoney (PSB) has submitted two witness statements to the Inquiry regarding the compliance methodology which PSB adopted for the refurbishment of the lobby smoke control system at Grenfell Tower ({PSB00001329}, {PSB00001373}).

4.2.4 Mr Mahoney's second witness statement states at paragraph 40 {PSB00001373}:

It follows that I did not design a Pressure Differential System, which are designed to comply with all the requirements of BS EN 12101-6.

4.2.5 He confirms that his design was a performance-based building-appropriate solution:

41. My design reflected a more common type of mechanical extract 'depressurisation' system. A performance-based building appropriate solution widely adopted as a type of smoke control system and which were often referred to within the industry as 'depressurisation' systems and is commonly called the ColtShaft mechanical shaft system.

4.2.6 At paragraph 52 he states

The System was similar to, but not the same as, the "Mechanical Extract, Natural Inlet" system detailed in the SCA Guide 2012.

4.2.7 Before confirming finally at paragraph 55 (bold by me).

55. The SCA Guide 2015 changed the description of the "Mechanical Extract, Natural Inlet" system type. The description in the 2015 Guide states that:

"6.4.2 Mechanical Extract, Natural Inlet

The system comprises mechanical extract shaft(s) serving one or more common spaces on all, or some, of the floor levels supplemented by the provision of natural inlet air provided by automatically opening vents or permanent vent to the outside (either directly or by way of a shaft, stairway or duct)."

56. The two figures showing the indicative layouts remained the same, but this change of wording in the ***SCA Guide 2015 acknowledged a type of system which allows for natural inlet air to be provided by way of a stairway, as was the case with the System."***

4.2.8 Whilst Mr Mahoney confirms the system is "referred to within the industry as a 'depressurisation' system" [paragraph 41]; he also confirms that there is "no comprehensive guidance available as to generic performance criteria for systems of this type" [paragraph 62].

4.2.9 Mr Mahoney also makes reference to BS 9991:2011, the *SCA Guide 2012* and the *SCA Guide 2015* but does not go on to confirm whether PSB's design was based on the guidance in those documents, either.

4.2.10 As a result, Mr Mahoney has not set out a clear basis or explanation for the alternative solution he proposed.

4.2.11 I have therefore expanded upon my original analysis of the compliance of PSB's design with the relevant building regulations and guidance.

4.2.12 In addition to my analysis of compliance with BS EN 12101-6:2005, to which ADB 2013 refers, I have further considered the extent to which PSB complied with either of the alternative approaches set out in:

a) BS 9991:2011 Fire safety in the design, management and use of residential buildings – Code of practice; and

b) *Guidance on Smoke Control to Common Escape Routes in Apartment Buildings (Flats and Maisonettes)* (2012 and 2015 revisions), Smoke Control Association

4.2.13 Please note that Mr Mahoney also refers in his second witness statement to a proprietary system, the ColtShaft Mechanical Shaft System, but no further information is provided on what Mr Mahoney means when he says that the PSB system "reflected" the ColtShaft system (see 4.2.5 and his paragraph 41 above) in the context of his design.

4.2.14 Therefore, I have provided a description of some proprietary systems, which are currently available , as a source of comparison with PSB's approach to the Grenfell Tower lobby smoke control system.

4.2.15 It is important to note there was no ColtShaft system installed at Grenfell Tower on the night of the fire, although Mr Mahoney does refer to being a former employee of Colt at paragraph 2 of his second witness statement {PSB00001373}.

4.2.16 Accordingly, in this section of my report I have set out the detailed requirements for smoke control systems in the context described in

4.2.17 Table 4-1.

Table 4-1: Documents providing guidance on the design of mechanical smoke ventilation systems

Title	Approach	Type of document	Described in section of this report
BS EN 12101-6:2005 Smoke and heat control systems — Part 6: Specification for pressure differential systems — Kits	Standard referred to from ADB 2013	British Standard (Specification)	4.3
BS 9991:2011 Fire safety in the design, management and use of residential buildings – Code of practice	Alternative approach- non statutory design guide	British Standard (Code of Practice)	4.4
Guidance on Smoke Control to Common Escape Routes in Apartment Buildings (Flats and Maisonettes) 2012 and 2015 Smoke Control Association	Alternative approach – Referred to in Annex E of BS 9991:2011	Industry Guidance	4.5
Proprietary smoke control systems	Bespoke systems developed by manufacturer	Manufacturer's literature	4.6

4.2.18 In Section 2.5.7 above, I have set out the primary design considerations emanating from the physical characteristics of Grenfell Tower and its existing safety measures; and I go on to explain below that both the SCA Guides and BS9991 are clear that the performance objectives for any system must be clearly devised and recorded.

4.2.19 The purpose of Section 4 is to demonstrate the level of complexity and the required detail in devising a specification for a lobby smoke control system.

4.2.20 In Section 4.8, I have set out the detailed specification for the use of dampers in smoke control systems. This expands on information I previously set out in sub-section 'J5.2.27 Dampers in depressurization systems' and section 'J12 Classification of dampers in accordance with ADB 2013 and UK testing requirements' of my Phase 1 report.

4.2.21 In Section 4.9 I have set out a detailed specification for ductwork in smoke control systems.

4.2.22 Finally, in Section **4.10**, I have set out the detailed specification for powered heat smoke and heat ventilators (fans) in smoke control systems.

4.3 Lobby smoke control systems in accordance with BS EN 12101-6

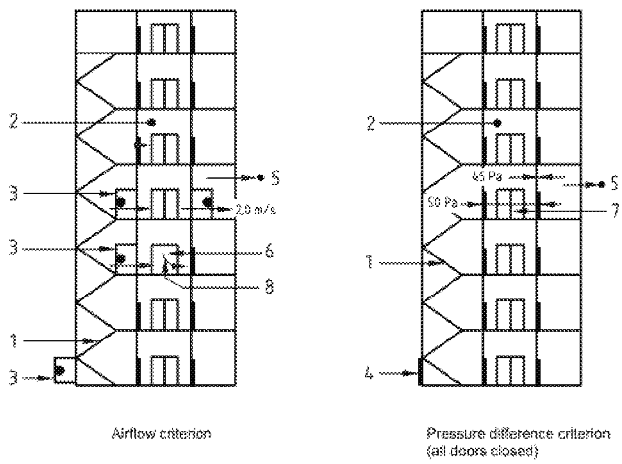
4.3.1 Paragraph 5.48 and paragraph 2.27 of ADB 2013 refer to the mechanical ventilation options that are available for the smoke control of escape routes. ADB 2013 paragraph 2.27 permits the use of pressure differentials to protect the stair from the ingress of smoke.

4.3.2 Pressure differential systems can operate in two ways:

a) Pressurisation (Figure 4-1) – maintaining a positive pressure within the protected space; or

b) Depressurisation (Figure 4-2) – removing hot gases from the fire zone, creating a lower pressure in the fire zone than the adjacent protected space.

4.3.3 As I explained in Section 2, the protected space can be defined as the stair, or the stair and the lobby, depending on the design requirement for the building under consideration.

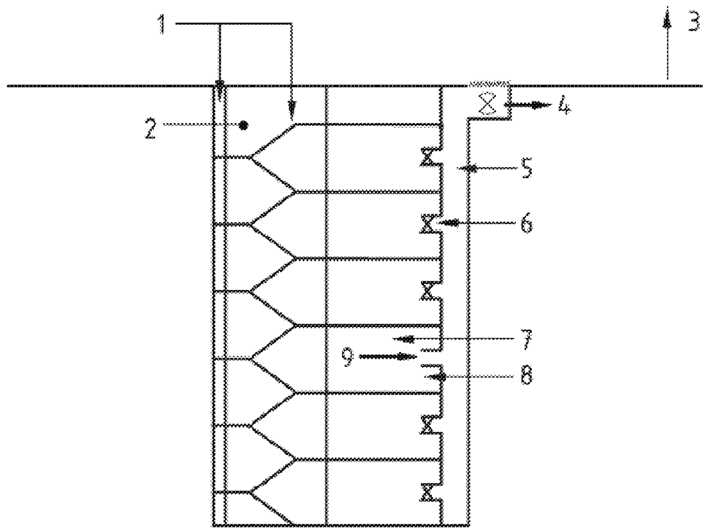


Key

1 Firefighting stair
2 Firefighting lobbies
3 Door open
4 Door closed
5 Air release path
6 Door open (firefighting lobbies)
7 Door closed (firefighting lobbies)
8 Air flow from firefighting lift shaft

Figure 3 — Design conditions for Class B systems

Figure 4-1: BS EN 12101-6:2005 Pressurisation system (left figure: doors open condition – Airflow criterion. Right figure: doors closed condition – pressure difference criteria)



Key

1 Make up air via shaft or protected space
2 Protected space
3 Ground floor
4 De-pressurization fan
5 Extract ductwork
6 Smoke detector operated fire dampers
7 Fire zone
8 External leakage
9 Open damper on fire floor

Figure 18 — De-pressurization in basements

Figure 4-2: BS EN 12101-6:2005 Depressurization system highlighting the extraction coming from the accommodation

4.3.4 BS EN 12101-6:2005 provides six different classes of system that may be used to protect stairs in different situations. I will now describe the class relevant to Grenfell Tower.

4.3.5 In Section 16 of my Phase 1 report {BLAS0000016} I explained that ADB 2013 would require the stair to be configured as a firefighting shaft given the height of Grenfell Tower.

4.3.6 The Exova Outline Fire Safety Strategy {EXO00000582} states:

The existing stair (and the lobbies thereto at each level) which serves the residential apartments forms part of the fire-fighting shaft serving the building.

4.3.7 Because the stair is a firefighting shaft, this demands certain performance requirements of the lobby smoke control system, in order to incorporate the requirements for firefighting.

4.3.8 BS EN 12101-6:2005 refers to this as a design procedure for firefighting requirements.

4.3.9 It provides for various Classes and gives examples where each of these classes can be used. It also references the section of the standard that explains the relevant design conditions:

Table 1 — Classes of systems

System class	Examples of use	Design conditions
Class A System	For means of escape. Defend in place	4.2 and Figure 2
Class B System	For means of escape and firefighting	4.3 and Figure 3
Class C System	For means of escape by simultaneous evacuation	4.4 and Figure 4
Class D System	For means of escape. Sleeping risk	4.5 and Figure 5
Class E System	For means of escape by phased evacuation	4.6 and Figure 6
Class F System	Firefighting system and means of escape	4.7 and Figure 7

Figure 4-3: Classes of pressure differential system in BS EN 12101-6:2005

4.3.10 As I have shown in Figure 4-3:, only the Class B and Class F systems in BS EN 12101-6:2005 incorporate the necessary design features for firefighting, hence their relevance to Grenfell Tower.

4.3.11 No reference is made to Class F by PSB (or others) in respect of the smoke control system installed in Grenfell Tower.

4.3.12 I note that Section 6.3.2 of the *SCA Guide 2015* states that Class F systems, as defined in BS EN 12101-6:2005, are:

included for use in Austria and not normally specified in the UK

4.3.13 This note is not included in BS EN 12101-6:2005 itself but, the following text is included in BS EN 12101-6:2005, directly below Table 1 of the standard.

The system examples to be applied will depend on national provisions valid in the place of use of the system or the decision of appropriate authorities.

4.3.14 Class B incorporates the design features for means of escape and firefighting.

4.3.15 As Mr Mahoney states in his first witness statement (at paragraph 52 {PSB00001329}) regarding the design of the smoke control system at Grenfell Tower *"I drew upon the principles in this standard to develop a building appropriate solution"*, where the relevant standard was BS EN 12101-6:2005.

4.3.16 As I have shown above, the design principles of the pressure differential systems described in BS EN 12101-6:2005 are dependent on their respective classes.

4.3.17 PSB's Technical Submission for the Lobby Ventilation System (Revision 6, {PSB00000214}), referred to the Class B depressurisation system from BS EN 12101-6:2005 .

4.3.18 In Table 4-2 I present a summary of the performance requirements of a Class B system. I have highlighted in blue the design conditions included in PSB's design.

Table 4-2: Performance requirements for Class B pressurisation/depressurisation systems

Design conditions	Class B
Pressure across lift and accommodation area	50Pa
Pressure across stairway and accommodation area	50Pa
Pressure across closed doors between each lobby and accommodation area	45Pa
Airflow criterion (a) between the staircase and the lobby	No particular criterion is provided in Clause 4.3.2.2 Airflow Criterion of BS EN 12101-6. However, I note that Clause 4.3.1 of that standard states "to achieve the minimum velocity **of 2 m/s through the open stair door…"**
Airflow criterion (b) between the lobby and fire compartment	2m/s through the open door **between the lobby and the accommodation** at the fire-affected storey
Doors to be open to achieve airflow criterion (a) above	No specific reference to what doors should be opened when demonstrating the airflow criterion in (a) above
Doors to be open to achieve airflow criterion (b) above	a) the stair and the lobby on the fire affected storey; b) the stair and the lobby on an adjacent storey; c) the firefighting lift shaft and the lobby on the adjacent storey; d) the stair and the external air at the fire service access level.
Alternative airflow criterion (for Class F systems only)	N/A
Door opening force	100N

4.3.19 It is important to note that a smoke control system using pressure differences must address both the pressure difference criterion and the airflow criterion; it is not one or the other.

4.3.20 The pressure criterion is relevant when the doors to the stair and lobby are closed to prevent smoke ingress through gaps around the doors, and the airflow criterion is relevant when these doors are opened during firefighter operations, as stated in Clause 4.3.2.2 *Airflow criterion* of BS EN 12101-6:2005:

The number of open doors assumed for design shall depend upon the location and type of firefighting facilities installed in the building, and in particular rising main outlets.

Where the hose passes through a door, that door shall be considered to be fully open.

4.3.21 Clause 4.3 of BS EN 12101-6:2005 for a Class B system states:

A Class B pressure differential system can be used to minimise the potential for serious contamination of firefighting shafts by smoke during means of escape and fire service operations.

During firefighting operations, it will be necessary to open the door between the firefighting lobby and the accommodation to deal with a potentially fully developed fire.

In some fire situations it may be necessary to connect hoses to fire mains at a storey below the fire storey and trail these via the stair to the lobby on the fire storey. It is, therefore, often not possible to close the doors between these lobbies and the stair whilst firefighting operations are in progress.

The velocity of hot smoke and gases from a fully developed fire could reach 5 m/s and under these conditions it would be impractical to provide sufficient through-flow of air wholly to prevent ingress of smoke into the lobby.

It is assumed that firefighting operations, such as the use of spray, contribute significantly to the holding back of hot smoky gases. It is, however, essential that the stair shaft be kept clear of serious smoke contamination.

To limit the spread of smoke from the fire zone to the lobby and then through the open door between the lobby and the staircase, a velocity of at least 2 m/s shall be achieved at the lobby/accommodation door.

To achieve the minimum velocity of 2 m/s through the open stair door it is necessary to ensure sufficient leakage from the accommodation to the exterior of the building. In the later stages of fire development more than adequate leakage will generally be provided by breakage of external glazing.

However, it cannot be assumed that windows will have failed before fire service arrival, and it is therefore necessary to ensure that sufficient leakage area is available via the external facade, the ventilation ductwork or specifically designed air release paths.

4.3.22 Based on the text above and Table 4-2, there are therefore five separate criteria set out in BS EN 12101-6:2005 which form the design conditions of a Class B system.

4.3.23 These are set out under the following Clauses:

a) Pressure difference criterion (Clause 4.3.2.1)
b) Airflow criterion (Clause 4.3.2.2)
c) Air supply (Clause 4.3.2.3)
d) Firefighting shaft (Clause 4.3.2.4)
e) Door opening force (Clause 4.3.2.5)

4.3.24 Figure 4-1, above, replicates Figure 3 of BS EN 12101-6: 2005. Section 4.3.2.1 of BS EN 12101-6 states "*The design requirements for a Class B system are shown in Figure 3.*"

4.3.25 BS EN 12101-6:2005 permits the Class B airflow and pressure performance to be achieved in one of two ways, by either:

a) pressurizing the stair, the lobby and the lift shaft (Clause 6.5.2.5 of BS EN 12101-6); or
b) depressurizing the accommodation (i.e. the flats in a residential building) (Clause 9.2.10 of BS EN 12101-6).

4.3.26 As explained in Mr Mahoney's first witness statement (paragraph 24 {PSB00001329})

"the design I developed was for a depressurisation system"

4.3.27 He confirms this at paragraph 37 in his second witness statement {PSB00001329}:

In contrast with the mechanical extract 'depressurisation' system I designed at Grenfell Tower,..

4.3.28 I have therefore set out the requirements for a depressurisation system in BS EN 12101-6:2005 below.

4.3.29 **Specific requirements for depressurisation pressure differential systems in accordance with BS EN 12101-6:2005**

4.3.30 In this section I present the requirements for all classes of depressurisation system as set out in Clause 9 of BS EN 12101-6:2005.

4.3.31 With respect to depressurisation systems, Clause 9.1 of BS EN 12101-6:2005 states:

The objective of a depressurization system is to achieve the same protection at the doorway between the depressurized space (e.g. a basement) and the protected space (e.g. a stairwell) as would be achieved by pressurizing the protected space. It is important to note that there is no protection of any part

of an escape route within the depressurized space itself, which may be entirely filled with smoke, or may even be fully involved in a fire. This constitutes a fundamental difference between depressurization and smoke exhaust ventilation. To be effective, each depressurized space shall be bounded on all sides by fire-resisting constructions, because any loss of integrity would result in equalization of pressure between the depressurization zone and external air. However, in compartmented buildings it may be possible to depressurize individual spaces. See Figure 17 for the typical features of a depressurization system.

The most appropriate use of depressurization systems is likely to be in basement spaces, see Figure 18 for layout.

4.3.32 It should be noted that "the depressurized space" at Grenfell Tower for a system that complied with BS EN 12101-6, would therefore be the flat as both the common lobby and the stairwell in Grenfell Tower were together the protected space.

4.3.33 The system as installed in Grenfell Tower depressurised the lobby thereby drawing smoke from the flat into the lobby. As a result the only protected space in PSB's design was the staircase.

4.3.34 I have shown this in Figure 4-4 below.

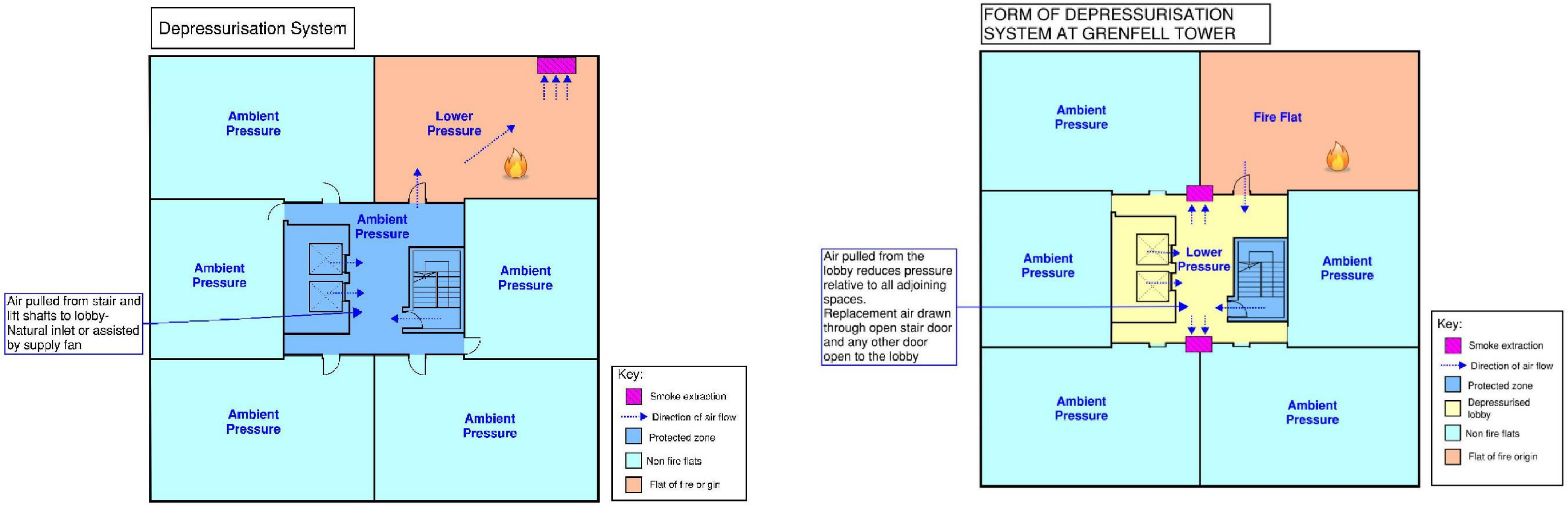


Figure 4-4 (a) Depressurisation system as illustrated in Section 2 of this report (b) form of depressurisation system designed by PSB for Grenfell Tower

4.3.35 Clause 9.2 of BS EN 12101-6:2005 goes on to define ten depressurisation requirements:

9.2.1 *Inlets from external air to the protected space shall be provided to ensure replacement airflow from the protected space to the depressurized space.*

9.2.2 *The replacement air intake shall be sited so that the air being drawn in to the protected space is not contaminated by the smoke produced by the fire.*

9.2.3 *The system shall consist of exhaust fans and if necessary ductwork to remove hot gases and smoke produced by the fire within the depressurization zone to the outside of the building.*

9.2.4 *Air inlets shall be provided for the necessary replacement air required to allow the pressure differential to develop across the closed doors and to meet the airflow velocities through the open door into the fire zone, initially for means of escape and/or subsequently for firefighting purposes.*

9.2.5 *The outlets of the exhaust ductwork shall be in such positions that smoke does not threaten the safety of occupants and firefighters or persons outside the building and does not contribute to external fire spread.*

9.2.6 *Depressurized zones shall be bounded on all sides (including the floor slab above and below) by constructions having fire-resistance at least equal to that required for the protected space.*

9.2.7 *All doors to the depressurization zone shall be self-closing.*

9.2.8 *The extraction ductwork from the depressurization zone shall meet the requirements for fire resistance for a period at least equal to the highest period of fire-resistance through which the ductwork passes, when tested and classified in accordance with prEN 13501-3.*

9.2.9 *The extraction fan from the depressurization zone shall be capable of handling smoke at a temperature of 1000 °C for unsprinklered buildings, or 300 °C for sprinklered buildings, when tested and classified in accordance with prEN 13501-4.*

9.2.10 *With all doors closed, the extraction rate of smoke and hot gases from the depressurization zone shall be capable of maintaining a pressure differential not less than that given in Clause 4 for the appropriate system class and, where relevant, the open door airflow criterion.*

4.3.36 The five Class B pressure differential requirements and the ten depressurisation requirements form the performance criteria of a BS EN 12101-6:2005 pressure differential system.

4.3.37 Fundamentally PSB's design could not provide that level of performance, as the lobby was not recognised in their design as part of the protected zone.

4.3.38 **Summary of how requirements apply to Grenfell Tower**

4.3.39 Clause 9 of BS EN 12101-6:2005 explains that depressurisation systems may be used to achieve the requirements of the six classes of system described in Clause 4 of the standard.

4.3.40 In all cases, the *accommodation* is depressurised with respect to both the stair and the lobby if present.

4.3.41 In Grenfell Tower, the 'accommodation' comprises the individual flats; this means smoke from the fire flat is prevented from entering the lobby and also the staircase.

4.3.42 A depressurisation system compliant with BS EN 12101-6:2005 Clause 9, as depicted in Figure 4-2, would require a mechanical extract from the flats to maintain them at a lower pressure than the lobby.

4.3.43 I presented in Section 2 an illustration of the how smoke and air would move in Grenfell Tower if a compliant BS EN 12101-6:2005 depressurisation system had been provided.

4.3.44 I have that image here in Figure 4-5.

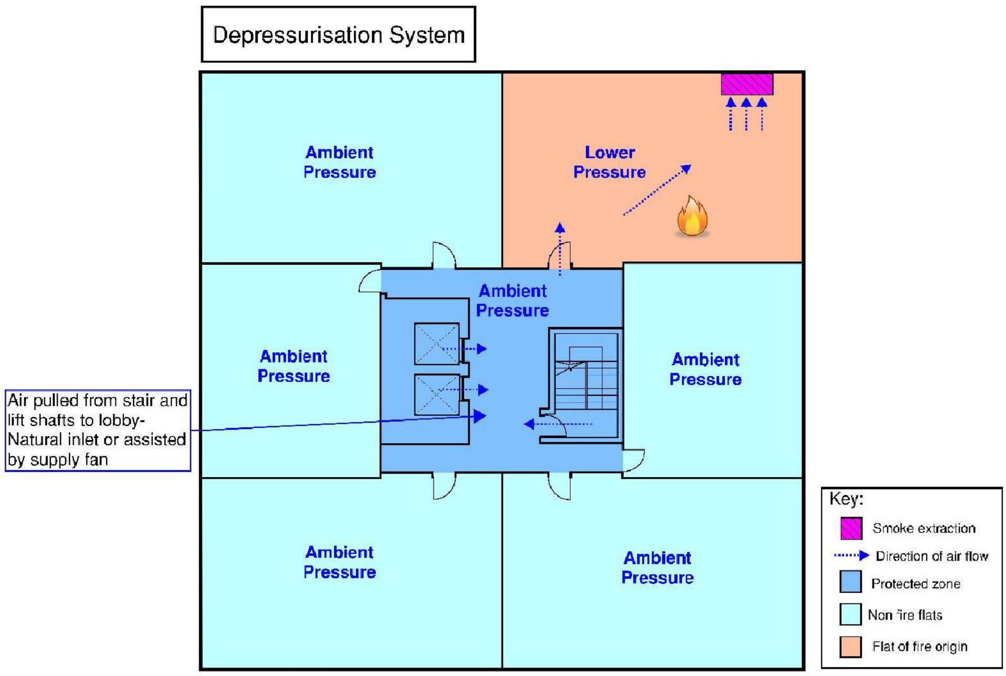


Figure 4-5: Movement of smoke in a depressurisation system compliant BS EN 12101-6:2005

4.3.45 In Table 4-3, I have summarised the design conditions of a Class B system from BS EN 12101-6:2005 and provided an explanation of how these could be considered at Grenfell Tower.

4.3.46 As required in Clause 4.3.2.2 of BS EN 12101-6:2005 I have considered the "location and type of firefighting facilities" in particular the "rising main outlets", and:

The number of open doors assumed for design shall depend upon the location and type of firefighting facilities installed in the building, and in particular rising main outlets. Where the hose passes through a door, that door shall be considered to be fully open.

4.3.47 Therefore, the design conditions relevant to Grenfell Tower are an open door between the staircase and the lobby on the fire-affected floor and an open door between the staircase and the lobby on an adjacent floor, during firefighting.

4.3.48 This open door configuration was appropriate for Grenfell Tower where the dry rising main was located within the lobby. The air flow criterion (b) should therefore incorporate those conditions.

Table 4-3: Performance requirements for Class B system as when considered for Grenfell Tower

Class B depressurisation requirements		**How BS EN 12101-6 applied to Grenfell Tower**
Pressure across lift and accommodation area	50Pa	The pressure differential between the lifts and the residential flats - 50 Pa.
Pressure across stairway and accommodation area	50Pa	The pressure differential between the lifts and the residential flats - 50 Pa.
Pressure across closed doors between each lobby and accommodation area	45Pa	The pressure differential between the common lobby and the residential flats - achieve a minimum of 45Pa.
Airflow criterion between the staircase and the lobby (a)	A criterion is not provided in Clause 4.3.2.2 Airflow Criterion of BS EN 12101-6. However, I note that Clause 4.3.1 *General* of that standard states *"the minimum velocity of 2 m/s through the open stair door…"*	A minimum velocity of 2m/s - through the stair door into the common lobby on the fire affected storey.
Airflow criterion between the lobby and fire compartment (b)	2m/s through the open door **between the lobby and the accommodation** at the fire affected storey.	A minimum velocity of 2m/s - through the flat front entrance doors from the common lobby on the fire affected storey.
Doors to be open to achieve airflow criterion (a)	Not specified	N/A

Class B depressurisation requirements		How BS EN 12101-6 applied to Grenfell Tower
Doors to be open to achieve airflow criterion (b)	a) the stair and the lobby on the fire affected storey; b) the stair and the lobby on an adjacent storey; c) the firefighting lift shaft and the lobby on the adjacent storey; d) the stair and the external air at the fire service access level.	a) the door to the protected stair and a flat front entrance door on the fire affected storey; b) the door to the protected stair and on an adjacent storey; c) the firefighting lift shaft and the lobby on the adjacent storey; d) both the Level 2 stair door to the main entrance foyer and the ground floor door at fire service level would have to be open to allow flow of external air into the enclosed stair.
Door opening force	100N	The flat front entrance doors and door to the protected stair on all levels of Grenfell Tower - a door opening force of less than 100N.
9.2.1 Inlets from external air to the protected space shall be provided to ensure replacement airflow from the protected space to the depressurized space.		Inlet air for the stair, lift shaft and lobbies.
9.2.2 The replacement air intake shall be sited so that the air being drawn into the protected space is not contaminated by the smoke produced by the fire.		Inlet air to be located remotely from exhaust from the flat.
9.2.3 The system shall consist of exhaust fans and if necessary ductwork to remove hot gases and smoke produced by the fire within the depressurization zone to the outside of the building.		Hot gases and smoke to be extracted from the flats; this could be achieved by powered exhaust directly to external air or by the use of duct work.
9.2.4 Air inlets shall be provided for the necessary replacement air required to allow the pressure differential to develop across the closed doors and to meet the airflow velocities through the open door into the fire zone, initially for means of escape and/or subsequently for firefighting purposes.		In addition to item 9.2.1 these air inlets should be sized appropriately to meet the pressure differential requirements.
9.2.5 The outlets of the exhaust ductwork shall be in such positions that smoke does not threaten the safety of occupants and firefighters or persons outside the building and does not contribute to external fire spread.		Exhaust from the flats to be designed so that it did not present an ignition risk for the combustible external wall construction.
9.2.6 Depressurized zones shall be bounded on all sides (including the floor slab above and below) by constructions having fire-resistance at least equal to that required for the protected space		In Grenfell Tower the level of fire resistance of the compartmentation was 120 minutes for the firefighting stair and compartment floors; therefore the flats would have to be bounded on all sides by 120 minute fire resisting construction.
9.2.7 All doors to the depressurization zone shall be self-closing.		The flat entrance doors to be self-closing.

Class B depressurisation requirements	How BS EN 12101-6 applied to Grenfell Tower
9.2.8 The extraction ductwork from the depressurization zone shall meet the requirements for fire resistance for a period at least equal to the highest period of fire-resistance through which the ductwork passes, when tested and classified in accordance with prEN 13501-3.	Any ductwork used to exhaust hot smoke from the flats - fire resisting.
9.2.9 The extraction fan from the depressurization zone shall be capable of handling smoke at a temperature of 1 000 °C for un-sprinklered buildings, or 300 °C for sprinklered buildings, when tested and classified in accordance with prEN 13501-4.	Grenfell Tower was an un-sprinklered building. The extraction fan capable of handling smoke at a temperature of 1 000 °C.
9.2.10 With all doors closed, the extraction rate of smoke and hot gases from the depressurization zone shall be capable of maintaining a pressure differential not less than that given in Clause 4 for the appropriate system class and, where relevant, the open-door airflow criterion	The fans designed to meet the performance criteria in rows 4 – 8 of this table.

4.4 Lobby smoke control systems in accordance with BS 9991:2011

4.4.1 Mr Mahoney makes passing references to BS 9991 without indicating whether or not it was relevant to PSB's design objectives or approach.

4.4.2 Below, I present a summary of the design conditions of a mechanical smoke control system as set out in BS 9991:2011.

4.4.3 Clause 26.1.1 sets out the performance objective for a smoke control system in a residential building:

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

COMMENTARY ON 26.1.1 Whilst the primary aim of smoke control in residential buildings is to protect the staircase enclosure it can also provide some protection to the adjacent protected corridor or lobby. In extended corridors, the primary objective of the smoke control system is to protect both the common corridor and the staircase enclosure for means of escape.

4.4.4 At clause 26.1.3 'Buildings with a single stair above 11m in height', BS 9991:2011 sets out four methods of smoke control for a protected corridor or lobby which are:

a) Automatic opening ventilators to the exterior of the building; or

b) A smoke shaft conforming to Clause 26.2.4; or

c) A mechanical smoke ventilation system conforming to Clause 26.2.5; or

d) A pressure differential system.

4.4.5 PSB's Technical Submission refers to the system as a *"mechanical extract system"*. BS 9991:2011 provides a description of a *'mechanical smoke ventilation system' [MSVS]* in Annex E, E.4:

The general principle is that a vent is provided to the lobby or corridor adjoining the stair to facilitate the removal of smoke through the vent prior to it entering the staircase enclosure. An MSVS uses fans to provide ventilation, rather than relying on buoyancy and wind forces as natural ventilation does. Most systems use a vertical shaft. Adverse wind or building stack pressures are less likely to affect a pressure differential system or an MSVS than a natural smoke control system.

4.4.6 Clause 26.2.5 sets out the requirements for mechanical smoke ventilation systems.

Where a mechanical smoke ventilation system uses a shaft, it should conform to 26.2.4.2a), f), g), h) and i).

A mechanical smoke ventilation system should demonstrate equivalent or better conditions in the lobby or corridor and stairs than the natural ventilation system that it replaces. NOTE 1 This is usually shown by a comparative computational fluid dynamics analysis.

The design of the mechanical smoke ventilation system should limit pressure differentials so that door opening forces do not exceed 100 N at the door handle when the system is in operation.

Additional consideration should be given to door opening forces, where applicable (see 35.1.6.1, Note 1).

A secondary power supply should be provided to the fans and all actuators and controls.

Fans should be provided with a standby fan that operates automatically upon failure of the duty fan. NOTE 2 Further information regarding mechanical smoke ventilation systems can be found in Annex E.

4.4.7 Accordingly, BS 9991:2009 requires evidence that a mechanical smoke ventilation system provides equivalent or better performance to a natural smoke system.

4.4.8 As I have explained in Section , where a mechanical smoke ventilation system is used to enable an extended travel distance through a lobby, a further performance requirement should be set to maintain tenable conditions within the lobby.

4.4.9 Therefore, for extended travel distances such as were present at Grenfell Tower, demonstrating equivalence to a naturally ventilated lobby with BS 9991-compliant travel distances would not be sufficient.

4.4.10 Per Clause 26.2.5 of BS 9991:2011, where a mechanical smoke ventilation system uses a shaft as part of the system, the shaft should conform to clause 26.2.4.2, paragraphs a), f), g), h) and i):

a) The smoke shaft should be fully open to the external air at the top and closed at the base

f) The top of the lobby or corridor vent should be located as close to the ceiling of the lobby or corridor as is practicable, and should be at least as high as the top of the door connecting the lobby or corridor to the stairwell.

g) The lobby or corridor vents, in the closed position, should have a minimum fire and smoke resistance performance of 30 min and a leakage rate no greater than 200 m3/h/m2 when tested in accordance with BS EN 1366-2.

h) The smoke shaft should be constructed of either non-combustible materials conforming to BS 476-4 or of any material which when tested in accordance with BS 476-11 does not flame or cause any rise in the temperature on either the centre of the specimen or the furnace thermocouples. The smoke shaft should run vertically from top to bottom with no more than 4 m of the shaft at an inclined angle (max 30°).

i) No services other than those relating to the smoke shaft should be contained within the smoke shaft.

4.4.11 BS 9991:2011 specifies performance criteria for door opening forces, including consideration of the appropriate door opening force limits as per Note 1 to Clause 35.1.6.1 which states:

BS 8300 states that, for most disabled people to have independent access through single or double swing doors, the opening force, when measured at the leading edge of the door, should be not more than 30 N from 0° (the door in the closed position) to 30° open, and not more than 22.5 N from 30° to 60° of the opening cycle. BS 8300 also gives more detailed guidance on the design of buildings and their approaches to meet the needs of disabled people.

4.4.12 Annex E sets out further guidance in E.6 Considerations for the selection of MSVS [Mechanical Smoke Ventilation System].

4.4.13 It advises that the extraction rate and replacement air provision should be selected so as to achieve adequate extraction from the lobby without drawing in smoke from the flat of fire origin (bold by me):

For the MSVS to operate effectively, consideration needs to be given to the route of the exhaust air, the inlet replacement air supply and the air flow within the space being ventilated. ***A judicial selection of the MSVS ventilation rate and adequate provision for replacement air is essential to ensure that air is extracted from the protected lobby or protected corridor without allowing smoke from the flat of fire origin to be drawn in.***

...

It is also important to ensure that replacement inlet air is provided, with careful consideration given to its location in relation to the point of extract, so that the system works to effectively extract smoke from the relevant space.

4.4.14 Where an extraction rate is too high relative to the replacement air provision, the system may inadvertently draw smoke out of the fire flat and into the lobby.

4.4.15 BS 9991:2011 therefore advises that ventilation rates be determined through calculation.

It is important that the ventilation rate of an MSVS is decided through an assessment of any specific risks within the building and verification through a computational fluid dynamics (CFD) analysis or mathematical calculation

4.4.16 BS 9991:2011 goes on to describe specific aspects which should be considered when designing the system to meet its performance criteria.

4.4.17 As I have set out above, the performance criteria for a mechanical lobby smoke ventilation system with compliant travel distances are equivalent to those of a natural ventilation system.

4.4.18 BS 9991: 2011 says that mechanical smoke ventilation systems may be used in corridors or lobbies with extended travel distances where the performance criteria include tenable conditions for means of escape in the lobby.

4.4.19 These performance criteria were relevant for Grenfell Tower, where the maximum travel distance in the lobby was 10.5m, exceeding the recommended 7.5m in BS 9991:2015 for an un-sprinklered building.

4.4.20 The specific aspects to be considered then became, as per section E.6 of BS 9991:2011, are:

When the sole purpose of an MSVS is to protect the means of escape, it is important that the following aspects are taken into account with regard to their effect on the ability of the system to meet its performance criteria.

a) Different fire locations (both close to and far from the point of extract).

b) Pressure differences across a flat front door with a variety of extraction rates.

c) A negative wind coefficient at the stair head vent.

d) Fire pressure and increasing fire growth.

When the purpose of an MSVS is also to aid fire-fighting operations, it is important that the following aspects are taken into account with regard to their effect on the ability of the system to meet its performance criteria, in addition to those aspects given in a) to d).

1) A variety of door opening sizes for the stair or corridor door (when closed, partially open and fully open).

2) Increased ventilation to a fire due to a broken window.

3) Low-level ventilation to the stair.

NOTE There are numerous different types of fan assisted system including a mechanical extract /natural inlet and a mechanical extract/mechanical inlet system. Further information on these can be found in the Smoke Control Association publication, "Guidance on smoke control to common escape routes in apartment buildings (flats and maisonettes)" [32]. This document also includes information regarding system controls (control panels, indication/ status panels, manual control points, etc.), which can be important considerations when selecting an MSVS.

4.4.21 **Summary of BS 9991:2011 design conditions and how they could apply to Grenfell Tower**

4.4.22 Table 4-4 sets out my summary of how the design conditions from BS9991:2011 for a mechanical smoke ventilation system to a residential lobby with extended travel distances could have been applied to Grenfell Tower.

Table 4-4: Requirements for a mechanical smoke ventilation system for an extended corridor as it applied to Grenfell Tower

Mechanical smoke ventilation system for an extended corridor		**How it could apply to Grenfell Tower**
Tenability criteria - stairs & lobbies	None specified for extended travel distances. Annex E refers to the *SCA Guide* for guidance.	The designer should define appropriate tenability criteria.
Scenarios to be considered – door opening	None specified for extended travel distances. Annex E refers to the *SCA Guide* for guidance.	The designer should define appropriate scenarios to be considered.

Mechanical smoke ventilation system for an extended corridor		**How it could apply to Grenfell Tower**
Design scenarios – means of escape	*a) Different fire locations (both close to and far from the point of extract).* *b) Pressure differences across a flat front door with a variety of extraction rates.* *c) A negative wind coefficient at the stair head vent.* *d) Fire pressure and increasing fire growth.*	a) Fire locations for different flats should be considered. b) Calculation of the pressure differentials created between the lobby and the flat under different extract rates, and between the lobby and the stair. c) Calculation of wind effects to the inlet air vent. d) Calculation of effect of fire on pressure differentials between flat and adjoining spaces.
Design scenarios – firefighting	*1) A variety of door opening sizes for the stair or corridor door (when closed, partially open and fully open).* *2) Increased ventilation to a fire due to a broken window.* *3) Low-level ventilation to the stair.*	1) Calculation of system performance when flat and stair doors are closed, partially open or fully open. 2) Calculation of effect of window breakage in the flat. 3) Calculation of effect of open door to stair at Level 2 from ventilated entrance foyer.
Method of analysis	Computational fluid dynamics (CFD) analysis or mathematical calculation.	The ventilation rate should be calculated to achieve the tenability and other performance criteria for a range of fire scenarios.
Shafts	Smoke shaft fully open to external air at top and closed at base. Constructed from non-combustible materials. Run vertically from top to bottom, with no more than 4m of the shaft at an inclined angle (max 30°C). No services with the smoke shaft.	All shafts extracting smoke from the lobbies should vent at roof level. Shafts should be non-combustible and contain no services. Shafts should be vertical; no horizontal shafts permitted (greater than 30°).

Mechanical smoke ventilation system for an extended corridor		How it could apply to Grenfell Tower
Vents	Lobby vent located as close to lobby ceiling as possible and at least as high as the top of the stair door. Vents to the lobby should have a minimum fire resistance of 30 min and smoke leakage no greater than $200m^3/(m^2h)$ when tested to BS EN 1366-2.	The vents within the lobbies should be positioned at least as high as the top of the stair. The fire resistance for vents is lower than those required by ADB for protected shafts. Therefore the provisions from ADB apply.
Secondary power	Secondary power supply was required for all fans, actuators and controls.	This should be provided.
Fans	A standby and duty fan with automatic switchover.	This should be provided.

4.5 Performance-based design approaches for smoke control systems - Smoke Control Association Guidance

4.5.1 In this section I set out guidance relevant to smoke control systems in residential buildings published by the Smoke Control Association (SCA).

4.5.2 The SCA is a specialist group within HEVAC (HEVAC is in this case the name of a group, not an acronym). HEVAC is a trade association and the `largest member of the Federation of Environmental Trade Associations (FETA){INQ00014728}.

4.5.3 In Section 2.2.62 above, I introduced the *Guidance on smoke control to common escape routes in apartment buildings (flats and maisonettes)* published by the SCA and the two specific versions relevant to this report (2012 and 2015 versions).

4.5.4 The first published edition of the *SCA Guide* from 2010 is referenced in Annex E, *Methods of smoke control,* in BS 9991:2011. The 2012 version (Revision 1) was available at the time of the design of the smoke control system as part of the refurbishment works at Grenfell Tower.

4.5.5 *SCA Guide 2015* was published after Revision 3 of PSB's Technical Submission was submitted to RBKC Building Control on 12th June 2015 {RBK00027396}. The proposals for the smoke control system were subsequently confirmed as 'satisfactory' by RBKC Building Control on 24th June 2015 {RBK00033900}.

4.5.6 The *SCA Guide 2015* was sent by RBKC Building Control to Rydon and JS Wright on 4th May 2016 with the covering email stating {RYD00076682}:

Remember that the testing of the powered vent system we are witnessing tomorrow should be in accordance with section 9 and item of the attached SCA guide.

4.5.7 The *SCA Guide 2012* and *SCA Guide 2015* provide guidance on design objectives and performance criteria for lobby smoke control systems, the different types of system to consider, performance requirements for equipment forming the system, as well as information regarding commissioning and maintenance.

4.5.8 Section 6 of the SCA Guide 2012 and 2015 provide guidance on the following types of system:

a) Natural Ventilation

b) Pressure differential systems

c) Mechanical (Powered) smoke ventilation

4.5.9 As stated in the introduction to Section 6.1 '*Commentary*' of the *SCA Guide 2012*:

Mechanical systems, as described in 6.4, may be designed to allow extended travel distances subject to agreement from the approving authorities.

4.5.10 Section 6.1 '*Commentary*' of the *SCA Guide 2015*:

Mechanical systems may be designed to allow extended travel distances subject to agreement from the approving authorities.

4.5.11 The *SCA Guide 2012* provided design recommendations for the following Mechanical (Powered) smoke ventilation systems:

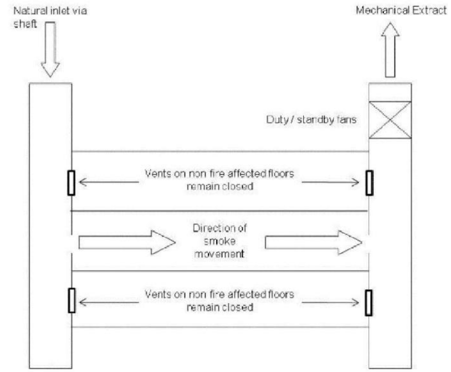
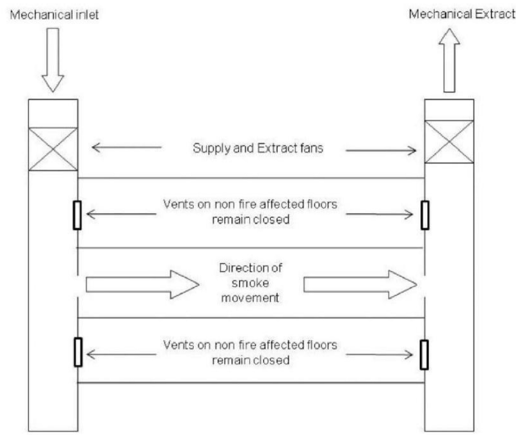
a) *Mechanical Extract, Natural Inlet*

b) *Mechanical Extract, Mechanical inlet*

4.5.12 The *SCA Guide 2015* referred to the two system types above and added a further system type called *Mechanical Extract only.*

4.5.13 I have provided the description of the three types of system in table below:

Table 4-5 Descriptions of systems from the SCA Guide

System type	Description from SCA Guide	Diagram from SCA Guide
Mechanical Extract, Natural Inlet	2012: *The system comprises mechanical extraction shaft(s) serving one or more common spaces on all, or some, of the floor levels. The mechanical extraction ventilation haft(s) should discharge directly to the outside.* *…The design of powered systems should take into consideration that the source of inlet air should not compromise normal passive compartmentation.* 2015: *The system comprises mechanical extract shaft(s) serving one or more common spaces on all, or some, floor levels supplemented by the provision of natural air inlet provided by automatically opening vents or permanent vent to the outside (either directly or by way of a shaft, stairway or duct). Typically, the mechanical extract is by a shaft although it can be via fans direct to the outside.*	**Figure 6.4.2a – Indicative layout showing a typical mechanical extract and natural inlet ventilation solution for a common access corridor using two shafts** 
Mechanical Extract, Mechanical Inlet	2012: *One typical example is a corridor designed with a reversible fan which provides mechanical extraction and a reversible fan providing mechanical air inlet. With this design, the system can be controlled by the fire detection system such that the fan closest to the initial point of detection can be selected as the smoke extract fan in means of escape mode.* 2015: *Typical examples are:* *a) Reversible fans which provide mechanical extract and mechanical air inlet. With this design, the system can be controlled by the fire detection system so that the fan closest to the initial point of detection can be selected as the smoke extract fan in means of escape mode with selected fans providing air inlet.* *b) Systems with dedicated extract and inlet fans.*	**Figure 6.4.3 – Indicative layout showing mechanical inlet and mechanical extract ventilation for a common access corridor.** 
Mechanical Extract only (SCA Guide **2015** only)	*The system comprises mechanical extract shaft(s) serving one or more common spaces on all, or some, of the floor levels. The system uses a single mechanical extract shaft, with replacement air typically provided by natural leakage. Air replacement forms a key component of a mechanical extract only system and the designer should specify how this is to be achieved and how this is to be confirmed and tested onsite to ensure excessive pressure does not occur across a closed door or otherwise compromise means of escape by pulling smoke into the common escape routes from the adjoining space.*	None provided.

4.5.14 I have provided a diagrammatic example of the three types of system listed in Table 4-5 above to illustrate how these would apply at Grenfell Tower in Figure 4-6 to Figure 4-8,

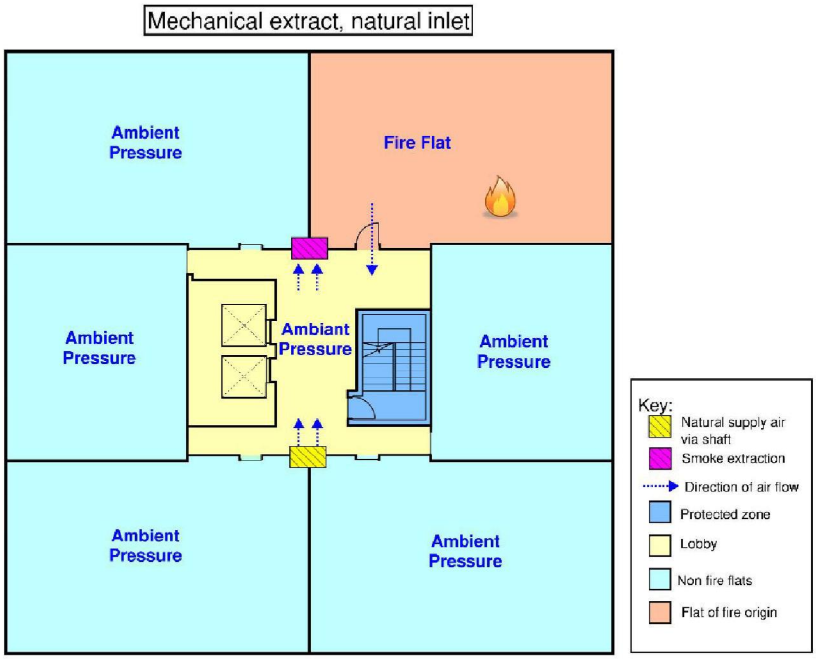


Figure 4-6: SCA Guide 2012 – Mechanical extract, natural inlet

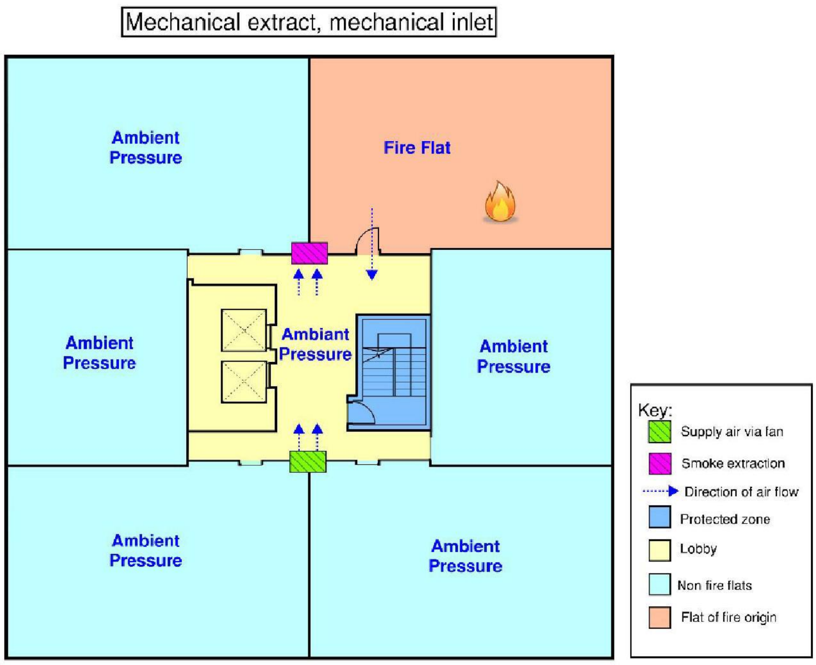


Figure 4-7: SCA Guide 2012 – Mechanical extract, mechanical inlet

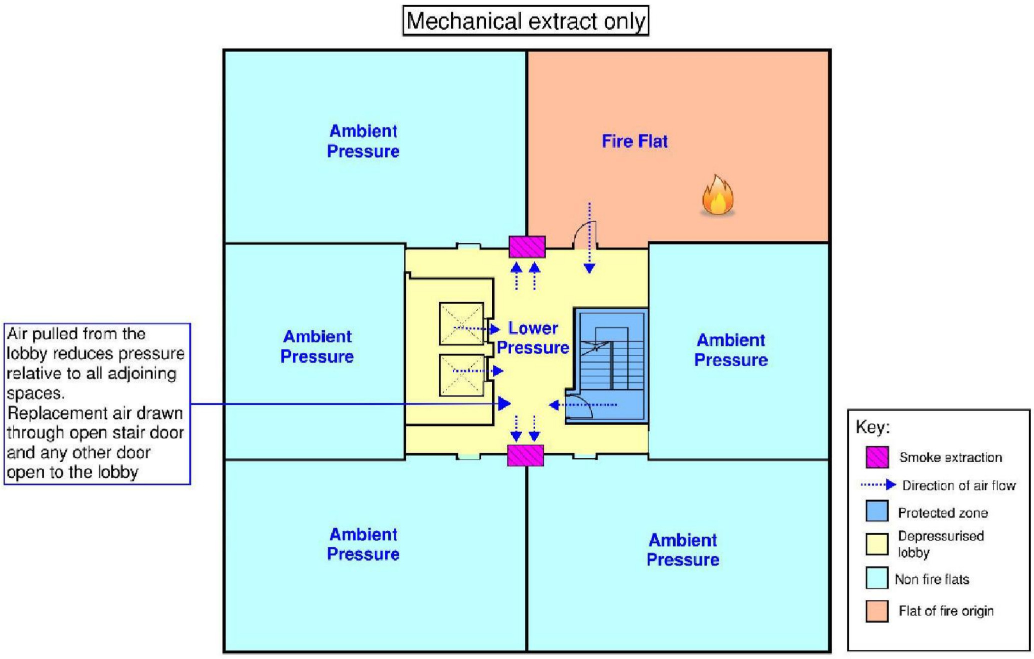


Figure 4-8: SCA Guide 2015 - Mechanical extract only

4.5.15 In the case of an extended travel distance in the lobby (as was the case in Grenfell Tower), Section 6.4 '*Mechanical (Powered) smoke ventilation* 6.4.1 *General principles'* of both the *SCA Guide 2012* and *SCA Guide 2015* states (bold by me):

*It is possible to design systems providing a higher performance that may then be used to allow extended travel distances in corridors ...... **In this case the system objectives and performance should follow the guidance in section 5.***

4.5.16 Section 5 of the *SCA Guide 2012* and *SCA Guide 2015* are both headed *Objectives and Performance Criteria.*

4.5.17 Section 5.1 '*General'* of the *SCA Guide 2012* and *SCA Guide 2015* states:

Where the building design and the ventilation system are in direct conformity to ADB to the Building Regulations (or equivalent outside England and Wales), there is no requirement to consider objectives or performance criteria as the ventilation system is deemed to be suitable by virtue of its prescription in ADB. This section then does not apply.

In other cases it is necessary to consider the objectives and performance criteria for the system

...

As with any alternative solution there are a number of methods which allow the investigation of its performance.

...

It is the responsibility of the assessing engineer to determine which method of investigation should be used.

4.5.18 Section 5 of the SCA Guide then provides a methodology for defining the objectives and performance criteria for the system, and methods by which to demonstrate that the proposed system meets the objectives and performance criteria.

4.5.19 As I have explained in my Phase 1 report {BLAS0000002}, and in Section 2 above, the building design at Grenfell Tower was not in direct conformity with ADB 2013 and therefore the designer of the system at Grenfell Tower would have to rely on the guidance set out in Section 5 of the *SCA Guide 2012* and *SCA Guide 2015*.

4.5.20 I have created a flow chart providing a high-level summary of how I understand the process of complying with section 5 of the *SCA Guide 2012* and *SCA Guide 2015*.

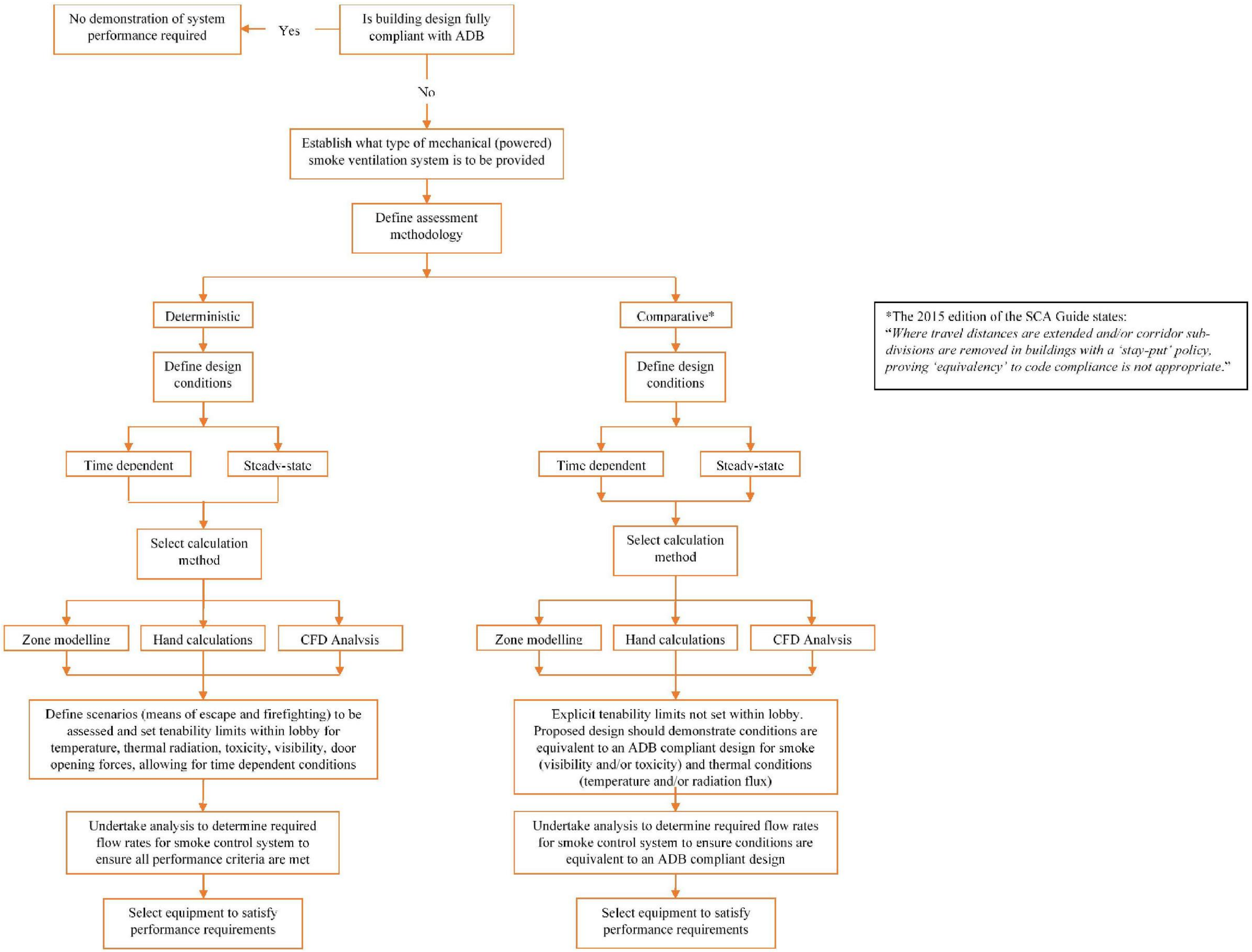


Figure 4-9: my understanding of the assessment methodology in the *SCA Guide 2012* and the *SCA Guide 2015* – performance-based design approaches

4.5.21 I note that both the *SCA Guide 2012* and *SCA Guide 2015* state:

Results should be presented in an appropriate form for each agreed criterion. Sufficient information should be provided to allow relevant parties to assess the analysis undertaken in relation to checking and meeting the required performance criteria.

The results of the analysis should be documented and may be provided in the form of a report, together with any necessary supporting animations from advanced modelling.

The documentation should include at least the following information:

• A description of the residential area and the proposed ventilation system

• The design criteria and performance objectives of the analysis

• The scenarios investigated

• Details of the techniques used and related information

• The results of the analysis

• A statement as to whether the design criteria and objectives have been met

For time dependent analyses, graphical results should be presented wherever possible to

quantitatively show conditions plotted against a time line.

A sensitivity analysis should be carried out and presented such that it allows important outputs between different scenarios to be easily compared.

4.6 Proprietary smoke control systems

4.6.1 These systems are somewhat similar in their principles of operation and design criteria, to the system designed and installed at Grenfell Tower by PSB. I describe two such systems in this section.

4.6.2 Mr Mahoney describes the Grenfell Tower system designed by PSB as similar to the ColtShaft mechanical shaft system in his second witness statement to the Inquiry (paragraphs 41 & 59-60 {PSB00001373}).

4.6.3 In Section 5 I present my comparison of the ColtShaft system with PSB's design and explain why I do not agree they are similar.

4.6.4 I note however, that where extended travel distances are present in a common corridor, as was the case in Grenfell Tower, Colt recommend using their *Colt Extended Corridor System* and not the Colt Shaft system. The Colt website states{INQ00014726}:

There are four types of Extended Corridor System:

- *Pull system – mechanical extract / natural inlet – outlet*

- *Push system - mechanical extract / natural inlet*
- *Push-pull – balanced system.*
- *Push-pull reversible - balanced system but with added flexibility.*

4.6.5 Nevertheless, below I describe the Colt Shaft mechanical since this is specifically referred to by Mr Mahoney.

4.6.6 I am aware of another proprietary smoke control system - the Flakt Woods Smoke Shaft Vent System and also present my analysis of this below.

4.6.7 I reiterate that neither of these systems was installed in Grenfell Tower; I have considered them merely to inform my analysis of PSB's design.

4.6.8 **ColtShaft Mechanical Shaft System**

4.6.9 The ColtShaft Mechanical Shaft System is a proprietary smoke control system developed by Colt International Ltd ('Colt').

4.6.10 I note from their website that Colt state that they are a leader in the field of smoke control systems{INQ00014679}:

Colt has the widest range of completed smoke control projects and the largest range of certified products of anyone in the field

4.6.11 Colt provide design, installation, commissioning and maintenance of their smoke control systems. They are also members of the Federation of Environmental Trade Associations (FETA), incorporating HEVAC and the Smoke Control Association {INQ00014680}.

4.6.12 From the Colt website {INQ00014678}, a ColtShaft Mechanical Shaft is described as:

ColtShaft is a mechanical fire-fighting shaft system that provides equivalent performance to a BRE shaft for the ventilation of common corridors and fire fighting lobbies.

4.6.13 The BRE shaft to which they refer is a natural ventilation system described in the BRE Report 79204 and which is referenced in BS 5588-5:2004 *Fire precautions in the design, construction and use of buildings. Access and facilities for fire-fighting* as a method of ventilation to a firefighting shaft.

4.6.14 Two versions of ColtShaft are described in Colt's literature{INQ00014681}: ColtShaft Variable and ColtShaft Constant; both forms are described as suitable for use in residential buildings.

4.6.15 The ColtShaft Variable is relevant to my investigation, as this system relied on a pressure-sensing device to measure the pressure differential between the lobby and the staircase; similar to the pressure switch in PSB's design.

4.6.16 The following excerpt from Colt's datasheet {INQ00014681} *"Smoke control and day to day ventilation systems for multi-storey residential buildings"* describes the ColtShaft Variable system:

> **The Colt Shaft Variable**
>
> The Colt Shaft Variable incorporates duty and standby variable speed extract fans linked to a pressure sensor via the control panel.
>
> The Colt Shaft Variable avoids excessive negative pressures without compromising the integrity of the stairs and lobby by automatically reducing the ventilation rate when the lobby doors are closed. It does this via a pressure sensor linked into the control system that varies the fan speed.
>
> With all doors open, the fan runs at full speed to extract smoke discharging from the accommodation. With all doors closed, the fan runs at minimum speed to help mop up any smoke leaking past the closed door. In intermediate conditions, the fan speed modulates to ensure adequate ventilation without excessive depressurisation.

4.6.17 This system includes a variable speed fan linked to a pressure sensor to maintain a specific pressure difference between the lobby and the stairs. A $1m^2$ vent is provided to the head of the stairs. A single extract shaft is provided. Figure 4-10 shows the ColtShaft operational diagram.

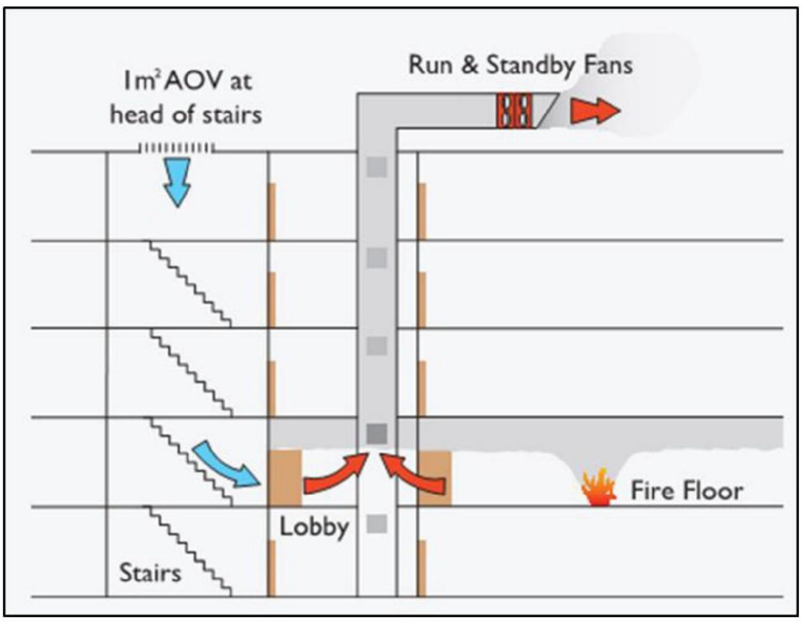


Figure 4-10: ColtShaft operational diagram (excerpted from {INQ00014681})

4.6.18 I have also shown, in Figure 4-11 a ColtShaft arrangement for the lift lobbies at Grenfell Tower.

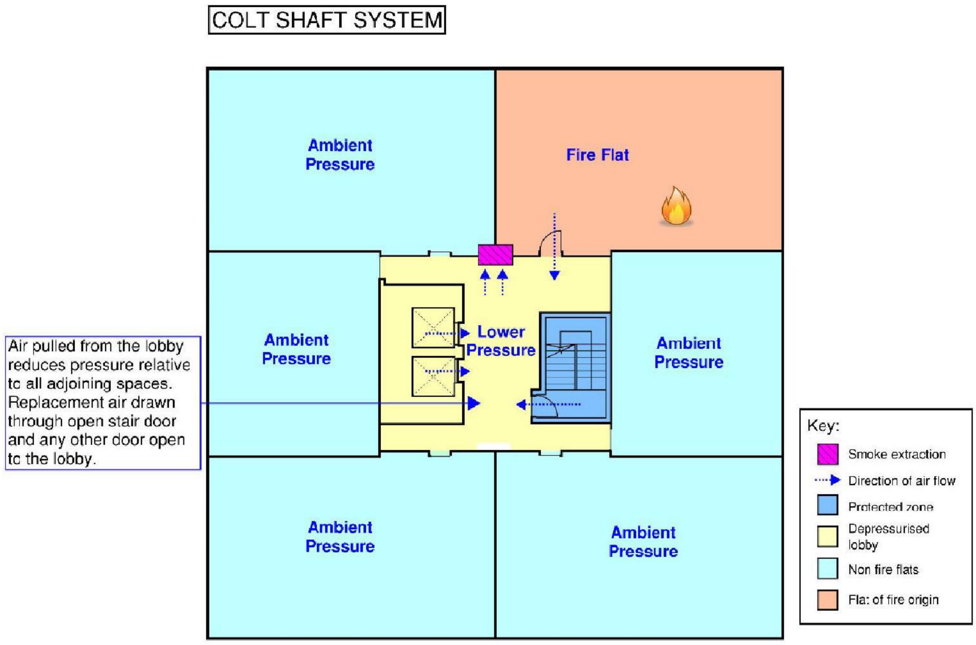


Figure 4-11: ColtShaft arrangement for Grenfell Tower

4.6.19 The publicly available Colt literature does not provide a detailed record of the assumptions as to which doors are assumed to be open or closed for the different stages of a fire (e.g. means of escape and firefighting).

4.6.20 However, Colt literature {INQ00014731} shows the system operating with the door to the protected stair on the fire floor and the door at the fire-service-access-level both open:

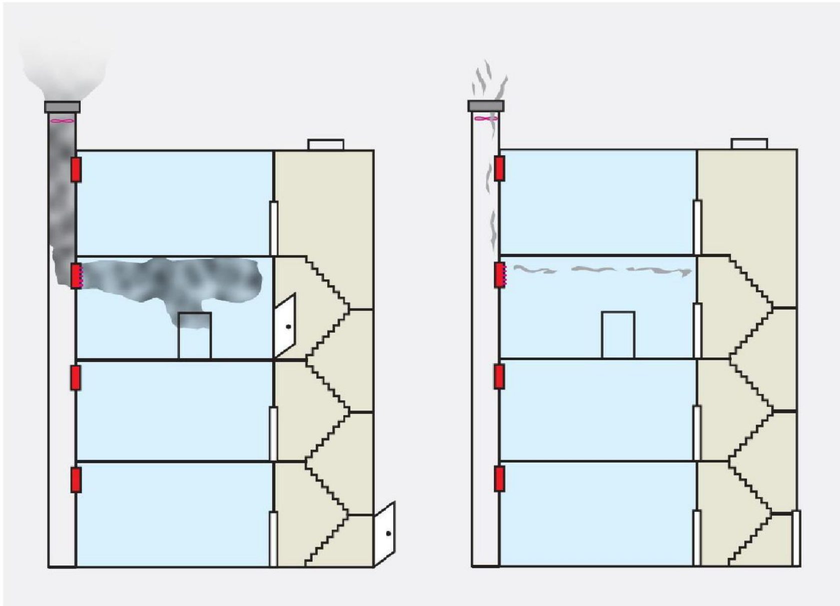


Figure 4-12 Excerpt from ColtShaft data sheet{INQ00014731}

4.6.21 This would be the case for means of escape as described in Section 2 of my report. The ColtShaft data sheet does not say how the system is intended to operate during fire and rescue service operations where the door on the floor below the fire floor is also open to allow the connection of hoses to the dry riser.

4.6.22 To aid in my understanding of the design parameters specified in the ColtShaft Mechanical Shaft system literature, I have referred to two Colt Technical Papers:

a) "*Mechanical Ventilation of Fire-fighting Shafts: Performance and Design*" dated December 2004 by Mr Paul Compton from Colt International Limited (*'the Colt 2004 design report'*) {BLA00005484}

b) "*CFD Analysis of Smoke Ventilation in a Fire Fighting Lobby with a 12MW Unsprinklered Fire*" dated 20th September 2007 by Mr P Compton from Colt International Limited (*'the Colt 2007 design report'*) {BLA00005483}.

4.6.23 I have presented the component specification from the above technical papers in Table 4-6 below.

Table 4-6: ColtShaft system specification from Colt literature

Component	**ColtShaft (from Mechanical ventilation of fire-fighting shafts: performance and design, 2004 {BLA00005484} and CFD Analysis of smoke ventilation in a fire fighting lobby with a 12MW un-sprinklered fire, 2007 {BLA00005483})**

Component	ColtShaft (from Mechanical ventilation of fire-fighting shafts: performance and design, 2004 {BLA00005484} and CFD Analysis of smoke ventilation in a fire fighting lobby with a 12MW un-sprinklered fire, 2007 {BLA00005483})
No. of shafts	1
Fire rating of shafts	{BLA00005484} states: *To be of fire rated construction.*
Area of shafts	{BLA00005484} states: *Nominal size 0.6 m^2 for buildings up to 30 m tall.*
Area of ventilator at head of stair	{BLA00005484} states: *Stairwell ventilator with a geometric area of $1m^2$, located at the head of the stairs.*
Extract fan specification	{BLA00005484} states: *Extract fan set comprising duty and standby fans with automatic changeover. Fans to be rated to operate at 300°C for 2 hours. An extract flow rate is also specified [Rate A].* The 2004 Colt technical paper {BLA00005484} describes the results of the four scenarios which were modelled in respect of mechanically ventilated shafts, at two different extract flow rates ('Rate A' and 'Rate B'): *Mechanically ventilated shaft at [Rate B] , door open condition* *Mechanically ventilated shaft at [Rate A], door open condition* *Mechanically ventilated shaft at [Rate A] door closed condition, no smoke seals* *Mechanically ventilated shaft at [Rate A] door closed condition, with smoke seals* The 2004 technical paper notes that worse performance was provided when extract flowrate of [Rate B] was provided. However, the 2007 technical paper by Colt detailed that an increased extract rate (greater than [Rate A] should be provided for unsprinklered Buildings. Colt literature (2007) does not state what the increased extract rate is. For door open condition, extract flow rate in the lobby calculated with the doors from the accommodation to the lobby, from the lobby to the stairs, from the stairs to the corridor and from the corridor to the exterior were all open and sized at $1.6m^2$ [from 2004 paper {BLA00005484}]. Fan serving single shaft. The extract rate in the Colt literature is extract rate in the lobby.
Maximum pressure drop permitted in shaft	{BLA00005484} states: *To be sized for a maximum pressure drop of 50Pa between highest and lowest storey served*
Floor area of lobby	$12.5m^2$ – rectangular (2.5m x 5m) [per BRE Report 79204]
Door openings from accommodation to lobby	1 door between lobby and accommodation

Component	ColtShaft (from Mechanical ventilation of fire-fighting shafts: performance and design, 2004 {BLA00005484} and CFD Analysis of smoke ventilation in a fire fighting lobby with a 12MW un-sprinklered fire, 2007 {BLA00005483})
Lobby damper geometric minimum area	{BLA00005484} states: *Minimum geometric area 0.8m^2. To be located in the shaft wall to the lobby, as high as possible in each lobby.*
Pressure differential controlled by sensor	Yes. {BLA00005484} states: *If the pressure in the lobby on the fire floor drops below -25Pa the fan slows on inverter control.* The rationale for the 25Pa difference is described in the 2004 technical paper {BLA00005484}: *An obvious concern was whether the mechanical extract would tend to draw excess smoke into the lobby through gaps around the closed door to the accommodation. This condition was therefore also modelled, with the addition of a pressure relief damper in the shaft to limit lobby depressurisation to 25 Pa.*
Smoke detection at each storey	Yes
Firefighter override	{BLA00005484} states: *to be installed at the base of the stairs, or other location agreed with the Fire Authority.*
Power supply	{BLA00005484} states: *A maintained power supply is required in accordance with the requirements of BS5588-5.*
Fire door performance between accommodation and lobby	{BLA00005484} states: *The fire door between the lobby and the accommodation is required to be smoke sealed (S rated).*

4.6.24 The ColtShaft system is an LABC-registered system (Certificate No.: EWW78A first issued 15th Nov 2010 and dated 2nd November 2015) {INQ00014683}. The certificate lists the following systems

Non-standard Colt Shaft and Standard Colt Shaft mechanical ventilation systems for means of escape; and Enhanced Colt Shaft, Standard Colt Shaft and Upgraded Colt Shaft for firefighting

4.6.25 It is not clear whether any of these products include the ColtShaft Variable system.

4.6.26 LABC registration means that the Local Authority Building Control (LABC) considers that the listed systems *"will meet the functional requirements of the building Regulations if the criteria detailed in this certificate are met"*.

4.6.27 It is noted in the LABC Certificate that Colt Shafts *"other than the standard shaft approach will be justified by project specific CFD analysis. All systems are subject to performance testing and commissioning at project completion."*.

4.6.28 CFD stands for Computational Fluid Dynamics. This is a method of numerical analysis which can be used to model the flow of air and smoke during a fire.

4.6.29 Therefore, the LABC Certificate makes clear that project-specific calculations are required for any system other than the *"standard shaft approach"*.

4.6.30 The LABC Certificate for the ColtShaft states {INQ00014683}:

"All systems are subject to performance testing and commissioning at project completion."

4.6.31 The procedures for commissioning and performance testing are not publicly available.

4.6.32 The use of independent certification schemes as a method to demonstrate compliance with the Building Regulations is outlined in the Introduction to ADB 2013 as follows:

Independent certification schemes

There are many UK product certification schemes

Such schemes certify compliance with the requirements of a recognised document which is appropriate to the purpose for which the product is to be used. Products which are not so certified may still conform to a relevant standard.

...

Building Control Bodies may accept the certification of products, components, materials or structures under such schemes as evidence of compliance with the relevant standard. Similarly, Building Control Bodies may accept the certification of the installation or maintenance of products, components, materials or structures under such schemes as evidence of compliance with the relevant standard. Nonetheless, a Building Control Body will wish to establish, in advance of the work, that any such scheme is adequate for the purposes of the Building Regulations.

4.6.33 **Flaktwoods Smoke Shaft Vent System**

4.6.34 I am also aware of FlaktWoods Ltd's *"Smoke Shaft Vent System"* which is described as a *"standardised modular mechanical smoke shaft system for protecting lobbies and corridors in tall buildings."*{INQ00014685}.

4.6.35 It differs from PSB's system in that pressure controls are not used to control the fan extract. Instead, there is a controlled partial opening of the stair/lobby door.

4.6.36 It is also an LABC-registered system (Certificate No. EW 626 first issued 16th March 2016, dated 18th April 2017) {INQ00014686}.

4.6.37 This system was also deemed to "*meet the functional requirements of the Building Regulations*" without individual CFD analysis required for each installation by LABC.

4.6.38 LABC stated this on the basis that {INQ00014685}:

"reference CFD models have been produced for systems at the extremes of the system parameters and these were vetted and approved by the LABC Type Approval process, so providing the building is within the scope of the system then an individual model is not needed."

4.6.39 I note, however, that Flaktwoods's literature {INQ00014684} clearly states that complex designs require the services of a suitably qualified fire engineer:

NOTE – Complex bespoke designs, for example those using twin shafts with reversible fans, fall outside the scope of this guidance and the design of such would require the services of a suitably qualified fire engineer.

4.6.40 I have therefore only provided limited information regarding the Flaktwoods Smoke Shaft Vent System for reference, firstly because this system is not referred to in Mr Mahoney's witness statements and secondly because the system in Grenfell Tower was a complex bespoke design outside the scope of Flaktwoods's registered system.

4.6.41 **Summary of review of proprietary mechanical smoke control systems**

4.6.42 It is my understanding that at the time of the design and installation of the smoke control system in Grenfell Tower, systems with some similar operating features to the final design proposed by PSB at Grenfell Tower were available.

4.6.43 I have also found that these proprietary systems, under specific design conditions, were registered by the LABC as *"meet(ing) the functional requirements of the Building Regulations"*.

4.6.44 The full extent of these scenarios upon which the registration of those proprietary systems was based is not publicly available.

4.6.45 However, I note that the requirement for supporting project-specific calculations for all ColtShaft systems other than the *"standard shaft approach"* (also reflected in the Flaktwoods literature), was required.

4.6.46 I understand this requirement for project-specific calculations to apply where the building design does not comply with the guidance in ADB, and so, a detailed analysis of the system design is required. This may include, for example, the use Computational Fluid Dynamics (CFD) modelling.

4.6.47 As I explain below, this is also consistent with the recommendations in BS9991:2011, the *SCA Guide 2012* and the *SCA Guide 2015* to undertake an analysis to demonstrate the performance achieved by smoke control systems which do not comply with the standards prescribed in ADB.

4.7 Summary of available Mechanical smoke control options

4.7.1 In Sections 4.3 to 4.6 I have summarised the types of mechanical smoke control system that were available to a designer during the Primary Refurbishment of Grenfell Tower.

4.7.2 In Table 4-7 I have summarised the key differences between the available types of mechanical smoke control system, specifically: the areas that are pressurised/ depressurised, how air is supplied and how extraction is provided (where relevant).

Table 4-7 Summary of available mechanical smoke control system types

				Pressure at a given location			
Guidance document	**System type**	**Supply air provided by**	**Extract provided by**	**Stair**	**Lobby**	**Adjacent accommodation**	**Fire zone**
BS EN 12101-6	Class B Pressurisation	Dedicated shaft with supply fan	N/A	Higher pressure	Higher pressure	Relatively lower pressure	Relatively lower pressure
BS EN 12101-6	Class B Depressurisation	Via dedicated shaft or through protected stair	Dedicated shaft with extract fan from fire zone	Ambient pressure	Ambient pressure	Ambient pressure	Lower pressure
SCA Guide 2012/ 2015	Mechanical Extract, Natural Inlet	Dedicated shaft or direct from outside	Dedicated shaft with extract fan	Ambient pressure	Ambient to Lower pressure	Ambient pressure	Not considered
SCA Guide 2012/ 2015	Mechanical Extract, Mechanical inlet	Dedicated shaft with supply fan	Dedicated shaft with extract fan	Ambient pressure	Ambient to Lower pressure	Ambient pressure	Not considered
SCA Guide 2015	Mechanical Extract only	Natural leakage	Dedicated shaft with extract fan	Ambient pressure	Lower pressure	Ambient pressure	Not considered
ColtShaft	ColtShaft	1m^2 inlet at head of protected stair	Dedicated shaft with extract fan	Ambient pressure	Lower pressure	Ambient pressure	Not considered
BS 9991:2011	Mechanical smoke ventilation system (natural inlet or alternative solution)	Required but type not specified	Dedicated shaft with extract fan	Ambient pressure	Ambient to Lower pressure	Ambient pressure	Not considered

4.8 Detailed specification for dampers in smoke control systems

4.8.1 In this section, I set out the detailed performance standard for dampers where they are used in a smoke control system in a high-rise residential building.

4.8.2 Whilst I explain the construction of the smoke control system in full in Section 6 of this report, to aid understanding of the required performance standard for the dampers I provide a brief description of the system in this section of my report.

4.8.3 In Grenfell Tower, smoke was to be extracted from the fire-affected lobby via four openings, two of which were connected to the north shaft which discharged upwards to the external air at roof, and two connected to the south shaft which discharged down to Level 2.

4.8.4 Dampers were relied upon to control the flow of hot gases from the fire floor – both by means of their opening on the fire-affected lobby only, and by means of all other dampers being closed in every other lobby. The flow of hot gases was then to be extracted up through the north shafts, and down through the south shafts, to the external air.

4.8.5 Dampers were also used to control the flow of hot gases at Level 2, where the vertical riser turned into a horizontal run to reach the exterior of the building above the main entrance canopy.

4.8.6 In the horizontal run at Level 2, the ventilation shaft split into two branches; one containing the smoke extract fan and one containing the environmental ventilation supply fan.

4.8.7 There are many types of damper, each with a unique fire performance standard. I will first set out the specific types of damper performance described in ADB 2013, for ventilation and smoke control systems.

4.8.8 I then explain the performance requirements for the dampers installed as part of the smoke control system, which are defined in ADB 2013 and which are necessary to meet the functional requirements of the Building Regulations.

4.8.9 I have also considered the available guidance on damper performance from the SCA Guides.

4.8.10 **Types of dampers for ventilation and smoke control systems**

4.8.11 There are three types of damper, each with a specific operational function in the event of a fire, and each having associated performance requirements.

4.8.12 The three damper types are: fire dampers, fire and smoke dampers and smoke control dampers.

4.8.13 Two of the three damper types are defined in ADB 2013 (fire dampers and fire and smoke dampers), as are the relevant European test and classification standards for those dampers.

4.8.14 The Industry body, the Association for Specialist Fire Protection (ASFP), have produced a document titled '*Grey book Volume 1: Fire dampers (European standards) E (integrity) & ES (integrity and leakage) classified 2nd edition'*. This document was published in October 2011. The foreword to this document states (bold by me):

Fire dampers (E and ES classified) represent a major method used in the United Kingdom and other countries to prevent fire and smoke from passing through heating, ventilation and air conditioning (HVAC) systems, from one compartment to another, and to maintain fire separation for means of escape.

It is common for UK industry to refer to 'E' classified products as 'fire dampers' and 'ES' classified products as 'fire and smoke dampers'.

Volume 1 is concerned with fire dampers tested to EN 1366-2 and classified according to EN 13501-3. Volume 1 does not refer to smoke control dampers which are tested to EN 1366-10 and classified according to EN 13501.4. These smoke control dampers will be covered in a separate Volume 2.

In simple terms, Volume 1 is intended to provide guidance for fire and smoke protection for means of escape routes; and for maintaining the fire compartment, whereas Volume 2 will be focussed on the use of smoke control damper systems in combination with ductwork.

4.8.15 The ASFP Grey book provided a clear explanation regarding the three types of damper and their differing purposes.

4.8.16 I note that the ASFP have not, to date, published volume 2 of the Grey book which was to deal with smoke control dampers.

4.8.17 In the remainder of this Section 4.8, I have set out a description of each type of damper, its intended purpose as derived from ADB 2013, its required performance and its associated classification method in full.

4.8.18 I have also stated where in Grenfell Tower each type of damper was required, based on its function.

4.8.19 <u>Fire Damper</u>

4.8.20 ADB 2013 defines a fire damper as follows:

Fire damper *Mechanical or intumescent device within a duct or ventilation opening which is operated automatically and is designed to prevent the passage of fire and which is capable of achieving an integrity E classification and/or an ES classification to BS EN13501-3:2005 when tested to BS EN1366-2:1999. Intumescent fire dampers may be tested to ISO 10294-5.*

4.8.21 The purpose of a fire damper is to close and remain closed during a fire; preventing the passage of fire. It is required by ADB 2013 to protect openings created by ventilation systems in internal compartmentation.

4.8.22 *B3 Section 10: Protection of openings and fire-stopping* of ADB 2013, requires fire dampers achieving Integrity 'E' classification where air handling ducts pass through fire separating elements, in order to maintain the integrity of those fire separating elements and so satisfy the compartmentation performance of functional requirement B3 Internal fire spread (structure).

4.8.23 The relevant test standard for fire dampers is BS EN 1366-2: 1999 *'Fire resistance tests for service installations. Fire dampers'*.

4.8.24 The introduction to BS EN 1366-2:1999 provides a description of the function of a fire damper as evaluated by the test method:

The purpose of this test is to evaluate the ability of a fire damper to prevent fire and smoke spread from one fire compartment to another through the air ductwork system which may penetrate fire separating walls and floors.

4.8.25 BS EN 1366-2:1999 sets out test procedures and performance criteria on the basis of integrity (E), insulation (I) and leakage (S) for a damper in the closed position.

4.8.26 As I have explained above, fire dampers protecting openings in compartmentation were only required by ADB 2013 to achieve the integrity (E) performance .

4.8.27 The required performance criteria for a fire damper to be classified with integrity (E) in BS EN 1366-2:1999 are:

a) A leakage rate not exceeding $360m^3/(m^2h)$ (corrected to 20°C)

b) Integrity criteria from BS EN 1363-1 Fire resistance test – part 1 general requirements (Cotton pad test, gap gauge test and flaming test)

4.8.28 The relevant classification standard for fire dampers is *BS EN 13501-3:2005 +A1:2009 'Fire classification of construction products and building elements Classification using data from fire resistance tests on products and elements used in building service installations: fire resisting ducts and fire dampers'*.

4.8.29 Therefore, where fire dampers are used to protect ventilation openings in fire-separating elements, they must achieve an 'E' integrity-only classification for fire resistance where the integrity performance is defined in BS EN 1366-2:1999.

4.8.30 <u>Fire and Smoke Damper</u>

4.8.31 ADB 2013 defines a fire and smoke damper as follows:

Fire and smoke damper *Fire damper which when tested in accordance with BS EN 1366-2:1999 meets the ES classification requirements defined in EN 13501-3:2005 and achieves the same fire resistance in relation to integrity, as the element of the building construction through which the duct passes. Intumescent fire dampers may be tested to ISO 10294-2.*

4.8.32 The purpose of a fire and smoke damper is to close and remain closed during a fire, where ai-handling ducts pass through fire-separating elements protecting an escape route.

4.8.33 The requirement for fire and smoke dampers to achieve an Integrity and smoke leakage 'ES' classification is derived from several parts of ADB 2013 including the provisions addressing functional requirement B1 Means of warning and escape and functional requirement B3 Internal fire spread (structure).

4.8.34 Specifically, from paragraph 5 of ADB 2013 under *General Provisions* it states (bold by me):

5.48 ... Note: Fire dampers activated only by fusible links are not suitable for protecting escape routes. ***However an ES classified fire and smoke damper which is activated by a suitable fire detection system may be used****. See paragraph 10.15.*

4.8.35 Within paragraph 8.42 *Openings into protected shafts* it states:

Openings in other parts of the enclosure to a protected shaft should be limited as follows:

...

b. Other parts of the enclosure (other than an external wall) should only have openings for:

...

iii. inlets to, outlets from and openings for a ventilation duct, (if the shaft contains or serves as a ventilating duct) which meet the provisions in Section 10;

4.8.36 And within paragraph 10.13 *Fire Dampers* it states (bold by me):

10.13 Where the use of the building involves a sleeping risk, such as an hotel or residential care home, fire dampers should be actuated by smoke detector-controlled automatic release mechanisms, in addition to being actuated by thermally actuated devices

...

Note: Fire dampers actuated only by fusible links are not suitable for protecting escape routes. ***However an ES classified fire and smoke damper which is activated by a suitable fire detection system may be used****. See paragraph 10.15.*

4.8.37 The relevant test standard and classification standard for a fire and smoke damper is the same as for a fire damper.

4.8.38 For a fire and smoke damper, in addition to the integrity performance criteria, a more stringent leakage criterion is required to achieve the 'S' classification

(less leakage is allowed through the fire and smoke damper, and therefore a lower rate must be measured in the test). The requirements are:

a) A leakage rate not exceeding $200m^3(m^2h)$ (corrected to 20°C)

b) Integrity criteria from BS EN 1363-1 Fire resistance test – part 1 general requirements (Cotton pad test, gap gauge test and flaming test).

4.8.39 A fire and smoke damper for ventilation openings in fire separating elements protecting escape routes achieves an 'ES' classification of fire resistance where the integrity and leakage performance is as defined in BS EN 1366-2:1999.

4.8.40 In summary, the volume of hot gases permitted to leak through a fire and smoke damper is lower than through a fire damper and this is why they are meant for use in protecting escape routes.

4.8.41 Smoke Control Damper

4.8.42 ADB 2013 does not include the phrase smoke control damper, nor does it specify its use directly.

4.8.43 The requirement for smoke control dampers is set out in *BS EN 12101-6:2005 'Smoke and heat control systems. Specification for pressure differential systems. Kits'.*

4.8.44 At paragraph 2.27 '*Smoke control of common escape routes by mechanical ventilation*' of ADB 2013, it refers to BS EN 12101-6:2005 for the design of smoke control systems using pressure differentials

4.8.45 I explain the relevant Clauses from BS EN 12101-6:2005, as follows. Clause 11.8.2 of BS EN 12101-6:2005 '*Requirements for distribution ductwork for pressure differential systems installation*' states (bold by me)

11.8.2.10 if different pressurized or depressurized zones are connected to the same fan or set of fans by a common system of ductwork and/or shafts, ***smoke control dampers*** *shall be used.*

4.8.46 The relevant part of the BS EN 12101 series, for smoke control dampers is *BS EN 12101-8:2011 'Smoke and heat control systems. Smoke control dampers'.*

4.8.47 In the introduction to BS EN 12101-8:2011 the assumed function of smoke control dampers is described and the tests it sets out for smoke control dampers are intended to demonstrate this function:

The tests defined in this standard are based on the assumption that when smoke is detected within a building, all smoke control dampers other than those serving the fire compartment/smoke reservoir (where the fire has initiated) remain closed or move to the closed position. All smoke control dampers serving the smoke affected fire compartment/smoke reservoir remain open or move to the open position, and the fan(s) started/natural vents opened.

4.8.48 The primary functional difference when comparing a smoke control damper with the other two types, is that a smoke control damper must be capable of opening and closing, in the event of a fire.

4.8.49 BS EN 12101-8:2011 '*Smoke and heat control systems. Smoke control dampers*' sets out the performance requirements and relevant test standard and classification standard for smoke control dampers. Paragraph 1 and 2 of the "*Introduction*" of BS EN 12101-8 states:

This European Standard contains the basic performance and requirements for smoke control dampers that are to be used in conjunction with pressure differential systems and smoke and heat control systems. ....

Particular reference is required to EN 1366-10, which defines the furnace testing associated with these products and EN 13501-4, which provides details on their fire resistance classification.

4.8.50 It follows that the relevant test standard for smoke control dampers is *BS EN 1366-10:2011 Fire resistance tests for service installations. Smoke control dampers.*

4.8.51 And the relevant classification standard is *BS EN 13501-4:2007 +A1:2009 'Fire classification of construction products and building elements. Classification using data from fire resistance tests on components of smoke control systems'.*

4.8.52 Therefore BS 12101-8:2011, BS EN 1366-10:2011 and BS EN 13501-4:2007 must all be read together in order to understand the performance requirements for a smoke control damper.

4.8.53 A definition of a smoke control damper is provided in Clause 3.27 of the test standard BS EN 1366-10:2011:

smoke control damper *device automatically or manually activated, which can be open or closed in its operational position, to control the flow of smoke and hot gases into, from or within a duct*

4.8.54 A useful description of the function of smoke control dampers in a smoke control system is provided in paragraphs 1 and 2 of the "Introduction" of BS EN 1366-10:2011 (bold by me)::

When smoke and heat exhaust ventilation are being considered, it becomes apparent that a clear path needs to be made between the area where heat and smoke is being generated (the fire) and the outside of the building.

To create this path there need to be ducts and the smoke extract path needs to remain uninterrupted. ***This means that smoke control dampers at the fire and along the path have to be open and remain open***. ***Smoke control dampers at branches, or on the surface of the duct, along the path need to be closed and remain closed***. *In fact, if the duct crosses a compartment boundary it becomes part of the fire compartment in which the fire started*

4.8.55 What this means is that, depending on the location of a given fire scenario, smoke control dampers may either need to move to the open or closed position so as to create a path for the ventilation of smoke and heat from the fire compartment, but without spreading fire and smoke to other compartments.

4.8.56 The function of a smoke control damper is different to that of a fire damper or a fire and smoke damper in that the latter are required only to close and remain closed during a fire.

4.8.57 It follows that the test procedures for determining the integrity (E) and/or smoke leakage (S) performance of smoke control dampers differ from the test procedures for a fire damper or fire and smoke damper.

4.8.58 I have set out the performance requirements for a smoke control damper to demonstrate the key differences between a smoke control damper and fire dampers and fire and smoke dampers. The requirements set out here are not exhaustive.

4.8.59 Paragraph 3 of the "Introduction" of BS EN 1366-10:2011 provides a description of the function of a smoke control damper that the test method evaluates:

The purpose of this European Standard is to define test methods to evaluate the abilities of smoke control dampers to;

1) be applicable to single compartment and/or multi compartment fire resisting applications;

2) be applicable to automatic systems or systems with manual intervention;

3) change state from closed to open at elevated temperatures, and vice versa;

4) once opened maintain a defined cross sectional area at elevated temperature;

5) maintain a satisfactory leakage performance when subjected to negative pressure at elevated temperatures.

4.8.60 Performance criteria are defined for single compartment and multi-compartment smoke control dampers. However, I have only set out the requirements for multi-compartment smoke control dampers as these are relevant to Grenfell Tower. This is because, in essence, every floor in Grenfell Tower was to be a multi-compartment floor.

4.8.61 Four performance criteria for determining the Integrity (E) of multi-compartment smoke control dampers are defined in Clause 4.4.1 BS EN 12101-8:2011 '*Smoke and heat control systems. Smoke control dampers*' as follows:

The assessment of integrity (E) of multi compartment smoke control dampers, as one of the fire resistance performance characteristics, shall be made on the basis of:

a) leakage through the damper at ambient and when closed after 5 min (automatic operation) or 30 min (systems with manual intervention) from the start of the fire test,

b) the ability of the damper to maintain its opening when subjected to the fire test,

c) cracks or openings in excess of given dimensions and ignition of a cotton pad and sustained flaming on the non-exposed side at the perimeter of the damper junction with the wall or floor or duct (the penetration),

d) the suitability for use of the damper at an under pressure, measured at ambient.

4.8.62 Two performance criteria for integrity (E), item (a) and (c) are the same as those required for a fire damper or a fire and smoke damper.

4.8.63 Accordingly, for a smoke control damper two additional criteria are defined for the purpose of determining Integrity (E) performance at (b) and (d) above.

4.8.64 The first is the ability of the damper to maintain its opening at elevated temperatures (b).

4.8.65 The smoke control damper is deemed to have failed the maintenance of opening test when the mass flow of air is restricted to 75% of the theoretical maximum flow rate through the damper.

4.8.66 This criterion is important as in the open position smoke control dampers are required to allow sufficient venting of hot smoke and gases from the fire through the ventilation system. This criterion is a test of a smoke control dampers performance as a ventilator.

4.8.67 The second is the suitability for use at an under pressure (d). When testing a smoke control damper, the intended operating pressure of the system within the ductwork is required to be known so that the test can be carried out at an appropriate pressure thereby demonstrating the suitability of the damper.

4.8.68 The requirement for smoke leakage performance (S), where required, for a smoke control damper is set out in BS EN 12101-8:2011 and BS EN 13501-4:2007 as 200 $m^3/(m^2h)$ (a) above.

4.8.69 The smoke leakage performance criteria are the same as those for a fire and smoke damper.

4.8.70 But it is important to note that the test <u>method</u> for evaluating both Integrity (E) performance and smoke leakage performance is different. The key differences are as follows:

a) A smoke control damper is subjected to a greater number of open/close cycles prior to testing. This is termed the durability of operational reliability. A smoke control damper intended for a combined smoke and environmental ventilation system is subjected to 10,200 open/close cycles prior to fire testing. A fire damper and fire and smoke damper is subject to just 50 open/close cycles.

b) The ability of a smoke control damper to change from the open to the closed position or vice versa at elevated temperatures is tested. This is required where a system is designed with a manual intervention function such as the firefighter override switches. Fire dampers and fire and smoke dampers are not subjected to this test.

4.8.71 These key requirements in the test methodology when evaluating the integrity and smoke leakage performance (ES) of smoke control dampers are more onerous than the conditions applied when testing fire dampers and fire and smoke dampers.

4.8.72 <u>Summary of key differences in performance for the three types of dampers</u>

4.8.73 In Table 4-8, I have summarised my description of the three types of dampers, their purpose as follows from ADB 2013 and the key differences in methods of testing and classification.

Table 4-8: The three types of dampers and the key test conditions leading to classification and differentiation

Type of Damper		Fire Damper	Fire and Smoke Damper	Smoke Control Damper
Required by ADB		Where air handling ducts pass through fire separating elements (paragraphs 10.11 to 10.15 of ADB 2013)	Where air handling ducts pass through fire separating elements protecting escape routes (paragraphs 10.11 to 10.15 of ADB 2013)	In mechanical smoke ventilation systems (paragraph 2.27)
Classification Standard		*BS EN 13501-3:2005 +A1:2009 Fire classification of construction products and building elements. Classification using data from fire resistance tests on products and elements used in building service installations: fire resisting ducts and fire dampers*	Same as Fire Damper	*BS EN 13501-4:2007 +A1:2009 Fire classification of construction products and building elements. Classification using data from fire resistance tests on components of smoke control systems*
Integrity (E)	Classification Required	YES	YES	YES
	Performance criterion – leakage 360m^3/(h.m^2)	YES	YES	YES
	Performance criterion – Cotton pad, gap gauge and flaming tests	YES	YES	YES
	Performance criterion – maintain of opening at elevated temperatures	NO	NO	YES
	Suitability at a given under pressure	NO	NO	YES
Smoke Leakage (S)	Classification Required	NO	YES	YES
	Performance criterion – leakage 200m^3/(m^{2}h)	NO	YES	YES
Test Standard		*BS EN 1366-2 Fire resistance tests for service installations. Fire dampers*	Same as Fire Damper	*BS EN 1366-10:2011 Fire resistance tests for service installations. Smoke control dampers*
Test method to evaluate performance (selected key differences)	Durability of operational reliability – no. of open/close cycles prior to test	50	50	10200
Test method to evaluate performance (selected key differences)	–Manual intervention - Change of damper open/close position at elevated temperatures –	NO	NO	YES

4.8.74 Dampers installed in Grenfell Tower as part of smoke control system

4.8.75 In the previous section I have described the three types of dampers available for different applications.

4.8.76 In this section I provide an explanation of each type of damper based on its function relevant to the Grenfell Tower smoke control system.

4.8.77 The smoke control system in Grenfell Tower was intended to ventilate smoke and heat from a fire-affected lobby via ventilation shafts to the north and south of the lobby.

4.8.78 At Ground Level and Levels 1 and 3 there were two openings per lobby to the ventilation shafts, one to the north shaft and the other to the south shaft. Dampers were provided to these openings. I have provided an example of the location of the dampers at Level 3 in Figure 4-13:.

4.8.79 All of these dampers were required to be smoke control dampers as they all needed to function in either the open or closed position, depending on the operation mode of the smoke control system.

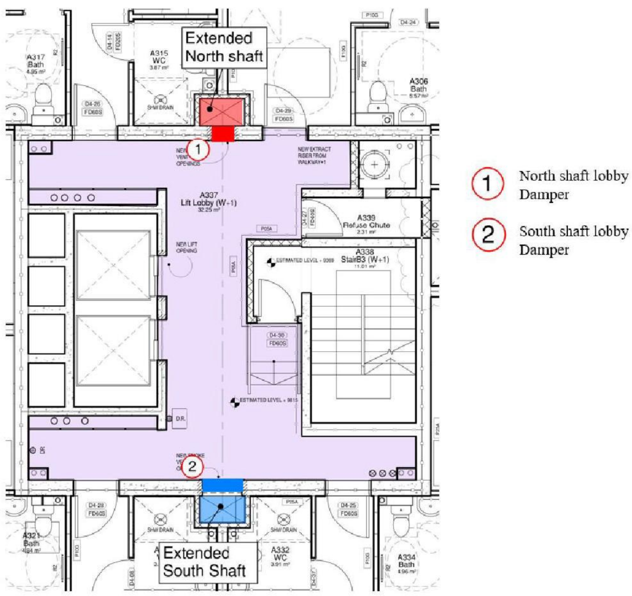


Figure 4-13: Location of smoke control dampers at Level 3

4.8.80 From Levels 4 to 23 there were four openings per lobby to the ventilation shafts, two each to the north and south shafts. Dampers were also provided to these openings.

4.8.81 All of these dampers were required to be smoke control dampers as they all needed to function in either the open or closed position, depending on the operation mode of the smoke control system.

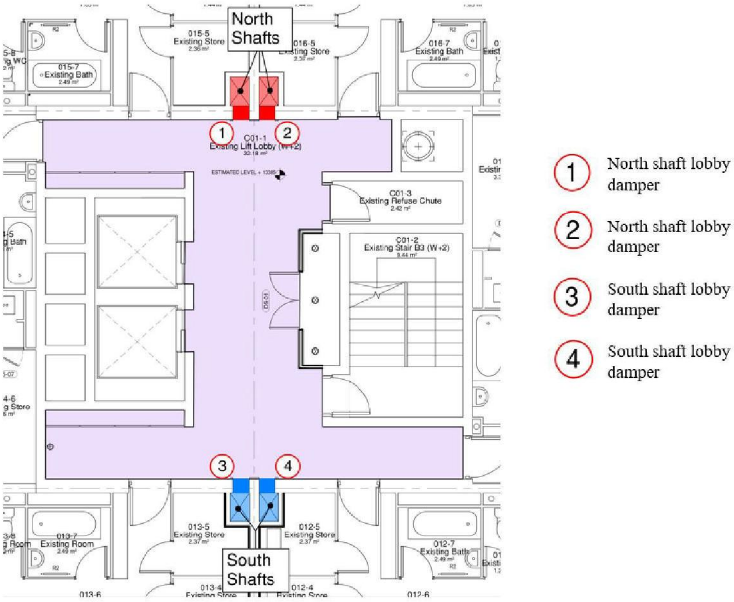


Figure 4-14: Location of smoke control dampers at level 4-23

4.8.82 At Level 2, horizontal ductwork was also provided to exhaust smoke from the south shaft to the exterior of the tower. Two branches of ductwork were provided: one containing the smoke extract fan and one containing an environmental supply fan.

4.8.83 There were four dampers installed as part of the refurbishment smoke control system on Level 2: two environmental shutoff dampers and two smoke fan shut off dampers. All four of these dampers were required to be smoke control dampers as they all needed to function in either the open or closed position, depending on the operation mode of the soke control system.

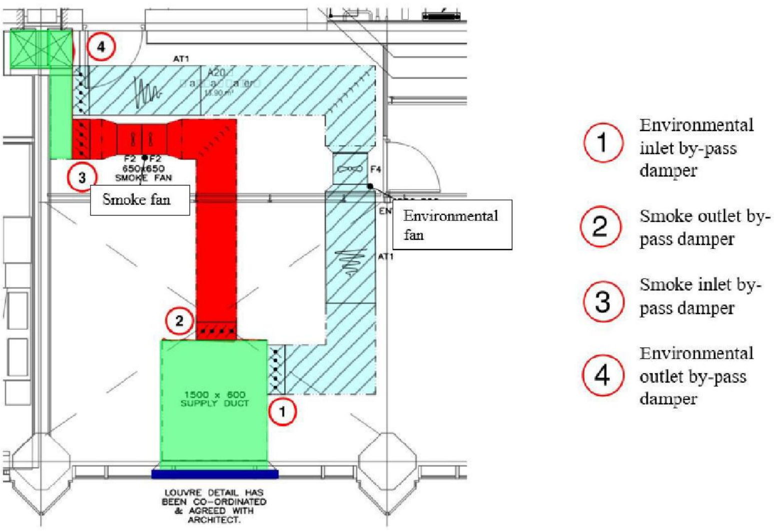


Figure 4-15: Location of smoke control dampers at level 2

4.8.84 **Building-specific performance standard for the required smoke control dampers**

4.8.85 ADB 2013 does not set out building-specific performance standards for smoke control dampers used in a mechanical ventilation system e.g. E60S or E120S.

4.8.86 I have therefore interpreted the performance standard by reviewing the provisions made for the smoke control of common escape routes by mechanical ventilation (paragraph 2.27) and protected shafts (paragraph 8.7).

4.8.87 Paragraph 2.27 of ADB 2013 refers to BS EN 12101-6:2005 '*Smoke and heat control systems —Part 6: Specification for pressure differential systems — Kits*' for guidance on the design of systems using pressure differentials.

4.8.88 Clause 11.8.2 of BS EN 12101-6:2005 '*Requirements for distribution ductwork for pressure differential systems – installation*' states (bold by me)

11.8.2.10 if different pressurized or depressurized zones are connected to the same fan or set of fans by a common system of ductwork and/or shafts, ***smoke control dampers*** *shall be used.*

4.8.89 As I have set out in the previous section, the relevant part of the BS EN 12101 series for smoke control dampers is BS EN 12101-8:2011, the relevant test standard is BS EN 1366-10:2011 and the relevant classification standard is BS EN 13501-4:2007.

4.8.90 None of these standards provide a building specific duration of performance or classification of performance, for a smoke control damper.

4.8.91 Paragraph 8.7 of ADB 2013 contains the requirement for spaces that connect compartments to be protected shafts. The smoke control system in Grenfell Tower penetrated every compartment floor and was therefore required to be a protected shaft.

4.8.92 Paragraph 8.37 sets out the performance requirements for the construction of a protected shaft:

The construction enclosing a protected shaft (see Diagram 31) should:

a. form a complete barrier to fire between the different compartments which the shaft connects;

b. have the appropriate fire resistance given in Appendix A, Table A1, except for uninsulated glazed screens which meet the provisions of paragraph 8.38; and

c. satisfy the provisions about their ventilation and the treatment of openings in paragraphs 8.41 and 8.42.

4.8.93 Based on Tables A1 A2 the required fire resistance for a protected shaft in a residential building more than 30m tall is REI120 (i.e. 120 minutes fire resistance in terms of loadbearing capacity (R), integrity (E), and Insulation (I)) with sprinklers). See definitions in Table 4-9 below.

Table 4-9: Definitions of loadbearing, integrity, and insulation per BS 476-20 and BS EN 13501-2 as referenced in ADB 2013

Parameter	Definition per:	
	Part of BS 476-20:1987 ***Fire tests on building materials and structures — Part 20: Method for determination of the fire resistance of elements of construction (general principles)***	**BS EN 13501-2:2007+A1:2009** ***Fire classification of construction products and building elements — Part 2: Classification using data from fire resistance tests, excluding ventilation services***
Loadbearing (R)	the ability of a specimen of a loadbearing element to support its test load, where appropriate, without exceeding specified criteria with respect to either the extent of, or rate of, deformation or both;	Loadbearing capacity R is the ability of the element of construction to withstand fire exposure under specified mechanical actions, on one or more faces, for a period of time, without any loss of structural stability.
Integrity (E)	the ability of a specimen of a separating element to contain a fire to specified criteria for collapse, freedom from holes, cracks and fissures and sustained flaming on the unexposed face	is the ability of the element of construction that has a separating function, to withstand fire exposure on one side only, without the transmission of fire to the unexposed side as a result of the passage of flames or hot gases. They may cause ignition either of the unexposed surface or of any material adjacent to that surface.
Insulation (I)	the ability of a specimen of a separating element to restrict the temperature rise of the unexposed face to below specified levels	is the ability of the element of construction to withstand fire exposure on one side only, without the transmission of fire as a result of significant transfer of heat from the exposed side to the unexposed side. Transmission shall be limited so that neither the unexposed surface nor any material in close proximity to that surface is ignited. The element shall also provide a barrier to heat, sufficient to protect people near to it.

4.8.94 The openings between each lobby and the ventilation shafts serving the lobby, were therefore required to be protected, as per paragraph 8.42 headed '*Openings into protected shafts*' of ADB 2013 (see Section 4.8.35, above).

4.8.95 Section 10 *Protection of openings and fire stopping*, paragraph 10.13 *Fire Dampers* of ADB 2013 requires openings to achieve an ES classification for the protection of escape routes (see Section 4.8.36, above).

4.8.96 Paragraph 10.15 of ADB 2013 defines the classification and minimum duration of performance (bold by me):

10.15 Fire dampers should be tested to BS EN 1366-2:1999 and be classified to BS EN 13501-3:2005. They should have an E classification equal to, or greater than, 60 minutes. ***Fire and smoke dampers should also be tested to BS EN 1366-2:1999 and be classified to BS EN 13501-3. They should have an ES classification equal to, or greater than, 60 minutes.*** *Note 1: Fire dampers tested using ad-hoc procedures based on BS 476 may only be appropriate for fan-off situations. In all cases, fire dampers should be installed as tested. Note 2: Paragraphs 5.46 and 8.40 also deal with ventilation and air-conditioning ducts.*

4.8.97 Accordingly, Paragraph 10.15 requires fire and smoke dampers in the protected shaft to achieve only E60S (i.e. 60 minutes integrity and smoke leakage performance) rather than the full REI 120 (i.e. loadbearing capacity, integrity and insulation). This provision in ADB 2013 assumes all dampers are shut and remain closed in the fire.

4.8.98 However, in a smoke control system one damper is open and so the protected shaft is part of the fire compartment. Accordingly, the full requirement for 120 minutes should be provided. Therefore, based on the requirements of Section 8 and Section 10 of ADB 2013 the performance classification required is E120S.

4.8.99 In summary, to comply with the performance standard provided at paragraph 2.27 of ADB 2013 a smoke control damper was required. Neither ADB 2013 nor the relevant standards specify a building specific duration of performance for this type of damper.

4.8.100 Based on Sections 8 and 10 of ADB 2013 the minimum duration of performance for a fire damper protecting an escape route is E120S.

4.8.101 Therefore, a smoke control damper tested to BS EN 1366-10:2011 and classified to BS EN 13501-4:2007 as E120S would satisfy the requirements of ADB 2013.

4.8.102 **Performance standards from industry Guidance - the *SCA Guide***

4.8.103 The *SCA Guide 2012* sets out performance standards for the installation and equipment used in ventilation systems in Section 8.

4.8.104 One product is listed in Section 8 for use in ventilating from a corridor or lobby into smoke shaft or a smoke control duct: "*Automatic opening vent (smoke control damper)*"

4.8.105 The *SCA Guide 2012* sets outs a performance standard of equivalence to E30Sa as follows:

The damper at the fire/smoke source must open to allow the smoke/heat to be extracted and therefore have proven ability to maintain its opening. ADB recommends that dampers on a non-fire floor should be closed and capable of performing to the equivalent of an E30Sa Fire Door. Dampers tested to the standards below should satisfy this requirement. Dampers should be actuated using drive open drive close actuators. Spring return actuators and fusible links must not be used.

4.8.106 A performance equivalent to an E30Sa fire door is required by ADB 2013 for natural smoke ventilation systems in paragraph 2.26, where they do not also connect different compartments. As I have set out above, at Grenfell Tower the shafts were also required to act as protected shafts and so the performance requirements for openings to protected shafts applied instead.

4.8.107 The *SCA Guide 2012* goes on to set out the relevant standards for testing and classification of smoke control dampers:

There are several applicable smoke control damper standards and these are listed below:

prEN 12101-8: Smoke and heat exhaust ventilation: Smoke control dampers

prEN 1366-10: Fire resistance tests for service installations: Smoke control dampers

BS EN 13501-4: Fire classification of construction products and building elements - part 4: classification using data from fire resistance tests on components of smoke control systems

NOTE: The above standards state that smoke control dampers under automatic control of a smoke control system working directly from fire or smoke sensor inputs must be proven by test to shut (and open) within 60 seconds, having been actuated 30 seconds after the start of the test.

4.8.108 The *SCA Guide 2012* then further defines three alternative methods of testing:

Any damper tested as fire resisting (tests are made using the standard time/temperature curve), supported by an ad hoc operation test at elevated temperature (e.g. 300° and/or 600°C for 1 hour etc) using a drive open/drive close actuator could also be acceptable:

These test standards are listed below:

BS EN 1366-2: Fire resistance tests for service installations: Fire dampers - plus ad hoc test report 300° and/or 600°C for 1 hour etc

BS EN 1366-2: Fire resistance tests for service installations: Fire dampers - plus modified HOT400/30 test from prEN1366-10 using 300° and/or 600°C for 1 hour etc

Dampers tested in the closed position to BS 476-20 could also be suitable.

4.8.109 Therefore, the *SCA Guide 2012* sets out four possible methods of demonstrating the performance of smoke control dampers used to ventilate from a lobby into a smoke shaft or smoke control duct:

a) Tested per the requirements of BS EN 12101-8:2011 to BS EN 1366-10:2011 and classified to BS EN 13501-4:2007;

b) Tested to BS EN 1366-2 plus ad hoc test report 300° and/or 600°C for 1 hour etc;

c) Tested to BS EN 1366-2 plus modified HOT400/30 test from prEN1366-10 using 300° and/or 600°C for 1 hour etc;

d) Tested in the closed position to BS 476-20

4.8.110 Item (a) above aligns with the method of demonstrating performance I derived from ADB 2013 in the previous sections, for a smoke control damper.

4.8.111 Items (b) to (d) appear to have been derived uniquely by the authors of the *SCA Guide*. I have found no other published standard setting out these methods of demonstrating performance.

4.8.112 I note that the four performance standards were changed in the *SCA Guide 2015* to become a single performance standard instead:

Smoke control dampers should as a minimum be classified to BS EN 12101-8. Further guidance on the application of the products is given in BS 7346 Part 8.

4.8.113 The *SCA Guide 2015* therefore recommends only one method of demonstrating performance of a smoke control damper, in accordance with BS EN 12101-8:2011 which, as I have set out above, is the relevant part of the BS EN 12101 series for smoke control dampers.

4.8.114 **Summary of tests, classification method, and building specific performance for smoke control dampers installed in the smoke control system**

4.8.115 In Table 4-10 I have set out the possible classifications for the dampers in Grenfell Tower as I have understood and explained them in this section.

4.8.116 For completeness please note that at the time of construction the vertical risers connecting each lobby in Grenfell Tower were required to achieve a fire resistance standard of 60 minutes in accordance with the London Building (Constructional) Bylaws. As I explained in Section 3 of my Phase 1 report {BLAS0000003}:

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

Figure 4-16: Section 3 of my Phase 1 report {BLAS0000003}

4.8.117 Therefore, to maintain compartmentation, by means of this protected shaft, with one open smoke control damper, as a minimum it would be reasonable for the design specification to refer to a 60-minute Integrity and smoke leakage standard (E60S) for the smoke control damper.

4.8.118 This is distinct from the 120-minute REI standard required by ADB 2013 for sprinklered blocks of flats at the time of the primary refurbishment (with reference to Table A1 and Table A2 of ADB 2013 for protected shafts).

Table 4-10: Summary of possible classifications for the dampers installed in Grenfell Tower

Standard	Type	Test standard	Classification standard	Building specific performance
ADB 2013, and BS EN 12101- 6	British standard referenced by statutory guidance	BS EN 1366-10:2011	BS EN 13501-4:2007	E60S
SCA Guide 2012	Industry guidance	BS EN 1366-10:2011	BS EN 13501-4:2007	Not specified
		BS EN 1366-2:1999 plus Ad hoc test report 300° and/or 600°C for 1 hour	Not specified	Not specified
		BS EN 1366-2:1999 plus modified HOT400/30 test from prEN1366-10 using 300° and/or 600°C for 1 hour	Not specified	Not specified
		Tested in the closed position to BS 476-20	Not specified	Not specified
SCA Guide 2015	Industry guidance	BS EN 1366-10:2011	BS EN 13501-4:2007	Not specified

4.9 Performance specification for ductwork in smoke control systems

4.9.1 The original north and south smoke shafts in Grenfell Tower were formed of masonry and served Levels 4 to 23 (refer to Section 6).

4.9.2 One of the north shafts and one of the south shafts were then extended down to ground level as part of the primary refurbishment.

4.9.3 Figure 4-17, shows a cross section through the lower floors of Grenfell Tower {PSB00000603}. The yellow boxes, red boxes and labels on the drawing were added by Rydon as an explanation to PSB for the route of the new smoke shaft to extend the system from Level 4 to Ground floor and hence where new openings were required to be cut through the existing construction.

4.9.4 Labels A-H indicated new openings to be provided for the extension of the north shaft with corresponding dimensions provided on page 4 of {PSB00000603}.

4.9.5 Labels 1-8 indicated new openings to be provided for the extension of the south shaft with corresponding dimensions provided on page 5 of {PSB00000603}.

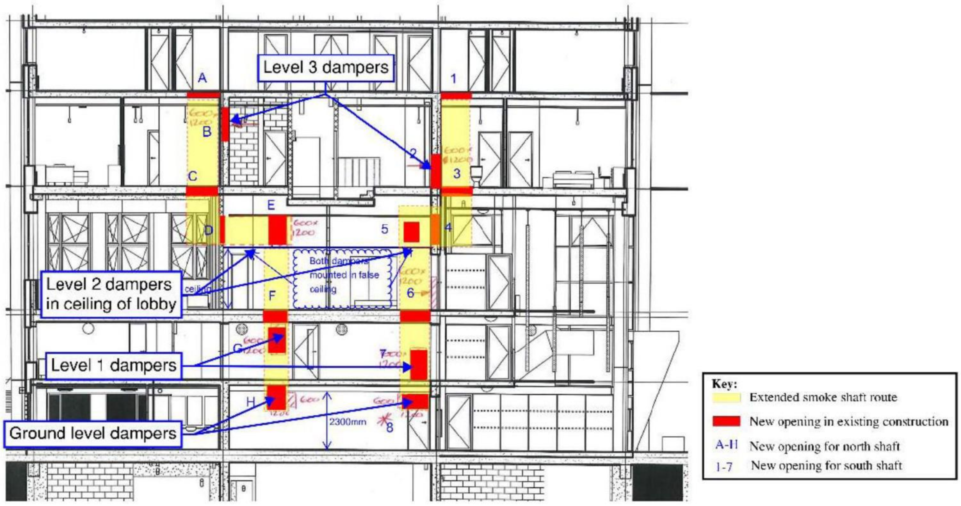


Figure 4-17: Cross section of Grenfell Tower showing location of new vertical shafts highlighted in yellow. Blue letters and numbering in the background per the original {PSB00000603}.

4.9.6 Neither the Studio E as built drawings nor the JS Wright as built drawings in the Rydon Building Manual {TMOM00000001} to {TMOM00002199} state what construction detail or materials were used for the extended smoke shaft.

4.9.7 I have found conflicting evidence for what material the extended vertical risers were constructed from.

4.9.8 On 24th June 2015 Mr North (Rydon) emailed Mr Bradbury (Rydon) stating {JSW00002590} (bold by me):

*Once I have drilled the openings from walkway plus 1 down to walkway for the AOV, am I then able to **close it in with blockwork**?*

4.9.9 Mr Bradbury responded the same day stating {PSB00000600}:

There is no requirement for any working parts or liners so the blockwork can be done straight away.

4.9.10 On 15th December 2015, Mr Hughes (Rydon) emailed Ms Williams KCTMO stating {RYD00061823} (bold by me):

The current status of the ventilation/ extraction system is

*Last core hole being finished today- **plasterboard shaft to be built afterwards***

4.9.11 As I am unable to confirm the construction of the new shafts between Ground Level and Level 3, I am unable to set out the specific performance requirements so as to carry out an assessment of compliance of the construction.

4.9.12 New horizontal metal ductwork was also provided connecting the extended south smoke shaft to a vent on the outside of the building at Level 2, and via the smoke extract fans shown below in Figure 4-18:.

Figure 4-18: Horizontal fire-rated ductwork at level 2

4.9.13 I provide the resulting performance standard, which I have derived from ADB 2013, as follows.

4.9.14 Performance standard derived from ADB 2013

4.9.15 Section 10 *Protection of openings and fire-stopping* of ADB 2013 states:

Ventilation ducts, flues etc.

10.9 Where air handling ducts pass through fire separating elements the integrity of those elements should be maintained.

There are three basic methods and these are:

- Method 1 Protection using fire dampers;
- Method 2 Protection using fire-resisting enclosures;
- Method 3 Protection using fire-resisting ductwork.

Figure 4-19: Excerpt of Section 10 of ADB 2013

4.9.16 The horizontal ductwork at Level 2 of the tower passed through the protected stair enclosure which was rated for a 120-minute integrity, insulation and load bearing performance. See Figure 4-20 below.

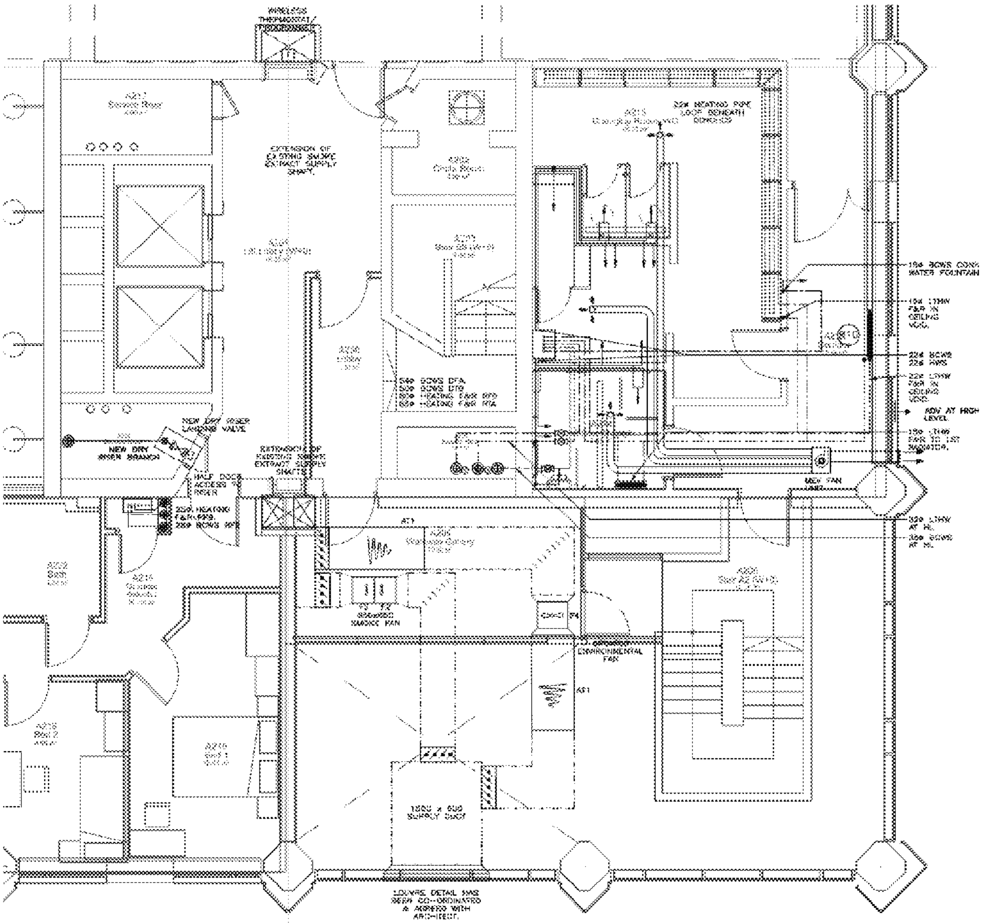


Figure 4-20: Excerpt from JSW As Installed drawing showing Level 2 ductwork passing through protected stair enclosure {TMOM00000152}

4.9.17 Paragraph 8.7 of ADB 2013 states:

Protected shafts

8.7 Spaces that connect compartments, such as stairways and service shafts, need to be protected to restrict fire spread between the compartments and they are termed protected shafts. Any walls or floors bounding a protected shaft ***are considered to be compartment walls or floors*** *for the purpose of this Approved Document*

4.9.18 A protected shaft is defined in Appendix E of ADB 2013 as:

A shaft which enables persons, air or objects to pass from one compartment to another and which is enclosed with fire-resisting construction.

4.9.19 The horizontal metal ductwork at Level 2 of Grenfell Tower was therefore required to be a protected shaft.

4.9.20 And paragraph 8.20 of ADB 2013 states:

8.20 ***Every compartment wall and compartment floor*** *should:*

a. form a complete barrier to fire between the compartments they separate; and

b. ***have the appropriate fire resistance as indicated in Appendix A, Tables A1 and A2.***

4.9.21 The horizontal metal ductwork at Level 2 passed through the 120-minute fire resistant protected stair.

4.9.22 The ductwork was therefore required to be fire rated to comply with Method 3 of Paragraph 10.9 of ADB 2013.

4.9.23 To maintain this fire resistance performance of the stair enclosure, the Level 2 duct work at Grenfell Tower was therefore required to achieve 120 minutes' stability, integrity and insulation when tested to the relevant part of BS 476 (in this case BS 476 Fire Tests on building materials and structures: Part 24 (1987) Method for determination of the fire resistance of ventilation ducts).

4.9.24 Or EI 120 to the relevant European standard (in this case BS EN 1366 Part 8: Smoke Extraction Ducts, Fire Resistance Tests for Service Installations) to provide a complete barrier to fire.

4.9.25 **Performance standard referred to from BS EN 12101-6:2005**

4.9.26 While ADB 2013 provides a specific performance standard for ductwork paragraph 2.27 of ADB 2013 also states:

2.27 As an alternative to the natural ventilation provisions in paragraph 2.26, mechanical ventilation to the stair and/or corridor/lobby may be provided to protect the stair(s) from smoke.

Guidance on the design of smoke control systems using pressure differentials is available in BS EN 12101-6:2005.

4.9.27 In Clause 11.8 *Requirements for distribution ductwork for pressure differential systems – installation* of BS EN 12101-6:2005, it is stated that (bold by me):

11.8.2.15 All smoke extraction pressurization release and depressurization ductwork and supporting construction shall have ***resistance to collapse and fire penetration*** *equal to that of the structure within which it is installed.*

11.8.2.17 Insulation of ducts shall be resistant to the transfer of excessive heat denoted by I(insulation) in the European classification of the resistance to fire performance.

4.9.28 As I have explained above, the Level 2 ductwork passed through the 120-minute fire resistant protected stair.

4.9.29 To maintain the fire resistance performance of the protected stair, the Level 2 ductwork at Grenfell Tower was therefore required to achieve 120 minutes' stability, integrity and insulation when tested to the relevant part of BS 476 (in this case BS 476-24) or EI 120 to the relevant European standard (in this case BS EN 1366 Part 8: Smoke Extraction Ducts, Fire Resistance Tests for Service Installations) to provide a complete barrier to fire.

4.9.30 Clause 11.8 also requires ductwork to be meet the requirements from BS EN 12101-7, BS EN 13501-3 and BS EN 13501-4 as follows:

11.8.2.1 Ductwork shall be tested and classified in accordance with prEN 13501-3 or prEN 13501-4 and shall have a classification performance appropriate to the design criteria according to prEN 12101-7.

4.9.31 These standards are:

a) BS EN 12101-7:2011 Smoke and heat control systems. Smoke duct sections;

b) BS EN 13501-3:2005+A1:2009 Fire classification of construction products and building elements. Classification using data from fire resistance tests on products and elements used in building service installations: fire resisting ducts and fire dampers; and

c) BS EN 13501-4:2007+A1:2009 Fire classification of construction products and building elements. Classification using data from fire resistance tests on components of smoke control systems.

4.9.32 These standards set out requirements for the integrity, insulation, and leakage performance for the ductwork.

4.9.33 Any additional building specific duration of performance required, is not addressed in these standards.

4.9.34 The minimum duration in respect of ductwork had to be at least equivalent to that of the separating element.

4.9.35 For Grenfell Tower, as I have explained above, in Section 3 the standard required was 120 minutes to comply with the GLC Section 20 Code of Practice.

4.9.36 **Performance standard referred to from industry guidance *SCA Guide 2012***

4.9.37 Section 8.2.6 *Smoke control ducts* of the *SCA Guide 2012* states (bold by me):

***Ductwork needs to maintain cross-sectional area at elevated temperature matching the fan specification, typically 300°C for 60 minutes**, so that an unacceptable increased pressure drop does not occur, reducing the rate of extraction.*

...

Smoke control duct sections can be tested to the standard/time temperature curve, confirming their fire resistance. The following are the CEN product standard (certification and CE marking), test standard and classification standards respectively.

prEN 12101-7: Smoke and heat exhaust ventilation: Smoke control duct sections

BS EN 1366-8: Fire resistance tests for service installations: Smoke extraction ducts (multi compartment)

BS EN 13501-4: Fire classification of construction products and building elements - part 4: classification using data from fire resistance tests on components of smoke control systems

As an alternative, any duct tested as fire resisting could meet this requirement, if these tests are made using the standard time time/temperature curve – these test standards are as follows:

• *BS 476-24: Fire tests on building materials and structures – part 24: Method for the determination of the fire resistance of ventilation ducts*

• *BS EN 1366-1: Fire resistance tests for service installations: Ducts*

• *Note: Although in these instances no specific limits are made with respect to loss of cross-sectional area, BS476-24 includes this as an additional observation, so careful examination of test reports should be made.*

4.9.38 In summary the recommended performance standard for smoke control ducts in the *SCA Guide 2012* is such that they must maintain a cross-sectional area at elevated temperature matching the fan specification (which in this case of Grenfell Tower was rated for 1000°C) when tested to BS EN 1366-8; BS 476-24; or BS EN 1366-1.

4.9.39 I note that maintenance of cross-sectional area is just one of five measures used to determine integrity performance in BS EN 12101-7:2011 and BS EN 13501-4:2007.

4.9.40 **Summary of requirements for the Grenfell Tower system**

4.9.41 In Table 4-11, I have summarised the classification options available to a designer for specifying the building specific performance for the horizontal metal ductwork at level 2 of Grenfell Tower.

Table 4-11: Summary of possible classifications for the horizontal metal ductwork at Level 2 of Grenfell Tower

Standard	Type	Test standard	Classification standard	Possible building specific performance
ADB 2013	Statutory guidance	BS 476-24	N/A	120 minutes stability, integrity and insulation)
ADB 2013, and BS EN 12101-6:2005	British standard referenced by statutory guidance	BS EN 1366-8	BS EN 13501-4:2007	EI 120
SCA Guide 2012	Industry guidance	BS EN 1366-8; BS 476-24; or BS EN 1366-1	N/A	Maintain cross-sectional area at 1000°C.

4.10 Performance requirements for fans in smoke control systems

4.10.1 **Smoke extract fans in Grenfell Tower**

4.10.2 Four smoke extraction fans were installed in the refurbishment smoke control system, one combined fan unit in the roof plant room (duty and standby) and one combined fan unit at Level 2 (duty and standby).

4.10.3 **Performance requirement from ADB 2013**

4.10.4 ADB 2013 does not specifically refer to a performance standard for smoke extract fans.

4.10.5 By means of paragraph 2.27 of ADB 2013 refers to BS EN 12101-6:2005 '*Smoke and heat control systems —Part 6: Specification for pressure differential systems — Kits*'.

4.10.6 In the next section I present the performance standard for smoke extraction fans referred to from BS EN 12101-6:2005.

4.10.7 **Performance standard referred to from BS EN 12101-6:2005**

4.10.8 Clause 9.2 of BS EN 12101-6:2005 is titled *Depressurization requirements* it states:

9.2.9 The extraction fan from the depressurization zone shall be capable of handling smoke at a temperature of 1 000 °C for unsprinklered buildings, or 300 °C for sprinklered buildings, when tested and classified in accordance with prEN 13501-4.

4.10.9 Grenfell Tower was an un-sprinklered building. BS EN 12101-6:2005 therefore recommended that the extraction fans were capable of handling smoke at a temperature of 1000°C when tested and classified in accordance with prEN 13501-4.

4.10.10 In a depressurisation system, hot gases are assumed to be extracted directly from the fire zone (i.e. the room or compartment in which the fire is assumed to occur) hence why the temperature cited for an un-sprinklered building is 1000°C.

4.10.11 **Performance standard referred to from the *SCA Guide 2012* and *2015***

4.10.12 The *SCA Guide 2012* stated:

8.2.8 All fans used for smoke extract should be tested and certified to BS EN 12101-3: 2002.

4.10.13 This is retained in SCA Guide 2015 at section 8.2.8.1.

4.10.14 No specific performance-rating is recommended for fans used in any form of depressurisation system.

4.10.15 Under recommendations for ductwork, I note that the *SCA Guide 2012* describes a specification as "*typically 300°C for 60 minutes*"

4.10.16 I do not know if this was intended for sprinklered or un-sprinklered buildings.

4.10.17 I note the *SCA Guide 2012* states:

At present, there is no testing regime within EN 12101-3 to cover the use of temperature rated fans with inverters.

Designers of smoke control systems who wish to have variable speed operation in emergency mode due to the nature of the design of the smoke control system should satisfy themselves that the combination of fan and inverter are compatible and will operate satisfactorily under the design conditions.

4.10.18 The significance of this is that the fans installed in Grenfell Tower were variable speed fans and therefore were fitted with invertors (an inverter allows control of the speed of the fan motor to match the ventilation needs), which means that the test methodology in BS EN 12101-3:2002 was not applicable.

4.10.19 I note that when BS EN 12101-3 was republished in 2015 a procedure for testing variable speed fans with inverters was included.

4.10.20 BS EN 12101-3:2015 was published one month after the purchase order was issued for the fans installed in Grenfell Tower {ELT00000029}.

4.10.21 Therefore, at the time of the design and construction of the smoke control system at Grenfell Tower, the designers were required to assess for themselves the suitability and performance of fans specified with a variable speed function.

4.10.22 **Temperature and duration classification for fans**

4.10.23 The relevant classification standard for smoke extract fans is BS EN 13501-4:2007+A1:2009 *Fire classification of construction products and building elements. Classification using data from fire resistance tests on components of smoke control systems.*

4.10.24 Clause 7.1 of BS EN 13501-4 defines the relevant test standard for smoke extraction fans is BS EN 12101-3 '*Smoke and heat control systems —Part 3: Specification for powered smoke and heat exhaust ventilators (fans)*'.

4.10.25 Both BS 13501-4 and BS EN 12101-3 refer to fans as *powered smoke and heat exhaust ventilators*; from Clause 3.9 of BS EN 13501-4 (bold by me):

powered smoke and heat exhaust ventilators

*powered device **(usually a fan)** that is suitable for exhausting hot gasses from a building under fire conditions*

NOTE Such devices are often able to function under fire conditions for a limited period only.

4.10.26 I note that BS EN 12101-3:2002, in addition to specifying the method of test for fans at elevated temperatures, also sets out temperature and duration classifications for smoke extract fans.

4.10.27 When BS EN 12101-3 was republished in 2015 these classifications were removed.

4.10.28 Therefore, from 2007, when BS EN 13501-4:2007 was published, until 2015 there were two possible means of classifying the temperature and duration performance of fans.

4.10.29 Neither standard contains a means of classification for a temperature of 1000°C as required by BS EN 12101-6:2005 for depressurisation extract fans in an un-sprinklered building.

4.10.30 Therefore, I have set out below the classifications that were available and therefore what could reasonably be specified by a designer at the time.

4.10.31 **<u>Classification of fans to BS EN 13501-4:2007</u>**

4.10.32 Clause 4.5 *Specific thermal actions* of BS EN 13501-4:2007 provides the following list of temperature exposures that can be applied to smoke control fans.

4.5.4 Powered smoke and heat exhaust ventilators

A constant temperature of:

200 °C, reached within 5 min to 10 min, or

300 °C, reached within 5 min to 10 min, or

400 °C, reached within 5 min to 10 min, or

600 °C, reached within 5 min to 10 min, or

842 °C following the standard temperature/time curve up to the specified constant temperature.

Figure 4-21: Excerpt of BS EN 13501-4:2007

4.10.33 The highest temperature that can be applied in the test is 842°C. I have excerpted in in Figure 4-22: the corresponding classes for these thermal actions.

7.5.4 Classes

F_{200}				120
F_{300}		60		
F_{400}			90	120
F_{600}		60		
F_{842}	30			

Figure 4-22: Excerpt from Clause 7.5 Classification of powered smoke and heat exhaust ventilators of BS EN 13501-4:2007

4.10.34 The highest classification in terms of temperature exposure is F842 30 which indicates the fan has been shown to be functioning satisfactorily by its continued ability to provide the initial volume or pressure within the defined limits for a period of 30 minutes at a temperature of 842°C.

4.10.35 **Classification of fans to BS EN 12101-3**

4.10.36 Section 6 of BS EN 12101-3:2002 is titled *Performance requirements and classification* and lists six possible classifications that can be obtained from the test methodology set out in BS EN 12101-3:2002.

4.10.37 These are: F200, F300, F400, F600, F842 or *not classified.*

4.10.38 Table 2 of the standard sets out the test temperature and functioning time required to achieve these classifications which I have reproduced in Figure 4-23:.

Table 2 — Test temperature and functioning time according to classification

Class	Temperature °C	Minimum functioning period minutes
F200	200	120
F300	300	60
F400	400	120
F600	600	60
F842	842	30
Not classified	as specified by sponsor	as specified by sponsor

Figure 4-23: Excerpt of Table 2 of BS EN 12101-3:2002

4.10.39 BS EN 12101-3:2002 also allowed fans classified as F832 30 as per BS EN 13501-4:2007. However it also included a provision for *"Not classified"*. For this classification it was possible for the test temperature and minimum functioning period to be specified by the test sponsor as shown in Figure 4-23:.

4.10.40 It was therefore possible for a test sponsor to carry out a test on a smoke extract fan to 1000°C under the *'Not classified'* provision in BS EN 12101-3:2002. However, no subsequent classification could be made to BS EN 13501-4:2007.

4.10.41 **Summary of performance standard for fans suitable for the Grenfell Tower system**

4.10.42 In Table 4-12, I have summarised the classification options available to a designer for specifying a smoke extraction fan.

Table 4-12: Summary of fan classification options

Standard	Type	Test standard	Classification standard	Possible classification
ADB, BS EN 12101-6:2005	British standard referenced by statutory guidance	BS EN 12101-3:2002	BS EN 13501-4:2007	F842 30
BS EN 12101-3:2002	British Standard	BS EN 12101-3:2002	BS EN 12101-3:2002	Tested at 1000°C to BS EN 12101-3:2002 and regarded as *"Not classified"* in accordance with Table 2 of BS EN 12101-3:2002
SCA Guide	Industry	BS EN 12101-	BS EN 12101-	Typically 300°C for 60

Standard	Type	Test standard	Classification standard	Possible classification
2012	guidance	3:2002	3:2002	minutes

4.10.43 It is on this basis I assess the design and installation of the lobby smoke control system in Grenfell Tower.

5 Description of the design approach taken to the refurbishment smoke control system

5.1 Introduction

5.1.1 In Section 4 I set out the detailed design principles and standards necessary to develop a performance specification for a lobby smoke control system, with particular reference to the performance standards relevant to Grenfell Tower at the time of the primary refurbishment.

5.1.2 Grenfell Tower as an existing building had fixed physical characteristics that required consideration, such as the extended travel distance in the lobby and the fixed positions of the smoke shafts.

5.1.3 Travel distances were deemed acceptable up to 15m in CP3:1971, but only once sufficient lobby cross ventilation was provided for during means of escape, but this wasn't the provision made in Grenfell Tower (refer to Section 3).

5.1.4 Consideration therefore needed to be made for a suitable alternative design approach to comply with the functional requirements of the Building Regulations.

5.1.5 Section 5 of the *SCA Guide 2012* and *SCA Guide 2015* are both headed *Objectives and Performance Criteria.*

5.1.6 Section 5.1 General of the *SCA Guide 2012* and *2015* both state:

It is the responsibility of the assessing engineer to determine which method of investigation should be used.

5.1.7 Mr Mahoney has not, in any contemporaneous design documents, set out a clear basis or explanation for the alternative solution he proposed by means of the lobby smoke control system for Grenfell Tower.

5.1.8 Therefore I have reviewed witness statements and design documentation as set out in Section 5.3 and 5.4 below, and provide my own analysis.

5.1.9 I have then compared my findings with the methodology set out in the *SCA Guide 2015* for a performance-based design of a mechanical extract system, and with other relevant British Standards.

5.1.10 As explained in section 4, I have also compared PSB's performance criteria with those of a proprietary smoke control system by Colt. This is because in his second witness statement {PSB00001373} Mr Mahoney explains (at paragraph 41) that his design "reflected" "*A performance-based building appropriate solution widely adopted as a type of smoke control system and which were often referred to within the industry as 'depressurisation' systems and is commonly called the ColtShaft mechanical shaft system.*"

5.1.11 Mr Mahoney states in his second witness statement that there is no published design methodology for such systems, despite his assertion that it is a widely adopted solution.

5.1.12 Accordingly, I have compared PSB's design with the range of available publications.

5.1.13 I consider the performance based design methodology set out in detail in the SCA Guides to be a reasonable methodology for any designer of a lobby smoke control system to rely on when formulating a performance-based solution for a lobby smoke control system.

5.1.14 Particularly for an existing condition such as that at Grenfell Tower, which originally also had means of escape and firefighting purpose for its lobby ventilation system.

5.1.15 I have not been able to establish why (based on the contemporaneous documentation) this work was not done, nor recorded, for the Grenfell Tower primary refurbishment project.

5.2 Review of information provided

5.2.1 I have reviewed the details of the smoke control system as recorded in PSB's Technical Submissions for the smoke control system, and many other documents.

5.2.2 Table 5-1 sets out the key documents I have relied upon.

5.2.3 I have recorded the additional evidence I have relied on in this Phase 2 report where I had not previously referred to it in my original Section J 6 of my Phase 1 report{BLAS0000031}.

5.2.4 I also rely on correspondence between relevant parties such as emails and letters however I have not individually listed these in the Table below.

5.2.5 No further design documentation has been made available to me in Phase 2.

5.2.6 I have obtained further evidence regarding the Tunstall auto-dialler connected to the Master Panel in the Hub room. I present this evidence separately in Section 7 of this report.

5.2.7 It should be noted that I have assumed that PSB's Technical Submission (Rev 6, {PSB00000214}) provides the final description of the as-built condition of the system. I had asked that Rydon, as main contractor, confirm this to the Public Inquiry during Phase 2. To date, Rydon have not provided such confirmation.

5.2.8 However, PSB have specifically confirmed to the Inquiry in writing ({PSB00001371}, dated 10th June 2019) that all relevant documents in their possession have been disclosed.

5.2.9 Witness evidence does not suggest that there were any subsequent revisions, either. Both Mr Mahoney and Mr Partlow confirm that Revision 6 was finalised during the commissioning process.

5.2.10 In his first witness statement, Hugh Mahoney {PSB00001329} states:

The System design and the description of the System within the Technical Submission documents underwent some changes as the Project developed... However, the broad design of the System, in terms of how it operated and the performance criteria which it was designed to achieve in smoke control mode, remained as described in the first revision of the Technical Submission and above.

5.2.11 Revision 1 of PSB's Technical Submission (dated 1st December 2014) is included within the Building Manual provided to KCTMO {TMOM00001764}.

5.2.12 Revision 1 states:

The Final smoke control system has been designed to provide the existing stairwell with protection from the ingress of smoke, from a fire within a dwelling, by means of a mechanical extract system. The system has been designed to provide an average open door velocity, across an open lobby/stairwell door of 2.0m/s. This velocity is in accordance with the recommendation for a Class B pressure differential system as defined in Code of Practice BSEN12101 Part 6: Specification for pressure differential systems — Kits. (bsen12101-6).

I [sic] *should be noted that as the system is designed to extract air from the lobby, via the open stairwell door, the system is not deigned* [sic] *to comply with all the requirements of the aforementioned Code of Practice.*

5.2.13 However, the latest recorded version of PSB's technical submission which I have been provided with, is Revision 6 dated 15th March 2016 {PSB00000214}.

5.2.14 The sentence "*I* [sic] *should be noted that as the system is designed to extract air from the lobby, via the open stairwell door, the system is not deigned* [sic] *to comply with all the requirements of the aforementioned Code of Practice*" was removed, as between Rev 2 and Rev 3 of the document. The documents indicate that JS Wright emailed PSB asking for the sentence to be deleted {PSB00000569}, as I explain in Section 5.11 below, and this sentence was also omitted from the final version i.e. Revision 6 of the technical submission.

5.2.15 Mr Partlow notes in his witness statement {PSB00001309} that Revision 6 "*was finalised during the commissioning process* (GP/7: {PSB00000214})".

5.2.16 Therefore, I have received no further evidence which contradicts my understanding that PSB's Technical Submission (Revision 6, {PSB00000214}) provides the final description of the intended construction of the smoke control system.

5.2.17 In Section 6 of this report I set out any differences I have found in the installed construction when compared with that described in PSB's Technical Submission (Revision 6, {PSB00000214}).

Table 5-1: Key documents relating to the smoke control system from Phase 1 and Phase 2 of the Inquiry

Document	Relativity Reference	Evidence referred to in Section J6 of Appendix J
PSB Smoke ventilation Electrical schematic	{TMOM00001859}	No
Main LV distribution schematic drawing	{TMOM00001891}	No
Studio E, drawing entitled Proposed Residential Plan (W+2), 1279 (04)105 Rev 00	{SEA00010474}	No
PSB (UK) Limited Schedule to Letter 10 June 2019PM.PDF	{PSB00001371}	No
PSB Technical Submission Rev 1	{TMOM00001764}	No
Max Fordham document entitled 'Grenfell Tower Smoke Ventilation Analysis Rev A' dated 6 May 2014	{MAX00002334}	No
Explanation of how the environmental ventilation works	{MAX00002664}	No
M&E - Smoke Control Proposals - Rev A.pdf	{RBK00002967}	No
Memorandum from Paul Hanson to John Allen: discussing B1 - Means of Escape Observations, Submission No: Preliminary P2 relating to Grenfell Tower regarding: (1) Upper Storey Powered Ventilation System (2) Consultation with Fire Authority regarding the lobby ventilation system (3) connection with different uses Dated: 06/12/2013	{RBK00003014}	No
RBKC Chronology version 2	{RBK00026860}	No
Submission 1a (S1a) to RBKC	{RBK00033900}	No
Existing Fire Safety Strategy Grenfell Tower Regeneration Project, London (DRAFT)	{EXO00000784}	No
WSP building management system final report	{MET00018469}	No
Appendix J Barbara Lane Supplemental Report	{BLAS0000031}	No
The Fire Safety Engineer Report (Version 2 - updated 22 October 2020) - Dr Barbara Lane Phase 2 Report	{BLARP20000017}	No
Regulation 38 Fire Safety Information Report (Version 2 - updated 23 October 2020) - Dr Barbara Lane Phase 2 Report	{BLARP20000021}	No
Section 2 Conclusions and Next Steps	{BLAS0000002}	No
Appendix G Barbara Lane Supplemental Report	{BLAS0000028}	No
2021.03.26 Second Witness Statement of Hugh Mahoney	{PSB00001373}	No

Document	Relativity Reference	Evidence referred to in Section J6 of Appendix J
2021.03.26 Second Witness Statement of Granville Partlow	{PSB00001372}	No
2018.09.28 - Witness Statement of Hugh Mahoney (PSB)	{PSB00001329}	No
2018.09.28 - Witness Statement of Granville Partlow (PSB)	{PSB00001309}	No
2018.10.26 Witness Statement of Alan Whyte (J S Wright Co Ltd)	{JSW00001892}	No
2020.12.21 Second Witness Statement of Alan Whyte	{JSW00007201}	No
2018.10.09 - Witness Statement of Matt Cross Smith (Max Fordham).pdf	{MAX00017304}	No
2018.11.21 Witness Statement of Paul Derek Hanson (RBKC)	{RBK00033894}	No
2018.11.21 Second Statement of Paul Derek Hanson	{RBK00033903}	No
Max Fordham, drawing entitled Core Services Smoke Ventilation Schematic, 4614 U(14)01_200 Rev T2	{PSB00000335}	Yes
PSB, drawing entitled Electrical Schematic, PSB 140001 Rev 05	{PSB00000267}	Yes
PSB, drawing entitled Master Panel Street Enclosure, PSB 140003 Rev 05	{PSB00000272}	Yes
PSB, drawing entitled Inverter Panel Street enclosure, PSB 140002 Rev 03	{PSB00000274}	Yes
PSB Smoke Ventilation Technical Submission - Lobby Smoke Control Systems at Grenfell Tower	Rev 6, {PSB00000214}	Yes
PSB Smoke Ventilation Technical Submission PSBUK1143-12 rev 2 (14.04.15).pdf embedding drawings of PSB Lobby Smoke Control components	Rev 2 {PSB00001236}	Yes
PSB Smoke Ventilation Technical Submission dated 12 November 2014	({PSB00000207} Rev 0)	Yes
PSB Above Ground Commissioning Report for AOV dated 28 April 2016	{PSB00000224}	Yes
Max Fordham - Grenfell Tower Employer's Requirements for MEP Services	{MAX00000960}	Yes
Exhibit CW/4 - 13 May 2014 Grenfell Tower Smoke Ventilation Analysis, Rev B by Matt Smith of Max Fordham':	{MAX00002335}	Yes
RBKC Memorandum from Paul Hanson to John Hoban (RBKC Building Control) - B1 Means of Escape of Observations re Submission 1 for Grenfell Tower Refurbishment Works	{RBK00002975}	Yes
J. S. Wright O&M manual (undated)- Grenfell Tower Rev 2	{RYD00000577}	Yes

Document	Relativity Reference	Evidence referred to in Section J6 of Appendix J
Operation and Maintenance Manual with Description of Electrical Services by R.J.Electrics Ltd. Dated: 01/05/16	{RYD00094130}	Yes
IMW/17 - Richard Midgley exhibit - data extracted from the PLC unit of the smoke control system	{MET00018070}	Yes
IMW/8 - Richard Midgley exhibit - data from HMI panel of the smoke control system	{MET00018074}	Yes

5.3 Witness statements – evidence regarding design

5.3.1 I have reviewed witness statements relevant to the design of the refurbishment smoke control system in Grenfell Tower, including from the following persons:

a) Matt Cross Smith (Max Fordham)

b) Hugh Mahoney (PSB)

c) Granville Partlow (PSB)

d) Alan Whyte (JS Wright)

e) Paul Hanson (RBKC Building Control)

5.3.2 I have reviewed these witness statements to assist in my understanding of how members of the Grenfell Tower primary refurbishment design team and the RBKC Building Control team both intended and understood the proposed system to comply with the Building Regulations.

5.3.3 **Matt Cross Smith (Max Fordham)**

5.3.4 One witness statement from Matt Cross Smith {MAX00017304}, dated 9th October 2018, has been made available to me.

5.3.5 In Paragraphs 28-63, Mr Cross Smith describes the development of the smoke ventilation system design at Grenfell Tower.

5.3.6 At paragraph 28 of Mr Cross Smith's witness statement {MAX00017304} he states that Max Fordham intended to bring the system up to a 'higher standard' than the pre-refurbishment system:

The works to the smoke ventilation system (SVS) were intended to bring the system up to a higher standard than what was currently installed and to extend it to serve the new spaces on the lower floors of the Tower.

5.3.7 Additionally, at paragraph 28 {MAX00017304} Mr Cross Smith states:

Upon further consultation with the specialist SVS designer (PSB), the intent was updated to bring it as close to current regulations as possible within the limitations of the existing shafts. According to the Building Regulations, the requirement was to make it no worse than the existing condition.

5.3.8 In paragraphs 34 to 37 of his witness statement {MAX00017304}, Mr Cross Smith states that it was not the intention to the bring the system *"up to the current standards"* due to the physical constraints of the building.

5.3.9 However, Mr Cross Smith explains that demonstrating to Building Control that the proposed system did not perform any worse than the existing system was difficult because the existing system was not working at that time (paragraph 36, {MAX00017304}).

5.3.10 Mr Cross Smith states at paragraph 38 of his witness statement {MAX00017304} that specialist assistance was sought from PSB to overcome this issue:

I got in contact with PSB as it was getting complicated with Building Control, and I felt that an engineered solution for the SVS may be the route to take. For this reason further specialist input would be required.

5.3.11 Mr Cross Smith provides no further information about how the design subsequently developed by PSB was intended to comply with the Building Regulations.

5.3.12 **Hugh Mahoney (PSB)**

5.3.13 Two witness statements have been made available to me from Hugh Mahoney: the first {PSB00001329} dated 28th September 2018 and a further statement dated 26th March 2021 {PSB00001373}.

5.3.14 At paragraphs 48 – 52 {PSB00001329} of his first witness statement, Mr Mahoney explains how the system was intended to comply with the Building Regulations:

48. ADB 2013 states that smoke control systems should be designed to control smoke in a common lobby and so protect the common stair in the event of a fire starting in a single location and being contained within a single compartment.

49. In line with this, the System was designed to operate on only one floor at any one time, with the dampers covering the vents to the shafts on all other floors to remain closed while the System was operating in smoke control mode on the affected floor.

50. The PSB design was for a depressurisation system, in other words a system which achieved smoke control using depressurisation principles achieved by mechanical extraction.

51. BS EN 12101-6:2005 is the relevant standard for designing pressure differential systems including depressurisation systems (as referred to in guidance document ADB 2013). It sets out functional objectives and measurable performance criteria.

52. I drew upon the principles in this standard to develop a building appropriate solution. The PSB design was in line with the performance criteria of BS EN 12101-6:2005. The primary performance criteria of the design required a minimum velocity of 2.0 m/s being achieved through an open common lobby door to the stair. In achieving the recommended flow rate, the design also included provision to ensure that the opening force on the door would not exceed 100N.

Figure 5-1: Excerpt from Mr Mahoney first witness statement {PSB00001329}

5.3.15 Therefore, Mr Mahoney simply describes the system as a depressurisation system and identifies BS EN 12101-6:2005 as the relevant standard for depressurisation systems.

5.3.16 Mr Mahoney has subsequently submitted a second statement {PSB00001373} to the Inquiry in order to *"...explain the approach that I took to the design of the System and the type of smoke control system that I designed"* (paragraph 4).

5.3.17 Mr Mahoney provides his explanation of the system design at paras. 31 to 41 of that second statement. In this revised explanation Mr Mahoney describes the mechanical extract depressurisation system and states (underlining in original):

36....These types of system should not be confused with "Pressure Differential Systems" which are designed to comply with all the requirements of BS EN 12101-6:2005 "Smoke and heat control systems. Specification for pressure differential systems. Kits"

40... I did not design a Pressure Differential System, which are designed to comply with all the requirements of BS EN 12101-6

5.3.18 The explanation provided in Mr Mahoney's second statement is consistent with my original analysis of PSB's design in Appendix J of my Phase 1 report {BLAS0000031}. As I highlighted in that first report, the system was not designed to comply with all of the requirements of BS EN 12101-6:2005.

5.3.19 Mr Mahoney describes his design at paragraph 41 of his statement as follows {PSB00001373}:

41….A performance-based building appropriate solution widely adopted as a type of smoke control system and which were often referred to within the industry as 'depressurisation' systems and is commonly called the ColtShaft mechanical shaft system.

5.3.20 Under the section *"Applicable research and guidance"* at paragraphs. 42 – 60 of his statement Mr Mahoney refers to the *SCA Guide 2012* which describes *"Mechanical (powered) smoke ventilation"* systems.

5.3.21 Mr Mahoney describes the system at Grenfell Tower as *"similar to, but not the same as, the "Mechanical Extract, Natural Inlet" system detailed in the SCA Guide 2012"*.

5.3.22 As I have described in Section 4, a *"Mechanical Extract, Natural Inlet"* system detailed in the *SCA Guide 2012* relies on a dedicated natural supply shaft or a direct opening to outside to provide the supply air. In the case of Grenfell Tower, the supply air was provided by natural leakage from the stair and therefore differed from the *"Mechanical Extract, Natural Inlet"* system.

5.3.23 Mr Mahoney refers to the change in the description of the *"Mechanical Extract, Natural Inlet"* system in the *SCA Guide 2015* to permit natural inlet air by way of a stair. He explains that this was consistent with the design of the system at Grenfell tower..

5.3.24 Mr Mahoney goes on to describe the performance criteria he selected at paragraphs 61 – 73 of his second statement. Mr Mahoney states {PSB00001373}:

62. There is no comprehensive guidance available as to generic performance criteria for systems of this type, even in the SCA Guide.

63. However, BS EN 12101-6 sets out guidance in relation to certain performance criteria relevant to Pressure Differential Systems which I felt were appropriate for the System.

…

66. Whilst the System did not operate in the same way as a Class B Pressure Differential System, the airflow it was designed to generate across the open door was similar to that aspect of the required performance criteria of a Class B Pressure Differential System. It is for this reason that I felt that it was appropriate to adopt the figure of 2.0m/s from BS EN 12101-6 for the System.

…

72. I designed the System to use pressure sensors which were set at around -25Pa in the lobby areas to ensure that the fans would be working at a rate which would mean that the door opening force would not exceed 100N. Each

floor was addressed individually, and the pressure sensors were required to be set specifically to allow for the leakages in each individual floor lobby.

73. These were the two principal performance criteria that I determined to be appropriate for the System.

5.3.25 As I have explained in Section 4, in the case where the presence of an extended travel distance such as Grenfell Tower needed to be considered, the *SCA Guide 2012* and *2015* state *"system objectives and performance should follow the guidance in section 5";* where section 5 of the *SCA Guide 2012* states:

Performance criteria should be based on tenability. The main criteria of interest are therefore likely to be visibility, temperature, thermal radiation and toxicity within the ventilated corridors/lobbies. For stairs these criteria should be adjusted to reflect 'relatively smoke free' conditions, although protection of the stairs can also be indicated as a function of maintaining a suitable positive ventilation flow from the stair to the corridor or lobby.

5.3.26 And section 5 of the *SCA Guide 2015* states:

Performance criteria are generally based on tenability. The main criteria of interest could include visibility, gas temperature, thermal radiation and toxicity within the common corridors, lobbies and stair enclosures. Selection of appropriate performance (acceptance) criteria for assessing a fire engineered system design should be established at the start of the design process, typically at the qualitative design review.

5.3.27 Mr Mahony chose three specific performance criteria: a velocity of 2m/s through the open door to the stair; a differential pressure of -25Pa between the stair and the lobby and a door opening force of less than 100N.

5.3.28 I am not aware of any documents which suggest that the selection of these criteria was based on a proposed performance for means of escape including visibility, temperature, thermal radiation, and toxicity, as would be recommended by either version of the SCA Guide.

5.3.29 Nor have I found evidence that Mr Mahoney analysed the performance intention of the original system as described in CP3 1971.

5.3.30 Mr Mahoney cites three further documents in his second witness statement the *SCA Guide 2012, SCA Guide 2015* and BS 9991:2011. However, he does not state that PSB's design was intended to comply with any of them.

5.3.31 Based on Mr Mahoney's second witness statement, I therefore understand that PSB intended to adopt an alternative approach by developing a *"performance-based building appropriate solution"*.

5.3.32 I note that Mr Mahoney states at paragraphs 59-60 of his second statement that the system designed for Grenfell Tower was intended to work in the same way as a proprietary system called the 'ColtShaft mechanical shaft system'.

5.3.33 I have set out my review of the ColtShaft mechanical shaft system, including its LABC registration in Section 4.6 of this report.

5.3.34 At paragraph 74 Mr Mahoney concludes that *"the basis of my design and the performance I specified for the System were sufficient to meet the requirements of the Building Regulations"*.

5.3.35 Mr Mahoney provides no explanation as to what the relevant requirements of the Building Regulations were, which he says were satisfied by the design which was adopted.

5.3.36 In Section 2, I have already set out my understanding of the requirements of the Building Regulations, in response to this new information received in March 2021, and use that as a basis to assess whether Mr Mahoney's design was sufficient to meet the Building Regulations' requirements (please refer to Section 10 for my conclusions on this subject).

5.3.37 **Granville Partlow (PSB)**

5.3.38 Mr Granville Partlow carried out the commissioning of the smoke control system at Grenfell Tower. In Section 8x, I have included my review of Mr Partlow's first and second witness statements to the Inquiry with respect to commissioning of the smoke control system.

5.3.39 In this section I review the content of his second witness statement only, insofar as it relates to the design of the smoke control system. In Appendix J of my Phase 1 report {BLAS0000031} I identified that the pressure differential to be achieved by the system between the stair and lobby was apparently required to be 50Pa as per PSB's commissioning Method Statement and Risk Assessment dated February 2016 {PSB00000941}.

5.3.40 This conflicted with PSB's Technical Submission (Rev 6, {PSB00000214}, 15th March 2016) which stated that the system they planned to design a system which would provide a pressure differential of -25Pa between the stair and lobby.

5.3.41 Mr Partlow describes setting the pressure switches to -25Pa in his first witness statement at paragraphs 39-40 {PSB00001309}.

5.3.42 In Mr Partlow's second witness statement dated 26th March 2021 {PSB00001372} at paragraphs 10 and 11 he states:

10. In paragraph 19 of my first statement, I refer to being provided with the "PSB Commissioning Method Statement and Risk Assessment 75019AG" {PSB00000941}.

11. The circumstances in which this document came to be produced are explained in email exchanges provided to the Inquiry. It was produced by me at a busy time. It contains errors and does not accurately reflect the System.

5.3.43 From this I now understand that the pressure differential of -25Pa between the stair and the lobby of Grenfell Tower specified in PSB's Technical

Submission (Rev 6, {PSB00000214}) was not changed at the time of commissioning.

5.3.44 **Alan Whyte (JSW)**

5.3.45 Alan Whyte has provided two witness statements to the Inquiry which have been made available to me: the first dated 26th October 2018 {JSW00001892} and the second dated 21st December 2020 {JSW00007201}.

5.3.46 In his first witness statement, Mr Whyte states that he liaised with RBKC Building Control regarding the approval of the smoke control system (paragraphs 52 and 53, {JSW00001892}).

5.3.47 Further, in paragraphs. 66 to 171 of his witness statement {JSW00001892} Mr Whyte explains his understanding of the design, installation, testing, and commissioning of the smoke control system.

5.3.48 Mr Whyte states that the design of the system was the responsibility of JSW's specialist sub-contractor, PSB {JSW00001892}:

69. PSB was responsible for designing the system, complying with all relevant requirements and standards, getting it approved, testing, commissioning and certifying it.

70. JSW engaged PSB as they were the experts in smoke control systems and JSW relied on their experience and expertise. JSW acted as a conduit for information passing between Rydon, as main contractor, and PSB as specialist sub-sub-contractor.

5.3.49 Mr Whyte's statement does not provide any further evidence regarding how the system was intended to comply with the Building Regulations.

5.3.50 Mr Whyte's second witness statement {JSW00007201} is concerned with a specific defect relating to the smoke control system raised on 1st June 2017 by Rydon. I present my analysis of known defects to the smoke control system in Section 11.2 of this report.

5.3.51 **Paul Hanson (RBKC Building Control)**

5.3.52 Mr Hanson has provided two witness statements to the Inquiry, both of them dated 21st November 2018 {RBK00033894} and {RBK00033903}. The latter statement addresses questions from the Inquiry regarding RBKC Building Control's filing system. I focus on the former {RBK00033894} in this sub-section regarding the smoke control system at Grenfell Tower.

5.3.53 Mr Hanson's role for Grenfell Tower is stated in paragraph 46 of his witness statement {RBK00033894} where he says:

My involvement from 2013 with the project was to provide advice to the Area Surveyor upon request; regarding the submitted plans and details under B1 (Means of warning and escape) of the Building Regulations 2010 for the works proposed between 2012 and 2016.

5.3.54 In relation to the design of the new smoke control system, Mr Hanson states at paragraph 52 of his witness statement {RBK00033894}:

The new smoke control system was designed in accordance with the principles of the Smoke Control Association (SCA) Guidance on Smoke Control to Common Escape Routes in Apartment Buildings (Flats and Maisonettes) Revision 1: June 2012. There is currently no British Standard for such systems, although they are the most commonly used systems in new large residential buildings. An explanation of 'smoke control systems' used in residential buildings is included below in paragraph 71 – 79.

5.3.55 Regarding demonstrating the performance of the smoke control system, Mr Hanson states at paragraph 56 of his witness statement {RBK00033894}:

The system installers J.S. Wright did not use a computer model and proposed using an air leakage test upon completion of the installation to show that the system achieved the objective of stopping smoke affecting the stairway.

5.3.56 Therefore, from Mr Hanson's witness statement I understand that he considered the system to be designed using the principles of the *SCA Gu*ide *2012*. However, none of the revisions of PSB's Technical Submission refer to the *SCA Guide 2012*. The first reference to the *SCA Guide 2012* is in Mr Mahoney's second witness statement dated 26th March 2021 {PSB00001373}.

5.3.57 I also note that in his 4th May 2016 email to Mr Hughes, Mr Hanson stated ({PSB00001130}, {JSW00002945}):

Remember that the testing of the powered vent system we are witnessing tomorrow should be in accordance withsection[sic] *9 and item of the attached SCA guide.*

5.3.58 The attached SCA Guide referred to in the e-mail was the 2015 version.

5.3.59 I note that Mr Hanson does not refer to the use of BS EN 12101-6:2005 in the design of the smoke control system.

5.3.60 Mr Hanson also states that no analysis was undertaken to demonstrate the performance of the system. Instead, a test of *'air leakage'* for the installed system was used to demonstrate performance.

5.3.61 In Section 5.11 below, I present my review of evidence obtained from the consultation with RBKC Building Control regarding how the system was considered to comply with the Building Regulations at the time.

5.3.62 I note that Mr Hanson was a member of the SCA's Guide committee at the time the *SCA Guide 2015* was published along with Mr Mahoney.

5.4 Basis for design of the refurbishment smoke control system

5.4.1 In this section I set out the basis for the design of the smoke control system in Grenfell Tower as I have determined it from the design documentation I have seen.

5.4.2 **Design by Max Fordham**

5.4.3 Max Fordham proposed a refurbishment of the original system, but on the basis of the same operational principles as the existing system installed in Grenfell Tower i.e. a mechanical smoke extract system which supplies fresh air from the South shafts and exhausts smoke from the North shafts {MAX00000960}.

5.4.4 The performance of the original design was unknown to Max Fordham or RBKC Building Control {MAX00004353} at the time.

5.4.5 The fire safety consultant, Exova, was also unaware of how the existing system operated. The Exova Existing Fire Safety Strategy dated 16th August 2012 {EXO00000784} noted the following about the existing smoke control system:

It is unknown how the fresh air ventilation shaft operates in a fire condition (the rate of extraction the system currently achieves both naturally and mechanically). It is also not known how the existing system performs as a natural shaft for the purposes of escape prior to fire service intervention.

5.4.6 A memorandum from Paul Hanson to John Hoban both of RBKC Building Control ({RBK00002975}, dated 10th November 2014) stated the following:

RBKC building control would be satisfied under the building regulations if either:-

a. The performance of the existing system is maintained. Details of the performance of the existing and proposed systems are requested to be submitted to enable RBKC to be satisfied that the system would not be adversely affected by the intended works.
Or
b. The ventilation extract rate is justified to be suitable for the propose.

Figure 5-2: Excerpt from memorandum from Mr Hanson to Mr Hoban (both RBKC Building Control) dated 10th November 2014 {RBK00002975}

5.4.7 The memorandum{RBK00002975} then described how a comparison between existing and proposed flowrates could be made.

5.4.8 The Employer's Requirements for MEP Services for Grenfell Tower {MAX00000960} dated 16th October 2013 states that the purpose of the new ventilation system was:

...to install a new ventilation system which will primarily be for fire safety and smoke control, but which will also provide some ventilation to reduce the possibility of the lobbies becoming uncomfortably warm due to heat emission from the heating pipes running through the lobbies.

5.4.9 {MAX00000960} set out the intended performance of the new system:

The new system will be a mechanical supply and extract system which does not rely on natural ventilation as the performance of a naturally ventilated system would be difficult to model and verify. As there are no directly applicable standards which can be referred to, it is considered that it would be reasonable to design the system to provide an air-change rate of approximately 15 air-changes/hour.

5.4.10 In Appendix J of my Phase 1 report at paragraph J6.2.8 {BLAS0000031} I explained that the performance of the smoke control system detailed in the Employer's Requirements dated 16th October 2013 {MAX00000960} was based on Revision B of the Smoke Ventilation Analysis by Max Fordham {MAX00002335}.

5.4.11 However, Revision A and Revision B of the Smoke Ventilation Analysis are dated the 6th and 13th May 2014 respectively and so were produced after the Employer's Requirements.

5.4.12 I note the document *'M&E Smoke Control Proposals- Rev A'* {RBK00002967} was prepared by Max Fordham and is dated 25th October 2013 shortly after the Employer's Requirements for MEP Services. It also describes a system intended to achieve *"an air-change rate of approximately 15 air-changes/hour"*.

5.4.13 The Max Fordham schematic for their proposed system is provided in {PSB00000335} (November 2013) and an excerpt from {PSB00000335} is shown in Figure 5-3.

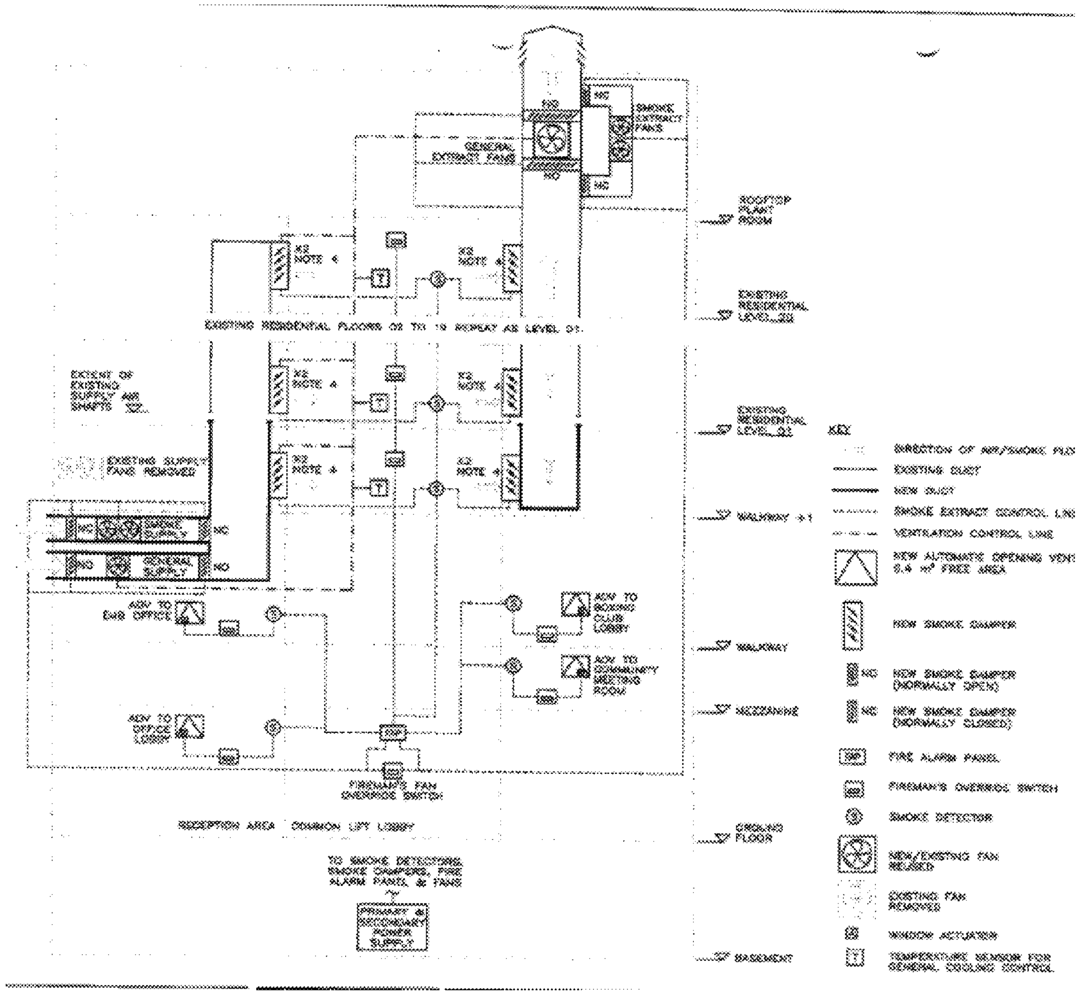


Figure 5-3: Excerpt from Max Fordham schematic {PSB00000335}.

5.4.14 A diagram indicating the supply and extract methodology was included in an email from Max Fordham to RBKC ({RBK00003017}, dated 7th November 2013). An excerpt from this email is shown in Figure 5-4.

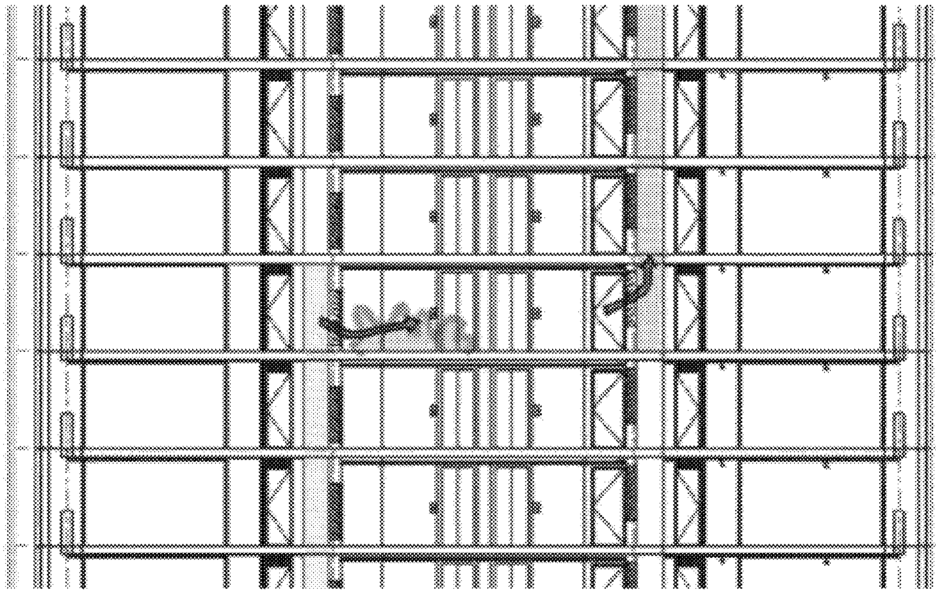


Figure 5-4: Excerpt from email from Max Fordham to RBKC ({RBK00003017}, dated 7th November 2013) showing the concept for smoke extract proposed by Max Fordham.

5.4.15 In Max Fordham's "*Grenfell Tower Smoke Ventilation Analysis Rev B*" dated 13th May 2014 {MAX00002335}, the expected performance of the existing system in natural ventilation and mechanical ventilation mode was calculated.

5.4.16 In natural ventilation mode, the flow rate through the smoke shafts was calculated as 1.0 m^3/s based on worst case ventilation from the top floor. In mechanical ventilation mode, I understand Max Fordham were not able to calculate the exact rate and instead were required to estimate a flow rate of 1.2 m^3/s in the smoke shaft.

5.4.17 In relation to the new system Max Fordham stated *"The new fans will be sized to provide a minimum of 5 m^3/s flow rate at the furthest point from the fans"*.

5.4.18 As I have already mentioned above, I understand from the witness statement of Mr Cross Smith that Max Fordham intended to provide a system which was *"no worse"* than the existing system. However, Max Fordham were unable to demonstrate this as the existing system was not working so at this point PSB were contacted for further specialist assistance {MAX00017304}.

5.4.19 Further I have found no evidence of an analysis of CP3 1971, or any other original standard, to establish the original core performance objectives of the lobby smoke control system at Grenfell Tower.

5.4.20 **PSB design development of the smoke control system**

5.4.21 PSB developed a design of the refurbishment smoke control system which is documented in a series of revisions of a Technical Submission. I reviewed

these in Appendix J of my Phase 1 report {BLAS0000031}. I have not seen any further design documentation by PSB since that time.

5.4.22 An email from Max Fordham to Artelia dated 19th October 2015 {MAX00005634} describes the switch from the Max Fordham mechanical supply and extract system to a mechanical extract only system proposed by PSB, where replacement air would not be supplied mechanically to the lobby:

> The system at Grenfell is non-standard and was not possible to bring up to current regs due to various structural limitations. We took advice from a specialist (PSB) initially which resulted in the value of 0.42m3/s. Subsequently we received some feedback from Building Control **(December '12)** which stated that either a CFD analysis or demonstration that the new system was an improvement over the existing system would be required.
>
> We requested the test certificates from the TMO maintenance contractor (RGE at that time) repeatedly with no success. At the time of writing our ERs and going out to Tender **(March '13)** we had still not received these or been able to test the existing system due to the poor condition that it was in. This was highlighted within the ERs and on the risk register.
>
> Subsequent to the Tender **(May '14)** we were instructed to produce a report for Building Control by the TMO. This was to show the Fire Brigade that work was progressing on the system in order to respond to an enforcement notice. We again went to PSB for advice and at this point they suggested that their recommendation would be to increase the air flow in order to bring it closer to current regulations. They also advised that Building Control would be more likely to accept the proposal if a larger flow rate was specified. Hence the 5m3/s figure.
>
> Further design development by JSW with PSB eventually resulted in a technical submittal whereby the system retained the 5m3/s figure but changed strategy from supply and extract system to an extract-only type system (based on further advice from PSB). This was what was presented to Building Control for approval and was subsequently accepted.

Figure 5-5: Excerpt from {MAX00005634}

5.4.23 Regarding the change from a mechanical supply and extract system to mechanical extract only, Mr Mahoney states in his first witness statement at Paragraph 23 {PSB00001329}:

> When I looked at these proposals, however, I could see that that could lead to problems with excessive pressure drop due to the high induct velocity within the existing builderswork shafts, which could result in inadequate flow being achieved through the shafts. As a result, I developed an alternative proposal which still reused the existing ducts and shafts as per the employer's requirements, but which could achieve the functional objectives set out in the relevant guidance in place at the time.

5.4.24 Further, in his second witness statement Mr Mahoney states at Paragraph 29 {PSB00001373}:

As well as the issues raised in paragraph 23 of my first statement, I was also aware that the lobby layout at Grenfell Tower was not a typical corridor arrangement. The two shafts were located on either side of the lobby, but there were additional areas coming off the main lobby area which provided access to the flats in each corner of the tower. One shaft had a grille at low level (the south side) and the other had a grille at high level (the north side). The location of the door from the lobby to the stair was also an issue as it was not positioned at the end of a corridor. I recognised that the specific orientation of the lobby and the position of the shafts and door to the stair in Grenfell Tower meant that it would not be possible to adequately mitigate the risk that smoke would enter the stair using a push-pull system. Given the size of the lobby and the position of the shafts there would also be dead spot areas in the lobby where there would be no air flow and therefore no mixing of air and smoke to create dilution.

5.4.25 Thus, Mr Mahoney sets out three concerns about installing a 'push-pull' system at Grenfell Tower in his two witness statements:

a) Excessive pressure drop in builders work shaft due to high in duct velocity impacting flow achieved;

b) Dead-end portions of corridor in each corner where there would be no airflow, and so, no dilution of smoke; and

c) Relative position of the smoke shafts to the stair and the position of the grilles which could result in smoke entering the stair.

5.4.26 With regards item a), excessive pressure drop can occur due to trying to push, or pull, air through shafts of insufficient area. The smaller the area of the shaft, the greater the velocity in the shaft, and hence the greater the pressure drop.

5.4.27 For item b), a push-pull system supplies air as well as extracts smoke and hot gas. Therefore, such a system dilutes as well as extracts smoke. However, for the dead-end portions, it is possible that areas of stagnant smoke could be present.

5.4.28 Lastly for item c), due to the geometry of the lobby, I am not able to state, without further analysis (e.g. CFD modelling), that a push-pull system would prevent any smoke entering the stair.

5.4.29 In their Technical Submission (Revision 6, {PSB00000214}), PSB categorise the system as a *"mechanical extract system"*.

5.4.30 Section 1.1.2 of PSB's submission notes that the system is designed to comply with one of the performance criteria in the Code for pressure differential systems, BS EN 12101-6:2005.

5.4.31 Additionally, while PSB's Technical Submission and the correspondence from Max Fordham indicate that the system was to be a *"mechanical extract"*

system, Section 3.3 of PSB's Technical Submission also states {PSB00000214}:

The open/closed door condition will be monitored by as [sic] *pressure sensor (see details below) which will maintain the pressure differential between the lobby and the stairwell. The system is designed to maintain -25Pa in the lobby with all doors closed and will maintain the fans at low speed setting.*

5.4.32 The system was intended to provide protection against smoke spread to the protected stair by extracting air from the lobby only and so lowering the pressure within the lobby relative to the stair, and all other adjoining spaces.

5.4.33 The design relied on lower pressure in the lobby compared to the stair - a pressure differential - to induce a flow of air through the stair door when open into the lobby. The direction and speed of air flow through the door was intended to inhibit smoke spreading from the lobby to the stair, i.e. to push it in the opposite direction.

5.4.34 When the stair door was closed, the system performance was intended maintain a pressure in the lobby 25Pa lower than in the stair.

5.4.35 Pressure differential systems rely on these two performance criteria, air flow through an open door and pressure difference across a closed door.

5.4.36 Accordingly, while the system is described as a *"mechanical extract system"*, the overall performance of the system, as described in PSB's Technical Submission, is a form of depressurisation system.

5.4.37 In Section 2 I illustrated how a depressurisation system is intended to lower the pressure in a fire zone relative to the protected zones. In Figure 5-6 I have illustrated how the form of depressurisation system design by PSB lowered the pressure in the lobby relative to the protected stair only.

5.4.38 In this form of design, as a consequence of lowering the pressure in the lobby, air is drawn through the open stair door and any other door which is open to the lobby.

5.4.39 When all doors to the lobby are closed, less air is able to flow into the lobby from the adjoining spaces. Therefore, if the rate of extraction from the lobby is not controlled, the pressure in the lobby will continue to decrease in comparison to the adjoining spaces. As a consequence, the force required to open either a flat door or a stair door for escape will increase; but more significantly smoke may be drawn into the lobby from the flat of fire origin.

5.4.40 The possibility of the flat door being open during firefighting operations, was acknowledged by Mr Mahoney in an email to David Bradbury (JS Wright) on 2nd August 2015, responding to queries raised by Max Fordham {ART00004481}, although this does not appear in any design documentation provided by PSB.

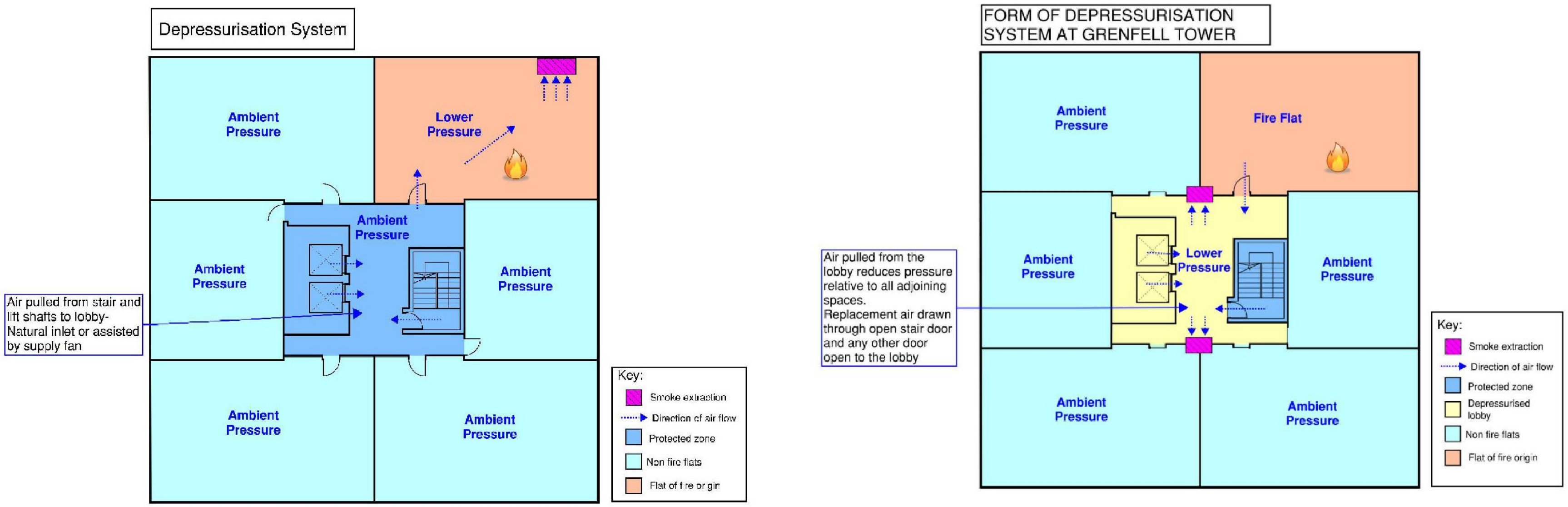


Figure 5-6 (a) Depressurisation system as illustrated in Section 2 of this report (b) form of depressurisation system designed by PSB for Grenfell Tower

5.4.41 There are a total of three performance criteria defined in PSB's Technical Submission {PSB00000214}. The first is in Section 1.1.2 'Smoke Control System':

The system has been designed to provide an average open door velocity, across an open lobby/stairwell door of 2.0 m/s

5.4.42 The second is in Section 3.3 'Mechanical Control System':

The system is designed to maintain -25Pa in the lobby with all doors closed and will maintain the fans at low speed setting

5.4.43 And, within Section 1.1.2, it is stated that the pressure controls specified are intended to ensure door-opening forces do not exceed 100N:

The control system will also have pressure sensors added into each ventilated lobby to control the speed of the fans to ensure that when the doors on the escape route are closed that the opening force on the door does not exceed 100N as detailed IN BSEN 12101-6

5.4.44 At paras. J6.2.24 – J6.2.27 of my Phase 1 report {BLAS0000031} I set out a conflict in the pressure differentials to be achieved by the PSB system as stated in PSB's Technical Submission and PSB's *Method statement & risk assessment* {PSB00000941} for commissioning. I have obtained e-mail evidence in Phase 2 which indicates that PSB's *Method statement & risk assessment* were prepared by Mr Granville Partlow {PSB00000939}.

5.4.45 Based on my review of Mr Partlow's second witness statement (described in Section 5.3) I understand the pressure differentials specified in PSB's Commissioning Method Statement and Risk Assessment to have been an error and that the pressure controls for the Grenfell Tower system were in fact set to -25Pa as per PSB's Technical Submission (Section 3.3, {PSB00000214}).

5.4.46 In the conclusions to my Phase 1 report (Section 2.21.40, {BLAS0000002}), I noted that I would investigate whether the lift shaft had been considered as required by Clause 6 of BS EN 12101-6:2005 as part of the system. Based on the evidence I have reviewed I have seen nothing to indicate that the lift shaft was considered as part of the development of the design of the smoke control system.

5.4.47 Mr Mahoney cites three documents relevant to PSB's design in his second witness statement to the Inquiry: BS EN 12101-6:2005, BS9991:2011 and *SCA Guide 2012*.

5.4.48 I have assessed the extent to which PSB's design considered the performance standards set out in these British Standards and industry guidance.

5.4.49 I present my review of the evidence of consultation with RBKC Building Control, regarding compliance of the smoke control system with the Building Regulations, in Section 5.11 below.

5.5 Comparison of PSB design with *SCA Guide 2012* and *2015* methodology

5.5.1 In Section 4 above I presented the types of smoke control system described in the *SCA Guide 2012* and *2015*.

5.5.2 The *SCA Guide 2012* was current when PSB submitted Revision 3 of their Technical Submission to RBKC Building Control (see Section 5.11, below).

5.5.3 Mr Mahoney states in paragraphs 51 and 52 of his second witness statement {PSB00001373}:

> 51. The SCA Guide 2012 contains a section entitled *"System Types" (Section 6)*, a subsection of which deals with *"Mechanical (Powered) smoke ventilation" (Section 6.4)*. Two specific types of mechanical extract system are described; the first is a *"Mechanical Extract, Natural Inlet"* system (*Section 6.4.2*) and the second is a *"Mechanical Extract, Mechanical Inlet"* system (*Section 6.4.3*).
>
> 52. The System was similar to, but not the same as, the *"Mechanical Extract, Natural Inlet"* system detailed in the SCA Guide 2012.

5.5.4 Therefore, PSB's system was not as per the example system types presented in Section 6 of the *SCA Guide 2012* (see Section 4.5, above), as I will explain.

5.5.5 The *SCA Guide 2012*, regarding the provision of inlet air for a mechanical extract, natural inlet system states:

Design of the system is dependent on the layout of the building and the recommended performance and design criteria (as detailed in Section 5). Air replacement forms part of the powered system and the designer should specify how this is to be achieved. The provision of replacement air is one way of ensuring that excess pressure does not occur across a closed door, and/or otherwise compromise means of escape.

5.5.6 From the above extract, the design of a mechanical extract, natural inlet system should therefore follow the performance and design criteria from Section 5 of the *SCA Guide 2012*, and the designer was responsible for defining how inlet air would be provided (or another means to avoid excess pressure across a closed door).

5.5.7 However, Mr Mahoney also states in paragraphs 55 and 56 of his second witness statement {PSB00001373}:

55. The SCA Guide 2015 changed the description of the *"Mechanical Extract, Natural Inlet"* system type. The description in the 2015 Guide states that:

> *"6.4.2 Mechanical Extract, Natural Inlet*
>
> *The system comprises mechanical extract shaft(s) serving one or more common spaces on all, or some, of the floor levels supplemented by the provision of natural inlet air provided by automatically opening vents or permanent vent to the outside (either directly or by way of a shaft, stairway or duct)."*

56. The two figures showing the indicative layouts remained the same, but this change of wording in the SCA Guide 2015 acknowledged a type of system which allows for natural inlet air to be provided by way of a stairway, as was the case with the System.

5.5.8 Within PSB's system at Grenfell Tower, permanent vents from the lobby direct to outside were not provided. Furthermore, automatically opening vents providing natural inlet air were not provided. PSB's system was not, therefore, a 'mechanical extract, natural inlet system' as described in the *SCA Guide 2015*.

5.5.9 Instead, the system was consistent with the mechanical extract only type system, as described in the *SCA Guide 2015,* at section 6.4.4:

6.4.4 Mechanical Extract only

The system comprises mechanical extract shaft(s) serving one or more common spaces on all, or some, of the floor levels. The system uses a single mechanical extract shaft, with replacement air typically provided by natural leakage. Air replacement forms a key component of a mechanical extract only system and the designer should specify how this is to be achieved and how this is to be confirmed and tested onsite to ensure excessive pressure does not occur across a closed door or otherwise compromise means of escape by pulling smoke into the common escape routes from the adjoining space.

The design of the system is dependent on the layout of the building and the recommended performance and design criteria (as detailed in Section 5).

5.5.10 Again, in the *SCA Guide 2015*, the recommended performance and design criteria (as detailed in Section 5) were to be considered.

5.5.11 It is on this basis that I present my analysis of PSB's design and in particular how they assessed the required performance for Grenfell Tower and the resulting design criteria they identified to demonstrate that performance.

5.5.12 **Objectives and performance criteria**

5.5.13 The *SCA Guide 2012* and *SCA Guide 2015* state:

It is possible to design systems providing a higher performance that may then be used to allow extended travel distances in corridors

...

In this case the system objectives and performance should follow the guidance in section 5.

5.5.14 Grenfell Tower had extended travel distances in the lobby exceeding 7.5m (per ADB 2013), needed to be considered, and if a protection solution was possible. Therefore, demonstrating the system in accordance with Section 5 of the SCA Guide was required.

5.5.15 In Table 5-2 below, I have presented the performance objectives and criteria from the *SCA Guide 2012* and *2015*.

5.5.16 In Section 4.5above, I presented a flow chart I derived recording the process a designer would likely follow when adopting the approach in the SCA Guide.

5.5.17 From the PSB documentation available to me, I have not seen any evidence that PSB undertook either a- comparative or deterministic assessment- of their system.

Table 5-2: Performance objectives and criteria from *SCA Guide 2012* and *2015*

<table>
<tr><th>Parameter</th><th>SCA Guide 2012</th><th>SCA Guide 2015 [Where travel distances within the lobby are not in accordance with ADB i.e. >7.5m]</th><th>Considered in PSB's design documentation</th></tr>
<tr><td>System objective</td><td>Any system should be designed to keep the stairs relatively free of smoke under design conditions.</td><td>The design objective of any system should be to maintain relatively smoke free conditions within the staircase such that it can be used for evacuation and fire service access/egress at all times. Where the travel distance from the furthest apartment to the door to the staircase or the door to a sterile lobby does not exceed 7.5m, this is considered to be the only design objective.</td><td>"The Final smoke control system has been designed to provide the existing stairwell with protection from the ingress of smoke..."</td></tr>
<tr><td>System objective</td><td>Any system should be designed to promote tenable conditions for travel through the ventilated corridors/lobbies during the escape period. It should be noted that this may only be possible when the apartment door is closed.</td><td>Where sprinklers are not provided and where the travel distances from the apartment to staircase or sterile lobby are over 7.5m but do not exceed 15m, the performance objectives of the system are to maintain the staircase relatively free of smoke and to ensure the designer's specified tenable limits for means of escape are met within the corridor.
Additional performance objectives for protection of firefighters are required where the building is of significant height and, therefore, under the relevant design guide (e.g. ADB) additional provisions for fire-fighting access, such as fire-fighting shafts, may be required.
Note: generally natural ventilation is not appropriate for corridors of this length, so the system provided should be mechanical.</td><td>I have found no evidence in PSB's design documentation that the travel distance in the lobby was reviewed, nor if maintaining tenable conditions within the lobby was considered.</td></tr>
<tr><td>Design conditions general guidance</td><td>BRE used 'steady-state' conditions in their work, assuming a number of design fire outputs and fixed door openings. While this approach allowed easy comparison of multiple geometries, it may not provide a good representation of reality, where conditions are expected to be transient, with the fire developing and doors opening and closing as time progresses. Nevertheless, since these steady-state conditions are readily available and simple to use, they can provide useful design conditions. The alternative is to use time dependent conditions with a set timeline of actions. This is more realistic but requires more complex analysis and time dependent performance criteria.</td><td>In its study of smoke ventilation where travel distances are code compliant, BRE focused its research on 'steady-state' conditions, examining a number of design fires and fixed door openings. This approach allows a straightforward comparison of different geometries and ventilation methods. It does not, however, capture the transient nature of an actual fire scenario, where the fire develops with time and doors open and close at various stages during the event. Nevertheless, an analysis of steady-state conditions can provide a convenient way to assess a smoke ventilation system, in particular with regard to the protection afforded to the stair enclosure and to after the arrival of the fire service, where fixed door opening conditions may be relevant.

The alternative approach, employing a timeline of events and actions, is more realistic but generally requires additional analysis and consideration of time dependent performance criteria, e.g. the time to return a corridor to conditions suitable for means of escape.</td><td>I have found no evidence in PSB's design documentation that they assessed the proposed system for Grenfell Tower using either steady-state or time dependent design conditions.</td></tr>
<tr><td>Steady-state design conditions</td><td>Table 5.1 Illustrative steady-state design conditions (buildings without sprinkler protection) – taken from BRE report 213179
<table>
<tr><th>Fire size in dwelling (kW)</th><th>Dwelling door opening width (m)</th><th>Approx temperature of smoke at door (°C)</th><th>Flow of smoke from room Mass (kg/s)</th><th>Flow of smoke from room Heat (kW)</th><th>Stair door opening width (m)</th><th>Condition</th></tr>
<tr><td>250</td><td>0.1</td><td>210</td><td>0.2</td><td>40</td><td>closed</td><td>Early stages of fire, relevant for MOE from fire compartment</td></tr>
<tr><td>1000</td><td>0.5</td><td>360</td><td>0.9</td><td>350</td><td>closed</td><td>Later stage of fire, relevant for MOE from other compartments and arrival of fire service</td></tr>
<tr><td>2500</td><td>0.78</td><td>690</td><td>1.4</td><td>1100</td><td>0.78</td><td>Late stages of fire, relevant for fire service intervention</td></tr>
</table>
A conservative design fire could have a rate of heat release of 250 kW/m^2 and a soot yield of 10%, based on the involvement of polyurethane foam.
Where it is decided that a steady state approach is to be undertaken the following time periods should be considered:
1. Fire development
2. Escape of the occupants
3. Firefighting activities.

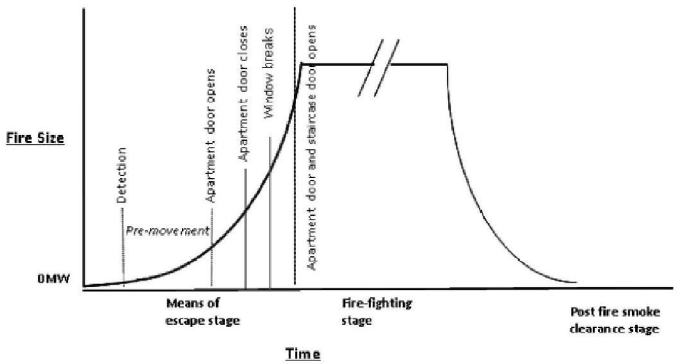
During these periods the fire conditions and open door conditions appropriate to the</td><td>Where the common area travel distance in the corridor or lobby exceeds that of a code compliant layout, then a time-dependent analysis is likely to be necessary. This might include a set of separate steady-state analyses, each representing a stage in the fire scenario where conditions are quasi-steady, e.g. during firefighting operations and where the door opening positions are fixed and the fire is burning at a (potentially full-developed) steady-state. However, the designer will need to undertake time-dependent calculations or simulations of part, or all, of the fire scenario timeline, e.g. to determine the time required to return the corridor to tenable conditions following a period of smoke exposure.</td><td>I have found no evidence in PSB's design documentation that they assessed the proposed system for Grenfell Tower using steady-state design conditions.</td></tr>
</table>

<table>
<tr><th>Parameter</th><th>SCA Guide 2012</th><th>SCA Guide 2015 [Where travel distances within the lobby are not in accordance with ADB i.e. >7.5m]</th><th>Considered in PSB's design documentation</th></tr>
<tr><td></td><td>circumstances as outlined in Section 5.3.2.1 of this document should be used. [See Time-dependent design conditions row below]</td><td>Table 5.2 Illustrative steady-state design boundary conditions (buildings without sprinkler protection, code compliant travel distances) – taken from BRE report 213179
<table>
<tr><th rowspan="2">Fire size in dwelling (kW)</th><th rowspan="2">Dwelling and stair door opening widths (m)</th><th rowspan="2">Size of low level vent to outside</th><th rowspan="2">Average temperature of smoke at door (°C)</th><th colspan="3">Flow of smoke from dwelling</th><th rowspan="2">Fire stage</th></tr>
<tr><th>Mass (kg/s)</th><th>Heat (kW)</th><th>Soot (kg/s) *</th></tr>
<tr><td>250</td><td>0.1</td><td>0.65m² (1.3m W by 0.5m H)</td><td>210</td><td>0.2</td><td>40</td><td>1.25 x 10⁻³</td><td>Early stages of fire, relevant to period following initial MOE</td></tr>
<tr><td>1000</td><td>0.5</td><td>1m² (1.4m W by 0.7m H)</td><td>360</td><td>0.9</td><td>350</td><td>5 x 10⁻³</td><td>Developed fire, relevant for later MOE and arrival of fire service</td></tr>
<tr><td>2500</td><td>0.78</td><td>1.9m² (2.1m W by 0.9m H)</td><td>690</td><td>1.4</td><td>1100</td><td>12.5 x 10⁻³</td><td>Immediately prior to flashover in fire compartment, relevant for fire service intervention</td></tr>
</table>
* This value corresponds to an effective heat of combustion of 20 000 kJ kg⁻¹ and a soot yield of 10%, and then represents an upper bound on the premise that all the soot enters the corridor (and is not vented to the outside or deposited on the internal surfaces). Alternative heats of combustion or soot yields would have a direct impact on the amount of soot entering the corridor.</td><td></td></tr>
<tr><td>Time-dependent design conditions</td><td>Table 5.3 below shows a typical basic generic time line. Other events, such as occupants escaping from other apartments, can be added as required. Project specific times need to be assessed for each event.
Table 5.3 typical time line for time dependent design
<table>
<tr><th>Event</th></tr>
<tr><td>Start of fire (ignoring any smouldering period)</td></tr>
<tr><td>Fire detected in dwelling</td></tr>
<tr><td>Door to dwelling opens (for occupant escape)</td></tr>
<tr><td>Door to dwelling closes</td></tr>
<tr><td>Ventilation system operates from corridor/lobby detection system</td></tr>
<tr><td>Door to stair opens (for occupant escape)</td></tr>
<tr><td>Door to stair closes</td></tr>
<tr><td>Apartment window breaks</td></tr>
<tr><td>Door to stair opens (fire service arrival) and remains open</td></tr>
<tr><td>Door to fire dwelling opens (fire service inspection)</td></tr>
<tr><td>Door to fire dwelling opens (fire service arrival)</td></tr>
</table>
Suitable design fires are recommended in CIBSE Guide E and BS 7974. The growth of the fire is likely to take a form similar to that shown in figure 5.1.</td><td>Table 5.3 presents a typical time line, and covers most of the events that might be considered in the design of the smoke control system. Other events, such as occupants escaping from other apartments, can be added as required.

The actual timings will depend on various factors such as the internal geometry of the apartment and the fire service attendance time and will generally need to be agreed on a project by project basis.</td><td>I have found no evidence in PSBs design documentation that they assessed the proposed system for Grenfell Tower using time dependent design conditions.</td></tr>
</table>

<table>
<tr><th>Parameter</th><th>SCA Guide 2012</th><th>SCA Guide 2015 [Where travel distances within the lobby are not in accordance with ADB i.e. >7.5m]</th><th>Considered in PSB's design documentation</th></tr>
<tr><td></td><td>

Figure 5.1 Typical time dependent fire



When using time dependent design, the performance criteria in 5.3.2.1.2 for steady state design are still applicable although transient excesses of short duration may be acceptable, for example upon opening of the apartment door.

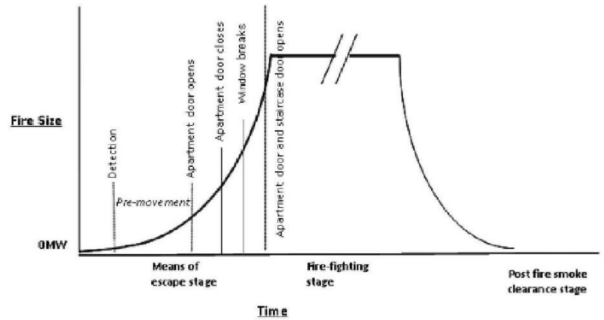
In addition it may be beneficial to set specific time dependent criteria such as the time taken to return the corridor to a specified visibility or other tenability criterion once the apartment door has closed. A suitable time might be approximately 2 minutes for a long corridor as recommended in the LDSA Fire engineering performance criteria Paper "Mechanical Smoke Venting of Residential Lobbies and Firefighting Shafts" dated July 2006.

</td><td>

Table 5.3 Typical time line for time-dependent design

<table>
<tr><th>Event</th><th>Note</th></tr>
<tr><td>Start of fire</td><td>Ignoring any smoldering period</td></tr>
<tr><td>Fire continues to burn at an increasing rate</td><td>A medium growth, t-squared fire (e.g. see PD 7974-1) is widely adopted</td></tr>
<tr><td>Fire detected in apartment</td><td></td></tr>
<tr><td>Door to apartment opens (for occupant escape)</td><td></td></tr>
<tr><td>Door to apartment closes</td><td>Generally this will be between 10s and 20s after the door opens</td></tr>
<tr><td>Door to stair opens (for occupant escape)</td><td></td></tr>
<tr><td>Door to stair closes</td><td>Generally this will be between 10s and 20s after the door opens</td></tr>
<tr><td>Ventilation system reaches operational state</td><td>Smoke detection in the corridor will initiate the ventilation system. Full operation not likely to occur until after the first occupants have evacuated the corridor.</td></tr>
<tr><td>Ventilation system continues operating</td><td>Ventilation assists in protecting the stair, and depending on the performance criteria, to clear smoke from the corridor.</td></tr>
<tr><td>Fire continues to burn at an increasing rate to reach max heat release rate for design</td><td>Assuming sufficient ventilation is available in the apartment and there is no fire suppression (e.g. sprinklers).
Additional ventilation by glazing failure is likely to be required.</td></tr>
<tr><td>Fire service access door(s) opens</td><td></td></tr>
</table>

</td><td></td></tr>
</table>

Parameter	SCA Guide 2012	SCA Guide 2015 [Where travel distances within the lobby are not in accordance with ADB i.e. >7.5m]	Considered in PSB's design documentation
		Door to stair opens (fire service arrival) and remains open — The degree of door opening is case dependant Door to fire apartment fully opens (fire fighting operations) — Ventilation protects the stair and reduces severity of conditions in the corridor. Recommendations for suitable design fires can be found, for example, in PD 7974-1:2003 and the BRE Trust publication FB 29 (2011) *Design Fires for use in Fire Safety Engineering*. The growth of the fire is likely to take a form similar to that shown in Figure 5.2. **Figure 5.2 Typical time-dependent design fire (buildings without sprinkler protection)** 	
Deterministic tenability criteria:			
General requirement	Selection of appropriate performance (acceptance) criteria for assessing a fire engineered system design should be established at the start of the design process, typically at the qualitative design review. It is not appropriate to give definitive values in this guidance as they need to be established on a case by case basis as part of the overall fire strategy. However, published information is available (see, for example, BS 7974:2001 and associated PD 7974 series Application of fire safety engineering principles to the design of buildings, BS 7899-2:1999 Guidance on methods for the quantification of hazards to life and health and estimation of time to incapacitation and death in fires and the SFPE Handbook of Fire Protection Engineering).	Performance criteria for means of escape, are generally based on tenability. The main criteria of interest could include visibility, gas temperature, thermal radiation and toxicity within the common corridors, lobbies and stair enclosures. Selection of appropriate performance (acceptance) criteria for assessing a fire engineered system design should be established at the start of the design process, typically at the qualitative design review. Where system performance is being assessed deterministically (and not compared to an ADB compliant one) it will generally be necessary to set acceptance limits for one or more performance criteria based on tenability. It is not appropriate to give definitive values here as they need to be established on a case by case basis as part of the overall fire strategy. However, published information is available (see, for example, BS 7974:2001 and associated PD 7974 series Application of fire safety engineering principles to the design of buildings, BS 7899-2:1999 Guidance on methods for the quantification of hazards to life and health and estimation of time to incapacitation and death in fires, the SFPE Handbook of Fire Protection Engineering and the ASHRAE Handbook of Smoke Control Engineering and CIBSE Guide E Fire Engineering.	No deterministic study recorded by PSB.
Minimum Visibility	A widely used smoke criterion is that of 10 metres visibility distance. It is often difficult to maintain a minimum visibility distance when the apartment door is open to the corridor; this is because the corridor fills with smoke generated by the apartment fire. BRE Report 213179 found that it was difficult under most smoke control scenarios to keep the corridor clear of smoke. The designer, approving authorities and other interested parties should take this into account when determining design and performance criteria.	**Means of escape** A commonly adopted conservative visibility distance limit is 10m (approx. $0.1m^{-1}$ optical density) as measured to a light reflective surface, representing an approximate value through which persons unfamiliar with a building would be prepared to travel … A lower value of 5m might be acceptable where the persons escaping are familiar with the building and the travel distance is relatively short. At a visibility distance of 5m (approx. $0.2m^{-1}$ optical density) conditions will remain tenable with respect to asphyxiant gases for at least 30 minutes (see PD 7974-6) for the majority of fires.	I have found no evidence in PSB's design documentation that a visibility tenability criteria was specified or agreed with RBKC building control.

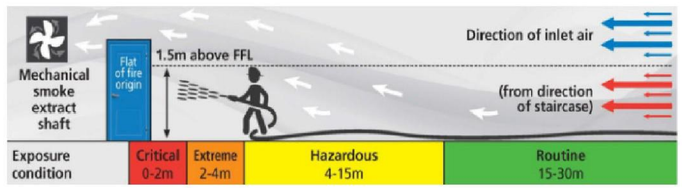
<table>
<tr><th>Parameter</th><th>SCA Guide 2012</th><th>SCA Guide 2015 [Where travel distances within the lobby are not in accordance with ADB i.e. >7.5m]</th><th>Considered in PSB's design documentation</th></tr>
<tr><td></td><td></td><td>
An alternative, and potentially more rigorous, approach is to determine whether or not the stair door is visible from the apartment entrances.
Firefighting
Publicly available and recent research relating to firefighter tenability is somewhat limited at present, however it is suggested that the criteria in Table 5.1 (as adopted by the Australasian Fire Authorities Council (AFAC)) could be applied by system designers when assessing this issue:
Table 5.1 Illustrative fire fighter tenability conditions
<table>
<tr><th>Exposure Condition</th><th>Maximum exposure time (minutes)</th><th>Maximum air temperature (0C)**</th><th>Maximum radiated heat flux (kW/m2)</th><th>Remarks</th><th>Recommended distance from apartment door*</th></tr>
<tr><td>Routine</td><td>25</td><td>100</td><td>1</td><td>General fire-fighting</td><td>15-30m</td></tr>
<tr><td>Hazardous</td><td>10</td><td>120</td><td>3</td><td>Short exposure with thermal radiation</td><td>4-15m</td></tr>
<tr><td>Extreme</td><td>1</td><td>160</td><td>4 – 4.5</td><td>For example, snatch rescue scenario</td><td>2-4m</td></tr>
<tr><td>Critical</td><td><1</td><td>>235</td><td>>10</td><td>Considered life threatening</td><td>0-2m</td></tr>
</table>
* This column and remarks are not part of the original research document and are the opinion of the SCA
** Measured at a height of 1500mm from FFL


Figure 5.1 Fire fighter tenability conditions
</td><td></td></tr>
<tr><td>Maximum Temperature</td><td>60°C</td><td>Means of escape
60°C

Firefighting
See minimum visibility row above.</td><td>I have found no evidence in PSB's design documentation that a maximum temperature tenability criterion was specified or agreed with RBKC building control.</td></tr>
<tr><td>Maximum Thermal radiation</td><td>2.5kW/m²
Note that the radiation flux criteria is sometimes expressed alternatively as a temperature of a smoke layer above head height, with a smoke temperature of 200°C corresponding approximately to a flux of 2.5 kW/m².</td><td>Means of escape
2.5kW/m²

Firefighting
See minimum visibility row above.</td><td>I have found no evidence in PSBs design documentation that a maximum thermal radiation tenability criterion was specified or agreed with RBKC building control.</td></tr>
<tr><td>Toxicity</td><td>No specific toxicity criteria defined.</td><td>No specific toxicity criteria defined. See 'minimum visibility' row above.</td><td>I have found no evidence in</td></tr>
</table>

Parameter	SCA Guide 2012	SCA Guide 2015 [Where travel distances within the lobby are not in accordance with ADB i.e. >7.5m]	Considered in PSB's design documentation
			PSBs design documentation that a maximum thermal radiation tenability criterion was specified or agreed with RBKC building control.
Condition for stair	…For stairs these criteria should be adjusted to reflect 'relatively smoke free' conditions, although protection of the stairs can also be indicated as a function of maintaining a suitable positive ventilation flow from the stair to the corridor or lobby. Visibility in the stairs should be greater than in the corridor. Note that it is generally accepted that if the visibility is acceptable then the toxicity conditions are likely also to be acceptable.	The design objective of any system should be to maintain relatively smoke free conditions within the staircase such that it can be used for evacuation and fire service access/egress at all times.	*"The Final smoke control system has been designed to provide the existing stairwell with protection from the ingress of smoke…"*
Maximum door opening force	100N	100N	Maximum door opening force of 100N
Pressure differential	Pressure differences between the corridor/lobby and adjacent stairs and accommodation should not cause door opening forces to exceed 100N at the door handle. This is unlikely to be exceeded if pressure differences across the door are limited to 60Pa.	It is important also to consider the potential impact of the pressure difference between the dwelling and the corridor to ensure that smoke is not unduly pulled into the corridor when the dwelling door is in a closed position. The maximum acceptable level of depressurisation in the corridor relative to the apartment will depend on factors such as the doorset construction, including the performance of the smoke seals and size of gap under the door. Air flows from the stair enclosure into the corridor, in the situation where the door is open, might be adopted as a performance criterion, with a minimum design air speed set to prevent the flow of smoke into the stair.	Maximum pressure differential stated as 25Pa between stair and lobby
Comparative study performance criteria			
Basis of assessment	An alternative method of assessment is to compare the performance of the proposed system with that of an ADB compliant system under the same design conditions. In this case the performance criterion is that tenability should be no worse than that provided by the ADB compliant system. Where the performance of a fire engineered system is being compared against an ADB compliant one, the assessment is essentially one of judicially comparing the smoke (visibility and/or toxicity) and thermal (temperature and/or radiation flux) conditions generated by the two systems.	Where travel distances are extended and/or corridor sub-divisions are removed in buildings with a 'stay-put' policy, proving 'equivalency' to code compliance is not appropriate. A detailed engineering analysis is required although in every design strategy the relevant prescriptive benchmarks and functional requirements should be used for comparison.	I have found no evidence in PSBs design documentation that a comparative study between the proposed smoke control system and an ADB compliant system was undertaken; nor a comparison with the original performance requirements such as described in CP3 1971.
Documentation			
Requirements for documentation recording design	Results should be presented in an appropriate form for each agreed criterion. Sufficient information should be provided to allow relevant parties to assess the analysis undertaken in relation to checking and meeting the required performance criteria. The results of the analysis should be documented and may be provided in the form of a report, together with any necessary supporting animations from advanced modelling. The documentation should include at least the following information: • A description of the residential area and the proposed ventilation system • The design criteria and performance objectives of the analysis • The scenarios investigated • Details of the techniques used and related information • The results of the analysis	Results should be presented in an appropriate form for each agreed criterion. Sufficient information should be provided to allow relevant parties to assess the analysis undertaken in relation to checking and meeting the required performance criteria. The results of the analysis should be documented and may be provided in the form of a report, together with any necessary supporting animations from advanced modelling. The documentation should include at least the following information: • A description of the residential area and the proposed ventilation system • The design criteria and performance objectives of the analysis • The scenarios investigated • Details of the techniques used and related information • The results of the analysis	See Section 5.5.18 for my analysis of the documentation provided by PSB against the SCA guide.

Parameter	SCA Guide 2012	SCA Guide 2015 [Where travel distances within the lobby are not in accordance with ADB i.e. >7.5m]	Considered in PSB's design documentation
	• A statement as to whether the design criteria and objectives have been met For time dependent analyses, graphical results should be presented wherever possible to quantitatively show conditions plotted against a time line. A sensitivity analysis should be carried out and presented such that it allows important outputs between different scenarios to be easily compared.	• A statement as to whether the design criteria and objectives have been met • Summary input/output data for the modelling used For time dependent analyses, graphical results should be presented wherever possible to quantitatively show conditions plotted against a time line. A sensitivity analysis should be carried out and presented such that it allows important outputs between different scenarios to be easily compared.	

5.5.18 **Documentation**

5.5.19 As I presented in Section 4, the *SCA Guide 2012* and *2015* set out a specific list of documentation that must be produced to demonstrate that the proposed system meets the agreed objectives and performance criteria.

5.5.20 I have analysed the available documents, and my findings are as follows.

5.5.21 PSB Technical Proposal

5.5.22 Mr Mahoney issued his design calculation for Grenfell Tower in a four page report titled "*Smoke Ventilation Proposal for Stair De-Pressurisation Systems at Grenfell Tower, Regeneration Project*" dated 22nd April 2014 {PSB00001233}.

5.5.23 The purpose of the report is stated as follows {PSB00001233}:

After discussions this report provides an alternative approach to designing a lobby smoke control system.

5.5.24 Section 2 is headed *System Requirements to BS EN 12101-6* and includes calculations of the required volumetric flow rate through an open door of $1.6m^2$ to achieve a flow speed of 2.0m/s, with the required volumetric flow rate increase by 50% to account for 'fabric losses'.

5.5.25 Section 4 of the document {PSB00001233} lists the components of the smoke control system.

5.5.26 In Table 5-3 below I have presented a summary of my analysis of the information contained within the PSB Smoke ventilation proposal report {PSB00001233} against the information to be included in accordance with the SCA Guide.

Table 5-3: Analysis of documentation provided by PSB against the SCA Guide 2012/2015

Information to be included per SCA Guide 2012/2015	Covered by PSB Smoke ventilation proposal report {PSB00001233}
A description of the residential area and the proposed ventilation system	No description of the residential area provided. System described as "*a de-pressurisation system which will protect the stairwell by providing an airflow from the stairwell into the lobby when the stairwell / lobby door is open.*"
The design criteria and performance objectives of the analysis	The only performance criteria provided were for open door velocity, maximum pressure difference and door opening force. These do not cover the range of performance and tenability criteria set out in the SCA Guide as presented Table 5-2).
The scenarios investigated	No specific scenarios investigated.
Details of the techniques used and related information	Hand calculations for flow through an open door presented only.
The results of the analysis	No comparative or deterministic analysis presented, and thus, no results of the analysis recorded.
A statement as to whether the design criteria and objectives have been met	Nothing stated.

5.5.27 PSB's Technical Submission

5.5.28 The design of the PSB system was recorded in a series of revisions of a Technical Submission reflecting the design development. The final version of the Technical Submission was Revision 6, dated 15th March 2016{PSB00000214}. There were no substantial changes to the design between the first issue and the final revision.

5.5.29 Revision 3, dated 12th June 2015 {RBK00001414}, of the Technical Submission was the version approved by RBKC Building Control. See Section 5.11 where I present my analysis of the consultation between PSB & RBKC Building Control for the smoke control system.

5.5.30 I present my analysis below based on the final version, Revision 6 {PSB00000214}, of PSB's Technical Submission.

Table 5-4 Analysis of documentation provided by PSB against the SCA Guide 2012/2015

Information to be included per SCA Guide 2015/2015	Covered by PSB Technical Submission Revision 6 {PSB00000214}
A description of the residential area and the proposed ventilation system	Section 1.1.1 provides a *Description of the Project* but does not describe the residential area (e.g. no reference to evacuation strategy, travel distances, active and passive fire protection measures). Section 1.1.2 provides a description of the final smoke control system.
The design criteria and performance objectives of the analysis	The only performance criteria provided were for open door velocity, maximum pressure difference and door opening force. These do not cover the range of performance and tenability criteria set out in the SCA Guide as presented Table 5-2).
The scenarios investigated	No specific scenarios investigated.
Details of the techniques used and related information	No record of techniques used to assess the system performance and related information provided (e.g. no hand calculations and supporting assumptions).
The results of the analysis	No comparative or deterministic analysis presented, and thus, no results of the analysis recorded.
A statement as to whether the design criteria and objectives have been met	Nothing stated.

5.5.31 <u>System specific requirements</u>

5.5.32 As I have explained in Section 4, the *SCA Guide 2012* and *2015* provided specific design recommendations for different types of smoke control system.

5.5.33 As I have explained above, Mr Mahoney states that the system he designed was most similar to a ‘mechanical extract, natural inlet system’ as described in the *SCA Guide 2012.*

5.5.34 When comparing the *SCA Guide 2015* and the PSB system, I have found that the system was consistent with the mechanical extract only type described in the *SCA Guide* 2015.

5.5.35 In Table 5-5, I have therefore presented my review of PSB’s design documentation against the design recommendations for a ‘mechanical extract only system’ in accordance with the *SCA Guide 2015*.

Table 5-5 Analysis of documentation provided by PSB against the recommendations of a Mechanical only system in accordance with the *SCA Guide 2015*

SCA Guide 2015 requirement		**Considered in PSBs design documentation**
6.4 Mechanical (Powered) smoke ventilation 6.4.1 General Principles	*Requirements of mechanical systems include a maintained power supply*	Yes
6.4 Mechanical (Powered) smoke ventilation 6.4.1 General Principles	*Requirements of mechanical systems include… fire resisting wiring*	Yes
6.4 Mechanical (Powered) smoke ventilation 6.4.1 General Principles	*Requirements of mechanical systems include…temperature classified equipment*	Partial- The temperature performance of the fans was considered but PSB made no reference to how the power and control equipment will be protected from the effects of fire or that they are temperature rated
6.4 Mechanical (Powered) smoke ventilation 6.4.1 General Principles	*Requirements of mechanical systems include… a standby fan unit*	Yes
6.4 Mechanical (Powered) smoke ventilation 6.4.1 General Principles	*Suitable air inlet and exhaust is needed to prevent damage to the system and to ensure that excessive pressurisation or depressurisation of the ventilated area does not occur.*	Yes
6.4 Mechanical (Powered) smoke ventilation 6.4.1 General Principles	*System designers should avoid opening ventilators on multiple floor levels*	Yes
6.4 Mechanical (Powered) smoke ventilation 6.4.1 General Principles	*Smoke shafts should be constructed of non-combustible material*	No- I have found no evidence that PSB considered construction of the smoke shafts
6.4 Mechanical (Powered) smoke ventilation 6.4.1 General Principles	*All vents to the lobbies/ corridors should have a fire/ smoke resistance performance at least equivalent to that of an E30Sa fire door. The fire rating of the vent needs to be agreed with the AHJ.*	No- Gilberts and BSB dampers were specified but the PSB documentation does not state what performance either of these dampers provide.

SCA Guide 2015 requirement		**Considered in PSBs design documentation**
6.4 Mechanical (Powered) smoke ventilation 6.4.1 General Principles	*Activation of the system is subject to discussion with the AHJ and other interested stakeholders.*	Yes
6.4 Mechanical (Powered) smoke ventilation 6.4.1 General Principles	*Upon activation of the system the smoke vent(s) on the fire floor, the vent(s) at the top of the smoke shaft(s) and the vent at the head of the stairway should open and any fans should run at the design speed.*	Yes (Noting that in Grenfell Tower the vent at the top of the stair is permanently open)
6.4 Mechanical (Powered) smoke ventilation 6.4.1 General Principles	*Vents on all other storeys should remain closed even if smoke is subsequently detected on floors other than the fire floor.*	Yes
6.4 Mechanical (Powered) smoke ventilation 6.4.1 General Principles	*It is possible to design systems providing a higher performance that may then be used to allow extended travel distances in corridors......In this case the system objectives and performance should follow the guidance in section 5*	No- I have found no evidence that PSB considered the impact of the extended travel distance at Grenfell Tower in their design. Further guidance of Section 5 of the SCA guide was not followed by PSB (refer to Section 4.5)

SCA Guide 2015 requirement		**Considered in PSBs design documentation**
6.4 Mechanical (Powered) smoke ventilation 6.4.1 General Principles	*The location of extract and inlet points should be designed to protect the stair and to ensure that the layout minimises the potential for heat and smoke in the corridor/lobby to affect escaping occupants and firefighters.*	No- The location of the extract and inlet points; and the geometry of the lobby in Grenfell Tower was fixed by the nature of the existing building. I have however found no evidence that PSB analysed the *layout and how to minimises the potential for heat and smoke in the lobby; they did not set for example,* tenability criteria for visibility, gas temperature, thermal radiation and toxicity within the lobbies nor demonstrated that their design would ensure that any relevant criteria were met when factoring in the restrictions of the existing building layout.
6.4 Mechanical (Powered) smoke ventilation 6.4.1 General Principles	*It is important to ensure that the location of the inlet air source in relation to the point of smoke extract does not create dead spots in the protected zone.*	No - The location of the extract and inlet points; and the geometry of the lobby in Grenfell Tower was fixed by the nature of the existing building. I have however found no evidence that PSB calculated how the geometry of the lobby in Grenfell Tower could result in a dead zone where the smoke would not be able to be extracted.

SCA Guide 2015 requirement		Considered in PSBs design documentation
6.4 Mechanical (Powered) smoke ventilation 6.4.1 General Principles	*It is recommended that extracting smoke away from the stairs should be the default position where travel distances are in excess of 7.5m. This will normally result in the extract shaft(s) being positioned remote from the stair.* *Where it is not possible to provide the extract(s) in a remote location from the staircase for extended corridor systems, the location of the extracts should be subject to early discussions with the AHJ.*	No- The location of the extract and inlet points; and the geometry of the lobby in Grenfell Tower was fixed by the nature of the existing building. The result of this was that the extract points were not remote from the stair. I have found no evidence that PSB incorporated how the location of the extract points would result in occupants having to pass through smoke to get to the protected stair, especially as the extract from the south shaft would pull the smoke down to low level in the lobby.
6.4 Mechanical (Powered) smoke ventilation 6.4.1 General Principles	*When calculating the rate of extract and making fan selections, adequate allowance should be made for system leakage, including for example, leakage through ductwork, smoke shaft and all other closed dampers in the system* *Calculation of the leakage rate should take account of the pressure to which the system is subjected.*	Yes
6.4 Mechanical (Powered) smoke ventilation 6.4.4 Mechanical extract only	*The system uses a single mechanical extract shaft, with replacement air typically provided by natural leakage*	Yes
6.4 Mechanical (Powered) smoke ventilation 6.4.4 Mechanical extract only	*Air replacement forms a key component of a mechanical extract only system and the designer should specify how this is to be achieved*	Yes

SCA Guide 2015 requirement		Considered in PSBs design documentation
6.4 Mechanical (Powered) smoke ventilation 6.4.4 Mechanical extract only	*Air replacement forms a key component of a mechanical extract only system and the designer should specify..... how this is to be confirmed and tested onsite to ensure excessive pressure does not occur across a closed door or otherwise compromise means of escape by pulling smoke into the common escape routes from the adjoining space.*	No- Design performance specification was for a -25pa pressure difference between the stair and the lobby however PSB made no reference to how this would be confirmed and tested onsite.
6.4 Mechanical (Powered) smoke ventilation 6.4.4 Mechanical extract only	The design of the system should take into consideration that the source of inlet air should not compromise normal passive fire separation.	Yes
6.4 Mechanical (Powered) smoke ventilation 6.4.4 Mechanical extract only	*Where only a single mechanical extract is provided the fans should be duty/standby fans as fan failure would result in failure of the system.*	Yes
6.4 Mechanical (Powered) smoke ventilation 6.4.4 Mechanical extract only	*The decision regarding the ventilation rates, undertaken by the designer, should reflect the specific risks presented within the building.*	No- I have found no evidence that PSB set ventilation rates on the basis of any specific scenario. For example escape through the lobby or other criteria caused by the restrictions of the existing building layout.
6.4 Mechanical (Powered) smoke ventilation 6.4.4 Mechanical extract only	*Mechanical extract only systems using natural leakage for replacement air are not suitable where extended travel distances occur, unless specific consideration of the risks is undertaken by the designer and approval obtained from the authority having jurisdiction.*	No- I have found no evidence that PSB considered the effect of an extended travel distance on their design or that they considered how a mechanical extract system using natural leakage may not be suitable for such an application.

5.6 Comparison of PSB's design with the BS EN 12101-6 Class B depressurisation pressure differential system

5.6.1 In Section 4.3 I presented an overview of a mechanical smoke control systems described in BS EN 12101-6:2005.

5.6.2 Despite making a pressure differential a primary design objectives, Mr Mahoney states in his second witness statement {PSB00001373} (bold by me):

*40. It follows that I did not design a Pressure Differential System, which are designed to comply with **all the requirements** of BS EN 12101-6.*

41. My design reflected a more common type of mechanical extract 'depressurisation' system. A performance-based building appropriate solution widely adopted as a type of smoke control system and which were often referred to within the industry as 'depressurisation' systems and is commonly called the ColtShaft mechanical shaft system.

5.6.3 Mr Mahoney confirms his design did not comply with *"all the requirements of BS EN 12101-6"*. I have however undertaken a comparison between PSBs design and the requirements of a Pressure Differential System to BS EN 12101-6 to understand what features in BS EN 12101-6 were considered.

5.6.4 As I have explained in Section 4, there are multiple classes of pressure differential system described in BS EN 12101-6, a function of the intended application.

5.6.5 I have compared the PSB design to a Class B system as Mr Mahoney states in his second witness statement {PSB00001373}:

66. Whilst the System did not operate in the same way as a Class B Pressure Differential System, the airflow it was designed to generate across the open door was similar to that aspect of the required performance criteria of a Class B Pressure Differential System. It is for this reason that I felt that it was appropriate to adopt the figure of 2.0m/s from BS EN 12101-6 for the System.

5.6.6 In Figure 4-5 I illustrated how the accommodation is depressurised with respect to the stair and lobby.

5.6.7 In Grenfell Tower the lobby was depressurised with respect to both the stair and the accommodation, which is not an arrangement shown in BS EN 12101-6:2005.

5.6.8 As the lobby was depressurised, this would encourage smoke from the flat on fire into the lobby. I presented an illustration of the movement of air and smoke by PSB's smoke control system during my oral evidence in Phase 1. I have reproduced that image here in Figure 5-7:.

5.6.9 The scenario of an open flat door during firefighting operations, was referred to by Mr Mahoney in an email to Max Fordham on 16th July 2015 {ART00004481}.

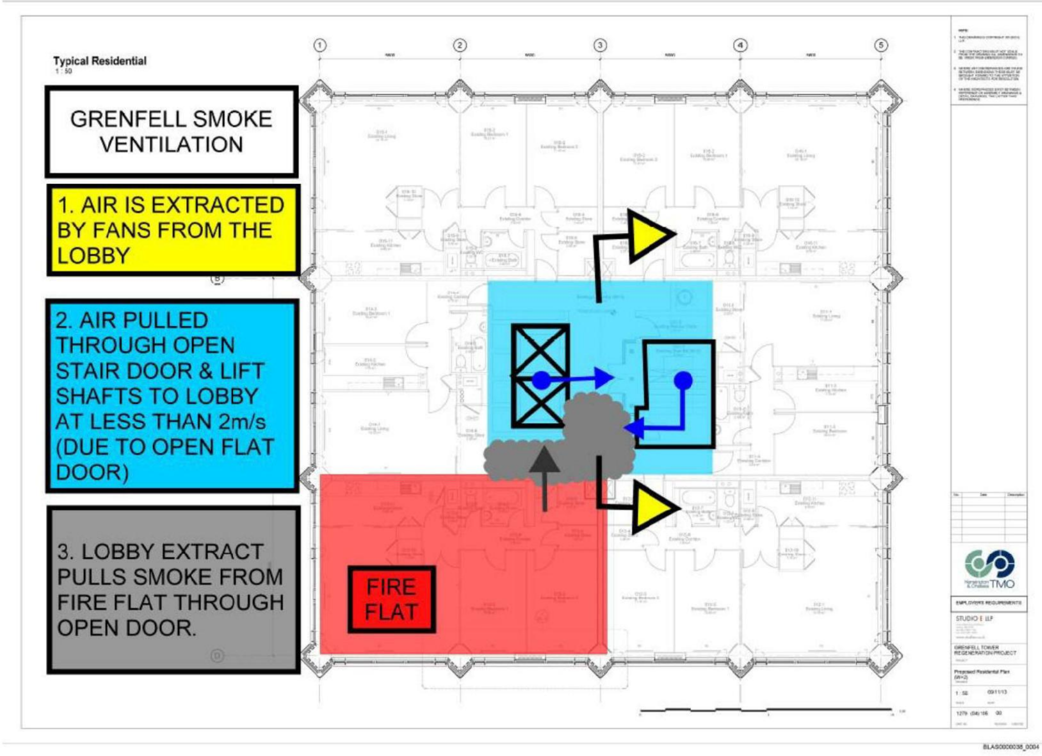


Figure 5-7: Movement of smoke in the Grenfell smoke control system {SEA00010474}

5.6.10 In Table 5-6 I have explained the extent to which the PSB design complied with the performance standards described in BS EN 12101-6:2005 for a Class B depressurisation pressure differential system.

5.6.11 Where the PSB design is in accordance with a Class B system I have indicated this in green; where the PSB system differed from the requirements of a Class B system I have indicated this in red.

Table 5-6: Comparison of PSB design with the performance standards for a Class B depressurisation system BS EN 12101-6:2005

Class B depressurisation performance standards		**How BS EN 12101-6 performance standards applied to Grenfell Tower**	**Comparison of PSB Design with Class B depressurisation performance standards**
Pressure across lift and accommodation area	50Pa	The pressure differential between the lifts and the residential flats was required to be 50 Pa	No
Pressure across stairway and accommodation area	50Pa	The pressure differential between the lifts and the residential flats was required to be 50 Pa	No
Pressure across closed doors between each lobby and accommodation area	45Pa	The pressure differential between the common lobby and the residential flats was required to achieve a minimum of 45Pa	No
Airflow criterion between the staircase and the lobby (a)	A criterion is not provided in Section 4.3.2.2 Airflow Criterion of BS EN 12101-6. However I note that Section 4.3.1 *General* of that standard states *"the minimum velocity of 2 m/s through the open stair door…"*	A minimum velocity of 2m/s was required through the stair door into the common lobby	Yes – *"…an average open door velocity, across an open lobby/stairwell door of 2.0m/s."*
Airflow criterion between the lobby and fire compartment (b)	2m/s through the open door **between the lobby and the accommodation** at the fire affected storey	A minimum velocity of 2m/s was required through the flat front entrance doors from the common lobby	No
Doors to be open to achieve airflow criterion (a)	Not specified	N/A	No - PSB do not specify that any door other than the stair door is open
Doors to be open to achieve airflow criterion (b)	a) the stair and the lobby on the fire affected storey; b) the stair and the lobby on an adjacent storey; c) the firefighting lift shaft and the lobby on the adjacent storey; d) the stair and the external air at the fire service access level.	a) the door to the protected stair and a flat front entrance door on the fire affected storey; b) the door to the protected stair and a flat front entrance door on an adjacent storey; c) the firefighting lift shaft and the lobby on the adjacent storey; d) the Level 2 stair door to the maintenance entrance foyer with permanent vents open to the outside	No - PSB do not specify that any door other than the stair door is open
Door opening force	100N	The flat front entrance doors and door to the protected stair on all levels of Grenfell Tower were required to have a door opening force of less than 100 N	Yes
9.2.1 Inlets from external air to the protected space shall be provided to ensure replacement airflow from the protected space to the depressurized space.		Inlet air was required for the stair, lift shaft and lobbies	Yes - *Make up air will be provided via the open lobby door*
9.2.2 The replacement air intake shall be sited so that the air being drawn in to the protected space is not contaminated by the smoke produced by the fire.		Inlet air was required to be located remotely from exhaust from the flat	No - A permanent vent was situated at the head of the stair. However, no performance stated that this should be remote from the smoke exhaust point.
9.2.3 The system shall consist of exhaust fans and if necessary ductwork to remove hot gases and smoke produced by the fire within the depressurization zone to the outside of the building.		Hot gases and smoke were required to be extracted from the flats; this could be achieved by powered exhaust directly to external air or by the use of duct work.	No – the PSB design provides depressurisation of the lobby and not the flats

Class B depressurisation performance standards	How BS EN 12101-6 performance standards applied to Grenfell Tower	Comparison of PSB Design with Class B depressurisation performance standards
9.2.4 Air inlets shall be provided for the necessary replacement air required to allow the pressure differential to develop across the closed doors and to meet the airflow velocities through the open door into the fire zone, initially for means of escape and/or subsequently for firefighting purposes.	In addition to item 9.2.1 these air inlets should be sized appropriately to meet the pressure differential requirements.	A permanently open louvre with a measured free area of 1m^2 is specified The pressure differentials in BS EN 12101-6:2005 were not specified as performance criteria.
9.2.5 The outlets of the exhaust ductwork shall be in such positions that smoke does not threaten the safety of occupants and firefighters or persons outside the building and does not contribute to external fire spread	Exhaust from the flats was required to be designed so that it did not present an ignition risk for the combustible external wall construction.	No performance for the smoke exhaust at Level 02 or Roof level is stated.
9.2.6 Depressurized zones shall be bounded on all sides (including the floor slab above and below) by constructions having fire-resistance at least equal to that required for the protected space	In Grenfell Tower the required level of fire resistance of the compartmentation was 120 minutes for the firefighting stair and compartment floors; therefore, the flats were required to be bounded on all sides by 120 minute fire resisting construction.	No performance stated.
9.2.7 All doors to the depressurization zone shall be self-closing.	The flat entrance doors were required to be self-closing.	No performance stated.
9.2.8 The extraction ductwork from the depressurization zone shall meet the requirements for fire resistance for a period at least equal to the highest period of fire-resistance through which the ductwork passes, when tested and classified in accordance with prEN 13501-3.	Any ductwork used to exhaust hot smoke from the flats was required to fire resisting.	No performance stated.
9.2.9 The extraction fan from the depressurization zone shall be capable of handling smoke at a temperature of 1 000 °C for unsprinklered buildings, or 300 °C for sprinklered buildings, when tested and classified in accordance with prEN 13501-4.	Grenfell Tower was an unsprinklered building. The extraction fan was therefore required to be capable of handling smoke at a temperature of 1 000 °C	No. Performance of fan stated as follows: *"Fans are tested in compliance with high temperature test standard directive 89/106/EEC to EN 12101-3 and are rated to one off emergency operation at 300°C for 2 hour."*
9.2.10 With all doors closed, the extraction rate of smoke and hot gases from the depressurization zone shall be capable of maintaining a pressure differential not less than that given in Clause 4 for the appropriate system class and, where relevant, the open door airflow criterion	The fans were required to be designed to meet the performance criteria in rows 4 – 8 of this table.	No performance stated. Fan curve from manufacturer literature provided. The pressure differentials in Clause 4 were not specified as performance criteria.

5.6.12 From my review in Table 5-6, I have found that the PSB design proposal met the criteria for airflow between the staircase and the lobby; door opening force; and air inlet for a Class B pressure differential system to BS EN 12101-6.

5.6.13 The most significant differences between the PSB design and a Class B system to BS EN 12101-6 were the differential pressure requirements between the stair and the lobby, the fire resistance performance of the extraction fan and the requirement to demonstrate a 2m/s air velocity through the door to the accommodation (which in the case of Grenfell Tower would be the residential flats).

5.7 Comparison of PSB design with *BS 9991:2011*

5.7.1 In Section 4.4 I presented an overview of a mechanical smoke control systems described in BS 9991:2011 for a mechanical smoke ventilation system would apply to Grenfell Tower.

5.7.2 In Table 5-7 below I describe the extent to which the PSB design satisfied those performance standards.

5.7.3 Where the PSB design is in accordance with a BS 9991:2011 system I have indicated this in green; where the PSB system differed from the requirements of a BS 9991:2011 system I have indicated this in red.

5.7.4 Annex E of BS 9991:2011 refers to the SCA Guide. I have set out my comparison of the PSB design with the *SCA Guide 2012* in Section 5.5 of this report.

Table 5-7: Comparison of PSB design with the performance standards described in of BS 9991:2011 mechanical smoke ventilation system for an extended corridor

Mechanical smoke ventilation system for an extended corridor		**How it applied to Grenfell Tower**	**Comparison of PSB's design with BS 9991 Mechanical smoke ventilation system for an extended corridor**
Performance criteria for conditions within – stairs & lobbies	None specified for extended travel distances Annex E refers to the *SCA Guide* for guidance.	The designer was required to define appropriate performance criteria	See Section 5.5 for my compliance analysis of the PSB system with the performance standards described in the *SCA Guide*.
Performance criteria – door opening force	None specified for extended travel distances Annex E refers to the *SCA Guide* for guidance.	The designer was required to define appropriate performance criteria	See Section 5.5 for my compliance analysis of the PSB system with the performance standards described in the *SCA Guide*.
Design scenarios – means of escape	*a) Different fire locations (both close to and far from the point of extract).* *b) Pressure differences across a flat front door with a variety of extraction rates.* *c) A negative wind coefficient at the stair head vent.* *d) Fire pressure and increasing fire growth.*	a) different flat of fire origin locations were required to be considered b) calculation of the pressure differentials created between the lobby and the flat under different extract rates c) calculation of wind effects to the inlet air vent d) calculation of effect of fire on pressure differentials between flat and adjoining spaces	No consideration of different fire occurring in different flats. No calculation of pressure differential across flat front door for any extraction rate. No calculation of any wind effects. No calculation of effect of increased pressure due to fire growth between flat and lobby.
Design scenarios – firefighting	*1) A variety of door opening sizes for the stair or corridor door (when closed, partially open and fully open).* *2) Increased ventilation to a fire due to a broken window.* *3) Low-level ventilation to the stair.*	1) calculation of system performance when flat and stair doors are closed, partially open or fully open 2) Calculation of effect of window breakage in the flat 3) Calculation of effect of open door to the enclosed stair at Level 2 and door at ground level from ventilated entrance foyer to allow external air flow into the enclosed stair.	No calculation of system performance with flat and stair doors closed. No calculation of the effect of window breakage in the flat. No calculation of the effect of an open door to the stairs at Level 2. Note that permanent louvres were instead provided to the main entrance lobby, after the system was commissioned, at the request of RBKC Building Control.
Method of analysis	Computational Fluid Dynamics (CFD) analysis or mathematical calculation	Calculation was required of the system performance	No calculations of system performance provided.
Shafts	Smoke shaft fully open to external air at top and closed at base Constructed from non-combustible materials. Run vertically from top to bottom, with no more than 4m of the shaft at an inclined angle (max 30°) No services with the smoke shaft	All shafts extracting smoke from the lobbies required to vent at roof level. Shafts were required to be non-combustible and contain no services. Shafts were required to be vertical; no horizontal shafts were permitted (greater than 30°)	Only one of the two extract shafts vented at roof level. The second shaft vented at Level 2. PSB did not state shafts were required to be non-combustible. Horizontal ducts were installed at Level 2.
Vents	Lobby vent located as close to lobby ceiling as possible and at least as high as the top of the stair door Vents to the lobby should have a minimum fire resistance of 30 min and smoke leakage no greater than $200m^3/(m^2h)$ when tested to BS EN 1366-2	The vents within the lobbies were required to be positioned at least as high as the top of the stair door. The fire resistance requirements for vents is lower than those required by ADB 2013 for protected shafts. The provisions from ADB 2013 apply.	No – the PSB design utilised the existing supply vents at floor level to the south shaft as extract vents; the position of these vents therefore did not comply. No – performance standard for dampers not specified by PSB.

Mechanical smoke ventilation system for an extended corridor		How it applied to Grenfell Tower	Comparison of PSB's design with BS 9991 Mechanical smoke ventilation system for an extended corridor
Secondary power	Secondary power supply was required for all fans, actuators and controls	This was required	Yes for controls. PSB's Technical Submission does not specify a secondary power supply for the fans. However, from the RJ Electrics record drawing {TMOM00001891} a secondary supply was provided which my team observed on site.
Fans	A standby and duty fan with automatic switchover.	This was required	Yes – provision of standby and duty fans with automatic switchover between standby and duty fans.

5.8 Comparison of PSB's design with a proprietary system (Colt)

5.8.1 Mr Mahoney states in paragraph 41 of his second witness statement {PSB00001373}:

> My design reflected a more common type of mechanical extract 'depressurisation' system. A performance-based building appropriate solution widely adopted as a type of smoke control system and which were often referred to within the industry as 'depressurisation' systems and is commonly called the ColtShaft mechanical shaft system.

5.8.2 In Section 4.6, I presented information from Colt's literature describing the ColtShaft mechanical shaft system and its use in residential buildings as a means of providing smoke control.

5.8.3 In this sub-section I present my comparison of the ColtShaft mechanical shaft system with the system designed by PSB.

5.8.4 I have reproduced my earlier Table 4-6, where I presented the ColtShaft mechanical shaft system performance from their 2004 and 2007 technical papers, below as Table 5-8, with the inclusion of a new third column recording the relevant specification by PSB for their system.

5.8.5 Whilst some of the principles of operation of the ColtShaft mechanical shaft and the PSB system are similar, insofar as the lobby is depressurised relative to the escape stair, with the pressure controlled by a pressure sensing device; the physical arrangement of the components and their performance specification differ.

5.8.6 I have reviewed the references cited in the LABC certificate, and I am also of the view that Colt considered a multi-scenario condition and produced a specification on that basis.

5.8.7 It is therefore my opinion that these systems cannot be compared, and my findings regarding the PSB system as installed in Grenfell Tower cannot be read as in any way relevant to an assessment of the effectiveness/compliance of any Colt system.

Table 5-8: Comparison of ColtShaft mechanical shaft specification from their 2004 and 2007 Technical Papers with the PSB system design

Component	ColtShaft (from Mechanical ventilation of fire-fighting shafts: performance and design, 2004 {BLA00005484} and CFD Analysis of smoke ventilation in a fire fighting lobby with a 12mw unsprinklered fire, 2007 {BLA00005483})	PSB Technical Proposal {PSB00001233} and Technical Submission (Revision 6, {PSB00000214})
No. of shafts	1	4 (2 No. North, 2 No. South) [Not stated in PSB Technical Submission]
Fire rating of shafts	{BLA00005484} states: *To be of fire rated construction.*	Not stated
Area of shafts	{BLA00005484} states: *Nominal size 0.6 m^2 for buildings up to 30 m tall.*	0.96m^2 aggregate area [Not stated in PSB Technical Submission]
Area of ventilator at head of stair	{BLA00005484} states: *Stairwell ventilator with a geometric area of 1m^2, located at the head of the stairs.*	Stairwell penthouse louvre which is permanently open [Area not stated in PSB Technical Submission]
Extract fan specification	{BLA00005484} states: *Extract fan set comprising duty and standby fans with automatic changeover. Fans to be rated to operate at 300°C for 2 hours. An extract flow rate is also specified [Rate A].* The 2004 Colt technical paper {BLA00005484} describes the results of the four scenarios which were modelled in respect of mechanically ventilated shafts, at two different extract flow rates ('Rate A' and 'Rate B'): *Mechanically ventilated shaft at [Rate B] , door open condition* *Mechanically ventilated shaft at [Rate A], door open condition* *Mechanically ventilated shaft at [Rate A] door closed condition, no smoke seals* *Mechanically ventilated shaft at [Rate A] door closed condition, with smoke seals* The 2004 technical paper notes that worse performance was provided when extract flowrate of [Rate B] was provided. However, the 2007 technical paper {BLA00005483} by Colt detailed that an increased extract rate (greater than [Rate A] should be provided for unsprinklered Buildings. Colt literature (2007) does not state what that increased extract rate is. For door open condition, extract flow rate in the lobby calculated with the doors from the accommodation to the lobby, from the lobby to the stairs, from the stairs to the corridor and from the corridor to the exterior were all open and sized at 1.6m^2 [from 2004 paper {BLA00005484}]. Fan serving single shaft. The extract rate in the Colt literature is extract rate in the lobby.	{PSB00000214} states: *One set of smoke extract fans will be mounted in series on the roof of the plantroom and connect via ductwork to one of the builders work shafts.... An additional fan set will be mounted on walkway level and connect to the other builders work shaft via run of galvanised ductwork... rated to one off emergency operation at 300°C for 2 hour.* The calculation of the fan capacities is not provided within {PSB0000214}. In the PSB Technical Proposal {PSB00001233} it is stated that the required extract flowrate to achieve 2.0m/s through the stair door was 3.2m^3/s. The PSB Technical Proposal {PSB00001233} includes: *Add 50% for unforeseen losses (this will cover unidentified fabric losses and closed motorised damper leakage as per BSEN12101-6.)* The PSB Technical Proposal {PSB00001233} states that with 50% added, the final flowrate though the open door was 4.8m^3/s, The total flow rate of the two fan sets provided was 5.6m^3/s PSB Technical submission Rev 6{PSB00000214}. The PSB Technical Proposal {PSB00001233} and PSB Technical submission Rev 6{PSB00000214} do not address: 1. the difference in extract flowrates between Colt shaft (Rate A from the lobby) and the extract rate for Grenfell Tower (4.8m^3/s) or the flowrate from the two fan sets which totalled 5.6m^3/s. 2. the possible consequences of the extract rate exceeding the calculated rate. 3. the possible consequences of the use of multiple shafts rather than a single shaft.
Maximum pressure drop permitted in shaft	{BLA00005484} states: *To be sized for a maximum pressure drop of 50Pa between highest and lowest storey served*	Not stated
Floor area of lobby	12.5m^2 – rectangular (2.5m x 5m) [per BRE Report 79204]	32m^2 - Irregular I-shape with dead end corridors to flat entrances. PSB's Technical submission Rev 6{PSB0000214} does not address possible consequences of the shape of the lobby on performance of the smoke extract system.
Door openings onto the lobby	1 door between lobby and accommodation	PSB's Technical submission Rev 6{PSB0000214} does not address the number of doors between the lobby and flats. However, there were maximum 7 doors (6 flats plus refuse store).
Lobby damper minimum geometric area	{BLA00005484} states: *Minimum geometric area 0.8m^2. To be located in the shaft wall to the lobby, as high as possible in each lobby.*	For L4-23, stated as opening width: 300mm, and opening length: 600mm. Four dampers per lobby, therefore, aggregate area: 0.72m^2 ({PSB00000214}) For G-L3, stated as opening width: 600mm, and opening length: 800mm. Two dampers per lobby, therefore, aggregate area: 0.96m^2 ({PSB00000214}) Note that in Grenfell Tower the dampers to south shaft are located at low level. PSB's Technical submission Rev 6{PSB0000214} does not address possible consequences of the south dampers being located at low level.

Component	**ColtShaft (from Mechanical ventilation of fire-fighting shafts: performance and design, 2004 {BLA00005484} and CFD Analysis of smoke ventilation in a fire fighting lobby with a 12mw unsprinklered fire, 2007 {BLA00005483})**	**PSB Technical Proposal {PSB00001233} and Technical Submission (Revision 6, {PSB00000214})**
Pressure differential controlled by sensor	Yes. {BLA00005484} states: *If the pressure in the lobby on the fire floor drops below -25Pa the fan slows on inverter control.* The rationale for the 25Pa difference is described in the 2004 technical paper {BLA00005484}: *An obvious concern was whether the mechanical extract would tend to draw excess smoke into the lobby through gaps around the closed door to the accommodation. This condition was therefore also modelled, with the addition of a pressure relief damper in the shaft to limit lobby depressurisation to 25 Pa.*	{PSB00000214} states: *The system is designed to maintain -25Pa in the lobby with all doors closed and will maintain the fans at lowspeed setting.*
Smoke detection at each storey	Yes	Yes
Firefighter override	{BLA00005484} states: *to be installed at the base of the stairs, or other location agreed with the Fire Authority.*	{PSB00000214} states: *A human Mechanical Interface Panel (HMI) will be located within the entrance area to provide the fire and rescue service with a central override facility to close all dampers in a single operation.* *A Key operated fire override switch will be located within the stairwell for each ventilated lobby, local to the automatic lobby ventilator, these switches will be in a normal auto position allowing the ventilation to be opened when the system operates. Once the fire override switch on the mimic override panel has been activated the floor override switch will allow the fire and rescue service the facility to open the dampers.*
Power supply	{BLA00005484} states: *A maintained power supply is required in accordance with the requirements of BS5588-5.*	{PSB00000214} states: *The master control panel will be provided with a primary and secondary supply in accordance with BS 8519 and the power supplies are to include an auto changeover panel and by pass switch arrangement with a single mains feed connection to the fan control panel.*
Fire door performance between accommodation and lobby	{BLA00005484} states: *The fire door between the lobby and the accommodation is required to be smoke sealed (S rated).*	PSB's Technical submission Rev 6{PSB0000214} did not include a requirement for smoke seals to the doors between the lobby and the accommodation

5.9 Use of the refurbished smoke control system for environmental ventilation

5.9.1 According to JS Wright's Health and Safety file for their works on Grenfell Tower {RYD00000577}, the smoke control system was also to be used to provide environmental ventilation to the lobbies in order to "*reduce the possibility of the lobbies becoming uncomfortably warm due to heat emission from the heating pipes running through the lobbies.*"

5.9.2 When used in environmental mode, the system utilised all of the same components as the smoke control system, with the following two exceptions:

a) At Level 2, instead of using the smoke control extract fans, a single environmental supply fan was provided in a bypass duct arrangement around the smoke control fans (please see Figure 5-8 and Figure 5-10).

b) Additionally, the environmental system was activated based on readings from five temperature sensors which were connected to the BMS system {MET00018469}, rather than being connected directly to the smoke control system. Please refer to Section 5.10 for a detailed description of all components of the system.

5.9.3 The design basis of the environmental ventilation mode is described in PSB's Technical Submission (Rev 6, {PSB00000214}), PSB's Electrical Schematic {TMOM0001859} and Max Fordham's Employer's requirements {MAX00002664}

5.9.4 When in use, warm air was exhausted from lobbies by the new dampers installed as part of the smoke control system. These consisted of:

a) Between Level 4 and Level 23 – a pair of dampers located at high level on the north side of each lobby served by the pair of existing builder's work vent shafts

b) Between Ground Level and Level 3 – a single damper located at high level on the North side of each lobby served by a newly constructed extension to the existing North vent shafts.

5.9.5 New run and standby fans (two fans in series) were installed at the top of the existing builder's work vent shafts at roof level. This fan set was used for both smoke and environmental exhaust and discharged at roof level.

5.9.6 When in use, fresh air was supplied to all lobbies by the new dampers installed as part of the smoke control system. These consisted of:

a) From Level 4 to Level 23 – a pair dampers located at low level on the south side of each lobby served by the pair of existing builder's work vent shafts.

b) From Ground Level to Level 3 – a single damper located on the south side of each lobby served by a newly constructed extension to the existing South vent shafts.

5.9.7 A single new environmental supply fan was provided at Level 2 to serve the South shafts. Shut-off dampers (motorised smoke and fire 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.

5.9.8 The operation of the environmental ventilation system is described in PSB's Technical Submission as operating on every floor at the same time. Activation would be achieved by a signal from the BMS, based on the output of five temperature sensors positioned in different lobbies up the building. This method of operation is described in Rev 6 of PSB's Technical Submission dated 15th March 2016.

5.9.9 A signal from a lobby detector to the smoke control system's control panel would initiate a sequence of events, within the smoke control software, that would override the environmental mode. The system would then switch to smoke control mode. I outline the operation of the refurbished system in smoke mode in Section 7.6.

5.9.10 On 15th April 2016, JS Wright sent an e-mail to PSB {PSB00001088} indicating that the noise of the environmental fan was unacceptably loud. The operation of the system was then changed.

5.9.11 A new method of operation was recorded in JS Wright's e-mail dated 22nd April 2016 {PSB00001111} which would permit the environmental fan to operate at a slower speed and therefore more quietly.

5.9.12 According to a document headed *"Explanation of how the environmental ventilation works"* {MAX00002664} prepared by David Hughes (Rydon) and emailed to Ms Williams (KCTMO) on 8th January 2016 {MAX00005457}, the design then became based on the five temperature sensors in the Ground – 5th – 10th – 15th – 20th floor lobbies; based on an activation temperature of 19 (noting I have seen evidence which suggests the activation temperature was 25 degrees (pg. 10, {MET00018469}) - taken as an average of the five temperature sensor readings. The system was programmed to be capable of operating this way during a specific time period only each day {MET00018469}.

5.9.13 Please refer to Section 7.6 for details of the final as built operating mode.

5.9.14 It is important to note that it appears there was also an external sensor (which was relevant to the operating mode of the system), but there is no documented evidence of where it was installed, nor how it was intended to operate. I deal with this in Section 7.

5.10 Primary components of the Smoke Control system

5.10.1 In this section I have set out the equipment as specified by PSB in their Technical Submission only.

5.10.2 In Section 6, I set out my investigation of the compliance of the installed equipment and components of the refurbishment smoke control system.

5.10.3 As described in PSB's Technical Submission (Rev 6, {PSB00000214}), between Ground Level and Level 23, the system consisted of the following:

a) Smoke exhaust was provided by a pair of dampers located at high level on the north side of each lobby (Levels 4 to 23).

b) The north dampers on Levels 4 to 23 were served by the original pair of north smoke shafts (as extended, aggregate area 0.48m^2) (see Section 3.3.17, above) leading to new exhaust fans and outlet on the roof.

c) Smoke exhaust was also provided by a pair of dampers located at low level on the south side of each lobby (Levels 4-23).

d) The south dampers on Levels 4 to 23 were served by the original pair of south smoke shafts (as extended, aggregate area 0.48m^2) (see Section 3.3.17, above) leading to new exhaust fans and outlet on at Level 2.

e) New horizontal ductwork was provided at Level 2 connecting the south smoke shafts to a louvre on the outside of the building, via the smoke extract fans. This ductwork was noted by PSB {PSB00000044} and JS Wright {HAR00007049} as requiring a 2-hour fire resistance rating (Figure 5-8).

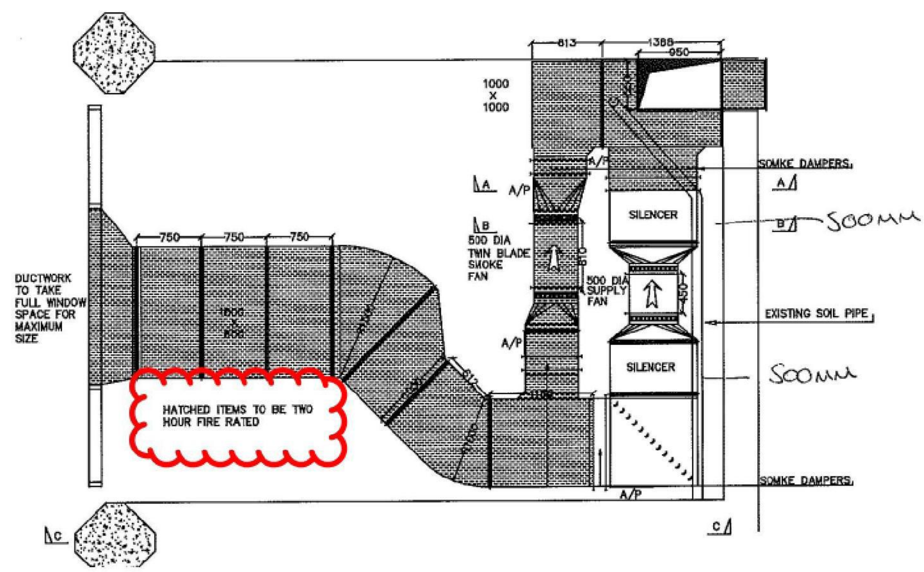


Figure 5-8: Excerpt from attachment to {HAR00007049} indicating extent of fire rated ductwork at Level 2

f) New builder's work shafts were created - linking the bottom of the existing north smoke shafts to each of the lift lobbies between Ground Level and Level 3 (see Section 4.9.2, above).

g) 4.9.2A new damper with an actuator (see Section 7.X) was provided on each of the levels between Ground Level and Level 3, served by the new north vent shaft as above.

h) Four new dampers were provided on every floor, each with an actuator (see Section 7.X) wired back to outstation

i) A new environmental fan was located at Level 2. In the event of a fire, this fan (and its associated unrated ductwork) was to be isolated from the smoke control system by automatically closing smoke dampers.

j) Fan shut-off dampers. Shut-off dampers are positioned on one or both sides of a fan. They are closed when the fan is off and open when the fan activates. They are intended to prevent outside air from circulating. through a fan when it is not operating. They may also be used, as in Grenfell Tower, to isolate part of a combined (smoke and environmental) ventilation system when that part is not in use (please refer to Section 7.13).

k) A permanently open vent at the head of the stairs.

l) A new permanently open vent in the Ground Floor entrance foyer.

m) A new master control panel with a Programmable Logic Controller (PLC) was located at Ground Floor level in the Hub room A010.

n) A new Human-Machine Interface (HMI) override panel was located within the Ground floor lobby.

o) New outstation module panels were provided on each floor in the new services cupboard to connect the smoke control system devices on each floor to the master control panel.

p) An override yellow key switch was provided in each ventilated lobby to be located in the stair.

q) A yellow key switch was provided in each ventilated lobby.

r) A pressure sensor was provided in each in each ventilated lobby to measure the pressure difference between the lobby and the stair at that level.

s) Battery back-up panels were provided on every second level. These panels provided a secondary power supply to the components described above (except the fans) in the event that the main building power supply failed.

t) A secondary wired power supply was provided, connected to Grenfell Walk, to provide power to the four smoke extract fans described above. This power supply was to be used in the event that the building main power supply failed. A change-over device was also provided to detect the failure of the main supply and automatically switch the fans onto the secondary power supply.

5.10.4 I have provided a simplified schematic of how the smoke control system was organised based on PSB's documentation in Figure 5-9.

5.10.5 In Section 6 and Section 7 I present my detailed analysis of the smoke control system components as were installed at Grenfell Tower, as this was in fact more extensive than described by PSB.

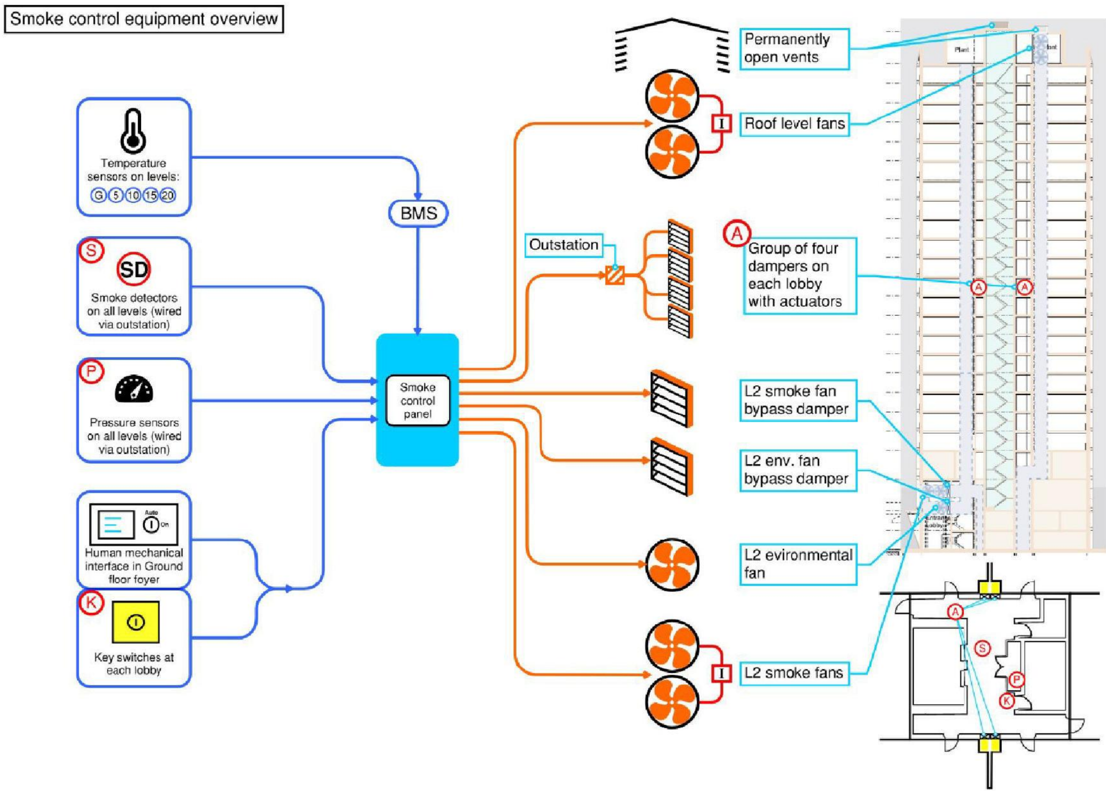


Figure 5-9: Schematic representation of the smoke control system components derived from the evidence

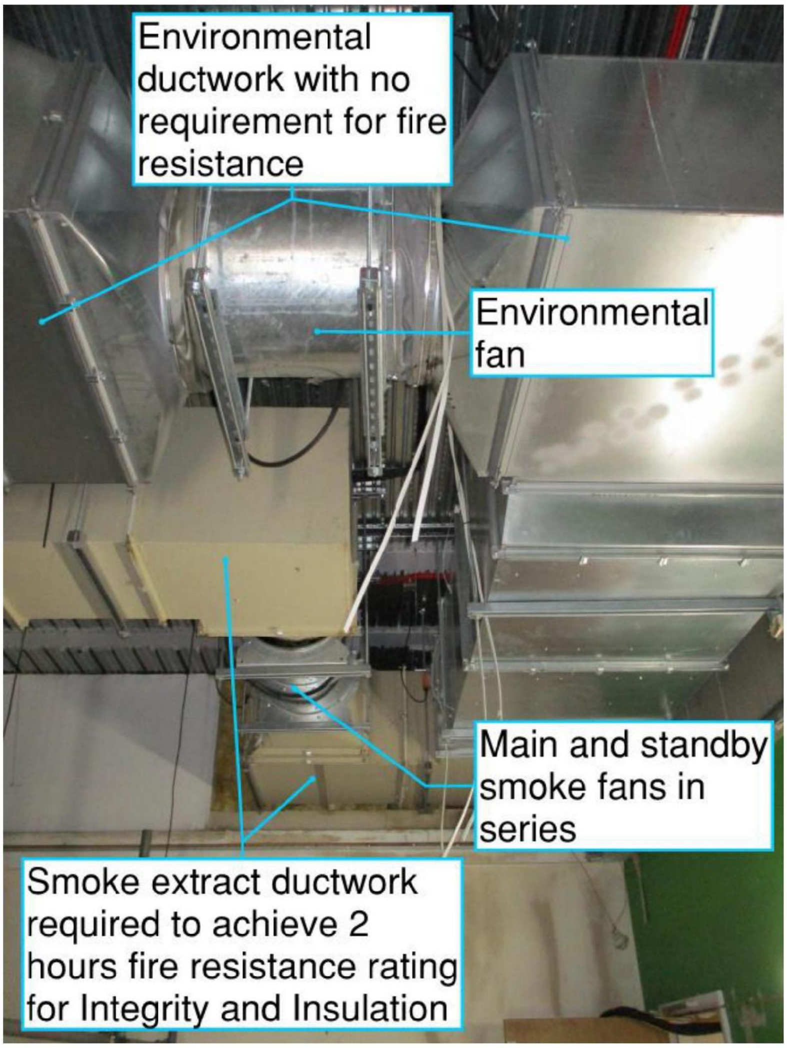


Figure 5-10: Level 2 smoke fans (rear) and environmental fan (front)

5.11 Consultation with RBKC Building Control

5.11.1 My detailed investigation of the consultation which was carried out with RBKC Building Control regarding the compliance of the primary refurbishment works with the Building Regulations is set out in my separate reports *The Fire Safety Engineer* (Version 2 Updated 22nd October 2020) {BLARP20000017} and *Regulation 38 Fire Safety Information* (Version 2 Updated 23rd October 2020) {BLARP20000021}. I will not repeat those investigations here.

5.11.2 I have reviewed the information requested by RBKC Building Control together with the information provided to them to see whether there is any further evidence of any explanation or analysis demonstrating how the system was deemed by all or any party to comply with the Building Regulations.

5.11.3 **Information requested by RBKC Building Control following consultation on Max Fordham's design**

5.11.4 On 25th October 2013 Max Fordham's proposal for replacement of the existing smoke control system with a mechanical supply and-mechanical extract which would achieve a performance of 15 air changes per hour for the lobbies (Revision A, dated 25th October 2013{RBK00002967}) was submitted to RBKC Building Control {RBK00003810}.

5.11.5 In their response on 6th December 2013 RBKC Building Control indicated that a performance objective of 10 air changes per hour would be insufficient {RBK00003014}:

> *The proposal for the new system indicates the intention to provide 10 air changes as a design objective. This appears to be using an approach for redesigning the system without a consideration of adverse affect. If you wish to consider redesigning the system to achieve a performance objective rather than match the performance of the existing system, justification for the proposed extract rate needs to be submitted, including performance modelling.*
>
> *However I would suggest without the need for modelling; that 10 air changes will not provide adequate ventilation to a lobby. An air change rate is a relative figure and is normally used to determine an adhoc ventilation rate for large spaces such as car parks. Air change rates have no relationship with fire size, height of rise of the smoke plume and apartment door leakage rates. The current method used to determine appropriate ventilation rates in residential lobby powered extract systems is to use fire modelling. You may be able to achieve a reasonable approximation of ventilation rates using CFD or a simpler zone model, if you wish to adopt this approach.*

Figure 5-11: Excerpt from {RBK00003014} (highlighting by me)

5.11.6 I note that in Mr Hanson's response above he refers to ten air changes, rather than the performance of fifteen air changes per hour which was actually outlined in Max Fordham's *Smoke Control Proposals* {RBK00002967}. Mr Hanson also sets out his concerns with the use of air change rates generally.

5.11.7 On 10th November 2014, RBKC Building Control supplied comments on the full plans submission (S1). Specific to the performance of the smoke control system, the memorandum authored by Paul Hanson, {RBK00002975} advised that one of two approaches could be undertaken to demonstrate compliance with the Building Regulations:

3. *Upper storey powered ventilation system*

The existing building appears to have an early push pull powered ventilation system providing powered extract and powered or natural inlet via enclosed riser shafts.

RBKC building control would be satisfied under the building regulations if either:-

a. *The performance of the existing system is maintained. Details of the performance of the existing and proposed systems are requested to be submitted to enable RBKC to be satisfied that the system would not be adversely affected by the intended works.*

Or

b. *The ventilation extract rate is justified to be suitable for the propose* [sic].

The Smoke Control association 'Guidance on smoke control in Apartment buildings' gives upto date guidance on powered residential extract systems.

Any new equipment for the system should comply with the recommendations of this guide.

If data on the existing system is available, a way forward might be to measure the flow rates of the present situation and provide information about the proposed system.

Therefore in order to consider your proposal details should be submitted of the following:-

- *Existing extract rate in m^3/s*
- *Existing 'inlet air' Supply rate in m^3/s*
- *Proposed extract rate in m^3/s*
- *Proposed 'inlet air' Supply rate in m^3/s*
- *Confirmation of design of existing system. Is it mechanical ventilation or natural or a combination*
- *Method of activation of natural/powered system and fire brigade controls*
- *Size of natural/powered vent shafts*

5.11.8 Therefore, either the refurbishment system needed to maintain the performance achieved by the existing system, or the ventilation extract rate for the new system needed to be justified as suitable for Grenfell Tower. I note that RBKC Building Control specifically refer to the *SCA Guide* as relevant guidance in the matter.

5.11.9 I have seen no further evidence of consultation with RBKC Building Control on the Max Fordham smoke control proposals.

5.11.10 Max Fordham carried out an analysis of the ventilation rate which could theoretically be achieved by the existing system in *Grenfell Tower Smoke Ventilation Analysis Rev B* dated 13th May 2014 {MAX00002335}. Max Fordham compared this to the increased proposed extract rate of $5m^3/s$.

5.11.11 I have found no evidence that either this analysis or the earlier version Revision A dated 6th May 2014 {MAX00002334} was submitted to RBKC Building Control.

5.11.12 I have found no evidence either of any comparison of the system installed in Grenfell Tower at that time, with the original requirements such as described in CP3 1971.

5.11.13 **PSB design information provided to RBKC Building Control**

5.11.14 The earliest reference I have found to consultation with RBKC on PSB's design is a meeting on 24th November 2014 described in the witness statement of Mr Cross Smith. I have not seen any minutes for this meeting. Mr Cross Smith states {MAX00017304} (bold by me):

On 24 November 2014 we attended a meeting with Building Control, PSB, JSW, Studio E and the TMO to discuss the SVS. The meeting was held in the estate office in the Tower. ***It was at this meeting that PSB and JSW put forward the pressurization system along the lines of the one that Hugh Mahoney had spoken to me about in May 2014.*** *This also removed the need for a fresh air inlet at the glazed level in the extension down of the SVS that Studio E was proposing.* [MCS/64, {MAX00004665}]. *This was a constructive meeting which I recall was led by PSB/JSW, in which the proposed works to the smoke ventilation system were discussed in detail with Building Control who in principle accepted the pressurization system that PSB/JSW were putting forward. This was a development of the design that had first been proposed by Hugh Mahoney at PSB at the end of April 2014* [MCS/57].

5.11.15 Over the course of 2015 JS Wright issued the following revisions of PSB's Technical Submission to RBKC:

a) PSB Technical Submission Revision 1 on 19th January 2015 {JSW00003149};

b) PSB Technical Submission Revision 2 on 14th April 2015 {RBK00003852}; and

c) PSB Technical Submission Revision 3 on 12th June 2015 {RBK00027396}.

5.11.16 As explained above, RBKC outlined two potential approaches in order to demonstrate compliance with the Building Regulations: showing that the proposed system was no worse than the existing system or justifying the ventilation extract rate with reference to the *SCA Guide*.

5.11.17 PSB's Technical Submission does not address whether the performance of the proposed system maintains the performance achieved by the existing system.

5.11.18 PSB's Technical Submission states in Section 1.1 *Base Documents* {PSB00000575}:

This Technical Submission is based in part upon the following documentation:

...

- *Specification*

...

2. *Max Fordham Grenfell Tower Smoke Ventilation Analysis Rev A dated 6th May 2014*

5.11.19 The Max Fordham Smoke Ventilation Analysis document {MAX00002334} proposed an extract rate of $5m^3/s$ and compared this to a theoretical performance of the existing system.

5.11.20 The PSB Technical Submission does not specify an extract rate to be achieved, nor does it provide any reference to the performance of the existing system.

5.11.21 Therefore, the design information submitted to RBKC Building Control did not provide a comparison of the proposed system performance against the existing system to demonstrate that it would be no worse; nor any consideration of the original performance objectives for means of escape and fire fighting.

5.11.22 The second approach outlined by RBKC was for the ventilation extract rate to be justified with reference to the up-to-date guidance in the *SCA Guide*.

5.11.23 Neither PSB's Technical Submission, nor Max Fordham's analysis referenced therein, provide a justification for an extract rate of $5m^3/s$. Further, both documents make no reference to the *SCA Guide*.

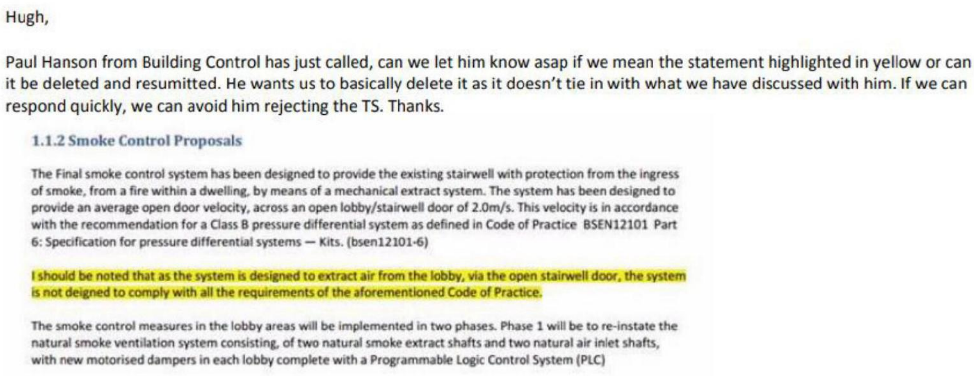
5.11.24 Therefore, I can find no evidence of a justification provided to RBKC Building Control that the extraction rate was *"suitable for the purpose"*.

5.11.25 PSB's Technical Submission did not set out the information RBKC requested in order to demonstrate compliance with the Building Regulations.

5.11.26 **RBKC acceptance of PSB's Design**

5.11.27 RBKC Building Control designated the submission of Revision 1 of PSB's Technical Submission as 'submission stage S1a' {RBK00026860}.

5.11.28 Prior to RBKC Building Control responding to the S1a submission, I have seen e-mail correspondence from JSW to PSB on 11th June 2015 indicating that Paul Hanson requested (by telephone) that a statement regarding non-compliance with all of the requirements of BS EN 12101-6:2005 should be deleted from the Technical Submission {PSB00000569} as it "doesn't tie in" with discussions:



Hugh,

Paul Hanson from Building Control has just called, can we let him know asap if we mean the statement highlighted in yellow or can it be deleted and resumitted. He wants us to basically delete it as it doesn't tie in with what we have discussed with him. If we can respond quickly, we can avoid him rejecting the TS. Thanks.

1.1.2 Smoke Control Proposals

The Final smoke control system has been designed to provide the existing stairwell with protection from the ingress of smoke, from a fire within a dwelling, by means of a mechanical extract system. The system has been designed to provide an average open door velocity, across an open lobby/stairwell door of 2.0m/s. This velocity is in accordance with the recommendation for a Class B pressure differential system as defined in Code of Practice BSEN12101 Part 6: Specification for pressure differential systems — Kits. (bsen12101-6)

I should be noted that as the system is designed to extract air from the lobby, via the open stairwell door, the system is not deigned to comply with all the requirements of the aforementioned Code of Practice.

The smoke control measures in the lobby areas will be implemented in two phases. Phase 1 will be to re-instate the natural smoke ventilation system consisting, of two natural smoke extract shafts and two natural air inlet shafts, with new motorised dampers in each lobby complete with a Programmable Logic Control System (PLC)

Figure 5-12: Excerpt from {PSB00000569}

5.11.29 I note that the system was not, in any event, designed to extract air from the lobby via the open stairwell door, but this may have been poor phrasing at the time

5.11.30 Subsequently, Mr Mahoney emailed Mr Bradbury and Mr Hanson on 12th June 2015 {RBK00027396} stating:

Hi David,

Please find attached my revision copy of the technical submission with the paragraph removed, as requested.

5.11.31 In Revision 3 of PSB's Technical Submission the paragraph highlighted in yellow in Figure 5-12 above has been removed {PSB00000575}.

5.11.32 Paul Hanson provided a memorandum dated 24th June 2015 responding as follows to the S1a submission {RBK00033900} (bold be me):

The proposals outlined in the Smoke Ventilation Technical submission PSBUK1143-12 rev 3 are satisfactory.

1. I note that there is the intention to bring the ventilation system down to also serves the existing ground level lobby adjacent to the lifts and switch room.

2. Final details of the key switch arrangements should be submitted when finalised.

*3. **Generally the components of the system should conform to the Guidance on Smoke Control to Common Escape Routes in Apartment Buildings (Flats and Maisonettes) Revision 1: June 2012 listed in section 11.3**.*

5.11.33 I have discussed the components of the system further in Section 7 and Section 8 of this report.

5.11.34 I have found no further evidence of RBKC requesting any justification for the proposed performance criteria set out in PSB's Technical Submission.

5.11.35 This was despite Revision 3 of PSB's Technical Submission failing to demonstrate the performance of the system using either of the two approaches RBKC originally requested.

5.11.36 Accordingly, I can find no evidence from the records of consultation with RBKC Building Control of an agreement as to how the system was intended to comply with the Building Regulations.

5.11.37 In his witness statement Mr Hanson states the smoke control system by PSB complied with relevant requirements for the following reasons {RBK00033894}:

52. The new smoke control system was designed in accordance with the principles of the Smoke Control Association (SCA) Guidance on Smoke Control to Common Escape Routes in Apartment Buildings (Flats and Maisonettes) Revision 1: June 2012...

56. The system installers J.S. Wright did not use a computer model and proposed using an air leakage test upon completion of the installation to show that the system achieved the objective of stopping smoke affecting the stairway.

5.11.38 I have found no reference to the *SCA Guide 2012* in the design documentation.

5.11.39 Nor have I found any evidence that PSB and RBKC agreed any design scenarios relevant to the functional requirements of the Building Regulations for their stated performance criteria.

5.11.40 I have seen evidence that on 3rd May 2016, prior to a demonstration of the operation of the smoke control system, David Hughes of Rydon sent Paul Hanson the final version of PSB's Technical Submission (Rev 6) and Cause and Effect analysis (Rev 4){RBK00003778}, the electrical schematic {RYD00076392} and the air speed readings for smoke extraction {RBK00003781}.

5.11.41 {RBK00003781} is a scanned copy of the email thread and the attachments are not included; {PSB00001124} and the attachments thereto suggests the 'commissioning report / sheets' attached to {RBK00003781} were prepared by Mr Partlow on 28th April 2016.

5.11.42 On either the 4th or 5th of May 2016 Mr Hanson attended a demonstration of the smoke control system. Mr Hanson recalls in his witness statement that it occurred on the 4th of May {RBK00033894}. The RBKC Building Control Chronology {RBK00026860} and Mr Hughes's email {RBK00003778} suggest the witnessing of the smoke control system in fact took place on 5th May 2016.

5.11.43 Mr Hanson describes the demonstration in paragraphs 63 and 64 of his witness statement {RBK00033894} as follows:

> 63. The demonstration on 4/5/2016 was limited to the sequence of operation of the system from activation of a small selection of the smoke detectors in the lobbies on a few floor levels. It did not involve a witnessing of the previously commission airflow rates etc. It was a demonstration of the sequence of operation. The sequence was as follows:

Figure 5-13: Excerpt from Mr Hanson's witness statement {RBK00033894}

5.11.44 Therefore, RBKC only observed the operation of the system based on a limited number of levels and smoke detectors. No demonstration of the system's performance was observed

5.11.45 As I present later in Section 8.5 regarding commissioning, Mr Mahoney (PSB) describes the system as a "Mechanical Extract, Natural Inlet" system.

5.11.46 In accordance with the *SCA Guide 2015*, for a mechanical shaft system such as a "Mechanical Extract, Natural Inlet" system, the automatic change over to the standby fan, automatic change over to the secondary power supply, and a cold smoke test (which would have been required due to the extended travel distance at Grenfell Tower) should also have been demonstrated to RBKC Building Control.

5.11.47 No measurements were taken when the system was operating in foreseeable design scenarios pertinent to means of escape and firefighting at the Tower.

5.11.48 As I set out in Section 8 the only measurements made appear to have been with a single stair door open.

5.11.49 In Section 2 of this report, I explained the range of foreseeable situations which arise in a fire event mean that different stair and flat door opening performance checks should be carried out, so that the performance of the system is tested in realistic conditions for means of escape and firefighting mode.

5.11.50 The *SCA Guide 2012* and *2015* versions also make clear the need to set out relevant scenarios, and I have demonstrated the significance of this regarding a system for Grenfell Tower in Table 5.2 above.

5.11.51 Ultimately for this performance-based design, the designer was required to set out foreseeable scenarios under which the system was required to perform,

and set the resulting performance objectives and design criteria. Building Control needed to understand this in order to confirm approval for the system; as well as to observe the system functioning as intended in the relevant design scenarios.

5.11.52 Finally, RBKC Building Control issued a Letter of Comfort, dated 2nd June 2016, which stated {RBK00003026}:

> 5] Various openable windows within the main entrance lobby to Grenfell Tower area required to be linked to main powered ventilation system for the building, so that such windows open on operation of the system and provide makeup air at the bottom shaft for the system.
>
> 6] A permanent notice indicating simple instructions / a guide on how to operate the powered ventilation system in the event of an incident should be fitted adjacent to the control panel for the system on the ground storey, for use by the LFEPA.
>
> ..
>
> I would confirm that once all matters mentioned in this letter have been addressed / completed, also the outstanding applicable paperwork relating to the powered ventilation system has been sent to this office for Councils consideraton and the documentation has been reveiwed and found to be satisfactory, this department should be in a position to issue the Building Regulations Completion Certificate for this project.

Figure 5-14: Excerpt from RBKC Building Control letter dated 2nd June 2016 {RBK00003026}

5.11.53 Therefore, as at June 2016, RBKC Building Control stated that works were still required to be completed for the smoke control system and that the *'outstanding applicable paperwork relevant to the powered ventilation system'* was required before a Completion Certificate could be issued.

5.11.54 I have not seen evidence that any further 'paperwork' regarding the smoke control system was provided to RBKC Building Control.

5.11.55 Overall and based on my review of the information provided to RBKC Building Control, I can find no further evidence of the stated basis of design and how it was intended to comply with the Building Regulations (Schedule 1 and Regulation 7).

5.11.56 I have already explained why the Completion Certificate should not have been issued by RBKC Building Control and do not deal with this matter any further here (see my separate report: *Regulation 38 Fire Safety Information* (Version 2 Updated 23 October 2020) {BLARP20000021}).

6 Evidence of the performance of the as-installed refurbished system

6.1 Changes to this section

6.1.1 In Section J7 of Appendix J to my Phase 1 report {BLAS0000031}, I explained the physical evidence I found during my own post-fire inspection of Grenfell Tower between 7th-9th November 2017 .regarding the refurbished smoke control system.

6.1.2 In this Section 6 I have expanded my investigation of the physical installation of the smoke control system to include additional evidence now available to me regarding the evidence of fire performance of the equipment installed in Grenfell Tower.

6.1.3 This additional evidence is listed in Table 6-1 below.

Table 6-1: Further evidence obtained in my Phase 2 investigation

Relativity Reference	Document
Fans	This evidence is reviewed in Section 6.4
{ELT00000036}	Elta's LPCB certificate of product approval
{JSW00003459}	Quotation for fans from Elta to PSB
Lobby Dampers	This evidence is reviewed in Section 6.5
{GBL00000002}	Series 54 Damper purchase order
{GIL00000013}	BMT/FEP/F14191 Revision A, *A fire resistance test performed on a Series 54 smoke evacuation damper Test conducted utilising the principles of EN 12101-2: 2003 Annex G*
Level 2 Dampers	This evidence is reviewed in Section 6.6
{JSW00000025}	Email from David Bradbury (JSW) to Matt Smith (MF) containing PSB technical submission rev 1 and several product brochures including BSB SC series damper tests
{JSW00001575}	Test specifications from BSB literature for SC series smoke control dampers
Level 2 Ductwork	This evidence is reviewed in Section 6.7
{FPL00000001}	Flamebar BW11 product specification from Fire Protection Ltd
{FPL00000028}	Flamebar BW11 LPCB certificate
{FPL00000036}	BRE Global assessment report No CC88343 for duct systems
{FPL00000037}	WarringtonFire Assessment Report 173531 *The Fire Performance of Flamebar BW11 Ductwork Subjected to Internal Temperature of 400°C*
Other	
{MET00065879}	BRE Client Report. GT site report on the operation of the smoke control system dated 10 February 2020.

6.1.4 I provide four new sub sections as a result; Section 6.4 – Section 6.7 inclusive.

6.1.5 In Section J7.2 – J7.7 of Appendix J of my Phase 1 report {BLAS0000031} I also set out my understanding at that time of the system controls including

operation of the system in both smoke and environmental mode and the operation of the HMI panel.

6.1.6 I have now expanded my investigation of the controls and operation of the smoke control system and this is presented separately, in Section 7 that follows.

6.2 Summary description of the works associated with the smoke control system

6.2.1 During the 2012-2016 primary refurbishment, the existing pairs of builders' work 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.

6.2.2 The pairs of shafts serving the north and south sides of the lobbies were extended downwards, as a single combined shaft, between Ground and Level 3 on each of the north and south sides of the lobby. The extension of the shafts is illustrated in Figure 6-1.

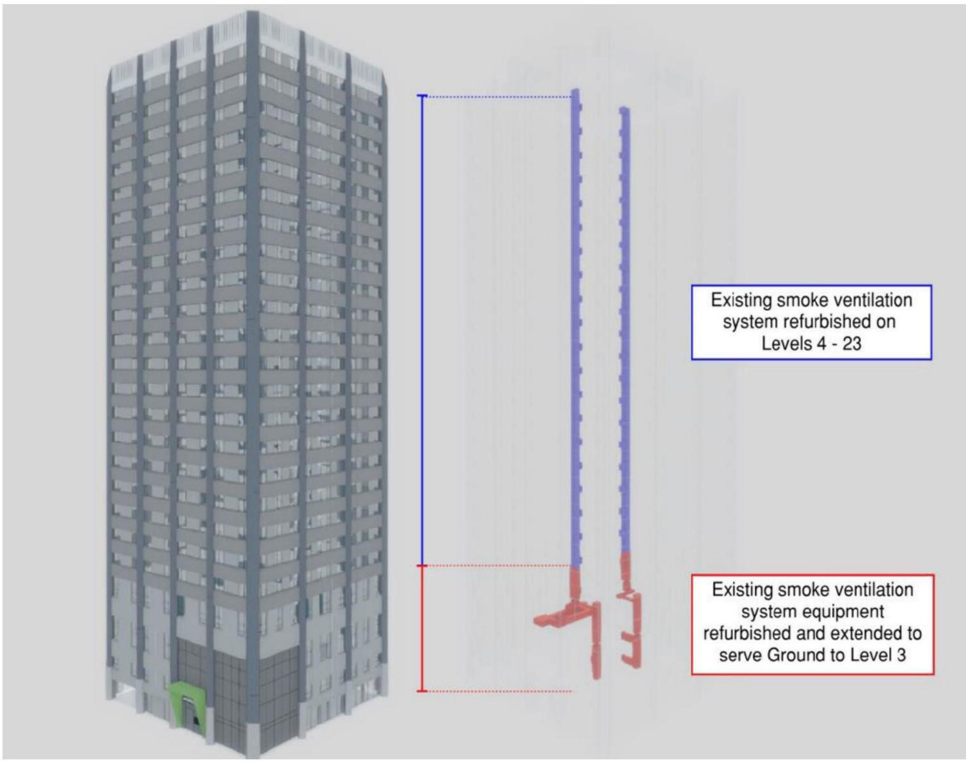


Figure 6-1: Extension of ventilation shafts in Grenfell Tower

6.2.3 The existing openings between the lobbies and the shafts on Levels 4 – 23 were retained.

6.2.4 The existing north shafts already extended to the roof plantroom to serve the roof fans.

6.2.5 New dampers, were fitted into the existing openings per lobby, in each smoke shaft. Two openings in the North Shaft are shown in Figure 6-4.

6.2.6 One new pair of combined smoke and environmental fans was provided at roof level serving the North shaft.

6.2.7 A pair of smoke extract fans and one new environmental fan were provided at Level 2, serving the South shaft.

6.2.8 The smoke fans installed at Level 2 and at Roof level were both configured as two fans installed in series i.e. one in front of the other where one of the fans was the primary fan and the 2nd fan was a "standby" fan that could activate in the event that the primary fan failed to operate.

6.2.9 New power supplies and controls were also provided for the refurbished lobby smoke control system.

6.2.10 New ductwork running horizontally was fitted running from the south shafts to the new Level 2 smoke and environmental fans and out to the louvre at the façade of the building, above the main entrance canopy, connecting to the outside air. See Figure 6-2 below.

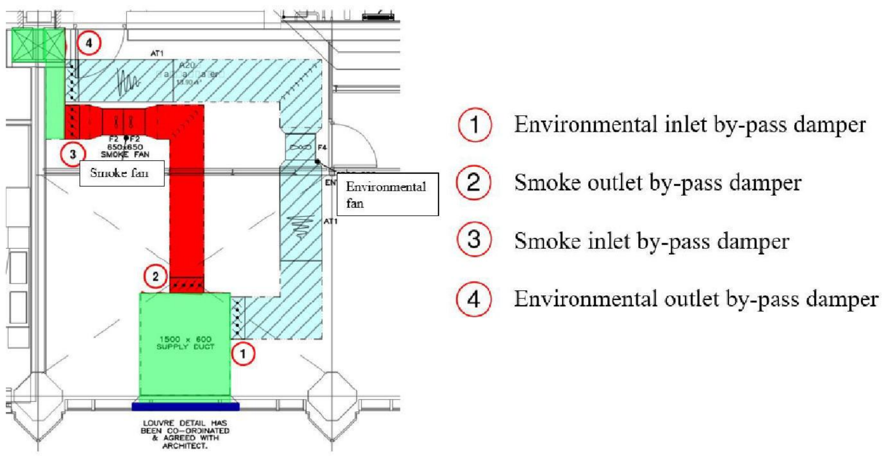


Figure 6-2: Layout of ductwork at Level 2. Light blue: environmental fan, dampers and ductwork. Red: smoke fans, dampers and ductwork. Green: shared ductwork, Dark Blue: external louvres. Dampers 1 and 4 serve the environmental fan. Dampers 2 and 3 serve the smoke fans.

6.2.11 Max Fordham's Employer's Requirement for MEP services {MAX00006475} dated 28/11/2013, noted that shafts shared for both environmental and smoke systems was unusual:

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.

6.2.12 The operation of the refurbished lobby smoke control system in environmental mode is detailed in Section 7.6.

6.2.13 The operation of the refurbished lobby smoke control system in smoke control mode is detailed in Section 7.5.

6.2.14 In the following sections, I describe the components of the system that I observed between Level 4 and Level 23 during my inspection of 7-9 November 2017.

6.3 My observations of the primary components of the refurbished smoke control system

6.3.1 In the following sections, I describe the components of the system that I observed between Level 4 and Level 23 during my inspection of 7-9 November 2017.

6.3.2 **North Shaft lobby dampers**

6.3.3 Smoke exhaust was provided by a pair of dampers located at high level on the north side of each lobby.

Figure 6-3: North dampers on Level 16 (My photo. Please refer to Section C2.1.20 of Appendix C of my Phase 1 report {BLAS0000024}).

Figure 6-4: North dampers on Level 4.

6.3.4 PSB specified Gilbert Series 54 dampers for the "Existing lobbies" in Section 2.1 Automatic lobby ventilators of their Technical Submission (Rev 6, {PSB00000214}).

6.3.5 In my Phase 1 report, I explained that the performance standard achieved by the dampers installed in Grenfell Tower required further investigation in Phase 2 (Section J7.1.45).

6.3.6 I present the results of my final assessment of the dampers in Section 6.5 below.

6.3.7 **Smoke control vent shafts**

6.3.8 The north dampers OVs were served by the original pair of north smoke shafts (as extended, aggregate area $0.48m^2$) leading to one new pair of combined smoke and environmental fans and the original outlet at roof level. The outlet is shown in Figure 6-5. I have provided pictures of the roof fans in Figure 6-12, Figure 6-13 and Figure 6-14 later in this section.

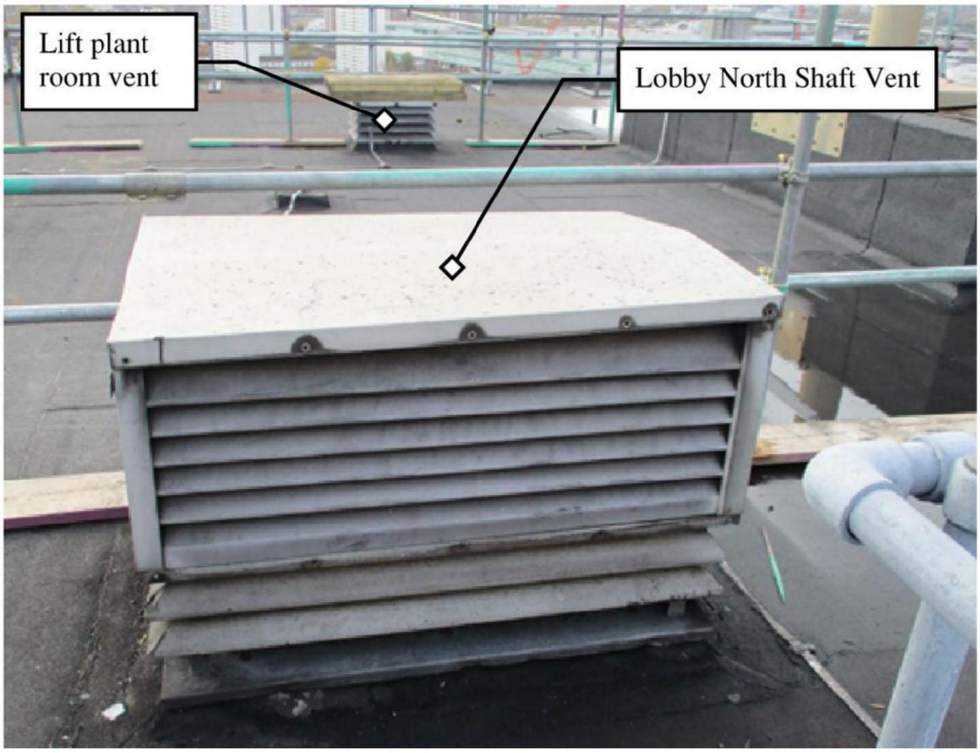


Figure 6-5: North vent shaft outlet

6.3.9 The south dampers (Section 6.3.35) were served by the original pair of north smoke shafts (as extended, aggregate area $0.48m^2$) leading to two new smoke control exhaust fans, a new environmental ventilation supply fan, ductwork and a louvred outlet on the face of the building at Level 2.

6.3.10 Figure 6-6 to Figure 6-11 are photographs of the builders works shafts taken by me.

6.3.11 In terms of the requirements for brickwork ducts used for pressure differential systems, Clause 11.8.2.8 of BS EN 12101-6:2005 states:

Brickwork ducts may be used provided that such ducts are used solely for air distribution and the internal surface is rendered to limit air leakage, a sheet metal lining is used, or it is shown that the leakage is satisfactory.

6.3.12 Figure 6-6 shows the inside of the South vent shaft at Level 5. The walls with yellow markings were constructed of masonry whilst the other two walls are formed by the concrete frame of the building.

6.3.13 Based on Figure 6-6 (showing one of the vent shafts at Level 5) it does not appear that the inside of the shaft is fully rendered.

Figure 6-6: Picture taken within one of the South vent shafts at Level 5 looking upwards

6.3.14 Figure 6-7 also shows the observed differences between the surface finish in different locations of the shaft.

6.3.15 The pattern of diagonal lines inside the shaft is replicated on the outside of the shaft, as presented in Figure 6-10. This pattern may be seen in both the grey and yellow areas of block.

6.3.16 The yellow areas of block also exhibit a different sandstone-like pattern in places.

6.3.17 The internal lining of the shaft was not therefore fully rendered with one material.

6.3.18 Mortar joints between blocks are clearly visible. These observations are replicated in Figure 6-7 to Figure 6-10 which show different portions of the shafts at Level 4, Level 7 and Level 23.

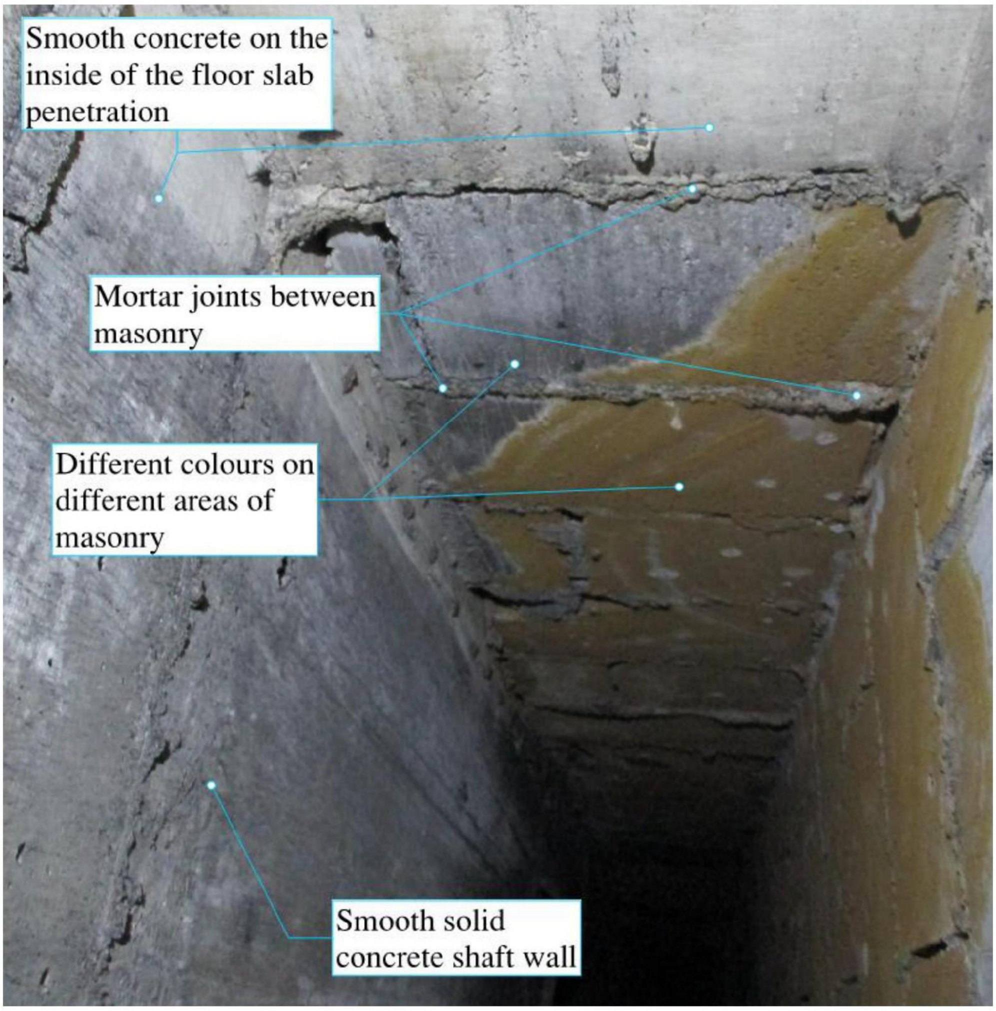


Figure 6-7: Inside of shaft at Level 4

Figure 6-8: interior of smoke shaft at Level 7

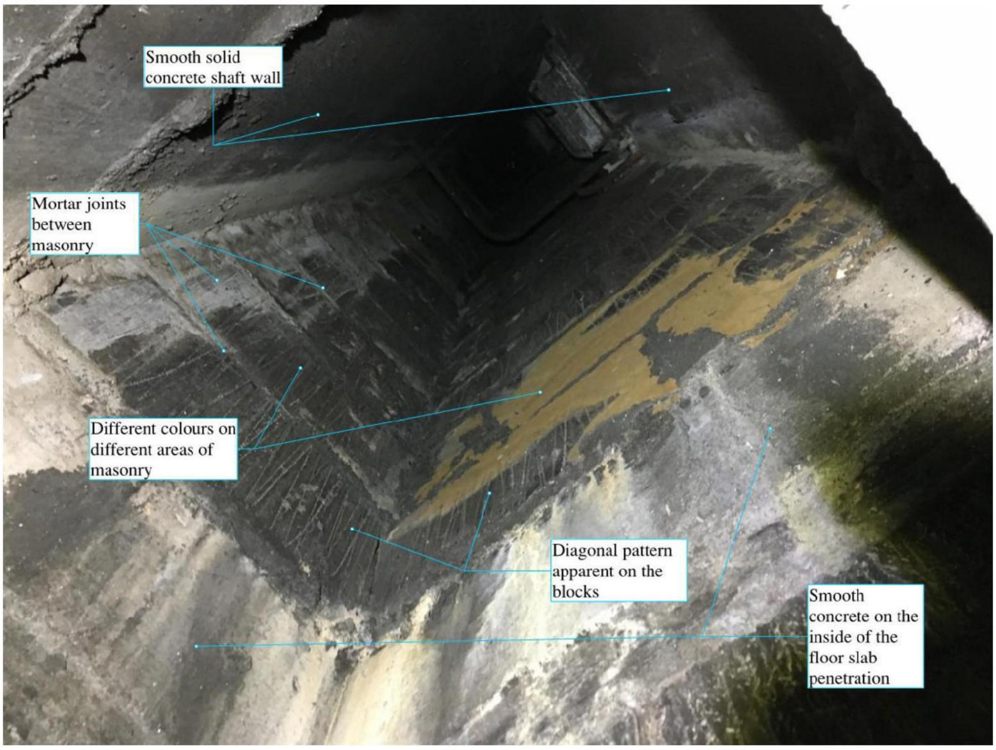


Figure 6-9: Inside of shaft at Level 7

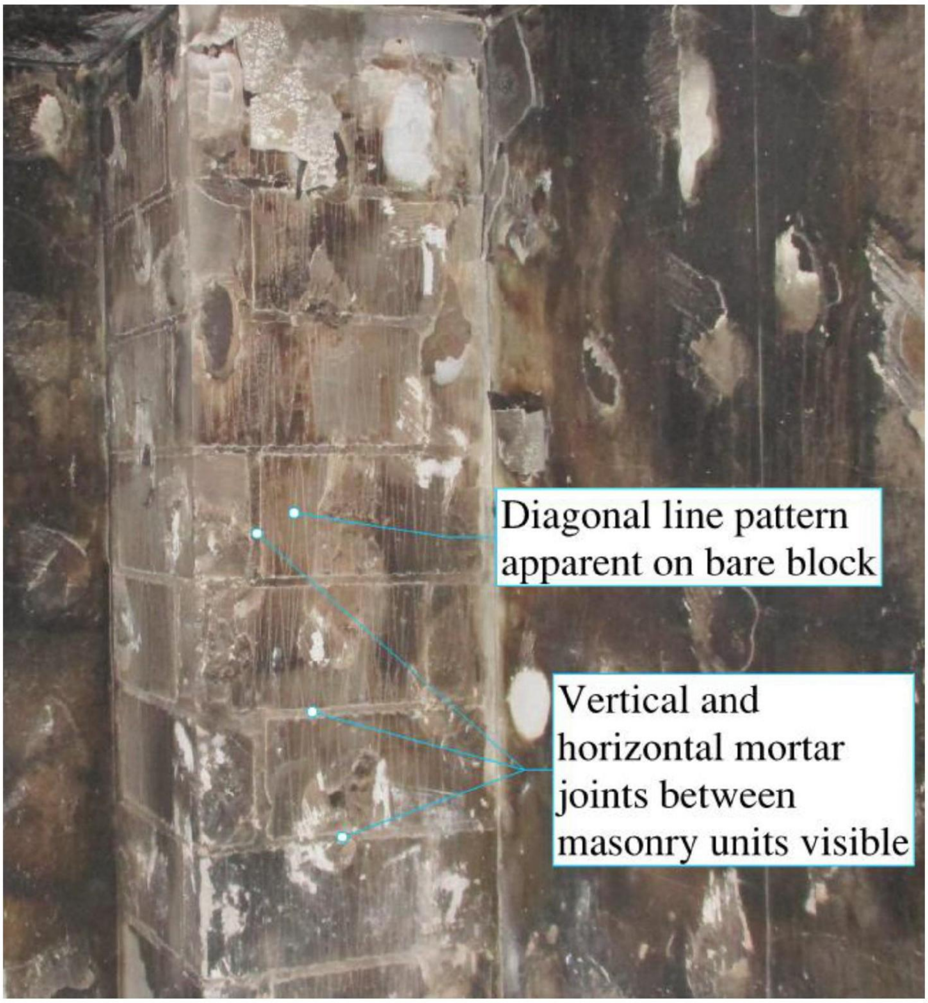


Figure 6-10: Exterior of smoke shaft masonry at Level 23

6.3.19 Figure 6-11 shows the inside of the north shaft at Level 22, where I observed it to have been destroyed as it rises up within Flat 195. The markings around the shaft indicate where the breeze block construction of the shaft was originally present.

6.3.20 I understand from an MPS photograph {MET00019926} taken on the day after the fire that the shaft was still in place at that time, and therefore the shaft wall must still have been present over the whole course of the fire on the 14th June 2017.

6.3.21 I observed the damper (shown in Figure 6-10) in this location to be open, however the condition of the sides of the damper blades indicate that the damper was not open during the fire but was instead opened by other parties after the fire.

6.3.22 I was unable to inspect the shaft at Level 22 due to debris, however there is no indication that the shaft was blocked in any way at this level.

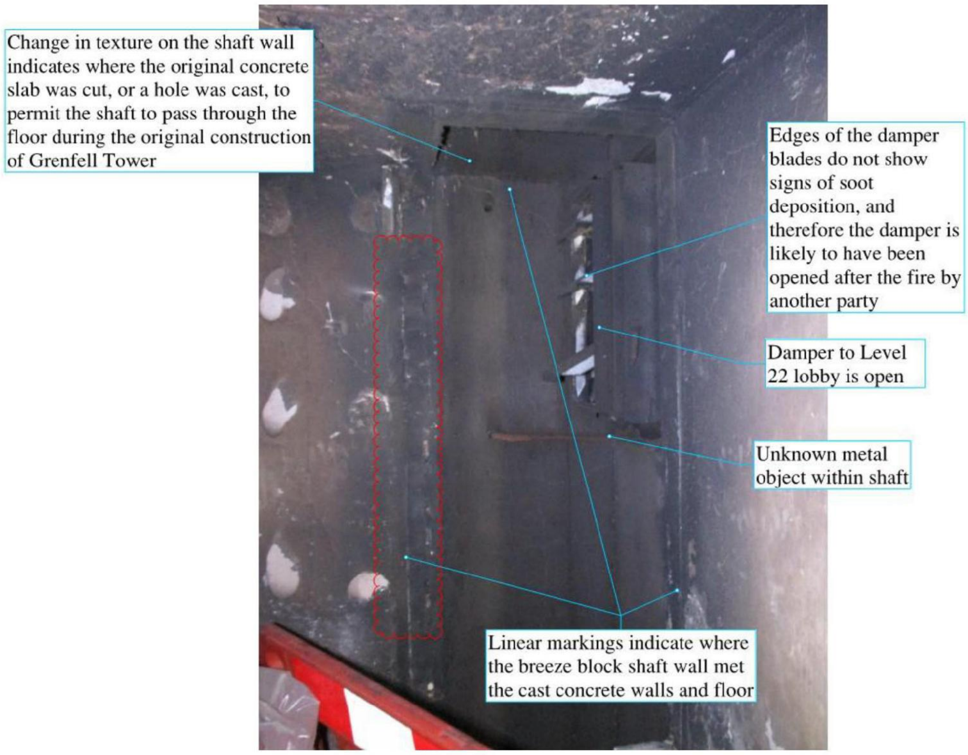


Figure 6-11: Destroyed smoke shaft in flat 195 on Level 22

6.3.23 On the basis of the images I have just presented, it does not appear that the whole of the inside of the shaft was rendered. Nor was it provided with a metal sheet lining to comply with BS EN 12101-6:2005.

6.3.24 I note this because, the *SCA Guide 2012* states:

A builder's work shaft should have a maximum leakage rate of 3.8 m3 per hour per m2 at 50 Pascals. This figure is derived from leakage data for walls in BS EN 12101-6 and is used to set a benchmark to limit air leakage from the shaft.

6.3.25 In the additional witness statements provided to me since my Phase 1 report, no further information has been provided as to how the existing shafts were assessed in order to confirm that leakage was satisfactory in accordance with PSB's design or in accordance with the recommendations made in the *SCA Guide 2012, SCA Guide 2015, BS 7346-8:2013* or BS EN 12101-6, before they were reused as part of PSB's smoke control system.

6.3.26 **Fans at Roof Level**

6.3.27 Figure 6-12 shows the smoke control fans (primary and standby fans arranged in series) at Roof level.

6.3.28 Figure 6-13 shows the detail of the fan information plate, confirming the manufacturer of the fan, Elta Fans Ltd, and the fire performance rating that it was classified as achieving - F300 at temperature 300°C for 120 minutes.

6.3.29 Figure 6-14 shows the fan as seen from above when standing on the roof and looking down the vent shaft.

6.3.30 Section 3.1 *Run and standby extract fan arrangement* of PSB's Technical Submission (Rev 6, {PSB00000214}) dated 15th March 2016 refers to the smoke extract fan at roof level above the plant room as an Elta fan type LCS063K2-A5/17RS.

6.3.31 I have not seen specific fire resistance test or classification reports for the Elta fans installed at Grenfell Tower. However, I have been provided with Elta's *Certificate of product approval* issued by LPCB {ELT00000036} and a quotation for the supply of fans from Elta to PSB, dated 16th March 2015 {JSW00003459} which detailed some performance specifications for these fans.

6.3.32 I set out my assessment of that evidence for the roof extract fans (as well as the Level 2 extract fans) in Section 6.4 below.

Figure 6-12: Environmental / Smoke control fans in the roof plant room

Figure 6-13: Post fire inspection of fan information plates stating that the temperature rating of the roof smoke fans was 300°C for 120 minutes.

Figure 6-14: Roof level fan unit observed 8th November from roof outlet above

6.3.33 **Natural ventilator at the head of the Stair**

6.3.34 Figure 6-15 shows the permanently open vent at the head of the stair.

Figure 6-15: Permanently open vent at head of stair

6.3.35 **South shaft lobby dampers**

6.3.36 Smoke exhaust was also provided by a pair of dampers located at low level on the south side of each lobby from Level 4 to Level 23. These dampers were fitted with the same type of dampers as I have described in Section 6.3.2.

Figure 6-16: South dampers on Level 16.

Figure 6-17: South dampers on Level 4, actuator also visible, grille removed on the left hand side.

6.3.37 Please refer to Section 6.5 below for my final assessment of these dampers.

6.3.38 **Fans, ductwork and dampers at Level 2**

6.3.39 At Level 2 smoke extract fans and ductwork were provided separately to environmental supply fan and ductwork, plus several dampers were also provided to separate the smoke extract and environmental air supply fans and ductwork.

6.3.40 The new smoke control fans (both duty and standby in series) provided at Level 2, are shown in Figure 6-18.

6.3.41 Section 3.1 Run and standby extract fan arrangement of PSB's Technical Submission (Rev 6, {PSB00000214}) dated 15th March 2016 refers to Elta fan type LCS050J2-A6/17RS as the specified fans at the walkway level of Grenfell Tower. I set out my assessment of the performance achieved by the smoke extract fans in Section 6.4.

6.3.42 An environmental fan was also located at Level 2. In the event of a fire, this fan (and its associated unrated ductwork) was to be isolated from the smoke control system by automatically closing smoke dampers. The smoke and environmental sections installed at Level 2 are shown in Figure 6-2.

6.3.43 According to the BRE Client Report GT site report {MET00065879} the damper labelled "2" in Figure 6-2 would have been permanently open while the rest of these dampers would have controlled the flow of air and smoke when the system needed to switch between environmental and smoke control mode.

The Smoke Extract Fan inlet damper was confirmed to be connected to a cable from Inverter Panel 1 but the Smoke Extract Fan outlet damper was NOT connected inside wiring junction box (see SOCO photographs). It was therefore presumed that it was intended for the Smoke Extract Fan outlet damper to be permanently open. Note that the Smoke Extract Fan outlet damper was open but the other three dampers were closed, when inspected by BRE in July 2017

6.3.44 PSB specified BSB SC Series dampers for the *"Walkway environmental fan set and plant room smoke extract fanset"* in Section 3.4 Bypass dampers of their Technical Submission (Rev 6, {PSB00000214}) (refer to Section 6.6).

6.3.45 I have not been provided with any further test reports or classification reports from BSB regarding the fire performance for the Level 2 dampers in the course of my Phase 2 work.

6.3.46 I note that I have been provided with the following emails with attached classification or test reports for BSB dampers, disclosed by BRE:

a) {BRE00020137}

b) {BRE00020150}

c) {BRE00020159}

d) {BRE00020626}

e) {BRE00028071}

6.3.47 None of these relate to the SC series of dampers as installed in Grenfell Tower.

6.3.48 They are for FSD-TD; FSD-TD-HF; FSD-C 2HH; FD and FSD-C 2HH models of BSB dampers and are therefore not relevant to my assessment.

6.3.49 I have instead reviewed the publicly available product literature for these dampers in Section 6.6.

6.3.50 New ductwork was provided connecting the existing south smoke shafts to a louvred vent on the outside of the building, via the smoke extract fans.

6.3.51 This ductwork (sand-coloured ducts shown in Figure 6-19) was noted in an email from Mr Bradbury (J S Wright) to Mr Mahoney (PSB) and Mr Peacock (J S Wright) on 9th November 2015 {JSW00003470} as requiring to be *"fire rated"*.

6.3.52 A JSW drawing attached to an email sent by Mr Sounes (Studio E) on 21st December 2015{HAR00007049} noted the ductwork as requiring to be "*Two hour fire rated*".

6.3.53 I present the results of my assessment of the performance of the level 2 ductwork with the performance requirements of ADB 2013 in Section 6.7 below.

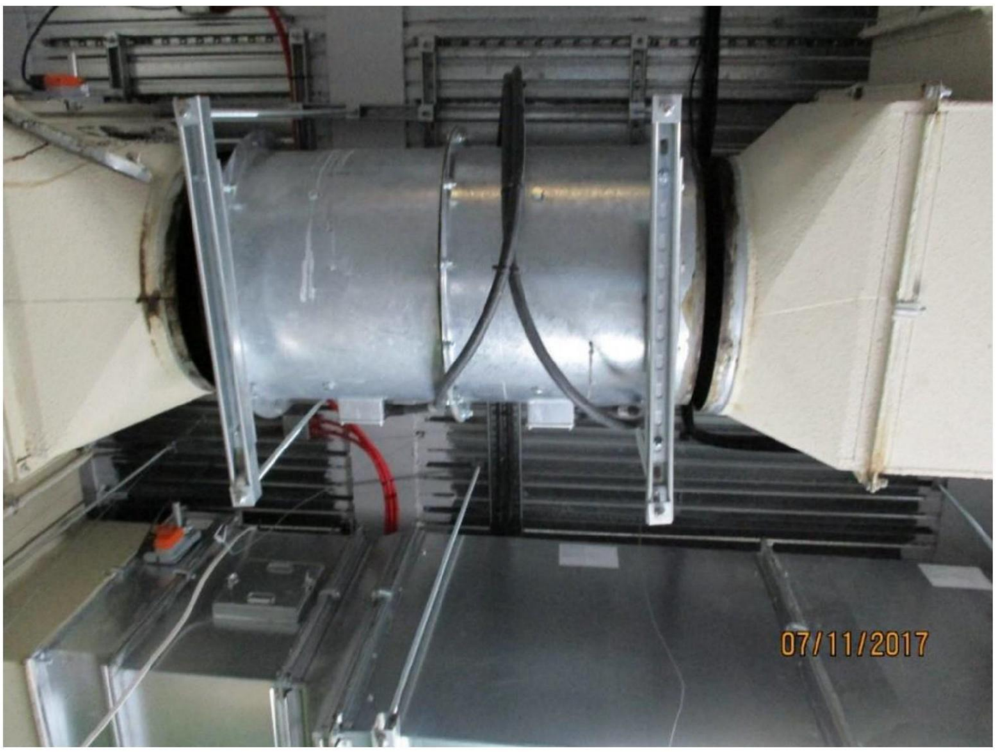


Figure 6-18: Smoke exhaust fans at Level 2

Figure 6-19: Fire-rated ductwork at level 2.

6.3.54 Figure 6-20 shows the louvre positioned in the façade of the building at Level 2.

6.3.55 When the system was operating in Environmental mode, this would act as an air intake for the supply fan at Level 2.

6.3.56 When the system was operating in smoke control mode this louvre would be an exhaust vent connected to the smoke extract fans at Level 2.

Figure 6-20: Smoke system intake / exhaust louvre at Level 2 (indicated with blue dashed line). In smoke mode, smoke will be exhausted from these louvres. In environmental mode, fresh air will be drawn into the building through these louvres (BLA00004531).

6.3.57 **New Dampers located in the lobby at Ground Level to Level 3**

6.3.58 The dampers associated with the new ductwork installed to extend the existing smoke shafts, were located in the lobby on Ground Level – Level 3.

6.3.59 These were all located on the lobby wall, and served by the north and south vent shafts.

6.3.60 Figure 6-21, shows a cross section through the lower floors of Grenfell Tower {PSB00000603}.

6.3.61 The yellow boxes, red boxes and labels on the drawing were added by Rydon as an explanation to PSB regarding the proposed route of the new smoke shaft to extend the existing system from Level 4 to Ground floor and hence where new opening were required to be cut through the existing construction.

6.3.62 Labels A-H indicated new openings to be provided for the extension of the north shaft with corresponding dimensions provided on page 4 of {PSB00000603}.

6.3.63 Labels 1-8 indicated new openings to be provided for the extension of the south shaft with corresponding dimensions provided on page 5 of {PSB00000603}.

6.3.64 I have used this drawing to indicate where the new lobby dampers were to be installed (Level 3 AOVs etc)

6.3.65 The new openings for the level 3 dampers are indicated with the original Rydon tagged B and 2; the new openings for the level 1 dampers are indicated with the original Rydon tagged G and 7 and the new openings for the ground level dampers are indicated with the original Rydon tagged H and 8.

6.3.66 The level 2 dampers were not proposed to be located in vertical position in the north or south shaft, but instead located in the ceiling of the level 2 lobby.

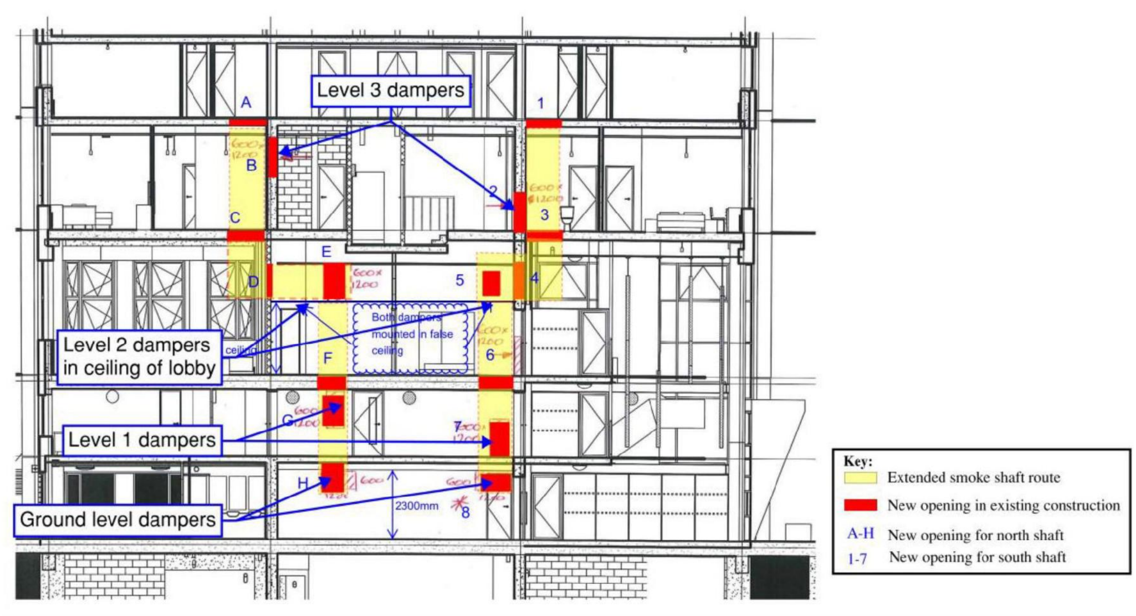


Figure 6-21: Locations of new openings for dampers provided to Levels Ground to 3 {PSB00000603} (Legend added by me)

6.3.67 PSB specified Gilbert Series 54 dampers for the "Lobbies to Ground floor, walkway and walkway mezzanine" in Section 3.2 Automatic lobby ventilators of their Technical Submission (Rev 6, {PSB00000214}).

6.3.68 I present the results of my assessment of the Gilbert Series 54 dampers in Section 6.5.

6.3.69 Control equipment

6.3.70 A master control panel and a Human Machine Interface (HMI) panel were both located at Ground Level.

6.3.71 The master control panel was located in the hub room A010. This control panel allowed the operator to access system configuration, maintenance and testing functions (Figure 6-23 and Figure 6-24).

6.3.72 Please refer to Sections 7.6 for a detailed explanation of the operation and programming of the system in environmental and smoke control modes respectively.

6.3.73 According to the Fire Access Plan Rev. 06 {TMOM00000006}, the Hub Room is separated from the Entrance Lobby and Lift Lobby by 120 minutes fire rated construction and is separated from the Community Room and the Community Room Lobby by 30 minutes fire rated construction (refer to Figure 6-22).

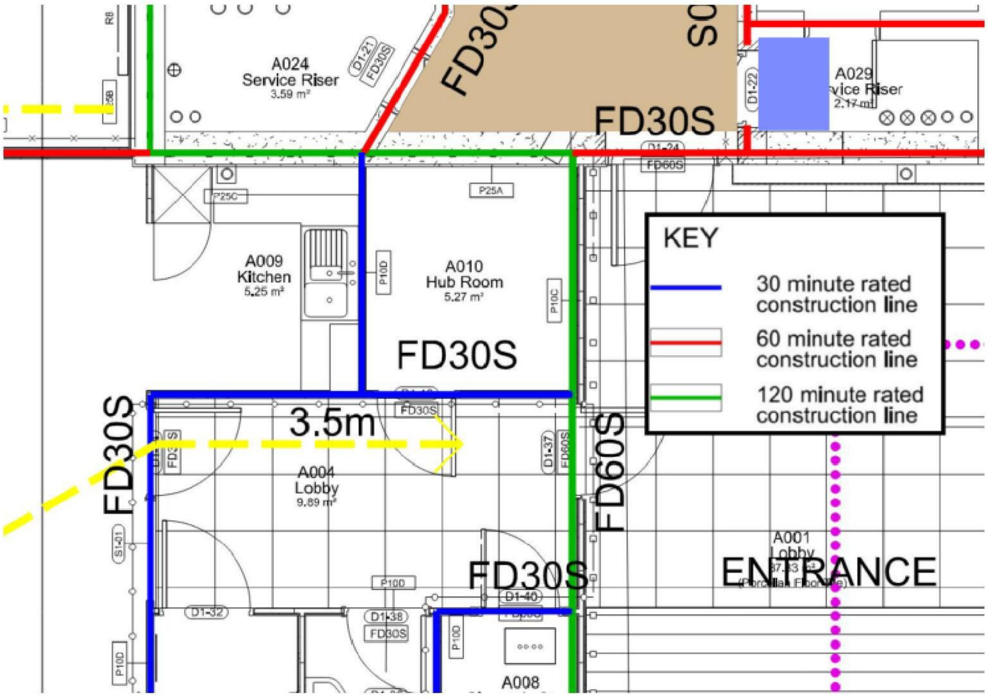


Figure 6-22: Fire rated construction around Hub Room (Extracted from {TMOM0000006})

Figure 6-23: Master outstation metal casing and labels, located in the Hub Room

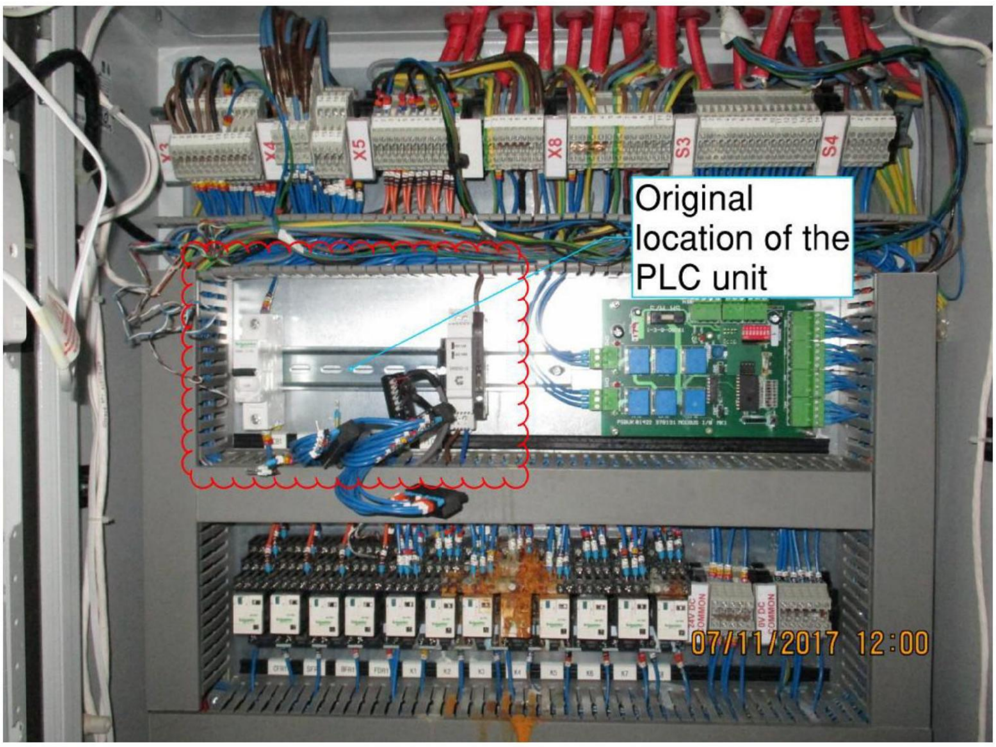


Figure 6-24: Master outstation internal wiring, identifying where the PLC was positioned before being removed by the MPS

6.3.74 The Human Machine Interface (HMI) panel was located within the Ground floor lobby (Figure 6-25).

6.3.75 The HMI panel was to allow fire fighters to make changes to the operation of the system including the floor of operation. Please refer to Section 7.9 for details of its programming and operation.

Figure 6-25: HMI panel, located in the Entrance Lobby, photographed on 14 June 2017 showing key switched to the 'On' position (Page 5 of {MET00077976})

6.3.76 According to the Fire Access Plan Rev. 06 {TMOM00000006}, the Ground floor lobby is enclosed in 120 fire rated construction, with the exception of the separation with the Ground floor lobby and the service riser which is 60 minutes fire rated construction (refer to Figure 6-26).

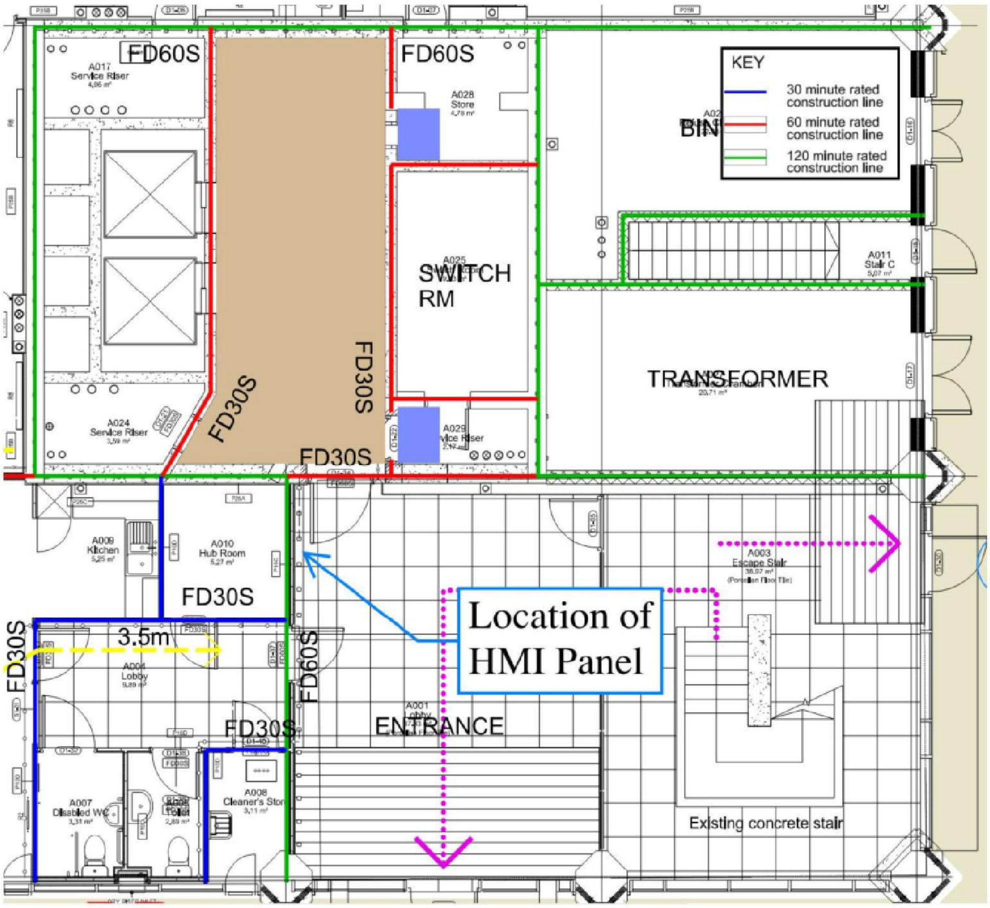


Figure 6-26: Fire rated construction around ground level entrance (Extracted from {TMOM0000006})

6.3.77 22 outstations were provided; one on every floor from Levels 2 to 23. The outstation on L3 was located behind an MDF wall panel in the lobby. The remaining outstations (L2 and L4-23) were located in the riser cupboard opposite the lifts (refer to Figure 6-27).

6.3.78 Outstations are control panels provided on each floor to manage the systems on that floor. The outstations then communicate with, and are controlled by, the master outstation described above.

Figure 6-27: Local outstation on Level 6

6.3.79 According to the Fire Strategy drawings Rev. 05 {TMOM00000007}, the riser cupboard housing the outstation is not indicated on the drawings.

6.3.80 The cupboard is within the lobby of the typical residential floor which is separated from the residential accommodation by 120 minutes fire rated construction and separated from the lift shaft and stair core by 60 minutes fire rated construction.

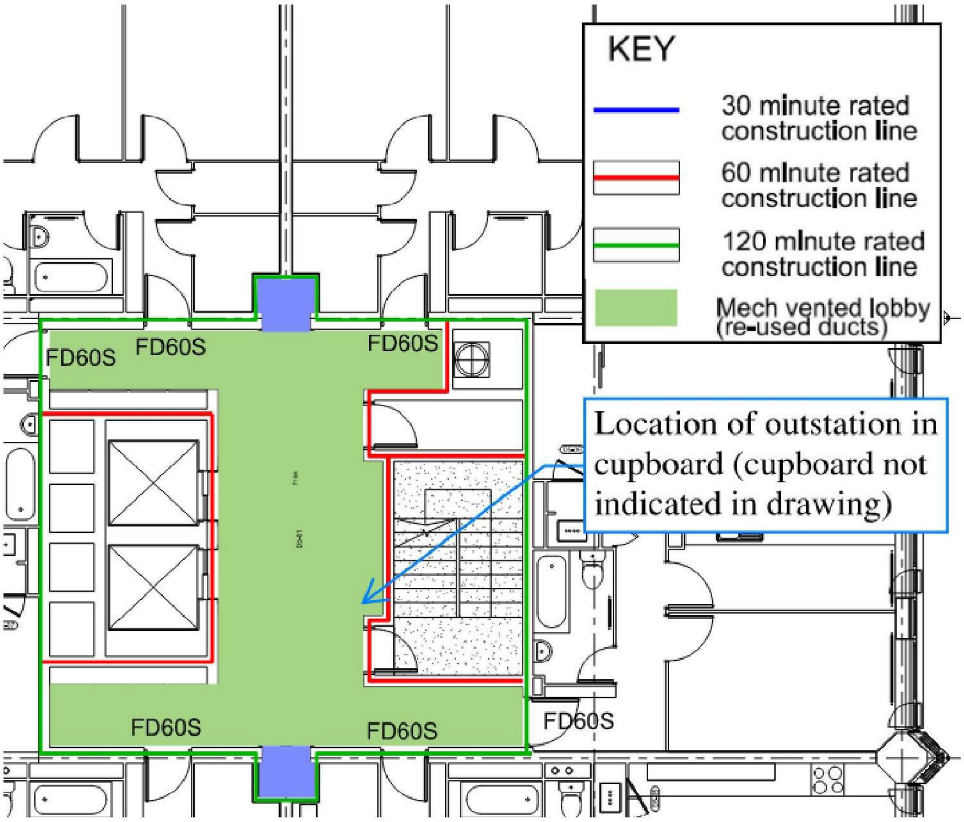


Figure 6-28: Fire rated construction around lobby of typical residential floor (Extracted from {TMOM00000007})

6.3.81 **Firefighter override – yellow key switch**

6.3.82 A Firefighter override key switch (yellow key switch) was provided in every lobby from Ground to Level 23.

6.3.83 In conjunction with an operation from the HMI panel, the yellow key switch could be used to change the floor of operation of the Lobby smoke control system to the floor on which the yellow key switch is operated.

6.3.84 I explain the operations in full in Section 7.

Figure 6-29: Fire fighter override key switch on Level 6

6.3.85 I note PSB's Technical Submission Rev 6 states that *"a key operated fire override switch to be located within the stairwell for each ventilated lobby"* (p.12, {PSB00000214}) where it would be separated from the effects of fire in the lobby, which is mechanically ventilated.

6.3.86 I have no evidence to explain why the switches were installed in the lobbies instead of the stairs.

6.3.87 Please refer to Section 7.20 where I present my review of RINAs findings regarding of the yellow key switch.

6.3.88 Please also refer to Sections 12 where I present my analysis of the lobby smoke control system performance on the night of the fire, the analysis of the smoke control system installation as a protected shaft on the night of the fire, and therefore the functionality of the yellow key switch in both cases.

6.3.89 **Pressure controls and pressure sampling tubes to detect the pressure difference between the stair and the lobby on that level.**

6.3.90 Pressure controls were provided on every floor (Figure 6-30).

6.3.91 These were used to control the speed of the fan between its low- and high-speed modes. This aspect of the operation of the smoke control system is detailed in Section 7.7.

6.3.92 PSB's Technical Submission (Rev 6, {PSB00000214}) describes the provision of a PA-DPS-8x Sontay Pressure Sensor pressure sensor (p.20; {PSB00000214}).

6.3.93 Rydon disclosed the data sheet for the PA-DPS-8x product {RYD00094061} which describes it an *"Air Differentail* [sic] *Pressure Switch"* which functions as a pressure switch rather than a pressure sensor as was stated in PSB's Technical Submission (Rev 6, {PSB00000214}). I have set out the consequential difference in terms of the control of the Grenfell Tower smoke control system in Section 7 of this report.

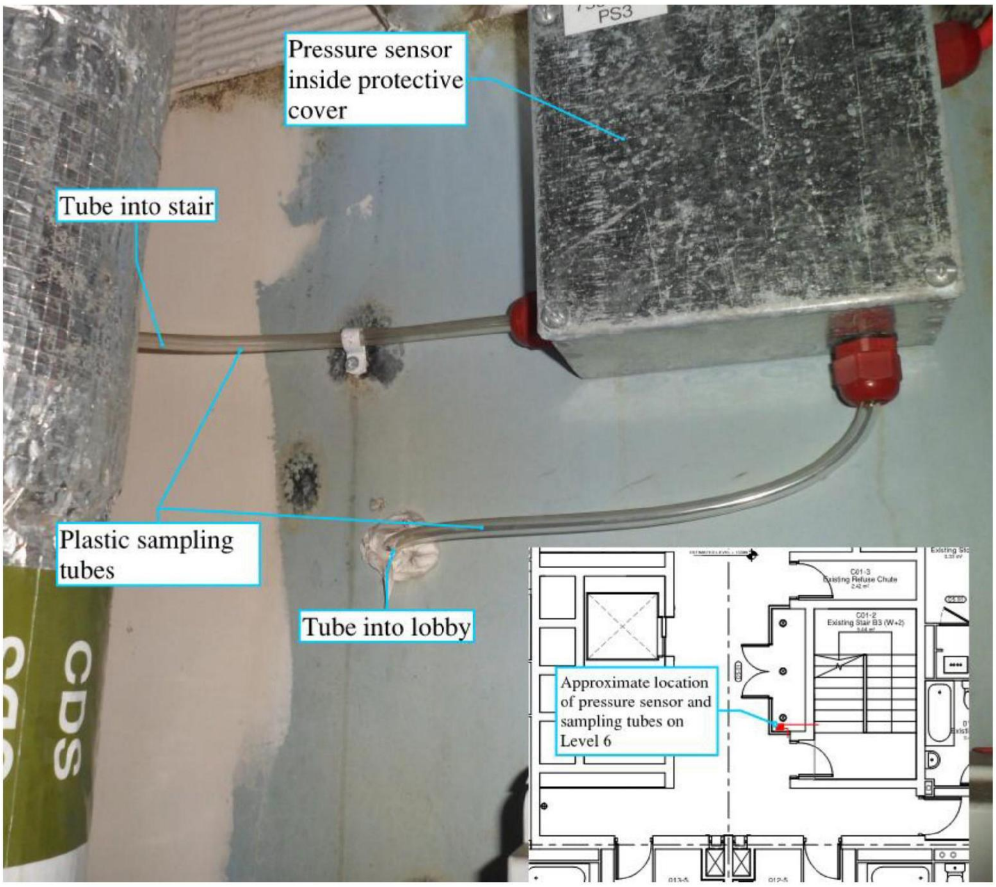


Figure 6-30: Pressure switch and pressure sampling tubes on Level 6

6.3.94 **Fan inverter control panels and power supplies**

6.3.95 Please refer to Figure 6-31 and Figure 6-32 which shows the invertor panels located in the Hub room.

6.3.96 The inverter panels provide speed control and power to the fans.

Figure 6-31: Environmental fan invertor panel located in the Ground Floor Hub Room

Figure 6-32: Invertor panel for the smoke fans located in the Ground Floor Hub Room

6.3.97 I set out my investigation of the operation of the inverters in the smoke control system in Section 7.14.

6.3.98 **Power and control cables**

6.3.99 I made no inspection of cable routes or individual cables as part of my post-fire inspection of 7-9 November 2017.

6.3.100 In Appendix J of my Phase 1 report {BLAS0000031}, I stated that I would conduct a review of the electrical drawings.

6.3.101 Please refer to my separate Appendix B of my Phase 2 report *Regulation 38 Fire Safety Information* (Version 2 Updated 23 October 2020) {BLARP20000021} where I found that electrical cable runways; protected power supplies and cables were not identified on plans provided by Rydon to KCTMO at the end of the works to comply with Regulation 38 of the Building Regulations 2010.

6.3.102 I have not therefore been able to instruct my specialist team to undertake a review of the power supplies and electrical cables for the smoke control system. My review in Section 7.15 is limited to identification of the secondary power sources provided at Grenfell Tower.

6.3.103 I have however made a specific assessment of the performance of power supply cables to the smoke control equipment within the lobbies, wherever it was material to my investigation of how the smoke control system operated on the night of the fire. I have assessed the type of cables installed for the operation of the dampers within the lobby in Section 7.12.

6.3.104 I have also reviewed the BRE report {MET00065879} for any further evidence from their site inspections regarding the as-built condition of the control wiring of the smoke control system.

6.3.105 From that review I note that BRE identified the following defects.

6.3.106 **Loose wiring connection to pressure switch at 1st floor**

6.3.107 The pressure switch at ground floor hub room serving the Level 1 lobby has two sensing points: one within the Level 1 lobby and one within the stairs at Level 1. The pressure switch monitors the pressure difference between the lobby and the stair and activates when the pressure difference exceed a setpoint.

6.3.108 BRE note in their inspection report {MET00065879} that, while checking the connection from Terminal X3/7 within the smoke control master panel to the 1st floor lobby pressure switch, continuity testing showed no electrical continuity and that the wire was loose in the terminal as it had not been tightened. This was illustrated by the exposed copper core having no marks (refer to Figure 6-33).

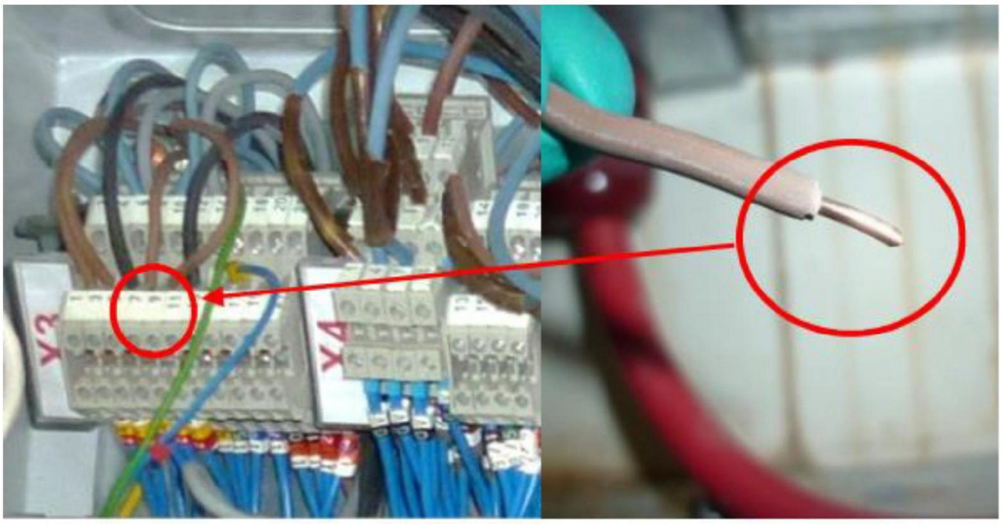


Figure 6-33: Master Panel – Unsecured wire in Terminal X3/7 failed continuity test {MET00065879}

6.3.109 According to my specialist team, Mr Wade and Dr Woodburn, in addition to being an indication of poor workmanship, this would result in the smoke control fans not being able to regulate their speed if the pressure switch operated.

6.3.110 However, as the affected pressure switch was on the 1st floor, which was unaffected during the fire, it is unlikely that this defect affected operation of the smoke control system on the 14th June 2017.

6.3.111 **Faulty connection of the Level 1 damper**

6.3.112 RINA's reconstruction report {MET00072161} highlights the following observations on the 1st level lobby dampers (on page 24):

The X4/12 cable output to the first floor lift lobby smoke damper was found to resting inside the terminal X4/11 terminal. From the photos in the BRE report [2], shown in Figure 10.1 below, it appears that this was as in-situ on site. This would have prevented these dampers from opening.

6.3.113 The loose wiring in the master panel would have prevented the 1st level lift lobby dampers from opening to extract the smoke if the system was activated at Level 1. These are indicated as location 'G' and '7' in Figure 6-34 for the north and south shaft respectively.

Figure 6-34: Locations of new openings for dampers provided to Levels Ground to 3 {PSB00000603} (Legend added by me)

6.3.114 I have summarised all wiring issues relevant to the controls of the smoke control system with my review of the software controls in Section 7 of this report.

6.4 Evidence of performance achieved – Smoke Extract Fans

6.4.1 This is a new section in full.

6.4.2 **Performance requirement**

6.4.3 The recommended performance for the smoke extract fans in BS EN 12101-6:2005 is that they are to be capable of handling smoke at a temperature of 1000°C when *"tested and classified in accordance with pr EN 13501-4"* (refer to Section 4.10).

6.4.4 The highest temperature classification in both pr EN 13501-4 and the full published version of the standard BS EN 13501-4 was 'F842 30' (i.e. resistant to 842°C for 30 minutes) and therefore lower than the 1000°C recommended by BS EN 12101-6:2005.

6.4.5 The *SCA Guide 2012* stated:

8.2.8 All fans used for smoke extract should be tested and certified to BS EN 12101-3: 2002.

6.4.6 No separate performance standard is recommended for fans used in any form of depressurisation system.

6.4.7 The 2002 version of BS EN 12101-3 allowed for a fan to be tested to 1000°C under the route termed *"Not classified"*.

6.4.8 The fans in a ColtShaft system are *"almost always F300 to EN 12101-3, that is to say 300C for 1 hour"* {INQ00014693}.

6.4.9 Therefore, in my opinion, it would have been reasonable for a designer to specify one of the following performance standards for the variable speed fans installed in Grenfell Tower:

a) Classified as 'F842 30' to BS EN 13501-4 when tested to BS EN 12101-3:2002; or

b) Tested at 1000°C to BS EN 12101-3:2002 and therefore regarded as *"Not classified"* in accordance with Table 2 of BS EN 12101-3:2002, noting there was no test procedure in the 2002 version of BS EN 12101-3 for variable speed fans.

6.4.10 I note the *SCA Guide 2012* and *2015* recommended the following for variable speed fans:

Designers of smoke control systems who wish to have variable speed operation in emergency mode due to the nature of the design of the smoke control system should satisfy themselves that the combination of fan and inverter are compatible and will operate satisfactorily under the design conditions.

6.4.11 My understanding of *"operating satisfactorily"* is that the fan and the inverter work at the correct speed and extraction rate to meet the design performance requirement.

6.4.12 Note the inverter provides the power and speed to the fan (located in the ground floor hub room for the level 2 fans and in the roof plant room for the roof level fans in Grenfell Tower).

6.4.13 In the following sections I have investigated what performance standard was specified during the primary refurbishment, what performance standard the installed product achieved as stated by the relevant manufacturer and any evidence to support that standard for the fans installed in Grenfell Tower.

6.4.14 **Product installed**

6.4.15 Four smoke extract fans were installed in the refurbishment smoke control system: one combined fan unit at roof level (duty and standby) and one combined fan unit at level 2 (duty and standby) (refer to Section 6.3.26 and 6.3.38).

6.4.16 In their letter to the Inquiry dated 15th May 2019 Elta fans stated {ELT00000028}:

As set out in detail in our response to the Request for Documents No. 1, Elta Fans was approached by PSB in November 2014. In August 2015, PSB issued a purchase order to Elta Fans (see Item 14 of initial response). An invoice was supplied to PSB by Elta Fans on 7 September 2015 (see Item 23 of initial response). Five fans and ancillary equipment were despatched to Grenfell

Tower (c/o Rydon Maintenance) on 8 September 2015 (see Item 24 of initial response). We do not understand this to constitute supply via a third party supplier.

6.4.17 The August 2015 purchase order {ELT00000019} does not refer to the type of fans ordered but I have found an order acknowledgment dated the same day {ELT00000014} which refers to the following fans:

a) Elta fan type LCS050J6A2-90.

b) Elta fan type LCS063K5-A2-100L.

c) Elta fan type LC056L3-A2-112.

6.4.18 The later invoice dated 7th September 2015 {ELT00000027} and the delivery note dated 8th September 2015 {ELT00000013} refer to the same fans listed above.

6.4.19 Neither the order acknowledgement, invoice nor delivery note refer to the fire performance of the fans.

6.4.20 I have found an earlier quote Elta Fans Ltd provided to JS Wright {JSW00003459} dated 16th March 2015 for the supply of the following Elta fans which provided additional information about the rating of the fan motor:

a) Elta fan type LCS050J2-A6/17RS with an F300 motor;

b) Elta fan type LCS063K2-A5/17RS with an F300 motor;

c) Elta fan type LC056L2-A3/25 with a *"Standard"* motor.

6.4.21 Again, no fire resistance performance specification was referred to in the quote other than that the motor for two of the fan types was for an F300 motor. I understand the fan described at item I to be the environmental fan which did not require a fire performance classification.

6.4.22 Section 3.1 *Run and standby extract fan arrangement* of PSB's Technical Submission (Rev 6, {PSB00000214}) dated 15th March 2016 refers to two types of smoke extract fans. These were:

a) Walkway level- Elta fan type LCS050J2-A6/17RS

b) Roof above plant room- Elta fan type LCS063K2-A5/17RS

6.4.23 In terms of a performance specification, PSB's Technical Submission (Rev 6, {PSB00000214}) states that both sets of fans *"are tested in compliance with high temperature test standard directive 89/106/EEC to EN 12101-3 and are rated to one off emergency operation at 300°C for 2 hour"*.

6.4.24 During my site visit of 7-9 November 2017, I was able to observe a plate fixed on the two roof level fans which identified the manufacturer of the fans installed as Elta Fans Ltd. The plate also identified the fan as a F300 for 120 minutes (refer to Figure 6-13).).

6.4.25 Due to limited access being available during my site visit of 7-9 November 2017, I did not observe a plate fixed to the fans installed at level 2 to independently allow me to identify the manufacturer or product of these fans. However, I have no evidence to suggest this was not also the 'F300' described in the Elta quote {JSW00003459}.

6.4.26 In summary, based on the quote provided by Elta Fans Ltd provided to JS Wright {JSW00003459}, PSB's Technical Submission (Rev 6, {PSB00000214}) and my observations on site, my understanding is that the roof level and level 2 smoke extract fans were F300 120 minute rated fans supplied by Elta Fans Ltd.

6.4.27 I have found no explanation in the evidence I have seen to date as to why PSB specified fans with a fire resistance performance of F300 for 120 minutes.

6.4.28 The specified duration of 120 minutes is in accordance with the fire resistance rating of the smoke shafts in Grenfell Tower.

6.4.29 The temperature rating of 300°C is, however, substantially lower than the 1000°C recommended by BS EN 12101-6:2005:2005 or even the preceding standard of 600°C from BS 5588-4:1998 for fans used in a depressurisation system (refer to Section 1).

6.4.30 Fan ratings at a temperature of 300°C are associated with sprinklered spaces (refer to Clause 9.2.9 of BS EN 1201-6) which was not the case at Grenfell Tower.

6.4.31 I have found no evidence either as to how PSB satisfied themselves regarding the compatibility of the specified Elta fans and inverters, nor their operation in fire mode as per the recommendation of the *SCA Guide 2012*, as was required in lieu of a specific test procedure at that time.

6.4.32 However, the inverter was located in the ground floor hub room for the level 2 fans and in the roof plant room for the roof level fans in Grenfell Tower and therefore not directly exposed to fire.

6.4.33 I have investigated what supporting evidence is available to verify the stated performance of F300 for 120 minutes in the following sections.

6.4.34 **Evidence of performance**

6.4.35 In their letter to the Inquiry {ELT00000028} Elta Fans Limited stated the following in response to the question *"Please provide a full specification and all fire test reports and certificates to support the fire performance for each of the fans supplied for the lobby smoke control system for Grenfell Tower"*:

Most of the documentation falling within this request has already been disclosed. Specifically, I refer you to Items 19, 20 and 21 of our initial response being Elta Fans' internal production test record for the three separate works orders. I also refer to Item 25 of our initial response, the BSI Certificate of Constancy of Performance. In addition, we now enclose a copy of the Loss Prevention Certification Board Certificate of Product Approval

dated 3 April 2019, first issued 29 February 2012 ("LPCB Certificate"). ***The smoke extract fans supplied to PSB (works order 20175578 (see Item 16 of initial response) and works 20175599 (see Item 17 of initial response)) were covered by the LPCB Certificate and the BSI Certificate of Constancy of Performance.*** *The product name is 'SmokeVent axial fan' the model numbers are LCS050 and LCS063. The LPCB Certificate is item number 27 on the amended inventory.*

6.4.36 I have not seen test reports or classification reports; the only certificate relevant to fire performance is the LPCB Certificate. I set out my review of that evidence here:

6.4.37 The third party *Certificate of product approval* No 937a Issue 6 {ELT00000036} issued by LPCB for Elta Fans Limited, referred to by Elta Fans Limited in their letter to the Inquiry, is dated 3rd April 2019 i.e. it bears a date which is long after the fire.

6.4.38 The certificate {ELT00000036} states it covers the following products shown in Figure 6-35:.

Products

Smoke and Heat Control Systems

SmokeVent axial fan

JetVent Impulse (flanged-standard thrust) axial fan

JetVent Impulse (flanged-enhanced thrust) axial fan

JetVent Impulse (flanged standard and enhanced thrust) axial fan

JetVent centrifugal (Mark I) fan

JetVent centrifugal (Mark II) fan

JetVent impulse (unflanged – standard thrust) axial Fan

JetVent impulse (flanged standard and enhanced thrust) axial fan

JetVent centrifugal (Mark III) fan

Figure 6-35: Excerpt from page 1 of LPCB *Certificate of product approval* No 937a Issue 6 (highlight by me) {ELT00000036}

6.4.39 Page 3 of the certificate lists the product name and model name of fans in the F300 'resistance to fire class'. I have excerpted the relevant part in Figure 6-36.

6.4.40 Models with the prefix 'LCS050' and 'LCS063' are listed which corresponds to the two fan types listed in the Elta fan quote {JSW00003459}. I note the product name is *"SmokeVent axial fan"* referred to in Figure 6-36 below.

Appendix to Certificate No: 937a **Issue: 06**

ELTA FANS LTD

Product Name	Model	Application Classes	Response Delay	Resistance to fire class	Motor temp. rating [1]	LPCB Ref. No.
	JFSR-CPA-400 2/4-3, JFSR-CPA-400 2-3	non smoke reservoir; dual purpose or emergency use			Class B/ Class H	
JetVent Impulse (flanged – enhanced thrust) axial fan [2, 5, 6, 7, 8]	LCS031-CPU 2/4-3, LCS035-CPU 2/4-3, LCS040-CPU 2/4-3, LCS031-CPR 2/4-3, LCS035-CPR 2/4-3, LCS040-CPR 2/4-3	Insulated or uninsulated; smoke reservoir or non smoke reservoir; dual purpose or emergency use	N/A	F200	Class F / Class H Or Class B/ Class H	937a/01
SmokeVent axial fan [2, 5, 6, 7, 8]	LCS025, LCS031, LCS035, LCS040, LCS045, LCS050, LCS056, LCS063, LCS071, LCS080, LCS090, LCS100, LCS112, LCS125, LCS140, LCS160, LCS180, LCS200, SCS025, SCS031, SCS035, SCS040, SCS045, SCS050, SCS056, SCS063, SCS071, SCS080, SCS090, SCS100, SCS112, SCS125, SCS140, SCS160, SCS180, SCS200, LCSCR025, LCSCR031, LCSCR035, LCSCR040, LCSCR045, LCSCR050, LCSCR056, LCSCR063, LCSCR071, LCSCR080, LCSCR090, LCSCR100,	Insulated or uninsulated; smoke reservoir or non smoke reservoir; dual purpose or emergency use	N/A	F300 [4]	Class F / Class H	937a/02

Figure 6-36: Excerpt from page 3 of LPCB *Certificate of product approval* No 937a Issue 6 (highlighting by me) {ELT00000036}

6.4.41 The resistance to fire class of page 3 of LPCB Certificate of product approval No 937a Issue 6 {ELT00000036} for the Smokevent axial fan states the product is rated as F300 and refers to note 4.

6.4.42 I have excerpted the "Notes" section of the appendix of the LPCB certificate in Figure 6-37.

6.4.43 This provides an explanation for the notes referred to on page 3 of the certificate and specifically note 4 to the F300 designation of the "*SmokeVent axial fan*" referred to within Figure 6-36.

Appendix to Certificate No: 937a **Issue: 06**

ELTA FANS LTD

Notes:

1. Motor temperature rating – classes given refer to temperature rise at ambient and motor insulation as detailed in section 4.2.3 of EN 12101-3: 2015.
2. Both horizontal and vertical installation is permitted.
3. Horizontal installation only is permitted.
4. Tested to 300°C for 120 minutes.
5. Only certified accessories should be used.
6. Use of guide vanes is permitted. Where this is the case the model code has +GV added, e.g. LCS025+GV.
7. Fan coding of units held within Select stock will be prefixed by the letter 'S', and the size expressed in mm (i.e. LCS025 becomes SLCS250).
8. No ducted cooling air is required.
9. Vertical installation only is permitted.
10. Tested to 400°C for 120 minutes.
11. LPCB REF No. 937a/01 product specification as per test report No. 61082/3 and 61082/4.
12. LPCB REF No. 937a/02 product specification as per test report No. 60942/1.
13. LPCB REF No. 937a/02, 937a/05 and 937a/06 product specification as per test report No. 60942/2.
14. LPCB REF No. 937a/03 and 937a/07 product specification as per test report No. 61082/1 and 61082/2.
15. LPCB REF No. 937a/04 and 937a/08 product specification as per test report No. 60298/1.

Figure 6-37: Excerpt from page 7 of LPCB *Certificate of product approval* No 937a Issue 6 (highlighting by me) {ELT00000036}

6.4.44 The F300 resistance to fire class of the Elta Fans Ltd *"SmokeVent axial fan"* was therefore tested for 300°C for 120 minutes as stated in Note 4 of the Appendix to Certificate No. 937a (refer to Figure 6-37) however no test standard is referred to.

6.4.45 I note from Figure 6-36, that the *"LPCB Ref No."* for the F300 variant of the Elta Fans Ltd *"SmokeVent axial fan"* was 937a/02.

6.4.46 From Figure 6-37, it can be seen that this corresponds to test report No. 60942/1 and No 60942/2.

6.4.47 Elta have not disclosed any test reports and the LPCB certificate does not describe which test standard the test reports rely on. Therefore, I have not been able to independently confirm that the F300 variant of the Elta Fans Ltd *"SmokeVent axial fan"* had been tested at 300°C for 120 minutes.

6.4.48 **Summary**

6.4.49 In summary based on the quote provided by Elta Fans Ltd to JS Wright {JSW00003459}, PSB's Technical Submission (Rev 6, {PSB00000214}) and my observations on site, my understanding is that the roof level and level 2 smoke extract fans were F300 120 minute rated fans supplied by Elta Fans Ltd.

6.4.50 However I have not been able to independently confirm the performance of the fans installed in Grenfell Tower, by means of a formal fire test report and associated classification report.

6.5 Evidence of performance achieved - Lobby dampers

6.5.1 This is a new Section in full.

6.5.2 **Relevant performance standard**

6.5.3 The required performance standard for the lobby dampers was E 60 S tested to BS EN 1366-10 and classified to BS EN 13501-4 as a minimum to comply with either ADB 2013, or BS EN 12101-6:2005 (refer to Section 4.8).

6.5.4 As the dampers were installed in a combined smoke control and environmental ventilation system the durability of operational reliability requirement (refer to Section 4.8 above for definition) was that the damper was opened and closed over 10,000 times prior to the BS EN 1366-10 test.

6.5.5 As the lobby dampers installed in Grenfell Tower could be manually overridden by the fire and rescue service the dampers would have also had to follow the test procedure for *"Manual intervention dampers"* set out in BS EN 1366-10.

6.5.6 I am unable to determine the pressure the smoke control dampers were required to be tested at under BS EN 1366-10 as no record of the intended operating pressure (i.e. the pressure difference between the smoke shafts and the lobbies) is set out in PSB's Technical Submission (Rev 6, {PSB00000214}).

6.5.7 I note that the *SCA Guide 2012* referred to four methods of demonstrating the performance of dampers for a smoke control system.

6.5.8 These alternative methods of demonstrating performance, which as I set out in Section 1, do not comply with the provisions of ADB and BS EN 12101-6:2005 were subsequently removed in the *SCA Guide 2015*.

6.5.9 In the following sections I have investigated what performance standard was specified, what performance standard was reported for the installed product and any evidence to support that standard for the dampers installed in Grenfell Tower.

6.5.10 **Product installed**

6.5.11 PSB specified Gilbert Series 54 dampers for the *"Existing lobbies"* in Section 2.1 *Automatic lobby ventilators* of their Technical Submission (Rev 6, {PSB00000214}).

6.5.12 PSB also specified Gilbert Series 54 dampers for the *"Lobbies to Ground floor, walkway and walkway mezzanine"* in Section 3.2 *Automatic lobby ventilators* of their Technical Submission (Rev 6, {PSB00000214}).

6.5.13 No performance specification is included in the PSB's Technical Submission (Rev 6, {PSB00000214}); the only relevant test standard referred to in Section 2.1 is *"Damper Section tested to EN1366 Pt2 Fire resistance test for service installations Part 2 Fire Dampers"*.

6.5.14 Issue No.3 of Exova's Outline Fire Safety Strategy {EXO00001106} issued on 7th November 2013 did not specify a performance standard for smoke control dampers in the common lobbies either, though the dampers were required to form part of a protected shaft as set out in ADB 2013, a protection

measure which should be referred to within a fire strategy document for a high-rise residential building.

6.5.15 Therefore, I have found no evidence of any designer specifying fire resistance or smoke leakage performance for the lobby dampers. I have explained why these are the reasonable functional requirements in Section 2 above.

6.5.16 I have been provided with a quotation Gilberts issued to JS Wright on 22 January 2015 for the purchase of their dampers in Grenfell Tower {GBL00000006}. This quotation references two sizes of Series 54 dampers to be supplied, one being 300mm×600mm and the other 600mm×1200mm.

6.5.17 The fire resistance performance specification of both these damper types are specified in the *"Additional Notes"* section of the Gilberts quotation {GBL00000006} as:

The damper has undergone an EN1366-2 test started from the closed position and lasted over 60 minutes for both fire integrity and smoke leakage (ES60) but has no formal certification

We have successfully and independently tested the Series 54 damper to EN 12101-2:2003 Annex G to achieve a B300 rating on the damper

6.5.18 I have also been provided with the damper purchase order Gilberts issued to JS Wright on 8th May 2015 (page 4 of {GBL00000002}).

6.5.19 Based on the Gilberts damper purchase order {GBL00000002} and the Gilbert Series 54 product brochure ({PSB00000201}, {EXO00000352}), the dampers ordered for the refurbishment smoke control system at Grenfell Tower were:

a) 40 No. Series 54 dampers for a structural opening of 350mm wide, 650mm high; and

b) 40 No. Series 54 dampers for a structural opening of 310mm wide, 750mm high.

6.5.20 There is no reference to a fire resistance performance specification in the Gilberts damper purchase order {GBL00000002}.

6.5.21 In summary, Gilberts Series 54 dampers were specified and purchased for Grenfell Tower. The Gilberts quotation {GBL00000006} refers to two different fire performance standards: BS EN 1366-2 ES60 and BS EN 12101-2: 2003 Annex G B300 rating.

6.5.22 I present my investigation of the evidence to support this stated performance in the following subsections.

6.5.23 **Evidence of performance**

6.5.24 I have reviewed the following documents to establish the fire resistance performance of the Gilberts Series 54 damper:

a) WF Test Report No. 309850 (report dated 06/10/2011) {JSW00002816}This report is for an un-named damper – described as having a blade thickness 1.0mm, motor open or closed design, and *"Fire tested to EN1366 Pt 2"*;

b) Test report BMT/FEP/F14191 Revision A {GIL00000013} *A fire resistance test performed on a Series 54 smoke evacuation damper Test conducted utilising the principles of EN 12101-2: 2003 Annex G* dated 9 October 2014;

c) Gilbert Series 54, product brochure ({PSB00000201}, {EXO00000352}) dated October 2011.

6.5.25 I have seen no further evidence regarding the fire resistance performance of the Gilberts Series 54 damper.

6.5.26 **WF Test Report No. 309850 - review**

6.5.27 The test sponsor is listed in WF Test Report No. 309850 as *"Gilberts (Blackpool) Ltd"*. This was the manufacturer of the dampers purchased for use in the refurbishment smoke control system {GBL00000002}.

6.5.28 This test report does not however include a product name for the tested specimen.

6.5.29 The *"Summary of Tested Specimen"* section of WF Test Report No. 309850 ({JSW00002816}) describes the specimen as (bold by me):

The damper had an internal opening of 910 mm wide by 1910 mm high. The damper was formed from ***1.5 mm*** *thick galvanised mild steel casing incorporating seven; twin skinned galvanised mild steel damper blades, formed from* ***1 mm thick galvanised mild steel****. The blades were nominally 909 mm in length by 308 mm high, with the exception of the small top blade which was nominally 108 mm high. The damper assembly incorporated a single electric actuator, referenced BLE 24, supplied by* ***Belimo Ltd***

The damper was fitted into a 2000 mm high by 1000 mm wide aperture

6.5.30 I note that the product brochure ({PSB00000201}, {EXO00000352}) for the Gilbert Series 54 damper purchased for use in the refurbishment smoke control system dated October 2011 also states (bold by me):

"The series 54 is manufactured from robust ***1.5mm*** *galvanised steel"*

"All series 54 dampers are fitted with a ***Belimo actuator"***

"It is available in a wide range of sizes ranging from 400 x 400 to 1000 x 2000 with sizes based on the structural opening (aperture) dimensions.

"Parallel blade assembly constructed from ***1.0mm thick*** *× 100mmto 300mm"*

6.5.31 The casing thickness, specified actuator, aperture size and blade thickness in WF Test Report No. 309850 are all either as described by, or within the range described by, the product brochure for the Gilbert Series 54 damper ({PSB00000201}, {EXO00000352}).

6.5.32 Therefore, I have reviewed the test report on the basis that it is relevant to the lobby dampers in Grenfell Tower.

6.5.33 I note however the dampers purchased for the refurbishment smoke control system at Grenfell Tower {GBL00000002} were 40 No. Series 54 dampers for a structural opening of 350mm wide by 650mm high and 40 No. Series 54 dampers for a structural opening of 310mm wide by 750mm high.

6.5.34 I note Clause 13.1 of BS EN 1366-2 states:

13.1 Size of fire damper

If smoke leakage is not required, a test result obtained for the largest fire damper is applicable to all dampers of the same type (including any aspect ratio) provided that the maximum dimensions do not exceed those tested and that the components remain in the same orientation as those tested.

If smoke leakage is required, an additional fire damper, representing the smallest size, shall satisfy the smoke leakage criteria when tested to the procedure described in 10.3.

Figure 6-38 Excerpt from Clause 13.1 of BS EN 1366-3 (highlighting by me)

6.5.35 This requirement is also specified in BS EN 12101-8:2011 Clause 4.4.1 as I have set out in Section 4.8 of this report.

6.5.36 The smoke dampers purchased for use in Grenfell Tower {GBL00000002} were smaller than the damper tested in test report WF No. 309850 {JSW00002816}.

6.5.37 Therefore, any smoke leakage performance obtained by the damper tested in test report WF No. 309850 {JSW00002816} would not be relevant to demonstrating the smoke leakage performance of the dampers installed in Grenfell Tower in accordance with clause 13.1 of BS EN 1366-2.

6.5.38 It is not stated in the standard explicitly why the smallest damper must be tested. However, my understanding is that as the surface area becomes smaller if it is exposed to a higher effective pressure.

6.5.39 Irrespective of this I have reviewed the test report to understand the performance of the larger Series 54 damper.

6.5.40 The objective of WF Test Report No. 309850 {JSW00002816} is stated as:

To determine the fire resistance performance of a multi bladed fire damper mounted within a standard flexible wall construction, when tested generally in accordance with BS EN 1366-2: 1999.

6.5.41 I also note the report introduction states: *"At request of the test sponsor the damper was in closed position at the commencement of fire test (Clause 10.4), and therefore the test* ***was not conducted fully in accordance with the standard."***

6.5.42 As the test *"was not conducted fully in accordance with the standard"* the test report cannot be used to classify the Series 54 damper to BS EN 13501-3.

6.5.43 With reference to this test, Mr Jones (Gilberts Technical Director) states in his witness statement {GBL00000010}:

The dampers on the non-fire floor would be closed and not subjected to heat. Since the EN 1366-2 test commences with the furnace at elevated temperature, which is not a normal condition for the non-fire floor damper, the test was started in the closed position.

6.5.44 While I note that the dampers on non-fire floors are to be activated from early detection and closed before they are exposed to significant fire exposure, in Grenfell Tower the dampers functioned as environmental vents as well as part of the smoke control system.

6.5.45 Therefore, the dampers may reasonably have been in an open or closed position at the time that the smoke control system was also activated due to fire.

6.5.46 My understanding is that this is the condition that the test is trying to represent - by starting the damper in the open position and assessing the damper's ability to close within 2 minutes.

6.5.47 In terms of the applicability of the damper tested in WF Test Report No. 309850 {JSW00002816} it is stated in the test report:

The damper had an internal opening of 910 mm wide by 1910mm high

The damper was fitted into a 2000mm high by 1000mm wide aperture

6.5.48 The conclusion of the test report states:

Conclusions

Evaluation against objective To determine the fire resistance performance of an insulated single bladed fire damper mounted within a standard flexible wall construction, when tested generally in accordance with BS EN 1366-2: 1999.The performance of the specimen was evaluated against the requirements of the Standard and achieved the following results:

PERFORMANCE CRITERIA	TEST RESULTS
Integrity (Leakage)	74 minutes
Smoke Leakage	0 minutes
Integrity (Cotton Pad)	*92 minutes
Integrity (Gap Gauge)	*92 minutes
Integrity (Sustained Flaming)	*92 minutes
Insulation	3 minutes
Leakage During Ambient Temperature Test (Clause 10.3)	256.8 m^3/hr

*The test duration. The test was discontinued after a period of 92 minutes.

Figure 6-39: Excerpt of conclusion of WF Test Report No. 309850 {JSW00002816}

6.5.49 From Figure 6-39:, it can be seen that the integrity (Leakage) performance achieved was 74 minutes. However, the smoke leakage performance achieved was 0 minutes.

6.5.50 The damper in this test therefore only provides integrity performance and no additional smoke leakage performance as was required for Grenfell Tower to comply with ADB 2013. This required the damper to achieve both integrity and smoke leakage performance for a period of 60 minutes (refer to Section 4).

6.5.51 Therefore, from my analysis of the test report:

a) As the test was not undertaken in compliance with Clause 10.4 of BS EN 1366-2:1999, classification to BS EN 13501-3:2005 was not possible;

b) As the damper tested exceed the size of damper supplied for Grenfell Tower the 'S' performance it established was not applicable;

c) Even if the results of the test were applicable, the damper achieved 0 minutes 'S' performance, therefore it could not meet the 60 minute 'S' classification required;

d) It achieved 74 minutes 'E' performance; however no 'E' classification was possible due to item 'a' above.

6.5.52 Comparing this to the "Additional Notes" section of the Gilberts quotation {GBL00000006}

The damper has undergone an EN1366-2 test started from the closed position and lasted over 60 minutes for both fire integrity and smoke leakage (ES60) but has no formal certification

6.5.53 I understand *'no formal certification'* to mean the damper could not be classified due to non-compliance with the required test procedure of BS EN 1366-2.

6.5.54 However, the statement 'lasted over 60 minutes for both fire integrity and smoke leakage (ES60)' is not correct as I have explained above.

6.5.55 I also note Gilberts do not advise the size of damper tested exceeded those supplied to Grenfell Tower, therefore any 'S' performance had it been achieved would have been inapplicable in any event.

6.5.56 Therefore, in addition to not complying with the requirements for an ES60 fire and smoke damper to comply with ADB 2013 or a smoke control damper to comply with BS EN 12101-6:2005, the Gilbert Series 54 dampers supplied to Grenfell Tower also did not meet PSB's own specification *"Damper Section tested to EN1366 Pt2 Fire resistance test for service installations Part 2 Fire Dampers"*.

6.5.57 I have examined the leakage performance described in this report further in the following sections as it is relevant to my investigation of the performance of the smoke control system on the night of the fire.

6.5.58 **<u>WF Test Report No. 309850 – Smoke leakage performance</u>**

6.5.59 As I described in Section 4.10, when undertaking a fire test of a damper, firstly a cycling operational test is undertaken to demonstrate the durability of operational reliability and this is followed by measurements of air leakage through the damper which is used to determine the integrity and smoke leakage performance.

6.5.60 For a BS EN 1366-2 fire and smoke damper this should be 50 cycles; for a BS EN 1366-10 smoke control damper this should be over 10,000 cycles

6.5.61 The leakage rate through the damper is then measured as follows - once before the fire test at ambient conditions then continuously throughout the fire test, with different limits to be checked for the measurements taken during the fire test.

6.5.62 These are dependent on whether an integrity only fire damper or the additional smoke leakage for a fire and smoke damper is required:

a) ambient smoke leakage test – smoke leakage must not exceed 200 $m^3/(m^2\ h)$ and integrity leakage must not exceed 360 $m^3/(m^2\ h)$;

b) fire test – smoke leakage must not exceed 200 $m^3/(m^2\ h)$ and integrity leakage must not exceed 360 $m^3/(m^2\ h)$ from 5 mins after test start.

6.5.63 Dampers in the compliant condition are therefore allowed a set limit of leakage whilst considered to meet the integrity and smoke leakage requirements. In section 13 I present my review of the impact this may have had, the night of the fire.

6.5.64 Figures for the ambient and fire test leakage are included within test report WF No. 309850 {JSW00002816}. The units these are reported in, 'm^3/h', differ to the units the allowable smoke leakage at ambient and during the fire test is specified in, '$m^3/(m^2h)$'. My understanding is that this is a typographical error and the correct units are '$m^3/(m^2h)$' as I explain below.

6.5.65 I have excerpted the ambient test leakage results 'Leakage During Ambient Temperature Test (Clause 10.3)' in Figure 6-39: and the fire test smoke leakage results in Figure 6-40:.

Calculated volume flow (Corrected to 20° C)

Time Minutes	Volume Flow Rate m3/h
0	-1.372
3	247.212
6	216.397
9	201.712
12	185.694
15	176.111
18	161.219
21	154.255
24	158.567
27	162.959
30	170.22
33	168.78
36	173.258
39	170.898
42	176.199
45	178.256
48	186.13
51	186.127
54	210.629
57	221.482
60	230.994
63	235.88
66	254.979
69	284.143
72	306.046
75	365.124
78	420.515
81	458.018
84	546.08
90	534.277

Figure 6-40: Excerpt from *Temperature and Leakage data* section of WF Test Report No. 309850 {JSW00002816}

6.5.66 I believe the 'm^3/h' to be a typographical error; it is stated in the *Test observations* section of the report at 74 minutes 20s that the leakage rate was 360 **$m^3/h.m^2$**

74	20	**The leakage rate through the fire damper exceeds 360$m^3/h.m^2$.**

Figure 6-41 Excerpt from *Test observations* section of WF Test Report No. 309850 {JSW00002816}

6.5.67 The reported 'calculated volume flow (corrected to 20°C)' at 75 minutes was **365.124 m^3/h**. Therefore, I have assumed the ambient smoke leakage result in Figure 6-39: and the fire test smoke leakage results in Figure 6-40: should read $m^3/(m^2h)$.

6.5.68 In Figure 6-39:, the 'Leakage During Ambient Temperature Test (Clause 10.3)' for the tested damper was reported as 256.8 m^3/h in WF Test Report No. 309850 {JSW00002816}.

6.5.69 The *Performance criteria and test results* section of WF Test Report No. 309850 {JSW00002816} states:

Integrity (Leakage)	Integrity (Leakage) - failure in accordance with the performance criterion of integrity is deemed to occur when leakage through the fire damper exceeds 360m³/h.m² measured after the first 5 minutes of the test duration. The integrity around the perimeter of the fire damper is also judged in accordance with the criteria given in BS EN 1363-1. The test specified that an under pressure of 300 ± 15 Pa be utilised. The specimen satisfied this criterion for duration of 74 minutes.
Smoke leakage	Smoke leakage - failure in accordance with the performance criterion of leakage is deemed to occur when leakage through the fire damper exceeds 200m³/h.m² measured after the first 5 minutes of the test duration. The test specified that an under pressure of 300 ± 15 Pa be utilised. The specimen did not satisfy this criterion after the first five minutes of the test.

Figure 6-42: Excerpt from *Performance criteria and test results* section of WF Test Report No. 309850 {JSW00002816}

6.5.70 Therefore, the tested damper did not satisfy the smoke leakage criterion of 200$m^3/(m^2$ h) after the first 5 minutes of the fire test as needed for a fire and smoke damper.

6.5.71 This can be seen in the detailed reporting of leakage through the damper during the fire test in Figure 6-40: where the calculated volume flow at 6 minutes was '216.397 m^3/ h [sic]'.

6.5.72 I have produced a graph of the calculated volume flow rate table (refer to Figure 6-40:) from the *Temperature and Leakage data* section of WF Test Report No. 309850 {JSW00002816}.

6.5.73 To achieve the smoke leakage classification S the recorded leakage must remain below 200 $m^3/(m^2h)$ for the duration of the required performance which in Grenfell Tower was 60 minutes.

6.5.74 The area circled in red shows where the recorded value exceeded 200 $m^3/(m^2h)$ after the first 5 minutes of the test.

6.5.75 I also note the leakage performance drops below the limit for smoke leakage from 9 minutes to 53 minutes after the start of the test. However, from 53 mins the leakage performance exceeds the limit for smoke (200 $m^3/(m^2h)$) and continues to rise at an increasing rate thereafter. Any increase above 200 $m^3/(m^2h)$ at any point in the test is considered to be a failure.

6.5.76 It is interesting to note that as a result of dropping below the smoke leakage limit of 200 $m^3/(m^2h)$ from 9 minutes to 53 minutes the cumulative leakage of

this damper was in fact lower than that of a damper with a constant leakage of 200 $m^3/(m^2h)$ which would have complied with ADB 2013.

6.5.77 The damper tested by Gilberts therefore exceeded both the ambient and fire test smoke leakage limits for 'S' performance which means it failed the smoke leakage test for a fire and smoke damper.

6.5.78 As a result of this, the conclusion of the test report states the damper achieved 0 minutes smoke leakage (S) as shown in Figure 6-39:.

6.5.79 I will therefore consider in Section 13 of this report the failure of the Gilbert Series 54 damper to resist the spread of smoke and heat in Grenfell Tower on the 14th June 2017.

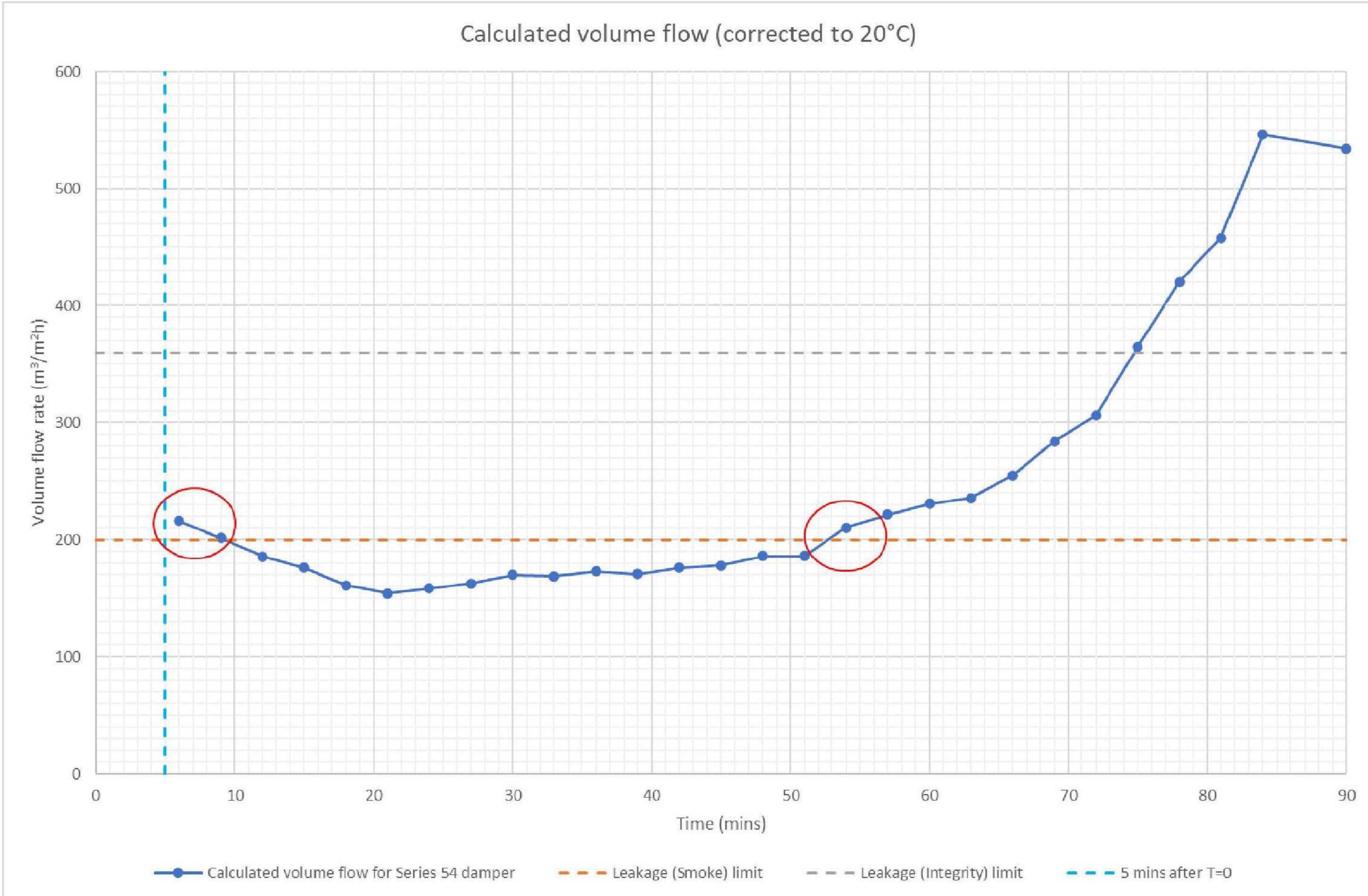


Figure 6-43: Graph of calculated volume flow rate *Temperature and Leakage data* section of WF Test Report No. 309850 {JSW00002816}

6.5.80 **BMT/FEP/F14191 Revision A**

6.5.81 The second test report I have reviewed is test report BMT/FEP/F14191 Revision A {GIL00000013} titled *"A fire resistance test performed on a Series 54 smoke evacuation damper Test conducted utilising the principles of EN 12101-2: 2003 Annex G"* dated 9 October 2014.

6.5.82 The test sponsor is listed in BMT/FEP/F14191 Revision A {GIL00000013} as *"Gilberts (Blackpool) Ltd"*. This was the manufacturer of the dampers purchased for use in the refurbishment smoke control system {GBL00000002}.

6.5.83 Section 1 *Introduction* of BMT/FEP/F14191 Revision A {GIL00000013} states:

The objective of this test was to establish the ability of the installed smoke evacuation damper to open under exposure to heat and to remain in the fire open position with not more than 10% reduction of the throat area after termination of the test and when the specimen had cooled.

The furnace was run to achieve 300(±60)°C within 5 minutes of the test, and maintain this temperature for 25 minutes after the specimen actuator had fully opened.

6.5.84 Section 4 *Description of specimen* of BMT/FEP/F14191 Revision A {GIL00000013} states the product tested was a *"Gilberts (Blackpool) Ltd Type 54 series smoke evacuation damper"*.

6.5.85 This was the product purchased for use in the refurbishment smoke control system at Grenfell Tower {GBL00000002}.

6.5.86 Section 2 *Specimen verification* of BMT/FEP/F14191 Revision A {GIL00000013} states:

The damper measured 2000mm high x 1000mm wide x 246mm deep (damper blades closed) 372mm (damper blades open)

6.5.87 BS EN 12101-2 is the standard for natural ventilation. Annex G (normative), *Test method for heat exposure*, sets out a test method for resistance to heat.

6.5.88 This test is relevant to a natural ventilator to demonstrate that it can open and stay open when exposed to heat where a natural smoke and heat ventilator is defined in BS EN 1201-2 as:

Product specifically designed to move smoke and hot gases out of a construction works naturally under conditions of fire

6.5.89 The test is therefore not relevant to how a smoke control damper in a pressure differential system was installed in the common lobbies of Grenfell Tower.

6.5.90 This test report is also not relevant to the fire resistance performance of Gilberts Series 54 damper as part of the refurbishment smoke control system

in Grenfell Tower to comply with BS EN 12101-6:2005 which required testing to BS EN 1366-10 or a fire and smoke damper to comply with ADB 2013 which required testing to BS EN 1366-2.

6.5.91 With reference to this test, Mr Jones (Gilberts Technical Director) states in his witness statement {GBL00000010}:

*"I also enclose at RJ6 a supplemental test document, which was not provided to HM or PSB, this report is **a supplemental comfort test** conducted to show that the damper when open and subject to elevated temperature would not collapse and would thus keep the damper airway clear."*

"The BMTRADA report dated 9 October 2014 - testing as it did the fire resistance of the dampers as against EN 12101-2:2003 Annex G - was only relevant to natural ventilators and therefore of no relevance to those sought by PSB."

6.5.92 The *SCA Guide 2012* which referred to four methods of demonstrating the performance of dampers in a smoke control system. These are:

a) Tested to BS EN 1366-10 and classified as E30Sa to BS EN 13501-4;

b) Tested to BS EN 1366-2 plus ad hoc test report 300° and/or 600°C for 1 hour etc;

c) Tested to BS EN 1366-2 plus modified HOT400/30 test from prEN1366-10 using 300°C and/or 600°C for 1 hour etc;

d) Tested in the closed position to BS 476-20:1987.

6.5.93 As I have stated in Section 4.8, I do not consider these methods to be compliant with the provisions of ADB 2013 and BS EN 12101-6:2005.

6.5.94 I note, however, that test report BMT/FEP/F14191 Revision A may have been considered by Gilberts as an "ad hoc" test that could be used in conjunction with a BS EN 1366-2 test report.

6.5.95 I have examined the test report BMT/FEP/F14191 Revision A {GIL00000013} for the purpose of identifying whether any of the test conditions required by BS EN 1366-10:2011 are replicated in this standard.

6.5.96 I have carried out this investigation only for the purpose of understanding the performance of the Gilbert Series 54 damper, as I have set out above.

6.5.97 I do not consider the damper to be compliant with the performance required for the Grenfell Tower smoke control system as it already failed to meet the ES60 requirement to BS EN 1366-2 as I have explained above.

6.5.98 The introduction to BMT/FEP/F14191 Revision A {GIL00000013} states:

The furnace was run to achieve 300(±60)°C within 5 minutes of the test, and maintain this temperature for 25 minutes after the specimen actuator had fully opened.

6.5.99 From my examination of the test report and procedures described in BS EN 12101-2 Annex G:

a) No durability of operational reliability cycling test sequence is carried out prior to the test of the damper opening at elevated temperatures; and

b) Damper operation is tested after just 5 minutes when the furnace temperature has reached 300°C, compared to testing damper operation after 25 minutes when the furnace has reached a temperature of 814°C in a manual intervention test to BS EN 1366-10.

6.5.100 Therefore, in addition to the smoke leakage performance of the Gilberts Series 54 damper, I shall also consider the performance of the damper to open/close at elevated temperatures in Section 13 of this report in my investigation of the performance of the smoke control system as a protected shaft.

6.5.101 **Gilbert Series 54, product brochure**

6.5.102 I have seen a product data sheet for a Series 54 *"smoke evacuation damper"* ({PSB00000201}, {EXO00000352}).

6.5.103 This is the damper specified in the *Technical Specification for PSB Lobby Smoke Control,* version 6 {PSB00000214} for use as the lobby dampers from ground to level 23 and was purchased for use in Grenfell Tower based on the damper purchase order {GBL00000002}.

6.5.104 Page 2 of the product data sheet for a Series 54 *"smoke evacuation damper"* ({PSB00000201}, {EXO00000352}) states:

A multi, parallel linked blade smoke damper the Series 54 is manufactured from robust 1.5 mm galvanised steel and is ***fully tested to the requirements of EN1366 Pt 2 for 1 hour.***

6.5.105 Based on my review of the WF Test Report No. 309850 {JSW00002816} which I presented in Section 6.5.26, the Gilbert Series 54 damper was not *"fully tested"* to BS EN 1366-2 as the test was undertaken with the damper in the closed position at the start of the test.

6.5.106 The product data sheet for a Series 54 "smoke evacuation damper" ({PSB00000201}, {EXO00000352}) is therefore incorrect.

6.5.107 I note that the current edition of Gilbert's literature for the Series 54 dampers (dated April 2017) {GIL00000009} indicates that the damper *"has no formal certification"* in accordance with EN 1366-2, although it is asserted that the damper lasted over 1 hour for fire integrity. It states:

> The damper has undergone an EN1366 Pt 2 test started from the closed position and lasted over 60 minutes for fire integrity (E60) but has no formal certification. In line with its role for smoke evacuation the unit has also been tested on its ability to open (and stay open) during heating and is approved to EN12101-2 : 2003 Annex G with a B300 rating.

Figure 6-44: Excerpt from Gilberts literature for Series 54 dampers, dated April 2017{GIL00000009}

6.5.108 In his witness statement, Mr Jones (Gilberts' Technical Director) states {GBL00000010}:

"All GBL brochures runs (sic) last about 2 years. ... It was believed that the reference to "fully tested" in the 2011 version was too vague, and sought to improve it. GBL's brochure at the time of supply of the series 54 dampers provided an accurate description of the relevant tests applied to the product."

6.5.109 Beyond the statement of Mr Jones, I currently have no information as to why Gilberts only retracted the assertion in their literature that the dampers were "*fully tested to the requirements of BS EN 1366 pt2*" in 2017, when it is apparent that (based on their quote to PSB) the company knew about the issue as early as 2015.

6.5.110 **Summary of available test evidence**

6.5.111 I have obtained evidence which confirms that the Gilberts Series 54 dampers were installed in the lobbies of Grenfell Tower.

6.5.112 I have found no evidence of any specific fire resistance or smoke leakage performance specification for the lobby dampers by any member of the primary refurbishment design team.

6.5.113 PSB's Technical Submission Rev 6 specified BS EN 1366-2 as the required test standard. This would have complied with ADB 2013 for a fire and smoke damper was not the relevant test standard to comply with BS EN 12101-8 for a smoke control damper.

6.5.114 I have seen no test report to BS EN 1366-10 or classification report to BS EN 13501-4 as required by BS EN 12101-8 and as relevant to one of the compliance options of the *SCA Guide* for the Gilberts Series 54 dampers installed in Grenfell Tower.

6.5.115 The only test evidence I have seen to date is one fire resistance test to BS EN 1366-2 and one fire resistance test to BS EN 12101-2 Annex G.

6.5.116 The significance of this is that:

a) The test condition for durability of operational reliability is substantially lower under BS EN 1366-2:1999 which requires only 50 operational cycles prior to elevated temperature testing when compared to BS EN

1366-10 which requires 10,000 operational cycles prior to elevated temperature testing. This means that the smoke control dampers when tested in a BS EN 1366-10 are proven to be effective after a much longer operational lifetime and as a part of a multi-compartment system;

b) The smoke control system used in Grenfell Tower incorporated a fire fighter override and therefore the position of the damper would have had to be changed 25 minutes into a BS EN 1366-10 test whereas in a BS EN 1366-2 test the damper is closed within two minutes of the test starting and remains closed for the remainder of the test. The BS EN 1366-10 test is therefore more onerous in this regard (because it is required to move under higher temperatures);

c) There are also differences between BS EN 1366-2 and BS EN 1366-10 depending on the intended operating pressure differential for the dampers. PSB did not specify the intended operating pressure differential for the dampers for their system and therefore I cannot fully assess how this would have impacted on the testing of the damper

6.5.117 In my opinion the lobby dampers installed in Grenfell Tower were therefore non-compliant with ADB 2013 and BS EN 12101-6:2005.

6.5.118 I have examined both test reports in order to understand the performance of the Gilberts Series 54 dampers relevant to my investigation into the fire and smoke spread in Grenfell Tower on 14th June 2017 only.

6.5.119 From this I have found that the Gilberts Series 54 damper (in addition to not achieving performance under the more onerous requirements in 6.5.116 above):

a) had 0 minutes smoke leakage performance (noting that when the full time period from 0 minutes to 60 minutes is considered, the cumulative leakage of the Gilberts Damper would not have been worse than a damper in the compliant condition that met the S requirement with a constant leakage of 200 $m^3/(m^2h)$ for one hour)

b) had 74 minutes integrity fire performance - however, I am unable to rely on the reported integrity performance as the test procedure was not carried out in accordance with BS EN 1366-2;

c) was tested after just 5 minutes when the furnace temperature had reached 300°C in a BS EN 12101-3 test compared to the 25-minute test required when the furnace had reached a temperature of 814°C in a manual intervention test to BS EN 1366-10.

6.5.120 Therefore, I will consider the actual leakage performance of Gilberts Series 54 damper and whether it failed to resist the spread of smoke and fire in Grenfell Tower on 14th June 2017 in Section 13.

6.6 Evidence of performance achieved-Bypass Dampers

6.6.1 This is a new Section in full.

6.6.2 **Performance requirements**

6.6.3 In, Figure 6-45, I have overmarked the location of the four Level 2 Bypass dampers. There were four dampers installed as part of the refurbishment smoke control system: two environmental shutoff dampers and two smoke fan shut off dampers.

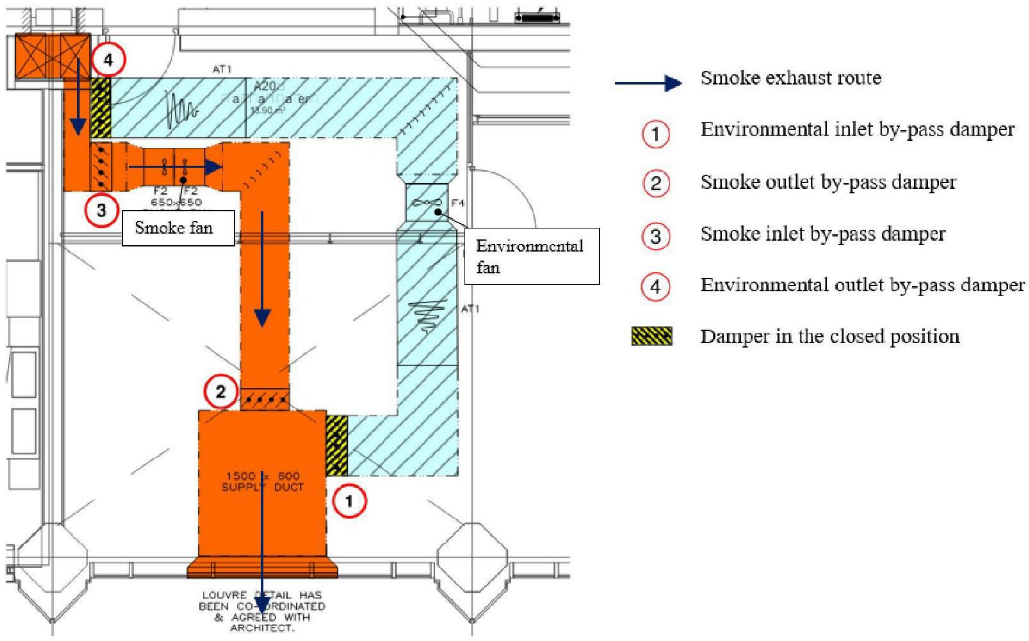


Figure 6-45: Fan shut-off damper locations: the environmental branch needs to be closed off and the smoke control branch needs to open

6.6.4 The dampers labelled as 1 and 4 in Figure 6-45 were part of the boundary of the smoke ductwork indicated in red.

6.6.5 They were required to achieve the same fire resistance performance as the lobby dampers (refer to Section 4.10).

6.6.6 The dampers labelled 2 and 3 in Figure 6-45 did not form an opening into the protected shaft. I note however that paragraph 11.8.2.10 of BS EN 12101-6:2005 states:

11.8.2.10 If different pressurized or depressurized zones are connected to the same fan or set of fans by a common system of ductwork and/or shafts, smoke control dampers shall be used.

6.6.7 As the environmental system and smoke control system used a common system of ductwork, the dampers labelled 2 and 3 in Figure 6-45 should have been smoke control dampers (i.e. tested to BS EN 1366-10).

6.6.8 The *SCA Guide* does not provide any performance criteria for bypass dampers.

6.6.9 **Product installed**

6.6.10 PSB specified BSB SC Series dampers for the *"Walkway environmental fan set and plant room smoke extract fanset"* in Section 3.4 *Bypass dampers* of their Technical Submission (Rev 6, {PSB00000214}).

6.6.11 No reference is made in PSB's Technical Submission (Rev 6, {PSB00000214}) to a performance requirement for these dampers.

6.6.12 I have not been provided with any purchase order for these dampers.

6.6.13 **Evidence of performance**

6.6.14 No fire resistance test reports, classification reports or third party certification has been provided to me for the BSB SC series of dampers.

6.6.15 The only evidence of the performance of the BSB SC series of dampers I have been provided with is a technical brochure titled *"Smoke Control Damper SC series elevated temperature smoke control damper"* {JSW00001575}.

6.6.16 The brochure was sent by Mr Bradbury (J S Wright) to Mr Smith (Max Fordham) by email on 12th January 2015 {JSW00000025}.

6.6.17 The meta data for the file states the pdf was last modified on 2nd December 2014.

6.6.18 Page 2 of the pdf of the SC series product brochure has a section titled *"Specifications and Testing"*. I have excerpted this in Figure 6-46.

Specifications and Testing

- Unless stated otherwise, flange models are suitable for classes A & B of DW144, with spigot models suitable for classes A, B & C of DW144
- Conformance to DW144 and Eurovent 2/2 classes A - C, as relevant
- Blade construction has been fire tested to BS476 part 20, 1987 for integrity and leakage
- Elevated temperature tests, reports 231297, 234486 and 27438 refer
- Resistance tested by BSRIA, report 15633/1 refers
- Leakage tested by BSRIA, report 15633/1refers
- 28 day salt corrosion tested. Chatfield report RLR3 refers

Figure 6-46: Excerpt of page 2 of "Smoke Control Damper SC series elevated temperature smoke control damper" {JSW00001575}

6.6.19 The test reports referred to on this page of the brochure (Reports 231297, 234486, 27438 and 15633/1) have not been provided to me.

6.6.20 I note that the *"Specifications and Testing"* section of *"Smoke Control Damper SC series elevated temperature smoke control damper"* {JSW00001575} excerpted in Figure 6-46 states *"Blade construction has been fire tested to BS476 part 20, for integrity and leakage"*.

6.6.21 Also it is stated in Note 1 to paragraph 10.15 of ADB 2013:

Note 1: Fire dampers tested using ad-hoc procedures based on BS 476 may only be appropriate for fan-off situations. In all cases, fire dampers should be installed as tested.

6.6.22 As there was no specific damper test methodology set out in BS 476-20:1987 it is not clear whether the 'fan-off' situation referred to is meant to refer to one where the dampers shall be closed only in the event that a powered fan is not operating.

6.6.23 The Level 2 bypass dampers were required to perform whilst the smoke extract fans were operating.

6.6.24 Therefore, as I have set out in Section 4.10, the relevant standard for fire resistance tests of fire and smoke dampers in England was BS EN 1366-2 as referred to by ADB 2013, the *SCA guide 2012* and BS 9991 with the relevant standard for smoke control dampers being BS EN 1366-10 as referred to by the *SCA Guide 2012* and BS EN 12101-8.

6.6.25 Irrespective of this I have not seen a BS 476-20:1987 test report for the BSB SC series of dampers therefore I am unable to independently verify the performance of the damper blade to BS 476-20:1987 and hence whether the damper complied with ADB 2013 or the *SCA Guide 2012*.

6.6.26 Page 4 of the pdf of SC series product brochure {JSW00001575} provided a description of the *"Elevated temperature test"* referred to in the *"Specifications and Testing"* section of the brochure. It stated:

A damper was placed into a furnace at ambient temperature (22°C), the furnace was ignited with the temperature being raised uniformly to 480°C and held for 30 minutes. The temperature was then raised to 700°C and held for a further 90 minutes. The temperature was then finally raised to 800°C for a further 120 minutes. The damper was then removed and whilst still "cherry red" was inspected and operated. The blades and linkage rotated freely with all rivets, welds and components remaining intact.

The scope of the test was to test the damper's operation at an elevated temperature, in addition to establishing its integrity and distortion. The conclusion of this test is that the design, construction and engineering tolerances permitted this product to be tested and operated at an "elevated temperature" successfully.

6.6.27 The described *"Elevated Temperature Test"* is not in accordance with the test procedure set out in BS EN 1366-2, BS EN 1366-10, or BS 476-20.

6.6.28 There is no reference to the pressure used in the furnace and no reference is made to the testing of the damper for leakage at ambient or during the fire test.

6.6.29 The test procedure describes a manually operated damper and examines its functionality, but does not indicate how the automatic actuation of the type of dampers which were to be installed at Grenfell Tower would have needed to function.

6.6.30 As I have stated above, I have not seen the test reports (Reports 231297, 234486, 27438) for this *"elevated temperature test"*, therefore I cannot assess the adequacy of BSB's test evidence against the requirements of Appendix A of the statutory guidance in ADB 2013.

6.6.31 The relevant standards BS EN 1366-2, BS EN 1366-10, or BS 476-20 are not referred to anywhere in BSB's brochure SC Series: Smoke Dampers – Elevated Temperature Smoke Control Damper.

6.6.32 In my opinion therefore there is no relevant evidence that the BSB SC Series dampers were compliant with either ADB 2013 or BS EN 12101-8.

6.7 Evidence of performance achieved- Level 2 ductwork

6.7.1 This is a new Section in full.

6.7.2 **Performance requirement**

6.7.3 New ductwork was provided connecting the south smoke shafts to a vent on the outside of the building, via the smoke extract fans shown below in Figure 6-47.

Figure 6-47: Fire-rated ductwork at level 2

6.7.4 The Level 2 duct work was required to achieve 120 minutes stability, integrity and insulation when tested to the relevant part of BS 476 (in this case BS 476-24).

6.7.5 Alternatively, it was required under EI 120 to the relevant European standard (in this case BS EN 1366-8) to provide a complete barrier to fire and smoke as it forms the extension of the 120 minute integrity and insulation smoke shafts, noting that BS EN 12101-6:2005 states:

11.8.2.15 All smoke extraction pressurization release and depressurization ductwork ***and supporting construction shall have resistance to collapse*** *and fire penetration equal to that of the structure within which it is installed.*

6.7.6 Product installed

6.7.7 PSB's Technical Submission (Rev 6) {PSB00000214}) does not specify a product for the new Level 2 ductwork or the products that would be used to provide fire resistance to the ductwork.

6.7.8 Issue No.3 of Exova's Outline Fire Safety Strategy {EXO00001106} issued on 7th November 2013 does not specify a performance standard for the Level 2 ductwork.

6.7.9 The performance specification of this ductwork was noted in an email from Mr Bradbury (J S Wright) to Mr Mahoney (PSB) and Mr Peacock (J S Wright) on 9th November 2015 {JSW00003470} as requiring to be *"fire rated"*.

6.7.10 A JSW drawing attached to an email sent by Mr Sounes (Studio E) on 21 December 2015{HAR00007049} noted the ductwork as requiring to be *"Two hour fire rated"*.

6.7.11 I have seen an invoice from Deptford Sheet Metal Ltd to Parkerr Contracting & Installation Ltd {DSM00000007} with the reference "Grenfell Tower" dated 29th January 2016 *"To manufacture, deliver and install" "GSS Ductwork & Fire Rated Ductwork"*. My understanding is therefore that Deptford Sheet Metal Ltd supplied the fire rated ductwork for use at Grenfell Tower.

6.7.12 As part of my work for Phase 2, I have seen a letter from a Mr Kinnear (Managing director of Fire Protection Ltd). In this letter Mr Kinnear states {FPL00000001}:

1. In an email dated 11 December 2015 FPL was asked by Deptford Sheet Metal Limited (Deptford) to fire spray 12 No items of ducting which were to be manufactured by them to our specification and 2 No smoke dampers to 2 hours stability and integrity to BS 476 part 24.
   The Flamebar BW11 coating applied provides 2 hours stability and integrity to BS 476 part 24 also insulation at 400°C for two hours.
   FPL work was carried out for Deptford and the fire spray and inspection of ductwork are detailed in supporting document No 7.
   FPL gave Deptford installation instructions and on completion visited site to assess the installation. The installation looked fine, with the exception that one clamp was missing. When FPL received photographs to show that the clamp had been installed, a Certificate of Conformity was then issued.

2. FPL did carry out a site inspection on the 21 January 16 by FPL employee Colin Childs who is a Firas supervisor.(See supporting document No.13)

Figure 6-48: Excerpt from *"Response by Fire Protection Limited to request for document No. 21"* {FPL00000001}

6.7.13 My understanding is therefore that the new ductwork at Level 2 supplied by Deptford Sheet Metal Ltd was coated with *"Flamebar BW11 coating"* to achieve *"2 hours stability and integrity to BS 476 part 24 also insulation at 400°C for two hours"* by Fire Protection Ltd.

6.7.14 This performance therefore failed to provide the 2-hour insulation criterion required by ADB 2013 whereby the measured average temperature on the unexposed face was less than 140°C after having been exposed to the standard fire curve which reaches over 1000°C after two hours and was therefore non-compliant.

6.7.15 The level two ductwork passed over the single escape route for the whole building, therefore it was important that the insulation criteria was considered in case temperature could impact on the escaping occupants or the operation of the fire and rescue service. Further. the insulation criteria prevents a secondary ignition of combustible materials in close proximity to the ductwork when heated also.

6.7.16 **Evidence of performance**

6.7.17 In terms of supporting evidence for the *"2 hours stability and integrity to BS 476 part 24 also insulation at 400°C for two hours"* fire resistance performance of the *"Flamebar BW11 coating"* when applied to ductwork, Mr Kinnear (Managing director of Fire Protection Ltd) states in his letter to the inquiry {FPL00000001}:

2. The specification of the ductwork supplied was Flamebar BW11 for 2 hour stability and integrity with 2 hour insulation at 400°C. See supporting documents Nos.:

Document No.19

BRE Red Book Live, 3rd Party certification, listing dated 20 July 2017 and date of first issue 1 May 2008 which is supported by Document No.20

Document No.20

LPCB Product 3rd Party certificate for BS476 part 24 for ducts dated 9 January 2008.

Document No.25

International Fire Consultants Fire test dated 10 February 1999.

Document No.26

BRE Assessment based on numerous fire tests Report No. CC 88343 Review 5 issue 2 dated 30 November 2016.

Document No.27

Warrington Assessment for 400°C Report No. 173531 dated 13 June 2008.

Figure 6-49: Excerpt from Mr Kinnear (Managing director of Fire Protection Ltd) letter to the inquiry{FPL00000001}

6.7.18 The primary source of evidence that I have reviewed is Document 26 Assessment report number CC 88343{FPL00000036}.

6.7.19 Section 1 *Objective* of Assessment report number CC 88343{FPL00000036} states:

To carry out an assessment of the fire resistance of your steel ventilation, smoke outlet and kitchen extract duct systems protected with Flamebar BW11

Fire Proofing and additionally, in some cases, with stone mineral wool, on the basis of fire resistance tests WF no. 156568 Issue 2, TE 82414, TE 82724 and TE 84033, for variations in the duct system due to fire rating, duct function, duct orientation, size of duct, supporting system and penetration details.

6.7.20 The document therefore provides a summary of the assessed performance of different thicknesses of applied Flambar BW11 and mineral wool for different duct arrangements.

6.7.21 Document 19 referred to by Mr Kinnear is issue 13 of LPCB certificate No. 277a {FPL00000028}. This was issued after the Grenfell Tower fire and I have not considered it further here.

6.7.22 LPCB certificate No. 277a Issue No.11{FPL00000029} summarises verbatim the fire resistance performance of ductwork protected by Flamebar BW11 for ventilation ducts, smoke outlet ducts and kitchen extract ducts as set out in BRE Assessment report number CC 88343{FPL00000036} therefore I have not considered it further here.

6.7.23 'Warrington Assessment for 400°C Report no 173531 dated 13 June 2008' was an "Ad hoc" test hence was not undertaken in accordance with a relevant British Standard. The test was also undertaken by the manufacturer's staff and not by a UKAS-accredited laboratory. The test exposure was a constant temperature of 400°C which is significantly less than the standard fire exposure required by BS EN 1366-8 or BS 476-24.

6.7.24 For these reasons I have not considered this test report further here.

6.7.25 **Assessment report number CC 88343 Review 4 Issue 2**

6.7.26 I have seen an assessment report {FPL00000036} produced by BRE Global dated 6th August 2012 titled *"An assessment of the fire performance of a proprietary design for vertical and horizontal ventilation, smoke outlet and kitchen extract duct systems"*.

6.7.27 The front cover of Assessment report number CC 88343{FPL00000036} stated it was prepared for Firespray International Limited.

6.7.28 Section 1 *Objective* of Assessment report number CC 88343 {FPL00000036} states:

To carry out an assessment of the fire resistance of your steel ventilation, smoke outlet and kitchen extract duct systems protected with Flamebar BW11 Fire Proofing and additionally, in some cases, with stone mineral wool, on the basis of fire resistance tests WF no. 156568 Issue 2, TE 82414, TE 82724 and TE 84033, for variations in the duct system due to fire rating, duct function, duct orientation, size of duct, supporting system and penetration details.

6.7.29 This BRE assessment report cites 11 separate test reports and 2 other BRE assessment reports relating to the performance of steel ductwork when exposed to fire tests.

6.7.30 The tests were undertaken on different thicknesses of applied Flamebar BW11, with or without applied mineral wool insulation.

6.7.31 Ten of the eleven tests were undertaken to BS 476-24 *Fire tests on building materials and structures. Method for determination of the fire resistance of ventilation ducts* and one to BS 476-22 *Fire tests on building materials and structures. Method for determination of the fire resistance of non-loadbearing elements of construction*

6.7.32 I have not been provided with the individual test reports on which the BRE Global Assessment Report No CC88343 {FPL00000036} is based and therefore I cannot verify if BRE has adequately and/or accurately considered the performance of the duct system in the assessment report upon which I understand that the LPBC certificate relies.

6.7.33 The conclusion section of BRE Global Assessment Report No CC88343 {FPL00000036} states:

An assessment has been carried out on your steel ventilation, smoke outlet and kitchen extract duct systems protected with Flamebar BW11 Fire Proofing and additionally, in some cases, with stone mineral wool, as tested in WF report no. 156568, TE 82414, TE 82724 and TE 84033 to BS 476: Part 24: 1987, for variations in the duct system due to fire rating, duct function, duct orientation, size of duct, supporting system and penetration details. The results of the assessment and other requirements are given in tables 1, 2 and 3, pages 22-24.

6.7.34 Table 1 is titled *"Normal ventilation ducts (fan on or off)";* Table 2 is titled *"Smoke outlet ducts (fan on or off)"* and Table 3 is titled *"Kitchen extract ducts or ducts containing combustible linings (fan on or off)".*

6.7.35 As the ducts installed at Level 2 of Grenfell Tower were part of a smoke control system, the relevant table is Table 2 of BRE Global Assessment Report No CC88343 {FPL00000036}.

6.7.36 The Notes to Table 2 provide that all ducts are protected with a certain thickness of Flamebar BW11 "Fire Proofing" and the ducts wrapped in mineral wool of a specific density and thickness (see Points 1, 3 and 5 of the Notes).

6.7.37 It therefore follows that, in accordance with Table 2 of BRE Global Assessment Report No CC88343 {FPL00000036}, to achieve the required 120 minutes integrity, insulation and stability in strict accordance with BS 476-24 the duct installed at Level 2 of Grenfell Tower must have been provided with a certain thickness of "Fire Proofing" and the duct then wrapped in mineral wool of a specific thickness and density.

6.7.38 The duct installed at Grenfell Tower was not provided with any external mineral fibre insulation.

6.7.39 I have found no evidence of a fire engineering assessment to confirm why this was acceptable as part of the design basis for the lobby smoke control system at Grenfell Tower.

6.7.40 However I have found no evidence that the lack of insulation performance either prevented the escape of residents, impacted the fire and rescue services operations or caused further ignition and therefore this does not appear to have been material on the night of the fire.

6.8 Summary of compliance of installed components of the smoke control system

6.8.1 I have provided a summary in Table 6-2, below, of my analysis in Sections 6.4 to 6.7, above, for the smoke extract fans, lobby dampers, level 2 bypass dampers, and level 2 ductwork respectively.

Table 6-2: Summary of compliance with functional requirements of Building Regulations for components installed at Grenfell Tower

Component	Product installed	Fire performance	Compliance status
Smoke extract fans	Level 2: Elta fan type LCS050J2-A6/17RS Roof: Elta fan type LCS063K2-A5/17RS	300°C for 2 hours per EN 12101-3	LPCB certificate provided - performance suitable for an un-sprinklered building not explained by designer
Lobby dampers	Gilbert Series 54 dampers	No test report per BS EN 1366-10 or classification per BS EN 13501-4 as required by BS EN 12101-8.	No- Smoke control dampers not specified or installed
Level 2 bypass dampers	BSB SC Series dampers	No test report per BS EN 1366-10 or classification per BS EN 13501-4 as required by BS EN 12101-8.	No- Smoke control dampers not specified or installed
Level 2 ductwork	Deptford Sheet Metal Ltd duct with Flamebar BW11 coating by Fire Protection Ltd.	2 hours stability and integrity to BS 476 part 24 also insulation at 400°C for two hours	No- no insulation provided

7 Controls and operation of the smoke control system

7.1 Overview

7.1.1 In this new section I have set out my expanded investigation into the controls and programme of operation of the smoke control system.

7.1.2 I have carried out this investigation because it is important to understand whether the smoke control system was capable of delivering the performance criteria set by PSB.

7.1.3 I also wanted to understand the operating potential of the system by the night of the fire.

7.1.4 This section should therefore be considered alongside Sections 8 and 9 that follow: Section 8, which is about the commissioning of the lobby smoke control system, because the operations I describe in this Section 7 needed to be proven during commissioning; and Section 9 because changes were then made to the system after commissioning.

7.1.5 It is necessary therefore, for me to set out what I have derived about the controls, from the evidence available.

7.1.6 I have relied on specialist technical assistance in order to produce this Section 7.

7.1.7 In Grenfell Tower, the smoke control system was also integrated with the following systems as follows:

a) It had an output to the BMS panel in the basement for fire activation and fault-monitoring;

b) It had an input from the BMS panel at roof level to activate the system in environmental mode;

c) It was connected to an auto-dialler.

7.1.8 Therefore, in smoke control mode the system's operation could potentially have been affected by the operation of these other systems, and I have investigated the hardware and software controls of the smoke control system on that basis.

7.1.9 This section expands on the evidence I originally set out in Sections J7.4 – J7.7 and J9.1-J9.4 in Appendix J to my Phase 1 report {BLAS0000031} regarding my analysis and understanding of the controls for the Grenfell Tower smoke control system at that time.

7.1.10 The LFB's operation of the system was described in Section J9.5 of Appendix J to my Phase 1 report {BLAS0000031} and therefore this topic is instead covered in Section 12 of this report.

7.1.11 In Phase 2 I have seen the following additional evidence relevant to the system controls, as set out in Table 7-1 below.

Table 7-1: Additional evidence relating to the smoke control system's controls provided to me post Phase 1

Relativity reference	Document name	Summary of content
{MET00065879}	Report by BRE titled *"GT site report"* dated 10th February 2020 for the Metropolitan Police Service (MPS)	The report summarises the work undertaken by BRE in February 2019 to "identify relevant components and wiring associated with the Master Panel and Outstations of the smoke detection system in the building, and the labelling of these components before their removal by MPS officers".
{MET00072161}	RINA report titled "HVAC Logic and Functionality Testing – Reconstruction and testing of Grenfell Tower smoke extraction system" Rev 1 dated October 2020	A report by RINA for the MPS setting out RINA's investigation into the operation of components of the Grenfell Tower smoke control system controls. See Sections 1.1 and 7.4 for my detailed description of the content of this report.
{PSB00001374}	PSB technical note titled "The HMI Panel and the Operation of the Fireman's Override Switch "HMI FOS Switch"" dated 15th April 2021.	A technical note by PSB providing details of their own investigation into the programming of the smoke control system controls, compared to the findings of my Phase 1 report and RINA's investigation (see above).
{PSB00001375}	Witness statement of Mr Michael Glowacki dated 15th April 2021	In his witness statement, Mr Michal Glowacki confirms that he was responsible for programming the control software at Grenfell Tower. Mr Glowacki also states: "…I confirm that the information contained within the Note [{PSB00001374}, see above] is true to the best of my knowledge and belief."

7.1.12 I have reviewed BRE's report (see Section 7.4) and PSB's technical note (see Section 7.5) alongside the findings from my Phase 1 review of the software.

7.1.13 I have set out my assessment of whether RINA's reconstruction of the system controls confirms, expands upon or differs from the findings in my Phase 1 review.

7.1.14 I have also made clear where the new information from PSB alters my understanding of the controls.

7.2 Summary of control devices

7.2.1 The control of the combined environmental and smoke control system installed at Grenfell Tower was complex because it included a primary and secondary power supply, software control and physically wired equipment spread over twenty-five floors, as I summarise below.

7.2.2 I explain in further detail the role of each of the key components of the system in the remainder of this section.

7.2.3 **Summary of physical control devices (system hardware)**

7.2.4 The lobby smoke control system's 'hardware' comprises all the installed physical devices on which it relies.

7.2.5 The following formed the signalling devices for the smoke control system:

a) One Main Smoke Control Panel (also termed "Master Outstation" and indicated to be located at Level 1 in PSB's Electrical Schematic {TMOM00001859}) located in the Ground Floor Hub Room;

b) Twenty-two outstations, one on every floor from Levels 2 to 23. The outstations are located in the service riser within the lobby on each floor except on Level 3 where it is located behind an MDF wall-panel;

c) One outstation located within the panel at ground floor Hub Room serving the Level 2 fans and dampers.

d) One outstation located within the panel at roof plant room serving the roof fans.

7.2.6 The following formed the input devices for the smoke control system:

a) Twenty-six smoke detectors, one in every lobby from ground level to Level 23 with an additional smoke detector in the community room lobby at ground floor and another detector in the boxing studio lobby at Level 2

b) Twenty-six yellow key switches, one in every lobby from ground level to Level 23 with an additional yellow key switch in the community room lobby at ground level and another such switch in the boxing studio lobby at Level 2.

c) Twenty-four pressure switches, one for every lobby from ground level to Level 23. The pressure switches are equipped with two pressure sampling points, one in the lobby and one in the stairwell to monitor the pressure difference between the two spaces.

d) One HMI panel located at the ground floor entrance lobby with a touchscreen panel and an override key switch.

7.2.7 The following devices formed the output devices of the smoke control system:

a) A total of eighty-eight dampers (in the north and south shafts) of which there were two in each lobby from ground level to Level 3, one connected to the north shaft and one connected to the south shaft on every floor. There were four dampers in each lobby from Levels 4 to 23, two connected to the north shafts and two connected to the south shafts on every floor.

b) Two automatic opening vents (AOVs), one in the community room lobby and the other in the boxing studio corridor.

c) Four smoke fans and four inverters that control each smoke fan respectively arranged as a set of duty and standby fans on Level 2 and a further set at Roof Level.

d) One environmental fan and the inverter that control the environmental fan provided on Level 2.

e) Four bypass dampers on Level 2, one connected to the inlet and another to the outlet of the environmental fan and smoke fan respectively.

7.2.8 Secondary power to the smoke control system was provided at Grenfell Tower by a combination of two methods.

7.2.9 The fans were served by a power supply from Grenfell Walk in the event of a mains failure. All other devices were provided with batteries in the event of a mains failure.

7.2.10 The components included:

a) Twelve battery back-up supply as indicated in PSB's electrical schematic {TMOM00001859} that power the outstations. From post-fire photographs taken on 10th August 2017 disclosed by MET {MET00071285}, I have not found the battery back-up located at Level 3 as indicated in the schematic;

b) A second mains supply from Grenfell Walk providing secondary power to the fan sets at Level 2 and Roof Level via automatic switching devices in the Ground Floor Hub and the roof plantroom.

7.2.11 I have relied on the following drawings to understand the secondary power as installed:

a) PSB's Smoke Ventilation System Electrical Schematic Rev E dated 3rd February 2016 {TMOM00001859}

b) JSW's Main LV Distribution Schematic diagram Rev RD dated June 2016.

7.2.12 I have illustrated how these devices were connected in Figure 7-1 and Figure 7-2.

7.2.13 In these figures, I have indicated the connectivity between the smoke control system and the Building Management System (see Section 7.17) as

well as to the auto-dialler (see Section 7.18). The type of cable connections indicated are based on the PSB Schematic {TMOM0001859} and based on my team's assessment of the connections between the BMS outstations. Please also see my analysis in Section 11 later.

7.2.14 Note that the cable connections between outstation and the dampers were investigated from post-fire photographs due to the significance in operation on the night of the fire. Where cables with red sleeves were found, it can typically be assumed they are fire-rated cables.

7.2.15 All of this demonstrates the scale and complexity of the system as installed in Grenfell Tower.

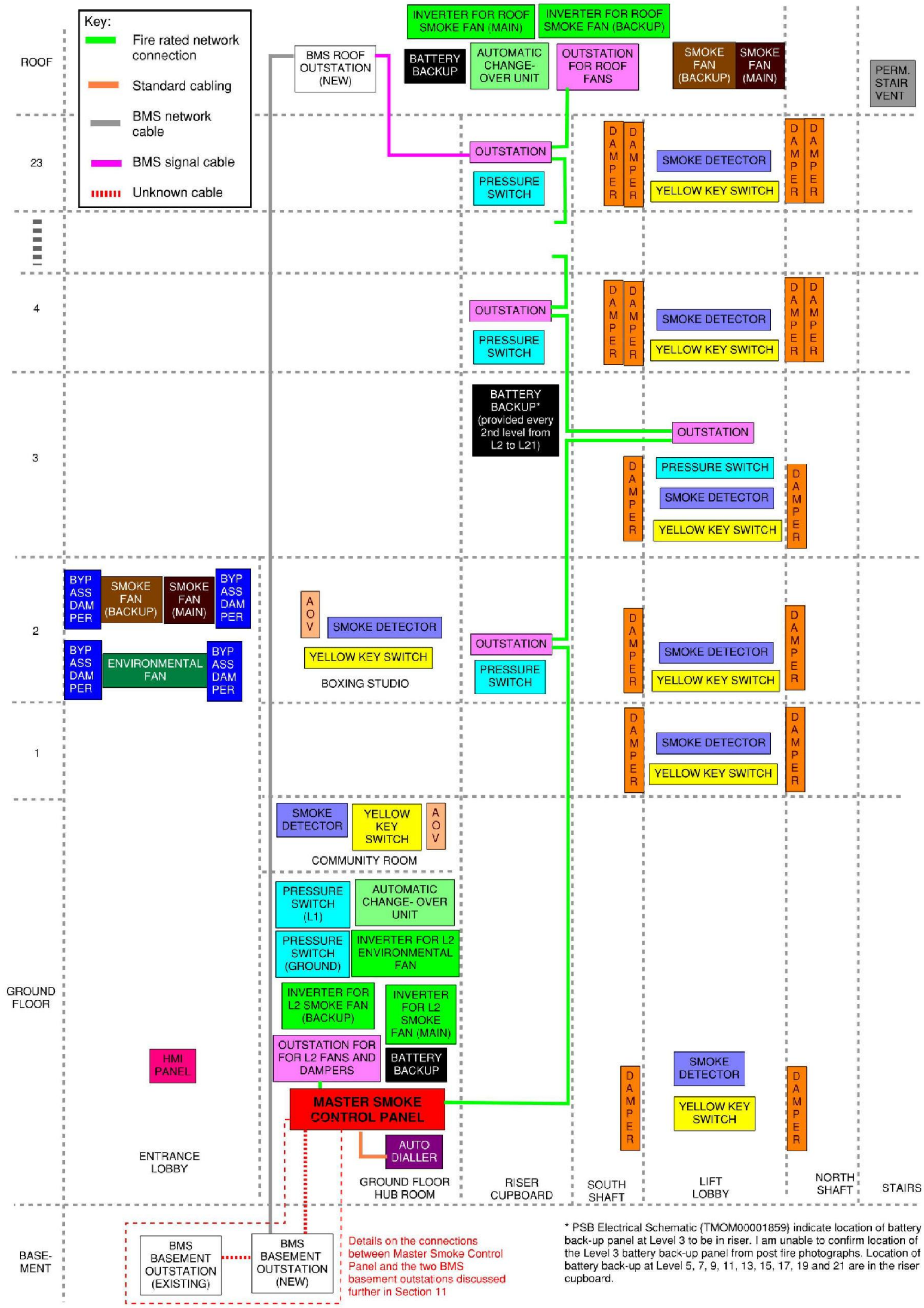


Figure 7-1: Components of the smoke control system and its locations within Grenfell Tower

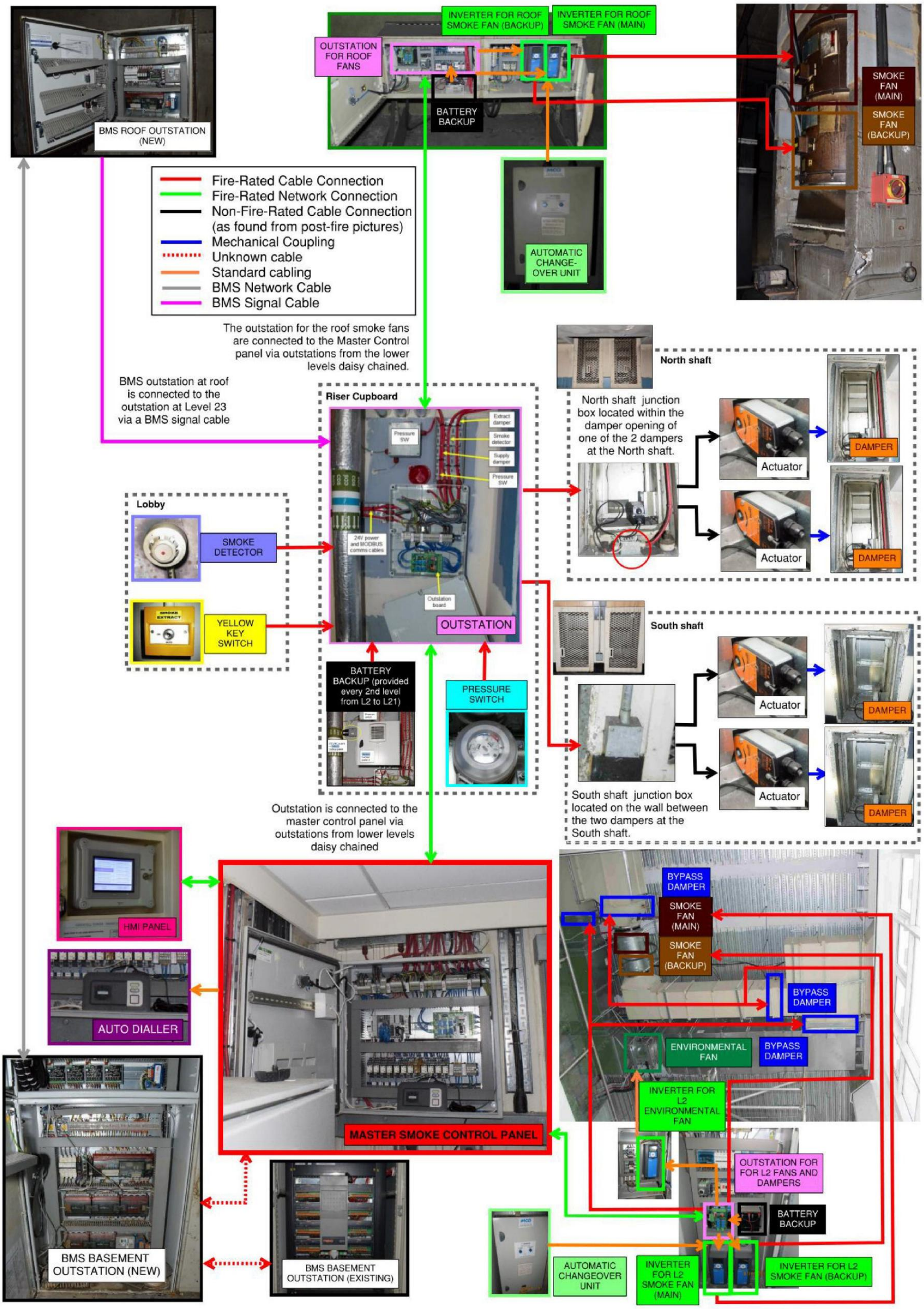


Figure 7-2: Connections between main components of the smoke control system. Please refer to further details on connections with BMS system illustrated in **Figure 7-48** also.

7.2.16 **Summary of software controls**

7.2.17 Specialists on my team have reviewed the following program files.

a) Files relating to the main control panel (PLC) which was located in the Ground Floor Hub room:

    i. Main control panel software retrieved from the control panel by the MPS (Revision 6, {MET00018070}).

    ii. A main control panel file ({MET00018071}) that appears to be a duplicate of MET00018070.

    iii. PDF printout of control panel software held on PSB's archive server ({PSB00001301}, version unknown, but appears to match {MET00018070}).

    iv. PDF printout of control panel software present on the main control panel ({PSB00001303}, version unknown but appears to match {MET00018070}).

b) Files relating to the HMI panel that was located in the Ground Floor foyer:

    i. HMI software retrieved from the HMI panel removed from Grenfell Tower by the MPS {MET00018074}.

7.2.18 Specialists on my team have also reviewed the latest revision of drawings by PSB of the physical wiring for the system control panels ({PSB00000267}, {PSB00000272} and {PSB00000274}).

7.2.19 I have identified three specific sets of software relevant to the operation of the environmental and smoke control system.

7.2.20 I present the different software packages below and indicate their purpose and current status with respect to the review my specialist team have carried out.

7.2.21 **Control panel software**

7.2.22 This software was installed on electronic devices called Programmable Logic Controllers (PLC) which formed part of the main control panel (also termed "Master Outstation" by PSB in their design documentation). The main control panel was located in the Ground Floor Hub room in Grenfell Tower.

7.2.23 This panel controlled the environmental and smoke control system, specifically which dampers should be opened and closed under different circumstances, and when environmental and smoke control fans should start, stop or change speed.

7.2.24 Temperature sensors used to control the system in environmental mode did not input directly into the main control panel. Instead, the lobby air temperature was monitored by the Building Management System (BMS) which I will describe in Section **7.16**. The smoke control system's main

control panel received *"a single hard wired "RUN" signal"* {MET00018469} which would run the smoke control system in environmental mode.

7.2.25 My team has reviewed this software in detail, with the results summarised in Section 7.19 below.

7.2.26 **Human Machine Interface (HMI)[1] software**

7.2.27 The HMI panel was present in the Ground Level entrance foyer and allowed people to input instructions via this panel, and so control (in part) the environmental and smoke control systems.

7.2.28 The HMI panel in Grenfell Tower provided access to the system's setup controls for the environmental system and the smoke control system. It also provided access to system status information, including whether the lobby dampers on each floor had been instructed to close or open and the status of the five fans attached to the system (four smoke fans and one environmental fan).

7.2.29 The HMI panel also allowed for specific control of the smoke control system. The HMI panel permitted a user to turn it off , to restart it and to select a specific floor from which it would extract smoke, apparently bypassing the need to activate the key switch on the floor of intended smoke extract. This feature would only activate when the HMI panel was turned from "Auto" to "ON".

7.2.30 The HMI panel also contained an alarm log. I understand that the data which this log held in relation to the system operations on 14th June 2017 was lost because the data was not removed from site and was very unfortunately overwritten by entries from the days after the fire {MET00017394}

7.2.31 I have reviewed RINA's report titled "*HVAC system memory analysis: Analysis of Grenfell fire alarm log system*" Rev 1 dated 19th March 2021 {MET00078854} and the report does not change my original opinion.

7.2.32 **Building Management System (BMS) software**

7.2.33 The BMS software has not been disclosed to me and so I have not reviewed it.

7.2.34 The BMS system does not control the operation of the system in smoke control mode so I have only described the interface of the BMS software with the main control panel. My description is based on JS Wright's 'O&M Manual for the smoke control system' {TMOM000001703} and my review of the main control panel software.

[1] PSB's Technical Submission (Rev 6) has referred to the HMI as "Human Mechanical Interface".

7.2.35 The BMS system was used to provide an input to the system in environmental mode. Specifically, the BMS handled the temperature data recorded in the lobbies on Ground Level, Levels 5, 10, 15 and 20 and apparently measured the average of the five floors to determine the demand for cooling. This is as described in the document "*Control System Description of Operation*" dated 24th September 2015 in Rydon's building manual provided to KCTMO {TMOM00001808}.

7.2.36 Based on the control system programming, a single signal was sent from the BMS to activate the system in environmental mode.

7.2.37 In David Hughes' oral testimony, however, Mr Hughes described that there was an additional "*temperature sensor outside that if the air outside was hotter than the air inside* (the environmental system) *wouldn't work*" (p. 218, Transcript 27th July 2020).

7.2.38 I have found an "Outside Air Temp" sensor with the BMS software as shown in the copy of the TREND work book (p.2, {DCS00000070}. The wiring diagram for the BMS basement control panel also shows connection to "Outside Air Temp (Weather Compensation" (p.14, {TMOM00001806}).

7.2.39 From these two documents, I am unable to determined how this outside air temperature sensor is programmed to operate with the other temperature sensors within the building as described in Section 7.2.35.

7.2.40 Please refer to Section 7.6 of this report for details of the programmed operation of the environmental ventilation system.

7.2.41 The smoke control system was also designed to send signals to the BMS to allow the BMS to turn off the boilers and gas supply located in the basement, on activation of the smoke control system {MET00018469}, as well as fault indication {PSB00000247}. I set this out in more detail in Section **7.17**.

7.2.42 However, WSP's report headed "*Grenfell Tower Building Management System Review for Metropolitan Police*" dated 20th April 2018 {MET00018469} states that this interface was not operational at the time of the fire. I have investigated whether the smoke control system was interfaced with the gas supply in Section **7.17** and deal with this issue later in Section 11 also as apparently this disconnection occurred after the system was handed over to the KCTMO.

7.2.43 During my Phase 1 investigation, it was not clear whether the temperature sensors were installed, and I still do not have evidence of their installation. However, there are written descriptions of their intended operation and I deal with that in Section 11.

7.2.44 In the same section, I have also analysed the evidence of all activity associated with the lobby smoke control system post-commissioning.

7.3 Summary of BRE report

7.3.1 Since my Phase 1 report, BRE produced a report for the MPS dated 10th February 2020, headed "*GT Site Report*" {MET00065879}, the introduction to which states as follows:

"This report summarises the work undertaken by BRE on site during February 2019 to identify relevant components and wiring associated with the Master Panel and Outstations of the smoke detection systemin the building, and the labelling of these components before their removal by MPS officers."

7.3.2 This report contains a very useful record of the physical components of the Grenfell Tower smoke control system following BRE's inspections on site at Grenfell Tower.

7.3.3 I have relied upon BRE's report and my own site inspections in developing my understanding of the state of the smoke control system in Grenfell Tower on the night of the fire.

7.3.4 Where necessary, I have included relevant excerpts from BRE's report in my report.

7.4 Partial reconstruction of the smoke control system by RINA

7.4.1 RINA was appointed by the Metropolitan Police Service to investigate "the functionality of the HVAC fire alarm smoke extraction system, and the interaction between the fire alarm system and lift operation, within Grenfell Tower" (p.3, {MET00072161}).

7.4.2 Their findings were recorded in a report prepared by RINA headed "HVAC Logic and Functionality Testing – Reconstruction and testing of Grenfell Tower smoke extraction system" Rev 1 dated October 2020 {MET00072161}.

7.4.3 The Introduction to RINA's report states:

"MPS provided RINA with the relevant electronic and electro-mechanical equipment that was associated with the smoke extraction system at Grenfell Tower. RINA re-assembled the equipment according to the installation details that were gathered during the removal of the equipment from the Grenfell Tower. The equipment was then tested at RINA's laboratory facilities."

7.4.4 I understand that the equipment provided to RINA was identified by BRE as recorded in their "*GT Site Report*" dated 10th February 2020 {MET00065879}.

7.4.5 **Test assembly used by RINA**

7.4.6 From RINA and BRE's report, I understand that the following physical devices were included in RINA's test assembly:

a) A Master Smoke Control Panel unit from the ground floor Hub Room of the Tower;

b) A Human Machine Interface (HMI) panel;

c) All outstations in the tower (one per floor from Level 2 to 23, see Section 7.2). Section 7 of RINA's report {MET00072161} identifies six outstations which were non-operational (those on Levels 13, 14, 15, 21, 22 and 23). The report states that the functions of these non-operational outstations were "simulated using computer software" in RINA's testing.

d) A single actuator from the right-hand side of the north damper on Level 6;

e) Firefighter's override switch from Level 2 and remains of the firefighter override switch from Level 11; and

f) A single pressure switch from Level 4.

7.4.7 The reconstruction did not involve use of the following equipment from the smoke control system:

a) Smoke fans or environmental fans;.

b) The inverters for the Level 2 or roof fans nor the outstation that provided control signals to the inverters;

c) The Level 2 bypass dampers;

d) Network cables between the master control panel, outstations and HMI panels – RINA provided their own cables to connect the master control panel, outstations and HMI panels together;

e) Battery back-up units;

f) Physical equipment connected to the outstations including pressure switches, smoke detectors, the fireman override switch, actuators and dampers. RINA simulated the input signals from these devices using physical switches attached to their test assembly. LED lamps were used to visualise activation of the dampers.

g) Cabling to the equipment listed above – RINA provided their own cables to connect the test assembly together.

7.4.8 In their report, RINA set out how the smoke control system was based around twenty-six "Fire Zones". Typically, a fire zone comprised a single floor, however there were two additional fire zones created to accommodate the non-residential lobby smoke control systems.

7.4.9 Figure 7-3, replicated from Table 4.1 in RINA's report, sets out the specific zone-numbering, and the outstations that controlled those zones. See my summary of the devices controlled by each of those outstations in Section 7.2.

Table 4.1: Outstation location details

Fire Zone	Floor	Panel	Board type	Modbus number
1	Ground	Master panel	Modbus I/O Mk1	1
		Inverter panel 1	Inverter	4
			Inverter	5
			Modbus I/O Mk1	6
-	Roof	Inverter panel 2	Inverter	9
			Inverter	10
			Modbus I/O Mk2	11
2	1	-	-	-
3	2	Outstation 1	Modbus I/O Mk1 v8	31
4	3	Outstation 2	Modbus I/O Mk1	34
5	4	Outstation 3	Modbus I/O Mk1	37
6	5	Outstation 4	Modbus I/O Mk1	40
7	6	Outstation 5	Modbus I/O Mk1	43
8	7	Outstation 6	Modbus I/O Mk1	46
9	8	Outstation 7	Modbus I/O Mk1	49
10	9	Outstation 8	Modbus I/O Mk1	52
11	10	Outstation 9	Modbus I/O Mk1	55
12	11	Outstation 10	Modbus I/O Mk1	58
13	12	Outstation 11	Modbus I/O Mk1	61
14	13	Outstation 12	Modbus I/O Mk1	64
15	14	Outstation 13	Modbus I/O Mk1	67
16	15	Outstation 14	Modbus I/O Mk1	70
17	16	Outstation 15	Modbus I/O Mk2	73
18	17	Outstation 16	Modbus I/O Mk2	76
19	18	Outstation 17	Modbus I/O Mk1	79
20	19	Outstation 18	Modbus I/O Mk1	82
21	20	Outstation 19	Modbus I/O Mk1	85
22	21	Outstation 20	Modbus I/O Mk1	88
23	22	Outstation 21	Modbus I/O Mk1	91
24	23	Outstation 22	Modbus I/O Mk1	94
25 (Community lobby)	Ground	Outstation 1	Modbus I/O Mk1 v8	32
26 (Boxing studio)	2	Outstation 1	Modbus I/O Mk1 v8	33

Figure 7-3: Table 4-1 extracted from RINA's report (p. 11, {MET00072161})

7.4.10 Scenarios tested by RINA

7.4.11 RINA did not provide a full list of scenarios tested.

7.4.12 RINA provided an example test run of the logic simulation as shown in Figure 7-4 below replicating Table 7.3.

Table 7.3: Example test run of the logic simulation

Action	Damper status	HMI Status	Time to react
System initiated	No change	-	-
Smoke on floor 4	Dampers begin to open on floor 4	Fire reported on floor 4	9 – 16 seconds
FOS activated on HMI	No change	HMI screen changes to firefighter mode	-
FOS activated on floor 11	Dampers begin to close on floor 4 and open on floor 11	Screen updates to show extracting floor	9 – 16 seconds
FOS deactivated on floor 11	No change	No change	-
FOS activated on floor 18	Dampers begin to close on floor 11 and open on floor 18	Screen updates to show extracting floor	9 – 16 seconds
FOS activated on floor 11	No change	No change	-
FOS deactivated on floor 18	No change	No change	-
FOS deactivated on floor 11	No change	No change	-

Figure 7-4: Example test run of simulation conducted by RINA {MET00072161}

7.4.13 RINA's reconstruction involved an investigation of how part of the controls functioned when sending signals from the master control panel to the outstations and from the outstations back to the master control panel.

7.4.14 This provides some useful information about the "commands" sent to and "commands" received from the outstations.

7.4.15 What it does not do is demonstrate how the components would physically respond to the signals, as they were not attached to the system during the reconstruction.

7.4.16 It is important to note that the outstations within the control panel for the Level 2 fans and within the control panel for the roof fans, which send the signals to the relevant fan inverters to regulate their speed [and thereby regulate the pressure difference between the lobby and the stair] were not incorporated in RINA's reconstruction.

7.4.17 This is a particularly significant omission when assessing how the fans were installed and commissioned and how they might operate at the two set speeds on the night of the fire as required to fulfil PSB's performance criteria, in smoke mode.

7.4.18 In short, components such as the fans and dampers, as wired in, at Grenfell Tower, did not form part of RINA's work. Therefore that part of the reconstruction could not enable me to assess how they would react to the "commands" from the controls system.

7.4.19 There is one exception to this – RINA incorporated an actuator from Level 6 in their reconstruction.

7.4.20 **Summary of findings by RINA**

7.4.21 Excerpted below are the findings from RINA's investigation:

"From environmental or standby mode, simulating smoke detected on a floor would cause the dampers on that floor to open.

After the first smoke detected signal, additional smoke detected signals for other floors had no effect.

Removing the smoke detected signal had no effect unless the system was reset from the HMI.

Intentional operation, or the short-circuit of a lift lobby FOS[2] *on any given floor had no effect without the HMI FOS being switched on first.*

FOS activated on a floor would open the dampers on that floor and close the dampers on the floor that the first smoke was detected.

Further FOS activations had no effect unless all the FOS were deactivated and another was then activated.

Removing the FOS activated signal had no effect (would not then re-open the dampers on the floor where smoke was detected or on any other floor where smoke had been detected).

On the deactivation of the HMI FOS switch, the system would revert to opening the dampers on the first smoke detected floor at the start of the fire, and close the remaining dampers. [Note this differs from the information now provided in the witness statement of Mr Michael Glowacki dated 15th April 2021 {PSB00001375}].

Activation of a pressure switch would reduce the extract fan speed from 100% to 50%.

Extraction override controls on the HMI would be deactivated if a FOS had been activated on any of the floors.

The visual appearance of the HMI screen would not change.

The screen would not show any error messages in this scenario.

[2] FOS is referred to in RINA's report as "*firefighter's override switch*"(p.2, {MET00072161})

The buttons would be present but pressing them would not result in any changes on the screen or in the lift lobby dampers.

The HMI control to power off the system would close all lift lobby dampers.

The HMI control to then restart the system does not reset the smoke detected signal."

7.4.22 Overall, the findings from RINA's partial reconstruction align with my Phase 1 analysis of the software and controls with one exception, as I explain in Section 7.5 below.

7.5 New PSB evidence

7.5.1 I have been provided with a technical note from PSB headed "*The HMI Panel and the Operation of the Fireman's Override Switch "HMI FOS Switch""* {PSB00001374} and the witness statement of Mr Glowacki dated 15th April 2021 {PSB00001375} (see Table 7-1).

7.5.2 The technical note from PSB {PSB00001374} explains what the system was designed to do in the following two circumstances:

a) When the HMI switch is turned from "Auto" to "On" and back to "Auto"; and

b) When the "Reset Fire Signal" button was activated on the HMI panel.

7.5.3 PSB have confirmed that, in both cases, the response of the smoke control system would have been to:

a) Turn off all the fans;

b) Close all the dampers;

c) Clear the value of the activated fire zone stored on the system and stop reading any new smoke-detected signals for 8 seconds;

d) Cut off power to the smoke detectors for 8 seconds to allow them to reset.

e) Restore power to the smoke detectors after 8 seconds and resume monitoring them for a new activated fire zone;

f) and

g) Go back into standby (i.e. with all fans being switched off and all dampers closed).

7.5.4 PSB have confirmed that with the system reset into "Auto" mode and on standby, it would restart on the floor that next reported a signal from one of the smoke detectors.

7.5.5 Where smoke was present on more than one floor, PSB could not predict the floor on which the system would be activated. This is because they could not

predict in what order the system would be monitoring signals from the reset smoke detectors.

7.5.6 I have set out this new information within my detailed assessment of the HMI programming in Section 7.9.

7.5.7 Mr Glowacki's witness statement confirms that he was responsible for "*programming the logic software*" in Grenfell Tower {PSB00001375} and that he agrees with the content of PSB's technical note {PSB00001374}.

7.6 Operation of the refurbished system – smoke mode

7.6.1 The design intent of the operation of the system in smoke mode according to PSB's Technical Submission Revision 6 {PSB00000214} is summarised in Figure 7-5.

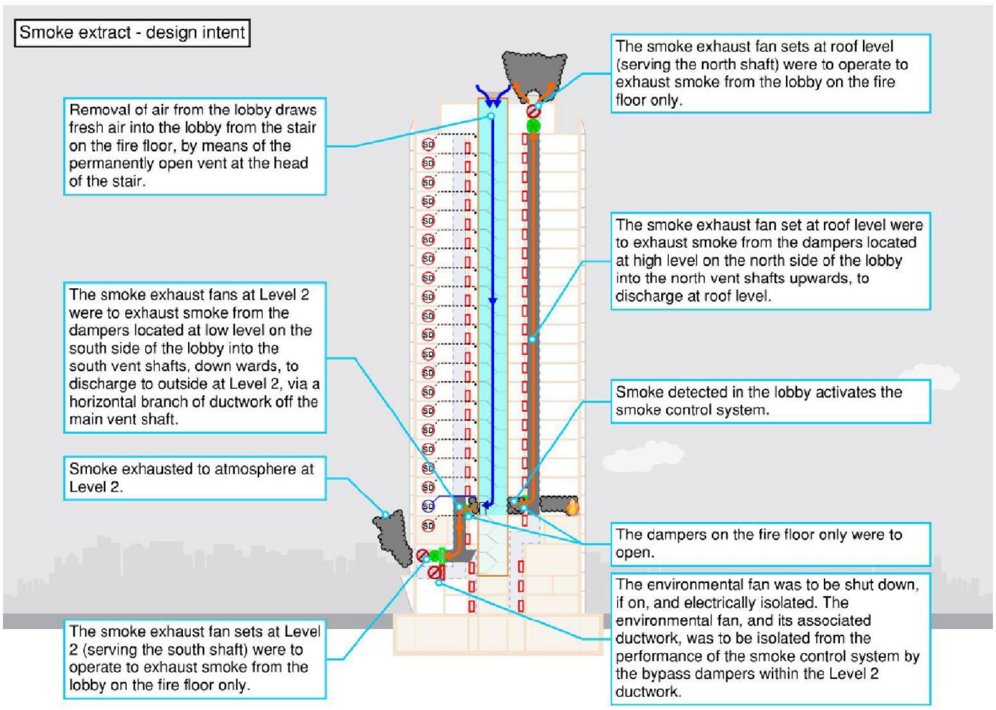


Figure 7-5: Programmed operation of the smoke control system

7.6.2 This operation is also shown schematically in Figure 7-6 and Figure 7-7. The blue dashed arrows indicate the fresh air inlet provided by the roof vent in the stairs through the door in the direction of the lobby. The red dashed arrows indicate the movement of smoke and hot gasses out of the lobby through the AOVs on the north and south side of the lobby.

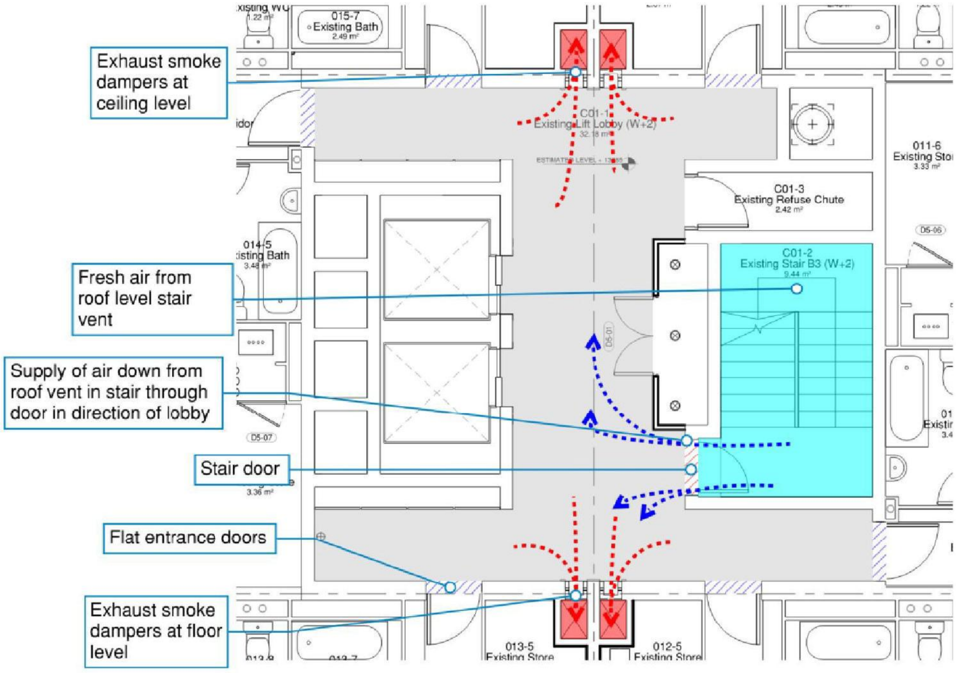


Figure 7-6: Design intent of the smoke extract system in Grenfell Tower for Level 2 to Level 23 (overlaid onto {SEA00010474})

7.6.3 The ground level and Level 1 lobby are an exception where the inlet air to the lobby smoke control system is provided via the permanently open fixed louvres in the main entrance foyer of the Grenfell Tower.

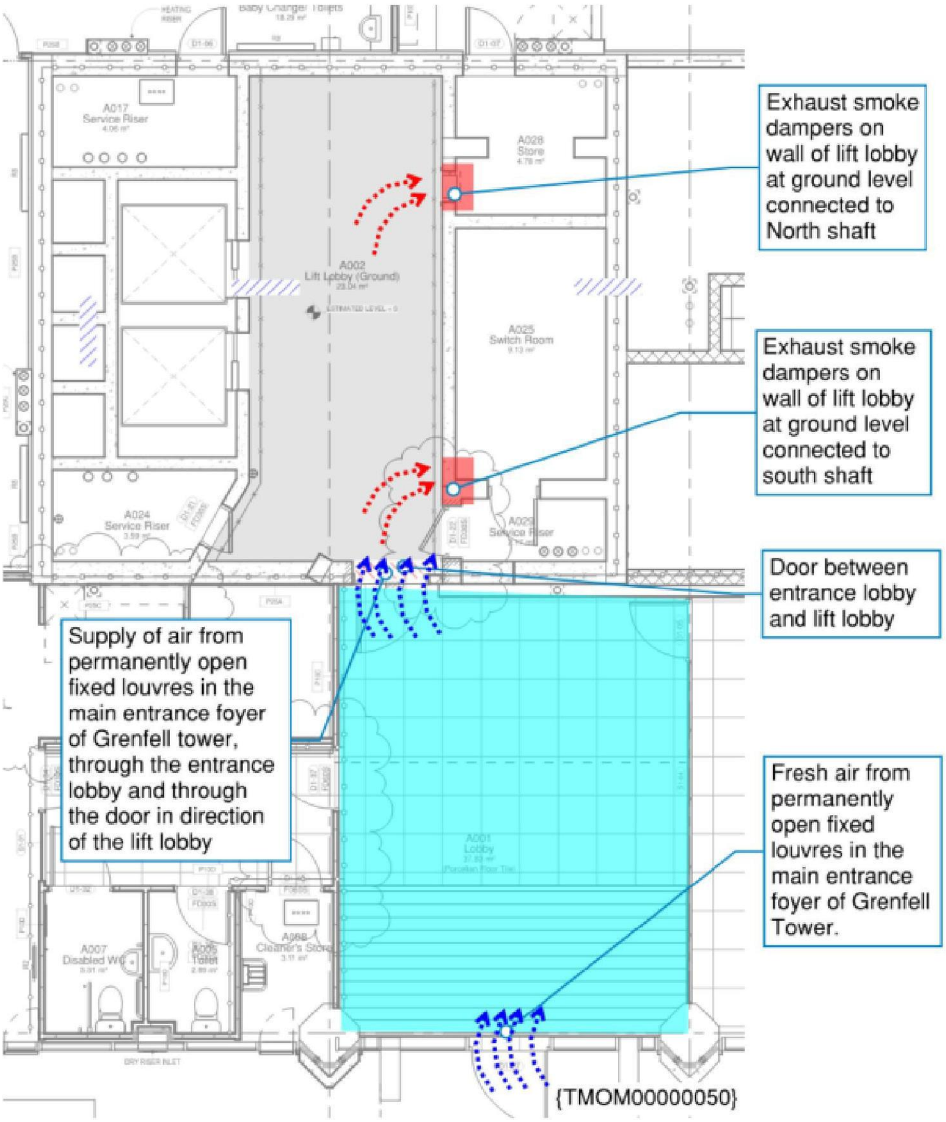


Figure 7-7: Design intent of the smoke extract system in Grenfell Tower for ground level lobby (overlaid onto {TMOM00000050})

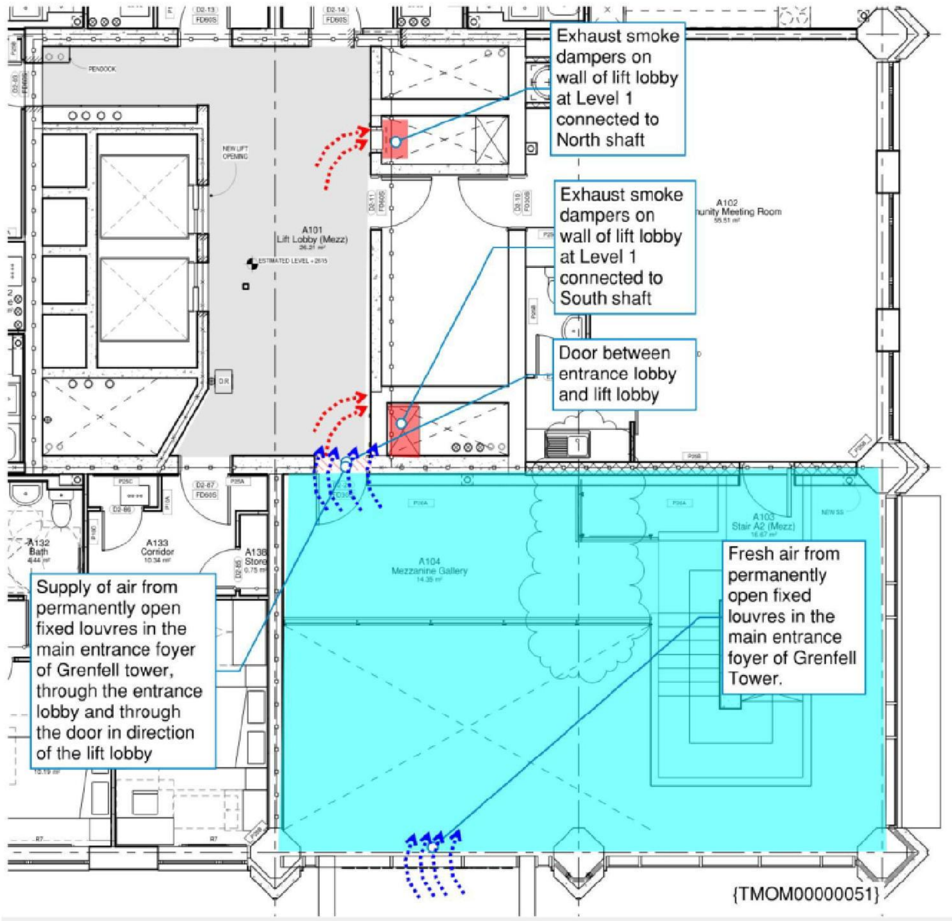


Figure 7-8: Design intent of the smoke extract system in Grenfell Tower for Level 1 lobby (overlaid onto {TMOM00000050})

7.6.4 It is also relevant here to record the following passages from Section 2.3.1 of PSB's Technical Submission Revision 6 {PSB00000214}:

a) Once the AOVs were closed on all other floors, they were to be 'electrically isolated to prevent them being opened to maintain separation and smoke contamination of the other floors'.

b) 'In the event of failure of the primary power supply the battery backup panel will provide a power secondary [sic] supply.'

c) 'Indication on the mimic repeater panel [the HMI panel] and main control panels shall indicate the core & floor on which the alarm has been triggered.'.

7.6.5 In the following sections, I set out more detail on how the smoke control system operated across the following four categories:

a) System inputs: the pressure switch, yellow key switch and the HMI panel;

b) System communications: the outstations;

c) System outputs: the dampers (and their actuators) and fans (and their inverters);

d) Secondary power supplies: the batteries and automatic switching devices.

7.6.6 In each of the following sections I address: PSB's specification for each component; the function of each component as I understand it from the available evidence; whether this function matched the original design intent; and the testing and commissioning which would therefore be required to demonstrate that the system functioned as intended.

7.6.7 In Section 8 I set out what this evidence demonstrates regarding the adequacy of commissioning, the available records of commissioning of each component, and the integrated system commissioning tests.

7.7 System inputs: Operation of the pressure switch

7.7.1 PSB design requirements for the pressure switch

7.7.2 PSB designed the system on the basis of a single door condition only, as I explain in Section 5. Specifically, the only door that the system performance considered to be open as part of the design was the fire door between the lobby and the stair.

7.7.3 If the stair door on the fire floor was opened, the flow of air into the lobby from the stair was intended to prevent smoke present within the lobby from flowing back out into the stair. This performance requirement is described in Section 1.1.2 of PSB's Technical Submission Revision 6 {PSB00000214}:

> The Final smoke control system has been designed to provide the existing stairwell with protection from the ingress of smoke, from a fire within a dwelling, by means of a mechanical extract system. The system has been designed to provide an average open door velocity, across an open lobby/stairwell door of 2.0m/s. This velocity is in accordance with the recommendation for a Class B pressure differential system as defined in Code of Practice BSEN12101 Part 6: Specification for pressure differential systems — Kits. (BSEN12101-6)

Figure 7-9: Section 1.1.2 of PSB's Technical Submission Revision 6 {PSB00000214}

7.7.4 A performance requirement was also set regarding the pressure within the lobby when the doors were closed, as described in Section 1.1.2 of PSB's Technical Submission Revision 6 {PSB00000214}:

> The control system will also have pressure sensors added into each ventilated lobby to control the speed of the fans to ensure that when the doors on the escape route are closed that the opening force on the door does not exceed 100N as detailed IN BSEN12101-6

Figure 7-10: Section 1.1.2 of PSB's Technical Submission Revision 6 {PSB00000214}

7.7.5 When the stair door was closed, the system was intended to maintain a pressure difference of 25Pa between the lobby and the stair (-25Pa in the

lobby compared to ambient[3]). This performance requirement is described in Section 3.3 of PSB's Technical Submission Revision 6 {PSB00000214}:

> speed of the fans between low speed (all doors closed) and high speed (door on fire floor open). The open/closed door condition will be monitored by as pressure sensor (see details below) which will measure the pressure differential between the lobby and the stairwell. The system is designed to maintain -25Pa in the lobby with all doors closed and will maintain the fans at low speed setting. Once a door to the smoke affected lobby, and only the smoke affected lobby, the pressure differential will be lost and the fans will automatically ramp up to full speed to extract air from the lobby at a rate which will pride an average face velocity of 2m/s across the open lobby / stairwell door.

Figure 7-11: Section 3.3 of PSB's Technical Submission Revision 6 {PSB00000214}

7.7.6 A pressure switch was included in PSB's design to register when the pressure difference between the stair and the lobby was:

a) Greater than 25Pa; or
b) Less than 25Pa.

7.7.7 I note that a pressure switch has a hysteresis (or a switching band) around its switching setpoint. I have taken a picture of the pressure switch installed at Level 4 from RINA's exhibits and found that the model installed is "PA-604-90" from the sticker label.

7.7.8 My team has found that the manufacturer of this pressure switch is Huba and the data sheet indicates that the hysteresis or switching band is 10 Pa[4].

7.7.9 This meant that when a pressure differential setpoint of 25Pa as indicated on the pressure switch, switching of states would only occur when the pressure differential was above 30 Pa or below 20 Pa. Therefore, when a pressure setpoint is stated in the remainder of my report, the practical pressure differential that would cause an activation/deactivation of a pressure switch would actually differ by +/- 5 Pa.

7.7.10 Figure 7-12 shows a schematic of how the pressure switch operation was connected to the smoke control system. As indicated in this diagram, the physical pressure switch was positioned within the service riser on each floor, with "clear plastic tubing" (p.120, {MET00039807}) leading to a single sampling points in each of the stair and the lobby on that floor. The pressure switch compares the pressure at each sampling point and sends a signal when the pressure difference exceeds 25Pa.

7.7.11 The pressure switch appears to be a simple part of the system's design. However, as I set out in the following sections, its operation has important

[3] The pressure in the stairwell would be at the same pressure as the ambient atmospheric pressure outside the building as there is a permanent vent at the top of the stair shaft open to external.

[4] https://www.hubacontrol.com/fileadmin/user_upload/domain1/Produkte/EN/Datenblatt/604_Pressure_Switch.pdf (Accessed: 14th May 2021)

implications for how the system works, compared to its original design, and the way in which it was commissioned.

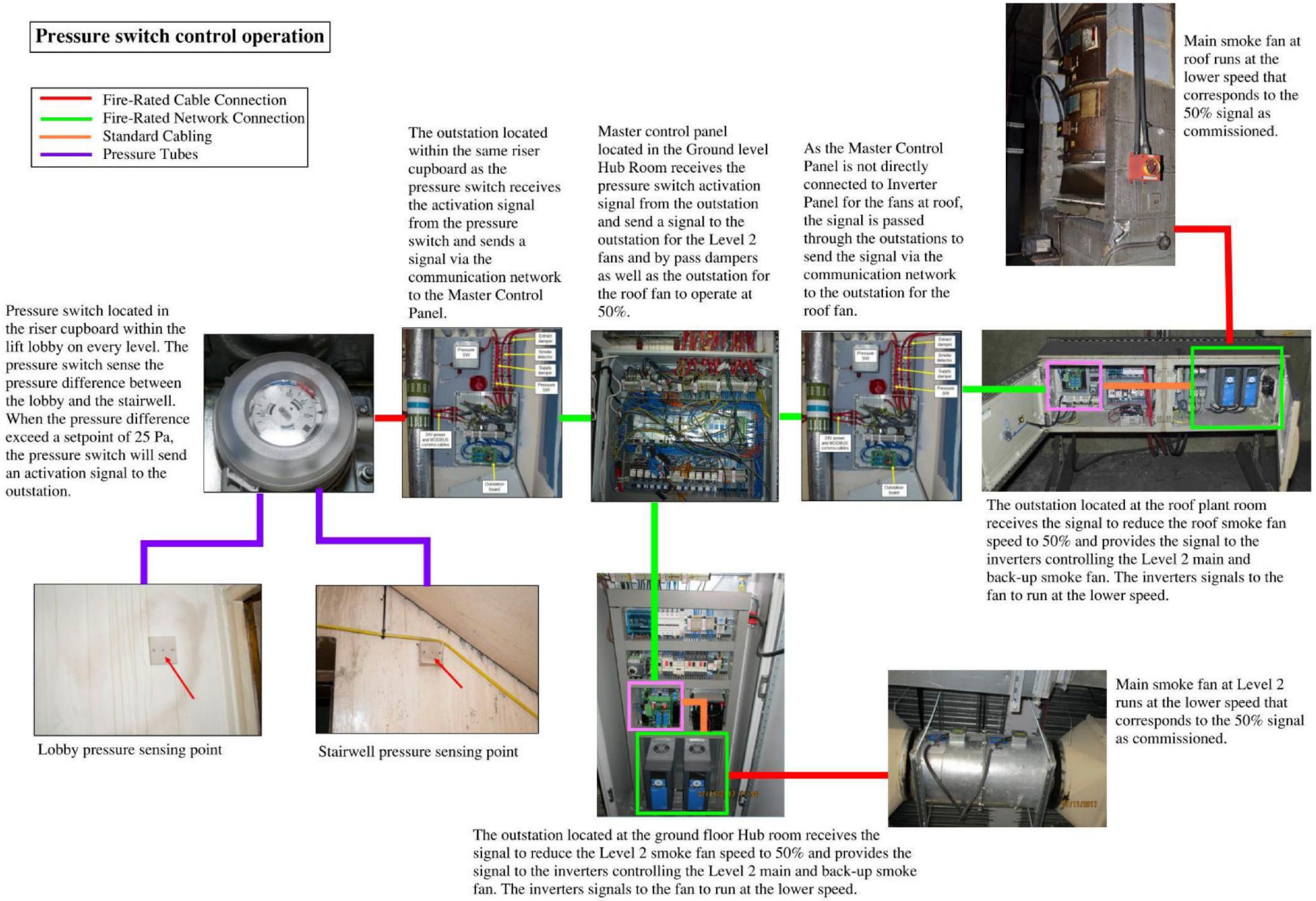


Figure 7-12: Pressure switch control operation

7.7.12 **Detailed function of the pressure switch**

7.7.13 The pressure switch has two positions: open (breaking the circuit) or closed (completing the circuit).

7.7.14 When the switch is open, the outstation on that floor receives no signal. When the switch is closed, (i.e. the pressure difference measured between the stair and the lobby exceeds 25Pa), the pressure switch provides a signal to the outstation on the floor.

7.7.15 The signal is then transmitted via the communications network to the main control panel at the ground floor hub room.

7.7.16 The PLC (Programmable Logic Controller) programme within the main control panel uses this input to determine the signal to be sent to the inverters at Level 2 and Roof Level.

7.7.17 This instructs the relevant fans to run at a specified speed (high speed or low speed).

7.7.18 I note that the pressure switch is a simple on-off signal and does not enable the actual pressure difference in the lobby to be measured. The switch only records whether the pressure difference is greater than, or less than, 25Pa (the set point).

7.7.19 This is an important point when determining what commissioning tests that are required.

7.7.20 The pressure levels in the lobbies cannot be taken from the smoke control system sensors.

7.7.21 I would expect therefore that commissioning tests of the functions caused by the pressure switches to have included:

a) Measurement of the ambient pressure in the lobby and the stair

b) Activation of the smoke zone in a given lobby.

c) Measurement of fan speed at level 2 and roof level to demonstrate it was running at 100% speed until the required depressurisation had been reached hence that the pressure switch was open.

d) 2nd measurement of the pressure in the lobby and the stair to demonstrate the differential pressure of -25Pa had been achieved between the lobby and the stair.

e) 2nd measurement of fan speed at level 2 and roof level to demonstrate it was running at 50% speed once the differential pressure of -25Pa had been achieved between the lobby and the stair hence the pressure switch was closed.

f) Door to the stair on the floor where the smoke zone had activated to be opened.

g) 3rd measurement of fan speed at level 2 and roof level to demonstrate it was running at 100% speed.

7.7.22 Refer to Section 8.8 where I provide an explanation of the equipment required to undertaken this.

7.7.23 **Conditions in which the 25Pa pressure differential could exist on any floor**

7.7.24 The smoke control system at Grenfell Tower only allowed for one scenario in which a 25Pa pressure difference could exist between the stair and the lobby, namely that all doors to the common lobby were closed (i.e. the stair door and all apartment doors) and the smoke control fans were extracting from that lobby.

7.7.25 PSB's Technical Submission (Rev 6)(p.18,{PSB00000214}) identified that the system could only respond to signals from the pressure switch on the fire floor.

7.7.26 My team's investigation into the system's programming has identified that there are no software interlocks applied between the fire floor and the pressure switches of that floor, which would enable only the pressure switch on the fire floor controlling the speed of the fan.

7.7.27 Therefore, a pressure difference exceeding 25Pa between the stair and the lobby on any level could also lead to the fan speed being reduced.

7.7.28 RINA's reconstruction found that an activation of a pressure switch would send a signal to the fan to run at a reduced speed of 50% from 100% (p.22, {MET00072161}).

7.7.29 However, the only means by which a 25Pa pressure difference should be created between the stairs and the lobby, is by the action of the smoke control system extracting from the floor of activation, with all doors to that lobby closed.

7.7.30 Therefore, it is unlikely that a pressure switch on a floor other than that on which the system had been activated could cause the fan speed to be reduced.

7.7.31 Regardless I would expect evidence of this being demonstrated during commissioning.

7.7.32 On the night of the fire however, if there were open dampers on another floor, for example faulty dampers, it could cause depressurisation of the lobby on that floor and so the pressure switch on that floor (rather than the fire floor) may then control the fans. I explore this further in Section 12.

7.7.33 **Conditions in which a reduced pressure differential could exist**

7.7.34 As soon as the stair door is opened, the pressure difference between the stairs and lobby reduces, and the fan is then instructed to operate at full speed *"which will provide an average face velocity of 2 m/s across the open lobby/stairwell door"*. This is the only condition discussed in PSB's design.

7.7.35 PSB's design does not address the impact of a flat-entrance door being opened when a window in that flat is also open (either left open or broken open by a fire). In this (reasonably foreseeable) scenario, even if the stair door is closed, the pressure difference between the stair and the lobby will reduce as both spaces are directly connected to the outside.

7.7.36 This condition could also cause the smoke control fans to run at full speed, drawing air (and potentially fire and smoke) into the lobby from the flat of fire origin at the specified 2m/s (see Figure 7-13), if the stair door is closed, otherwise if open it will draw from both, at a nominal 1m/s, the same as if another other apartment doors is open, this will also reduce flow.

7.7.37 PSB's design does not consider how this operation might affect the tenability of the lobby space, either for escape by occupants of other flats on the fire floor, or for attending fire crews.

7.7.38 As I have set out in Section 5 PSB did not incorporate the risk of smoke entering the lobby as a performance consideration for their design for the primary refurbishment.

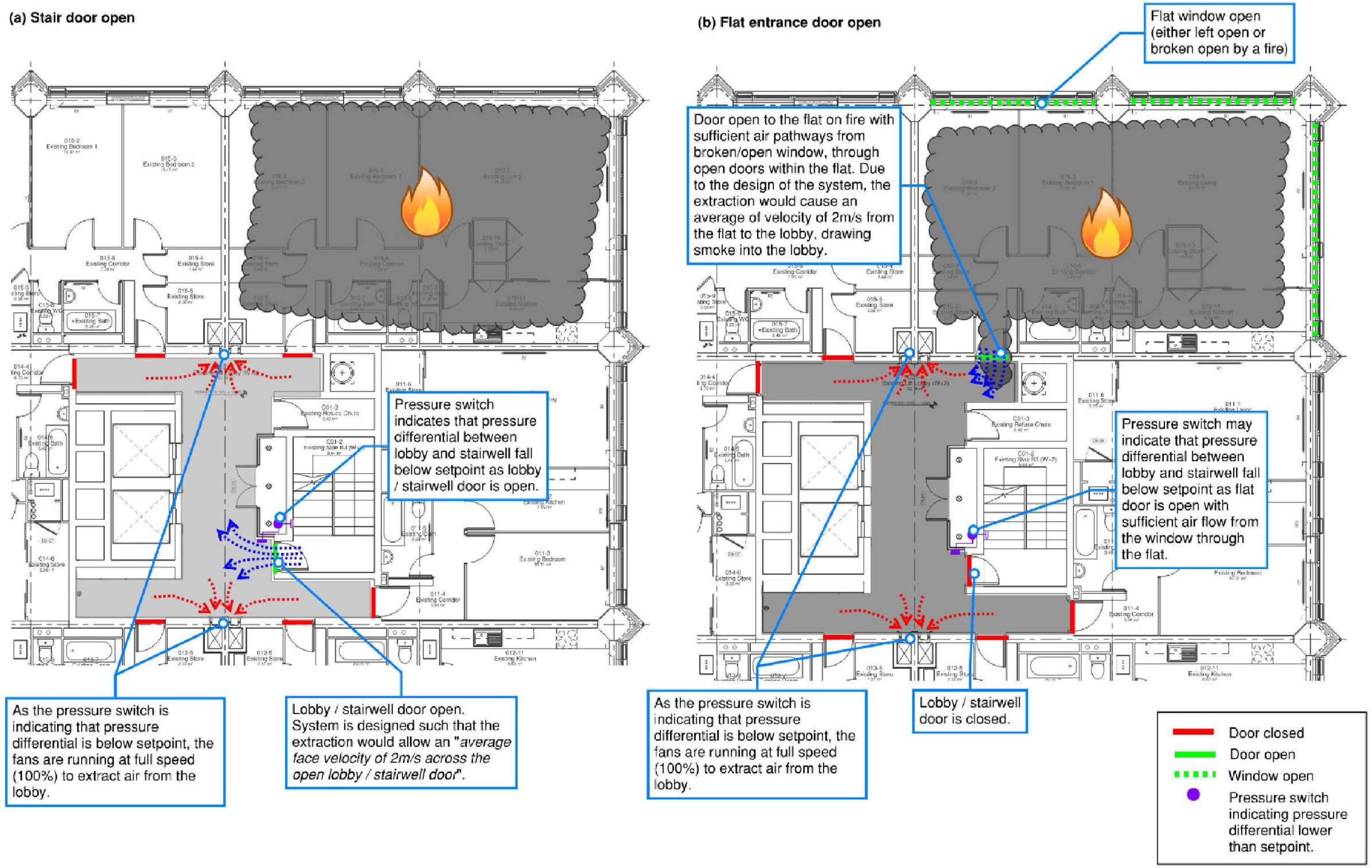


Figure 7-13: Comparison of conditions leading to a reduced pressure difference in the lobby with a) the stair door open and b) the flat entrance door open

7.8 System inputs: Operation of the yellow key switch (firefighter override switch)

7.8.1 As shown in Figure 7-14, the firefighter override switch (yellow key switch) located within the lobby on every floor was connected to the outstation on the same floor with the exception of the Ground Level and Level 1 lobby yellow key switch which is connected directly to the Master Control Panel at Ground level Hub Room. As explained in Section 7.11, the outstations were connected in a daisy-chain with the outstations on the floors above and below. The lowest outstation was at Level 2 and connected to the Master Control Panel.

7.8.2 Figure 7-14 shows a picture of a firefighter override switch ('FOS') at Level 6. The FOS is activated via a key and can be switched from "AUTO" to "ON".

7.8.3 When any FOS is switched from "AUTO" to "ON", this activation sends a signal via the communications network between the outstations to the master control panel.

7.8.4 If the HMI panel key switch is also set to "ON", then the main control panel switches operation of the smoke control system to that floor. This involves:

a) The outstation on the currently active floor signalling the dampers to close on that floor; and

b) The outstation on the floor with the active FOS signalling the dampers on that floor to open.

7.8.5 The fans will then draw air from the floor with the active FOS.

7.8.6 Only one FOS can be active at any one time. Activation of a second FOS, while the first is still set to "ON" will not change the system operation.

7.8.7 The first FOS must be set back to "AUTO" before the second will have any effect.

Figure 7-14: Firefighter override switch from Level 6. {MET00077990}

7.9 System inputs: Operation of the Human Machine Interface (HMI) panel

7.9.1 PSB's stated purpose for the HMI panel

7.9.2 A Human Machine Interface (HMI) panel was provided in the Ground floor entrance foyer. The HMI had a key switch permitting two modes of operation: "Auto" and "On". This is shown in Figure 7-15.

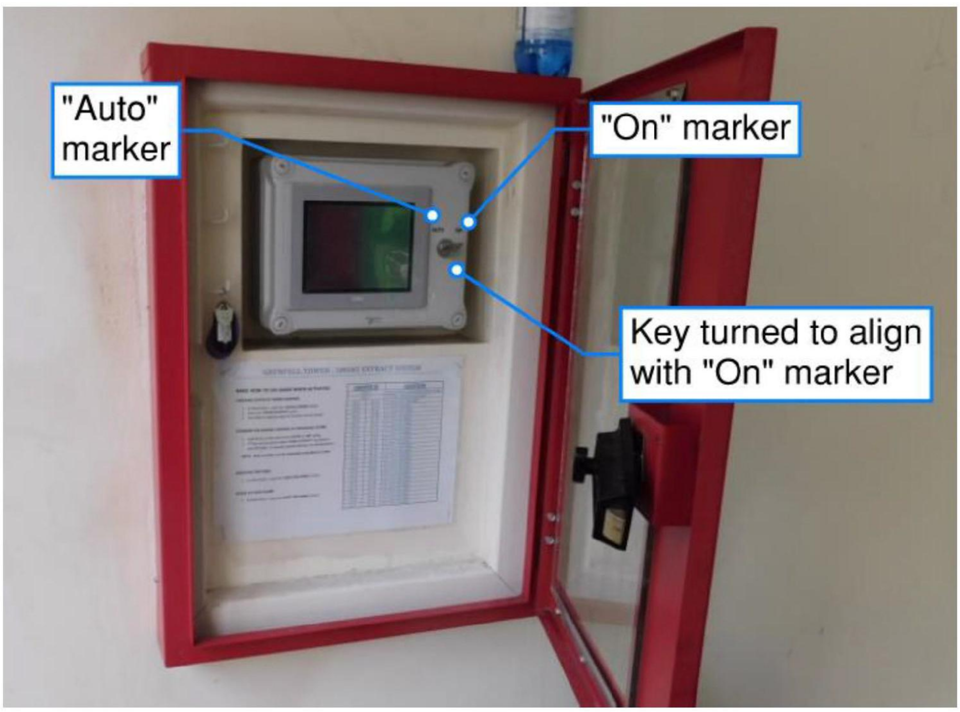


Figure 7-15: Photograph of HMI panel after the fire (MET00018915)

7.9.3 The purpose of this panel was set out in Section 1.1.2 of {PSB00000214} as below:

> A human Mechanical Interface Panel (HMI) will be located within the entrance area to provide the fire and rescue service with a central override facility to close all dampers in a single operation.

Figure 7-16: Section 1.1.2 {PSB00000214}

7.9.4 In PSB's Technical Submission Revision 6 (p.4, {PSB00000214}), closing all dampers in a single operation can be carried out, as explained as follows:

"If HMI override is activated the Fan system shuts down and all dampers and stairwell ventilator will close"

7.9.5 There is no stairwell ventilator in Grenfell Tower as there is a permanently open vent at the top of the stair shaft.

7.9.6 I have understood "*HMI override is activate*" to mean that the HMI key switch was turned from "*Auto*" to "*ON*".

7.9.7 My team's software simulation does not indicate that the "*fan system shuts down and all dampers... will close*". Instead, the fans continue running and the damper remain open on the floor of activation. RINA's reconstruction also found that when the HMI key switch was turned on, there is no change in damper status {MET00072161}.

7.9.8 The only way the fan system shuts down and all dampers will close in a single operation, is when the "Turn System Off" on the HMI touchscreen panel was activated. This screen with the "Turn System Off" button is only available when the HMI key switch has already been turned "ON (Figure 7-17).

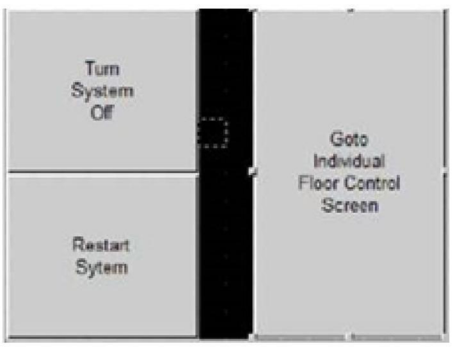


Figure 7-17: Fireman's override main screen (left) taken from {MET00018074}.

7.9.9 PSB's Technical Submission Revision 6 (p.7,{PSB00000214}), also indicates that the AOVs shall close automatically "*upon reset of the fire alarm or by override selection*".

7.9.10 There is a "Reset Fire Signal" on the main touch screen of the HMI panel menu when the HMI FOS is on "AUTO" (Figure 7-17).

7.9.11 My team's analysis has found that pressing the "RESET FIRE SIGNAL" button on the main touch screen of the HMI panel would cause the fans to de-energise and the dampers to close.

7.9.12 This aligns with the specification in PSB's Technical Submission, although it should be noted that if smoke were still present in one of the lobbies, then the associated smoke detector would reactivate the system.

7.9.13 **Other functions enabled by the HMI panel**

7.9.14 In addition to the simple functions of resetting the system and turning the smoke control system off, the HMI panel provided access to a range of other functions.

7.9.15 PSB's Technical Submission, however, did not clarify the function of other control features on the HMI panel. The HMI panel was programmed with a complex series of commands to enable the smoke control system to be activated on any floor in Grenfell Tower, either by the activation of the HMI touch screen or by the use of the physical yellow key switches provided to each floor.

7.9.16 This is important because the interaction of the programming of the HMI panel commands and the physical yellow key switches leads to a range of outcomes, all of which would need to be tested as part of commissioning of the system to ensure that the system continued to work as intended.

7.9.17 From my team's analysis of the programming of the system at the time of the fire, the smoke control system would respond to the different controls available on the HMI as follows:

7.9.18 In "Auto" mode – On detection of smoke in a lobby, the activation sequence as described in Section 7.6 would occur.

7.9.19 If the HMI were left in 'Auto' then the system would continue its automatic (programmed) response. This would mean the fireman's override touch screens on the HMI (Figure 7-17) would not be available and the yellow key switches in each lobby, even if used, would not have any effect (see Section 7.9).

7.9.20 Switching the HMI panel from "Auto" to "On" does not initiate any immediate changes in the operation of the smoke control system. This was corroborated by RINA's investigation {MET00072161}.

7.9.21 If the HMI were set to "On" fire fighters could operate the smoke system from the HMI firefighter override touch screens and to press "Turn System Off" or "Restart System" or to change the floor of operation of the smoke control system (Figure 7-17).

7.9.22 If the HMI were set to "On" fire fighters could operate the smoke control system using the (yellow) key switch in one lobby at a time, to change the floor of operation to the floor that lobby is located on (see Section 7.9).

7.9.23 If the HMI were set to ‘On’, the panel could display the status of the signal to the fans and dampers, as shown in Figure 7-21 and allow fire fighters to change the floor of operation of the smoke system from the touch screen as shown in Figure 7-23.

7.9.24 For example, this screen was recorded as active when SM Green (LFB) photographed the HMI panel on 14th June 2017 after the fire (Figure 7-18).

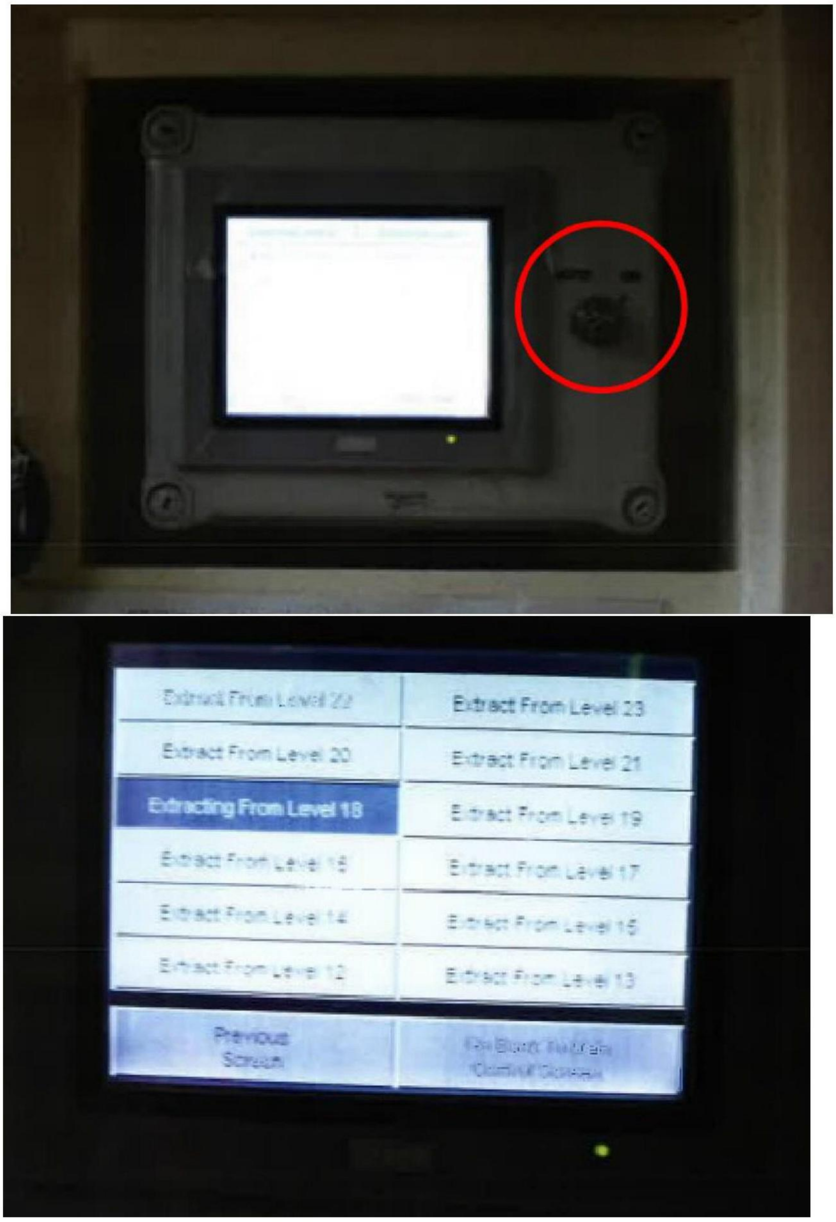


Figure 7-18: HMI FOS is switched to “ON” (p.5, {MET00077976}) (top). HMI individual floor control touch screen can be accessed. (p.9, {MET00077976}) (bottom)

7.9.25 If the HMI were set to ‘On’, operation of a yellow key switch on any floor could close the dampers open at the time due to an automatic smoke

detection activation, and then open the dampers at the level on which the yellow key switch had been activated (see Section 7.9).

7.9.26 Therefore, activation of a yellow key-switch when the HMI was "ON" would override any automatic smoke detection activation, effectively becoming the highest priority signal and overriding any signal from a smoke detector.

7.9.27 The key switches on the floors were interlocked such that the first lobby key switch activated would have to be turned off before the lobby switch on any other floor could function. (Note that the key switches could be physically turned on more than one floor, however only the first key switch would initiate any effects in the smoke control system programming, see Section 7.9).

7.9.28 If the HMI panel were set to "ON" , the touch screen used to manually override the floor of operation, and a key switch then operated, the system would operate on the floor where the key switch had been operated, overriding the HMI panel command. The system would not act on any further manual override instructions - either from another key switch or the HMI panel touch screen - until the yellow key-switch had been turned off. The yellow key switch therefore appears to have taken precedence over the operation from the HMI touch screen

7.9.29 My team's initial analysis of the programming (which I presented in my Phase 1 report) indicated that switching the HMI from "Auto" to "On" and back to "Auto" would reset the damper positions, while the extract fans continued to run. On consideration of the additional evidence from RINA and PSB, I have now revised my understanding of this action.

7.9.30 If the HMI were set to "ON", the firefighter override touch screen would show a "Turn Off System" button. If the "Turn Off System" button were pressed, the system would turn the smoke fans off and AOVs would close. The system would not react to any automatic activation or yellow key-switch activation until the "Restart System" button had been pressed.

7.9.31 My team's analysis of the programming shows that if the "Restart System" button on the Fireman's override touch screen on the HMI panel were pressed, the system would restart at the original floor of automatic activation, even if a yellow key-switch had been activated on a different floor before the system was turned off and restarted (see Section 7.9.40).

7.9.32 My team's analysis of the programming shows that while in Auto, if the 'Reset Fire Signal' button on the HMI touch screen menu first screen were pressed, and smoke activated a smoke detector in one or more of the lobbies, then the system would restart on the floor from which a signal from a smoke detector was first received, regardless of the floor of original operation. I note that PSB in their note, *The HMI Panel and the Operation of the Fireman's Override Switch "HMI FOS Switch""* {PSB00001374},

stated that resetting the fire signal would cause the system to react like the "Auto" to "ON" to "Auto" scenario. I discuss this in Section 7.9.33.

7.9.33 **Findings of RINA and PSB regarding de-activation of the HMI key-switch**

7.9.34 Regarding the operation of the yellow key-switches in the lobbies, the results of RINA's reconstruction testing {MET00072161} are consistent with my description of the system in Items 7, 8 and 12 of Section 7.9.17 above.

7.9.35 However, for Item 10, RINA's report states:

"on the deactivation of the HMI FOS switch, the system would revert to opening the dampers on the first smoke detected floor at the start of the fire and close the remaining dampers."

7.9.36 This does not match my team's initial analysis of the software, which indicated that the system would revert to the lowest floor of smoke activation. However, it is not clear from RINA's report whether their testing allowed for activation of smoke detectors on multiple floors.

7.9.37 However, I have also been provided with a technical note by PSB providing their own description of the programming of the main control panel, and the impact of turning the HMI panel from "AUTO" to "ON" and back to "AUTO". See Section 7.5.

7.9.38 In summary, PSB say that on re-activation of the system, if smoke were still present on multiple floors, the smoke control system would start to extract from one of those floors. However, due to the way the system is programmed it was not possible to predict which floor might be the first to activate.

7.9.39 My team has re-examined the programming evidence and concurs with PSB's assertion of the system operation in this respect. I note that the effect of de-activating the smoke detectors for a programmed 8 seconds, was not considered in my team's initial investigation.

7.9.40 Therefore, in the event that the fire brigade set the HMI panel to "ON" and then back to "AUTO", the system resets itself and can then activate again on any floor where there is smoke.

7.9.41 Whilst the fire brigade could determine the new floor of activation after reset, from the status message on the HMI menu screen as described in Section 7.9.44; this was not explained to them in the instructions left beside the HMI Panel.

7.9.42 This change in state, as a consequence of this operation, could reasonably be expected to be communicated clearly in the instructions.

7.9.43 **Touch screen images**

7.9.44 Screens visible in "Auto" mode

7.9.45 Figure 7-19 presents the main menu page for the HMI panel touchscreen. This screen was only shown when the HMI switch was in the "AUTO" position. This image has a space where it states: "*System Healthy*". This space is used for system status messages to be displayed. All of the possible messages are presented in Figure 7-20.

Figure 7-19: HMI menu first screen

No.	Message
Msg0	System Healthy
Msg1	Cooling/Heating Fault- INV Panel 1
Msg2	Mains Supply Fault- INV Panel 1
Msg3	Environmental Fan Fault- INV Panel 1
Msg4	Main Extract Fan Fault- INV Panel 1
Msg5	Backup Extract Fan Fault- INV Panel 1
Msg6	PSU Supply Fault- INV Panel 1
Msg7	Cooling/Heating Fault- INV Panel 2
Msg8	Mains Supply Fault- INV Panel 2
Msg9	Environmental Fan Fault- INV Panel 2
Msg10	Main Extract Fan Fault- INV Panel 2
Msg11	Backup Extract Fan Fault- INV Panel 2
Msg12	PSU Supply Fault- INV Panel 2
Msg13	PSU Supply Fault- Battery Panel
Msg14	System Fault, Contact PSB!!!
Msg15	Service Required
Msg16	Environmental Control OFF
Msg17	Fireman's Switch Available
Msg18	Running Environmental Sequence
Msg19	DF1 Fan Fault- DOL Panel 1
Msg20	DF2 Fan Fault- DOL Panel 1
Msg21	DF3 Fan Fault- DOL Panel 2
Msg22	DF4 Fan Fault- DOL Panel 2
Msg23	
Msg24	
Msg25	
Msg26	
Msg27	
Msg31	Fire Detected - Ground Floor
Msg32	Fire Detected - Level 1
Msg33	Fire Detected - Level 2
Msg34	Fire Detected - Level 3
Msg35	Fire Detected - Level 4
Msg36	Fire Detected - Level 5
Msg37	Fire Detected - Level 6
Msg38	Fire Detected - Level 7
Msg39	Fire Detected - Level 8
Msg40	Fire Detected - Level 9
Msg41	Fire Detected - Level 10
Msg42	Fire Detected - Level 11
Msg43	Fire Detected - Level 12
Msg44	Fire Detected - Level 13
Msg45	Fire Detected - Level 14
Msg46	Fire Detected - Level 15
Msg47	Fire Detected - Level 16
Msg48	Fire Detected - Level 17
Msg49	Fire Detected - Level 18
Msg50	Fire Detected - Level 19
Msg51	Fire Detected - Level 20
Msg52	Fire Detected - Level 21
Msg53	Fire Detected - Level 22
Msg54	Fire Detected - Level 23
Msg55	Fire Detected in Community ...
Msg56	Fire Detected in Boxing Stu...
Msg57	Fire Detected - Level 26
Msg58	Fire Detected - Level 27
Msg59	Fire Detected - Level 28
Msg60	Fire Detected - Level 29
Msg61	Fire Detected - Level 30
Msg62	Fire Detected - Level 31
Msg63	Fire Detected - Level 32
Msg64	Fire Detected - Level 33
Msg65	Fire Detected - Level 34
Msg66	Fire Detected - Level 35
Msg67	Fire Detected - Level 36
Msg68	Fire Detected - Level 37
Msg69	Fire Detected - Level 38
Msg70	Fire Detected - Level 39
Msg71	
Msg72	
Msg73	
Msg74	
Msg75	
Msg76	
Msg77	

Figure 7-20: Available system status messages (from {MET00018074})

7.9.46 The first screen of the HMI panel could therefore display information as to what floor the fire had been detected on, and a range of specific information relating to faults in different parts of the system.

7.9.47 I assume that Messages 57 to 70 are default messages that were not deleted from the system as they refer to floors that do not exist at Grenfell Tower.

7.9.48 Based on my understanding of the HMI system's programming, on activation of a smoke detector, the HMI panel would exhibit a message indicating only the location of that activation. The fire message would override any other messages that the system would otherwise be reporting.

7.9.49 If the HMI Panel were set to "Auto", pressing the "Status Screen" button would show the damper status screen excerpted in Figure 7-21.

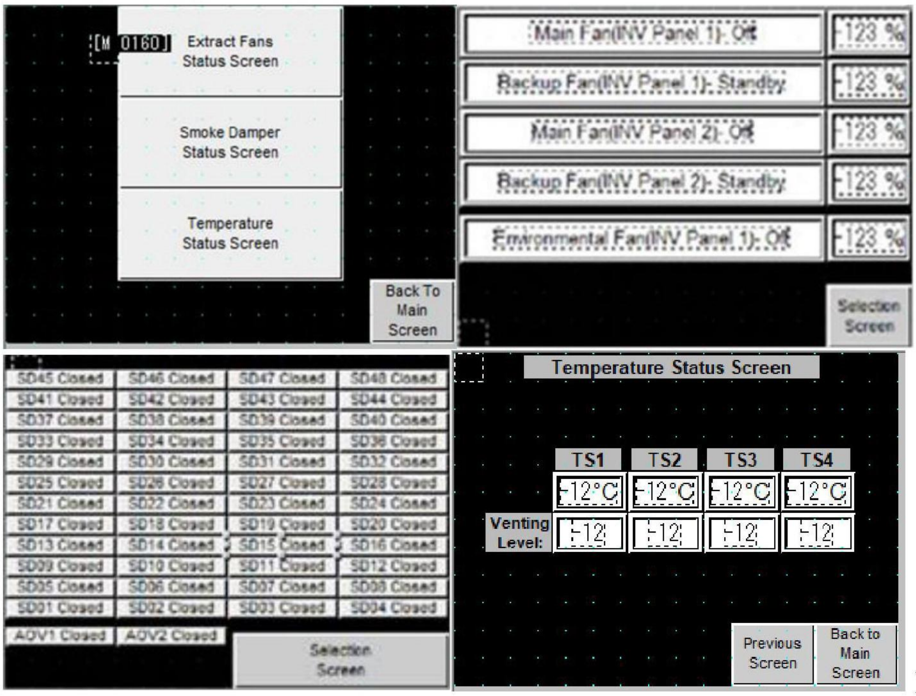


Figure 7-21: Status screen menu when "Status Screen" button is pressed from the HMI menu first screen (top left). "Extract Fans Status Screen" (top right). "Smoke Damper Status Screen" (bottom left). "Temperature Status Screen" (bottom right). All screens shown are taken from {MET00018074}.

7.9.50 The damper status on this screen is based on the most recent control signal sent to the dampers, and not the physical state of the dampers at that time. See Section 7.12 for details. Therefore, the damper status screen on the HMI panel could not be relied upon to verify the physical position (open or closed) of the dampers in each lobby of Grenfell Tower.

7.9.51 It is not clear to me whether the persons carrying out the commissioning and maintenance of the smoke control system were aware that the damper status screen on the HMI panel was not based on an actual signal back from the damper to the HMI Panel.

7.9.52 In Section 8, I set out my investigation of whether any visual inspections of the open/closed position of the lobby AOVs was carried out during either commissioning or maintenance of the smoke control system.

7.9.53 **Screens visible in "ON" mode**

7.9.54 If the HMI were turned "ON" with the panel in fireman's override mode, the main screen would appear as shown in Figure 7-22. I have explained the functions of the "Turn System Off" and "Restart System" buttons in Section 7.9.1.

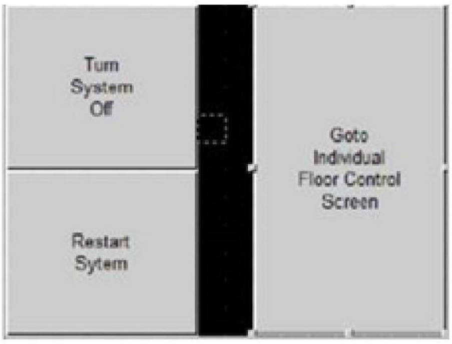


Figure 7-22: Fireman's override main screen (left) taken from {MET00018074}.

7.9.55 If the button labelled "Go[-]to Individual Floor Control Screen" were pressed the "Individual Floor Control Screen" would appear as shown in Figure 7-23.

7.9.56 This would allow the firefighters to change the floor of activation from that indicated on the HMI touchscreen panel, as explained in Section 7.9.17.

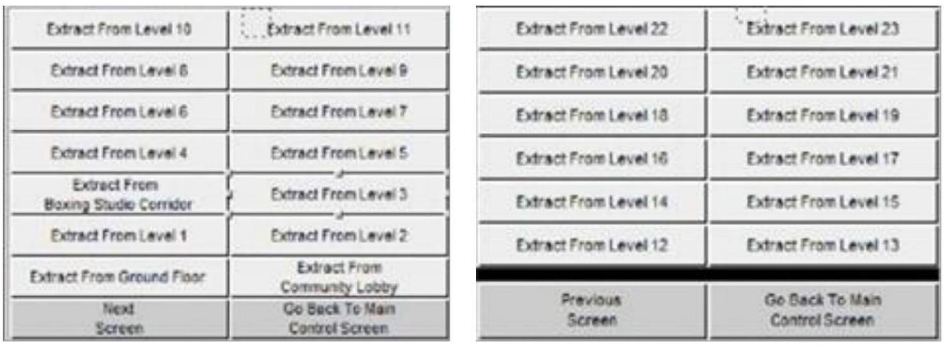


Figure 7-23: Fireman's override Individual Floor Control Screens taken from {MET00018074}.

7.9.57 If firefighters used the HMI touch screen on the "Individual Floor Control Screen" or activated the fireman override switch in one of the lobbies (there should no other fireman override switch activated at this point), the "Individual Floor Control Screen" would indicate the level which was selected for extraction as seen in Figure 7-18 which shows the message "*Extracting from Level 18*".

7.9.58 My team's analysis has found that this screen did not always accurately indicate the level the system is operating at.

7.9.59 For example, in the scenario where activation of a detector caused the system to operate at Level 4 with the HMI set to "Auto", turning the HMI to "ON" as explained in Section 7.9.17 (Item 3) would not make changes to the system's operation and the system would continue to operate at Level 4.

7.9.60 However, the "Individual Floor Control Screen" on the HMI screen would not show that the system was extracting on any floor as no yellow key switch would have been activated at this point (Figure 7-22). Therefore, although the system was operating at Level 4, there would be no indication of that on the HMI screen.

7.9.61 Following the scenario above, an activation of the yellow key switch on another floor e.g. Level 11, would cause the system to operate at Level 11 and the "Individual Floor Control Screen" on the HMI panel to display the message *"Extracting from Level 11"*.

7.9.62 If the "System Turn Off" button were selected, followed by the "Restart System", the system would re-activate on the original floor of automatic activation, as explained in Section 7.9.17 (Item 12).

7.9.63 My investigation into the HMI panel has shown it to be a complex device with many different possible controls. Further complexity is introduced by the interaction between the signals sent by the HMI panel to the main control panel and the signals sent by the yellow key-switches to the lobby on each floor.

7.9.64 A clear understanding of these interactions was required to enable an adequate set of commissioning tests to be undertaken to ensure that the controls would enable the system to be operated reliably and to ensure that operation of several different controls would not lead to any unexpected operation of the smoke control system.

7.9.65 In Section 7.10, I set out my investigation of whether the HMI panel could be used - in conjunction with the printed instructions provided within the HMI panel enclosure in the Ground floor entrance lobby - to manually control the smoke control system in Grenfell Tower.

7.10 Instructions provided next to the HMI panel

7.10.1 A set of instructions was provided directly below the HMI panel in Grenfell Tower, as indicated in Figure 7-24 (instructions detailed in Figure 7-25). I note that the title of the instructions was:

"Basic how to use guide when activated"

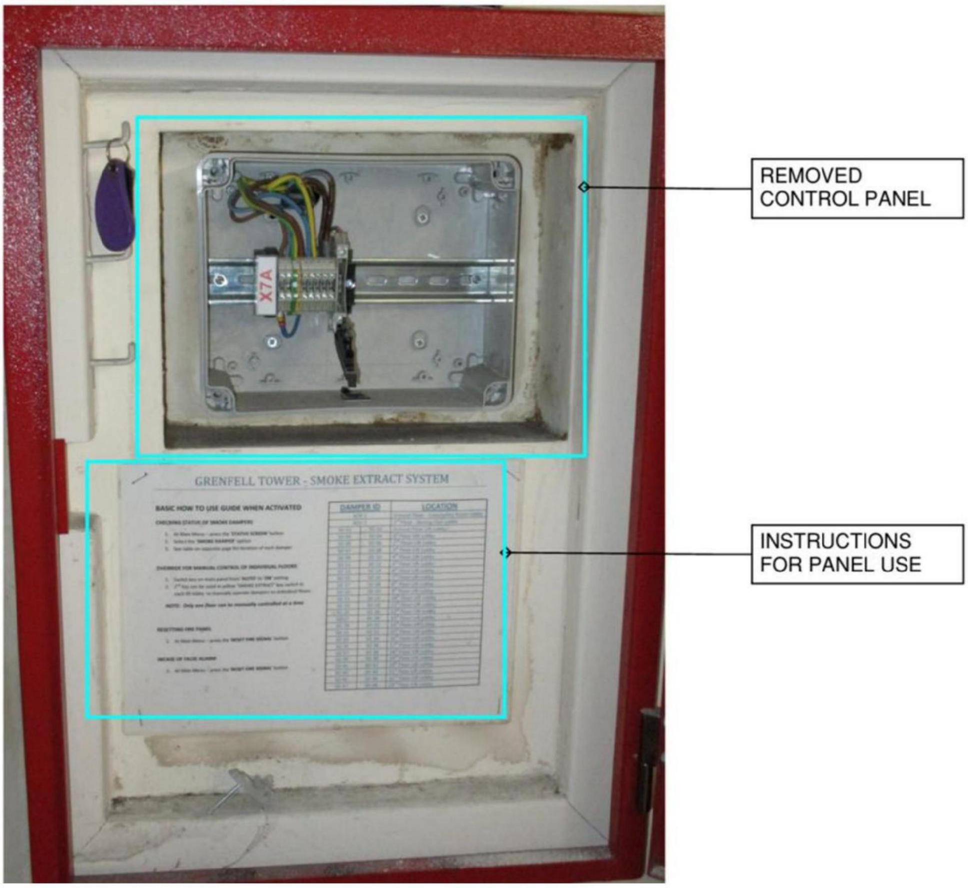


Figure 7-24: Instructions located adjacent to the HMI panel

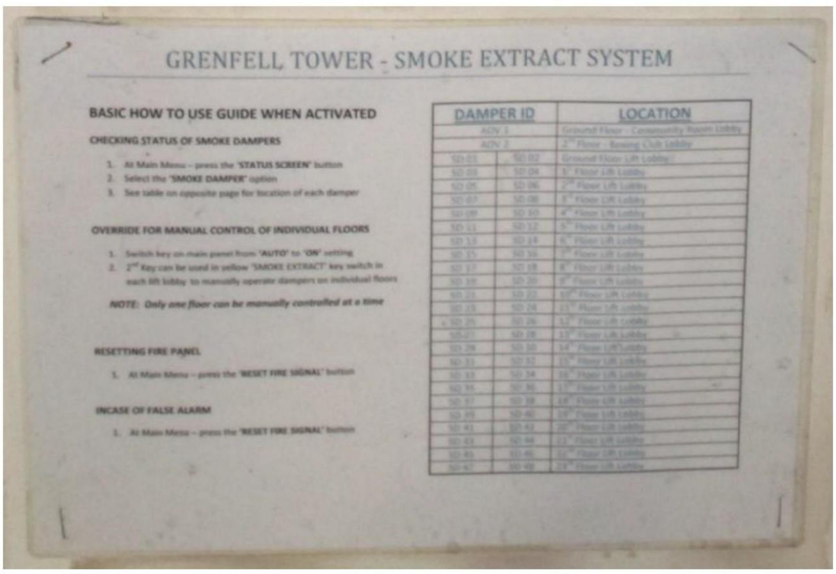


Figure 7-25: Detail of laminated instructions sheet

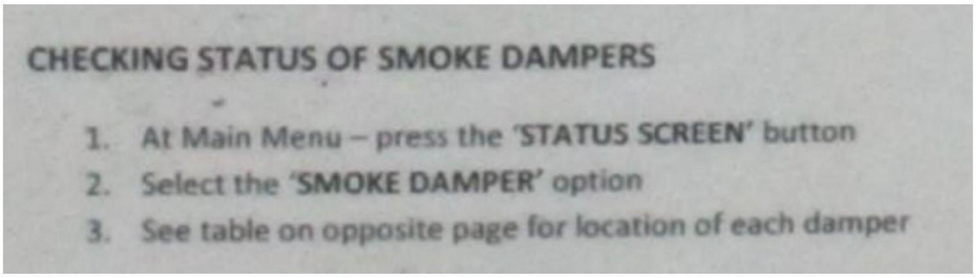
7.10.2 The instructions provided for the Grenfell Tower smoke extract system are broken into four parts:

a) *Checking status of smoke dampers*
b) *Override for manual control of individual floors*
c) *Resetting fire panel*
d) *Incase* [sic] *of false alarm*

7.10.3 I will go through each of these in the sections below and compare them to the input screens from the HMI that I have extracted from the HMI programming software ({MET00018074}).

7.10.4 **Checking status of smoke dampers**

7.10.5 The instructions for checking smoke dampers are as shown in Figure 7-26:


CHECKING STATUS OF SMOKE DAMPERS

1. At Main Menu – press the **'STATUS SCREEN'** button
2. Select the **'SMOKE DAMPER'** option
3. See table on opposite page for location of each damper

Figure 7-26: Excerpt of first instruction set

7.10.6 As can be seen in Figure 7-27, the Status Screen button was on the far right. The term on the button matches the term used in the instructions.

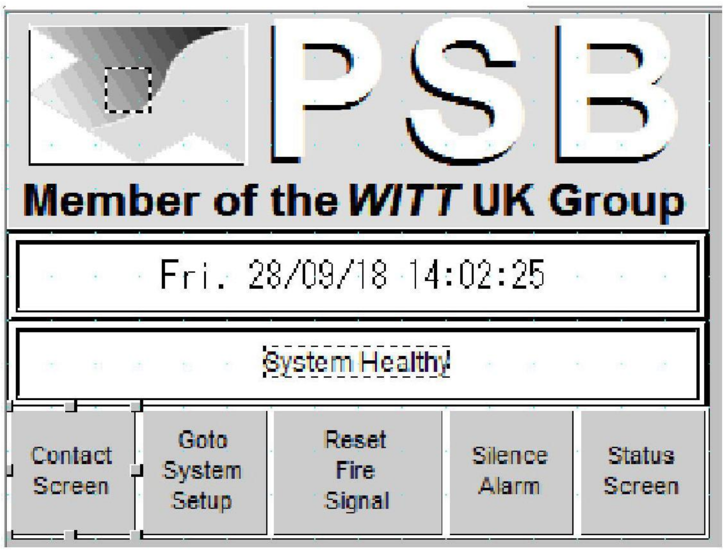


Figure 7-27: Main screen of HMI panel menu

7.10.7 On pressing the Status Screen Button, the user would be presented with the following screen:

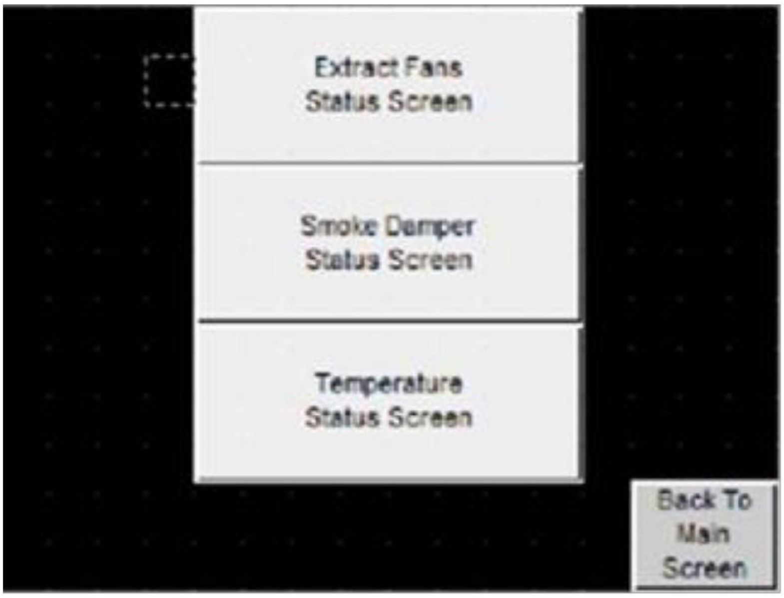


Figure 7-28: HMI Status screen menu

7.10.8 This screen would allow the user to view the status of either the fans or the dampers. The instructions would then tell the user to select the "Smoke Damper" option. Pressing this button would return the user to the following screen:

Figure 7-29: Damper status screen

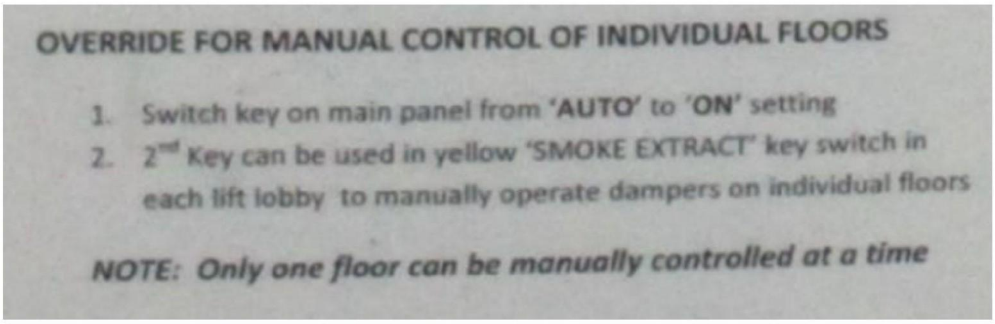
7.10.9 All of the damper IDs on the instructions sheet are replicated on the HMI screen, enabling the user to understand where each pair of dampers was positioned in the building.

7.10.10 As explained in Section 7.12, the status shown on the touch screen only reflected the power signal sent to operate the damper actuator on each floor and not the actual position/state of the dampers. It could not be relied upon to understand the physical open/closed position of the dampers.

7.10.11 The instructions provide no guidance as to the purpose or use of the "Fan Status" or "Temperature Status" screens, the other two tiles on the touchscreen in this mode.

7.10.12 **Override for manual control of individual floors**

7.10.13 The second set of instructions (Figure 7-30) explains to the user how to gain manual control of the smoke extract system and direct it to activate on a specific floor.



OVERRIDE FOR MANUAL CONTROL OF INDIVIDUAL FLOORS

1. Switch key on main panel from **'AUTO'** to **'ON'** setting
2. 2nd Key can be used in yellow 'SMOKE EXTRACT' key switch in each lift lobby to manually operate dampers on individual floors

NOTE: Only one floor can be manually controlled at a time

Figure 7-30: Excerpt of second instruction set

7.10.14 If the user inserted the key and turned the system from "Auto" to "On", the following screen would appear:

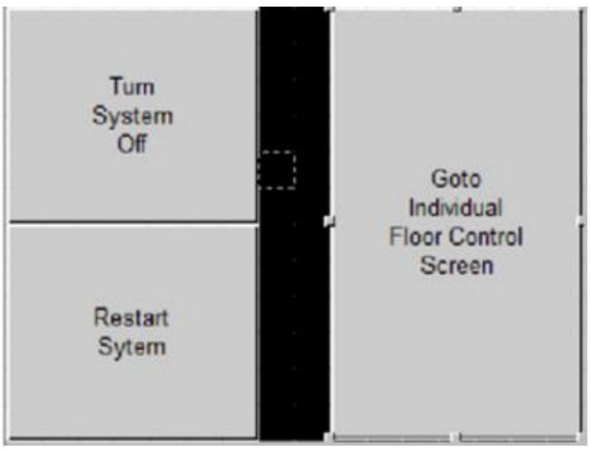


Figure 7-31: Fire brigade override screen

7.10.15 This screen would provide the user with three options. However, the instructions would not indicate what each option does.

7.10.16 Instead, the printed instructions would direct the user to the yellow key-switch in each "lobby", noting that only one can floor could be manually controlled at one time.

7.10.17 The instructions state that only one floor can be manually controlled at any one time. However, they do not make clear the more complex requirements, which were that a user had to turn off the yellow key-switch at the floor of operation before another yellow key-switch could be operated to change the floor of operation.

7.10.18 The options on this screen include options to turn the system off and to restart the system. The instructions do not explain to the user what might happen if either of these options is selected.

7.10.19 My investigation into the control software indicates that operating the "Turn System Off" option would close all the dampers and shut the fans off.

7.10.20 A user would then need to press the "Restart System" for the system to restart.

7.10.21 However, as I have explained in Section 7.9.17 (item 12), activation of the "Restart System" option would restart the system (restarting the fans and re-operating the dampers on the original fire floors), regardless of whether a manual yellow key switch had been activated elsewhere. This should not be confused with a system reset.

7.10.22 The override screen also provided access to an "individual floor control screen", presented below:

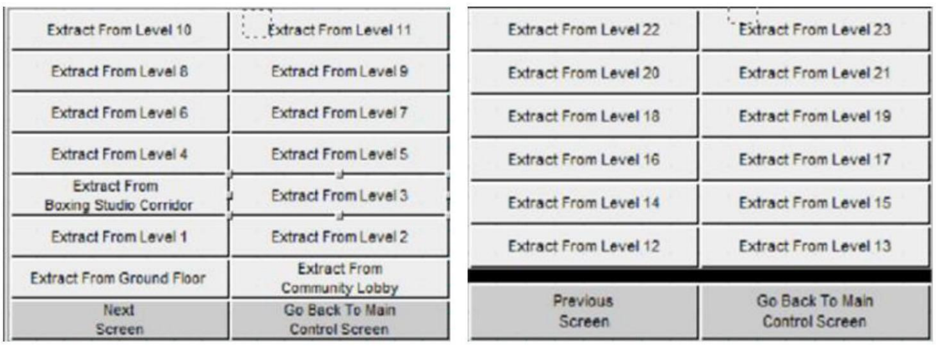


Figure 7-32: HMI Individual floor control screens

7.10.23 This took the form of a series of tiles on the touch screen, one for each floor. The instructions do not explain what would happen if one of these tiles were pressed by the user.

7.10.24 The instructions do not explain that the yellow key-switches' activation took precedence over a subsequent user activation on one of these buttons.

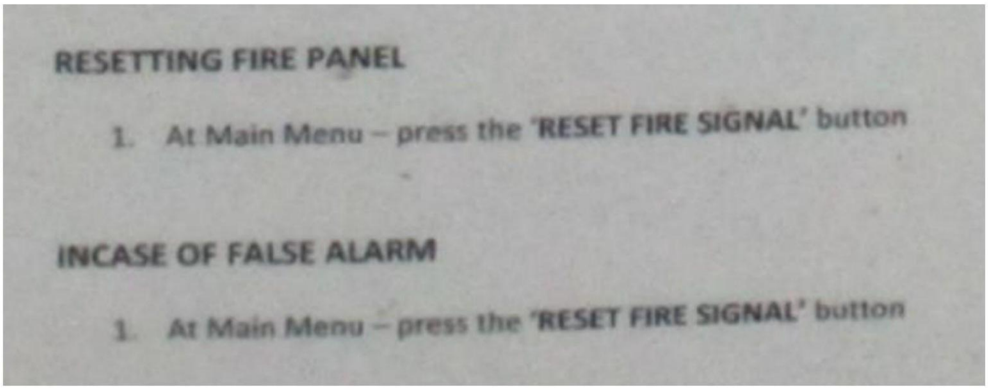
7.10.25 This could lead firefighters into thinking that they could override the system from the HMO panel once it had already been activated by a yellow key switch.

7.10.26 **Resetting fire panel and In Case of False Alarm**

7.10.27 The final two instructions relate to resetting of the smoke control system.

7.10.28 The HMI panel button on the main screen of the HMI panel (Figure 7-27) states "Reset Fire Signal".

7.10.29 The instructions state:


RESETTING FIRE PANEL

1. At Main Menu – press the 'RESET FIRE SIGNAL' button

INCASE OF FALSE ALARM

1. At Main Menu – press the 'RESET FIRE SIGNAL' button

Figure 7-33: Final excerpt of instructions

7.10.30 The instructions do not explain what would happen to the smoke control system on pressing the reset button.

7.10.31 As I have explained in Section 7.9.17 (Item 13), resetting the fire signal when smoke was present on one or more floors of the building, would clear the value of the activated fire zone stored on the system, and for 8 seconds the system would not read any new smoke detected signals.

7.10.32 This is because PSB have confirmed the system would cut off power to the smoke detectors for 8 seconds to allow them to reset. After 8 seconds, the system would restore power to the smoke detectors and resume monitoring them for the next new activated fire zone.

7.10.33 **Functions not explained in the instructions**

7.10.34 In Section 7.9, I set out the specific functions that the HMI panel allowed a user to undertake by means of the touchscreen.

7.10.35 The following functions were not explained in the instructions provided adjacent to the HMI panel:

a) The ability to change the floor of operation using the HMI touchscreen interface ("individual floor control screen") if the HMI panel were switched to "ON"

b) How the touch screen "Individual floor control screen" interacted with the use of the yellow key-switch provided on every floor. Both could not operate at the same time and the yellow key switch activation would override any touch screen instruction.

c) The potential for inaccuracy of the damper status screen as they could not indicate whether each damper was physically open or closed.

d) The "Individual floor control screen" did not necessarily show the actual floor of activation, and this could lead to confusion for the firefighters when conducting their operations.

7.10.36 **Conclusions on effectiveness of smoke control system instructions**

7.10.37 These instructions, as their title suggests, provided a very basic indication of how to use the system.

7.10.38 The instructions provide specific guidance on how to:

a) Select a floor of operation manually by activation of the yellow key-switch but did not indicate that the floor of operation could also be selected directly from the HMI screen.

b) Reset the system by pressing the "reset fire signal" button but did not explain the consequences of doing that.

7.10.39 The instructions also did not provide any guidance on what several of the tiles on the touchscreen would do if pressed.

7.10.40 The instructions did not expand on the consequences of using some of the controls to operate the system. Nor did they specify any indicators which could be observed within the building to confirm its operation.

7.10.41 It is my opinion it would be unreasonable to expect a highly complex level of interaction with this system in a major fire. Equally, the level of complexity hidden within the system is striking.

7.10.42 However it is clear there is little guidance provided in the relevant published documents on this subject – please see Table 11-4 below.

7.10.43 I present what evidence I have of the LFB's interaction with the system on the night of the fire in Section 12 below.

Table 7-2 Guidance on information required to be provided to the fire brigade on the operation of the smoke control system in the event of a fire

Relevant Guidance	Requirement on instructions to be provided to fire brigade in the building on operation of the smoke control system	Requirement on training to be provided to the fire brigade on the operation of the smoke control system
BS 9999: 2008 Fire safety in the design, management and use of buildings. Code of practice.	Operating instructions required to be provided in emergency packs for the fire and rescue service but does not specific requirements on the operation instructions. ***Annex M "Operational information (emergency packs) for the fire and rescue service*** *Emergency packs should provide operational information needed by fire crews at the time of an incident, in a simple and useable format. Where appropriate they should include the following information:* … *c) any relevant information (including **operating instructions**) relating to equipment/fixed installations provided for means of escape or fire-fighting;* …	No reference to training the fire service about how to use the smoke control system.
BS 9991:2015 Fire safety in the design, management, and use of residential buildings – Code of practice	Operating instructions required to be provided in emergency parks for the fire and rescue service but does not specific requirements on the operation instructions. ***52 Information for fire and rescue service use*** *In large or complex residential buildings, particularly high buildings or those having extensive accommodation below ground level, it is of considerable advantage to the fire and rescue service if appropriate information about the building is made available to them. Where appropriate this should include:* … *b) relevant information (including **operating instructions**) relating to equipment/fixed installations provided for means of escape or fire-fighting;*	No reference to training the fire service about how to use the smoke control system.
CIBSE Guide E: Fire Safety Engineering (3rd Edition)	No reference to providing operating instructions.	No reference to training the fire service about how to use the smoke control system.
BS EN 12101-6:2005 Smoke and heat control systems. Specification for pressure differential systems. Kits	No reference to providing the Fire and Rescue Service with operating instructions for the smoke control system ***14 Documentation*** ***14.1 Approving authority requirements*** *The approving authority shall be provided with full details of the installation. These shall include:* … *f) full operational details describing in words and by diagram the exact sequence of actions that will occur in the pressure differential system and in the normal ventilating system when a fire occurs in the building (see Clauses 4 and 7);*	No reference to training the fire service about how to use the smoke control system.

Relevant Guidance	Requirement on instructions to be provided to fire brigade in the building on operation of the smoke control system	Requirement on training to be provided to the fire brigade on the operation of the smoke control system
PAS 79:2012 Fire risk assessment guidance and a recommended methodology	No reference to providing the Fire and Rescue service with operating instructions for the smoke control system.	*16 xiv. In large and complex premises, it is important that there are arrangements for local fire and rescue service crews to familiarize themselves with the premises and* ***with, for example, the facilities for firefighting*** *and potential risks to firefighters.* *In some such premises, there might be a need for pre-planning emergency procedures with the fire and rescue service.*
Local Government Association - Fire safety in purpose-built blocks of flats (2012)	No reference to providing the Fire and Rescue service with operating instructions for the smoke control system but recommends provision of plans detailing information on the services within the building *79.12 In large, more complex blocks of flats, it can be of great assistance to the fire and rescue service to keep plans on the premises detailing information on the layout of the building* ***and its services****. This can be helpful at the time of an incident in dealing with the emergency.*	Not specifically training but familiarisation visits. *"88.1 Fire and rescue services routinely undertake visits to certain premises in order for operational crews to become familiar with the features of the building, including:* *...* ***• the provision of any special facilities for their use****, such as fire-fighting lifts and fire mains."*
BS 5588-5:2004 Fire precautions in the design, construction and use of buildings. Access and facilities for fire-fighting	No reference to providing the Fire and Rescue service with operating instructions for the smoke control system. *12 Drawings for fire service use* *In large or complex buildings and those having extensive accommodation below ground level, it can helpthe fire service if drawings of the building showing fire protection and escape facilities are made available.* *Drawings should include plans and sections to a scale agreed with the enforcing authorities.* *...* *Examples of items that should be indicated on the plans include:* *...* ***j) smoke outlets and control systems;***	No reference to training the fire service about how to use the smoke control system.
SCA Guide 2012 / 2015	No reference to providing the Fire and rescue service with operating instructions	No reference to training the fire service about how to use the smoke control system.

7.11 System communications: Operation of the outstations

7.11.1 There are 22 outstations in Grenfell Tower, one on every floor from Levels 2 to 23. The outstations are located in the service riser within the lobby for each level, with the exception of the outstation on Level 3 which is located behind the MDF wall panel of the lobby.

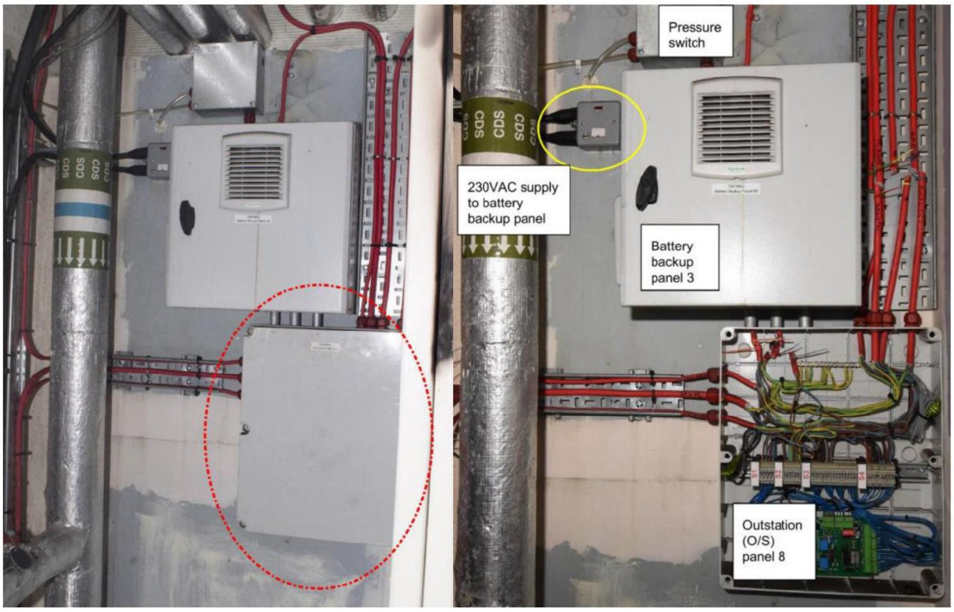


Figure 7-34: Outstation located within lobby riser cupboard at Level 9 *enclosed in a wall mounted plastic box* {MET00039807} (left, {MET00072087}). Same outstation with box cover removed (Figure 118, {MET00039807}) (right).

Figure 7-35: Outstation located behind MDF wall panel at Level 3 {MET00071284} (left). MDF wall panel removed with outstation circled {MET00071284} (right).

7.11.2 The outstations would send signals from input devices connected to them and onwards to the Master Control panel. This panel ran the software that ultimately operated the smoke control system.

7.11.3 The input devices connected to the outstations included the firefighter override switch, smoke detectors and the pressure switch, which were on the same level as the outstation with the exception of ground level and Level 1 devices which were connected directly with the Master Control Panel.

7.11.4 The outstation would also receive signals from the Master Control panel and would send the signals to the output devices connected to them. These included the inverters that control the fans, and the dampers which were connected via junction boxes and actuators.

7.11.5 The outstations provided on every other floor from Level 2 to Level 21 as well as at ground and roof level were powered by the building main electrical supply, but also had a battery backup feed as a 24V supply input to the outstations (see Section 7.2.10).

7.11.6 As an example, Figure 7-36 shows the different devices connected to the outstation on Levels 4 to 23.

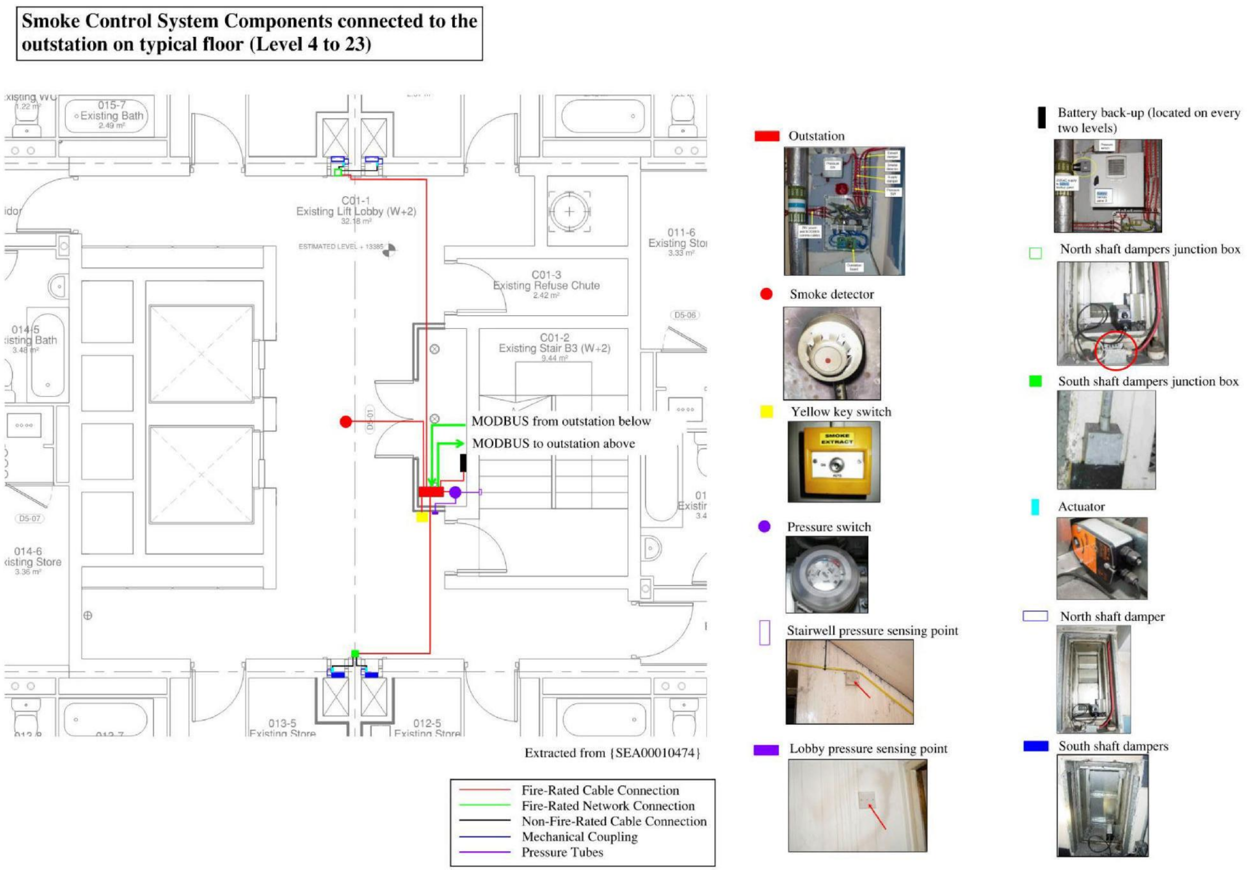


Figure 7-36: Outstation on a typical floor (Levels 4 to 23) with connected smoke control components.

7.11.7 The outstations were connected to the outstation of the floor below and the outstation at the floor above (p.26, {MET00065879}) forming a communications daisy-chain up the building.

7.11.8 The various input and output devices on Level 1 did not have a dedicated outstation, but instead were connected directly to the main control panel on Ground floor.

7.11.9 There was also an outstation within the panel at ground level Hub room that housed the inverters for the fans at Level 2. This outstation provided signals to the dampers at Level 2 and the inverters to control the fans at level 2.

7.11.10 Another outstation was also located within the panel at the roof plant room, that housed the inverters for the roof fans. This outstation provided signals to the inverters to control the fans at roof level.

7.11.11 The HMI panel located at the Ground floor lobby was directly connected to the main control panel only and did not connect directly to the outstations on each floor.

7.12 System output: Operation of the dampers

7.12.1 The dampers on each lobby were operated by an actuator. The actuators were "*mounted on the bottom right-hand side of the damper and had a metal protective cover*" (p.118, {MET00039807}). An actuator is a motor that can be "*energised by applying 24 volts to the open/close electrical terminals*" in order to change the position of the damper blades.

7.12.2 Figure 7-37 below shows examples of dampers in an open and closed position. The dampers are driven open or closed by the actuators which are connected to the dampers via mechanical coupling.

Figure 7-37: South shaft dampers at Level 11 in an open position {MET00071754} (left). South shaft damper at Level 4 in a closed position.

7.12.3 Figure 7-38 shows the electrical connections from a damper back to the outstation, via an electrical junction box.

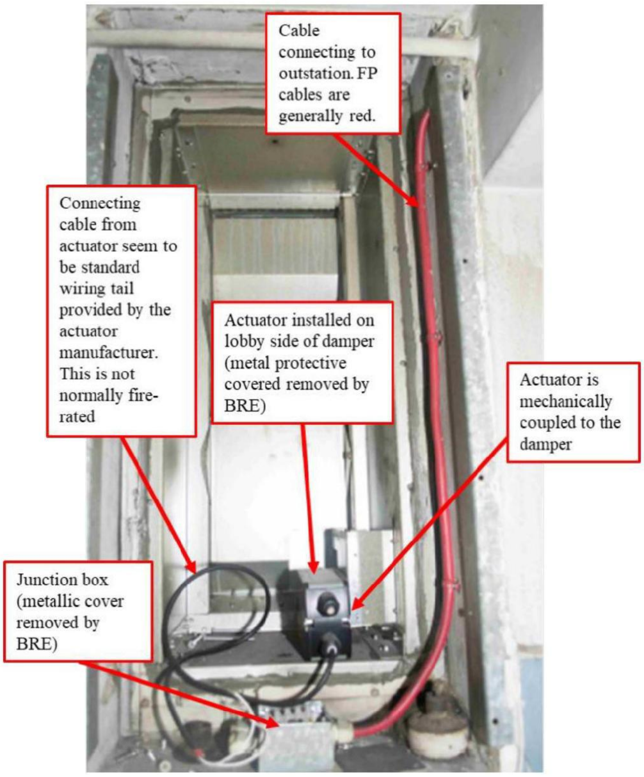


Figure 7-38: Wiring connections from the damper.

7.12.4 Figure 7-39 shows a close-up image of the actuator from the Level 6 damper.

7.12.5 BRE's on-site investigation report (p.118, {MET00039807}) identifies that each actuator had two sets of cables exiting the casing. One set of cables was connected to the outstation as described above and this enabled the electrical power to be applied to the damper to drive it open or closed.

Figure 7-39: Actuator from Level 6 North AOV {MET00071966}

7.12.6 With regard to the other cable, BRE stated that (p.118, {MET00039807}):

"the second cable was connected to two internal auxiliary switch contacts which 'made' when the damper motor was in the fully open and fully closed position to provide an electrical feedback signal. This cable had been cut off at the cable gland on every actuator inspected by BRE which indicates that the smoke control system did not utilise the damper position electrical feedback facility."

7.12.7 The signal cables were cut, and therefore feedback could not be provided to the main control panel, or the HMI panel, in relation to the physical position of the dampers. The HMI panel could only identify those dampers to which open/close signals had been sent.

7.12.8 RINA also reported this finding (p.7, {MET00072161}).

7.12.9 Therefore, the dampers on each floor could be opened by the following four methods:

a) Activation of a smoke detector in the lobby;

b) Activation of a yellow key-switch in the lobby (only applicable when HMI switch is on "ON");

c) Activation via the HMI touch screen in the ground level entrance lobby; and

d) Manual override at the actuator, using a hand crank inserted into the slot on the actuator, and so physically open the dampers (see Figure 7-40). BRE's onsite investigation found that the actuators can only be manually overridden through this method when "*the linkage between the actuator and the damper was mechanically separated*...[which] *could only be done if the three screws retaining the actuator to the damper frame were removed.*" {MET00039807}.

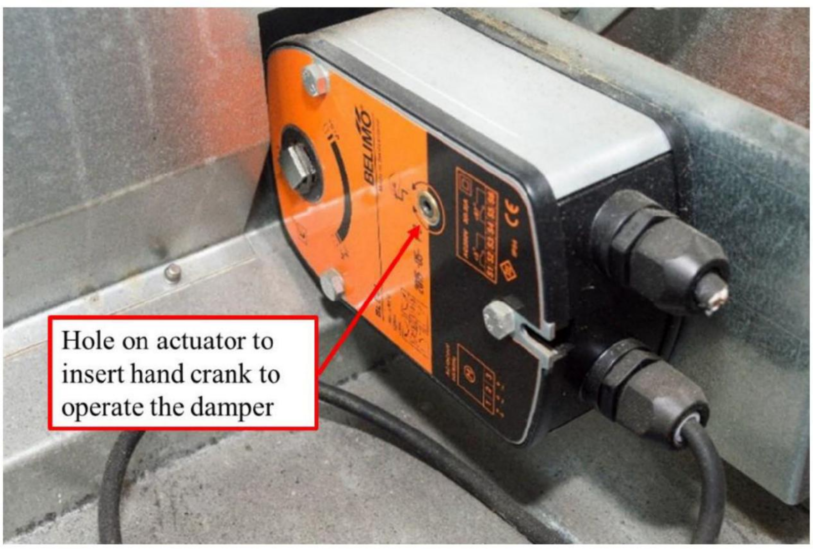


Figure 7-40: Manual override of the actuator via a hand crank.

7.12.10 Only the dampers on the active floor should remain open. The dampers to the lobby on all other floors should remain closed or become closed.

7.12.11 The end-to-end activation of the dampers through each of these control systems is illustrated in Figure 7-41, Figure 7-42 and Figure 7-43

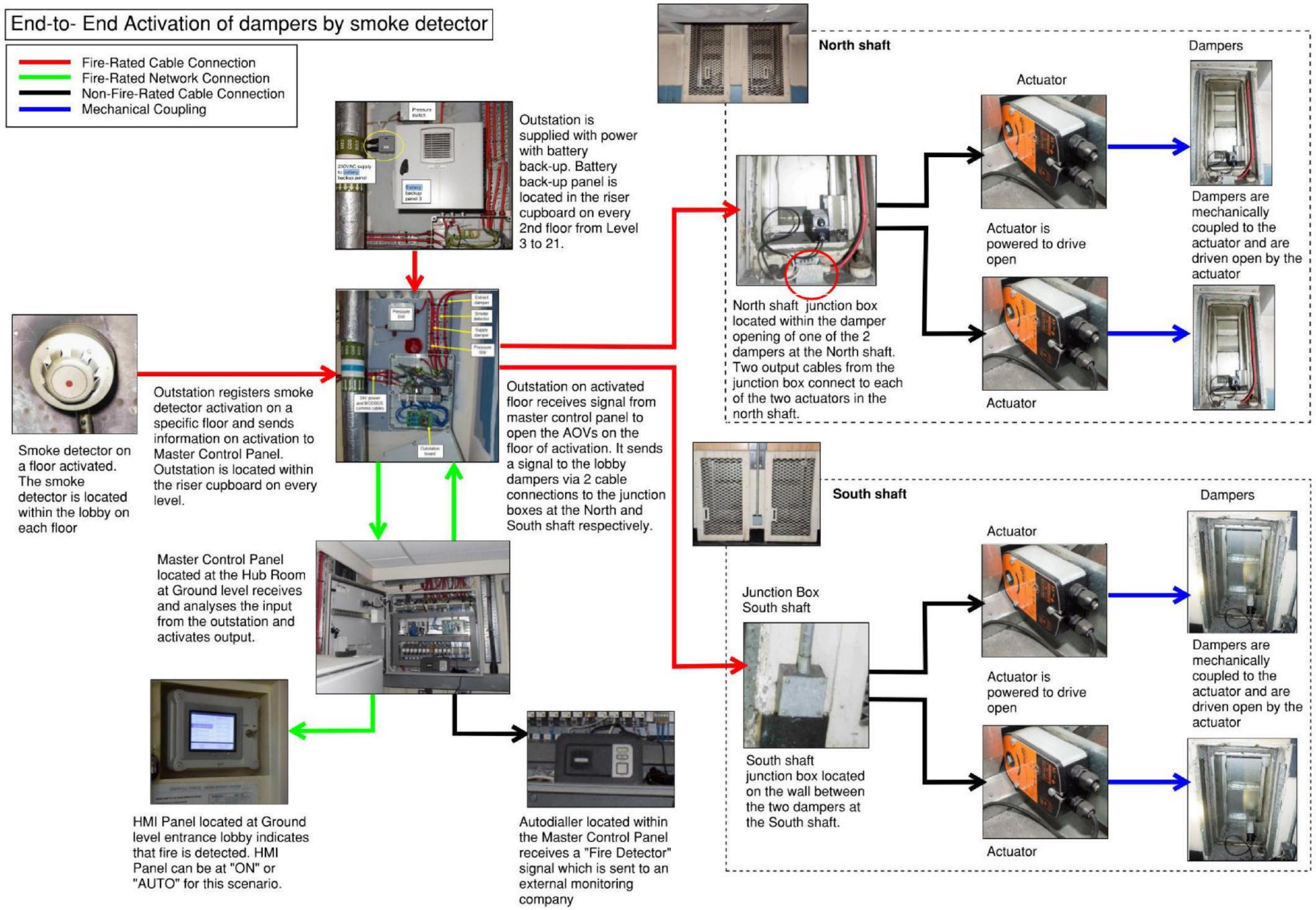


Figure 7-41: Activation of a smoke detector that cause the damper of that floor to open.

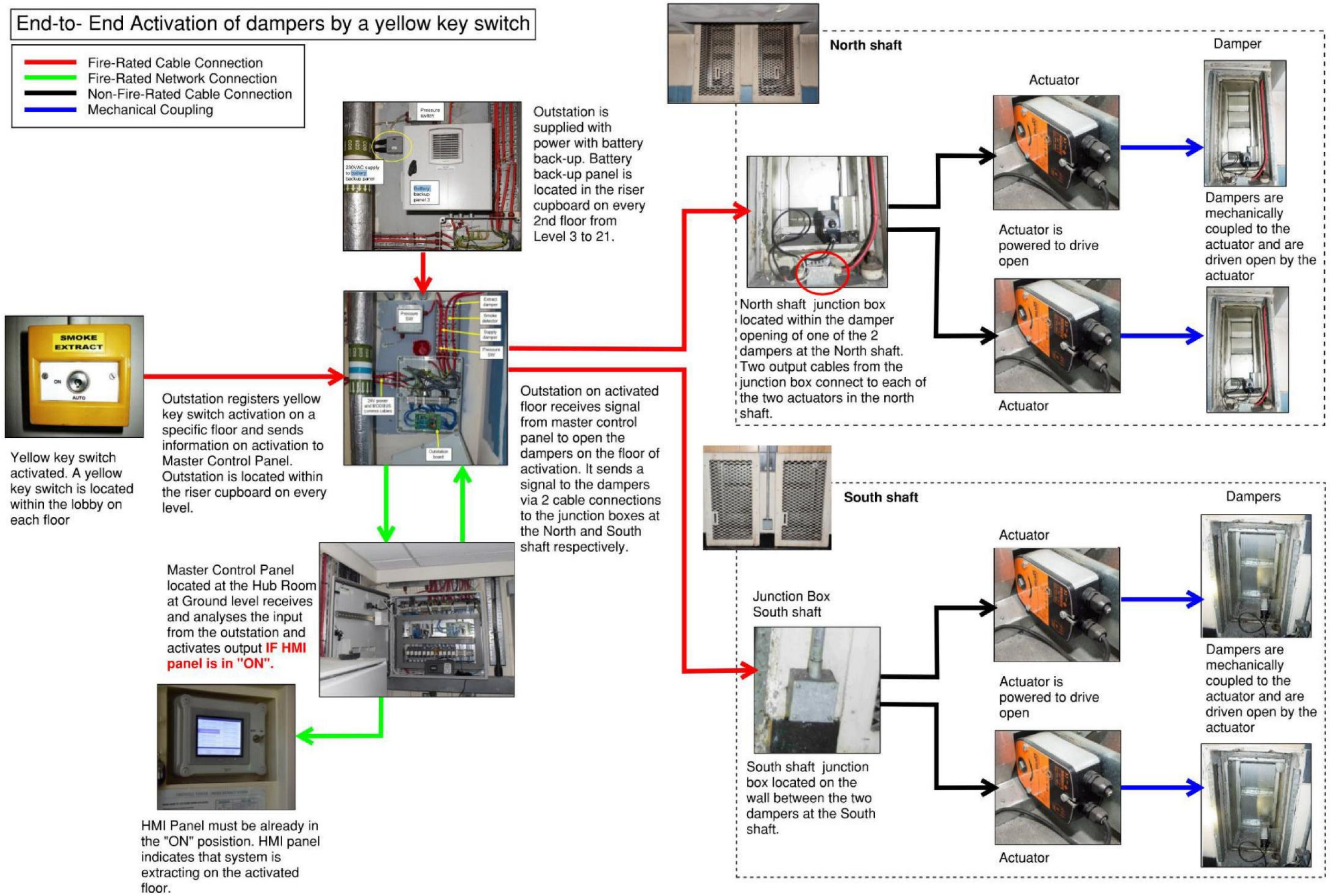


Figure 7-42: Activation of a fireman's override switch on that floor (if the HMI were set to "ON") which would cause the damper of that floor to open.

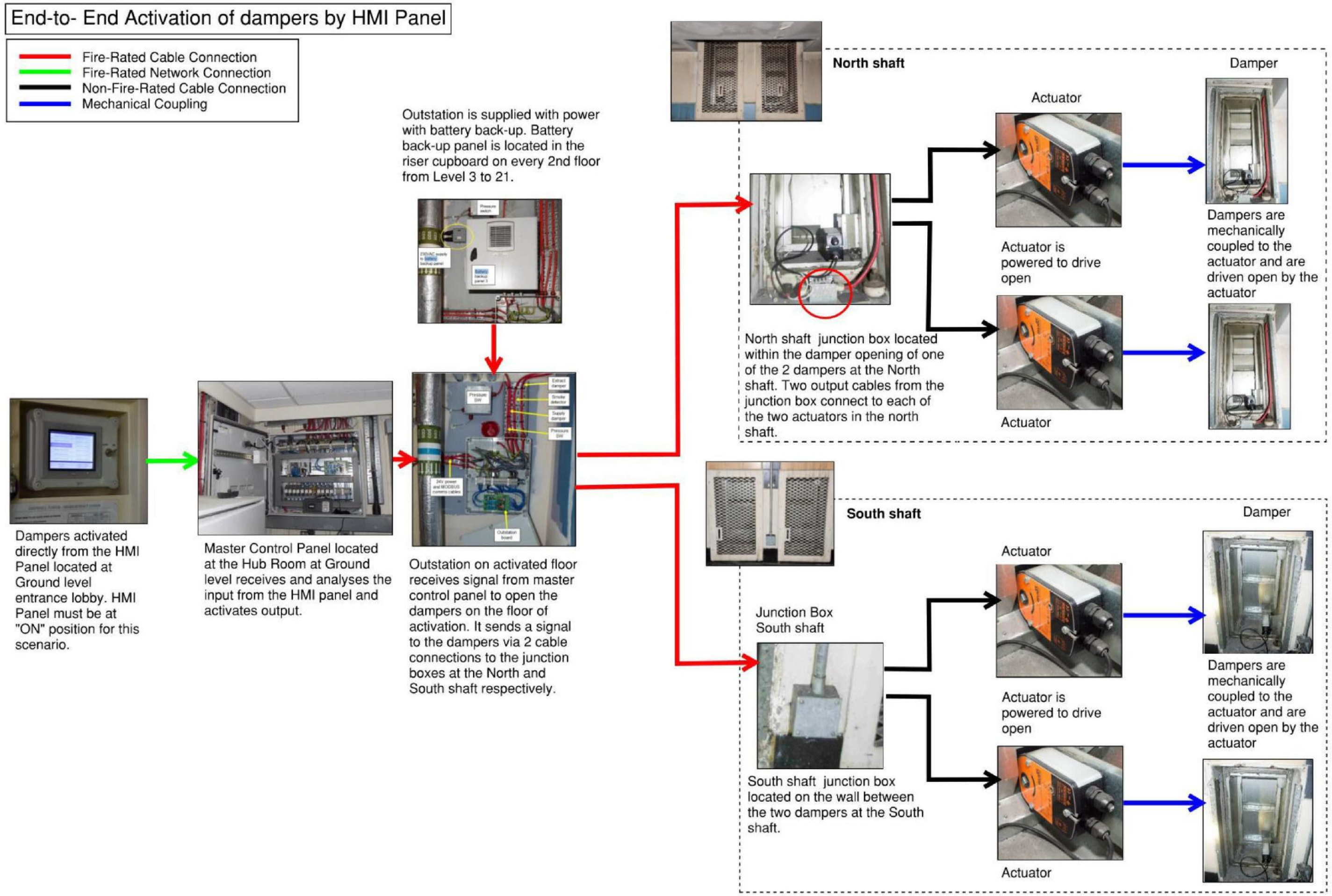


Figure 7-43: Activation via HMI touch screen (if the HMI were turned to "ON") which would cause the damper of that floor to open.

7.13 System output: Operation of the bypass dampers and the Level 2 fans in environmental and smoke mode

7.13.1 A set of dampers was provided in the ductwork at Level 2 to enable the environmental fans and smoke control fans to be separated from the other fan when in operation. Four dampers were provided on site, as indicated in Figure 7-44 and Figure 7-45.

7.13.2 The intended operation of fans and dampers at Level 2 is set out in Figure 7-44, Figure 7-45 and Table 7-3.

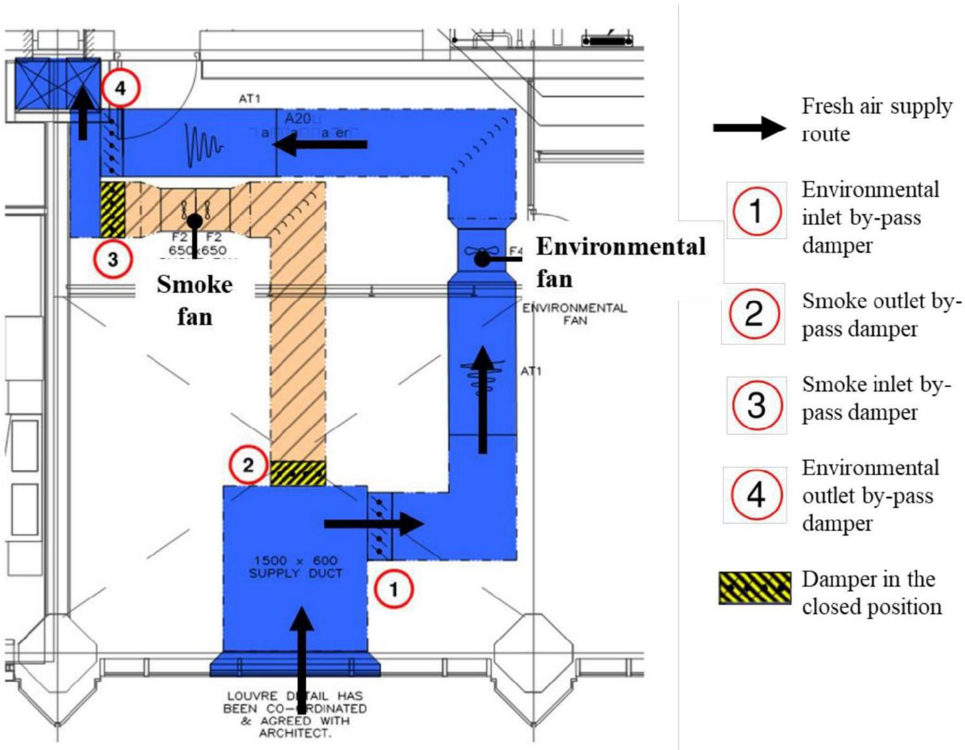


Figure 7-44: Smoke system at Walkway Level (Level 2) – environmental operation. Original drawing was within {RYD00000577}

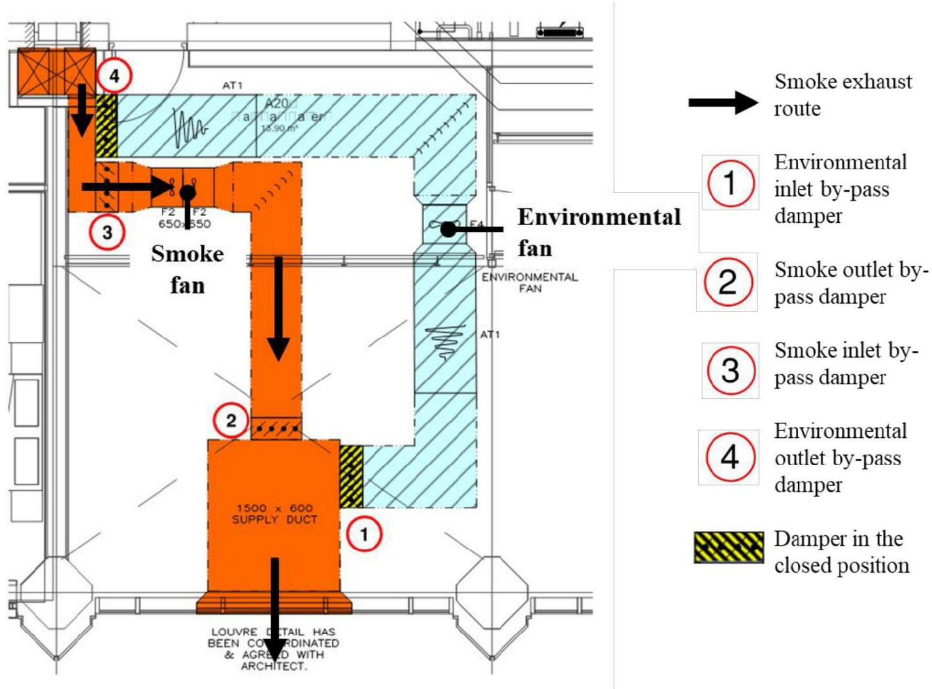


Figure 7-45: Smoke system at Walkway Level (Level 2) – smoke control operation. Original drawing was within {RYD00000577}.

Table 7-3: Programmed operation of fans and dampers at Level 2 for environmental and smoke operations.

	Environmental mode	Smoke mode
Smoke fan	off	on
Environmental fan	on	off
Damper 1	Open	Closed
Damper 2	Closed	Open
Damper 3	Closed	Open
Damper 4	Open	Closed

7.13.3 Issues regarding the Level 2 fans and damper operations

7.13.4 First, damper 2 was found to be "permanently open" by BRE.

7.13.5 The control wiring for the Level 2 environmental fan bypass dampers (Damper 1 and Damper 4 in Table 7-3) were investigated in BRE's site report {MET00065879}.

7.13.6 They reported that the bypass dampers for the environmental fan were wired to operate simultaneously as required, as they were connected by cable from a single set of terminals in the wiring junction box, to a cable from the outstation within the panel housing the fan inverters. The location of the junction box is not specified in the BRE report. I have no further evidence to support BRE's findings.

7.13.7 Contrary to the expected operation of the dampers, BRE found no wired power supply to the bypass damper connected to the outlet of the smoke fan (Damper 2 in Table 7-3). The damper was found to be in an open position; this indicated that the damper could have been "*permanently open*" {MET00065879} since handover.

7.13.8 Mr Partlow also described this damper in his second witness statement dated 26th March 2021 where he stated that the damper "*was not connected to the System*" and was "*permanently open*" as "*PSB's design only called for 3 dampers… so this damper was effectively redundant*" (p.7, {PSB00001372}).

7.13.9 According to PSB's Technical Submission Revision 6, dated 15th March 2016, there were only three quantities of by-pass dampers (p.21, {PSB00000214}).

7.13.10 I also note that while PSB referred to "bypass dampers to environment system clos[ing]", they also referred to a single "bypass damper to the smoke extract fan set open[ing]" (p.4, {PSB00000214}).

7.13.11 Therefore, BRE's findings that damper 2 was permanently open would not have adversely affected the system in environmental mode as it would not have affected the fresh air supply route.

7.13.12 It also would not affect the operation of the system in smoke mode as damper 2 was required to be open.

7.13.13 Figure 7-50 shows how the direction of airflow required from the environmental and smoke mode will not be affected with the damper 2 being permanently open.

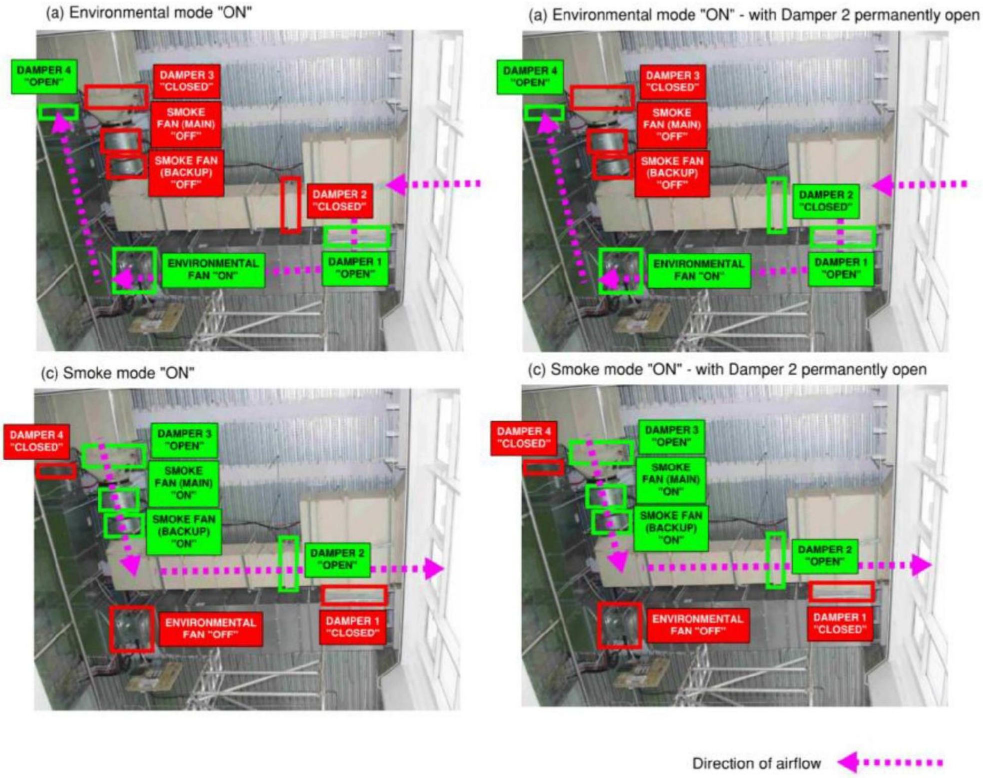


Figure 7-46: Illustration on how the permanently open damper 2 will not affect operation in environmental mode and smoke mode

7.13.14 Secondly there were discrepancies in documentation describing the connection between the bypass dampers and their outstation.

7.13.15 There is evidence that the bypass dampers at Level 2 associated with both the smoke control and environmental fans (refer to Dampers 1 – 4 as set out in Figure 7-44 and Figure 7-45 above) could not have operated as intended.

7.13.16 This is because I have identified that the "For Build" drawings by PSB {PSB00000274} appear to show wiring to all four of the bypass dampers at Level 2, the arrangement of which would not permit the dampers to operate as intended by PSB's design. Specifically, the connections to the individual terminals on the four dampers do not match the required connections, at the outstation, on the damper actuator data sheet for the Belimo actuator SM24A {PSB00000911}. From post-fire photographs taken on 21st February 2019 disclosed by MET{MET00040668}, there is evidence that the BLE24A actuator was installed for all 4 bypass dampers ({MET00040674}, {MET00040671}, {MET00040702}, {MET00040656})

7.13.17 If this was the case, on the 14th June 2017 each of those dampers may have been stuck in either an open or closed position, as they were not controllable. Then the environmental bypass dampers were not capable of closing, and the smoke control bypass dampers were not capable of opening, as was intended in PSB's Technical Submission, Revision 6 {PSB00000214}).

7.13.18 This may be a documentation error rather than an as-built error. I have seen no further photographic evidence regarding whether the correct connections (as per the damper actuator sheet {PSB00000911}) were provided.

7.13.19 However there is also no evidence these dampers were either commissioned or maintained (refer to Section 8). PSB's commissioning report {PSB00000224} stated that the bypass dampers were inspected during the commissioning process however Mr Partlow does not explain how this inspection was undertaken.

7.13.20 Further the BRE have also presented their findings on the wiring of the four bypass dampers as found on site. These findings only describe the connection from the by-pass dampers to the wiring junction box and not how it is then wired within the outstation.

7.13.21 The reconstruction by RINA did not include the operation of the Level 2 bypass dampers.

7.13.22 If the documentation reflects the installed condition, there is a possibility that had the bypass dampers been stuck closed, they would have caused the extraction system from the south shaft to be ineffective. The fans may also be damaged if they are forced to operate when the bypass dampers located at the fan inlet and fan outlets are shut.

7.13.23 This would have caused the smoke extraction from the fire floor, via the south shaft, to be reduced. I explore this further in Section 12.

7.13.24 I note that that BRE's post-fire investigation found that Damper 1, 3 and 4 were found to be in the closed position {MET00039807} while Damper 2 was found to be "permanently open" as discussed in Section 7.13.15.

7.14 System output: Operation of the fans at Level 2 and Roof level

7.14.1 I have set out in Section 7.9 how the fans would be operated by signals from the main control panel, and how their operation would be controlled by signals from the HMI panel.

7.14.2 I have also set out in Section 7.7 how the speed of the smoke control fans in Grenfell Tower was controlled by signals from the pressure switches provided on each floor.

7.14.3 The signals to operate the fans were sent via the communications network from the main control panel to the outstations within the panels located at ground floor hub room and at Roof Level. The outstations then sends the signal to the inverters to operate the relevant fans.

7.14.4 My investigation, and that of RINA's, indicate that the fans would operate as required by PSB's design.

7.14.5 However, adequate commissioning was required to demonstrate that the fan operation would lead to adequate airflow from the active floor to:

a) Enable 2m/s flow of air through the stair door when it was open; and

b) Maintain a minimum pressure difference of 25Pa between the lobby and the stair when the stair door was closed.

7.14.6 I have presented my review of the equipment required to measure these criteria in Section 8.8.

7.15 Secondary power supplies

7.15.1 Secondary power to the smoke control system was achieved at Grenfell Tower by a combination of two methods.

7.15.2 The fans were served by a power supply from Grenfell Walk in the event of a mains failure.

7.15.3 All other devices were provided with batteries in the event of a mains failure.

7.15.4 The components include:

a) Ten battery backup panels on every second floor between Levels 3 and 21 – serving the outstations on each floor (2 outstations per battery panel) and all associated input and output devices on those levels (dampers, smoke detectors and pressure sensors);

b) Two battery back-ups – one in each invertor panel (at Ground and Roof Levels);

c) A second mains supply from Grenfell Walk providing secondary power to the fan sets at Level 2 and Roof Level via automatic switching devices in the Ground Floor Hub and the Roof Plantroom.

7.15.5 Commissioning of the smoke control system required adequate tests of each of these devices because it was a requirement to demonstrate full performance of the smoke control system, in all relevant scenarios, in the event of a mains failure.

7.15.6 I explain my findings in Section 8.

7.16 Implication of the environmental mode's functioning

7.16.1 In the previous sections I have set out in detail how each of the key components of the smoke control system operated, and therefore contributed to the smoke control system performing as intended.

7.16.2 The smoke control system was also used to provide environmental ventilation (see Section 5.9).

7.16.3 The operation of the system in this mode is important because the operation of the system in environmental mode must not compromise the ability of the system to perform its smoke control function.

7.16.4 It is also important as any mechanical issues with components in environmental mode may also be a sign there are mechanical issues in smoke mode. The components are the same – just the fans operate at different speeds, and the pressure switches are not used in environmental mode.

7.16.5 This is particularly important with regard to commissioning testing. I would expect testing to be undertaken to demonstrate that the smoke control system could operate from any of the possible "non-fire" states. These states were (p.11, {MET00018469}:

a) Environmental-off (night time between 20:00 and 09:00 when the BMS was programmed not to activate environmental mode, see Section 7.16.39);

b) Environmental standby (daytime between 09:00 and 20:00, see Section 7.16.39);

c) Environmental mode operating (see below).

7.16.6 I set out my assessment of commissioning of the system, and if PSB considered these three states when commissioning the smoke control system, in Section 8.

7.16.7 There is conflicting information available to me regarding the intended operation of the system in environmental mode.

7.16.8 Here I set out both the original intent and the revised programming of the system available to me in the evidence.

7.16.9 I have done this as Mr Partlow required this information in order to develop an adequate series of commissioning tests.

7.16.10 **Original proposed system of operation**

7.16.11 The health and safety file issued by JS Wright and included in Rydon's Building Manual ({TMOM00001931}, {TMOM00001703}), states that the environmental ventilation system would operate on every level at the same time, i.e.:

a) All dampers to the lobby would be open;

b) The environmental fan at Level 2 would be running at full design speed; and

c) The smoke control fans at roof level would be running at full design speed.

7.16.12 Therefore, if this mode of operation were activated, on activation of smoke control mode:

a) All the lobby dampers would need to close, except for those on the fire floor;

b) The environmental fan at Level 2 would shut down and the dampers would isolate the fan from the rest of the system; and

c) The Level 2 smoke control fans would run at full design speed.

7.16.13 **Revised system of operation**

7.16.14 Project correspondence available to me contradicts this and appears to confirm this operation method was changed as I describe below.

7.16.15 The change of approach was adopted due to the original single speed environmental supply fan located at Level 2 generating too much *"break-out noise"* (noise to the space around the fan), as set out in {PSB00001093} (email from JS Wright to PSB 15/04/16). Mr Alan Whyte, Senior Contracts Engineer from JS Wright, proposed software modifications to PSB which altered:

a) How dampers were controlled in environmental mode; and

b) Fan-run speeds (speeds were reduced from the full design run speed using a device called an inverter).

7.16.16 The specific state of many of the components of the smoke control system on activation of smoke control mode would therefore differ to the original operational design, specifically:

a) Lobby dampers would be either open or closed; and

b) The smoke control fan would be running at a different speed.

7.16.17 It is my opinion that the smoke control system would need to be commissioned from this new mode of operation as a starting point, and not from the originally designed operation.

7.16.18 In Section 8, I set out what action PSB took regarding this revised mode of operation during the commissioning process for Grenfell Tower.

7.16.19 **Evidence of the revised operation being implemented and commissioned**

7.16.20 The program changes were provided to the commissioning team led by Mr Partlow on 25th April 2016 (email from Mr Glowacki to Mr Partlow, {PSB00001113}).

7.16.21 This was prior to Mr Partlow's final commissioning day on 28th April 2016 (p.3, {PSB00001309}).

7.16.22 However, Mr Partlow states in his second witness statement (dated 26th March 2021) {PSB00001372} that he "*was not involved in the detail*" of the "*installation of the inverter*".

7.16.23 Mr Partlow says he "[understood] *that PSB subsequently provided this inverter*" but the installation "*was not however undertaken by PSB*".

7.16.24 Mr Partlow did not discuss the effect which adding the new invertor would have had on the commissioning of the system in his witness statement.

7.16.25 There is no record of any testing of the operation of the environmental system in this altered mode during the commissioning tests listed in Mr Partlow's witness statement (p.3, {PSB00001309} prior to handover of the system.

7.16.26 I have found evidence that subsequently, in June 2017, the environmental system was reported not to be working. I have set out this evidence separately in Section 1.

7.16.27 **My investigation of environmental mode programming**

7.16.28 My team's review of the software downloaded from the master control panel and the HMI panel after the fire, shows the control system at Grenfell Tower was programmed to operate in the revised mode of operation for the environmental system at the time of the fire.

7.16.29 Operation of environmental mode relied upon a signal from the BMS. I have not been provided with the programming of the BMS in Grenfell Tower. However, this is a not a substantial limitation for my analysis as I have been provided with and relied on WSP's report titled "*Grenfell Tower Building Management System Review for Metropolitan Police*" dated 20th April 2018 {MET00018469} to obtain information on the temperature sensors connected to the BMS system and the link to the smoke control system.

7.16.30 My teams analysis have found that the input from the roof BMS panel to the refurbished smoke control system via the Level 23 outstation, was a direct signal that would be overwritten via the software within the master smoke control system when there was a fire activation signal; and should therefore not have affected the operation of the lobby smoke control system.

7.16.31 There are software controls between the refurbished BMS system in the basement and the master smoke control panel at the ground floor hub room. There are 4 signals sent from the master smoke control panel to the refurbishment BMS system in the basement: a fire activation signal and three fault signals.

7.16.32 In Section 1, I set out the evidence that there were changes made to the refurbished and/or existing BMS system in order to remove the interface between the smoke control system and the gas shut off valve in the basement.

7.16.33 Figure 7-47 presents my understanding of the environmental mode control, as a result of my team's detailed review of PSB's disclosure and the control programmes for the main control panel {MET00018070} and the HMI panel {MET00018074}.

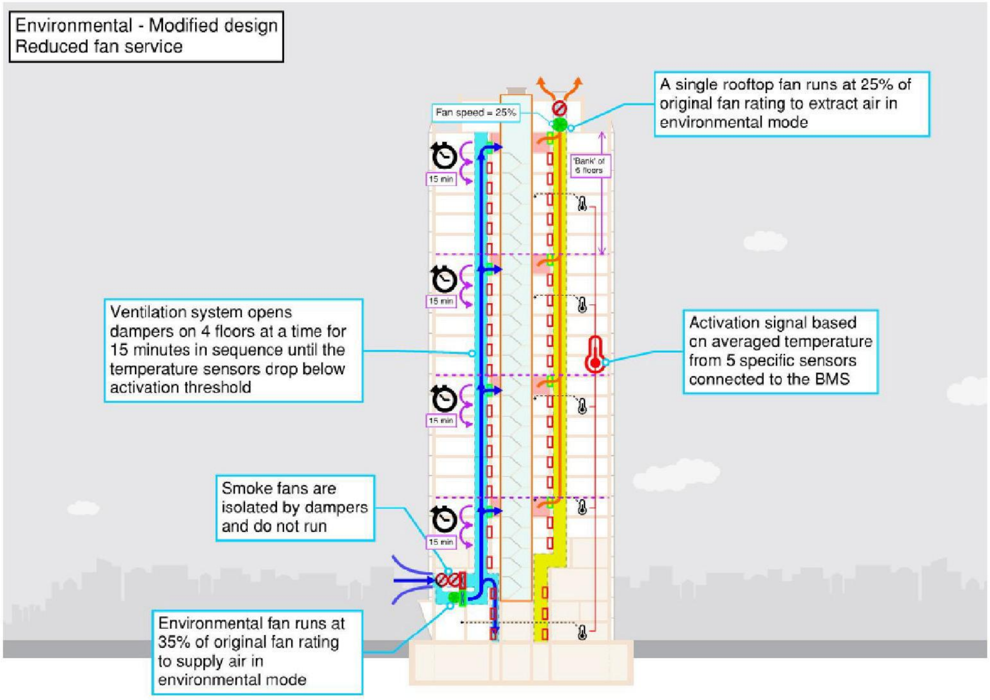


Figure 7-47: illustration of the environmental mode control programme

7.16.34 I have also described the BMS system by means of a schematic in Figure 7-48 below.

7.16.35 According to my analysis, the environmental system was programmed to operate as follows:

a) Five temperature sensors ({TMOM00001701}) were apparently connected to the BMS, one each in the lobby at Ground, Levels 5, 10, 15 and 20. I have set out in Section 7.2.37 that Mr Hughes oral evidence suggest that there is an outdoor air temperature sensor that is relevant to the environmental system although documentation does not provide information on how the system is programmed to include the outdoor air temperature and I have no evidence that it was physically installed;

b) The BMS system monitored the temperature sensor readings. The BMS calculated the average of the temperature sensor readings and when it exceeded the temperature set point of 25°C, it sent a single activation signal to the main control panel of the smoke control system to operate in environmental mode (p.11, {MET00018469});

c) On receiving the signal, the HMI panel was programmed to send a signal to the Master Smoke Control Panel, which then sent the signal to the outstation in the panel housing the inverters for the Level 2 instructing environmental fan to operate at "*35% speed*" to supply air to the lobbies. The Master Smoke Control Panel also sends a signal up to the outstation in the panel housing the inverters controlling the roof fans instructing the roof fan to operate at "*25% speed*" to extract air from the open dampers

in four lobbies at a time according to the damper sequencing ({JSW00002066} and {MET00018070}).The original proposed system of operation required the fans to be signalled to run at 100% duty {PSB00001093} as stated in Section 7.16.10, and this was also stated in the cause-and-effect matrix dated 3rd February 2017 {PSB00000232};

d) The two shut-off dampers associated with the environmental fan at Level 2 were sent a signal to open;

e) The floors in the building were split into four groups of six levels. The dampers on each floor were programmed such that the four dampers in the top level in each of the four groups would open, namely Levels 5, 11, 17 and 23 for 15 minutes before the operation shifts to the next lower floor, namely Levels 4, 10, 16 and 22;

f) This operation sequence would continue until the dampers on every floor of each set of floors had opened for fifteen minutes each, and then the system would move back to the top set of floors, and move its way down again;

g) This pattern of operation would continue until the average temperature recorded by the temperature sensors at Ground Level and Levels 5, 10, 15 and 20 had dropped below the threshold level of 25°C (p.10, {MET00018469}), at which point the activation signal from the BMS would stop and the environmental system would shut down; and

h) Then the dampers on each floor would shut, the fans would turn off and the shut-off dampers associated with the Level 2 fan would close.

7.16.36 This system of operation was in place at the final commissioning on 28th April 2017. This is evidenced by the fact that this programming was sent to the commissioning team {PSB00001113} on 25th April 2016 and {PSB00001124} includes measurements of flow velocities at the dampers for the reduced fan flowrates at roof and Level 2 fans, as required for this mode.

7.16.37 RINA's reconstruction, which I summarise in Section 7.4, also produced results consistent with steps 5 and 6 of Section 7.16.34 when they simulated the environmental control input from the BMS to the smoke control system software {MET00072161}.

7.16.38 I note that RINA's report highlighted that the damper sequence in environmental mode did not include the automatic opening windows in the ground floor community lobby and second floor boxing studio. However, these windows were not part of the environmental ventilation system and so were not required to be part of the damper sequence.

7.16.39 I understand from the WSP report headed "Grenfell Tower Building Management System Review For Metropolitan Police" (p.11,{MET00018469}) dated 20th April 2018, that the BMS was programmed to send a signal to activate environmental mode only "*between the hours of 09:00 and 20:00*".

7.16.40 The fire on 14th June 2017 started at 00:55, and therefore the BMS should not have been capable of activating the system in environmental mode at this time.

7.17 Implication of BMS panel connections

7.17.1 I have relied on the following documents in my understanding of the BMS system connection to the smoke control system. Only documents (a) – (c) were included in Rydon's building manual that has been provided to KCTMO:

a) Grenfell Tower Refurb Basement Control Panel MCP01 Issue 1.3 wiring diagram dated June 2015 {TMOM00001806}

b) Grenfell Tower Refurb Basement Control Panel MCP02 Issue 1.2 wiring diagram dated July 2015 {TMOM00001807}

c) Control System Description of Operation Issue 2 dated 24th September 2015 {TMOM00001808}

d) Master Smoke Control Panel wiring diagram Revision 5 dated 23rd June 2015 {MET00018036}

e) TREND workbook (paper copy of software) Issue 2 dated 15th March 2016 {DCS00000070}

7.17.2 There were two connections between the Grenfell Tower BMS and the smoke control system main control panel.

7.17.3 These connections were:

a) The environmental mode activation signal from the BMS panel on the roof, to the smoke control system via the outstation at level 23, as described in Section 7.16 above; and

b) Four signals from the smoke control main control panel in the ground level Hub room to the refurbished BMS panel in the basement, via software controls only, relating to the condition of smoke detection (three fault signals and a "fire alarm active" signal

7.17.4 I note the four signals records in the PSB drawings {MET00018036} align with the input signals to the BMS TREND software {DCS00000070}; however, the Direct Control Systems (DCS)[5] basement control panel drawings {TMOM0001806} appear not to have been coordinated with the PSB drawings and show five different inputs.

7.17.5 The uncoordinated drawings make it difficult to explain the precise connections between the two systems. I discuss this further in Section 1.

[5] Direct Control Systems (DCS) Limited was JSW's Building Management System (BMS) specialist sub-contractors

7.17.6 I have visualised the BMS connections in Figure 7-48.

7.17.7 There is evidence an interface to the gas shut off facilities in the basement was disconnected. I set out the evidence in detail in Section 11 of this report.

7.17.8 However as it is not known what the specific changes were made to BMS system in the basement were, it is unknown whether these changes would affect the BMS panel on the roof, to which it was connected. It should have had no impact.

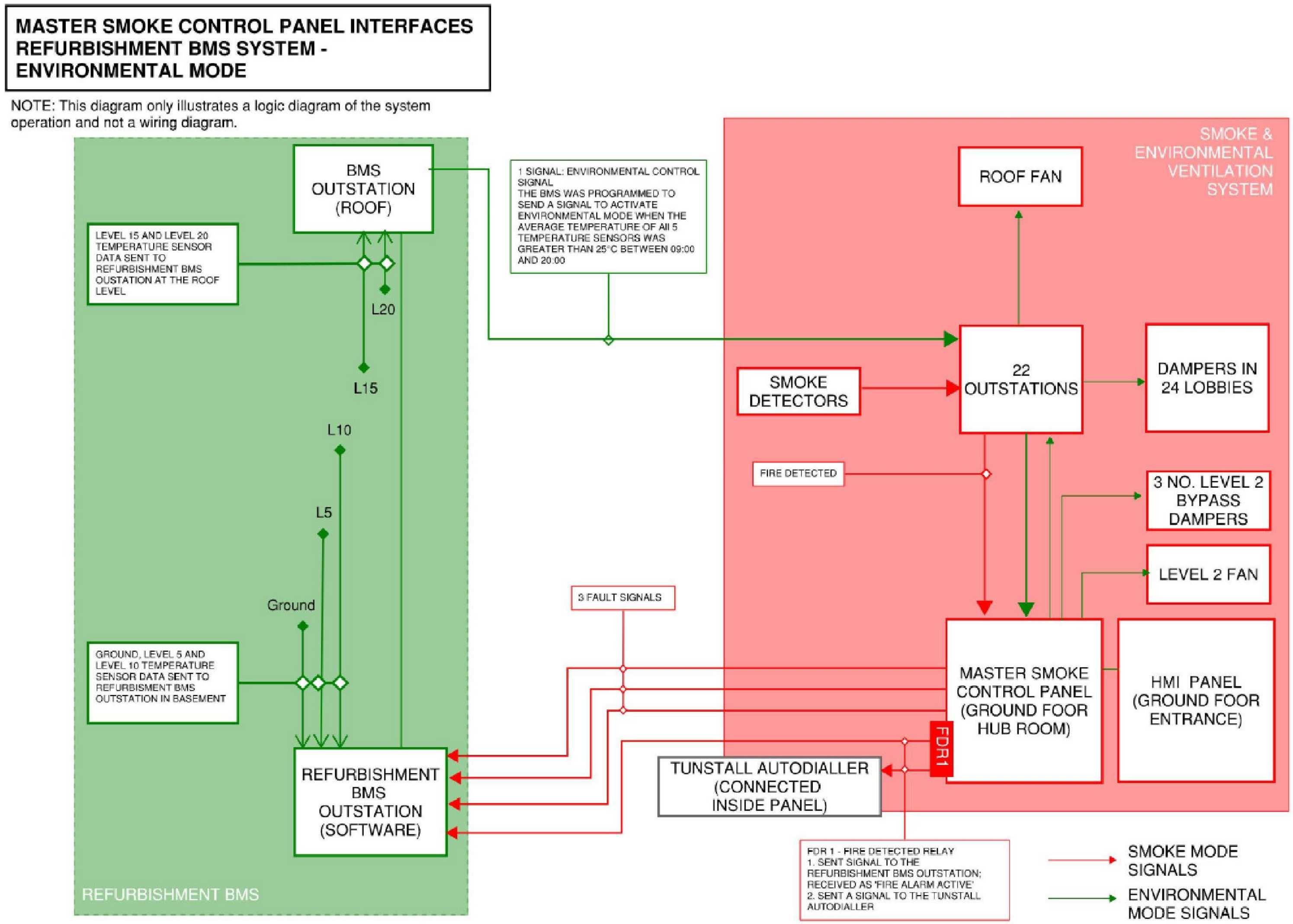


Figure 7-48: Schematic of BMS connections

7.18 Implication of the auto-dialler connection

7.18.1 On the 4th May 2016 {TMOM00001927} a device was connected to the Master Smoke Control Panel in the Hub Room at ground floor, a **Lifeline unit (Lifeline Vi+)** {THL00000015}**.**

7.18.2 On receipt of a fire alarm the Lifeline unit would alert Tunstall's monitoring centre (via a telephone line) and automatically retrieve customer database records for the call-handler to take appropriate action.

7.18.3 This device was fitted after the last day of commissioning by Mr Partlow on the 28th April 2016.

7.18.4 I explain this evidence in detail in Section 9 below, as I stated in my Phase 1 report I would investigate the consequences, if any, of making this connection after the commissioning process was completed.

7.18.5 The connection between the Master Smoke Control Panel and the auto-dialler is described in Tunstall's witness statement {THL00000015} and also in RINA's reconstruction report {MET00072161}.

7.18.6 In Tunstall's submission to the Inquiry {THL00000015}, it was stated that the Lifeline dialler unit was connected to "'*clean contact outputs' from a smoke vent system*".

7.18.7 I understand "*clean contact outputs*" to mean that the type of connection that enables an output signal only from the Master Smoke Control Panel to the auto-dialler.

7.18.8 From my team's analysis I understand that the activation of a smoke detector in any of the lobbies in Grenfell Tower sent a signal to the Master Smoke Control Panel via the outstation located on the same floor.

7.18.9 This signal activated the "Fire Detected Relay" (FDR1) within the Master Smoke Control Panel which then sent a signal to the auto dialler.

7.18.10 I therefore understand that the auto-dialler could not send any signal back to the Master Smoke Control Panel which would be the only possible way the auto-dialler could have affected the operation of the smoke control system.

7.19 My analysis of the main control panel and HMI panel software

7.19.1 My team's investigation of the software in the main control panel and HMI panel and my analysis of the as-built drawings has resulted in the following findings. Where relevant I have also set out RINA's findings against my own.

7.19.2 In this investigation my team used specific scenarios to test the programmed response of the system and to confirm whether the response from the software programming obtained matched the intended response as defined in PSB's Technical Submission, Revision 6 {PSB00000214}.

7.19.3 **Fire on Level 4**

7.19.4 My team's analysis shows that the programming of the system would correctly perform the smoke control mode as described in the PSB's Technical Submission, Revision 6 (PSB00000214), when a smoke detector was activated, on Level 4.

7.19.5 Figure 7-49 provides a diagram showing my understanding of the programmed operation of the smoke control system as of the 14th June 2017.

7.19.6 Specifically, the extract fans at Level 2 and Roof Level were programmed to activate, and the system would have correctly selected the Level 4 AOV dampers to open, and to close all other lobby dampers on levels G – 23.

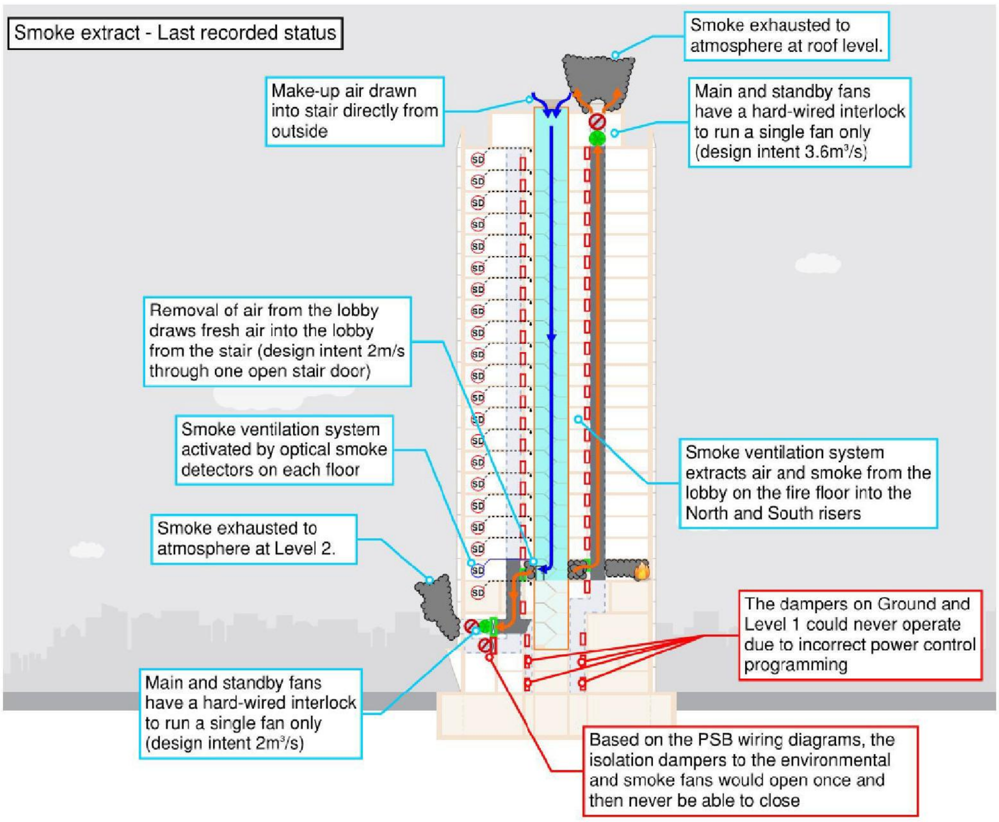


Figure 7-49: Programmed operation of the smoke control system

7.19.7 RINA's tests of the smoke control system also confirmed that detection of smoke at Level 4 would lead to the dampers opening at Level 4 as required. {MET00072161}.

7.19.8 **Fire on Ground or 1st Floor**

7.19.9 There is evidence that the Ground and Level 1 lobby vent AOVs which opened into the main north and south shafts could not have operated as intended.

7.19.10 Specifically, the control software appears to have been programmed such that power could not be supplied to either open or close these dampers.

7.19.11 The dampers affected are shown in Figure 7-50 (G and H connected to the North shaft and 7 and 8 connected to the South Shaft).

Figure 7-50: Location of Ground and Level 1 dampers that the control software could not operate

7.19.12 In the absence of power to drive these dampers open or closed, the only method to change their state was manually.

7.19.13 This suggests that if the smoke extract had been activated for either the Ground Level or Level 1 lobby, with the dampers in the closed position, they could not have been be powered open, and so the smoke control system would not have been able to draw air from those lobbies as it was required to do.

7.19.14 This is the case for automatic activation by the smoke detectors in the lobbies, or by manual activation of the system on those levels via the HMI or the yellow key switches.

7.19.15 RINA's reconstruction did not simulate the operation of the ground level lobby dampers {MET00072161} therefore, this result cannot be corroborated with RINA's data.

7.19.16 As stated in Section 7.4, RINA's reconstruction report also highlighted a fault in the damper connection that would have prevented the damper from opening when activated at Level 1.

7.19.17 RINA does not make it clear in their report whether this would have affected one or both dampers (p.25, {MET00072161}). However, from BRE's GT site report {MET00065879}, Table 5 (p. 16) states that X4/11 is connected only to the "lower smoke damper" at Level 1.

7.19.18 Table 5 of BRE's report is based on PSB's wiring table with confirmation and additional information from BRE's visual inspection. This meant that the lower smoke AOV at Level 1 connected to the South shaft would be affected.

7.19.19 Therefore, in addition to having a software-programming issue, the Level 1 AOV would not be able to operate due to a physical hardware issue.

7.19.20 I have investigated whether these issues were identified or rectified during either the process of commissioning or maintenance of the smoke control system in Section 8.

7.19.21 **Interface of non-residential lobby ventilation with system controls**

7.19.22 In their report, RINA identified inconsistencies during their examination of the smoke control system relating to fire zones 25 and 26. As indicated in Figure 7-3, fire zones 25 and 26 correspond to the community room lobby at ground level and the 2nd floor boxing studio corridor.

7.19.23 RINA's report states:

• Fan speeds and directions for the smoke extraction system were not programmed into the PLC for fire zones 25 and 26. This would not have caused an issue in the case of the 2017 fire, however, this would have prevented smoke extraction if a fire was detected in these zones first.

• The FOS for zones 25 and 26 were not programmed to prevent further recognition of the other FOS switches. However, due to the order of the logic, only the FOS in fire zone 25 could be overwritten by the FOS in fire zone 26. This would not have caused an issue in the case of the 2017 fire.

• It is unclear to RINA where the FOS in fire zones 25 and 26 were physically located, however, they were referred to in the logic program, and connections were present in the outstation with cables exiting out of cable glands before being cut away.

7.19.24 Figure 7-51 and Figure 7-52 show the smoke control components in the community room lobby at Ground Level and the boxing club corridor at Level 2.

7.19.25 Neither of the AOVs for these spaces were connected to the north or south smoke shafts, any builders' work shafts, Level 2 ductwork or either the roof or Level 2 fans serving the residential smoke control system.

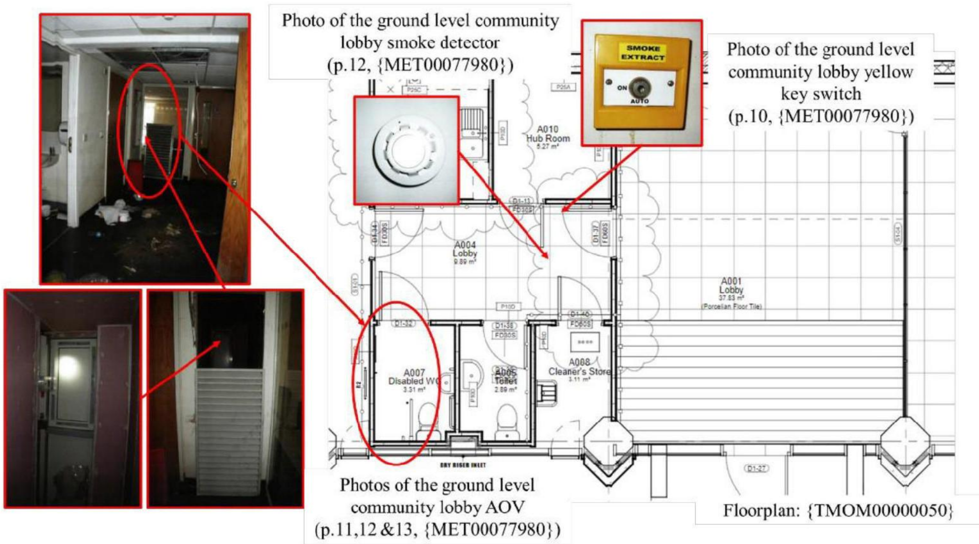


Figure 7-51: Smoke control system components within the community room lobby at Ground floor

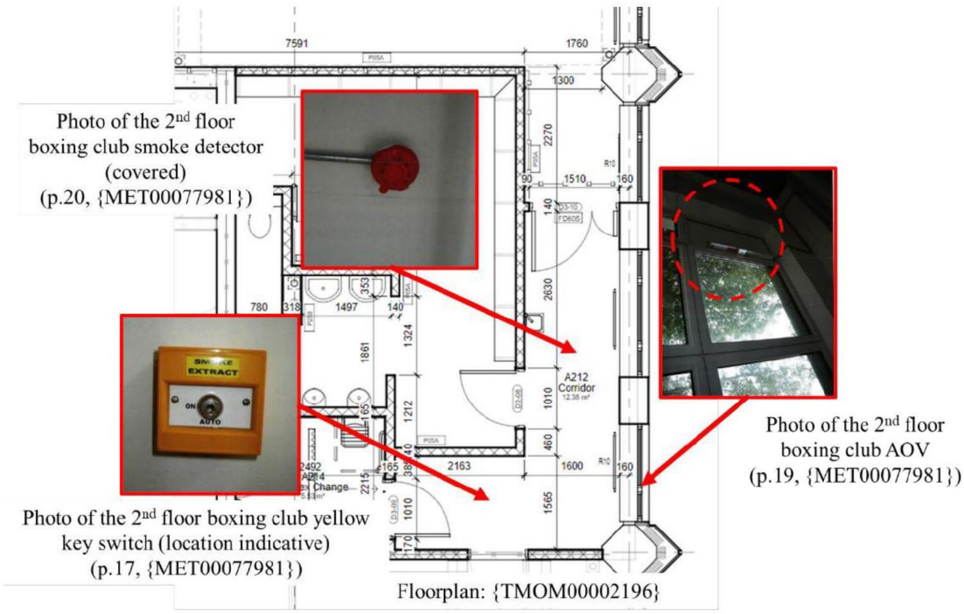


Figure 7-52: Smoke control system components within boxing club corridor at Level 2

7.19.26 As these zones are separate to the lobby smoke control system, smoke detection in these zones was not required to activate the smoke control fans and the fireman override switch was not required to be interlocked to the other fireman override switches within the residential lobbies.

7.19.27 RINA's findings are therefore consistent with the intended operation of the system, although they have been presented as faults by RINA.

7.20 Unintentional activation of the system on other floors due to hardware issues

7.20.1 RINA's investigation identified potential weaknesses in the controls due to the physical construction of the physical yellow key-switch FOS and damper actuators at elevated temperatures (Section 7.9).

7.20.2 **Impact of damage to yellow key switches on smoke control system operation**

7.20.3 Where the HMI panel is "ON", a short circuit of the yellow key switch controls in a lobby could send an unintended signal to the main control panel, via the local outstation, and cause the system to register an activation on that floor in the main control panel. (pages 14 and 27, {MET00072161})

7.20.4 The control panel would then signal the system to operate from that floor, opening the dampers there and closing them on all other floors.

7.20.5 Furthermore, the manual controls to activate the smoke control system on any other floor (either by other key switches or by the HMI panel) would be locked out until such time as the short circuit of the damaged key-switch ended.

7.20.6 RINA obtained the physical yellow key switch from Level 2 at Grenfell Tower. It had a sticker identifying the model of the key switch as "KAC Alarm Co. Ltd K21SYS-11".

7.20.7 RINA found an online data sheet[6] indicating that the "K21SYS-11" model has an operating temperature range from -20°C and +55°C and IP24 rating.

7.20.8 According to the manufacturer's literature for the yellow key-switch mentioned in Rydon's building manual provided to KCTMO {TMOM00001778}, the switch to be installed was in the "KAC Class 9000 range" and had an operating temperature of between -30°C and +70°C with IP rating 24D.

7.20.9 I am unable to determine which key-switch was installed throughout the rest of Grenfell Tower.

7.20.10 RINA concluded the FOS as "*a weak point in the system in the event of a severe fire*" as it was "*vulnerable to heat damage, dust and water ingress*" which could allow "*several of the FOS devices in the hottest parts of the fire to short circuit, causing the smoke dampers to behave unpredictably*".

7.20.11 Note that the yellow key-switch was indicated to be located in the stairwell at each level in PSB's Technical Submission (Revision 6) {PSB00000214}, but shown to be located in the lobby on each level in PSB's Electrical Schematic {TMOM00001859}.

[6] https://docs.rs-online.com/9bc3/0900766b81306f91.pdf (Accessed: 12th May 2021)

7.20.12 There is no specific reference in ADB 2013 on protecting the yellow key switches from the effects of fire.

7.20.13 Paragraph 2.28 of ABD 2013 refers to BS 12101-6:2005 for guidance of smoke control systems using pressure differentials

7.20.14 Clause 10.3.1 of BS EN 12101-6:2005 states that "*Computerised control systems shall be used to control the various operational functions of a pressure differential system, and will rely on the use of specific software to carry out the modes of operations required of that system in accordance with prEN 12101-9.*"

7.20.15 I note that prEN 12101-9 has not been published. Clause 10.3.2.4 of BS EN 12101-6:2005 also states that "*Signalling systems providing the information to and from the computerised control centre shall be protected from the effects of fire for a period complying with national provisions valid in the place of use of the system.*"

7.20.16 The yellow key switch is a component of the signalling system as it provides information on whether the smoke control system is activated at a particular floor.

7.20.17 Based on Clause 10.3.2.4, the yellow key switches shall be protected from the effects of fire for 120 minutes since the lobby where the system is used is required to be 120 fire rated construction.

7.20.18 Section 8.2.12 of SCA Guide 2012 states:

For mechanical systems a manual switch providing off/auto or off/auto/boost (if boost is provided) facility should be installed close to the designated fire service access point. For systems that are switchable between a 'normal' and 'boost' mode, the manual switch should be provided at each floor level and in a place of relative safety (usually the stair enclosure) so that fire fighters can operate it locally, prior to entering the risk area on the relevant floor.

7.20.19 Therefore, SCA guide recommends that the yellow key switch is placed where fire fighters can operate the yellow key switch without entering a risk area.

7.20.20 However yellow key switch was installed within the lobby in Grenfell Tower on the night of the fire.

7.20.21 **Impact of damage to damper actuators on smoke control system operation**

7.20.22 The actuators for the dampers could also cease to function due to heat damage from the fire.

7.20.23 RINA has obtained the physical damper actuator from the Level 6 right-hand damper from the North shaft of Grenfell Tower.

7.20.24 The information printed on the unit states that the operating temperature range of -20°C and +50°C.

7.20.25 Therefore, in the event of a fire, the hot smoke in the lobby could lead to the dampers failing to operate, including when instructed by manual operation of the HMI panel or yellow key switches.

7.20.26 RINA concluded that:

"In RINA's opinion, based on product information, the smoke damper actuators and the FOS were not designed to withstand exposure to the heat from an ongoing fire. As these units were exposed in the lift lobbies it is likely that the system had not be designed to function reliably in a scenario where significant heat or fire were present in these areas."

7.20.27 RINA presented a scenario where these weaknesses could result in dampers opening on other floors as found in the post-fire condition below:

1. Smoke was detected on floor 4, where the fire started;
2. The dampers opened on floor 4, and closed of the remaining floors;
3. As the fire progressed, the FOS on floor 11 melted, shorting the contacts;
4. The dampers closed on floor 4, and opened on floor 11;
5. Fire damaged the cable junctions or all four actuators on floor 11, preventing them from moving;
6. The FOS on floor 11 fell away from the casing, causing it to deactivate;
7. Fire damaged the cables, cable connections, or both actuators for the dampers on the north side of floor 18;
8. The FOS on floor 18 melted, shorting the contacts;
9. The dampers remained open on floor 11 due to damage;
10. The dampers opened on floor 18 (south side only due to damage on the north side);
11. FOS switches on other floors melted or short circuited due to fire damage;
12. Dampers remained in this position for the remainder of the fire.

Figure 7-53: Possible scenario extracted from RINA's report {MET00072161}

7.20.28 I have considered RINA's scenarios when producing my own analysis of the evidence available to me regarding events in Grenfell Tower on the night of the fire. My findings are presented in Section 12 and 13 below.

7.20.29 I have included in my review an assessment of whether conditions on the night of the fire might have allowed the destruction of the yellow key switch by causing it to short-circuit; and I have also reviewed the effect of increased temperature on other controls equipment such as the actuator and the cables.

7.21 Summary of controls and operational issues identified

7.21.1 My team's analysis of the programming for the smoke control system concluded that the software was programmed to activate the fans and dampers correctly for the activation of a smoke detector on any level above Level 2.

7.21.2 However, there were several defects found with the devices below Level 2, as set out in Table 7-4 below, including the wired connections for the controls.

7.21.3 These defects relate to floors unaffected by the fire on 14th June 2017 with the exception of the issues relating to the Level 2 dampers which serve the main smoke extract system.

7.21.4 I summarise these issues here as they are relevant to my investigation regarding the adequacy of the commissioning, the maintenance regime and, therefore, the overall operating potential of the smoke control system on the night of the fire.

7.21.5 Furthermore, in a different fire scenario (i.e. a fire on those lower floors), these defects may have had a practical impact on the overall operation of the smoke control system, evacuation of residents and firefighting.

7.21.6 In the preceding sections I have set out the full complexity of the smoke control system in Grenfell Tower. The system was made up of about two hundred key electronic and mechanical components. The system also had two overlapping systems of manual control, i.e. the HMI panel and the yellow key-switches.

7.21.7 Commissioning of this system therefore required a robust understanding of all the components, and how they were intended to operate in order for the system to meet the performance criteria specified by PSB.

7.21.8 I have set out how operation of the system could lead to unexpected results, specifically based on operation of the pressure switch when any door other than the stair door was open, and also based on untrained use of the HMI panel in conjunction with the yellow key switches.

7.21.9 The instructions provided to the fire service were wholly inadequate to allow attending firefighters to understand the full complexity of the system.

7.21.10 I set out my investigation of the commissioning and maintenance of the smoke control system in Section 8.

7.21.11 I have provided my analysis of the issues found with the lobby smoke control system, after handover, in Section 1 and confirm whether these issues were addressed satisfactorily before the fire.

Table 7-4 Summary of faults and issues with the smoke control software.

Expected action	Location	Identified issue / fault	Reference	Potential impact
Lobby dampers open/close as required on detection of fire or by manual activation of the system via the HMI or the yellow key switch	Ground Level and Level 1 lobby	The control software is programmed such that power could not be supplied to the damper and would not be powered upon activation at Ground and 1st level. (Section 7.19.8)	My team's analysis	Smoke extract could not be provided to Ground Level or Level 1 lift lobbies.
Lobby AOVs open/close as required on detection of fire or by manual activation of the system via the HMI or the yellow key switch	Level 1 lobby (South shaft damper)	Loose wire connections at the terminal connected to the 1st floor lobby damper (Section 6.3.112)	RINA's reconstruction {MET00072161} and BRE's GT site report {MET00065879}	Smoke extract could not be provided to Level 1 lobby on the south shaft.
Pressure switch provides output signal to the smoke control system to vary the speed of the fans	Level 1 lobby	Loose wire connections at the terminal connected to the 1st floor lobby pressure switch (Section 6.3.106)	BRE's site investigation {MET00065879}	Fan speed could not be reduced and Level 1 lobby door could be prevented from opening by excessive pressure difference
Bypass dampers at Level 2 should open/close accordingly in environmental/ smoke mode	Level 2	Wiring connections on PSB drawings do not match the required connections on the damper actuator sheet (Section 7.13.16)	My team's analysis	The Level 2 fans could have been prevented from extracting from the fire floor, reducing the system performance.

8 Evidence of commissioning

8.1 Changes since my Phase 1 report

8.1.1 In Section J8 of Appendix J of my Phase 1 report {BLAS0000031}, I set out my investigation of the commissioning of the smoke control system in Grenfell Tower based on the evidence then available to me.

8.1.2 I have not had any further records of the commissioning process disclosed to me in Phase 2.

8.1.3 However, I have now had sight of further witness statements from relevant individuals regarding their commissioning activities.

8.1.4 I review those statements in Section 8.3 and, where necessary, have made amendments to my final explanation of the commissioning process.

8.1.5 PSB have now confirmed, by means of a second witness statement from Mr Mahoney {PSB00001373}, that they do not consider their design complied with BS EN 12101-6:2005. I have therefore expanded my assessment of the commissioning process to include a comparison with industry guidance produced by the Smoke Control Association and other relevant British Standards.

8.1.6 This Section 8 therefore supersedes my assessment of commissioning in my Phase 1 report.

8.1.7 In Appendix J of my Phase 1 report {BLAS0000031} I detailed matters relating to the commissioning and handover of the smoke control system that were to be revisited as part of my Phase 2 investigations.

8.1.8 I have reproduced these in Table 8-1, below, and confirm where I have now addressed them.

Table 8-1 Matters outlined in my Phase 1 report to be revisited during Phase 2

Relevant section from Appendix J {BLAS0000031}	Relevant section of this report
J8.6.15 In this e-mail, Max Fordham also stated: *"They should also demonstrate reversion to fire mode in the event of a fire alarm if they haven't already done so."* J8.6.16 I have seen no evidence to indicate that the reversion to fire mode was tested by Rydon, or any of their subcontractors, after the demonstration to RBKC Building Control on the 5th May 2016.I note that the TMO's response to Max Fordham was: *"Nothing at the moment."* J8.6.17 I will update this part of my report at Phase 2in the event any	Refer to Section 8.10 of this report.

Relevant section from Appendix J {BLAS0000031}	Relevant section of this report
further evidence of commissioning of the smoke control system is provided to me.	
J8.8.6 I am unclear at this time whether the autodialler had any impact on the smoke system performance the night of the fire. J8.8.7 I will investigate this further in Phase 2.	Refer to Section 9 of this report.
J8.10.3 In Phase 2 I will investigate what training was provided to both representatives of the TMO and London Fire Brigade, in how to use this system properly.	Refer to Section 8.13.3 of this report.
J8.12.6 In Phase 2 I will provide my opinion on the documentation provided to the regulatory authorities, and the documentation provided to the responsible person.	Summary provided for completeness at Section 8.15 below

8.2 The importance of commissioning

8.2.1 Commissioning is required to demonstrate compliance with Regulation 7 of the Building Regulations 2010, which states (bold by me):

"7. Building work shall be carried out—

(a) with adequate and proper materials which—

(i) are appropriate for the circumstances in which they are used,

(ii) are adequately mixed or prepared, and

(iii) are applied, used or fixed so as ***adequately to perform the functions for which they are designed;"***

8.2.2 Approved Document 7: 2013 Materials and Workmanship, provides guidance on how to comply with Regulation 7 of the Building Regulations. It states (highlighting by me):

Limitations

Regulation 7 applies to all building work. However, in accordance with regulation 8 and Schedule 1, the standards of materials and workmanship need be no more than are necessary to:

a. *for Parts A–D, F–K, N and P (except for paragraphs G2, H2 and J7) of Schedule 1:* secure reasonable standards of health or safety for people in or about the building

b. *for Part E of Schedule 1:* secure reasonable resistance to the passage of sound for the welfare and convenience of people in or about the building

c. *for Part L of Schedule 1:* conserve fuel and power

d. *for Part M of Schedule 1:* provide access to buildings and their facilities for people.

Figure 8-1 Excerpt from Approved Document 7: 2013

8.2.3 Where materials are defined as:

Materials include:

a. manufactured products such as components, fittings, items of equipment and systems
b. naturally occurring materials such as stone, timber and thatch
c. backfilling for excavations in connection with building work.

Figure 8-2 Excerpt from Approved Document 7: 2013

8.2.4 The smoke control system would therefore fall to be considered as a 'material' under Regulation 7, meaning that it would be required to "*adequately perform the functions for which* [it was] *designed"*.

8.2.5 Without commissioning there can be no evidence that active building systems can "*adequately perform the functions for which they are designed"*.

8.2.6 This is why, as part of the commissioning process described, for example, in the SCA Guide 2012, it is said to be *"imperative"* that the smoke control system is *"witness tested by the approving authority to prove its compliance with the project specification and the approved design criteria"*.

8.2.7 Further to this, section 14.1 of BS EN 12101-6 states that (bold by me)

on completion, ***the results*** *of the tests carried out on the pressure differential system should be provided to the* ***Approving Authority to demonstrate compliance of the system.***

8.2.8 The separate duty to provide evidence to the responsible persons no later than the completion of building works is set out in Regulation 38 of the Building Regulations 2010 (previously Regulation 16B) *Fire Safety Information* as follows:

(2) The person carrying out the work shall give fire safety information to the responsible person not later than the date of completion of the work, or the date of occupation of the building or extension, whichever is the earlier.

8.2.9 The importance of documentation being handed over to the *relevant person* after commissioning is discussed in the guidance documents relating to compliance with Regulation 38.

8.2.10 The documentation must include commissioning and witness testing certificates, as set out in section 9.2 of the SCA Guide 2015:

9.2 Documentation

All smoke control systems should be handed over to the end user with a complete set of documentation. This should include at least:

- Design information detailing the performance criteria for the system and a description of the system
- A control philosophy or cause and effect diagram
- As installed drawings
- Relevant CE marking or type test certificates
- Installation and commissioning certificates
- Witness testing certificates or other evidence that the system was tested in front of the authority having jurisdiction (AHJ)
- Operation, maintenance and testing instructions
- Instructions for fire service use

This information should meet the requirement of regulation 38 of the Building Regulations (England and Wales), requiring the person carrying out the work to provide sufficient information for persons to operate and maintain the building in reasonable safety. It will also assist the eventual owner/occupier/employer to meet their duties under the Regulatory Reform (Fire Safety) Order.

Figure 8-3 Excerpt from the SCA Guide 2015

8.2.11 My findings on whether all relevant fire safety information was provided following the primary refurbishment are set out in my separate Phase 2 report relating to *Regulation 38 Fire Safety Information* {BLARP20000021}.

8.2.12 In section 8.14 below, I summarise my findings regarding the documentation provided on handover of the smoke control system.

8.2.13 I have also carried out a detailed review of the information provided for maintenance of the components of the commissioned lobby smoke control system in Section 11.

8.2.14 While I analyse the adequacy of documentation/completion in coming to my conclusions, the key issue remains whether or not the requirements of the *Building Regulations 2010* had been complied with (including the functional requirements in Schedule 1 and Regulation 7 (a) (iii)) i.e. did the commissioning process demonstrate that the lobby smoke control system was adequate to perform the functions for which it was designed?

8.2.15 The importance of commissioning active fire protection measures is referenced several times in ADB 2013.

8.2.16 Specifically, Appendix G *Fire safety information* states that, in *complex buildings*, records of the following should be provided as part of the Regulation 38 fire safety information:

i. Specifications of any fire safety equipment provided, including operational details, operators manuals, software, system zoning and routine inspection, testing and maintenance schedules. ***Records of any acceptance or commissioning tests.***

8.2.17 I note here that ADB does not provide a definition, or guidance, with regards to what constitutes 'simple buildings' or 'complex buildings'.

8.2.18 As I explained in Section B2 of Appendix B to my *Module 2 Regulation 38 Report updated 23 October 2020* {BLARP20000020} I consider Grenfell Tower to be a complex building because:

a) The building comprised twenty-five storeys with a basement (Ground t to Level 23 plus a plant floor at Roof level);

b) 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;

c) Occupants from the flats were provided with a single means of escape via the single stair core;

d) a 'stay put' evacuation strategy was in place, and so, relied on a high degree of fire compartmentation;

e) an existing smoke control system to the lobbies to protect the single means of escape stair was modified and extended to serve four additional levels (ground to level 3);

f) firefighting relied entirely on this single escape stair also; and

g) it was not a sprinklered building.

8.2.19 I also note that the travel distance in the common lobby exceeded the recommended 7.5m in ADB 2013, and was 10.5m from the furthest flat entrance fire door. At the time of the original construction this travel distance was deemed to be acceptable with suitable lobby ventilation – this was not provided in Grenfell Tower as I have explained in Section 3 of my report above.

8.2.20 Another important point in terms of complexity is that the dry rising main was located in the lobby and not the protected stair case.

8.2.21 These two additional points introduce complexity particularly relevant to achieving performance objectives by means of mechanical smoke control systems.

8.2.22 Therefore, taking into consideration all of these points I consider Grenfell Tower to be a complex building

8.2.23 The SCA Guide 2012 provides detailed information on commissioning, and states at Section 9 (bold by me):

As smoke control systems are primarily life safety systems and/or for assistance to the fire and rescue service it is imperative that the smoke control system is tested by the installer and then ***offered for witness testing to the authority having jurisdiction (AHJ) to prove its compliance with the project specification and the approved design criteria.***

BS7346 Part 8 sets out the recognised code of practice for commissioning and acceptance testing of a smoke control system including examples of certification. The following sections provide useful guidance intended to supplement that given in BS 7346 Part 8.

8.2.24 This text was retained in the SCA Guide 2015.BS 7346-8: 2013 is titled *Components for smoke control systems - part 8: code of practice for planning, design, installation, commissioning and maintenance.*

8.2.25 It defines commissioning as:

the act of ensuring that all components and the smoke control system are installed and operating as planned

8.2.26 Further, BS EN 12101-6 *Smoke and heat control systems - Specification for pressure differential systems - Kits* defines commissioning as *"the act of ensuring that all components, kits and the system are installed and operating in accordance with the manufacturer's instructions and this document".*

8.2.27 Therefore, the commissioning process should produce a system which is physically demonstrated to comply with both the project specification and the approved design criteria and accompanied with sufficient documentation to enable its maintenance and operation after handover.

8.2.28 The SCA Guide deals with Documentation as I set out in Figure 8-3.

8.2.29 The Grenfell Tower lobby smoke control system was required to function in the event of a single flat fire and in doing so meet the functional requirements of the Building Regulations.

8.2.30 In my review of the available commissioning information in this section, I have set out wherever I have found evidence that the system was commissioned against the performance requirements of PSB's Technical Submission Revision 6 {PSB00000224}.

8.2.31 I have also assessed the commissioning process which was undertaken against the full set of requirements for commissioning set out in guidance produced by the Smoke Control Association (SCA) and relevant British Standards such as BS EN 12101-6, and BS 7346 Part 8 because they are referred to in the SCA guidance.

8.2.32 I note that RBKC Building Control provided PSB with the *SCA Guide 2015* on 4th May 2016 {RYD00076682}, so I consider it appropriate to use this version of the Guide to assess PSB's commissioning process.

8.2.33 The commissioning process in each of these documents applies to any smoke control system.

8.2.34 It is the responsibility of the designer to adequately document all the cause and effect scenarios needed to demonstrate the performance criteria for the specific smoke control system have been met.

8.2.35 It is the role of the commissioning engineer to create a commissioning process which verifies the system (as installed) functions as intended under all of the scenarios relevant to the design and its performance criteria.

8.2.36 It is the role of Building Control to witness any relevant tests, and review relevant documentation, to satisfy themselves that, first, the performance criteria enable compliance with the relevant functional requirement of the Building Regulations and, secondly, that the installed system adequately performs the functions for which it was designed.

8.2.37 In doing so, Building Control can confirm the system is compliant with Schedule 1 and Regulation 7 of the Building Regulations.

8.2.38 Finally, as stated in BS 7346-8: 2013, it is the role of the responsible person to witness acceptance tests which demonstrate that the system functions in accordance with the approved performance criteria.

8.3 Witness evidence regarding commissioning

8.3.1 I have reviewed a number of witness statements relevant to the commissioning of the smoke control system in Grenfell Tower, including the following:

a) Hugh Mahoney and Granville Partlow (PSB).

b) Alan Whyte (JS Wright).

c) David Hughes (Rydon).

d) Paul Hanson (RBKC Building Control).

8.3.2 I have reviewed these witness statements to analyse how the commissioning of the smoke control system in Grenfell Tower was carried out, recorded and reported to RBKC Building Control.

8.3.3 **Hugh Mahoney (PSB)**

8.3.4 In his second witness statement to the Inquiry, Mr Mahoney states at paragraph 41 {PSB00001373}:

My design reflected a more common type of mechanical extract 'depressurisation' system. A performance-based building appropriate solution widely adopted as a type of smoke control system…

8.3.5 In relation to the performance criteria for this system, at paragraph 52 of his first witness statement, Mr Mahoney states {PSB00001329}:

The PSB design was in line with the performance criteria of BS EN 12101-6:2005. The primary performance criteria of the design required a minimum velocity of 2.0 m/s being achieved through an open common lobby door to the stair. In achieving the recommended flow rate, the design also included provision to ensure that the opening force on the door would not exceed 100N.

8.3.6 And in his second witness statement to the Inquiry, Mr Mahoney states (bold by me) {PSB00001373}:

66. Whilst the System did not operate in the same way as a Class B Pressure Differential System, the airflow it was designed to generate across the open door was similar to that aspect of the required performance criteria of a Class B Pressure Differential System. It is for this reason that I felt that it was appropriate to adopt the figure of 2.0m/s from BS EN 12101-6 for the System.

....

72. I designed the System to use pressure sensors which were set at around -25Pa in the lobby areas to ensure that the fans would be working at a rate which would mean that the door opening force would not exceed 100N. Each floor was addressed individually, and the pressure sensors were required to be set specifically to allow for the leakages in each individual floor lobby.

73. These were the two principal performance criteria that I determined to be appropriate for the System.

8.3.7 At paragraph 53 of his first witness statement Mr Mahoney states {PSB00001329}:

I was aware that Granville would commission the System to meet these performance criteria on site and I understand that he has provided a witness statement to the Inquiry.

8.3.8 I have found no evidence that, at the time the system was installed, Mr Mahoney set out the scenarios which would influence the commissioning tests as he was required to do and so as to demonstrate that the installed system met the performance criteria he had set for the *"performance-based building solution"* which PSB had proposed for Grenfell Tower.

8.3.9 The only reference Mr Mahoney makes to the results of a commissioning test is at paragraph 70 of his second witness statement {PSB00001373}, where he cites the records of airflow speed through the open stair as evidence of the system's satisfactory performance:

I have been shown the flow readings taken by Granville Partlow, PSB's Commissioning Engineer from the System in April 2016 which demonstrate that the System did in fact achieve a-minimum velocity of 2.0 m/s across all the open lobby doors.

8.3.10 The minimum velocity of 2 m/s across all lobby doors is one of the three performance criteria that Mr Mahoney referred to in his second witness statement {PSB00001373}. Mr Mahoney makes no detailed reference to the overall commissioning process to be relied upon, including the means to verify and demonstrate the differential pressure of 25 Pa between the stair and the lobby, a stair door opening force of less than 100N, and why all measurements were required on every floor. Nor does he refer to the need to

perform the process and take measurements in the range of scenarios which were reasonably foreseeable, and should have formed the basis of his design.

8.3.11 As set out in Section 5, there were many other performance criteria needed to be set out and proven by PSB in order to demonstrate their system could meet the functional requirements of the Building Regulations.

8.3.12 **Granville Partlow (PSB)**

8.3.13 Mr Granville Partlow was the Group Service and Engineering Manager at PSB in 2016. He carried out the commissioning of the new smoke control system at Grenfell Tower that year (para 4, {PSB00001309}).

8.3.14 Two witness statements have been disclosed to me for Mr Partlow.

8.3.15 The first statement is dated 28th September 2018 {PSB00001309}.

8.3.16 The second statement is dated 26th March 2021{PSB00001372}. That statement was not provided in response to a Rule 9 request from the Inquiry.

8.3.17 Mr Partlow's Role

8.3.18 In his first witness statement {PSB00001309}, Mr Partlow states:

11. In my role as Group Service and Engineering Manager (my position in 2016 when I commissioned the System) I was responsible for the day to day running of the service department for all of the companies within the Witt UK Group. Typically, my role involved commissioning and servicing a variety of products that were designed and installed by one of the companies in the Witt UK Group or by another company. The products I commissioned and serviced included all forms of smoke ventilation, extraction and control systems.

8.3.19 At paragraph 16 of his first witness statement {PSB00001309}, Mr Partlow states:

I cannot recall exactly what I did during each visit to Grenfell Tower, but I used the same essential step by step process I always use when commissioning a smoke control system

8.3.20 Documents used by Mr Partlow as the basis for commissioning the Grenfell Tower system

8.3.21 Mr Partlow describes his preparation for commissioning together with the documentation he used for the commissioning process at paragraphs 17 to 24 of his first witness statement.

8.3.22 Mr Partlow states that he was provided with:

"PSB Commissioning Method Statement and Risk Assessment 75019AG" (GP/3: PSB00000941).

"PSB E-800 Electrical Schematic Rev. E" (GP/4: PSB00000429).

"Panel and Outstation Data for Job Number 75019AG Rev. 02" (GP/5:PSB00001256).

"PSB Fans and Damper Operation Cause and Effect Chart" (GP/6: PSB00000232)

"Technical Submission" for the Lobby Smoke Control System at Grenfell Tower. (GP/7: PSB00000214).

8.3.23 In my Phase 1 report, I said I would investigate how PSB's *"Commissioning Method Statement and Risk Assessment 75019AG"* {PSB00000941} was produced.

8.3.24 In his second witness statement, written after the issue of my Phase 1 report, Mr Partlow confirms that he himself produced this document (para 11, {PSB00001372}) (Bold by me):

10. In paragraph 19 of my first statement, I refer to being provided with the "PSB Commissioning Method Statement and Risk Assessment 75019AG" {PSB00000941}.

11. The circumstances in which this document came to be produced are explained in email exchanges provided to the Inquiry. ***It was produced by me at a busy time.***

8.3.25 Later in this statement, Mr Partlow states that the *"PSB Commissioning Method Statement and Risk Assessment 75019AG"* {PSB00000941}:

11 ... ***contains errors and does not accurately reflect the System.***

....

13. None of the inadequacies in the Method Statement hindered my understanding of the System or what I was required to do in undertaking the commissioning exercise on site.

8.3.26 Mr Partlow does not set out those errors in his statement.

8.3.27 In my view, one of the errors which he is likely referring to is the reference to 50 Pa as the design differential pressure.

8.3.28 This is because Section 4 of the Method Statement is headed *System Description* and includes a summary of how the system was intended to work. The pressure difference between the stair and the lobby was intended to be 50Pa in *"firefighting mode"*.

8.3.29 As I have explained in Sections 5 and 7.8 of this report, this conflicts with PSB's Technical Submission (Revision 6, {PSB00000214}, dated 15th March 2016) which records the intended pressure difference as -25Pa.

8.3.30 I also note that BRE's report on the post-fire condition of the system {MET00039807} made the following observations on the settings of the

pressure switches (located in the riser cupboards on each floor at Grenfell Tower):

139 BRE inspection of the lobby/stairwell differential pressure switches on a number of floors showed them to have a switching pressure of about 30 Pa (...) but the scale range was very large (0-300 Pa) so it was difficult to discern a precise value from a visual inspection.

8.3.31 This is more in line with PSB's Technical Submission (Revision 6, PSB00000214, 15th March 2016) than PSB's *Commissioning Method Statement and Risk Assessment* {PSB00000941}.

8.3.32 Figure 8-4 is a photograph from the BRE report of the 6th floor pressure switch (there was one switch contained in each riser cupboard in every lobby at Grenfell Tower). I have marked it with a red circle around the arrow indicating that the pressure set point was set somewhere between 20 and 40 Pa. This does not indicate the measured pressure difference between the stair and the lobby. It is the pressure difference which would cause the switch to activate .

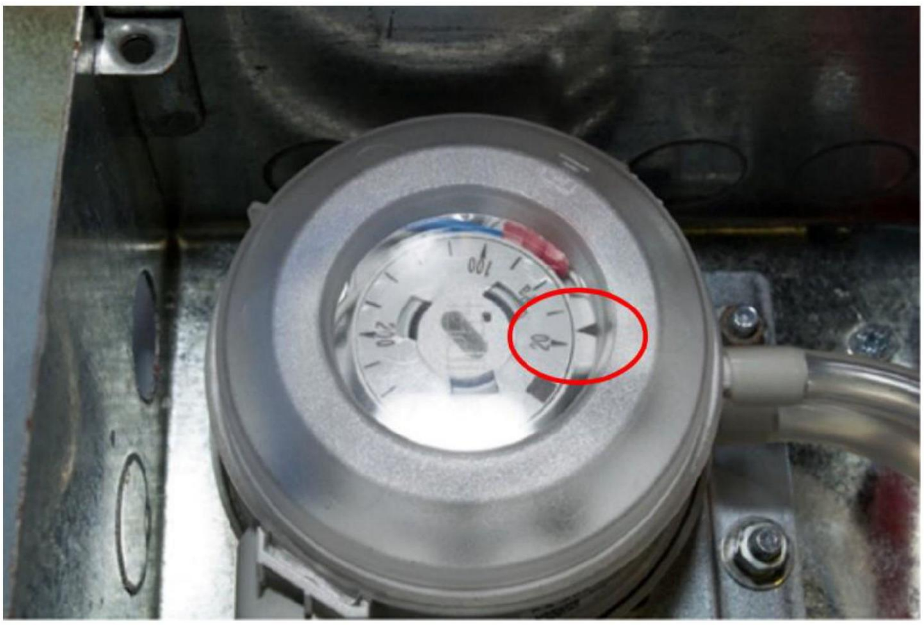


Figure 8-4: 6th floor pressure switch, reprinted from BRE report {MET00039807} (red circled added by me)

8.3.33 I am not aware of any other errors in PSB's *Commissioning Method Statement and Risk Assessment* {PSB00000941} but that will be a matter for PSB to clarify (given that Mr. Partlow's statement referred to 'errors' in the plural).

8.3.34 Dates on which the Grenfell Tower lobby smoke control system was commissioned

8.3.35 In his first witness statement (dated 28th September 2018) {PSB00001309}, Mr Partlow states that he attended Grenfell Tower on the following dates:

- Wednesday 3rd to Friday 5th February 2016 [3 days]
- Monday 8th to Friday 12th February 2016 [5 days]
- Monday 15th to Thursday 18th February 2016 [4 days]
- Monday 14th to Thursday 17th March 2016 [4 days]
- Tuesday 26th to Thursday 28th April 2016 [3 days]

8.3.36 In his second witness statement (dated 26th March 2021) {PSB00001372}, Mr Partlow states (bold by me):

4. In paragraph 13 of my first statement, I said that I attended Grenfell Tower to "commission" the System on dates between February and April 2016. I now appreciate that the word "commissioning" may have different meanings to different people. I used the word to encompass all of my activities on site associated with testing and commissioning the System.

5. As I was asked to attend site to check and test components of the System on numerous occasions as it was being installed, it may help to clarify my use of the word "commissioning" in my first statement.

*6. **My visits to Grenfell Tower in February 2016** were to check the progress of the installation of the System and, where possible, test the **functionality of the components which had been installed. I was not "commissioning" (in the strict sense) the System in line with the performance criteria at this stage**. Obviously, I could not confirm that it was a viable system until construction was complete.*

*7. There was value in these visits because I was able to take preliminary readings to help me confirm that the installation of the System was heading in the right direction and to identify any issues with the installation. Any issues which were identified could be rectified in preparation for **the final commissioning exercise**.*

8.3.37 Mr Partlow does not draw the same distinction on the nature of his visits on the seven days he attended Grenfell Tower in March and April 2016, so I have assumed that it was during this period that he carried out his *final commissioning exercise* in line with the performance criteria.

8.3.38 Mr Partlow's description of the commissioning process

8.3.39 At pages 7-17 of Mr Partlow's first witness statement {PSB00001309}, is a section headed *The Commissioning Process - Step by Step.*

8.3.40 Here, Mr Partlow provides a description of his recollection of the specific steps of the *commissioning process* he undertook.

8.3.41 Mr Partlow sets out 10 steps to this process.

8.3.42 Below are the headings he gives for each of these steps {PSB00001309}.

Step 1 Dead testing of the electrical cabling (paragraphs 34-35)

Step 2 Identification of each component and check it was wired correctly (paragraphs 36- 45)

Step 3 Applying power to the system and checking the power supply to the outstations (paragraphs 46-61)

Step 4 Applying power to the system and checking the inverter panel and fans at roof level (paragraphs 62-64)

Step 5 Connecting the master control panel (paragraphs 65-66)

Step 6 Connecting and applying power to the PLC Unit, HMI Panel (paragraphs 67-71)

Step 7 Connecting the fans to the Master Control Panel (paragraphs 72-73)

Step 8 Setting the damper timer function (paragraphs 74-77)

Step 9 System Testing (paragraphs 78-92)

Step 10 Cause and Effect Check (paragraphs 93-111)

8.3.43 Step 10 has the following subheadings: *Testing the System in smoke control mode, Activating the System in smoke control mode when operating in environmental mode* and *Taking readings - March and April 2016.*

8.3.44 In his second witness statement {PSB00001372}, Mr Partlow does not say which of the ten steps related to testing *the functionality of the components which had been installed* and which related to the *final commissioning exercise* as per the distinction he draws in paragraph 6 of that statement .

8.3.45 So far as I understand, Step 9 was intended to be the validation of *the functionality of the components which had been installed* and the Step 10 *Cause and Effect Check* was intended to validate the integrated systems' performance as against the performance criteria set out in PSB's Technical Submission Revision 6{PSB00000214}; and PSB's *Fans and Damper Operation Cause and Effect Chart* {PSB00000232}.

8.3.46 As stated in section 9 of the SCA Guide 2012 (bold by me):

As smoke control systems are primarily life safety systems and/or for assistance to the fire and rescue service it ***is imperative that the smoke control system is tested by the installer and then witness tested by the approving authority*** *to prove its compliance with the project specification and the approved design criteria.*

8.3.47 In my opinion, the integrated systems' performance tests described in Step 10 constitute the *final commissioning exercise* and were required before Building Control attended their acceptance tests.

8.3.48 Mr Partlow's description of the formal record of commissioning results

8.3.49 Mr Partlow provided the following exhibits to his first witness statement {PSB00001309}:

Exhibit Reference	Inquiry Reference No	Document Description
GP/1	PSB00000140	Purchase Orders from JS Wright (dated 21st January 2016)
GP/2	PSB00000144	Purchase Orders from JS Wright (dated 26th January 2016)
GP/3	PSB00000941	PSB Commissioning Method Statement and Risk Assessment 75019AG (dated February 2016)
GP/4	PSB00000429	PSB E-800 Electrical Schematic Rev. E
GP/5	PSB00001256	Panel and Outstation Data for Job Number 75019AG Rev. 02
GP/6	PSB00000232	PSB Fans and Damper Operation Cause and Effect Chart
GP/7	PSB00000214	Technical Submission for the Lobby Smoke Control System at Grenfell Tower Revision 6
GP/8	n/a	Modbus Outstation Cards
GP/9	PSB00000234	Grenfell Tower Environmental Mode and Normal mode readings
GP/10	PSB00001257	PSB Above Ground Commissioning Report 76005 (dated 26th February 2016)
GP/11	PSB00000224	PSB Above Ground Commissioning Report 76005 (dated 28th April 2016)
GP/12	PSB00000225	PSB UK Operating and Maintenance Instructions for the Above Ground Smoke Ventilation System
GP/13	PSB00001258	PSB UK Completion Certificate (Signed). Project Ref DP.29111.9497 and 75019 (03.05.16)
GP/14	PSB00000474	Correspondence from JS Wright regarding potential fault in relation to the AOV's at Grenfell Tower (dated 6 June 2017)
GP/15	PSB00000479	Quote for one service visit in relation to the potential fault report (dated 12 June 2017)

Figure 8-5 List of exhibits to Mr Partlow's first witness statement

8.3.50 Of these, PSB's *Above Ground Commissioning Report 76005* (dated 28th April 2016) {PSB00000224} and PSB's *UK Completion Certificate (Signed). Project Ref DP.29111.9497 and 75019* (dated 3rd May 2016) {PSB00001258} are the only documents I have seen which record any results of the commissioning process (Mr. Partlow having clarified in his second witness statement that the 28th February 2016 report was not intended to be used as evidence of commissioning).

8.3.51 I note that RBKC Building Control were sent a pdf with the filename "*Grenfell tower readings in fire*" {RBK00003781} as part of the certification documents they received on 4th May 2016 {RYD00076725}.

8.3.52 Mr Partlow did not include this document in his list of exhibits but it would appear to also form part of the formal record of the results of the commissioning process, and sent to RBKC Building Control, presumably to demonstrate compliance with Regulation 7.

8.3.53 <u>Signing of the completion certificate</u>

8.3.54 The completion certificate produced by PSB dated 3rd May 2016 {PSB00001258} and provided in Part 2 of Rydon's Building Manual {TMOM00000043} and Part 3, Section 1, Sub-section 1.2 of the same

{TMOM00001862}, stated as follows:

This is to certify that the "Above Ground Smoke Ventilation System" supplied by PSB-UK for integration into: -

Grenfell Tower,
Grenfell Road
Notting Hill
London, W11 1TQ

Has been Mechanically & Electrically tested in accordance with the schedules laid out in the contract and is fully operational, in line with the agreed specification(s).

Figure 8-6 Excerpt from PSB's commissioning certificate{PSB00001258}

8.3.55 Mr Partlow's first witness statement {PSB00001372} stated as follows in relation to the completion certificate:

49. At paragraph 147 of my first witness statement, I stated that I signed the completion certificate on 3 May 2016 {PSB00001258}.

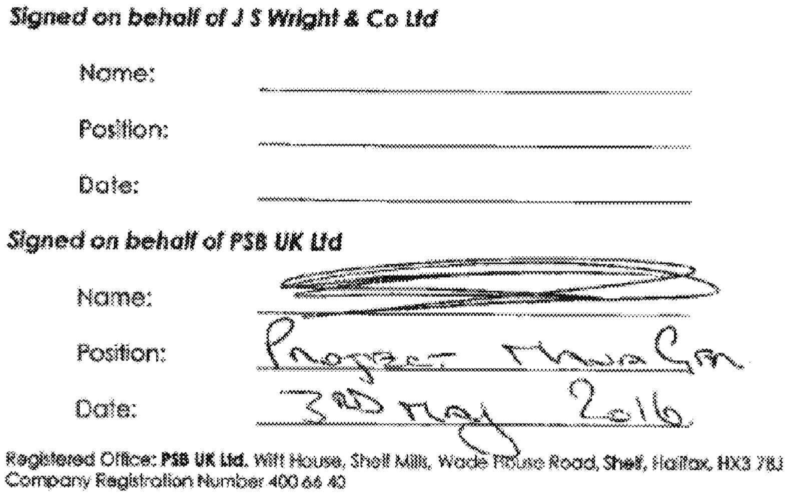
50. After reviewing the documents again, I can see that it was David Harrison of PSB that signed off the completion certificate not me. The commissioning engineer would normally sign off the commissioning report, which I did.

8.3.56 PSB's *Above ground commissioning* report {PSB00000224} dated 28th April 2016 was signed by both Mr Whyte and Mr Partlow as follows:

PSB-UK	CLIENT: JSWright
Name: GRANVILLE PARTLOW	Name: A Whyte
Signature: [signature]	Signature: [signature]
Position: COMMISSIONING ENGINEER	Position: Engineer.
Date: 28th April 2016	Date: 28/04/16.

Figure 8-7 Excerpt from PSB's *Above Ground Commissioning Report* dated 28th April 2016 {PSB00000224}

8.3.57 PSB's Completion certificate dated 3rd May 2016 {PSB00001258} was signed as follows:


Signed on behalf of J S Wright & Co Ltd

Name: ____________

Position: ____________

Date: ____________

Signed on behalf of PSB UK Ltd

Name:

Position: Project Manager

Date: 3rd May 2016

Registered Office: PSB UK Ltd. Wilf House, Shelf Mills, Wade House Road, Shelf, Halifax, HX3 7BJ
Company Registration Number 400 66 40

Figure 8-8 Excerpt from PSB's *Completion certificate* dated 3rd May 2016 {PSB00001258}

8.3.58 I cannot determine whether, as Mr Partlow says, this is David Harrison's signature.

8.3.59 However, this has not materially affected my analysis of the commissioning process.

8.3.60 **Alan Whyte (JS Wright)**

8.3.61 I have been provided with two witness statements from Mr Whyte (JS Wright).

8.3.62 The first statement {JSW00001892}is dated 26th October 2018.

8.3.63 The second statement {JSW00007201} is dated 6th November 2020. This statement does not refer to the commissioning process.

8.3.64 In his first witness statement (dated 26th October 2018) {JSW00001892}, Mr Whyte states:

I have been employed by JSW since October 2013 and am currently employed in the role of senior contracts engineer, a position I have held since December 2015. Prior to that I worked as contracts engineer.

8.3.65 The only documents on commissioning to which Mr Whyte refers are PSB's interim and final commissioning reports at paragraphs 81 and 117 respectively. These seem to be the principal documents on commissioning which PSB sent to JS Wright and I have treated them as such.

8.3.66 **David Hughes (Rydon)**

8.3.67 I have been provided with two witness statements from Mr Hughes (Rydon).

8.3.68 The first statement is dated 26th September 2018 {RYD00094213}.

8.3.69 The second statement is dated 5th September 2019 {RYD00094349} and corrects a date to which he referred in paragraph 61.7 of his first statement.

8.3.70 At paragraph 89 of his first statement (dated 26th September 2018) {RYD00094213}, Mr Hughes describes how Rydon organised the witnessing of the smoke control system on 28th April and 5th May 2016:

We ran two witnessing sessions for the commissioning of the Smoke Extract System. The first session was on 28th April 2016 and, my recollection is that the following were invited to attend: Tony Batty, Clerk of Works, Alan Whyte of JS Wright, Steve Blake, Nicholas Davis from the LFB, Kemal Mehmet from Engie (formally Cofely's), Claire Williams, Paul Steadman, from KCTMO, and Matt Smith, from Max Fordham. An engineer from PSB, Granville Partlow, demonstrated the system. There were no adverse comments from any of the attendees. The second session took place on 5th May 2016 for RBKC Building Control, as detailed earlier in this statement.

8.3.71 Mr Hughes's statement provides no further information on the commissioning process. I also reviewed the transcript of Mr. Hughes' oral evidence in Phase 2 (Module 1) of the Inquiry hearings, and this too does not provide further information about the 28th April 2016 and 5th May 2016 sessions.

8.3.72 Mr Hughes's witness statement does, however, describe further activity regarding Mr Hughes's engagement with RBKC Building Control and the information they required for approval:

61.7 .... Following the demonstration Paul Hanson requested that we do not fit the smoke seals to the lobby doors on the bottom 4 floors. This was to do with the need for "make up air" i.e. to replace air sucked out by the smoke extract system. I liaised a number of times with Paul Hanson over the remaining information he required to issue his approval of the smoke extract system and associated AOVs.

8.3.73 I have found a series of emails between 5th and 21st July 2016 {CST00000009} which discuss this issue. Please see Section 5.11 where I have set out the evidence regarding Rydon's consultation with RBKC Building Control on how this should be resolved.

8.3.74 Please also refer to Section 9 where I explain the issues that arose regarding the provision of make-up air to the lower lobbies at Grenfell Tower, and specifically that they were not ventilated by means of the penthouse louvre at the top of the stair enclosure.

8.3.75 **Paul Hanson (RBKC Building Control)**

8.3.76 As I have described in Section 5, Mr Hanson's witness statements to the Inquiry are both dated 21st November 2018({RBK00033894} and {RBK00033903})

8.3.77 The witness statement {RBK00033903} contains no information regarding the commissioning of the smoke control system therefore I have relied on the statement {RBK00033894}.

8.3.78 Regarding the demonstration of the performance of the smoke control system, Mr Hanson states at paragraph 56 of his first witness statement {RBK00033894} (bold by me):

The system installers J.S. Wright did not use a computer model and ***proposed using an air leakage test upon completion of the installation to show that the system achieved the objective of stopping smoke affecting the stairway.***

8.3.79 Therefore, physical measurement of the performance of the installed smoke control system appears to have been agreed with RBKC Building Control as part of the approval process.

8.3.80 As I have explained in Section 5, I do not know why this single measurement was deemed to be acceptable in lieu of a numerical model.

8.3.81 Mr Hanson confirms that RBKC received commissioning certification which relied on airflow rate measurements {RBK00033894}:

60. The smoke control, system was commissioned (tested) by the installer J. S. Wright who provided commissioning certification confirming the installation met the objectives for the smoke control system. I had no involvement in witnessing such tests. The commissioning results show a flow rate exceeding 2 m/s at all floor levels (Ref: FORT01225831)

8.3.82 My understanding is that the *"Certification"* to which Mr Hanson refers consists of the five documents attached to an email from Mr Whyte (JS Wright) on 4th May 2016 {RYD00076725}.

8.3.83 My assumption is that these documents were provided as evidence of compliance with Regulation 7, i.e. that they documented how the system had been fully commissioned and had been proven to achieve the required performance criteria set out in PSB's Technical Submission Revision 6 {PSB00000214}.

8.3.84 This was in preparation for Building Control's witnessing of tests the following day (5th May 2016).

8.3.85 The five documents were:

a) PSB's Technical Submission Revision 6{PSB00000214}.
b) PSB's *Above ground commissioning report* {PSB00000224}
c) PSB's *E-800 Electrical Schematic Rev. E* {PSB00000429}.
d) PSB's *Fans and Damper Operation Cause and Effect Chart* {PSB00000232}.
e) *Grenfell tower readings in fire* {RBK00003781}.

8.3.86 The two documents which record the commissioning results are *Grenfell tower readings in fire* {RBK00003781} and PSB's *Above ground commissioning report* {PSB00000224}.

8.3.87 The air velocity results from the *"Grenfell tower readings in fire"* PDF file are excerpted below (red box added by me to highlight the fact that the flow rate exceeded 2m/s at all floor levels as stated by Mr Hanson {RBK00033894}):

Floor Level	Open Door M/sec	Low grille low speed M/sec	Low grille high speed M/sec	High grille low speed M/sec	High grill high speed M/sec
G	2.9	-0.6	1.6	3.5	7.1
1	3.3	2	7.2	3.5	9
2	4.6	2.4	7.1	4	7
3	5.1	2.7	7.2	5.7	9
4	4.2	0.6	5.1	2	5.8
5	4.4	-0.5	5	1.7	5.4
6	3.6	-0.4	4.8	1.9	5.6
7	4	0.5	4.8	1.7	5.7
8	3.9	0	4.6	2	5.6
9	3.6	0.3	4.7	1.9	5.6
10	3.5	0	4.4	2.1	5.8
11	3.4	0.9	4.1	2.1	5.9
12	3.8	-0.9	3.7	2.1	5.9
13	3.8	-0.6	3.3	2.3	6.2
14	3.4	-0.1	3.5	2.4	6.1
15	3.3	-0.5	3.6	2.2	5.8
16	3.6	-0.8	3.4	2.2	5.9
17	3	-0.7	3.4	2.2	6.2
18	3.5	0.8	3.1	2.3	6.2
19	3.7	-0.8	3	2.4	6.2
20	3.4	-0.7	3.2	2.4	6.2
21	3.3	-0.7	2.8	2.3	6.5
22	3.2	0	2.6	2.6	6.5
23	3	0	2.8	2.5	6.2

the higher than normal readings on levels 1 and 3 were due to missing grilles all readings are in metres per second fans at 100% speed

Figure 8-9 Grenfell Tower smoke control system air velocity sent to Mr Hanson {RBK00003784} attached to {RBK00003781}

8.3.88 Mr Hanson also states that RBKC attended a demonstration of the system on 5th May 2016, but that this did not include any assessment of the system's performance {RBK00033894}.

8.3.89 My understanding is therefore that these were the formal witnessing tests by which Rydon sought to demonstrate compliance with Regulation 7 and RBKC Building Control sought to satisfy themselves of the operational performance of the system as against Part B of the Building Regulations 2010:

62. Although commissioning certification had been issued, I knew from past experience (visiting sites with the Council's former Mechanical and electrical engineer) that there can be problems with 'inlet air' functioning properly. I suggested to John Hoban the Area Surveyor (building control officer), that we attend a working demonstration of the system. Alan Whyte from J. S. Wright (the smoke control system installers), also attended to demonstrate the system on 4/5/2016.

63. The demonstration on 4/5/2016 was limited to the sequence of operation of the system from activation of a small selection of the smoke detectors in the lobbies on a few floor levels. It did not involve a witnessing of the previously commission airflow rates etc. It was a demonstration of the sequence of operation.

8.3.90 Mr Hanson states that RBKC became aware at the demonstration that no inlet air vents were provided at Ground floor level, as were required to provide a replacement air path.

8.3.91 In section 9 of this report, I set out the evidence of changes made to the system after PSB's completion of the commissioning process.

8.3.92 Mr Hanson has not provided any further evidence of the commissioning process, nor why he considers the set of documentation he was provided with, coupled with the tests he witnessed, allowed him to reach a view on either Part B of Schedule 1, or Regulation 7, of the Building Regulations.

8.4 Overview of the commissioning process

8.4.1 Once all the individual components (or sub-systems) of a complete smoke control system are installed, functional performance testing is usually carried out to ensure each component can function as required.

8.4.2 This is done firstly at a component level (e.g. detector or damper connected and functioning), then at sub-system level (e.g. controller reading detectors or driving dampers) and finishes with full system *end-to-end* testing (e.g. complete system responding to the approved Cause &Effect scenarios).

8.4.3 Accordingly, each component of the system must be checked for its correct functional performance before the integrated system is tested.

8.4.4 The system should then be demonstrated again to Building Control during formal witnessing tests.

8.4.5 Based on my experience, it is also typical for the designer to provide a high level narrative for the commissioning team so that they understand what to do, together with providing a cause and effect matrix to reflect the components and the required sequence of operation for all relevant scenarios the system has been designed for.

8.4.6 This can be a high level cause and effect matrix, if contractually others are responsible for setting out a detailed cause and effect matrix.

8.4.7 This enables the cause and effect logic to be programmed into the Master Control Panel accurately, and ensures that the Responsible Person can also understand the ongoing testing requirements.

8.4.8 This narrative and the final cause and effect matrix are critical to ensure that the performance of the system is clearly narrated to those that have duties to commission it and then to maintain and test it.

8.4.9 This is reflected in the Documentation list provided in Section 9.2 of both the 2012 and 2015 SCA Guide.

8.4.10 As in section 8.3.39 above, at pages 7-17 of Mr Partlow's first witness statement {PSB00001309} is a section headed *The Commissioning Process - Step by Step.*

8.4.11 In these pages Mr Partlow describes the specific steps of the *commissioning process* he recalls having undertaken, dividing them into 10 steps.

8.4.12 I am particularly interested in Step 9, *System Testing*, and Step 10, the *Cause and Effect Check.*

8.4.13 As I mention above, my understanding is that Steps 1- 8 were tests of the individual components (or sub-systems) prior to the testing of individual systems at Step 9 and final integrated systems at Step 10.

8.4.14 The final step in commissioning is to carry out integrated systems testing. This is to validate the performance of the whole system as against the design specification.

8.4.15 The individually commissioned sub-systems are tested to make sure that they can operate in the various modes required in the event of a fire.

8.4.16 Mr Partlow refers to Step 10 of this process as the *Cause and Effect Check* with the following subheadings: *Testing the System in smoke control mode*, *Activating the System in smoke control mode when operating in environmental mode* and *Taking readings - March and April 2016.*

8.4.17 My understanding is that this part of Mr Partlow's process was the full integrated systems testing.

8.4.18 At paragraph 52 of his first witness statement {PSB00001329}, Mr Mahoney states that the performance criteria for the system was:

a minimum velocity of 2.0 m/s being achieved through an open common lobby door to the stair. In achieving the recommended flow rate, the design also included provision to ensure that the opening force on the door would not exceed 100N.

8.4.19 At paragraph 53 he states:

I was aware that Granville would commission the System to meet these performance criteria on site and I understand that he has provided a witness statement to the Inquiry.

8.4.20 In Section 8.3, I presented the list of documents which Mr Partlow says he received before commissioning the system in Grenfell Tower.

8.4.21 Mr Partlow does not say who supplied them.

8.4.22 More importantly, these documents do not reveal what (if any) guidance or British Standards were used to develop the commissioning methodology on which Mr Partlow relied.

8.4.23 Accordingly, I have looked through the guidance available to PSB's *"Group Service and Engineering manager"* to undertake the commissioning.

8.4.24 On 4th May 2016, RBKC Building Control sent PSB the Smoke Control Association (SCA) document: *Guidance on Smoke Control to Common Escape routes in apartment Buildings (Flats and Maisonettes) Rev 2: October 2015*, stating as follows in their covering email {PSB00001130}:

"Remember that the testing of the powered vent system we are witnessing tomorrow should be in accordance with section 9 and item [sic] *of the attached SCA guide."*

8.4.25 I note that Section 9.1 of the *SCA Guide 2015*, headed *Commissioning and Acceptance Testing*, refers to a further relevant British standard:

BS 7346 Part 8 sets out the recognised code of practice for commissioning and acceptance testing of a smoke control system including examples of certification. The following sections provide useful guidance intended to supplement that given in BS 7346 Part 8.

In addition extract rates for mechanical systems should be proven. Guidance to testing airflows can be found in the BSRIA Guide Commissioning Air Systems.

Where smoke tests/ system demonstrations are being completed for AHJ to witness, it would be expected that the specialist contractor confirms the method statement for the test/ demonstration in advance, which would include agreed acceptance criteria.

8.4.26 The full title of BS 7346 Part 8 is *Components for Smoke Control Systems Part 8: Code of practice for planning, design, installation, commissioning and maintenance*.

8.4.27 Section 9.2 SCA Guide 2015, goes on to deal with documentation, advising that all smoke control systems should be handed over to the end user with a complete set of documentation.

8.4.28 Section 9.3 then deals with six different test procedures, which I explain later.

8.4.29 Accordingly, with reference to the commissioning process described in *SCA Guide 2015,* which as I go on to explain also references BS EN 12101-6: 2005 and BS 7346 Part 8, I have reviewed the documents below:

a) PSB's Technical Submission Revision 6 {PSB00000214};

b) PSB's *Commissioning Method Statement and Risk Assessment 75019AG* {PSB00000941};

c) PSB's *E-800 Electrical Schematic Rev. E* {PSB00000429};

d) PSB's *Fans and Damper Operation Cause and Effect Chart Rev 04* {PSB00000232};

e) PSB's commissioning certificate {PSB00001258};

f) *Grenfell tower readings in fire* {RBK00003781}.

8.4.30 In Sections 8.5-8.7 below, I summarise the recommendations in these documents.

8.4.31 In Sections 8.9 and 8.10, I then assess PSB's commissioning documentation (listed in section 8.4.21 above) against these recommendations.

8.5 Smoke Control Association (SCA) Guidance 2015

8.5.1 Section 9 of the *SCA Guide 2015* is headed *9 Commissioning and Acceptance testing.*

8.5.2 Section 9.3 is headed *Test procedures* and sets out the relevant commissioning test procedures for the following types of system:

a) Airflow measurement

b) Stairwell ventilator;

c) Wall mounted ventilator;

d) Natural ventilator Shaft System;

e) Mechanical Shaft System;

f) Pressure Differential System (pressurisation and **de-pressurisation**).

8.5.3 In his second witness statement {PSB00001373}, Mr Mahoney states (bold by me):

37. In contrast with the mechanical extract 'depressurisation' system I designed at Grenfell Tower, the types of Pressure Differential Systems referenced in BS EN 12101-6 are either:

a. Positive Pressure Differential Systems which pump air into the protected space. In the case of Grenfell Tower, the protected space was the stairwell. I discussed at paragraph 32(4) of my first statement the impracticability of a installing a positive Pressure Differential System at Grenfell Tower, as it would have meant cutting large holes through the concrete slab to accommodate supply ducts to the stair, lobby and lift shaft, and accommodation air release paths.

b. Depressurisation systems which extract air direct from the fire zone. In the case of Grenfell Tower, the fire zone was the fire flat. Such a system would have been inherently impractical at Grenfell Tower as it would have required large holes to have been cut in the concrete slab to accommodate new supply and smoke extract ducts from each flat.

38. In my experience, the classes of Pressure Differential System set out in BS EN 12101-6 are not commonly used in residential developments in the UK.
*40. It follows that **I did not design a Pressure Differential System**, which are designed to comply with all the requirements of BS EN 12101-6.*

41. My design reflected a more common type of mechanical extract 'depressurisation' system.

8.5.4 Mr Mahoney goes on to clarify:

55. The SCA Guide 2015 changed the description of the "Mechanical Extract, Natural Inlet" system type. The description in the 2015 Guide states that:

"6.4.2 Mechanical Extract, Natural Inlet

The system comprises mechanical extract shaft(s) serving one or more common spaces on all, or some, of the floor levels supplemented by the provision of natural inlet air provided by automatically opening vents or permanent vent to the outside (either directly or by way of a shaft, stairway or duct)."

...

57. I knew from experience that a mechanical extract system of the "Mechanical Extract, Natural Inlet " type, which created a depressurised space resulting in an induced air flow across the open door to the stair (flowing from the stairwell into the lobby), would afford the stair in Grenfell Tower the best form of protection available.

58. "Mechanical Extract, Natural Inlet" type smoke control systems were (and remain) commonly used in the industry.

59. An example of this type of system, which works in the same way to that which I designed for Grenfell Tower (using extraction through shafts to create a depressurised space resulting in an induced air flow across the open door to the stair), as referenced above this is commonly referred to, in the Building Services Industry, as the ColtShaft mechanical shaft system.

8.5.5 The SCA Guide 2015 test procedure for a Mechanical Shaft System is set out at Section 9.2; and the test procedure for a Pressure Differential system (pressurisation and de-pressurisation) is given at Section 9.3.

8.5.6 The Mechanical Shaft system test as described by the SCA Guide 2015 makes no mention of pressure differentials (a fundamental parameter of PSB's design) yet the Pressure Differential system test procedure does, including making reference to BS EN 12101-6.

8.5.7 I note that Mr Whyte (JS Wright) specifically stated by email to Mr Hanson (RBKC Building Control) on 4th May 2016:

Below are the acceptance testing requirements from the Smoke Control Association Guide ***for pressure differential systems****, with items to be demonstrated tomorrow in red.*

8.5.8 J S Wright therefore appear to have been of the opinion that the commissioning methodology for pressure differential systems from the SCA Guide 2015 was the relevant guidance.

8.5.9 The SCA Guide 2015 refers primarily, to BS 7346-8:2013 as the recognised code of practice *"for commissioning and acceptance testing of a smoke control system"*.

8.5.10 This British Standard lists thirteen specific inspections and tests at commissioning which should be undertaken for smoke control systems.

8.5.11 To date, PSB have not confirmed which test procedures they relied upon for commissioning, despite being instructed by RBKC Building Control to rely on the SCA Guide 2015.

8.5.12 Therefore it is necessary for me to compare their activities with both options provided in the SCA Guide 2015, as well as BS EN 12101-6, and BS 7346-8:2013.

8.5.13 In Table 8-2 below I have compared the commissioning tests recommended in the SCA Guide 2015 for a mechanical shaft system and pressure differential system.

Table 8-2 Comparison of mechanical shaft system and pressure differential system commissioning tests from the SCA guide 2015

Mechanical shaft system	Pressure differential system (pressurisation and de-pressurisation)
	BS EN 12101-6 provides a detailed set of test procedures which should be carried out
Operate each shaft ventilator via the activation of the designated manual or automatic device. Only one shaft ventilator into one shaft should open at any time, all ventilators on other floors should remain closed. The test should confirm that this continues to be the case even if an automatic signal is received on floors other than the original floor.	Operate each shaft ventilator via the activation of the designated manual or automatic device.
	Check that the fan(s) operate at the same times as the opening of the dampers, measure its performance and check against the design value.
Check the automatic change over is operational for the standby fan.	Check the automatic change over is operational for the standby fan.
Check the automatic change over is operational for the secondary power supply.	Check the automatic change over is operational for the secondary power supply.

Mechanical shaft system	Pressure differential system (pressurisation and de-pressurisation)
	Inspect the motor drive for correct operation and extension.
Check the ventilators in the smoke shaft and the fans operate in accordance with the design cause and effect and inspect for correct operation.	Operate the ventilators and fans in accordance with the design cause and effect and inspect for correct operation and extension
Measure the flow rate into the shaft system at the ventilator furthest from the fan position.	
Check the maximum forces required to open escape doors whilst the system is operating in means of escape mode and record results. The recorded force must not exceed 100N.	Check the maximum forces required to open escape doors while the system is operating in means of escape mode and record results. The recorded force must not exceed 100N.
Check the operation of the manual control point(s) to ensure the system operates as requested. Where a manual control point for firefighting use is provided at each floor level to switch between fan speeds then the operation of this switch should also be checked that it results in the correct action.	Check the operation of the manual control point(s) to ensure the system operates as requested
	Where applicable, the operation and function of the pressure sensors should also be checked.
Carry out a cold smoke test if appropriate (generally only for systems used to allow extended travel distances).	
Reset the system on completion of test.	Reset the system on completion of test.
Provide a certificate of test	Provide a certificate of test
Provide a certificate of compliance with the design intent.	Provide a certificate of compliance with the design intent.

8.5.14 As shown in Table 8-2, when one considers the combined recommended commissioning tests for a mechanical shaft system and a pressure differential system, there are fifteen separate tests that could have been undertaken.

8.5.15 In Section 8.10, I compare the commissioning tests undertaken by PSB for the smoke control system installed in Grenfell Tower compared to the tests listed in Table 8-2.

8.6 BS EN 12101-6 Test procedures and test readings

8.6.1 BS EN 12101-6 describes in Clause 12 five ‘acceptance tests’ which should be undertaken for a pressure differential system; and they could have been

reasonably adapted for use to test the lobby smoke control system at Grenfell Tower.

8.6.2 Clause 13.6 of BS EN 12101-6:2005, headed *Re-tests*, states:

The entire pressure differential system shall be re-tested in accordance with 12.1 (acceptance testing) following any modification to the building that could affect the pressure differential system, e.g. alterations to internal partitions, extensions and alterations to the pressure differential system

8.6.3 In addition, Clause 14 of BS EN 12101-6:2005 headed *Documentation* provides guidance on the installation details which should be provided to the approving authority (Clause 14.1) and to the owner/occupier (Clause 14.2).

8.6.4 Clause 14.1 *Approving authority requirements* states

"*The approving authority shall be provided with full details of the installation. These shall include:*

a) full calculations showing the design criteria (see Clause 15);

b) full specification details of the equipment used (see Clause 11);

c) complete plans showing position and protection of the fan and associated electrical control equipment, and the location of fresh air inlets (see Clause 11);

d) constructional details of the ductwork and duct terminals used for the pressure differential system (Clauses 5 and 11);

e) any other relevant constructional information required by the approving authority (see Clause 11);

f) full operational details describing in words and by diagram the exact sequence of actions that will occur in the pressure differential system and in the normal ventilating system when a fire occurs in the building (see Clauses 4 and 7);

g) a complete maintenance schedule indicating the maintenance checks needed for each item of the equipment and the frequency of these checks (see Clause 12 [sic]*);*

h) on completion, the results of the tests carried out on the pressure differential system (see Clause 13*[Sic]*)."

8.6.5 I note that BS EN 12101-6 specifically states that the "*results*" of the tests carried out need to be provided to the approving authorities.

8.6.6 Clause 14.2 *Owner/occupier requirements* sets out the steps which should be taken to describe the purpose and operation of the installation:

"*The occupier/owner of the building shall be provided with a clear description of the purpose and operation of the installation. This shall include:*

a) a clear description of the purpose of the installation (see Introduction);

b) a concise statement in words assisted by diagrams of the operation of the installation giving a clear indication of the sequence of events that will follow an alarm of fire (see Clause 4);

c) a complete maintenance schedule indicating the maintenance checks needed for each item of the equipment and the frequency of these checks (see Clause 13);

d) a check list in the maintenance schedule of the actions necessary for maintenance, together with a register that will form a record of the maintenance carried out and in which any faults found, and any corrective actions taken, may be recorded (see Clause 13);

e) a set of 'as installed' drawings for retention on the site (see Clause 13);

f) a statement to indicate that alterations to:

– accommodation areas (e.g. sub-dividing floor areas);

– floor covering under doors

may affect the operation of the pressure differential system (see Clause 13)."

8.7 Guidance in BS 7346-8: Code of practice for planning, design, installation, commissioning and maintenance

8.7.1 Section 8 of BS 7346-8 is headed *'Commissioning, documentation, certification and acceptance'*.

8.7.2 Clause 8.1 of BS 7236-8:2013 addresses commissioning and states (bold by me):

8.1 Commissioning

NOTE The process of commissioning involves thorough testing of the installed smoke control equipment, including interactions with other systems.

The responsibility of the commissioning engineer is to ***verify*** *that the system operates correctly in the manner designed and that the installation workmanship is of an adequate standard. It is therefore necessary for the* ***commissioning engineer to be provided with the agreed specification*** *for the system.*

8.1.1 The system should be ***commissioned by a competent person*** *(see 8.1.2), who has access to the requirements of the designer (i.e. the system specification) and any other relevant documentation or drawings.*

8.1.2 The person commissioning the smoke control system should possess at least a basic knowledge and understanding of the activities covered in Clause 5, Clause 6 and Clause 7.

8.7.3 BS 7236-8 then lists thirteen specific inspections and tests at commissioning. I have excerpted these below:

8.1.3 At commissioning, the entire system should be inspected and tested to ensure that it operates satisfactorily and that, in particular:

a) labelling or other means of visual identification, if specified, have been carried out;

b) the agreed "cause and effect" requirements are correctly implemented (see 6.7) and the system is tested and responds to any planned method of initiation;

c) no changes to the building since the time of the agreed design have compromised the system's conformity with the design specification (e.g. erection of new partitioning that affects the effectiveness of the smoke control system);

d) siting of control, indicating and power supply equipment is inspected and verified;

e) primary power supplies are inspected as far as reasonably practicable;

f) secondary power supplies and the actual load currents of the system, in all circumstances, are close to the predictions used by the designer to determine the capacity;

g) when the primary power is removed, the secondary power supply operates within the interruption time specified in BS EN 12101-10;

h) when the duty equipment fails, standby equipment operates, e.g. duty standby fan sets and uninterruptable power supplies (UPS) equipment;

i) labels, visible when secondary power supplies (e.g. batteries) are in their normal position, are fixed to batteries, indicating the date of installation;

j) as far as it is reasonably practicable to ascertain, the specified cable type has been used in all parts of the system and the workmanship conforms to the design and relevant standards;

k) all fault monitoring functions operate correctly by simulation of fault conditions;

l) all relevant documentation has been provided to the relevant responsible person;

m) on completion of commissioning, a certificate signed by a competent person (see the example given in B.3) is issued.

8.7.4 Clause 8.1 of BS 7236-8:2013 also then states:

All results obtained during the commissioning process should be clearly recorded.

8.7.5 Clause 8.3 Certification of BS 7346-8:2013 states (Bold by me):

8.3 Certification

8.3.1 On, or as soon as practicable after, completion of each of the following processes, a certificate should be issued by the organization(s) responsible for the process, certifying compliance with the recommendations of this standard relating to the following, and clearly identifying any deviations (see Annex B).

a) Design.

b) Installation.

c) Commissioning.

d) Acceptance.

8.3.3 The person(s) who signs these certificates should be competent to verify whether the recommendations of this standard in respect of the process to which each certificate refers have, or have not, been satisfied.

NOTE The relevant responsible person might subsequently rely on the certificates as, for example, evidence of compliance with legislation. ***Liability could arise on the part of any person or organization that issues a certificate without due care in ensuring its validity.***

8.3.4 Where modifications are carried out to a system, the relevant responsible person should request that the organization responsible for the work issues a ***modification certificate*** *(see B.6).*

8.7.6 Clause 8.4 *Acceptance* of BS 7346-8:2013 states (bold by me):

8.4.2 Acceptance procedures should be carried out in accordance with the agreed specification, including any tests that are to be witnessed and details of the witnessing procedure.

8.4.3 Before accepting a system, the relevant responsible person (or appropriate representative of the responsible person) should check that:

a) all installation work appears to be satisfactory;

b) the system fully operates when the primary power supply is removed;

c) the following documents have been provided to the relevant responsible person:

1) as-fitted drawings;

2) operating and maintenance instructions;

3) certificates of design, installation and commissioning;

4) a logbook;

d) sufficient representatives of the user have been adequately trained in the operation of the system;

e) all relevant tests defined in the specification have been witnessed.

8.7.7 Annex B of BS 7346-8:2013 then provides *Model certificates* including an example of a commissioning certificate in Annex B.3 and an example of an acceptance certificate in Annex B.4.

8.8 Equipment required to commission the system

8.8.1 Mr Partlow states at paragraph 24 of his first witness statement {PSB00001309}:

> 24. I take the following equipment with me when commissioning a system:
>
> 1) A multimeter, used for measuring basic electrical tests, voltage, current, etc.
> 2) A calibrated anemometer, used for measuring airflow speed
> 3) Basic electrical tools – screwdrivers, pliers, etc.
> 4) A set of two way radios, to enable me to communicate with other individual(s) involved in the commissioning process.

8.8.2 Neither BS EN 12101-6, the SCA 2015, nor BS 7346-8 provide a list of equipment that is required to undertake commissioning tests.

8.8.3 Based on my review of the recommended tests to be undertaken (as presented in Section 8.5, 8.6, and 8.7) the equipment listed below would have been required to allow the smoke control system in Grenfell Tower to be fully commissioned:

a) Multi-meter
b) Manometer
c) Balometer/Hood
d) Anemometer
e) Force gauge/ Spring balance
f) Fire service override key.

8.8.4 In the following sections I provide an explanation of what each piece of equipment measures and how it would have been used in Grenfell Tower.

8.8.5 I have referred to guidance produced by the Building Services Research and Information Association (BSRIA) titled *"Commissioning air systems"* i below . The scope of this document is for *"ducted air distribution systems in buildings" not* smoke control systems however similar equipment is used in both cases to measure velocity of air, pressure differentials and performance of components.

8.8.6 I note that this document was referenced in a 2019 CPD by Colt titled *"Commissioning and maintenance of smoke control systems"*{INQ00014729}.

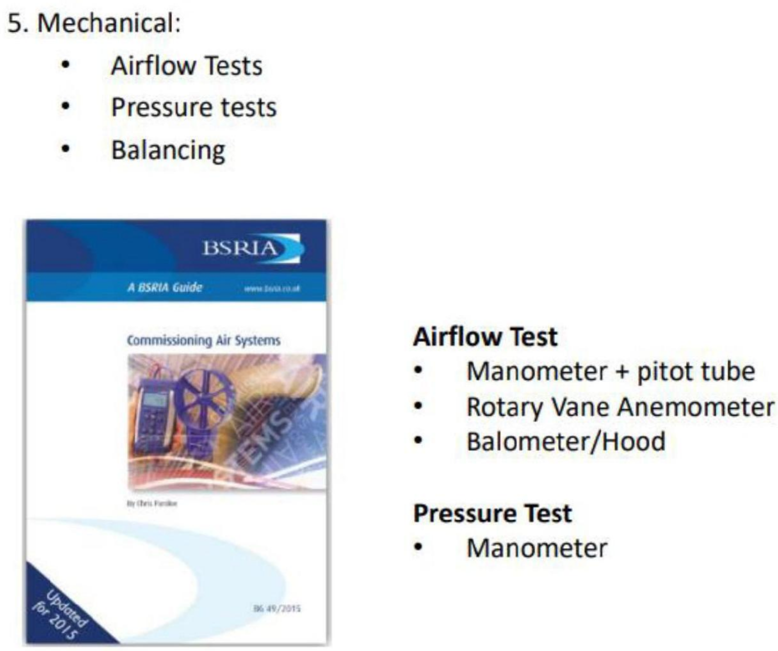


Figure 8-10 Excerpt from Colt CPD

8.8.7 It is also referred to by the SCA Guide 2015 in Section 9.3.1 *Airflow measurement* as I discuss below.

8.8.8 **Multimeter**

8.8.9 A multimeter is defined[7] as a:

multirange multifunction measuring instrument intended to measure voltage, current and sometimes other electrical quantities such as resistance

8.8.10 As part of the commissioning process at Grenfell Tower I would expect that this device would be used to demonstrate that all of the electrical components such as the dampers, fans, outstations, and inverter panels were receiving the voltage and drawing the correct current in order to function.

8.8.11 Mr Partlow states that he took a multimeter to site for the commissioning tests.

8.8.12 **Micromanometer**

8.8.13 The BSRIA guide " *"Commissioning air systems"* states:

Pressure reading instruments are used for measuring:

- *Total, static, velocity pressures in a ductwork system when used with a pitot tube*

[7] https://www.electropedia.org/iev/iev.nsf/display?openform&ievref=312-02-24; Accessed:14/05/2021

- *Static pressures in ductwork by the use of side wall connections*
- *Differential pressures between one space and another*

The main type of instrument now used is an electronic micromanometer which has largely superseded the traditional liquid filled manometer tests sets

8.8.14 In Grenfell Tower a micromanometer could be used to measure the differential pressure in the lobbies and on the stairwells.

8.8.15 If the micromanometer was used in conjunction with a pitot tube it could also be used to measure the velocity of air downstream for the level 2 and roof fans; and/ or the velocity of the air movement in the smoke shafts.

8.8.16 I note that Section 9.3.1 of the SCA Guide 2015 states:

Where it is difficult to undertake reliable pitot tube readings for mechanical smoke extraction systems due to the orientation of dampers, shafts and the fan location, the following guidance should be used.

BSRIA BG49/2013 clarifies that damper/grille flow rates can be considered as the average velocity multiplied by the grille face area with no correction for the free area of the grille.

8.8.17 Please refer to Section 8.8.25 where I present my review of the equipment required to measure air velocity.

8.8.18 An example of a pitot tube/ manometer is shown in Figure 8-11.

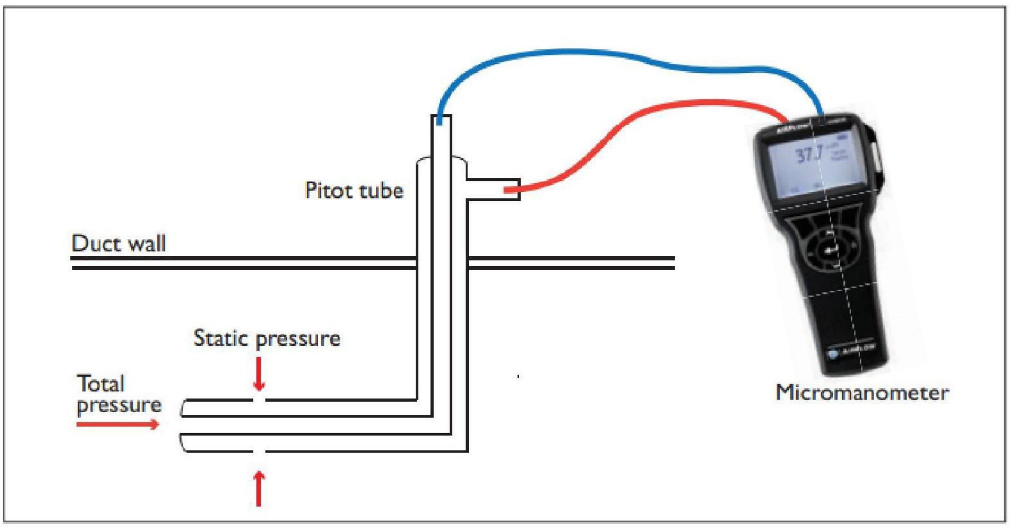


Figure 8-11 Pitot tube operating principle (from Figure 9 of BSRIA guide *"Commissioning air systems")*

8.8.19 Mr Partlow does not refer to having a micromanometer on site in Grenfell Tower.

8.8.20 **Air capture hood (Balometer)**

8.8.21 The BSRIA guide "*"Commissioning air systems"* states:

Air capture hood (balometer)

These are lightweight collapsible assemblies used for the measurement of flowrates at supply and extract diffusers

8.8.22 I have shown an image of an air capture hood (balometer) in Figure 8-12.

Figure 8-12 Air capture hood (balometer) (from Figure 14 of BSRIA guide *"Commissioning air systems")*

8.8.23 In Grenfell Tower an air capture hood (balometer) could have been used to measure the flow rate of extraction through the lobby dampers on each floor.

8.8.24 Mr Partlow does not refer to having an air capture hood (balometer) on site in Grenfell Tower.

8.8.25 **Rotating vane Anemometer**

8.8.26 The BSRIA guide "*"Commissioning air systems"* states:

The main application of the rotating vane anemometer is the measurement of flow rate at grilles hoods and other relatively large openings

8.8.27 I have shown an image of a rotating vane anemometer in Figure 8-13.

Figure 8-13 Rotating vane anemometer (Figure 10 from BSRIA guide *"Commissioning air systems"*)

8.8.28 In Grenfell Tower a rotating vane anemometer could have been used to take a range of air velocity measurements through the open door between the stair and the lobby.

8.8.29 This could also have been used to measure the air velocity through the lobby dampers on each level in order to calculate the flow rate of air through the damper.

8.8.30 Mr Partlow does refer to having an anemometer onsite in Grenfell Tower.

8.8.31 **<u>Force gauge/ Spring balance</u>**

8.8.32 A spring balance is a described as[8]:

a type of mechanical force gauge or weighing scale. It consists of a spring fixed at one end with a hook to attach an object at the other. It works by Hooke's Law, which states that the force needed to extend a spring is proportional to the distance that spring is extended from its rest position.

8.8.33 In Grenfell Tower a spring balance would be used to measure the door opening force for the door between the depressurised lobbies and the stair.

8.8.34 Mr Partlow does refer to having a spring balance on site at Grenfell Tower.

8.8.35 In his second witness statement dated 26th March 2021, Mr Partlow states:

[8] https://en.wikipedia.org/wiki/Spring_scale; accessed: 14/05/2021

27. From memory, ***during the final commissioning exercise****, Alan Whyte of JS Wright obtained a spring balance device so that we could take and record the necessary door opening force readings.* ***I myself did not keep any record of the readings that were taken***

8.8.36 **<u>Fire service override switch key</u>**

8.8.37 A key was needed to operate the fire service override switches.

8.8.38 Mr Partlow does refer to having a fire service override switch key on site in Grenfell Tower.

8.8.39 **<u>Summary</u>**

8.8.40 In Table 8-3 below I have summarised the equipment required to commission a smoke control system; what it is used for; the unit of measurement (where applicable and whether Mr Partlow took this equipment to site at Grenfell Tower.

Table 8-3 Summary of commissioning equipment

Equipment	Purpose when used in the context of commissioning the smoke control system at Grenfell Tower	Unit of measurement	Equipment to site by Mr Partlow	Relevant to Mr Mahoney's Performance criteria
Multimeter	Measuring that electrical components of the system are receiving the required voltage and drawing the correct current	Voltage (V) Ampere (A)	Yes	Criteria not specified by Mr Mahoney
Micromanometer	Measuring differential pressure between the lobby and the stair	Pascals (Pa)	Mr Partlow does not refer to this equipment	Pressure differential between stair and lobby of -25Pa
Air capture hood (Balometer)	Measuring volume flow rate through dampers	m^3/s	Yes	Criteria not specified by Mr Mahoney
Rotating vane Anemometer	Measuring air velocity through the door between the lobby and the stair	m/s	Yes	Velocity of air through door to stair of 2m/s
Force gauge/ spring balance	Measuring Door opening force	Newtons (N)	No, equipment was supplied by JS Wright	Door opening force of less than 100N
Fire service override switch key	Operating damper override controls	N/A	Mr Partlow does not refer to this equipment	Criteria not specified by Mr Mahoney

8.9 Documents relevant to PSB's commissioning process

8.9.1 In this section I present the documents I have seen which are relevant to setting the performance criteria for the system, developing the commissioning methodology and recording the results of the commissioning process.

8.9.2 In Sections 8.8 and 8.10, I present my review of these documents against the recommendations from industry guidance and relevant British Standards.

8.9.3 **Documents setting the performance criteria for the system**

8.9.4 As I set out in Section 5 above, section 1.1.2 of PSB's Technical Submission Revision 6 {PSB00000214} sets the following performance criteria for the system in the scenario described:

> The Final smoke control system has been designed to provide the existing stairwell with protection from the ingress of smoke, from a fire within a dwelling, by means of a mechanical extract system. The system has been designed to provide an average open door velocity, across an open lobby/stairwell door of 2.0m/s. This velocity is in accordance with the recommendation for a Class B pressure differential system as defined in Code of Practice BSEN12101 Part 6: Specification for pressure differential systems — Kits. (BSEN12101-6)
>
> The control system will also have pressure sensors added into each ventilated lobby to control the speed of the fans to ensure that when the doors on the escape route are closed that the opening force on the door does not exceed 100N as detailed IN BSEN12101-6

8.9.5 Additionally at paragraph 52 of his first witness statement {PSB00001329}, Mr Mahoney states that the performance criteria for the system was:

a minimum velocity of 2.0 m/s being achieved through an open common lobby door to the stair. In achieving the recommended flow rate, the design also included provision to ensure that the opening force on the door would not exceed 100N.

8.9.6 At paragraph 53 he states:

I was aware that Granville would commission the System to meet these performance criteria on site and I understand that he has provided a witness statement to the Inquiry.

8.9.7 I note that the *"open door velocity"* performance criteria set in PSB's Technical Submission Revision 6 {PSB00000214} refers to a single-door-opening scenario - the door between the lobby and the stairwell.

8.9.8 As I have explained in Section 2, the relevant functional requirement in ADB 2013 is that:

b) The flat entrance door, where the fire has occurred, is assumed open when occupants escape;

c) The lobby door to the stair, on the fire floor, is assumed open as occupants escape enter the protected stairway, and proceed to a place of safety at their own pace.

8.9.9 The above may not necessarily occur simultaneously. However, during firefighting the flat entrance door and the door from the stair into the lobby on the floor of fire origin will be open.

8.9.10 I note the dry fire main was not located within the protected stair at Grenfell Tower, and instead was in the lobby. The door between the lobby and the stair on the floor below would also therefore be open.

8.9.11 On 2nd August 2016, Mr Mahoney addressed both of these scenarios in response to an email from Mr Cross Smith (Max Fordham) {ART00004481}, stating (bold by me):

This system will not be extracting smoke ***during the evacuation phase*** *as air will be drawn through the open stairwell door and it will pull in clean air from the stairwell. During* ***firefighting operations*** *air will again be pulled in from the stairwell. Should a window, in the fire affected flat, break then some smoke may be extracted during firefighting operations.* ***i.e. the flat door is open and the stairwell door is open.***

8.9.12 Section 5 of PSB's Technical Submission Revision 6 {PSB00000214} headed *Appendices* refers to documents named *"Annex 01 Fans and Dampers operation"* and *"PSB E 75015 800 Rev E Electrical schematic".*

8.9.13 By email dated 15th March 2016 {PSB00001053}, Mr Harrison (PSB) wrote as follows to Mr Whyte (JS Wright):

Hi Alan

Please find attached the updated Technical Submission Rev 6

8.9.14 The files attached to this email are named *Grenfell Tower Tech Sub Lobby Smoke Control Systems Rev 6.pdf, E75015-800E.pdf* and *75015AG1 Grenfell Tower Cause & Effect Rev 04.pdf.*

8.9.15 In his first witness statement {PSB00001309}, Mr Partlow says he was provided with Revision 4 of the *"PSB Fans and Damper Operation Cause and Effect Chart"* dated 3rd February 2016 {PSB00000232}.

8.9.16 Mr Partlow also appears to have assisted in drafting the final version of this document - on 3rd February 2016, he emailed Mr Whyte (JS Wright) stating {PSB00000947} *"Updated cause and effect as requested".*

8.9.17 In total I have been provided with seven revisions of the "*PSB Fans and Damper Operation Cause and Effect Chart*":

a) Rev 00 dated 10th June 2015 {PSB00000226}.

b) Rev 01 dated 19th June 2015{PSB00000227}.

c) Rev 02 dated 15th July 2015{PSB00000228}.

d) Rev 03 dated 15th July 2015{PSB00000229}.

e) Rev 04 dated 29th January 2016{PSB00000230}.

f) Rev 04 dated 1st February 2016{PSB00000231}.

g) Rev 04 dated 3rd February 2016{PSB00000232}.

8.9.18 The first version was issued by Mr Yeadon (PSB) to Mr Bradbury (JS Wright) by email on 10th June 2015 {PSB00000013}.

8.9.19 The version that Mr Partlow assisted in drafting appears to be the final revision of the document and was listed as one of the appendices of PSB's Technical Submission Revision 6 {PSB00000214}.

8.9.20 The final version {PSB00000232} describes 25 smoke zones and the corresponding operation of the dampers on a given floor if the smoke zone is activated, as well as whether the four smoke fans and environmental fan will be operating at either 100% speed or not at all.

8.9.21 I have provided an excerpt of this cause-and-effect matrix in Figure 8-14.

Job Name: **Grenfell Tower, North Kensington**
Project Number: **75015AG1 Rev 04**
Issue Date: **03/02/2016**

<u>KEY</u>
o = Operated
x = not operated

Fans And Damper Operation

		Dampers																										AOV	
		Ground Floor		Floor 01		Floor 02		Floor 03		Floor 04		Floor 05		Floor 06		Floor 07		Floor 08		Floor 09		Floor 10		Floor 11		Floor 12		Community Room	Boxing Club
LEVEL	Fire Zone	SD01	SD02	SD03	SD04	SD05	SD06	SD07	SD08	SD09	SD10	SD11	SD12	SD13	SD14	SD15	SD16	SD17	SD18	SD19	SD20	SD21	SD22	SD23	SD24	SD25	SD26	AOV1	AOV2
Ground floor	SDE01	o	o	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	SDE25	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	o	x
Floor 01	SDE02	x	x	o	o	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Floor 02	SDE03	x	x	x	x	o	o	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	SDE26	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	o
Floor 03	SDE04	x	x	x	x	x	x	o	o	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Floor 04	SDE05	x	x	x	x	x	x	x	x	o	o	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Floor 05	SDE06	x	x	x	x	x	x	x	x	x	x	o	o	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Floor 06	SDE07	x	x	x	x	x	x	x	x	x	x	x	x	o	o	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Floor 07	SDE08	x	x	x	x	x	x	x	x	x	x	x	x	x	x	o	o	x	x	x	x	x	x	x	x	x	x	x	x
Floor 08	SDE09	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	o	o	x	x	x	x	x	x	x	x	x	x
Floor 09	SDE10	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	o	o	x	x	x	x	x	x	x	x
Floor 10	SDE11	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	o	o	x	x	x	x	x	x
Floor 11	SDE12	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	o	o	x	x	x	x
Floor 12	SDE13	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	o	o	x	x
Floor 13	SDE14	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Floor 14	SDE15	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Floor 15	SDE16	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Floor 16	SDE17	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Floor 17	SDE18	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Floor 18	SDE19	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Floor 19	SDE20	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Floor 20	SDE21	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Floor 21	SDE22	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Floor 22	SDE23	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Floor 23	SDE24	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	ENVIRONMENTAL	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	x

		Dampers																						Fans				
		Floor 13		Floor 14		Floor 15		Floor 16		Floor 17		Floor 18		Floor 19		Floor 20		Floor 21		Floor 22		Floor 23		Floor 02			Roof	
LEVEL	Fire Zone	SD27	SD28	SD29	SD30	SD31	SD32	SD33	SD34	SD35	SD36	SD37	SD38	SD39	SD40	SD41	SD42	SD43	SD44	SD45	SD46	SD47	SD48	MF1	BF1	EF1	MF2	BF2
Ground floor	SDE01	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	100%	100%	x	100%	100%
	SDE25	x	x	x	x	x	x	x	x	xx	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Floor 01	SDE02	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	100%	100%	x	100%	100%
	SDE26	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Floor 02	SDE03	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	100%	100%	x	100%	100%
Floor 03	SDE04	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	100%	100%	x	100%	100%
Floor 04	SDE05	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	100%	100%	x	100%	100%
Floor 05	SDE06	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	100%	100%	x	100%	100%
Floor 06	SDE07	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	100%	100%	x	100%	100%
Floor 07	SDE08	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	100%	100%	x	100%	100%
Floor 08	SDE09	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	100%	100%	x	100%	100%
Floor 09	SDE10	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	100%	100%	x	100%	100%
Floor 10	SDE11	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	100%	100%	x	100%	100%
Floor 11	SDE12	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	100%	100%	x	100%	100%
Floor 12	SDE13	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	100%	100%	x	100%	100%
Floor 13	SDE14	o	o	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	100%	100%	x	100%	100%
Floor 14	SDE15	x	x	o	o	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	100%	100%	x	100%	100%
Floor 15	SDE16	x	x	x	x	o	o	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	100%	100%	x	100%	100%
Floor 16	SDE17	x	x	x	x	x	x	o	o	x	x	x	x	x	x	x	x	x	x	x	x	x	x	100%	100%	x	100%	100%
Floor 17	SDE18	x	x	x	x	x	x	x	x	o	o	x	x	x	x	x	x	x	x	x	x	x	x	100%	100%	x	100%	100%
Floor 18	SDE19	x	x	x	x	x	x	x	x	x	x	o	o	x	x	x	x	x	x	x	x	x	x	100%	100%	x	100%	100%
Floor 19	SDE20	x	x	x	x	x	x	x	x	x	x	x	x	o	o	x	x	x	x	x	x	x	x	100%	100%	x	100%	100%
Floor 20	SDE21	x	x	x	x	x	x	x	x	x	x	x	x	x	x	o	o	x	x	x	x	x	x	100%	100%	x	100%	100%
Floor 21	SDE22	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	o	o	x	x	x	x	100%	100%	x	100%	100%
Floor 22	SDE23	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	o	o	x	x	100%	100%	x	100%	100%
Floor 23	SDE24	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	o	o	100%	100%	x	100%	100%
	ENVIRONMENTAL	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	x	o	100%	100%

Notes:

This chart is to be read in conjunction with our schematic drawing:

1 Allow BMS fault signal
2 Standard Override switch i.e. Auto/On to activate the same equipment as a Fire Zone
3 Standard operation of fans by pressure differential switches. i.e. High and low speed based upon open/closed doors
4 Shut Off Damper (COD) Is open when the fan is running and closed when the fan has stopped.
5 Standard Auto-changeover on duty fan failure
6 Contacts to provide signal that mains power has been lost to signal standby power supply
7 Backup Fan (BF) to Stand-by until Main Fan (MF) fault occurs, then operate at speed set in a table

Figure 8-14 Excerpt from "PSB Fans and Damper Operation Cause and Effect Chart" {PSB00000232}.

8.9.22 As I have explained in Section 5, the SCA Guide 2015 methodology would require the designer to develop a series of fire scenarios, set performance criteria; then demonstrate the proposed system could meet those criteria.

8.9.23 The result of these calculations in the case of Grenfell Tower would be a set of fire scenarios with an associated extraction rate, pressure differential between the lobby and the stair as well as air velocity through the door to the protected stair.

8.9.24 The cause and effect matrix should therefore refer to all of these scenarios and what equipment should be activated in each case.

8.9.25 This would then have to be repeated on each floor.

8.9.26 In the case of Grenfell Tower this is further complicated by the fact that the system was intended to operate in smoke control mode and environmental mode.

8.9.27 The cause and effect matrix should also therefore contain a scenario for activating the smoke control system from the three possible Environmental modes: off, standby and operation.

8.9.28 It should have contained a scenario for demonstrating that the pressure differential generated when the environmental system was operating did not exceed the 25 Pa limit as the pressure switches were to have no control over the system in Environmental mode.

8.9.29 This would then form the basis of the commissioning methodology.

8.9.30 I have reviewed the "PSB Fans and Damper Operation Cause and Effect Chart" {PSB00000232}and identified key items that have not been addressed in the cause and effect chart in the following sections.

8.9.31 Firstly, the "PSB Fans and Damper Operation Cause and Effect Chart" {PSB00000232}does not state what device causes the activation of the smoke zone. In Grenfell Tower, the smoke zone could be activated either by the smoke detector, the fire service override switch or manually on the HMI panel (see Section 7 of my report).

8.9.32 I would therefore expect each of the defined scenarios to be repeated during the commissioning process for each of the three possible activation methods.

8.9.33 The system off and restart system functions of the HMI panel would also have to be demonstrated as part of the commissioning process.

8.9.34 The complexity of all of the possible interactions between the HMI panel; fire service override switches and smoke detectors is provided in Section 7. The cause and effect matrix should include the functions and interactions of the HMI panel to ensure that any actions by the fire brigade on the HMI panel in the event of a fire would be able to provide the desired response.

8.9.35 I note that there is no reference in the "*PSB Fans and Damper Operation Cause and Effect Chart*" {PSB00000232} to the effect of a mains power failure; duty fan failure; the pressure switch opening or closing; or activation of a fire service override switch.

8.9.36 The "*PSB Fans and Damper Operation Cause and Effect Chart*" {PSB00000232} refers to dampers SD01 to SD48 stating which floor they are on.

8.9.37 On Levels 4-23, dampers were wired together in pairs in each shaft (i.e. the north shaft dampers received one signal and the south shaft dampers received another signal) rather than individually (refer to Section 7), hence why there are only two dampers listed per floor in the "*PSB Fans and Damper Operation Cause and Effect Chart*" {PSB00000232}.

8.9.38 I note that the "*PSB Fans and Damper Operation Cause and Effect Chart*" {PSB00000232} does not state what dampers are intended to represent the north or south dampers on a given floor. This would have been important for Mr Partlow to know when commissioning the dampers.

8.9.39 The performance of the fans is only shown as either '100% speed' or 'not operating'. PSB's Technical Submission Revision 6 {PSB00000214} states (bold by me):

> *The control system will also have pressure sensors added into each ventilated lobby to* ***control the speed of the fans*** *to ensure that when the doors on an escape route are closed that the opening force on the door does not exceed 100N as detailed in BS EN 12101-6*

8.9.40 The design of the system was such that the fans were in fact required to operate at high speed or low speed depending on whether the pressure sensor was open or closed respectively and not to operate solely at 100% speed as shown in the "*PSB Fans and Damper Operation Cause and Effect Chart*" {PSB00000232}.

8.9.41 The operation of the fans at less than 100% speed when the pressure switch closed therefore does not appear to have been considered in the "*PSB Fans and Damper Operation Cause and Effect Chart*" {PSB00000232}.

8.9.42 The notes section of *"PSB Fans and Damper Operation Cause and Effect Chart"* {PSB00000232} states:

Notes: **This chart is to be read in conjunction with our schematic drawing:**

1	Allow BMS fault signal
2	Standard Override switch i.e. Auto/On to activate the same equipment as a Fire Zone
3	Standard operation of fans by pressure differential switches. i.e. High and low speed based upon open/closed doors
4	Shut Off Damper (COD) Is open when the fan is running and closed when the fan has stopped.
5	Standard Auto-changeover on duty fan failure
6	Contacts to provide signal that mains power has been lost to signal standby power supply
7	Backup Fan (BF) to Stand-by until Main Fan (MF) fault occurs, then operate at speed set in a table

8.9.43 However, none of these notes are referenced in the main cause and effect table so it is unclear how these notes apply to the defined scenarios.

8.9.44 For example, Note 2 states that the "high and low speed" settings of the fan will be checked based on the configuration of "open/closed doors".

8.9.45 However, "*PSB Fans and Damper Operation Cause and Effect Chart*" {PSB00000232} only refers to the fans operating at 100% speed or not at all. No reference is made to a *"Low speed"*.

8.9.46 There is also evidence that there were changes in the programming of the system in environmental mode on 25th April 2016. The cause and effect matrix was not revised to reflect the changes. These changes include the following:

a) The roof fans are indicated to be operating at 100% when the system is operating in environmental mode. There is only an activation indication for the environmental fan at Level 2. I have explained in Section 7.16 how the design speed of these fans was reduced to 25% for the roof fan and 35% for the environmental fan at Level 2.

b) All dampers on every floor were indicated to be activated when the system is operating in environmental mode. However, my analysis of the control software indicates that the environmental sequence involved the dampers being activated in groups of 4 (L5, L11, L17 and L23) for the 15 minutes and change to the level below. This finding is supported by RINA's reconstruction {MET00072161} and described in Mr Whyte's email dated 15th April 2016 {PSB00001093}

8.9.47 Therefore, the final revision of the cause and effect matrix did not reflect the actual operation of the system by the night of the fire.

8.9.48 There is also no reference in the "*PSB Fans and Damper Operation Cause and Effect Chart*" {PSB00000232} to activating the system in the environmental mode and then activating a smoke detector to ensure that the smoke control system overrides the environmental mode.

8.9.49 I note that, on 15th April 2016, Mr Whyte (JS Wright) sent an email to Messrs. Harrison, Partlow, Midgley and Hill describing a *"Change to operations of Environmental System"* {JSW00003769} where the fan was designed to run at 25% speed in environmental mode rather than at 100%. I have found no subsequent update to the Environmental scenario shown in Revision 04 of the "*PSB Fans and Damper Operation Cause and Effect Chart*" dated 3rd February 2016{PSB00000232} to account for this change.

8.9.50 The cause and effect matrix does not refer to the three possible non fire states below and how the smoke control system should react if a smoke zone is activated in any of these three states:

a) Environmental off (night time between 20:00 and 09:00 when the BMS was programmed not to activate environmental mode, see Section 7.16.27)

b) Environmental standby (day time between 09:00 and 20:00, see Section 7.16.27)

c) Environmental mode operating

8.9.51 I would expect all three scenarios to be demonstrated as part of the commissioning process

8.9.52 Switching the system from operating in environmental mode to smoke mode also involved complex operations to the dampers and fans located at Level 2. The following events would have to be observed:

a) The environmental fan at Level 2 shuts down

b) The two bypass dampers at Level 2 connected to the environmental fan closes

c) The two bypass dampers Level 2 connected to the fan opens

d) The smoke fan at Level 2 runs

8.9.53 I have described in Section 7 the complex operations required to execute the switchover in system operation at Level 2. However, this is not reflected in the cause and effect matrix either.

8.9.54 The "*PSB Fans and Damper Operation Cause and Effect Chart*" {PSB00000232}also does not indicate the interface between the smoke control system and the BMS system. In Section 7 and 11, I have described how a fire alarm activation in the smoke control system would send a signal to the new basement BMS system to shut down the new boilers connected to it. This is not indicated on the cause and effect matrix.

8.9.55 The "*PSB Fans and Damper Operation Cause and Effect Chart*" {PSB00000232}also does not check how the smoke control system was to respond to an input from the BMS system to run the system in environmental mode.

8.9.56 The cause and effect matrix as presented, was over simplistic, and for many performance requirements, it was wrong.

8.9.57 **Documents setting out the commissioning methodology**

8.9.58 On 1st February 2016, PSB emailed JS Wright a *Method statement & risk assessment* relating to commissioning of the smoke control system {PSB00000941}.

8.9.59 The method statement appears to have been adapted by Mr Partlow from an existing method statement of PSB's sent to him by a Mr Haigh (Contracts Manager, PSB) on 1st February 2016 (see {PSB00000941} and {PSB00000938} respectively) (refer to Section 5.4.44).

8.9.60 As I have explained in Section 8.3, Mr Partlow acknowledges that this document contains errors which I understand to be related to the intended pressure differential rather than to the commissioning process itself.

8.9.61 PSB's Method Statement {PSB00000941} contains the following sections:

1.0 Scope of Works

2.0 Hazard Identification.

3.0 Risk Assessment

4.0 System Description

5.0 Briefing Arrangements

6.0 Permits to Work

7.0 Plant and Equipment.

8.0 Supervision

9.0 PPE

10.0 Public interface arrangements

11.0 Emergency Procedures

12.0 Working Hours

13.0 Inspection & Test Plan

14.0 Revision Control.

15.0 Attached Documents.

8.9.62 Section 1 of PSB's Method Statement {PSB00000941} identifies the following 'Scope of Works':

1.1 Carry out the commissioning of the PSB control panel.
1.2 Carry out the commissioning of the main extract fans.
1.3 Carry out the commissioning of the lobby dampers and AOV's
1.4 Carry out the commissioning of the outstations and keys switches.
1.4 Carry out the commissioning of the Stair core systems.
1.5 Carry out the commissioning of the Overall System in line with latest Cause & Effect.
1.6 Carry out client witness tests demonstrating 3rd party interfaces.
1.7 Hand over operational system.

Figure 8-15 Excerpt from PSB's Method Statement {PSB00000941}

8.9.63 Sections 1.1 to 1.4 lists the individual components of the system which should be commissioned followed by the full system integration tests (Section 1.5).

8.9.64 Section 13 of PSB's method statement {JRP00000289} is headed *"Inspection and test plan"* and lists the installation tasks to be completed before commissioning was undertaken.

8.9.65 Neither here, nor in any other section, does the method statement set out which measurements should be taken (and where) to demonstrate that the

system met the performance criteria in PSB's Technical Submission Revision 6 {PSB00000214} of 2m/s air velocity through an open lobby/stairwell door and a differential pressure of -25Pa resulting in a door-opening force of less than 100N.

8.9.66 Nor is any reference made to the *"PSB Fans and Damper Operation Cause and Effect Chart"* {PSB00000232} which was appended to PSB's Technical Submission Revision 6 {PSB00000214}.

8.9.67 I note that Mr Cross Smith (Max Fordham) raised concerns around the adequacy of this method statement in an email to Mr Hughes (Rydon) on 5th February 2016 {JSW00002309} in which he stated:

Tony forwarded on the RAMS document from PSB. The system description within Section 4 is not particularly clear to me. For example, there is no mention of extracting from both shafts simultaneously or of the operation of the dampers between smoke rated fans and general ventilation fans.

The commissioning test also does not mention the additional dampers between fans or take into account that some of the extract dampers in the lift lobbies may already be open. Could you request that PSB revise it to more accurately reflect the system installed at Grenfell?

8.9.68 In March 2016, Mr Cross Smith (Max Fordham) raised further concerns about the environmental system stating {ART00005660}:

I am still not entirely clear as to the operation of the environmental ventilation. This may be better tackled in a separate document as it is not all within PSB's control. The elements that I am unsure about are; there are environmental supply fans but no mention of extract fans. Do the smoke extract fans at rooftop level perform this function? There is no mention of the number and location of temperature sensors for environmental system. Also, how is this system controlled?

8.9.69 In the context of the information I have set out in Section 5, it can be seen that all of these points raised by Max Fordham are entirely reasonable queries in the context of the overall system performance required for Grenfell Tower.

8.9.70 They also needed to be closed out by PSB before commissioning commenced.

8.9.71 **Documents recording the results of the commissioning process**

8.9.72 The following certification documentation was sent to RBKC Building Control on 4th May 2016 {RYD00076725}:

a) PSB's Technical Submission Revision 6 {PSB00000214};
b) PSB's *Above ground commissioning report* {PSB00000224};
c) PSB's E-800 Electrical Schematic Rev. E {PSB00000429};
d) PSB's Fans and Damper Operation Cause and Effect Chart {PSB00000232};
e) *Grenfell tower readings in fire* {RBK00003781} (providing air velocity measurements).

8.9.73 I have treated these documents as the formal commissioning record required to comply with Regulation 7.

8.9.74 In his first witness statement Mr Partlow states {PSB00001309}:

139. At PSB we use a standard "Above Ground Commissioning Report" which is completed once the commissioning process is complete. The document is PSB's record of the commissioning process which they provide to the client and which we hold on file. I use the standard "Above Ground Commissioning Report" to record the commissioning process and take out any sections that are not relevant to the project I am working on.

....

"Above Ground Commissioning Report 76005 (28th April 2016)" - (GP/11: PSB00000224)

146. The report dated 28th April 2016 demonstrates that the whole System (including ground level to floor 3) had been tested and commissioned. The document was signed, on page 6 of the document, by Alan Whyte of J S Wright.

8.9.75 PSB's commissioning report dated 28th April 2016 {PSB00000224} to which Mr Partlow refers is seven pages long.

8.9.76 It lists the results of the commissioning of the Grenfell Tower smoke control system and concludes *"All systems are operating according to design"*.

8.9.77 In sections 8.10-8.12 below, I compare the results as presented in this document to the recommended scope of the commissioning process set out in (1) the SCA Guide 2015, (2) BS EN 12101-6 and (3) BS 7346-8.

8.9.78 In Figure 8-16, I have excerpted the air velocity results stated in a PDF document with the filename "Grenfell tower readings in fire" {RBK00003781}.

Floor Level	Open Door M/sec	Low grille low speed M/sec	Low grille high speed M/sec	High grille low speed M/sec	High grill high speed M/sec
G	2.9	-0.6	1.6	3.5	7.1
1	3.3	2	7.2	3.5	9
2	4.6	2.4	7.1	4	7
3	5.1	2.7	7.2	5.7	9
4	4.2	0.6	5.1	2	5.3
5	4.4	-0.5	5	1.7	5.4
6	3.6	-0.4	4.8	1.9	5.6
7	4	0.5	4.8	1.7	5.7
8	3.9	0	4.6	2	5.6
9	3.6	0.3	4.7	1.9	5.6
10	3.5	0	4.4	2.1	5.8
11	3.4	0.9	4.1	2.1	5.9
12	3.3	-0.9	3.7	2.1	5.9
13	3.3	-0.6	3.3	2.3	6.2
14	3.4	-0.1	3.5	2.4	6.1
15	3.3	-0.5	3.6	2.2	5.8
16	3.6	-0.3	3.4	2.2	5.9
17	3	-0.7	3.4	2.2	6.2
18	3.5	0.8	3.1	2.3	6.2
19	3.7	-0.3	3	2.4	6.2
20	3.4	-0.7	3.2	2.4	6.2
21	3.3	-0.7	2.8	2.3	6.5
22	3.2	0	2.6	2.6	6.5
23	3	0	2.3	2.5	6.2

the higher than normal readings on levels 1 and 3 were due to missing grilles all readings are in metres per second fans at 100% speed

Figure 8-16 Grenfell Tower smoke control system commissioning readings sent to Mr Hanson {RBK00003784}.

8.9.79 In his first witness statement Mr Partlow states {PSB00001309}:

"PSB UK Completion Certificate (Signed). Project Ref DP.29111.9497 and 75019 (03.05.16)" - (GP/13: PSB00001258)

147. Alan Whyte of JS Wright confirmed to me on the 28th April that he was happy that the System was working and "signed it off". I signed a completion certificate on 3rd May 2016 - "PSB UK Completion Certificate (Signed). Project Ref DP.29111.9497 and 75019 (03.05.16) (GP/13: PSB00001258).

8.9.80 This certificate states {PSB00001258}:

This is to certify that the "Above Ground Smoke Ventilation System" supplied by PSB-UK for integration into: -

Grenfell Tower,
Grenfell Road
Notting Hill
London, W11 1TQ

Has been Mechanically & Electrically tested in accordance with the schedules laid out in the contract and is fully operational, in line with the agreed specification(s).

Figure 8-17 Excerpt of PSB Completion Certificate {PSB00001258}

8.9.81 No further information is provided in this document regarding the performance that the system was certified to have achieved.

8.9.82 As Mr Hughes (Rydon) states at paragraph 89 of his first witness statement {RYD00094213}, Rydon ran two *"two witnessing sessions for the*

commissioning of the Smoke Extract System", one on 28th April 2016 and the other on 5th May 2016.

8.9.83 I have found no formal record of any results measured during this demonstration; – it would be typical that all data had already been gathered at that stage.

8.10 Commissioning – test procedures from the SCA Guide 2015

8.10.1 In my opinion the two most relevant test procedures for commissioning the Grenfell Tower smoke control system in accordance with the SCA Guide 2015 were either that for a mechanical shaft system or that for a pressure differential system (refer to Section 8.5).

8.10.2 As I have described in Section 8.5, when one considers the combined recommended commissioning tests for a mechanical shaft system and a pressure differential system there are fifteen separate tests that could have been undertaken.

8.10.3 As PSB did not document what commissioning methodology they used when commissioning the system at Grenfell Tower, I have compared PSB's documentation (set out below) against the fifteen combined requirements for a mechanical shaft system and a pressure differential system from the SCA Guide 2015.

a) PSB's Technical Submission Revision 6{PSB00000214};

b) PSB's *Above ground commissioning report* {PSB00000224};

c) PSB's *Commissioning Method Statement and Risk Assessment 75019AG* {PSB00000941};

d) PSB's *E-800 Electrical Schematic Rev. E* {PSB00000429};

e) PSB's *Fans and Damper Operation Cause and Effect Chart* {PSB00000232};

f) *Grenfell tower readings in fire* {RBK00003781};

g) PSB's commissioning certificate {PSB00001258}.

8.10.4 Items a), b), d), e) and f) were the *"certification"* documents issued to RBKC Building Control on 4th May 2016 {RYD00076725}.

8.10.5 Where insufficient evidence is provided in PSB's commissioning report {PSB00000224} I have looked to the witness statement of Mr Partlow for evidence that a test was undertaken.

8.10.6 **Each motorised damper should be operated via the activation of the designated manual or automatic device/**

8.10.7 The refurbished smoke control system contained the following dampers:

a) four lobby dampers per floor from levels 4-23 resulting in a total of eighty dampers;

b) two lobby dampers per floor on the Ground level and Levels 1-3 resulting in a total of eight dampers;

c) four fan bypass dampers on Level 2 (noting that one damper was not wired in);

There was also one AOV in the lobby to the community room and one AOV in the lobby to the boxing gym.

8.10.8 Accordingly, there was a total of 92 dampers in Grenfell Tower and two AOVs which needed to be commissioned.

8.10.9 PSB's commissioning report {PSB00000224} stated the following regarding the dampers:

DAMPERS/DOOR ACTUATORS/WINDOW ACTUATORS

Number – Location	Type	Open	Closed	Damage	Pass	Fail
SD01 to SD48	damper	ok	ok	ok	yes	
CD01 & CD02	damper	ok	ok	ok	yes	

Figure 8-18 Excerpt from PSB's commissioning report{PSB00000224}

8.10.10 In his first witness statement Mr Partlow states {PSB00001309} (bold by me):

143. The "SD" numbers relate to the dampers; "SD09" was the first damper on floor four and "SD48" the last damper on floor 23.

144. The references to "CD01" and "CD02" relate to the shut off dampers which enabled the system to switch from environmental mode to smoke control mode. ***The dampers were numbered in the same way on the cause and effect spreadsheet.***

8.10.11 As I explained in Section 8.8 above, on Levels 4-23 the dampers were wired together in pairs - one pair per shaft - (i.e. the north shaft dampers reviewed one signal and the south shaft dampers received another signal) rather than individually, which is presumably why only two dampers are listed per floor in the "*PSB Fans and Damper Operation Cause and Effect Chart*" {PSB00000232}, SD01 to SD48.

8.10.12 The environmental fan bypass dampers on Level 2 were also wired together as a pair. I note that one of the two smoke control dampers was not connected to the system (refer to Section 7).

8.10.13 My understanding is that 'CD01' and 'CD02' in PSB's commissioning report {PSB00000224} refer to the fan by-pass dampers at Level 2 but there is no

indication as to which of them is the environmental by-pass damper and which is the smoke by-pass damper.

8.10.14 There is no reference to dampers CD01 and CD02 in the "*PSB Fans and Damper Operation Cause and Effect Chart*" {PSB00000232}.

8.10.15 I note that the AOVs in the lobbies to the community room and boxing club are referred to in the *"PSB Fans and Damper Operation Cause and Effect Chart"* {PSB00000232} but not in PSB's commissioning report {PSB00000224}. Therefore, it is not clear whether Mr Partlow considered these as part of his commissioning process.

8.10.16 Mr Partlow describes how the lobby dampers were checked in his first witness statement {PSB00001309}:

79.At Grenfell Tower Gary Doyle and I tested levels 4-23 first. I was located at the HMI panel at ground level whilst Gary Doyle went up to each level to activate each smoke detector.

80. The detector was activated using a can of artificial smoke to spray the smoke head. This is the only way to activate the system when it is set to run.

81. Gary Doyle checked to make sure that the dampers on that level opened by checking that the red led light on the smoke detector was lit and that the LED near the output on the relevant Modbus Outstation card was lit (which showed that the correct signals were being sent and received and the dampers were activated). Gary Doyle also carried out a visual check that the dampers were working.

8.10.17 The operation of the lobby dampers appears to have been confirmed only through a visual check at the level on which they were intended to open but without the necessary corresponding check that the dampers on all other floors remained closed as required from the mechanical shaft commissioning test to the SCA Guide 2015.

8.10.18 Furthermore, Mr Partlow does not say whether the grille on the front of the dampers had been removed to allow Mr Doyle to carry out his visual check.

8.10.19 Mr Partlow himself described the difficulty of making a visual observation of the damper in his first witness statement {PSB00001309}:

42. Grilles were fastened on to the front of the shafts where the dampers were located so it was not possible to see the dampers and actuators (the motors that drove the dampers) that clearly.

8.10.20 As I have set out in Section 7.13, the lobby dampers on Ground Level and Level 1 were non-functional as the control software appears to have been programmed such that power could not be supplied to either open or close these dampers. In *"PSB Fans and Damper Operation Cause and Effect Chart"* {PSB00000232} these dampers were referred to as SD01 to SD04.

8.10.21 PSB's commissioning report {PSB00000224} states that all of these dampers were considered to be a *"Pass"*.

8.10.22 As I have shown in Figure 8-18, PSB's commissioning report {PSB00000224} only refers to two of the four shut-off dampers at Level 2.

8.10.23 In his 2nd witness statement Mr Partlow states {PSB00001372}:

38. I have been asked about damper "CD04" located in the ductwork at mezzanine level and which was referred to in the Above Ground Commissioning Report {PSB00000224}.

39. In paragraphs 143 to 145 of my first witness statement, I explained how the SD and CD designations in the Above Ground Commissioning Report related to (respectively) the lobby dampers and shut off dampers used in the System.

40. "CD04" was one of the shut off dampers in the ductwork at mezzanine level. This damper was not connected to the System. It was permanently open because PSB's design only called for 3 dampers at this level (not the 4 installed), so this damper was effectively redundant. This was not an error in commissioning and did not have had any adverse effect on the operation of the System.

8.10.24 **Check that the fan(s) operate at the same times as the opening of the dampers, measure its performance and check against the design value**

8.10.25 In relation to the fans, PSB's commissioning report {PSB00000224} states:

Number	Auto	Open	Off	Damage	Pass	Fail
FOS 01 to 24	ok	ok	n/a	ok	yes	
	operation	reset				
Smoke detector SDE01 to 24	ok	ok		ok	yes	
	operate					
Pressure switch PS01 toPS24	ok			ok	yes	
	Correct function					
Outstation 1 to 22	ok			ok	yes	
Inverter panel 1 & 2	ok			Ok	yes	
Main panel	ok			ok	yes	
Fans x 5	ok			ok	yes	
Battery panels x 10	ok			ok	yes	

Figure 8-19 Excerpt from PSB's commissioning report{PSB00000224}.

8.10.26 No reference is provided in PSB's commissioning report {PSB00000224} to any direct measurement of the performance of the fans and their output as

BLA...

against the design performance or any check conducted to make sure the fans operated at the same times as the dampers opened.

8.10.27 The airflow measurements provided to RBKC on 3rd May 2016 {RBK00003781} are for the velocity through the stair door, and the velocity of the air in front of each of the four dampers on a given level. (Please see Section 8.10.62 and Section 8.11.31 where I present my review of the velocity through the stair door, and the velocity of the air in front of each of the four dampers).

8.10.28 No direct measurements of the fan performance appear to have been taken to show that they achieved the intended flow rate of $2m^3/s$ per fan as stated in PSB's Technical Submission Revision 6{PSB00000214}.

8.10.29 **Check the automatic change over is operational for the standby fan**

8.10.30 PSB's commissioning report {PSB00000224} makes no reference to what checks they made that the automatic change-over was operational for the standby fan at either Roof Level or Level 2.

8.10.31 I have excerpted the only reference to the commissioning of the fans PSB's commissioning report {PSB00000224} below:

Number	Auto	Open	Off	Damage	Pass	Fail
FOS 01 to 24	ok	ok	n/a	ok	yes	
	operation	reset				
Smoke detector SDE01 to 24	ok	ok		ok	yes	
	operate					
Pressure switch PS01 toPS24	ok			ok	yes	
	Correct function					
Outstation 1 to 22	ok			ok	yes	
Inverter panel 1 & 2	ok			Ok	yes	
Main panel	ok			ok	yes	
Fans x 5	ok			ok	yes	
Battery panels x 10	ok			ok	yes	

Figure 8-20 Excerpt from PSB's commissioning report{PSB00000224}

8.10.32 As I found in Section 8.8, *"PSB Fans and Damper Operation Cause and Effect Chart"* {PSB00000232} the notes section states at Note 5 *"Standard auto-changeover on duty fan failure"*.

8.10.33 None of the 27 scenarios listed in "*PSB Fans and Damper Operation Cause and Effect Chart*" {PSB00000232} refer to Note 5 of the document.

8.10.34 It is therefore unclear how this was meant to be addressed in the commissioning process.

8.10.35 There is no reference in either of Mr Partlow's witness statements as to how he made sure that the automatic changeover was operational for the standby fan at either Roof Level or Level 2.

8.10.36 **Check the automatic change over is operational for the secondary power supply**

8.10.37 PSB's commissioning report {PSB00000224} stated the following regarding a simulated mains failure:

Electrical	Installed	Tested
Control Panel Software Loaded	yes	Yes
System Cause and Effect Fully Programmed	yes	Yes
Ensure correct operation of system under simulated mains failure	yes	yes
Ensure correct operation of system in case of failure in one part	yes	Yes
Carry out cable survey and check certification	yes	yes

Figure 8-21 Excerpt from PSB's commissioning report{PSB00000224}

8.10.38 As I have explained in Section 7, secondary power to the smoke control system was achieved at Grenfell Tower by a combination of two methods.

8.10.39 Mr Partlow makes no reference to the operation of the system under simulated mains failure in his ten-step description of the commissioning process in his first witness statement {PSB00001309}.

8.10.40 The only time that Mr Partlow refers to the operation of the system under simulated mains failure is in his second witness statement {PSB00001372}:

48. I also recall at some point providing a demonstration to staff from KCTMO who would be responsible for testing the System. As part of that demonstration, I:

a. Replicated the effect of a fire on the ground floor and a failure of the primary power supply whilst the System was still in fire mode, so that the System would change over to the secondary power supply and still operate (which it did).

8.10.41 To ensure the full system was operating correctly under secondary power either the mains power failure to the building or a localised power failure at all 24 outstations and both fans would have to be simulated.

8.10.42 In either case, all 24 outstations would have to be inspected that they changed over to the secondary power supply and both fans would also need to be inspected that they were operating and providing the required volume flowrate of extraction under secondary power.

8.10.43 There is no evidence in PSB's commissioning report {PSB00000224} or Mr Partlow's witness statement that these inspections were undertaken.

8.10.44 **The motor drive should be inspected for correct operation and extension**

8.10.45 The term *"Motor drive"* is not defined in the SCA Guide 2012.

8.10.46 The only two components in the smoke control system in Grenfell Tower with motor drives are the damper actuators and the smoke extract fans (please see Section 7 of my report).

8.10.47 PSB's commissioning report {PSB00000224} does not refer to damper actuators.

8.10.48 Each of the 92 dampers (including the lobby and Level 2 bypass dampers) was fitted with an actuator. (Note that one of the smoke bypass dampers was not connected to the system so its actuator was in fact redundant.)

8.10.49 I have not seen any record of commissioning tests undertaken for the actuators individually – I have only seen tests to demonstrate that the dampers would automatically open and close during a fire event.

8.10.50 In relation to the fans, PSB's commissioning report {PSB00000224} states as follows:

Number	Auto	Open	Off	Damage	Pass	Fail
FOS 01 to 24	ok	ok	n/a	ok	yes	
	operation	reset				
Smoke detector SDE01 to 24	ok	ok		ok	yes	
	operate					
Pressure switch PS01 toPS24	ok			ok	yes	
	Correct function					
Outstation 1 to 22	ok			ok	yes	
Inverter panel 1 & 2	ok			0k	yes	
Main panel	ok			ok	yes	
Fans x 5	ok			ok	yes	
Battery panels x 10	ok			ok	yes	

Figure 8-22 Excerpt from PSB's commissioning report {PSB00000224}

8.10.51 No reference is provided in PSB's commissioning report {PSB00000224} to any direct measurement of the performance of the fans and their output against the performance criteria.

8.10.52 **The ventilators and fans should operate in accordance with the design cause and effect and should be inspected for correct operation and extension**

8.10.53 In Section 7 I present a full cause-and-effect analysis for the smoke control system in Grenfell Tower. I have summarised the main steps below:

a) Smoke zone is activated by a detector, or manually via the HMI panel.

b) Environmental system shuts down if on (depending on the temperature sensor measurements) or in standby mode (day time between 09:00 and 20:00, see Section 7.16.27).

c) Smoke control system is activated.

d) Roof level and level 2 duty fans operate at reduced power (refer to Section 7).

e) If floor of smoke zone activation is on a given level at Levels 4-23, all four lobby dampers open on that level. If this occurs on Ground Level to Level 3, both dampers open on the level of the activation.

f) Lobby dampers on all other floors close.

g) If the door to the protected stair is opened the pressure switch would detect the change in pressure from the sampling points in the stair and lobby, and send a signal to the fans to increase in speed.

h) If the mains power fails to the building or there is a localised failure on a given floor, secondary power to the smoke control system was achieved at Grenfell Tower by a combination of two methods. The fans were served by a power supply from Grenfell Walk in the event of a mains failure. All other devices were provided with batteries in the event of a mains failure.

i) If either of the duty fans fails at Level 2 or Roof Level the backup fan would activate.

j) If the fire service override switch on the HMI panel was turned to “On” and a fire service override switch was activated on a given floor other than the floor where the detector was activated, the dampers on the floor where the detector was activated would close and the dampers on the floor where the fire service override had been activated would open.

8.10.54 As I found in Section 8.9, the "*PSB Fans and Damper Operation Cause and Effect Chart*" {PSB00000232} that Mr Partlow used to commission the Grenfell Tower smoke control system did not address several key scenarios relating to the interaction between the smoke control and environmental systems; control of the fan speed by the pressure switches, activation of the system from different sources such as the HMI panel, smoke detectors and fire service override switches.

8.10.55 In relation to cause-and-effect testing, PSB’s commissioning report {PSB00000224} states:

Check List

Have you checked the following?

1	Cause and effect	Yes
2	All drawings up to date	Yes
3	PLC and HMI up to date with latest software	Yes
4	Remote station's	Yes
5	Panel and panel room clean and tidy	Yes
6	Cooling fan filters clean and thermostat set to about 30°C	Yes
7		
8		

Figure 8-23 Excerpt from PSB Commissioning report {PSB00000224}

8.10.56 PSB's commissioning report {PSB00000224} makes no reference to the 27 scenarios described in the *"PSB Fans and Damper Operation Cause and Effect Chart"* {PSB00000232}.

8.10.57 Under Step 10 *Cause and Effect check* in Mr Partlow's description of the commissioning process in his first witness statement {PSB00001309}, he refers to testing the system's operation in *smoke control mode, environmental mode* and *activating smoke control mode when the system was in environmental mode.*

8.10.58 With reference to the *environmental mode* test Mr Partlow states:

99. The System was programmed to open the dampers on a 15 minute cycle on four levels at a time in the following rotation when the System was operating in environmental mode:

G,6,12,18

1,7,13,19

2,8,14,20

3,9,15,21

4,10,16,22

5,11,17,23

100. We tested the System in environmental mode by simulating the input from the Building Management System (which operated the heating systems for the building) and triggering a signal at the Main Control Panel. We then carried out the same checks as those carried out for the System when it was running in smoke control mode.

8.10.59 Mr Partlow therefore does not confirm whether his *environmental mode* test was undertaken when the environmental system was in standby mode or from another starting condition.

8.10.60 As I have found in Section 8.3, at paragraph 79 to 81 of his first witness statement {PSB00001309}, Mr Partlow describes Mr Doyle undertaking a visual inspection of the operation of the damper only at the level on which the smoke detector was activated. Mr Partlow describes in these paragraphs that

he activated the system for smoke control mode by spraying the detector with artificial smoke.

8.10.61 I note that the HMI panel own its own could not confirm that the damper was in the correct position based on its wiring condition (refer to Section 7) so an individual check of all 92 dampers would have to be undertaken for each of the 27 cause-and-effect scenarios described in PSB's Fans and Damper Operation Cause and Effect Chart" {PSB00000232}.

8.10.62 **Measure the flow rate into the shaft system at the ventilator furthest from the fan position.**

8.10.63 PSB's Technical Submission Revision 6 {PSB00000214} did not set a performance criterion for flow rate into the shaft system from the lobby dampers.

8.10.64 PSB's commissioning report {PSB00000224} does not record measurements of the flow rate into the shaft system from the lobby dampers.

8.10.65 I note the measured air velocity through the dampers on each floor was issued to RBKC Building Control on 4th May 2016 {RYD00076725}.

8.10.66 The results are excerpted below:

Floor Level	Open Door M/sec	Low grille low speed M/sec	Low grille high speed M/sec	High grille low speed M/sec	High grill high speed M/sec
G	2.9	-0.6	1.6	3.5	7.1
1	3.3	2	7.2	3.5	9
2	4.6	2.4	7.1	4	7
3	5.1	2.7	7.2	5.7	9
4	4.2	0.6	5.1	2	5.8
5	4.4	-0.5	5	1.7	5.4
6	3.6	-0.4	4.8	1.9	5.6
7	4	0.5	4.8	1.7	5.7
8	3.9	0	4.6	2	5.6
9	3.6	0.3	4.7	1.9	5.6
10	3.5	0	4.4	2.1	5.8
11	3.4	0.9	4.1	2.1	5.9
12	3.8	-0.9	3.7	2.1	5.9
13	3.8	-0.6	3.3	2.3	6.2
14	3.4	-0.1	3.5	2.4	6.1
15	3.3	-0.5	3.6	2.2	5.8
16	3.6	-0.8	3.4	2.2	5.9
17	3	-0.7	3.4	2.2	6.2
18	3.5	0.8	3.1	2.3	6.2
19	3.7	-0.8	3	2.4	6.2
20	3.4	-0.7	3.2	2.4	6.2
21	3.3	-0.7	2.8	2.3	6.5
22	3.2	0	2.6	2.6	6.5
23	3	0	2.8	2.5	6.2

the higher than normal readings on levels 1 and 3 were due to missing grilles all readings are in metres per second fans at 100% speed

Figure 8-24 Grenfell Tower smoke control system commissioning readings sent to Mr Hanson {RBK00003784}

8.10.67 The SCA Guide 2015 states (Bold by me):

BSRIA BG49/2013 clarifies that damper/grille flow rates can be considered as the average velocity ***multiplied by the grille face area with no correction for the free area of the grille****.*

The readings should be taken as per the grid system recommended in Table 6 of the BSRIA document *and the most favourable reading should be taken in each position making an allowance for the deflection of the grilles. In some circumstances depending on the grille finish, it may be necessary to record the readings 500mm away from the grille by means of a clear 4 sided box extension and the velocity multiplied by the box area.*

It is recommended that the flow rates are recorded at the closest and most remote damper from the fan to ensure the required extraction rate through the damper/grille is achieved.

8.10.68 I have excerpted Table 6 from the BSRIA document BG49/2013 in Figure 8-25.

Table 6 : Averaging grids for velocity measurements at grilles

Depth of grille (mm)	Width of grille (mm) and number of readings							
	up to 150		150-300		300-460		over 460	
	Down	Across	Down	Across	Down	Across	Down	Across
up to 150	1 (Centre)		-	2	-	3	-	4
150-300	2	-	2	2	2	3	2	4
300-460	3	-	3	2	3	3	3	4
Over 460	4	-	4	2	4	3	4	4

Figure 8-25 Excerpt of Table 6 from the BSRIA document BG49/2013

8.10.69 The width of the dampers in the existing lobbies in Grenfell Tower was 300mm with a depth of 600mm as stated in PSBs Technical Submission Rev 6 {PSB00000214}. Mr Partlow should therefore have taken an average of 12 velocity measurements for each damper.

8.10.70 As shown in Figure 8-24, Mr Partlow only recorded one air flow velocity per damper. I have also found no evidence that Mr Partlow multiplied these values by the area of the dampers to obtain the volume flow rate into the damper.

8.10.71 This point was specifically noted by RBKC Building Control on 4th May 2016 where Mr Hanson emailed My Hughes (Rydon) stating:

Hi David,

The figures you have sent do not appear to be extract readings - they should be in meters cubed per second (m^3/s). The readings you sent are velocity readings in meteres per secomd (m/s).

	speed in M/sec	speed in M/sec
G	1	1

Figure 8-26 Excerpt from email {RBK00048818}

8.10.72 Check the operation of the manual control point to ensure the relevant damper(s) close and the fan(s) shut down

8.10.73 As I explained in Section 6, a firefighter override key switch (yellow) was provided in every lobby from Ground Level to Level 23.

8.10.74 In reference to the activation of manual control points, PSB's commissioning report {PSB00000224} states:

Number	Auto	Open	Off	Damage	Pass	Fail
FOS 01 to 24	ok	ok	n/a	ok	yes	
	operation	reset				

Figure 8-27 Excerpt from PSB Commissioning report {PSB00000224}.

8.10.75 In his first witness statement, Mr Partlow {PSB00001309} states:

145. The references to "FOS" relate to the fireman's override switches. There were 24 override switches, one on each floor of Grenfell Tower (including the ground floor).

8.10.76 PSB's commissioning report {PSB00000224} also records:

Fire Service Override	Installed	Tested
Check functionality of the Fire Service override switch	yes	yes

Figure 8-28 Excerpt from PSB Commissioning report {PSB00000224}.

8.10.77 There is no reference in the *"PSB Fans and Damper Operation Cause and Effect Chart"* {PSB00000232} to the activation of a fire-service override switch and the subsequent effect on the operation of the dampers i.e. what dampers would open and what dampers would close.

8.10.78 Therefore, it is not clear how Mr Partlow checked the functionality of the fire-service override switches.

8.10.79 Under Step 10 *Cause and effect check* of his first witness statement, Mr Partlow states {PSB00001309}:

The fireman override switches demonstration

129. As regards the individual floor level fireman override switches, these yellow box switches were located just inside each lobby next to the door to the stairwell on each level.

130. As with the HMI screen these fireman's override switches could only be activated once both (1) the system had automatically detected smoke and was operating in smoke control mode and (2) the main override switch mounted on the HMI panel had already been turned to the "on" position.

131. Each fireman's override switch was operated by a key. The same key could be used to operate any of the individual floor level switches. Once these

switches were enabled as described above, any one of the switches could be activated by using the key to turn it to the "on" position.

132. Once the key was turned to the "on" position in one of these switches, it would remain there and could not be removed until it was turned back to the off position (in the same way as the switch mounted on the HMI panel).

133. Once one floor level override switch had been activated in this way, it would "lock out" any other manual override operation. In other words, until the switch was turned back off, it would not be possible to direct the system to operate on a different level either from the HMI panel touch screen or from another individual fireman's override switch on a different floor level.

134. Successfully activating the fireman's override switch on a level would direct the system to operate in smoke control mode on that floor.

135. This was demonstrated.

8.10.80 The steps required to activate the fire-service override switch are also described in PSB's commissioning Method Statement {PSB00000941}.

8.10.81 Mr Partlow therefore states that the functionality of the fire-service override switches was tested on every floor but does not confirm how he determined that the dampers at the level on which the switch was activated had opened and that all of the other dampers had remained closed as required.

8.10.82 As Mr Partlow explains, if the fire service override switch on the HMI panel was turned to "On" and a fire-service override switch was activated on a level other than that on which the detector was activated, the dampers on the floor where the detector activated would close and the dampers on the floor where the fire service override had been activated would open.

8.10.83 A visual check of the position of the dampers on both the floor where the detector activated and the floor where the fire-service override had been activated would therefore be required. This would have to be done for all 24 fire-fighter override switches (one per floor).

8.10.84 Mr Partlow does not say whether he undertook these visual checks of the damper position on both floors for all 24 fire-service override switch activations.

8.10.85 **Reset the system on completion of test**

8.10.86 PSB's commissioning report {PSB00000224} does not refer to the system having been reset upon completion of the test.

8.10.87 **Provide a certificate of test**

8.10.88 PSB's issued a Completion certificate dated 3rd May 2016 {PSB00001258}.

8.10.89 The signing of the PSB's Completion certificate dated 3rd May 2016 {PSB00001258} and PSB's *Above ground commissioning* report {PSB00000224} are considered in paragraphs 8.3.36-8.3.39.

8.10.90 Check the maximum forces required to open escape doors while the system is operating in means of escape mode

8.10.91 The *SCA Guide 2015* states *"Check the maximum forces required to open escape doors while the system is operating in means of escape mode and record results. The recorded force must not exceed 100N".*

8.10.92 This was also one of the performance criteria in PSB's Technical Submission Revision 6 {PSB00000214} set out below:

The control system will also have pressure sensors added into each ventilated lobby to ***control the speed of the fans*** *to ensure that when the doors on an escape route are closed that the opening force on the door does not exceed 100N as detailed in BS EN 12101-6*

8.10.93 In Grenfell Tower there were 22 doors between the enclosed stair and the depressurised lobbies from level 3-23; and one door between the open stair and the pressurised lobby on level 2.

8.10.94 There was no direct connection between the open stair and the depressurised lobby on ground floor.

8.10.95 I would therefore expect that the door-opening force had been tested and recorded for all 23 doors; or that a representative number of doors had been tested with an analysis demonstrating why the number of tests undertaken was sufficient to demonstrate compliance with the SCA guide.

8.10.96 There is no documented record in PSB's commissioning report {PSB00000224} of any door-opening forces being measured at Grenfell Tower.

8.10.97 In his second witness statement dated 26th March 2021, Mr Partlow says he did not measure the door-opening force but instead exercised judgement on what the force might be prior to the final commissioning {PSB00001372} (bold by me):

22. As part of my work at Grenfell Tower, I verified that the door opening force for each common lobby door did not exceed 100N while the System was operating in smoke control mode on that floor.

23. ***Prior to the final commissioning in April 2016****, I did this by setting the pressure switches to the required level on each floor and* ***judging the door opening force.*** *This was based on my experience. The objective was to ensure that the common lobby door could be opened comfortably when the System was operating.*

27. From memory, ***during the final commissioning exercise****, Alan Whyte of JS Wright obtained a spring balance device so that we could take and record the necessary door opening force readings.* ***I myself did not keep any record of the readings that were taken****, but I believe these were taken on 28th April 2016. I have since seen an email dated 4th May 2016 where Alan Whyte subsequently confirmed to RBKC building control that "Pull strength*

required is between 65 & 80N dependant on existing door and closer" {JSW00006202}.

28. I have been asked whether I took door opening force readings at each of the flat doors connecting to a common lobby. This was not part of my commissioning exercise. I don't think it was necessary for the System and in any event, it would not have been practical in a building that remained occupied with residents throughout. On a new-build project and depending on the system, this can be something that is included in a commissioning exercise.

8.10.98 Based on Mr Partlow's witness statement, it would appear that he did not measure the door-opening force, on any floor, for the 27 scenarios described in the *"PSB Fans and Damper Operation Cause and Effect Chart"* {PSB00000232} and whether the requirement set out in PSB's Technical Submission Revision 6 {PSB00000214} was met in all scenarios.

8.10.99 In Figure 8-29, I have excerpted the email dated 4th May 2016, to which Mr Partlow refers, in which Mr Whyte discusses the maximum door-opening force with RBKC Building Control {JSW00006202} .

8.10.100 I note, as stated in the email, that the items to be *"demonstrated tomorrow"* are *"in red"*. Therefore, it appears that Mr Whyte was not in fact confirming to RBKC Building Control that the pull strength was between 65 and 80N based on previous measurements.

Hi Poul.

Please find attached the latest issued cause and effect, schematic and des-ops for the smoke ventilation system at Grenfell.

At short notice our specialist are unable to attend, and as such I will be attempting to satisfy requirements.

Below are the acceptance testing requirements from the Smoke Control Association Guide for pressure differential systems, with items to be demonstrated tomorrow in red.

Please let me know if this will not be suitible

• Operate each motorised damper by activation of the designated manual or automatic device. – This has been carried out as per commission certification, I assume you would only want to see a proportion of smoke heads activated.
• Check that the fan(s) operate at the same times as the opening of the dampers, measure its performance and check against the design value. Design value is an open door velocity of not less than 2m/s as per attached, a figure which is exceeded in all areas as per attached readings. Random floors to be demostrated
• Check the automatic change over is operational for the standby fan. To be demostrated
• Check the automatic change over is operational for the secondary power supply.To be demostrated
• Inspect the motor drive for correct operation and extension.
• Operate the ventilators and fans in accordance with the design cause and effect and inspect for correct operation and extension. System to be set in environmental mode, and fire simulated to prove cause and effect
• Check the maximum forces required to open escape doors while the system is operating in means of escape mode and record results. The recorded force must not exceed 100N. Pressure differential set at 25p/a on all floors. Pull strength required is between 65 & 80N dependant on existing door and closer
• Check the operation of the manual control point(s) to ensure the system operates as requested. Please note the system can only be activated by detection of smoke (no break glasses), once activated, system can be stopped or other floor opened via main panel or override on each floor.
• Where applicable, the operation and function of the pressure sensors should also be checked. Fan speed change to be demonstrated on opening of doors
• Reset the system on completion of test.
• Provide a certificate of test
• Provide a certificate of compliance.

Figure 8-29 Excerpt of email dated 4th May 2016 {JSW00006202}.

8.10.101 I have also found evidence regarding measured door-opening force in a later e-mail from PSB to JS Wright dated 26th May 2016 {PSB00001152} which states:

The control system will also[sic] *has pressure sensors added into each ventilated lobby to control the speed of the fans to ensure that when the*

doors on the escape route(s) are closed that the opening force on the door does not exceed 100N as detailed in BS EN 12101-6, this was witnessed by your Mr Alan Whyte and ***the reading, which was not recorded in our commissioning sheets but read as 85N on the scale provided by J S Wright.***

8.10.102 No explanation is provided in the email as to why JS Wright had requested this information from PSB.

8.10.103 The email appears to refer to a single reading taken of 85N without any explanation as to who took this measurement and when or on what floor.

8.10.104 The measurements required were door-opening forces for all 23 doors separating the protected stair from the depressurised lobbies, in each of the 27 scenarios described in *"PSB Fans and Damper Operation Cause and Effect Chart"* {PSB00000232}.

8.10.105 The recorded force to open that specific (albeit unknown) door was 85N, and therefore that single door was apparently compliant with the performance described in PSB's Technical Submission Revision 6{PSB00000214}, namely that *"When the doors on the escape route are closed that the opening force on the door does not exceed 100N as detailed in BSEN12101-6"*.

8.10.106 In conclusion it appears that only one door-opening force was measured in Grenfell Tower out of a total of 22 doors between the enclosed stair and the depressurised lobbies from level 3-23; and one door between the open stair and the pressurised lobby on level 2.

8.10.107 That measurement was not subsequently recorded in PSB's commissioning report {PSB00000224} or in any of the other certification documents sent to RBKC.

8.10.108 **The operation and function of the pressure sensors should also be checked**

8.10.109 As I explained in Section 7, twenty four pressure switches were installed in Grenfell Tower, one for every lobby from Ground Level to Level 23. The pressure switches were equipped with two pressure sampling points, one in the lobby and one in the stairwell to monitor the pressure difference between the two spaces.

8.10.110 I would expect that commissioning tests of the pressure switches to have included:

a) Measurement of the ambient pressure in the lobby and the stair

b) Activation of the smoke zone in a given lobby.

c) Measurement of fan speed at level 2 and roof level to demonstrate it was running at 100% speed until the required depressurisation had been reached hence that the pressure switch was open.

d) 2nd measurement of the pressure to demonstrate the differential pressure of -25Pa had been achieved between the lobby and the stair.

e) 2nd measurement of fan speed at level 2 and roof level to demonstrate it was running at 50% speed once the differential pressure of -25Pa had been achieved between the lobby and the stair hence the pressure switch was closed.

f) Opening the door to the stair on the floor where the smoke zone had activated.

g) 3rd measurement of fan speed at level 2 and roof level to demonstrate it was running at 100% speed hence that the pressure switch was open.

8.10.111 This ought to have been repeated on all 24 floors.

8.10.112 In relation to the pressure switch, PSB's commissioning report {PSB00000224} states:

Number	Auto	Open	Off	Damage	Pass	Fail
FOS 01 to 24	ok	ok	n/a	ok	yes	
	operation	reset				
Smoke detector SDE01 to 24	ok	ok		ok	yes	
	operate					
Pressure switch PS01 toPS24	ok			ok	yes	

Figure 8-30 Excerpt from PSB Commissioning report {PSB00000224}.

8.10.113 Mr Partlow describes testing the pressure switches during the setup of the system in his first witness statement {PSB00001309} under *Step 2 – Identification of each component and check it was wired correctly* as follows:

39. I checked that the pressure switch was mounted in the correct area in the staircase and lobby and that it activated if the air resistance changed (I did this by sucking air through a piece of plastic pipe which I attached to the static tube which formed part of the pressure switch). I checked to make sure it was connected into the correct connector on the outstation. I also set the pressure switch to 25 Pa at this stage.

40. This would be revisited when the system was powered up and I was looking to ensure the primary performance criteria for the System were met as per the design. Essentially this means ensuring that affected doors could be opened easily when the System was operating (a door opening force of less than 100N), and that air flow from the protected stair to the common lobby on the floor where the System activated would be enough to control smoke in the common lobby and so protect the common stairs when the common lobby door was opened (an open door air flow rate of a minimum of 2.0 m/s). I did this by turning a dial (marked 0-130 Pa) located in the pressure switch using a screwdriver.

8.10.114 I also note the manufacturer's recommendation for the pressure switch states {TMOM00001792}:

The PA-DPS will be damaged if subjected to excessive pressure. Do NOT test the unit by blowing into the inlet ports.

8.10.115 Mr Partlow's test of the function of the pressure sensor during system set-up could therefore have damaged the unit.

8.10.116 As I have explained in Section 7, the function of the pressure switch is to decrease the speed of the smoke fan from 100% to 50% when the pressure switch was activated. The pressure switch is activated when the pressure difference between the lobby and the stair exceeds 25Pa . I have further explained the operation of the pressure switch in Section 7.

8.10.117 Mr Partlow describes testing this functionality in his first witness statement {PSB00001309} at paragraph 81 under *Step 9 systems testing*, as follows:

I also asked him to open and close the door to the stair to check that the fan speed increased when the door was open.

8.10.118 The results of this test appear to have been recorded in the PDF document named "Grenfell tower readings in fire" {RBK00003781} which records air velocity readings at the "high" and "low" damper operating at either a "high speed" or a "low speed". However, there is no reference in this document as to whether the high/low speeds were specifically initiated by the pressure switch.

8.10.119 These results were issued to RBKC Building Control on 4th May 2016 {RYD00076725}.

8.10.120 **Carry out a cold smoke test if appropriate (generally only for systems used to allow extended travel distances)**

8.10.121 No description of this test is provided in the SCA Guide 2015.

8.10.122 My understanding is that in this test consists of {INQ00014730}:

A smoke machine can be set up at an agreed most critical location and will pollute the area with smoke for a pre-set time. The ventilation system will then be activated and can be evaluated as to its efficiency in removing the smoke over a set period of time. Using cold smoke can also identify any dead spots within the system.

8.10.123 I have found no reference to this test having been undertaken at Grenfell Tower by PSB in any of their documentation.

8.10.124 Mr Partlow also makes no reference to having undertaken this test in either of his witness statements.

8.11 Test procedures from BS EN 12101-6

8.11.1 As I have explained in Section 8.5 above, the most relevant systems to which Section 9 of the SCA Guide 2012 refers are a *"Mechanical Shaft System"* or a *"Pressure Differential System (pressurisation and de-pressurisation)"*, noting Mr Mahoney states his *"Mechanical extract 'depressurisation' system"* design did not fully comply with all of the design requirements of BS EN 12101-6 for a pressure differential system (refer to Section 8.3).

8.11.2 I note that Mr Whyte (JS Wright) specifically stated in an email to Mr Hanson (RBKC Building Control) on 4th May 2016:

Below are the acceptance testing requirements from the Smoke Control Association Guide ***for pressure differential systems****, with items to be demonstrated tomorrow in red.*

8.11.3 J S Wright therefore appear to have been of the opinion that the commissioning methodology for pressure differential systems from the SCA Guide 2015 was the relevant guidance.

8.11.4 Section 9.3.5 of the SCA Guide 2012, headed "Pressure Differential System (pressurisation and de-pressurisation)" states:

"BS EN 12101-6 provides a detailed set of test procedures which should be carried out, and recorded for this type of system and in addition to the test readings taken in accordance with the standard, the following inspections are also recommended"

8.11.5 Therefore, while the smoke control system at Grenfell Tower may not have been designed fully in compliance with the performance criteria in BS EN 12101-6, they are generally relevant to the performance criteria set out in PSB's Technical Submission Revision 6{PSB00000214.}

8.11.6 This is because BS EN 12101-6 provides a methodology to test all three of the criteria specified by PSB.

8.11.7 Accordingly, in this section I have reviewed PSB's documentation recording the procedures and test readings taken during their commissioning process to determine what if any tests and readings from BS EN 12101-6 were undertaken.

8.11.8 **BS EN 12101-6 – Pressure differential test (Acceptance Test 1)**

8.11.9 The procedure required was as follows:

a) Initiate the pressure differential system operation. Allow fans to operate for at least 10 min to establish steady air temperatures.

b) Switch off the pressure differential system fans, leaving all other components in their operational mode.

c) Measure the pressure differential between the pressurized space and the relevant accommodation.

d) Measure the pressure differential between the staircase that is to be pressurized and the relevant accommodation, on at least two storeys.

These readings shall be taken using a calibrated manometer, with the appropriate tube connections.

The pressure differential measured on at least two storeys shall comply with the minimum values indicated, i.e.:

50Pa across lift well and accommodation area.

50Pa across stairway and accommodation area; and

45Pa across closed doors between each lobby and accommodation area

8.11.10 Because Grenfell Tower was 24 storeys tall, the note to Section 12.2 *Acceptance test requirements* of BS EN 12101-6 required this procedure to be carried out at least three times, with floors assessed in groups of eight.

8.11.11 The Grenfell Tower smoke control system was not designed to meet the three pressure criteria from BS EN 12101-6.

8.11.12 Instead, only one pressure criterion was defined as stated in Section 3.3 *Mechanical control system* of PSB's Technical Submission Revision 6 {PSB00000214} *"The system is designed to maintain -25Pa in the lobby with all doors closed and will maintain the fans at low speed setting".*

8.11.13 I have therefore taken this as the required performance criterion to be demonstrated in place of items c) and d) listed above.

8.11.14 I have found no written documentation of any pressure differential measurements in any of the following certification documentation that were issued to RBKC Building Control on 4th May 2016 {RYD00076725}:

a) PSB's Technical Submission Revision 6{PSB00000214};
b) PSB's *Above ground commissioning report* {PSB00000224};
c) PSB's E-800 Electrical Schematic Rev. E {PSB00000429};
d) PSB's Fans and Damper Operation Cause and Effect Chart {PSB00000232};
e) Grenfell tower readings in fire{RBK00003781} (providing air velocity readings).

8.11.15 I have therefore reviewed Mr Partlow's witness statements for evidence that pressure testing was undertaken.

8.11.16 Mr Partlow's first witness statement {PSB00001309} listed the equipment that he carried with him to site:

1) A multimeter, used for measuring basic electrical tests, voltage, current, etc.
2) A calibrated anemometer, used for measuring airflow speed
3) Basic electrical tools – screwdrivers, pliers, etc.
4) A set of two way radios, to enable me to communicate with other individual(s) involved in the commissioning process.

Figure 8-31 Excerpt from witness statement of Mr Partlow dated 28th September 2018 {PSB00001309}

8.11.17 This equipment contains an anemometer, which is a device to take airflow readings. It does not contain a calibrated device for taking pressure readings.

8.11.18 Mr Partlow does not describe taking measurements of a pressure differential of *"-25Pa in the lobby with all doors closed"* during commissioning in March to April 2016 (which he covers at paragraphs 102 to 111 of his first witness statement {PSB00001309}).

8.11.19 Mr Partlow states in his second witness statement {PSB00001372} that *"prior to the final commissioning"*, *"I would then check the pressure differential at the common lobby door using a pressure differential monitor."*

8.11.20 Mr Partlow does not say whether or not the smoke control system was running when he took the measurements *"prior to the final commissioning"*.

8.11.21 When conducting Acceptance Test 1 of BS EN 12101-6, the measurements should be taken when the fans are turned off.

8.11.22 In any event, I have found no recorded evidence of the results of these tests referred to by Mr Partlow as having been undertaken prior to commissioning.

8.11.23 I cannot therefore determine whether or not the measured pressure differential achieved the required performance criteria of *"-25Pa in the lobby with all doors closed"*.

8.11.24 **BS EN 12101-6 – Net pressure differential (Acceptance Test 2)**

8.11.25 The procedure required that:

a) Within fifteen minutes of completing the requirements of section 12.2.1 of BS EN 12101-6 (described in Section 8.11.8 above) the second acceptance test was to measure the net pressure differential across each door separating a pressurized and an unpressurized space to the relevant accommodation on all floor levels with the pressure differential system running. In the case of Grenfell Tower, this would have been between the flats and the common lobbies.

b) The change in measurement between the first pressure reading (described in Section 8.11) and the second pressure readings was to be compared, with the performance requirements specified for the intended pressure differences.

8.11.26 Because Grenfell Tower was 24 storeys tall, BS EN 12101-6 required this procedure to be carried out at least three times, with floors assessed in groups of eight.

8.11.27 As I have stated above, the design requirement in Section 3.3 *Mechanical control system* of PSB's Technical Submission Revision 6 {PSB00000214} was a pressure differential of *"-25Pa in the lobby with all doors closed"* .

8.11.28 Mr Partlow states in his second witness statement {PSB00001372} that *"prior to the final commissioning"*, *"I would then check the pressure differential at the common lobby door using a pressure differential monitor."*.

8.11.29 Mr Partlow does not state whether or not the smoke control system was running when he took the measurements *"prior to the final commissioning"*. When conducting Acceptance Test 2 of BS EN 12101-6, the measurements should be taken when the fans are running.

8.11.30 As I have stated above, I have found no written documentation of any pressure differential measurements in any of the following certification documentation that was sent to RBKC Building Control on 4th May 2016 {RYD00076725}

8.11.31 **BS EN 12101-6 – Airflow Criterion (Acceptance Test 3)**

8.11.32 The procedure required was as set out below.

The open-door criteria in section 4 of BS EN 12101-6 is that the air supply is sufficient to maintain a minimum airflow of 2 m/s through the open door between the lobby and the accommodation at the fire-affected storey.

During this test all of the following doors were required to be open in the case of Grenfell Tower, those between:

a) the stair and the lobby on the fire-affected storey;

b) the stair and the lobby on an adjacent store;

c) the firefighting lift shaft and the lobby on the adjacent storey;

d) the stair and the external air at the fire service access level.

The air release path on the fire floor was also required to be open.

8.11.33 The open doors listed above are intended to replicate firefighting operations in a non-residential building where the fire and rescue service use the floor below the fire floor as a bridgehead when they exit from the firefighting lift and attach a hose to the fire main on that floor.

8.11.34 The fire and rescue service then run the hose through the door to the firefighting stair on the floor below the fire, then back through the door to the lobby on the fire-affected door, and finally to the door of the flat on fire.

8.11.35 I have illustrated this in Figure 8-32 below which I have adapted from Diagram 52a of ADB 2013:

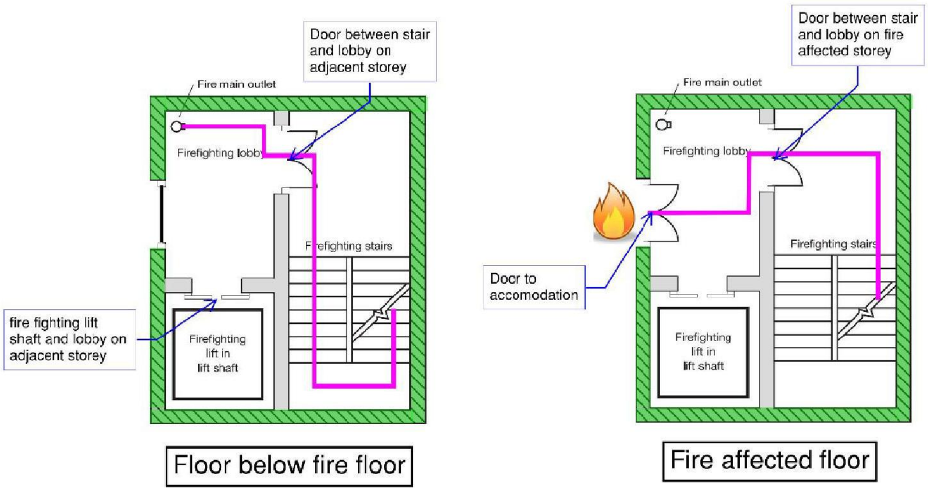


Figure 8-32 Example of firefighting operations in a non-residential building (adapted from Diagram 52 of ADB 2013).

8.11.36 BS EN 12101-6 states that the test(s) shall be carried out as follows:

Measure the air velocity using a calibrated anemometer.

The measurement of flow velocity through the flat doors shall be taken with all other doors open or closed as stated in J8.7.12 above.

The doorway shall be clear of obstructions.

Take at least 8 measurements, uniformly distributed over the doorway, to establish an accurate air velocity. Calculate the mean of these measurements or alternatively move an appropriate measuring device steadily over the cross section of the open door and record the average air velocity.

The calibration of all test equipment shall be such that the measurements are accurate to ± 5 %.

8.11.37 While the scenario in BS EN 12101-6 is designed around a non-residential building this scenario is relevant to Grenfell Tower as the fire main was located in the common lobbies. Therefore, a hose would have to pass through the door between the stair and lobby on the adjacent storey, the door between the stair and lobby on the fire-affected storey and finally the door into the flat on fire.

8.11.38 PSB's Technical Submission Revision 6 {PSB00000214} did not set a performance criterion for air velocity through the doors to each flat as the system was not designed to fully comply with BS EN 12101-6.

8.11.39 Instead, Section 3.3 *Mechanical control system* of PSB's Technical Submission Revision 6 {PSB00000214} stated: *"Once a door to the smoke affected lobby, and only the smoke affected lobby, the pressure differential will be lost and the fans will automatically ramp up to full speed to extract air from the lobby at a rate which will pride [sic]* ***an average face velocity of 2m/s across the open lobby/ stairwell door".***

8.11.40 I have therefore relied on this as the performance requirement for Acceptance Test 3.

8.11.41 The measured air velocity through the open lobby/stairwell door on each floor was issued to RBKC Building Control on 4th May 2016 {RYD00076725}.

8.11.42 The results are excerpted below:

Floor Level	Open Door M/sec	Low grille low speed M/sec	Low grille high speed M/sec	High grille low speed M/sec	High grill high speed M/sec
G	2.9	-0.6	1.6	6.5	7.1
1	3.3	2	7.2	6.5	9
2	4.6	2.4	7.1	4	7
3	5.1	2.7	7.2	5.7	9
4	4.2	0.6	5.1	2	5.8
5	4.4	-0.5	5	1.7	5.4
6	3.6	-0.4	4.8	1.9	5.6
7	4	0.5	4.8	1.7	5.7
8	3.9	0	4.6	2	5.6
9	3.6	0.3	4.7	1.9	5.6
10	3.5	0	4.4	2.1	5.8
11	3.4	0.9	4.1	2.1	5.9
12	3.8	-0.9	3.7	2.1	5.9
13	3.8	-0.6	3.3	2.3	6.2
14	3.4	-0.1	3.5	2.4	6.1
15	3.3	-0.5	3.6	2.2	5.8
16	3.6	-0.8	3.4	2.2	5.9
17	3	-0.7	3.4	2.2	6.2
18	3.5	0.8	3.1	2.3	6.2
19	3.7	-0.8	3	2.4	6.2
20	3.4	-0.7	3.2	2.4	6.2
21	3.3	-0.7	2.8	2.3	6.5
22	3.2	0	2.6	2.6	6.5
23	3	0	2.8	2.5	6.2

the higher than normal readings on levels 1 and 3 were due to missing grilles all readings are in metres per second fans at 100% speed

Figure 8-33 Grenfell Tower smoke control system commissioning readings sent to Mr Hanson {RBK00003784}

8.11.43 Mr Partlow describes the procedure used to carry out this commissioning test in *Step 10 - Cause and Effect check* of his first witness statement dated 28th September 2018 {PSB00001309}:

> 106. I took airflow readings using an anemometer from the top, middle and bottom of each door on each level when the System was operating in smoke control mode. The readings I recorded were an average figure of the readings taken from around the door.
>
> 107. I also took the following readings at the grille covering each damper on each floor:
>
> 1) When the system was operating in smoke control mode and the fans were operating at low speed (the door to the stair was closed).
> 2) When the system was operating in smoke control mode and the fans were operating at high speed (the door to the stair was open).
> 3) When the system was operating in environmental mode.

8.11.44 Mr Partlow then provides further details in his second witness statement (dated 26th March 2021) {PSB00001372}:

20. The open-door airflow velocity readings in smoke control mode were taken using an anemometer by taking a number of airflow readings, normally between 10 and 12, from different locations across and up and down the common lobby door on each floor. I made a note of the readings and used them to calculate the average reading for each door. I recorded the average readings in column 2 of the second page of the readings at {PSB00000234}.

21. I did not retain the 10 to 12 individual readings for each door as the average figure was the only one that had to be formally recorded for commissioning purposes. I normally dispose of my working notes a short time after a job has finished. After my work at Grenfell Tower had finished, but before the fire occurred, I disposed of my working notes which contained the individual readings for each door.

8.11.45 The door on which the measurement in each test was made is reported as "*the common lobby door… on the floor where the system has activated.*"

8.11.46 Mr Partlow's second witness statement (dated 26th March 2021) {PSB00001372} does not refer to any other doors being specifically opened when he took airflow readings through the "*common lobby door*".

8.11.47 Figure 8-16 shows that five air velocity measurements were recorded on a given floor, one through an open door and the others through the "high" and "low" "Grille".

8.11.48 I understand these to be one of the dampers in the north and south shaft respectively when the fan was operating at either a "high speed" or a "low speed" depending on whether the pressure switch was open or closed respectively.

8.11.49 The only door position that is recorded on the record of airflow measurements {RBK00003784} is that of the single open door. As Mr Partlow states this was the airflow through the "*common lobby door*".

8.11.50 No other information is recorded about which of the other doors in the building were open or closed when the test was undertaken.

8.11.51 In the case of Grenfell Tower, for means of escape, the entrance to the flat on fire and the door to the protected stair on that level would be open. In the case of firefighting operations, the door to the stair on the floor below the fire would also be open. This would result in two separate door open scenarios to be considered in the commissioning process.

8.11.52 Mr Partlow does not appear to have been asked to replicate either scenario in the commissioning of the smoke control system in Grenfell Tower; – the only open door was that to the stair on the fire floor.

8.11.53 There is conflicting evidence on the number of measurements of air velocity Mr Partlow took on each door. In his first witness statement (dated 28th

September 2018) {PSB00001309} he states *"I took airflow readings using an anemometer from the top, middle and bottom of each door"* whereas in his second witness statement (dated 26th March 2021) {PSB00001372} he states:

"The open-door airflow velocity readings in smoke control mode were taken using an anemometer by taking a number of airflow readings, normally between 10 and 12, from different locations across and up and down the common lobby door on each floor".

8.11.54 As I set out in Section 8.5, BS EN 12101-6 required eight readings per door.

8.11.55 There is no documentary evidence that Mr Partlow took any more than one measurement per door as shown in Figure 8-16.

8.11.56 **BS EN 12101-6 – Opening-door force (Acceptance Test 4)**

8.11.57 The following procedure was required:

a) The opening force at a particular door shall be measured as follows:

b) Actuate the pressure differential system.

c) Fasten the end of the force-measuring device (e.g. a spring balance) to the door handle, on the side of the door in the direction that it opens.

d) Release any latching mechanism, if necessary, holding it open.

e) Pull on the free end of the force-measuring device, noting the highest value of force measured as the door opens.

8.11.58 Section 12.2.4.1 of BS EN 12101-6 states:

"The fourth acceptance test shall be to measure the opening door force on the doors between the pressurized and unpressurized spaces as defined in Clause 4."

8.11.59 As I have explained in Section 5, Section 1.1.2 of PSB's Technical Submission Revision 6 sets the following performance criteria for the system {PSB00000214} in the scenario as described:

The control system will also have pressure sensors added into each ventilated lobby to control the speed of the fans to ensure that when the doors on the escape route are closed that the opening force on the door does not exceed 100N as detailed IN BSEN12101-6

8.11.60 As I have explained in Section 8.10 above, I have found no record of door-opening forces in any of the certification documents sent to RBKC Building Control on 4th May 2016 {RYD00076725}.

8.11.61 In Grenfell Tower there were 22 doors between the enclosed stair and the depressurised lobbies from level 3-23; and one door between the open stair and the pressurised lobby on level 2.

8.11.62 I would expect that the door-opening force had been tested and recorded as a minimum for all 23 doors separating the protected stair from the depressurised lobbies.

8.11.63 BS EN 12101-6 – Activation of the system (Acceptance Test 5)

8.11.64 The following procedure was required:

> The last test shall be to operate the automatic fire detection system (smoke detector) by injecting smoke into the detector head. This shall in turn operate the central fire alarm panel, thus activating the pressure differential system.

8.11.65 In relation to cause-and-effect testing, PSB's commissioning report {PSB00000224} states:

Check List

Have you checked the following?

1	Cause and effect	Yes
2	All drawings up to date	Yes
3	PLC and HMI up to date with latest software	Yes
4	Remote station's	Yes
5	Panel and panel room clean and tidy	Yes
6	Cooling fan filters clean and thermostat set to about 30°C	Yes
7		
8		

Figure 8-34 Excerpt from PSB's commissioning report {PSB00000224}.

8.11.66 As stated by Mr Partlow under Step 10 *Cause and Effect check* of his description of the commissioning process in his first witness statement {PSB00001309}, the cause-and-effect testing included his activating the system by injecting smoke into the detector head.

8.12 Commissioning – test procedures from BS 7346-8

8.12.1 Section 9.1 of the *SCA Guide 2015*, headed *Commissioning and Acceptance Testing,* refers to a further relevant British Standard:

8.12.2 In the following section, I compare the commissioning tests from BS 7346-8 against PSB's formal record of the results of the commissioning process as listed in Section 8.9.

8.12.3 Where I have already provided an assessment of a BS 7346-8 commissioning test as it was also listed as a test in the SCA Guide 2015 or BS EN 12101-6, I have provided a relevant cross reference in Table 8-4 below.

Table 8-4 BS 7236-8 commissioning tests

BS 7236-8 commissioning test	Section of report where this test has been considered
Labelling or other means of visual identification, if specified, have been carried out	Refer to Section 8.12.5

BS 7236-8 commissioning test	Section of report where this test has been considered
The agreed "cause and effect" requirements are correctly implemented (see 6.7) and the system is tested and responds to any planned method of initiation;	Refer to 8.9
No changes to the building since the time of the agreed design have compromised the system's conformity with the design specification (e.g. erection of new partitioning that affects the effectiveness of the smoke control system)	Refer to Section 8.12.7
Siting of control, indicating and power supply equipment is inspected and verified	Refer to Section 8.12.12
Primary power supplies are inspected as far as reasonably practicable	Refer to Section 8.12.18
Secondary power supplies and the actual load currents of the system, in all circumstances, are close to the predictions used by the designer to determine the capacity	Refer to Section 8.10.36
When the primary power is removed, the secondary power supply operates within the interruption time specified in BS EN 12101-10	Refer to Section 8.10.36
When the duty equipment fails, standby equipment operates, e.g. duty standby fan sets and uninterruptable power supplies (UPS) equipment	Refer to Section 8.10.29
Labels, visible when secondary power supplies (e.g. batteries) are in their normal position, are fixed to batteries, indicating the date of installation	Refer to Section 8.12.20
As far as it is reasonably practicable to ascertain, the specified cable type has been used in all parts of the system and the workmanship conforms to the design and relevant standards	Refer to Section 8.12.24
All fault monitoring functions operate correctly by simulation of fault conditions	Refer to 8.9
All relevant documentation has been provided to the relevant responsible person	Refer to Section 8.15

BS 7236-8 commissioning test	Section of report where this test has been considered
On completion of commissioning, a certificate signed by a competent person (see the example given in B.3) is issued	Refer to Section 8.15

8.12.4 Where insufficient evidence is provided in PSB's commissioning report {PSB00000224} I have also looked to the witness statements of Mr Partlow for evidence that a test was undertaken.

8.12.5 **Labelling or other means of visual identification, if specified, have been carried out**

8.12.6 PSB's Commissioning Report {PSB00000224} does not refer to any check that the system was labelled correctly. However my site inspection indicated that each of the components of the smoke control system which I observed had been provided with a label identifying the component.

8.12.7 **No changes to the building since the time of the agreed design have compromised the system's conformity with the design specification**

8.12.8 In relation to modifications to the system, PSB's Commissioning Report {PSB00000224} states:

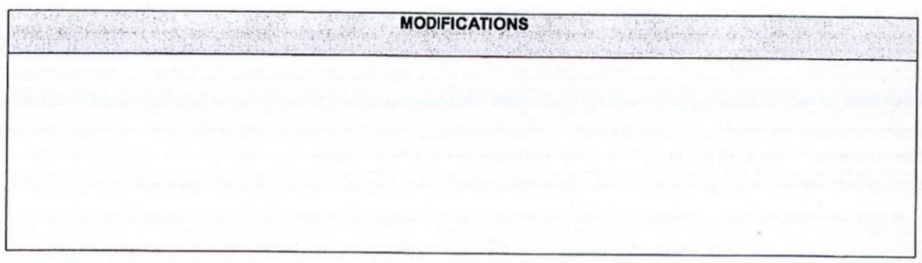

MODIFICATIONS

Figure 8-35 Excerpt from PSB's Commissioning Report {PSB00000224}.

8.12.9 As I noted in Section 7.16, new environmental programming and a new environmental fan inverter was installed in Grenfell Tower immediately prior to the formal commissioning process.

8.12.10 There is no assessment in either PSB's Commissioning Report {PSB00000224} or in Mr Partlow's witness statements that this change to the previously agreed design would not compromise the smoke control system's conformity with the design specification.

8.12.11 A number of changes to the building also occurred subsequent to the commissioning carried out by Mr Partlow. These are discussed further in Section 9. I have found no evidence that the system was recommissioned after these changes were made, nor how those changes were deemed not to require commissioning.

8.12.12 **Siting of control, indicating and power supply equipment is inspected and verified**

8.12.13 There is no reference in PSB's Commissioning Report {PSB00000224} to Mr Partlow individually checking the location of all the control, indicating and power supply equipment.

8.12.14 The certification documentation sent to RBKC Building Control on 4th May 2016 {RYD00076725} included the following documents which referred to the location of the control, indicating and power supply equipment:

a) PSB's Technical Submission Revision 6 {PSB00000214}.
b) PSB's E-800 Electrical Schematic Rev. E {PSB00000429}.

8.12.15 I have found the following errors or omissions in the location of the control, indicating and power supply equipment as stated in PSB's Technical Submission Revision 6 {PSB00000214} when comparing them to my site investigations:

a) It was stated that there is one outstation module panels per ventilated lobby located in the "service riser existing lobbies". There are no outstations serving the lobbies at Ground Level and Level 1. The dampers, smoke detector and pressure switch at Ground Level were in fact connected to the Master smoke control panel in the ground floor hub room. There is an outstation within the panel containing the inverter at ground level hub room controlling the Level 2 fans and another outstation within the panel containing the inverter at roof level controlling the roof fans. The level 3 outstation is also not located within the service riser but within the lobby behind the MDF wall panel.

b) The fire service override switch is stated as being located within stairwell. The fire service override switch was actually located in the lobby on each floor.

c) The Master smoke control panel is stated as being located in the service riser at Level 1. The panel was actually located in the ground floor hub room.

d) The battery back-ups are stated as being located on every fifth floor. The battery backup panels were actually located on Level 3 (though not found in post-fire pictures) and Levels 5, 7, 9, 11, 13, 15, 17, 19 and 21. There is also a battery backup at ground level within the panel containing the inverters for fans at Level 2 as well as a battery backup at roof level within the panel containing the inverters for the roof fans.

e) The pressure switch is stated to be located within the stairwell at every level. pressure switch on Levels 2 and Levels 4 to23 was in the riser cupboard with sensing points to lobby and stairwell. The pressure switch for Ground level and Level 1 are located in the ground floor hub room. The pressure switch for Level 3 is located within the Level 3 lobby behind the MDF wall panel.

8.12.16 I have found the following errors or omissions in the location of the control, indicating and power supply equipment in PSB's *E-800 Electrical Schematic Rev. E* {PSB00000429}:

a) The Master Outstation is also the Master Smoke Control Panel. This is located in the Ground Floor hub room and not Level 1 as indicated in the document..

b) Inverter Panel 1 is located in the Ground floor hub room and not within the riser.

c) The HMI panel is not in the same lobby as the damper. Instead it is located in the entrance lobby.

d) The Level 1 pressure switch is indicated as located within Level 1 riser. The ground Level and Level 1 pressure sensor was located in Ground floor hub room instead.

e) There are a pair of dampers for the environmental and smoke extract fans respectively. Only one damper was indicated for the environmental and smoke extract fans in the document.

f) The Level 3 outstation and pressure sensor is not located within the riser. It is located within the dry riser compartment behind an MDF panel within the lobby.

g) I am unable to find the Level 3 battery back-up in post-fire pictures.

8.12.17 Accordingly, Mr Partlow does not seem to have verified that all of the certification documents issued to RBKC Building Control accurately reflected the siting of the control, indicating and power supply equipment.

8.12.18 **Primary power supplies are inspected as far as reasonably practicable**

8.12.19 There is no reference in PSB's Commissioning Report {PSB00000224} to Mr Partlow inspecting the primary power supply.

8.12.20 **Labels are fixed to batteries, indicating the date of installation**

8.12.21 In relation to the batteries, PSB's Commissioning Report {PSB00000224} states:

Battery number	Battery Volts	Battery Ah	Actual Volts	Actual Ah	Pass	Fail
1 to 24	12	7	12	7	yes	

Figure 8-36 Excerpt from PSB Commissioning Report {PSB00000224}.

d) .

8.12.22 I note that PSB Commissioning Report {PSB00000224} refers to batteries numbered 1 to 24 indicating that there are 24 batteries I do not know what 24 batteries he meant.

8.12.23 There is no reference to Mr Partlow inspecting the labels fixed to the batteries in PSB's certification documentation.

8.12.24 The specified cable type has been used in all parts of the system and the workmanship conforms to the design and relevant standards

8.12.25 PSB's Commissioning Report {PSB00000224} states the following regarding the electrical cabling:

Electrical	Installed	Tested
Control Panel Software Loaded	yes	Yes
System Cause and Effect Fully Programmed	yes	Yes
Ensure correct operation of system under simulated mains failure	yes	yes
Ensure correct operation of system in case of failure in one part	yes	Yes
Carry out cable survey and check certification	yes	yes

Figure 8-37 Excerpt from PSB Commissioning Report {PSB00000224}.

8.12.26 I have seen no evidence in either PSB's Commissioning Report {PSB00000224} or in Mr Partlow's witness statements {PSB00001309}, {PSB00001372} that the fire resistance performance of the installed cables was checked against the design specification in PSB's Technical Submission Revision 6 {PSB00000214} which required the following cables:

2.4.2: Power and Control cables

The electrical wiring for the system shall be provided in fireproof cable with a CWZ classification.
Power/Controls wiring – FP200 Enhanced or equivalent.
ASI Network – FP200 Enhanced or Equivalent.
Fan Cables - FP600 Enhanced or equivalent.
COMMS - Firetuf or Equivalent.
And installed in accordance with the Electrical Wiring Regulations and BS8519.

8.13 Compliance status of the commissioning process

8.13.1 In Table 8-5, I have summarised the compliance of the documented evidence that the smoke control system in Grenfell Tower was commissioned in accordance with relevant industry guidance or British Standards.

8.13.2 Please refer to Section 8.11 where I discuss how the BS EN 12101-6 commissioning tests could have been adapted for use in Grenfell Tower.

Table 8-5 Summary of commissioning status

Guidance document	Test	Documented evidence test was undertaken at Grenfell Tower
SCA Guide 2015	Each motorised damper should be operated via the activation of the designated manual or automatic device	No - Not all dampers are recorded as having been commissioned in PSB's commissioning report {PSB00000224}.
SCA Guide 2015	Check that the fan(s) operate at the same times as the opening of the dampers,	No - no direct measurements of the fans performance were recorded in PSB's commissioning report {PSB00000224}.

Guidance document	Test	Documented evidence test was undertaken at Grenfell Tower
	measure its performance and check against the design value	
SCA Guide 2015	Check the automatic change over is operational for the standby fan	No - I have found no evidence this test was undertaken.
SCA Guide 2015	Check the automatic change over is operational for the secondary power supply	Partial – PSB's commissioning report {PSB00000224} states that this test was done but this was not on the PSB cause-and-effect document.
SCA Guide 2015	The motor drive should be inspected for correct operation and extension	No
SCA Guide 2015	The ventilators and fans should operate in accordance with the design cause and effect and should be inspected for correct operation and extension	Partial – PSB's commissioning report {PSB00000224} states that this test was done but does not provide evidence for all twenty-seven scenarios on the PSB cause and effect document.
SCA Guide 2015	Measure the flow rate into the shaft system at the ventilator furthest from the fan position.	Partial – The measured air velocity through the lobby dampers on each floor was issued to RBKC Building Control on 4th May 2016 {RYD00076725} however there is no contemporaneous documented evidence that more than one reading was taken per floor, where an average reading was required to comply with the SCA Guide 2015 which would then have to be multiplied by the opening area of the damper which was not done.
SCA Guide 2015	Check the operation of the manual control point to ensure the relevant damper(s) close and the fan(s) shut down	Partial – PSB's commissioning report {PSB00000224} states that the functionality of the firefighting override switch was tested but does not confirm how it was confirmed that the dampers at the level on which the switch was activated opened and the other dampers were closed.
SCA Guide 2015	Cold smoke test	No - PSB's commissioning report {PSB00000224} does not refer to this test having been undertaken
SCA Guide 2015	Reset the system on completion of test	No - PSB's commissioning report {PSB00000224} does not refer to a resetting of the system upon completion of the test.
SCA Guide 2015	Provide a certificate of test	Yes
SCA Guide 2015	Provide a certificate of compliance	Yes
SCA Guide 2015	Check the maximum forces required to open escape doors while the system is	No - There is no record in PSB's Commissioning report {PSB00000224} of any measured door-opening forces being recorded at

Guidance document	Test	Documented evidence test was undertaken at Grenfell Tower
	operating in means of escape mode	Grenfell Tower.
SCA Guide 2015	The operation and function of the pressure sensors should also be checked	Partial – PSB's commissioning report {PSB00000224} states that the function of the pressure sensors was tested but provides no results of any tests to verify this.
BS EN 12101-6	Pressure differential test (Acceptance Test 1) adapted to performance in PSBs Technical Submission Rev 6{PSB00000214}	No - No pressure measurements were recorded in PSB's commissioning report {PSB00000224}.
BS EN 12101-6	Net pressure differential (Acceptance Test 2) using the performance criteria in PSBs Technical Submission Rev 6{PSB00000214}	No - No pressure measurements were recorded in PSB's commissioning report {PSB00000224}.
BS EN 12101-6	Airflow Criterion (Acceptance Test 3) using the performance criteria in PSBs Technical Submission Rev 6{PSB00000214}	Partial -The measured air velocity through the open lobby/stairwell door on each floor was issued to RBKC Building Control on 4th May 2016 {RYD00076725} which met PSBs design requirements however there is no documented evidence more than one reading was taken per floor, where an average reading was required in the PSB Technical Submission Rev 6. .
BS EN 12101-6	Opening door force (Acceptance Test 4) using the performance criteria in PSBs Technical Submission Rev 6{PSB00000214}	No - There is no documented record in the PSB Commissioning report {PSB00000224} of any measured door opening forces recorded at Grenfell Tower.
BS EN 12101-6	Activation of the system (Acceptance Test 5) using the performance criteria in PSBs Technical Submission Rev 6{PSB00000214}	Partial – PSB's commissioning report {PSB00000224} states this test was done but does not provide evidence for all twenty-seven scenarios in the PSB cause-and-effect document
BS 7346-8	Labelling or other means of visual identification, if specified, have been carried out	No - No reference in PSB's commissioning report {PSB00000224} that this was done.
BS 7346-8	The agreed "cause and effect" requirements are correctly implemented (see 6.7) and the system is tested and responds to any planned method of initiation;	Partial – PSB's commissioning report {PSB00000224} states that this test was done but does not provide evidence for all twenty-seven scenarios on the PSB cause and effect document.
BS 7346-8	No changes to the building since the time of the agreed design have compromised the system's conformity with the design specification	No - I have seen no evidence that PSB requested information that no modifications be made to the system prior to commissioning.
BS 7346-8	Siting of control, indicating and power supply equipment	No - There is no reference in PSB's Commissioning Report {PSB00000224} to Mr

Guidance document	Test	Documented evidence test was undertaken at Grenfell Tower
	is inspected and verified	Partlow individually checking the location of all of the control, indicating and power supply equipment.
BS 7346-8	Primary power supplies are inspected as far as reasonably practicable	No - There is no reference in PSB's Commissioning Report {PSB00000224} to Mr Partlow inspecting the primary power supply.
BS 7346-8	The specified cable type has been used in all parts of the system and the workmanship conforms to the design and relevant standards	Partial – PSB's commissioning report {PSB00000224} states this test was done but I have seen no evidence in either PSB's Commissioning Report {PSB00000224} or in Mr Partlow's witness statements {PSB00001309} and {PSB00001372} that the fire resistance performance of the installed cables was checked against the design specification in PSB's Technical Submission Revision 6 {PSB00000214}.
BS 7346-8	All relevant documentation has been provided to the relevant responsible person	No- Refer to Section 8.15

8.13.3 As shown in Table 8-5, there is limited documented evidence that any of the commissioning tests recommended by the SCA Guide 2015, BS EN 12101-6 or BS 7346-8 were undertaken by Mr Partlow in their entirety.

8.13.4 In my opinion one of most significant issues was the lack of adequate cause and effect documentation reflecting the full performance of the lobby smoke control system, and therefore it appears this caused also, an inadequate set of test procedures to be relied upon.

8.14 Training and instruction

8.14.1 In Phase 2 I have not seen any evidence that appropriate training was provided to representatives of either the KCTMO for maintenance purposes or the London Fire Brigade regarding how to use the system in the event of a fire.

8.14.2 The importance of providing training on the smoke control system at handover is emphasised in BS 7346-8.

8.14.3 For example, section 8.4 of BS 7346-8, headed *Acceptance*, states:

8.4.3 Before accepting a system, the relevant responsible person (or appropriate representative of the responsible person) should check that:

d) sufficient representatives of the user have been adequately trained in the operation of the system;

8.14.4 This is further reflected in the example *Acceptance certificate* in Annex B4 of BS 7346-8 which states:

sufficient representatives of the user have been adequately trained in the use of the system, including, at least, all means of triggering voice alarm announcements and silencing and resetting the alarm.

8.14.5 I do not consider the briefing described by FF Walton in his oral evidence (transcript of 20th September 2018, at page 69[9]) to constitute appropriate training. As FF Walton stated, he stopped the briefing early and *"asked for such detailed instructions to be sent to the local station so that they could be uploaded onto the ORD appropriately"*.

8.14.6 On 28th April 2016 Mr Partlow gave a demonstration of the smoke control system (as stated in paragraph 113 of his witness statement dated 28th September 2018 {PSB00001309}):

113. On the 28th April 2016 I was asked to attend a demonstration of the System. This was organised at the request of J S Wright. So far as I was concerned this was an opportunity to demonstrate the System to PSB's client, J S Wright. PSB was also informed that representatives from Building Control would be present. In the event, a number of other persons were also present. To the best of my recollection this demonstration included Alan Whyte (J S Wright), representatives of Rydon, two people from the London Fire Brigade, someone from the management company and at least one Building Control Officer. I cannot recall the names or job titles of these individuals.

8.14.7 Mr Partlow describes the demonstration of the HMI panel at paragraphs 120 to 128 of his witness statement dated 28th September 2018 {PSB00001309} and paragraph 48 of his witness statement dated 26th March 2021 {PSB00001372}.

8.14.8 I further note that, according to his witness statement (RYD00094213) on 26th July 2016, David Hughes (Rydon) provided a site tour:

92: I ran a tour for the local fire brigade on 26th July 2016. This tour was arranged by Janice Wray, health and safety manager at KCTMO, who also attended. I believe that Janice took a register of everyone that attended.

93: I showed them the following:

93.1 Operation of the HMI (Human Mechanical Interface) panel for the smoke extract system.

8.14.9 In his oral evidence during Module 1 of Phase 2,[10] Mr. Hughes was asked about the above tour as follows:

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[9] https://assets.grenfelltowerinquiry.org.uk/documents/transcript/Transcript-of-further-LFB-evidence-20-September-2018.pdf; Accessed:10/05/2021

[10] Day 27 transcript at [212]

Q. Can you remember how you demonstrated the operation of that HMI panel and the AOVs for the Fire Brigade?

A. No, I don't remember specifically , but I knew it was a fairly simple system that I obviously had - - well ,I got to learn how it worked through -- with - - sorry, with JSW and PSB, so it was quite a simple one. I think I just showed the Fire Brigade the very simple thing, and there was a little instruction manual to the side and it sort of explained that . Because -- as I say, to the side there was a little instruction manual which related the numbers on the panel to the levels that the AOVs were on in the building , so the floor levels .

8.14.10 Mr Partlow describes providing training to the LFB and KCTMO (PSB00001309):

"150: I also recall returning to Grenfell Tower in May 2016 to provide training on the operation of the System, but I cannot now recall precisely when that was."

8.14.11 I do not have any other evidence of what this training involved or for whom it was provided.

8.14.12 Please refer to Section 11 where I present my review of the training provided to ESAs and evidence that the system was not adequately maintained.

8.14.13 I have no further evidence of training provided to representatives of KCTMO or LFB on how to operate the smoke control system using the HMI panel.

8.15 Documentation to be provided at handover

8.15.1 I have set out the recommendations in published guidance for documentation to be provided upon handover of the smoke control system in Sections 8.5 as described by the *SCA Guide 2015*, 8.6 for BS EN 12101-6 and 8.7 for BS 7346-8 above.

8.15.2 In Table 8-6 I have compared this guidance to the certification documents sent to RBKC Building Control on 4th May 2016 {RYD00076725} and also provided in the Rydon Building Manual ({TMOM00002199} to {TMOM00002199}).

8.15.3 From the evidence available to me, the documentation produced by PSB does not describe the functional objectives of the smoke control system. Specifically, the PSB documentation does not state if the system is provided to maintain tenable conditions within the lobby for means of escape and/or, to assist firefighters in carrying out their firefighting operations.

8.15.4 As I have shown in Section 5, the SCA Guide 2015 recommends that this is considered and documented by the designer.

8.15.5 I note the following from the *SCA Guide 2015* which states:

Smoke control systems form an element of the overall fire engineering strategy for apartment buildings and should not be designed in isolation. It is the responsibility of the designer of the smoke control systems to ensure that any proposed systems complement the fire safety strategy and provide a suitable level of fire safety.

8.15.6 The SCA Guide and BS EN 12101-6 require design information to be included in the documentation at handover; including information describing the purpose of the system.

8.15.7 Even though Grenfell Tower had extended travel distances in the common corridor, this fact was not recorded in any of the PSB documentation, in spite of the fact that it had a significant bearing on the performance considerations relevant to the system, when determining what protection was possible within the physical constraints of an existing building.

8.15.8 The PSB documentation does not record how their smoke control system complements the fire safety strategy for the building to provide a suitable level of fire safety.

8.15.9 By failing to address the fundamental reasons why the smoke control system was provided, it is difficult to appreciate the importance of the system as part of the overall fire safety strategy for Grenfell Tower.

Table 8-6 summary of handover information provided for the smoke control system

Guidance document	Documentation required	Provided to RBKC building control {RYD00076725}	Provided in the Rydon Building Manual
SCA Guide 2015 Section 9.2	Design information detailing the performance criteria for the system and a description of the system	Yes	Partial – the version of PSB's Technical submission in the building manual is Revision 1 which was superseded {TMOM00001764}
SCA Guide 2015 Section 9.2	A control philosophy or cause and effect diagram	Yes	No
SCA Guide 2015 Section 9.2	As installed drawings	No	Yes ({TMOM00000149} to {TMOM00000154} and {TMOM00000130} to {TMOM00000136}) And {TMOM00000142}, {TMOM00000143})
SCA Guide 2015 Section 9.2	Relevant CE marking or type test certificates	No	No

Guidance document	Documentation required	Provided to RBKC building control {RYD00076725}	Provided in the Rydon Building Manual
SCA Guide 2015 Section 9.2	Installation and commissioning certificates	No	Yes - Completion certificate {TMOM00001862}
SCA Guide 2015 Section 9.2	Witness testing certificates or other evidence that the system was tested in front of the approving authority	N/A	No
SCA Guide 2015 Section 9.2	Maintenance and testing instructions/ Operation, maintenance and testing instructions	Yes	Partial - Some maintenance information was provided but not for each item of equipment {TMOM00001763} {TMOM00000003} {TMOM00001764}
SCA Guide 2015 Section 9.2	Instructions for fire service use	No	No
BS EN 12101-6:2005 Section 14	Full calculations showing the design criteria	No	N/A Approving authority requirement
BS EN 12101-6:2005 Section 14	Full specification details of the equipment used	Partial	N/A Approving authority requirement
BS EN 12101-6:2005 Section 14	Complete plans showing position and protection of the fan and associated electrical control equipment, and the location of fresh air inlets	No	N/A Approving authority requirement
BS EN 12101-6:2005 Section 14	Constructional details of the ductwork and duct terminals used for the pressure differential system	No	N/A Approving authority requirement
BS EN 12101-6:2005 Section 14	Any other relevant constructional information required by the approving authority	No other constructional information requested	N/A Approving authority requirement

Guidance document	Documentation required	Provided to RBKC building control {RYD00076725}	Provided in the Rydon Building Manual
BS EN 12101-6:2005 Section 14	Full operational details describing in words and by diagram the exact sequence of actions that will occur in the pressure differential system and in the normal ventilating system when a fire occurs in the building	No	N/A Approving authority requirement
BS EN 12101-6:2005 Section 14	A complete maintenance schedule indicating the maintenance checks needed for each item of the equipment and the frequency of these checks	Yes	N/A Approving authority requirement
BS EN 12101-6:2005 Section 14	On completion, the results of the tests carried out on the pressure differential system	Partial- Air velocity results and PSB Commissioning Report {PSB00000224} provided but the full results of all individual tests are not recorded	N/A Approving authority requirement
BS EN 12101-6:2005 Section 14	A clear description of the purpose of the installation	N/A Occupier/owner requirements	Partial – the version of PSB's Technical submission in the building manual is Revision 1 which was superseded {TMOM00001764}
BS EN 12101-6:2005 Section 14	A concise statement in words assisted by diagrams of the operation of the installation giving a clear indication of the sequence of events that will follow an alarm of fire	N/A Occupier/owner requirements	Partial – the version of PSB's Technical submission in the building manual is Revision 1 which was superseded {TMOM00001764}. No diagrams of the operation of the installation provided.

Guidance document	Documentation required	Provided to RBKC building control {RYD00076725}	Provided in the Rydon Building Manual
BS EN 12101-6:2005 Section 14	A complete maintenance schedule indicating the maintenance checks needed for each item of the equipment and the frequency of these checks	N/A Occupier/owner requirements	Partial – Some maintenance information was provided but not for each item of equipment
BS EN 12101-6:2005 Section 14	A check list in the maintenance schedule of the actions necessary for maintenance, together with a register that will form a record of the maintenance carried out and in which any faults found, and any corrective actions taken, may be recorded	N/A Occupier/owner requirements	No
BS EN 12101-6:2005 Section 14	A set of 'as installed' drawings for retention on the site	N/A Occupier/owner requirements	Yes
BS EN 12101-6:2005 Section 14	A statement to indicate that alterations to: – accommodation areas (e.g. sub-dividing floor areas); – floor covering under doors may affect the operation of the pressure differential system	N/A Occupier/owner requirements	No
BS 7346-8 Section 8.2	Certificates for design, installation and commissioning of the system	No	Yes- Completion certificate {TMOM00001862}

Guidance document	Documentation required	Provided to RBKC building control {RYD00076725}	Provided in the Rydon Building Manual
BS 7346-8 Section 8.2	A list of equipment provided and its configuration (e.g. schematic diagram), including use and operation of the system	Partial- Electrical schematic {TMOM00001888} shows equipment in wrong location	Partial- Electrical schematic {TMOM00001888} shows equipment in wrong location
BS 7346-8 Section 8.2	Routine weekly and monthly testing of the system by the user or their appointed agent	Partial- Some information provided in PSB Technical submission Revision 6 {PSB00000224}	Partial - Some maintenance information was provided but not for each item of equipment {TMOM00001763} {TMOM00000003} {TMOM00001764}1
BS 7346-8 Section 8.2	Information about service and maintenance of the system	Partial- Some information provided in PSB Technical submission Revision 6 {PSB00000224}	Partial - Some maintenance information was provided but not for each item of equipment {TMOM00001763} {TMOM00000003} {TMOM00001764}
BS 7346-8 Section 8.2	The importance of ensuring that changes to the building, such as relocation of partitions, do not affect the standard of protection	No	No
BS 7346-8 Section 8.2	Other user responsibilities	No	No
BS 7346-8 Section 8.2	As-fitted drawings indicating the positions of all control, indicating and power supply equipment	Partial- Electrical schematic shows some equipment in wrong location	Partial- Electrical schematic {TMOM00001888} shows some equipment in wrong location
BS 7346-8 Section 8.2	As-fitted drawings indicating the positions of all equipment that might require routine attention or replacement	No	No

Guidance document	Documentation required	Provided to RBKC building control {RYD00076725}	Provided in the Rydon Building Manual
BS 7346-8 Section 8.2	As-fitted drawings indicating the type, sizes and actual routes of cables	Partial - Electrical schematic {TMOM00001888} shows type and size of cables but not actual routes	Partial - Electrical schematic {TMOM00001888} shows type and size of cables but not actual routes
BS 7346-8 Section 8.2	A logbook (see Annex C) for recording the information	No	No
BS 7346-8 Section 8.2	A record of any agreed deviations from the original design specification	No	No
BS 7346-8 Section 8.2	Design certificate	No	No
BS 7346-8 Section 8.3	Installation certificate	No	No
BS 7346-8 Section 8.3	Commissioning certificate	Yes- Completion certificate {TMOM00001862}	Yes- Completion certificate {TMOM00001862}
BS 7346-8 Section 8.3	Acceptance certificate	No	No

9 Change made to the system post-commissioning (pre-handover of the building)

9.1 Overview

9.1.1 In this section I present my review of changes to the smoke control system that occurred after PSB signed the completion certificate for their works on 3rd May 2016 {PSB00001258} and before practical completion of the primary refurbishment works on 4th July 2016 {ART00006689}.

9.1.2 PSB's Completion Certificate {PSB00001258} recorded that the Grenfell Tower smoke control system was *"fully operational, in line with the agreed specification."*

9.1.3 PSB's Completion Certificate {PSB00001258} also provided for the document to be countersigned by JS Wright.

9.1.4 On 3rd May 2016 David Harrison (PSB) emailed Alan Whyte (JS Wright), requesting that he *"complete the attached document for inclusion in the O&M"* {PSB00001122}. I have not found a version signed by JS Wright.

9.1.5 From the evidence available to me, it would appear that the following changes were made after 3 May 2016:

a) An auto dialler was installed on 4th May 2016 (see Section 9.2); and

b) Permanently open louvres were installed in the external wall to the entrance lobby in June 2016 (see Section 9.3).

9.1.6 As these occurred after commissioning was completed, it was necessary at the time, and therefore as part of my investigation, if these changes merited a re-testing of the system.

9.1.7 In Appendix J of my Phase 1 report, I set out the following matters in relation to the auto-dialler which I intended to revisit as part of my Phase 2 investigations (see Table 9-1 below):

Table 9-1: Matters outlined in my Phase 1 report to be revisited during Phase 2

Relevant section from Appendix J {BLAS0000031}	**Relevant section of this report**
J7.2.2 The unit installed by Tunstall was not the unit previously proposed by Rydon/RJE for this purpose. {PSB00001090} (excerpt below) showed how the auto dialler (marked as 'redialler') was to be installed into the PSB control system. However, I have not yet seen any documentation clearly stating how the Tunstall unit was actually installed.	See Section 9.2.44
J8.8.2 I have not been provided with records of commissioning of the auto dialler.	See Section 9.2.32
J8.8.6 I am unclear at this time whether the auto dialler had any impact on the smoke system performance the night of the fire. *J8.8.7 I will investigate this further in Phase 2*	See Section 9.2.44

Relevant section from Appendix J {BLAS0000031}	Relevant section of this report
J9.1.17 At this time, I have not been provided with any information on how the specific devices installed for communicating with Tunstall in Grenfell Tower were connected to the smoke control system, nor the software that ran on the device in Grenfell Tower and in the relevant Tunstall control centre system.	See Section 9.2.44

9.1.8 Therefore I have considered whether the changes made to the system would require a re-testing of the lobby smoke control system pursuant to section 13.6 of BS EN 12101-6: 2005:

13.6 Re-tests

The entire pressure differential system shall be re-tested in accordance with 12.1 (acceptance testing) following any modification to the building that ***could affect the pressure differential system****, e.g. alterations to internal partitions, extensions and alterations to the pressure differential system.*

9.1.9 Following my investigations I have concluded that the installation of the auto-dialler did not affect the pressure differential system and, accordingly, that no re-testing of the lobby smoke control system was required prior to handover on 4th July 2016 {ART00006689}.

9.1.10 However, the (permanently open) fixed louvres in the main entrance foyer of Grenfell Tower did affect the pressure differential system because their purpose was to provide inlet air to the lobby smoke control system when it operated at either Ground Level or Level 1.

9.1.11 Accordingly, on Ground Level and Level 1 the system required re-testing against PSB's performance criteria for the system {PSB00001329}. That performance criteria was as follows:

a minimum velocity of 2.0 m/s being achieved through an open common lobby door to the stair. In achieving the recommended flow rate, the design also included provision to ensure that the opening force on the door would not exceed 100N.

9.1.12 This re-testing was required prior to handover on 4th July 2016 {ART00006689}.

9.1.13 As mentioned in Section 8 of this report, I have not found any evidence that these floors were commissioned, or that the necessity of re-testing was considered by either Rydon or their sub-contractors (i.e. JS Wright and PSB) at the time.

9.2 Installation of Tunstall Auto-dialler in Grenfell Tower

9.2.1 **What is an auto-dialler?**

9.2.2 An auto-dialler is a device capable of automatically transmitting fire alarm signals to an alarm-receiving centre which can then summon the fire brigade.

9.2.3 BS 9991:2011 Clause 22.1 reads as follows (bold by me):

> ***Where rapid summoning of the fire and rescue service is considered critical to the safety of occupants (e.g. on the basis of a fire risk assessment),*** *facilities should be provided for* ***the automatic transmission of alarm signals to an alarm receiving centre****, unless there are reliable arrangements for summoning the fire and rescue service by persons in the building. Automatic transmission should also be considered if occupants are mobility impaired to a degree that would cause them to be at high risk in the event of fire, or if there is any reason to suspect that occupants would be unlikely or unable to alert the fire and rescue service.*

9.2.4 **Requirement to provide an auto-dialler for the smoke control system per the Employer's Requirements**

9.2.5 The requirement for an auto dialler was included in Max Fordham's "*Employer's Requirements for MEP Services*" dated 28th November 2013 {MAX00006475}:

> *Central Panel:*
> *As described in Section U10 above, a central control panel shall be provided for the lift lobbies smoke control system. In addition to the indication provided for the smoke system, provide indication of fire being detected in any of the new areas described above. The Contractor shall include for the cost of this panel, but shall discuss with Building Control to agree if this is required or not.*
> *Include for a dial-up connection to the local Fire Brigade or an approved monitoring centre.*

9.2.6 I understand from e-mail correspondence between Max Fordham, KCTMO, Artelia and Rydon between December 2014 and January 2015 that the auto-dialler was intended to replace the existing dial-out facility in Grenfell Tower {TMO10008486}.

9.2.7 Mr O'Conner (Rydon) describes the existing dial-out facility together with concerns about its continued operation in his e-mail of 5th Dec 2014 to Ms Williams (KCMTO) {TMO10008486} as follows:

> *The system currently installed appears to be a smoke vent release system and operates with the activation of a smoke detector on the lift lobbies. (This is currently out of operation). This in turn sets off a sounder in the old concierge to alert the duty operative who will then look at the fire panel to see what floor the alarm has gone off on and manually press the button on the Tunstall system to call CAS who alerts the fire brigade. As the concierge is no longer in place, In* [sic] *the event of a fire there is no autodial procedure to alert the Fire brigade at present.*

9.2.8 This exchange led to Claire Williams then raising queries on 23rd December 2014{TMO10008486} regarding the "system designed at tender" due to the recognition that the concierge was no longer on site at Grenfell.

9.2.9 E-mail correspondence from Mr Booth of Artelia, to Ms Williams of KCTMO, dated 5th January 2015 shows that Mr Booth understood that Rydon had not included the provision of a new auto-dialler service in their tender:

My understanding was the smoke detection system was designed and tendered assuming that a concierge would be in attendance as this was the operation at that time. However the concierge has now been removed and you were checking with your team what arrangements TMO need to put in place now you don't have a concierge.
It was thought that you would want the alarm to be forwarded onto a 24hour manned arrangement for the smoke detection alarm. This will require an additional phone line to be ordered and installed and confirmation given where you want the alarm forwarded onto. My pre Christmas brain remembers you requesting this from your maintenance team but I can't remember what the answer was as to where you wanted the alarm to go to. The phone line will need to be ordered by TMO for the ongoing payment arrangements.

9.2.10 However, Mr Cross Smith, of Max Fordham, confirmed that the requirement for a new auto-dialler had been in the Employer's Requirements, stating as follows on 5th January 2015 {TMO10008486}:

We have been pretty clear in our ERs about what should be allowed for by the contractor for this. We have stated that a central control panel shall be provided with a dial-up connection to the local fire brigade or approved monitoring centre. Whether this is connected to the phone line used for the existing auto dialler (our initial assumption) or to a new line is less clear.

9.2.11 One of the attachments to his email, "Central Panel" contains the following sentence:

Include for a dial-up connection to the local Fire Brigade or an approved monitoring centre.

9.2.12 On 6th January 2015 {TMO10008486} Mr Cross Smith stated:

Rydon/Wrights should confirm that this is acceptable with Building Control and the Fire Officer. It can also be discussed with them where the most suitable place for the auto-dialler to connect to would be (Fire Station or other monitoring organisation).

9.2.13 **Provision of an auto-dialler by PSB**

9.2.14 The evidence shows that the auto-dialler next became a significant focus for Rydon in 2016.

9.2.15 On 17th February 2016, RJ Electrics, a sub-contractor of JS Wright, asked PSB to confirm the following {PSB00000991}:

how the dial up facility from your main panel worked. This is appertaining to asking the building owners how they wish the dial up to work within their organisation etc.

9.2.16 Mr Mahoney replied as follows on 18th February 2016:

the smoke control system does not have the requirement for dial up, as this is not a requirement of the smoke control specification for the project.

9.2.17 The meeting minutes for the 'Handover Countdown Meeting #6' {ART00005349} on 23rd February 2016, at item 3.6, *Fire Alarm Monitoring,* state that there is an "*existing Phone line that works*" and a "*contract existing with Tunstall*". Ms Williams was asked to supply Mr Blake (Rydon) with "*a telephone number and IP address details*".

9.2.18 On 25th February 2016 Ms Williams (KCTMO) provided details of the Tunstall monitoring centre for the required auto-dialler to JS Wright and RJ Electrics {MAX00006016}.

9.2.19 On the same day, Mr Blake (Rydon) stated that "*BT* [have] *been to site and located a line box which we have wired to* [and] *from the hub room*".

9.2.20 I understand that the line box (a single master socket) was connected to an existing phone line which was then serving "*the existing (redundant) fire alarm panel*". {MAX00005980}.

9.2.21 On 26th February 2016, Mr Richard Midgley (PSB) provided information to JS Wright on an auto-dialler "*INFORMA Speech Dialler*" manufactured by Honeywell {JSW00001856}.

9.2.22 Based on the "*INFORMA Speech Dialler*" engineering information sheet, the speech-dialler "*will use a telephone line to dial a pre-programmed telephone number, and reply* [with] *a previously recorded message, thereby alerting the recipient of the call to the alarm*" {JSW00001856}.

9.2.23 On 2nd March 2016, David Harrison (PSB) provided a quote to supply the equipment for an auto-dialler for the smoke control system {PSB00001049}. The quote includes "*1 No 8EP276A SPEECH DIALEER[sic]*". I understand this to be the "*INFORMA Speech Dialler*" proposed by Mr Midgley[11].

9.2.24 The quote from PSB was confirmed by Alan Whyte (JS Wright) on 14th March 2016 {PSB00001049}. JS Wright submitted a purchase order to Rydon for the supply of equipment including the "*8EP276A Speech dialler*" on 15th March 2016 {PSB00000153}.

9.2.25 RJE installed the "*INFORMA Speech Dialler*" on 15th April 2016 as stated in an email from Alan Whyte {PSB00001088}:

[11] https://www.security.honeywell.com/uk/product-repository/8ep276a-uk (Accessed on 3rd May 2021)

Andy of RJE is installing the supplied kit today, and we need early next someone from PSB to set it up. Could you please confirm availability with a date and time of attendance.

9.2.26 However, difficulties with the installed equipment then ensued.

9.2.27 On 22 April 2016 Andy Bridges of RJE wrote to Paul Eden of Tunstall stating {RYD00091225}:

Thanks for the call. Please find attached information on the installed dial out unit. With regard to meeting one of your engineers early next week, as I said I'm flexible, moving between sites at the moment so whenever you're engineer is available I will make sure I can be there.

FYI the connections we're currently using to trigger the dial out unit can be found on the appendix on page 15 (Active Low).

9.2.28 On 27th April 2015, Mr Andy Bridges (RJ Electrics) again wrote to Paul Eden (Tunstall) {RYD00091225} stating:

One of your engineers contacted me on Monday morning soon after we spoke, thanks for that. Unfortunately I didn't catch his name as we only talked on the 'phone.

The upshot was that after reviewing the dial-out info I provided he confirmed that the unit was not suitable to message the Tunstall response system, but Tunstall could provide a suitable unit to connect to our smoke extract panel.

We left it that he was going to organise an engineer / planner to visit site with me to survey the installation and provide a quote to KCTMO to install and connect the necessary apparatus.

9.2.29 On the same day, Mr Eden (Tunstall) explained the problem to Steve Blake (Rydon) {RYD00091229}(bold by me):

We believe the Tunstall equipment at the site was removed some time ago. Tunstall no longer maintain the equipment so we have now knowledge of what was on site. ***The dialler installed is an audio only dialler and has no data protocol to interface with the Tunstall Response centre so would never have been compatible.*** *Do you know to whom you forwarded the dialler information too please?*

9.2.30 The 'INFORMA Speech Dialler' provided by PSB was removed and replaced by a Tunstall auto-dialler as I explain below.

9.2.31 The product sheet for the 'INFORMA Speech Dialler' was incorrectly included in the Rydon Building Manual provided to KCTMO {TMOM00001886}.

9.2.32 **Installation of an auto dialler unit by Tunstall**

9.2.33 In their submission to the Inquiry {THL00000015}, Tunstall stated that a quote was requested from Mr Blake (Rydon) to connect a dialler unit to the

smoke control system in Grenfell Tower on 21st April 2016 and that a survey was carried out by a Tunstall employee on 28th April 2016.

9.2.34 Tunstall provided a quote to supply and install a 'Lifeline Vi' to the smoke control system on 29th April 2016 {THL00000018}.

9.2.35 An auto-dialler was then *"fitted and programmed"* by Mr Ricketts (Tunstall) on 4th May 2016 {THL00000015}.

9.2.36 The Rydon Building Manual provided to KCTMO includes a Tunstall visit report dated 4th May 2016 {TMOM00001927}.

9.2.37 This visit report records the works carried out as:

IEE - Installed Extra Equipment, Lifeline Vi. Connected to smoke extraction system.

9.2.38 Tunstall's visit report was signed off by a Mr Richard Hamilton of RJ Electrics.

9.2.39 The auto-dialler was installed one day after PSB signed a completion certificate for the lobby smoke control system {PSB00001258}. The installation of the auto-dialler unit was therefore carried out post-commissioning.

9.2.40 The function of the dialler unit supplied and installed by Tunstall, is described by Tunstall as follows {THL00000015} (bold by me):

*In the event of the **smoke vent system being triggered**, it would in turn **trigger the Lifeline unit (Lifeline Vi+)**. The Lifeline unit would then, **via the telephone connection, alert Tunstall's monitoring centre** and automatically retrieve customer database records for the call handler to take appropriate action. On the night of the fire, this action involved calling the fire brigade and subsequent follow up calls as dictated by the customer's procedures.*

9.2.41 On 5th May 2016 Rydon notified Tunstall that {RYD00091331}:

We ran a demonstration today for building control and apparently the reference number given was registered to another building.

....

Obviously we need to have the correct arrangements in place - can you confirm as a matter of priority

9.2.42 Tunstall returned to Grenfell Tower the next day, on 6th May 2016, to reprogramme the dialler and carry out a test involving the monitoring centre *"following a test performed by the customer on 5 May 2016"*. {THL00000015}.

9.2.43 The Lifeline Vi User Guide {TMOM00001926} and Lifeline Vi Installation and Programming Guide {TMOM00001925} were also included in Rydon's Building Manual provided to KCTMO.

9.2.44 Interface between the Tunstall Lifeline Vi and the smoke control panel

9.2.45 As set out in Section 7 of this report, in the event of a lobby smoke detector activation, a fire detected signal was sent to the Master Smoke Control Panel.

9.2.46 Based on a post-fire photograph taken on 10th August 2017, provided by the Metropolitan Police {MET00071310} (see Figure 9-1) it can be seen that the auto-dialler device was located within the Master Smoke Control Panel in the Hub Room at ground floor.

9.2.47 The dialler unit in the photograph in Figure 9-1 is identical to the Lifeline Vi unit {TMOM00001926}.

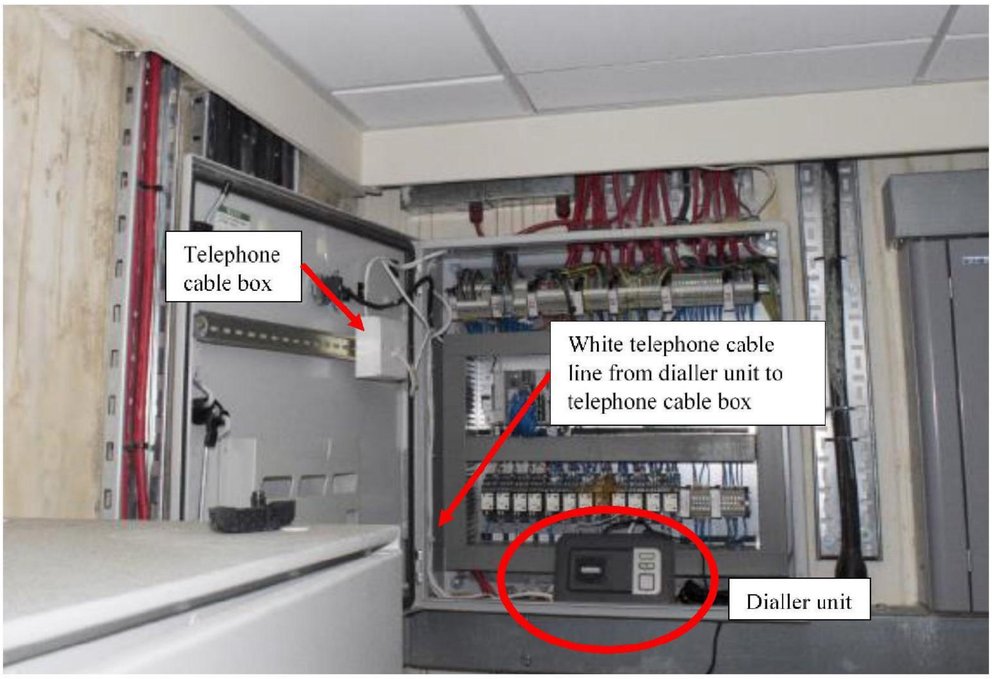


Figure 9-1: Master Smoke Control Panel at Hub Room with dialler unit (annotated by me) {MET00071310}

9.2.48 A Lifeline Vi device required a connection to a telephone line to alert the Tunstall monitoring centre upon receipt of a fire alarm signal {TMOM00001925}.

9.2.49 As can be seen in Figure 9-1, there is a telephone cable line from the dialler unit to the telephone cable box within the Master Smoke Panel.

9.2.50 A Lifeline Vi unit also requires a hardwire input connection from the Master Smoke Control Panel through "*normally open or normally closed volts free contacts*" {TMOM00001925} in order to automatically alert the Tunstall monitoring centre upon receipt of a fire-detected signal.

9.2.51 The connection between the Master Smoke Control Panel and the auto-dialler is described in Tunstall's submission to the Inquiry {THL00000015} and also in RINA's reconstruction report {MET00072161}.

9.2.52 In Tunstall's submission to the Inquiry {THL00000015}, it is said that the Lifeline dialler unit was connected to "'*clean contact outputs' from a smoke vent system*".

9.2.53 I understand "*clean contact outputs*" to mean the type of connection which only enables an output signal from the Master Smoke Control Panel to the auto-dialler.

9.2.54 Therefore, there was no feedback signal possible from the auto-dialler back to the Master Smoke Control Panel. This would be the only possible way the auto dialler could affect the operation of the smoke control system.

9.2.55 Having reviewed the reconstruction by RINA {MET00072161} and PSB's wiring diagrams {MET00018036}, I understand that the signal to the auto-dialler was generated by a fire-detected relay within the Master Smoke Control Panel.

9.2.56 RINA's assessment of the programmable logic controller (PLC) located in the Master Smoke Control concluded that {MET00072161} (bold by me):

In the event of a fire being detected by a smoke alarm, the outputs of the logic system:- ... ***Operated a relay in the Master Panel labelled FDR1 which Activates the auto dial***

9.2.57 In PSB's wiring diagram of the Master Smoke Control Panel {MET00018036}, FDR1 was labelled as the "*FIRE DETECTED RELAY*".

9.2.58 Based on my team's analysis I understand that the activation of a smoke detector in any of the lobbies in Grenfell Tower sent a signal to the Master Smoke Control Panel via the outstation located on the same floor. This signal activated the "Fire Detected Relay" (FDR1) within the Master Smoke Control Panel which then sent a signal to the auto dialler.

9.2.59 I understand the "Fire Detected Relay" is a simple electrical switch and therefore only indicates that a smoke detector has been activated.

9.2.60 The location of that detector is not part of the of the signal sent to the auto-dialler.

9.2.61 The auto-dialler then triggers a call to the Tunstall monitoring service via the telephone connection, tagged with an agreed identification number for Grenfell Tower.

9.2.62 The Tunstall monitoring service therefore records only that a smoke detector has activated in the building tagged with that identification number.

9.2.63 I have not personally inspected evidence of the physical connection of the auto-dialler to FDR1 in the Master Smoke Control Panel.

9.2.64 However, call logs disclosed by the Tunstall monitoring service {THL00000019} indicate that the auto-dialler was functioning between 6th May 2016 and 16th June 2017 and therefore it is reasonable to assume that the

auto-dialler was fully connected to the Master Smoke Control panel and the telephone cable.

9.2.65 **The requirement for re-commissioning**

9.2.66 BS EN 12101-6:2005 describes the conditions which would require re-testing of the entire pressure differential system:

13.6 Re-tests

*The entire pressure differential system shall be re-tested in accordance with 12.1 (acceptance testing) following any modification to the building that **could affect the pressure differential system**, e.g. alterations to internal partitions, extensions and alterations to the pressure differential system.*

9.2.67 The installation of the auto-dialler only involved a connection to an output from the Master Smoke Control panel and did not provide any inputs to the smoke control system.

9.2.68 Therefore, the auto-dialler did not form part of any "*alterations ... to a pressure differential system*" as per section 13.6 of BS EN 12101-6:2005.

9.2.69 It is on this basis I conclude that the lobby smoke control system was not required to be re-commissioned following the installation of the auto-dialler.

9.2.70 **Auto-dialler - protocol in the event of a fire**

9.2.71 Email correspondence available to me indicates that Ms Williams (KCTMO) led the activity to finalise the protocols in the event of activation of a smoke detector in the lobbies of Grenfell Tower. These protocols included agreeing upon the activity required of Tunstall.

9.2.72 Ms Williams wrote to Mr Hughes (Rydon) on 27th April 2016 {TMO10044983}:

Dave

We are putting together protocols for what happens in the case of the detection system being activated, so I need a couple of answers to the below:

.....

What I need to know is what effect the smoke detection system has on various M&E elements, so that I know what needs resetting, eg:

A Lifts: Does it bring the lifts to ground floor?

B Boilers: Grenfell and the existing ones at the finger blocks?

C AOVs

D Smoke panel

E Door entry system

F Fans serving internal bathrooms and refuse chute

9.2.73 Ms Williams also noted in her email {TMO10044983}:

Our process will be that we will be using the autodialler to Tunstall, who will then call the CAS (Call out service) at the TMO, but we will be asking Tunstall to call the fire brigade in all instances. We are then telling Tunstall who to contact, including the TMO Out of Hours service, so if I can have the responses to the above we should be able to finalise our arrangements.

9.2.74 On 27th April 2016, Mr Hughes responded as follows "*to the best of* [his] *knowledge*" {TMO10045033}:

1 Can I please have a copy of the latest fire strategy document? I have an original version, but want to make sure it has not changed, drawings would be useful. Exova Fire Strategy attached (not updated from tender as far as I'm aware) & fire strategy drawings attached (to be updated to as builts?[sic])

2 Where did the disconnection of the gas main come into the fire strategy? Was it part of Exova's recommendation, or was this in the Max Fordham specification? We've followed Max Fordhams specification which would have used the outline fire strategy as guidance. Matt should be able to confirm this

What I need to know is what effect the smoke detection system has on various M&E elements, so that I know what needs resetting, eg:

A Lifts: Does it bring the lifts to ground floor? No

B Boilers: Grenfell and the existing ones at the finger blocks? They both appear to reset after short duration outages- longer durations should probably be checked

C AOVs All part of the system – when reset button is pressed, should all return to normal as long as there is no smoke present

D Smoke panel As above

E Door entry system No effect

F Fans serving internal bathrooms and refuse chute No effect

9.2.75 Ms Williams forwarded that email to Ms Wray and Mr Bosman on 5th May 2016 stating {TMO10045033}:

I am putting this together into a protocol, and will be checking the 'to my belief' responses this am

9.2.76 Therefore, at the time that the PSB provided auto-dialler was found to be incompatible with the Tunstall monitoring service, on 27th April 2016, Ms Williams was developing the protocol to be followed by Tunstall. She was also seeking confirmation of the integrated system's cause and effect, as listed A-F in her email above.

9.2.77 I have also found evidence that KCTMO included a specific protocol for the Estate Services Assistants (ESAs) weekly checks on the lobby smoke control system.

9.2.78 I have reproduced the relevant section below, taken from the document entitled "*Estates Services Monthly Check at Grenfell Tower*" dated 16th November 2016 {TMO00828849}:

Weekly - the TMO need to check that the smoke ventilation system is working. This entails ringing Tunstall on [redacted]*, giving the postcode W11 1TQ and note that they manage the fire panel as a disbersed unit, and that a fire test is due. Grenfell's ID is 54000 9001. They then:*

Ring 999 for the fire brigade

Ring TMO/Pinnacle/estates services –

Boilers: Engie on [redacted]*/JSWright (Rydon sub-c)*

Smoke vent system: estates services

Ring CAS (community alarm service) to update on [redacted]

To do the test you can activate an alarm by using 'smoke in a can' and then press 'reset'. (The tel no of the autodialler is [redacted]*)*

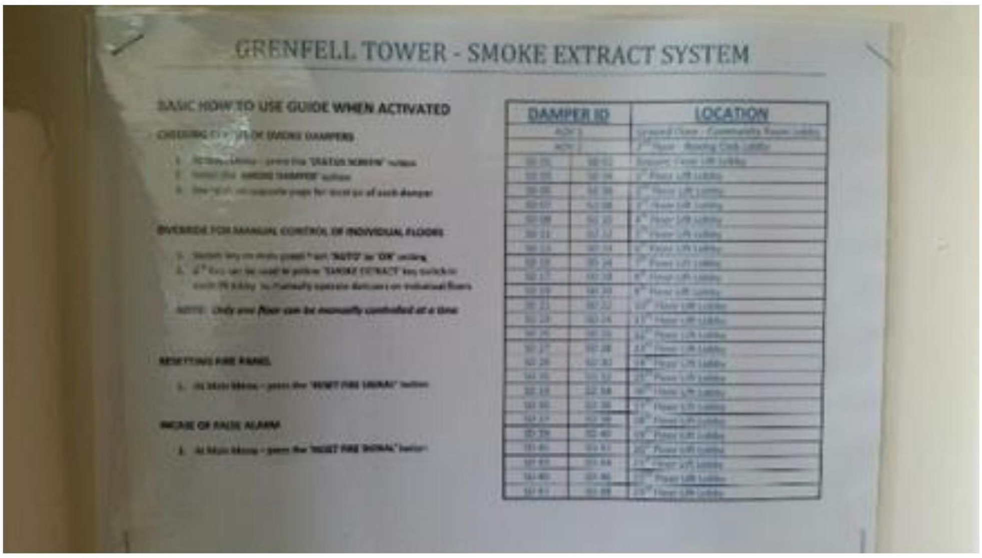


Figure 9-2: Excerpt from {TMO00828849}

9.2.79 The metadata for the document registers the author as Claire Williams with the document created on 23 June 2017, and last modified on 23 June 2017, by Janice Wray.

9.2.80 I note too, the information provided in a document entitled "*Grenfell and Smoke Detection System – Who Does What December 2016*"

{TMO00853686}. The metadata for this file records Claire Williams as author with the document created and last modified on 20 December 2016.

9.2.81 I have reproduced this below:

GRENFELL AND SMOKE DETECTION SYSTEM – WHO DOES WHAT December 2016

Just for clarification all instructions will be handled by Tunstall:

In the event of a Fire alarm activation

1 Tunstall will call 999 giving Grenfell address as Grenfell Road, London W11 1TQ . There is a drop key to the block main door. The fire panel is in the ground floor foyer.

2 Tunstall will call Estate services During working hours the caretakers are available on [redacted]. Caretakers will need to reset the smoke detection system.

3 Tunstall will call TMO or Pinnacle on [redacted]. For an OOH call Pinnacle need to contact estates services to reset the smoke detection system. The Grenfell Tower boilers should reset, however the boilers serving Barandon, Testerton and Hurstway will not. OOH Pinnacle will need to call Engie [redacted] who service the B, T & H boilers.

4 Tunstall will then call CAS once steps 1,2,3 has been completed just to update.

Figure 9-3:Excerpt from "*Grenfell and Smoke Detection System – Who Does What December 2016*" {TMO00853686}

9.2.82 With regards the distribution of the above document Ms Williams states in her witness statement at Paragraph 23 {TMO00842312}:

> Following the installation of the smoke detection system, the TMO sent a reminder note with its understanding of the system to Tunstall **(CW/5, 'Grenfell and Smoke Detection System – Who does what':).** I also forwarded this information to various relevant persons within the TMO as a reminder, along with maintenance and servicing information that had been sent to the Estate Services Team which outlined what they should look out for when carrying out their weekly and monthly checks at Grenfell **(CW/6, '20 December 2016 Email from Claire Williams to various personnel within the TMO':).**

9.2.83 I have also reproduced exhibit CW/6 showing the distribution internally at KCTMO {TMO00842298}:

Emma Henderson

From:	Claire Williams
Sent:	20 December 2016 16:54
To:	Nicola Bartholomew; Olivia Hutchison; Adrian Bowman; Janice Wray; John Griffin
Cc:	Louise Nezandonyi
Subject:	Grenfell - just a reminder of the OOH stuff
Attachments:	GRENFELL AND SMOKE DETECTION SYSTEM ACTIONS.docx; Information sheet _ MONTHLY CHECKS AT GRENFELL TOWER.docx

Dear all

I attach:

1. the brief that has gone to Tunstall should the smoke detection system be set off
2. the estates services brief on what to check at Grenfell. I would like to see if we can organise a fire test weekly starting in January – Louise, we can discuss.

I am just reminding you too that Grenfell generally has a 'stay put' policy in case of fire.

Shout if you have any queries.

Claire Williams
Project Manager

http://www.kctmo.org.uk

t: [redacted]
m:
a: The Network Hub, 292a Kensal Road, London, W10 5BE
P Before printing, please think about the environment

Kensington & Chelsea TMO

Figure 9-4 Excerpt from {TMO00842298}

9.2.84 Tunstall have also explained to the Inquiry the action which they would take in the event of fire {THL00000001}:

Requested by SJONES **UNT: 540009001 (Details Display)** **24 July 2017 21:58:05**

Notes

Subject	activation instructions
Creator	Z_SULLIVAN
Created On	16 May 2017 18:05:03
Deletion Date	<No Deletion Date>

Contents
In the event of an activation

1ST call Fire Brigade 999
main door can be accessed by LFB drop key.
The fire Panel is on the ground floor foyer, Fire Brigade will re-set alarm.

2ND Call Estate Services on [redacted] this phone is always diverted to an on call caretaker,(if no anwer leave a message for them, explained them that the fire Panel has gone off and that they need to reset the smoke detection system). IF NO REPLY GO TO 3RD STEP AND ASK THEM TO GET HOLD OF THE ON CALL CARETAKER TO ATTEND. AS WELL AS ASKING BOILER ENGINEERS TO ATTEND.

3rd call [redacted] and explain that the fire alarm at Grenfell tower has gone off (advise that the when the alarm goes off the Grenfell tower boiler should re-set themselves the boilers serving Barandon, testerton and hurstway walk will not so ENGIE the boiler engineer will need called on [redacted] to reset the boiler.

4TH Call CAS to to advise and update on steps 1-3..

Figure 9-5: Excerpt from {THL00000001}

9.2.85 The protocol recorded by Tunstall is consistent with the steps described by KCTMO in the following two documents: "*Estates Services Monthly Check at Grenfell Tower*" {TMO00828849} and "*Grenfell and Smoke Detection System – Who Does What*" {TMO00084393}.

9.2.86 **Auto-dialler Call History**

9.2.87 Tunstall have disclosed to the inquiry a document entitled *Q5a Call history from commissioning date* {THL00000019} with the first entry recorded on 6th May 2016 and the last entry on 16th June 2017.

9.2.88 This call history provides evidence of smoke detector activations in Grenfell Tower on 45 different occasions from 6th May 2016 to 16th June 2017. Also logged are other activations such as outgoing calls.

9.2.89 The fire-registered calls include 'Mains Failure' and 'Alarm call failed'.

9.2.90 I have reviewed the Tunstall call history for Grenfell Tower {THL00000019} in Section 11.5 of this report for evidence of deliberate activation of the smoke control system, as would be expected from KCTMO's requirement to carry out a system of planned maintenance

9.2.91 In Section 12 I have also reviewed the call history as part of my investigation of the operation of the smoke control system on the night of the fire.

9.2.92 The call history also provides evidence of the time of the first activation of a smoke detector in Grenfell Tower on the night of the fire (14th June 2017), which was logged at 00:55:01 as below:

02/06/2017 10:08:42	540009001	Smoke Detector	Test Engineer/warden
09/06/2017 10:21:43	540009001	Smoke Detector	Test Engineer/warden
14/06/2017 00:55:01	540009001	Smoke Detector	Fire Service Called
14/06/2017 01:04:20	540009001	Outgoing call	Contact Requested
14/06/2017 04:13:32	540009001	Outgoing call	Check Resident

Figure 9-6: Excerpt from { THL00000019}

9.2.93 As I have explained above, the call history records only that a smoke detector has been activated. The location of the smoke detector could not be included in the signal, therefore I have analysed other evidence to confirm what floor smoke was likely first detected on.

9.2.94 This is presented in Section 12 of this report.

9.3 Fixed louvres to the main entrance

9.3.1 I have been provided with evidence that RBKC Building Control requested a new source of replacement air for the lobby smoke control system to the lower floors of Grenfell Tower. This was installed after the completion certificate for the smoke control system had been issued on 3rd May 2016 {TMOM00001862}.

9.3.2 Replacement air specification by PSB

9.3.3 Regarding the provision of make-up air to enable the lobby smoke control system, Revision 6 of PSB's Technical Submission specified 'makeup air', another term for the replacement air, to be provided via the open lobby door on the fire floor, and a permanently open vent at the top of the stair i.e. the so-called 'penthouse louvre': {PSB00000214}:

The mechanical system will operate as follows:

- Smoke Extract mode: the by-pass damper assembly will shut off the connection to the environmental fan system and all four dampers in the lobby open, to extract air from the lobby through all four openings. Make up air will be provided via the open lobby door.

...

The mechanical system will operate as described above and the mechanical environmental system as follows:

- On alarm signal all dampers in the smoke affected lobby open (four dampers per lobby on the existing twenty floors and two dampers on the ground floor, walkway and walkway mezzanine areas)
- All other dampers close and all other floors are then locked out
- Environmental controls are locked out
- By pass dampers to environmental systems close
- By pass damper to the smoke extract fan set opens
- Make air is provided via the stairwell penthouse louvre which is permanently open.
- Smoke Extract Fans are initiated.
- Pressure sensor in smoke affected lobby active to regulate fan speed

Figure 9-7: Excerpts from Section 1.1.2 of PSB Technical Submission, Rev 6 {PSB00000214}

9.3.4 To aid comprehension, in Figure 9-8 I have illustrated the replacement air path specified by PSB.

9.3.5 However, the original stair only connected to the lobbies of Grenfell Tower from Levels 2 to 23.

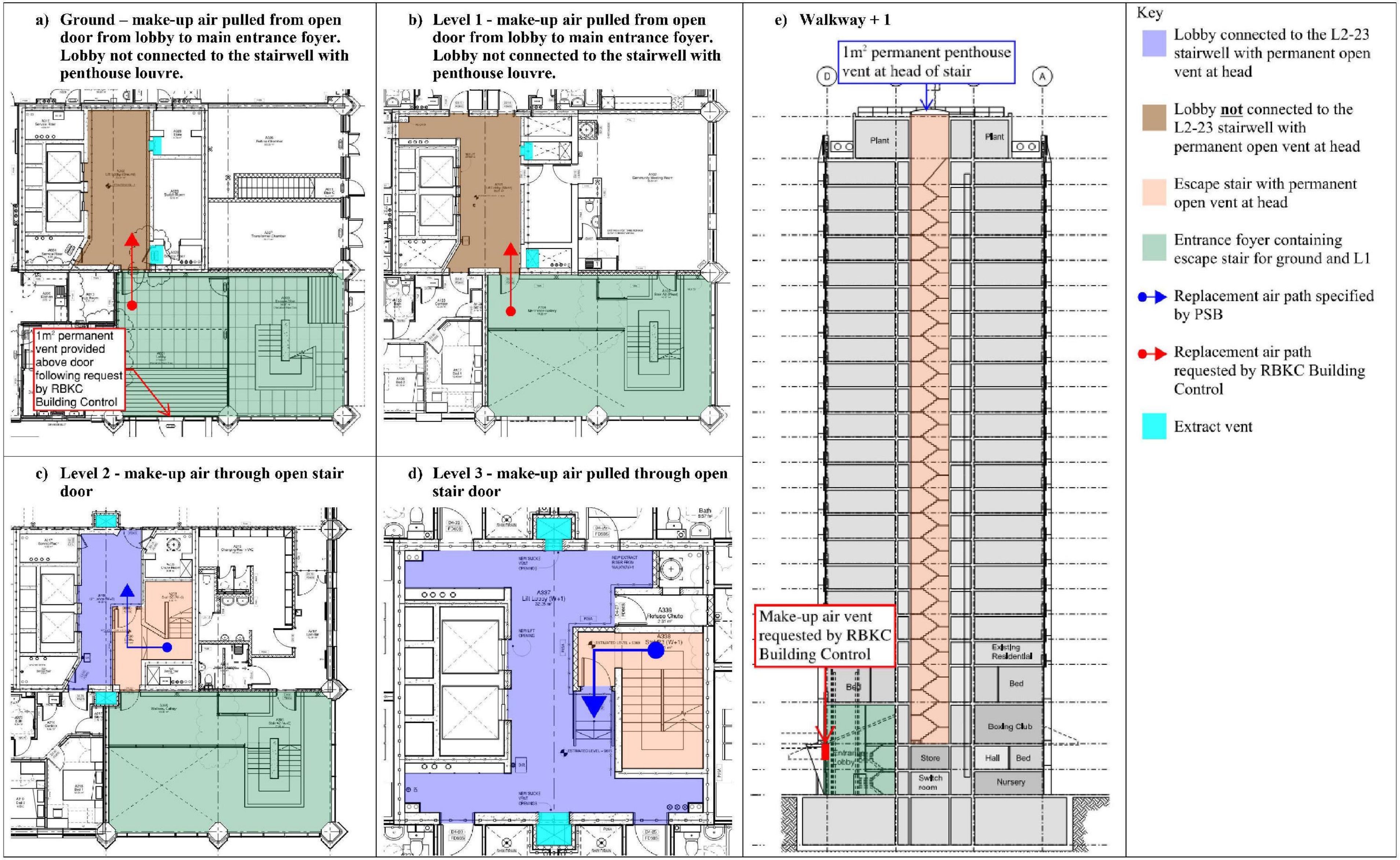


Figure 9-8: Lobby arrangement at Ground to Level 3 to demonstrate how the Ground Level and Level 1 did not connect to the 'penthouse louvre' at the top of the main stair

9.3.6 At Ground Level and Level 1 the lobbies did not connect to the original stair. If the smoke control system attempted to extract smoke from the lobbies on these levels, no replacement air could be drawn through the permanent open vent at the head of the stair, as was required by PSB's design. The lobbies at Ground Level and Level 1 were accessed from doors to the main entrance foyer (see Figure 9-8a and b). No source of replacement air for these lobbies was specified by PSB.

9.3.7 Escape from the Level 2 lobby was through two doors, the first to the central stair with the permanent open vent at the head, the second to the main entrance foyer (see Figure 9-8c). Replacement air was therefore intended to be sourced through the permanent open vent at the head of the stair via the first door between the lobby and the stair.

9.3.8 Escape from Level 3 and above was through a door direct to the stair with the permanent open vent at the head. (see Figure 9-8d). Replacement air was therefore intended to be sourced through the permanent open vent at the head of the stair via the door between the lobby and the stair.

9.3.9 Thus, the performance specification in PSB's Technical Submission did not specify how replacement air was to be provided to the lift lobbies at Ground Level and Level 1, in the event the lobby smoke control system needed to be activated there.

9.3.10 RBKC Building Control request for replacement air for the smoke control system

9.3.11 Following attendance at a demonstration of the lobby smoke control system on 5th May 2016, Mr Hanson (RBKC Building Control) states in his witness statement at paragraph 64 {RBK00033894}:

> It was discovered that no inlet air vent was provided at Ground floor level (to serve as makeup air to the Ground floor powered lobby vent). I was later told by John Hoban (the Area Surveyor) that the missing inlet air vent had been added, this was achieved by an automatically opening vent (AOV), via a window at Ground floor level opening into the stairway, the AOV triggered by smoke detection in the common lobby at that level. Apart from the missing inlet air at Ground floor level, the demonstration showed the system operated in the correct sequence as the table above.

Figure 9-9: Paragraph 64 of {RBK00033894}

9.3.12 I note that Mr Hanson states that he was informed that an AOV linked to the smoke detection was provided as a source of inlet air to the ground floor common lobby. However, from the available evidence (which I present below) a permanent vent was provided instead.

9.3.13 On 2nd June 2016 RBKC Building Control issued Rydon with a letter {RBK00020176} listing outstanding issues to be resolved including item 5 which stated (bold by me):

5] Various openable windows within the main entrance lobby to Grenfell Tower area required to be linked to main powered ventilation system for the building, so that such windows open on operation of the system and ***provide makeup air*** *at the bottom shaft for the system*

9.3.14 Therefore, RBKC requested automatic opening windows to provide replacement air to *"the bottom of the shaft system"*.

9.3.15 Whilst the letter of comfort from RBKC refers to the provision of an automatic opening vent, instead a permanent vent was provided (as I set out below).

9.3.16 In an email thread, on 2nd June 2016 Mr Hughes (Rydon) wrote to Mr Whyte (JS Wright) {JSW00001895} describing the issues affecting the bottom four floors of Grenfell Tower:

As discussed, they've asked for the environmental AOV's in the entrance lobby to be linked to the smoke extract system to allow make up air into the lift lobbies on the bottom four floors.

9.3.17 From my assessment in Figure 9-8, only the Ground and Level 1 lobbies were affected by PSB's failure to specify a source of replacement air.

9.3.18 On 9th June 2016 Mr Bradbury (JSW) wrote to Mr Blake (Rydon) stating {JSW00001895}:

> Steve, Following our telephone conversation:
>
> We have received a response from PSB and I've just spoken to them for further clarification. PSB have stated their commissioning results show that the system is achieving the design requirement without an AOV on the ground floor, therefore they are satisfied with the set up. however from speaking with Paul at building control I understand their concern is that leakage around doors and opening doors may not always satisfy the make-up air, therefore PSB have suggested that an opening / free area of **1m²** is allowed for in the ground floor entrance lobby area to atmosphere.

Figure 9-10: Excerpt from email dated 9th June from Mr Bradbury to Mr Blake {JSW00001895}

9.3.19 In the email exchange above, Mr Bradbury refers to a response from PSB advising that the ground floor lobby had been commissioned, "*achieving the design requirement*" without an AOV at ground floor.

9.3.20 However, Mr Bradbury goes on to state that PSB had advised JS Wright that a permanent vent of free area $1m^2$ should be provided to the ground floor entrance lobby.

9.3.21 It is unclear to me why this was suggested if the system had been commissioned and achieved the necessary design requirement.

9.3.22 In Figure 9-11, I have excerpted the air velocity commissioning results that were sent to RBKC building control demonstrating the velocity through the open door on levels 1, 2, and 3 exceeded PSBs design criteria of 2m/s.

Floor Level	Open Door M/sec
G	2.9
1	3.3
2	4.6
3	5.1

Figure 9-11 Grenfell Tower smoke control system commissioning readings sent to Mr Hanson {RBK00003784}

9.3.23 This proposal to provide fixed louvres at ground level was submitted by Mr Hughes (Rydon) to Mr Hanson (RBKC Building Control) on 13th June 2016 via email {RYD00080637}:

Following our conversation, and your conversations with our sub-contractors (JSW&PSB), we are going to change 2no windows under the front entrance canopy (see attached photo) to fixed louvres.

This is to allow make up air into the entrance lobby.

9.3.24 Mr Hughes (Rydon) attached the following photo to the email to demonstrate to Mr Hanson (RBKC Building Control) the location of the windows which were to be removed and replaced with fixed louvres. I have added a red outline to show the location of these windows:

Figure 9-12: Photograph attached to Mr Hughes email {RYD00080637}

9.3.25 Mr Hanson (RBKC Building Control) raised no objection to this proposal, stating via email one week later, on 20th June 2016 {JSW00001895}:

I have no objection to a fixed louvre solution for the makeup air- with the 1m² geometric free area.

9.3.26 A later photograph shows the glass above the entrance door replaced by a louvre. I have marked up the location of the fixed louvres which were installed below the canopy in Figure 9-13:

Figure 9-13: Mark-up showing fixed louvres of Figure 10.5 from the Chairman's Phase 1 report

9.3.27 The fixed louvres installed above the main entrance were permanently open and therefore could allow make-up air from the main entrance lobby to enter the lobbies at Ground Level and Level 1 (see Figure 9-8).

9.3.28 As these changes affected the pressure differential system at Ground Level and Level 1, as these louvres acted as inlet air for the lobby door open condition, re-testing of the system was required to confirm compliance with the performance criteria required by PSB - both the minimum velocity through the open lobby door, and the opening force on the door, plus confirmation of the correct function of the pressure switch.

9.3.29 As I explained in Section 8 of this report, I have not found evidence that these floors were either commissioned in the first place, nor re-tested when this change was made.

10 Compliance of the refurbished system with the functional requirements of the Building Regulations

11 Operational condition of the smoke control system prior to 14th June 2017

11.1 Overview

11.1.1 In this section I present the evidence available to me regarding the condition of the smoke control system following practical completion of the primary refurbishment which took place on 4th July 2016 {ART00006689}.

11.1.2 I have reviewed this evidence in order to understand the operating potential of the smoke control system on the night of the fire on 14th June 2017.

11.1.3 In Chapter 7 of my Module 3 report {BLARP20000033}, I presented my investigation of KCTMO's system of maintenance and, specifically, the arrangements made by KCTMO for the maintenance of the smoke control system.

11.1.4 I presented the inspection, testing, and maintenance requirements from the available British Standards, and my analysis of the evidence of maintenance activity and frequency of (overall) maintenance activity by KCTMO's appointed maintenance contractors as against those British Standards.

11.1.5 However, I have now carried out a further detailed analysis of the records of maintenance available for the smoke control system and I present this here in Section 11.

11.1.6 This analysis expands and therefore supersedes my assessment of the records of maintenance presented in Section 19.6 of my Module 3 report regarding the lobby smoke control system {BLARP20000033}.

11.1.7 Section 11 is organised around the following key activities which occurred after practical completion of the primary refurbishment on 4th July 2016 and which therefore fell under the remit of the KCTMO:

a) Section 11.2 – Reported defects and faults with the system post-commissioning and evidence that these were resolved prior to the night of the fire;

b) Section 11.3 – The apparent removal of the interface between the system and the landlord gas supply shut off in the basement;

c) Section 11.4 – Instructions on maintenance of the system in the Rydon Building Manual {TMOM00000003};

d) Section 11.5 – Records of the Tunstall auto-dialler call history showing activation of the smoke detectors prior to the night of the fire.

e) Section 11.6 – Records of planned maintenance of the system post-commissioning, by KCTMO's Estate Services Assistants, as well as KCTMO's planned maintenance contractor, Allied Protection;

f) Section 11.7 –The resulting operating potential of the system prior to the night of the fire.

11.2 Reported defects and reported faults with the system post-commissioning

11.2.1 I have identified three sources of information describing post-commissioning defect reports relevant to the smoke control system:

a) The Rydon defect-tracking spreadsheet, *"Grenfell Tower Weekly Report 09-06-2017"* dated 9th June 2017 {RYD00092614};

b) Rydon document titled *"Grenfell Defects Inspections - 30/05/2017"* {RYD00092598}; and

c) Risk Assessments undertaken by Mr Stokes on behalf of KCTMO.

11.2.2 According to the metadata, the Rydon defect-tracking spreadsheet {RYD00092614} was created on 9th June 2017 by Emma Kelly. Ms Kelly was a *"maintenance coordinator"* for Rydon {HAR00007708}. The spreadsheet lists a total of 174 defects recorded between 15th June 2016, around the time of practical completion, and 6th June 2017.

11.2.3 The spreadsheet appears to have been extracted from a database system and records work orders raised against a specific contact; in this case, all entries are recorded against the contract 'AC3482' {RYD00092614}. The status of the work orders is also recorded - whether the work remained in progress and if so whether it had been passed on to a specialist contractor.

11.2.4 The witness statements available to me from Rydon do not discuss the origin of the spreadsheet or how it was used at the time.

11.2.5 Of note is that the 'AOV system':

Contract	WO Number	Address	Description
AC3482	33689	Communal Grenfell Tower Grenfell Road Notting Barns London	BMS panel - no alarm
AC3482	33703	Communal Grenfell Tower Grenfell Road Notting Barns London	AOV System not working properly

Service By	Created	Target Complete	Finished
J S Wright & Co -	01/06/2017 11:15:10	16/06/2017 11:14:00	Works refered to specialisted contractor
J S Wright & Co -	01/06/2017 17:18:23	29/06/2017 17:18:00	Works refered to specialisted contractor

Figure 11-1: Excerpts from Cells A7 to H8{RYD00092614}

11.2.6 I am assuming that the "AOV system" referred to here, means the lobby smoke control system.

11.2.7 I present my review of the reported defect, its relevance to the smoke control system and whether it was resolved by the night of the fire, in Section 11.2.12.

11.2.8 Mr Stokes undertook two risk assessments of Grenfell Tower after the new smoke control system was installed - in April and June 2016. In the 'Significant findings and action plan' for both assessments ({CST00000451}

and {CST00000101}) Mr Stokes stated *"At the roof level there is a coil of fire alarm cable not connected at one end to anything."*.

11.2.9 I present my review of this item identified by Mr Stokes and whether it was resolved in Section 11.2.54.

11.2.10 The Rydon document *"Grenfell Defects Inspections - 30/05/2017"* {RYD00092598} records defects identified during an 'End of Defects' inspection carried out by Rydon with Ms Williams of KCTMO present (Paragraph 118, {RYD00094213}).

11.2.11 The Rydon document makes reference to the two defects I present below and describes them as *"AOV Vents not working??"* and *"Roof Plant Room – loose AOV cable goes to AOV"* {RYD00092598}.

11.2.12 ***AOV system not working properly* as recorded in Rydon's defect-tracking spreadsheet**

11.2.13 On 1st June 2017 an item was recorded in the Rydon defect-tracking spreadsheet {RYD00092614} with the description *"AOV System not working properly"* (see Figure 11-1).

11.2.14 The target date for the work order was stated as 29th June 2017 with the note "*Works refered*[sic] *to specialisted*[sic] *contractor"*.

11.2.15 Mr Hughes refers to this incident at paragraphs 118 to 121 of his witness statement {RYD00094213}. He states the defect was identified during a two-day 'End of Defects' (EOD) inspection at the end of May 2017.

11.2.16 Mr Hughes confirmed that on "*30th May 2017, he walked round Grenfell Tower with Claire Williams, Tom Bishop, Rydon site agent, and on the 1st June 2017, Gary Martin, site manager, joined us*." (Paragraph 118, {RYD00094213}).

11.2.17 I have found an email from Mr Hughes (Rydon) to JS Wright's aftercare email address with the subject *"Environmental Mode not working on Grenfell AOV"* dated 1st June 2017 {RYD00086508}.

11.2.18 In this email Mr Hughes states *"I walked all 24 floors on Tuesday and it was not operating on any floor"*. Mr Hughes requested that JS Wright *"investigate and remedy"* the issue.

11.2.19 I have reviewed Mr Hughes oral statement (Transcript 27th July 2020[12]) and discuss his responses in Section 11.2.39 below.

11.2.20 I have excerpted the photos attached to Mr Hughes email below {RYD00086508}:

[12] https://assets.grenfelltowerinquiry.org.uk/documents/transcript/Transcript%2027%20July%202020.pdf; Accessed:19/05/2021

Figure 11-2: 2017-06-01 12.08.15.jpg attached to {RYD00086508}

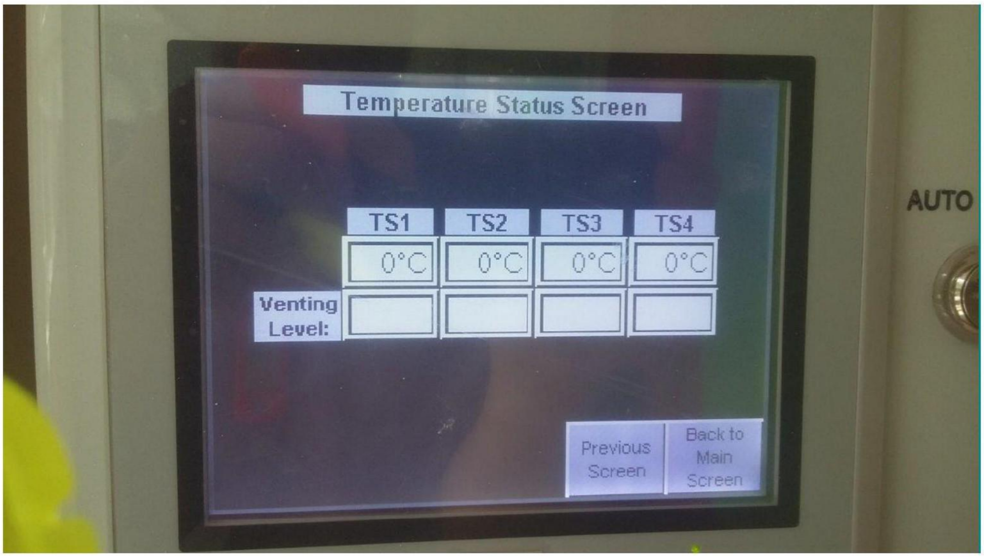


Figure 11-3: 2017-06-01 12.07.42.jpg attached to {RYD00086508}

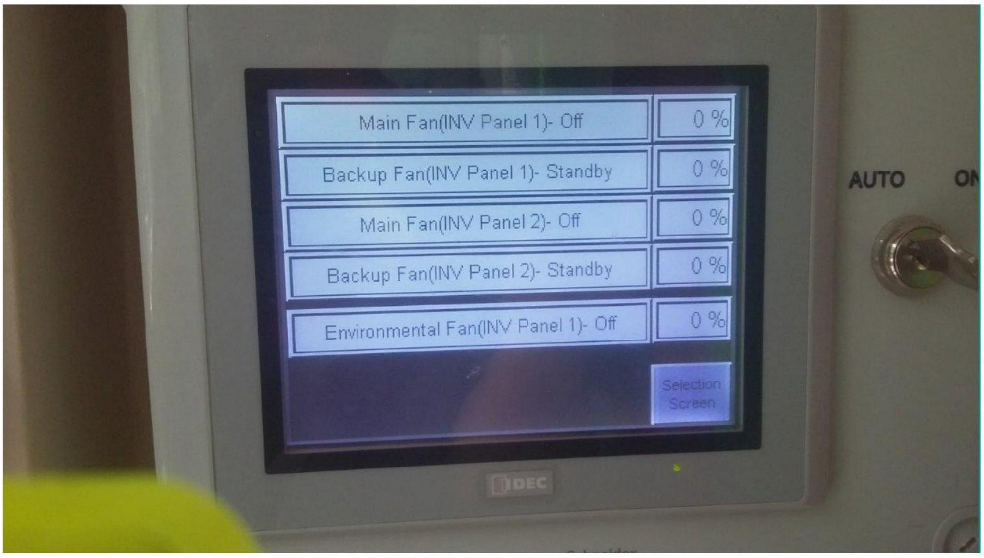


Figure 11-4: 2017-06-01 12.08.08.jpg attached to {RYD00086508}

11.2.21 As I have explained in Section 7.16 of this report the environmental mode would only operate if the average temperature recorded by the five temperature sensors exceeded the set point of 25°C and only between the hours of 09:00 and 20:00 (p.11, {MET00018469}).

11.2.22 If the average temperature recorded by the five temperature sensors was less than 25°C between 09:00 and 20:00 the environmental mode would not operate.

11.2.23 From the above photographs, the HMI panel indicated that all lobby dampers were closed and all fans were off. The file name for the photographs record the images as being taken at 12:07 and 12:08, at which time the environmental system would operate if the average of the 5 temperature sensor readings exceed 25°C.

11.2.24 There is no evidence that Mr Hughes had checked whether the temperatures in the lobbies met this criterion at the time of his inspection and therefore it is not known if the system should have been operating at that time.

11.2.25 In Mr Hughes oral statement, he described that there was an additional "*temperature sensor outside that if the air outside was hotter than the air inside (the environmental system) wouldn't work*" (p. 218, Transcript 27th July 2020).

11.2.26 As described in Section 7, I have now found an "*Outside Air Temp*" sensor with the BMS software as shown in the copy of the TREND work book (p.2, {DCS00000070}. The wiring diagram for the BMS basement control panel also shows connection to "*Outside Air Temp (Weather Compensation)*" (p.14, {TMOM00001806}).

11.2.27 From these two documents, I am unable to determine how this outside air temperature sensor (the sixth temperature sensor) is programmed to operate in combination with the other temperature sensors within the building (Please

refer to Section 7 on my understanding of how those internal temperature sensors operated).

11.2.28 I have also not found evidence of the physical location of this external sensor either.

11.2.29 Mr Hughes took a photograph as shown in Figure 11-3, of a 'Temperature Status Screen' with four readings of 0°C.

11.2.30 As I have explained in Section 7 the refurbishment[13] BMS system handled the data from five temperatures sensors in the lobbies, by means of the BMS panel in the basement.

11.2.31 I do not know how the sixth sensor was connected, or not, to the BMS system.

11.2.32 The BMS provided a simple signal to the Smoke Control Master Panel.

11.2.33 From my team's review of the BMS interface it did not send temperature data to the Smoke Control Master Panel (refer to Section.16 7.16).

11.2.34 Therefore, it would appear that the Temperature Status Screen was redundant.

11.2.35 There is no reference to a defect with the smoke extract mode. The only defect recorded is in relation to the environmental mode. However, I have seen no evidence that Rydon undertook any inspection or test to ascertain whether the smoke extract mode was operational that day.

11.2.36 I have found evidence that JS Wright contacted PSB on 7th June 2017 {PSB00000103} and 12th June 2017 {PSB00000480} to arrange for PSB to carry out an inspection of the system together with Direct Control Systems (JS Wright's BMS sub-contractor {JSW00001957}).

11.2.37 I understand this to be in relation to the defect which Rydon raised by e-mail on 1st June 2017 {RYD00086508} and recorded in the Rydon defect-tracking spreadsheet {RYD00092614}.

11.2.38 This is based on the JS Wright job number for the work (JSW11670) mentioned in the email from JS Wright to PSB {PSB00000103} and an automated email from JS Wright to Rydon assigning the defect as JSW11670 {RYD00092584}.

11.2.39 JS Wright also sent an email to Direct Control Systems with the subject 'JSW11670 – Grenfell Tower AOV' and attached the photos from Rydon with the file names prefixed 'JSW11670'{DCS00000084}.

11.2.40 The final email in the chain is from PSB to JS Wright on 12th June 2017 {PSB00000480} offering to halve their quote to attend site.

13 References to a 'refurbishment' system (BMS, boiler etc) are to those systems installed as the result of the primary refurbishment (rather than the systems in place prior to the primary refurbishment)

11.2.41 I have not seen any response from JS Wright to confirm that the quote was acceptable and asking PSB to undertake the work.

11.2.42 Nor have I seen evidence of anyone from Rydon, JS Wright or PSB visiting Grenfell Tower to inspect the reported defect.

11.2.43 Neither Mr Whyte's nor Mr Hughes's witness statements refer to this issue being resolved.

11.2.44 Accordingly, so far as I am aware, no-one established whether or not the environmental system was working prior to the fire on 14th June 2017.

11.2.45 As I have explained in Section 7, the system was designed such that activation of a smoke detector in any lobby would override the environmental mode (see Section 7.6) and switch the system into smoke mode.

11.2.46 However, as I have described in Section 8, I have seen no evidence of this override being tested during the commissioning process.

11.2.47 Mr Hughes provided evidence as part of his oral testimony to the Inquiry regarding the defect reported for environmental mode. In response to a question from Ms Grange QC, Mr Hughes stated (Phase 2 Hearings, Day 27, Page 217, lines 8-19):

I understand that Claire would be, yeah, rightly worried. But also , it ' s come to light afterwards that it might not have been such a big thing anyway, because it was a really hot day when we done that walk-around, and the environmental system also had a shut- off system on it , which if the air outside is hotter than the air inside , then it wouldn't work, it wouldn't basically bring in hotter air . The idea was to keep the lobby areas cooler. So if it was hotter outside than it was inside , it wouldn't bring the air in , and it was a really hot day that we done our -- sort of the two days we did the walk-around were hot days, so - -

11.2.48 Therefore, Mr Hughes suggests that the environmental mode defect may not in fact have been a defect, and that the system not operating on 30th May 2017, was in accordance with the how the system was intended to operate.

11.2.49 Mr Hughes states in his oral evidence that the system had a 'shut-off', which if the air was hotter outside the Tower than inside the lobbies, the environmental mode was programmed not operate, in order to prevent warmer air from outside being brought into the lobbies.

11.2.50 I have not seen from the evidence available to me that the environmental mode was designed with such a function as described by Mr Hughes in his oral testimony.

11.2.51 The PSB Technical Submission (Rev 6, {PSB00000214}) does not describe the 'shut-off system' referred to by Mr Hughes.

11.2.52 Further, the Building Management System Description of Operation document states {TMOM00001747}:

ENVIRONMENTAL COOLING

The outstation receives and interprets signals from temperature sensors mounted on the ground, fifth, tenth, fifteenth and twentieth floors. On a demand for cooling as measured by the average of the five floors, a signal is sent to the packaged environmental/smoke system.

The packaged system upon receiving this signal opens the intake air/floor dampers and starts the environmental fans.

(Note the temperature sensors on the ground, fifth and tenth floors are served from MCP01 outstation)

11.2.53 The Description of Operation document does not describe the provision of an external temperature sensor and that such a sensor would be relied upon to ascertain if the environmental mode should operate.

11.2.54 **Roof Plant – Loose/unconnected fire-protected cable**

11.2.55 The KCTMO Action Tracker spreadsheet dated 14th June 2017 {TMO10017386} records the steps that were taken by KCTMO in response to the actions Mr Stokes raised in his 2016 record of significant findings and action plans ({CST00000451}, {CST00000101}) relevant to the unconnected cable at roof level (see section 11.2.7 above).This action was assigned to Ms Bartholomew (KCTMO) on 9th August 2016, approximately three months after Mr Stokes first raised it on 26th April 2016.

11.2.56 The action was marked as ‘partially completed’ by Ms Wray on 24th May 2017, approximately 13 months after Mr Stokes first raised it. The action taken is stated as *“Order raised for Allied Protect* [sic] *to attend site with ESA [Estate Services Assistant], investigate and report back”* {TMO10017386}.

11.2.57 I have found evidence that Allied Protection carried out a site visit on 25th May 2017.

11.2.58 The site report from Allied Protection dated 25th May 2017 {LAK00000014} states in the field *“Comments on findings/ works carried out”*:

“fp cable is coiled up in ceiling awaiting for a smoke detector to be fitted by other engineers from another company”

11.2.59 In an email to Ms Wray on the same date {TMO10016917}, Mr Heffernan (KCTMO Contracts Manager) stated as follows:

We believe that the device that is to be installed is in relation to the AOV system, and from the information that Paul has provided it seems as thou [sic] *the company that manages the AOV system will be returning to site to install this device as part of their defects.*

11.2.60 I note that there was no fire detection zone on Level 24 (page 11, {MET00072161}) and therefore it was not intended that any smoke detectors be installed in the roof plant room as part of the smoke control system.

11.2.61 When referring to 'other engineers from another company' attending to fix the cable, it is not clear who Allied Protection meant {LAK00000014}.

11.2.62 I understand that Rydon later observed the loose cable during their visit on 30th May 2017 as recorded in their document *"Grenfell Defects Inspections - 30/05/2017"*.

11.2.63 Under the heading *Roof Plant Level* the report states {RYD00092598}:

loose AOV cable goes to AOV

11.2.64 The Rydon report indicates that the cable was for an automatic opening vent rather than a smoke detector as Allied Protection had stated in their 'Call Out (Repair) Visit Certificate'.

11.2.65 There is no reference to this defect in the Rydon defect-tracking spreadsheet {RYD00092614}.

11.2.66 I have seen no evidence of Rydon confirming to KCTMO that this issue had been resolved {RYD00092598}.

11.2.67 I note that Mr Whyte (JS Wright) undertook a site inspection after the fire on 2nd October 2018 as described in paragraph 199 of his witness statement {JSW00001892}:

I noticed a loose cable in plant room. A damper was indicated on the as fitted drawings but there was in fact no need for a damper in that location. The cable appeared to have been installed in the expectation that the damper was required but this was not the case. The cable was therefore unnecessary and was just left

11.2.68 Mr Whyte did not exhibit a photograph of the cable in his witness statement.

11.2.69 I have identified a damper at roof level, labelled 'COD3' in PSB's Electrical Schematic {TMOM00001859}, which does not appear to have been installed during the primary refurbishment:

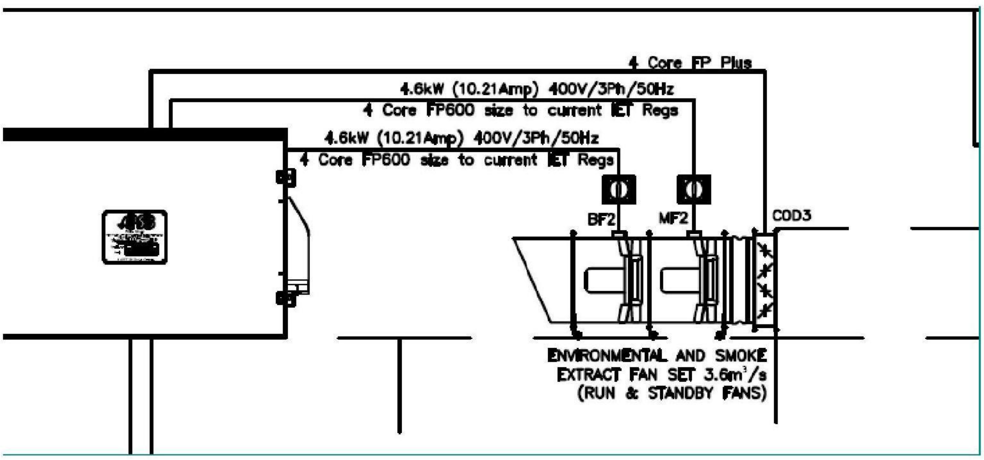
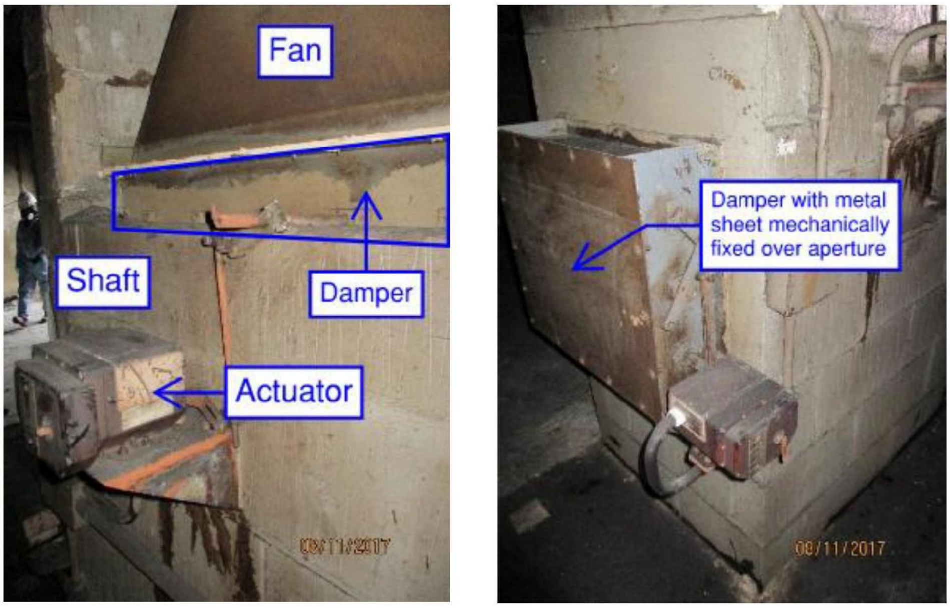


Figure 11-5: Excerpt from {TMOM00001859} showing damper 'COD3' at roof level

11.2.70 During my site visit on 8th November 2017, I observed a damper between the smoke shaft and extract fans at roof level, as well as a damper with a metal sheet fixed over its aperture (see Figure 11-6).

11.2.71 Regarding the damper between the shaft and the extract fans, the BRE on site investigation report records that the damper "*was found in a partially open position and the damper actuator was redundant (not connected to the new smoke control system)*" (Section 6.7, page 121 {MET00039807}).



a) Damper between head of smoke shaft and extract fan

b) Damper at side of shaft with metal sheet mechanically fixed over aperture

Figure 11-6: Damper between north smoke shaft and extract fan at roof level

11.2.72 Furthermore, a photograph (Photo 172 {MET00071361}) taken by BRE after the fire showed that the cable had 'fan' written on it by hand in black marker.

11.2.73 The 'Examination Report' by BRE {MET00071346} provides a description of each photograph taken by BRE and labels Photo 172 {MET00071361} "*unconnected cable labelled 'FAN'*".

11.2.74 Additionally, photographs 176-181 ({MET00071365}, {MET00071366}, {MET00071367}, {MET00071368}, {MET00071369}, {MET00071370}) as recorded at {MET00071346} trace the route of the cable labelled 'fan'.

11.2.75 Mr Stokes, Rydon, and Allied Protection have not provided photographs of the loose cable in the roof plant room to which they referred. Accordingly, I cannot confirm that the above photographs, taken after the fire, are of the same loose cable.

11.2.76 It is possible that the loose cable was installed but later deemed unnecessary because the new damper below the roof extract fan set was not installed.

11.2.77 In my view, given that the loose cable was not connected to either the control panel or a damper, it would not affect the smoke extract system as the controls did not feature a feedback system and so would not register a fault.

11.3 Removal of interface between smoke control panel and landlord gas supply shut off

11.3.1 **Scope of my investigation**

11.3.2 In my Phase 1 Appendix J report {BLAS0000031}, I presented evidence to the effect that, on activation, the smoke control system was not sending a signal to the refurbishment BMS to turn off the boilers and landlord gas supply {MET00018569}.

11.3.3 In this section, I present further evidence on the interface between the smoke control system and the BMS.

11.3.4 I present my investigation into an interface created between the refurbishment smoke control system and an existing solenoid valve in the basement which automatically shut off the landlord gas supply.

11.3.5 The purpose of my investigation is to understand whether the interface and its subsequent removal could have negatively impacted the operating potential of the smoke control system.

11.3.6 I have investigated the basic function of the interface and considered how and when it was installed and removed.

11.3.7 I have taken advice from a senior controls expert in Arup, Mr Darren Wright, to help me understand certain aspects of the BMS system. This has enabled me to form a view on the resulting performance of the smoke control system.

11.3.8 The additional evidence I have received in Phase 2 includes:

a) The Building Manual provided by Rydon to KCTMO ({TMOM00000001} to {TMOM00002199}); and

b) Evidence from Direct Control Systems who designed, installed and commissioned the refurbishment BMS System ({DCS00000001} to {DCS00000091}).

11.3.9 **Gas supplies to Grenfell Tower and automatic shut-off equipment**

11.3.10 In Appendix K of my Phase 1 report {BLAS0000032}, I have set out my observations of the gas supplies to Grenfell Tower made during my site inspections in addition to descriptions of the gas supplies provided by Cadent {CAD00000004}.

11.3.11 There were three gas supplies to Grenfell Tower: a single landlord gas supply to the heating and hot water plant in the basement and two domestic gas supplies.

11.3.12 The landlord gas supply was contained within the basement only. The two domestic supplies entered the building through the basement and supplied the flats on Levels 4 - 23 of Grenfell Tower.

11.3.13 I observed a solenoid valve which had been fitted to the landlord gas supply in the basement. A solenoid valve can be used to shut off the gas supply automatically.

11.3.14 Previously, in Figure K.3 of {BLAS0000032}. I indicated where I observed the landlord gas supply and solenoid valve during my inspection of the basement and I have reproduced that figure here in Figure 11-7:.

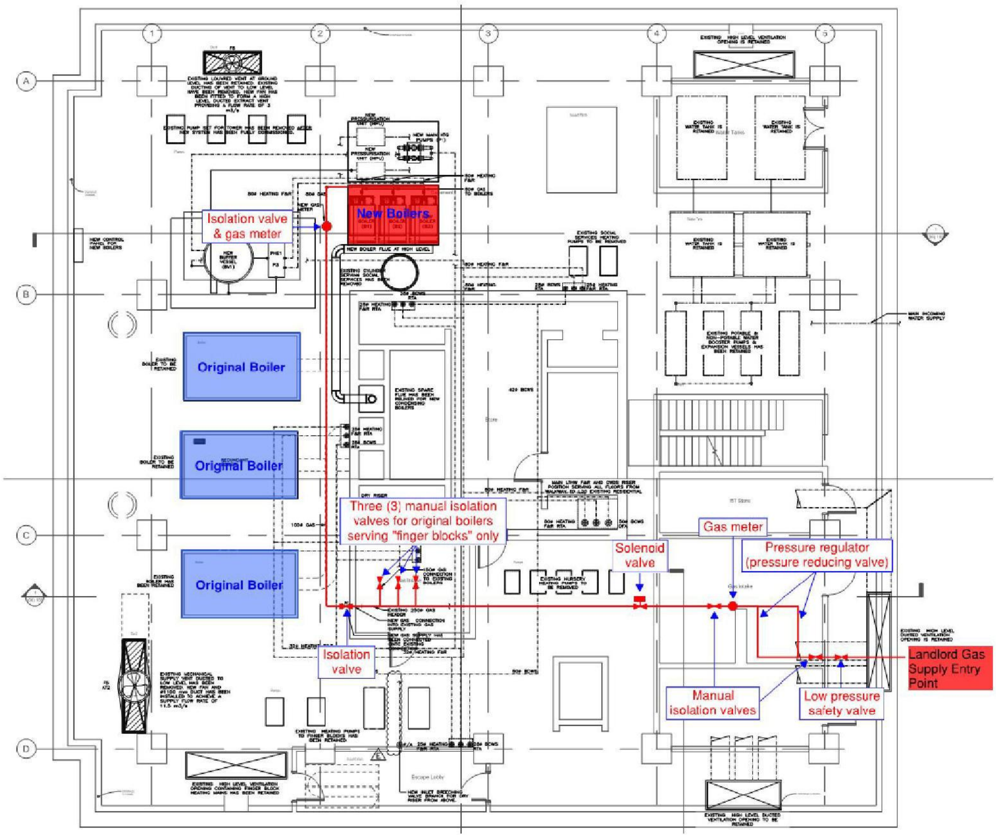


Figure 11-7: Figure K.3 Landlord system in basement of Grenfell Tower from {BLAS0000032}

11.3.15 During the refurbishment, new boilers were installed in the basement to supply heating and hot water to Grenfell Tower.

11.3.16 Existing boilers were retained. These supplied the adjacent finger blocks.

11.3.17 Both sets of boilers were connected to the single landlord gas supply. The solenoid valve I observed was located upstream of both the existing and new boilers.

11.3.18 **Pre-refurbishment interface with the landlord gas supply solenoid valve**

11.3.19 From WSP's Grenfell Tower *Building Management System Review for Metropolitan Police* {MET00018469}, I understand that the landlord gas supply solenoid valve existed prior to the refurbishment works. On page 12, the WSP report states:

this allowed us to identify the electrical connections to the gas solenoid valve and the associated safety circuit within the old MCC (for which no drawings or documentation have been found so far).

11.3.20 I read *"old MCC"* to mean the Motor Control Centre panel of the existing BMS system.

11.3.21 There is no record of an interface between either the pre-refurbishment smoke control system or basement detection system, and the landlord gas supply, in any of the four fire risk assessments carried out by Mr Stokes prior to the start of the primary refurbishment works ({CST00000334}, {CST00000447}, {TMO00831859} and {CST00000092}). Please refer to Chapter 8 of my Module 3 report for my assessment of the adequacy of Mr Stokes's fire risk assessments {BLARP20000027}.

11.3.22 No other evidence is available to me regarding the presence or otherwise of an interface between the pre-refurbishment smoke control system and the landlord gas shut off before the primary refurbishment works.

11.3.23 **Specification for interface between smoke control system and landlord gas shut-off**

11.3.24 I have investigated whether any design documents prepared for the primary refurbishment, specify an interface between the smoke control system and the gas shut-off for the basement landlord gas supply.

11.3.25 There is no specification for an interface of the landlord gas shut-off with the smoke control system in Max Fordham's *Employer's Requirements for MEP Services* document dated 28th November 2013 {MAX00006475}.

11.3.26 Nor is there any such specification in the Exova Outline Fire Safety Strategy Issue 3 dated 7th November 2013 {EXO00001106} or in any other tender documentation for the primary refurbishment.

11.3.27 As I explained in my separate Phase 2 report *The Fire Safety Engineer Report (Version 2 - updated 22 October 2020)* {BLARP20000017}, I have not found any advice from Exova on the requirement for an interface with the landlord gas supply solenoid valve or any system of fire detection in Grenfell Tower as part of the fire strategy development for the primary refurbishment.

11.3.28 I have only found evidence of Exova providing advice to KCTMO on this requirement *after* the primary refurbishment which I set out in Section 11.3.78 below.

11.3.29 **Evidence of installation of an interface between the smoke control system and landlord gas shut off during the primary refurbishment**

11.3.30 I have found no evidence of a specification for an interface between the smoke control system and landlord gas shut-off in any revisions of PSB's Technical Submission.

11.3.31 The earliest reference I have found to an interface being provided between the refurbishment smoke control system and the landlord gas shut-off is in a document produced by Direct Control Systems in August 2015, *"CONTROL SYSTEM DESCRIPTION OF OPERATION GRENFELL TOWER"* (attachment to {JSW00002408}).

11.3.32 Direct Control Systems were a subcontractor of JS Wright's, appointed to design, install and commission the new BMS (Building Management System) in the basement {DCS00000020}:

Description of works to be carried out (include any drawing numbers and specification references)
Design, installation and commissioning including working and record drawings and O&M manualfor the BMS system controls and wiring to all new basement plant including main panel, LTHW pressurisation units gas circuit and valve, 3 No boilers and shunt pumps, htg pumps, disconnection of existing htg pumps, social services cylinder and pumps, new heat meters to risers, picking up gas and water meter in basement and new plate heat exchanger. Panel to roof plant room montoring cold water boosterand h/l & l/l tank alarms. Lobby general extract fan including panel and connections to fire alarm panel allTechnically as you quotation attached dated 27th May 2015. JSW T & C's apply

Figure 11-8: Excerpt from {DCS00000020}

11.3.33 This document (attached to {JSW00002408}) describes the existing controls conditions for the gas shut-off and the interface of the gas valve with the 'building fire alarm system':

GAS SAFETY CIRCUIT

In the event [that] *any of the thermal links positioned above each boiler or the associated emergency knock-off buttons* [is] *operated, or the existing gas safety circuit operates, or the natural gas detector monitors a gas leak, the existing gas valve will close and shutdown the new and existing boiler plant.*

A visual alarm will be raised on the control panel fascia. The alarm will be relayed to the outstation and displayed on the touch screen

The gas valve is also interlocked with the building fire alarm system.

11.3.34 The description of the gas safety circuit is identical in 'Issue 2' of the *Control system description of operation Grenfell Tower* dated 24th September 2015 (attached to {JSW00003416}).

11.3.35 The description of the gas safety circuit was updated in the final issue, Issue 3 of *Control system description of operation Grenfell Tower* dated 14th March 2016 {DCS00000059}:

GAS SAFETY CIRCUIT

The gas solenoid valve remains energized provided all the following interlocks are established:

(i) Fire alarm system

(ii) New Boiler thermal links (3 off)

(iii) New emergency stop buttons (3 off)

(iv) Gas detection sensor (healthy state)

(v) Existing plantroom safety devices (vi) Supply fan air differential pressure switches

(vii)Extract fan air differential pressure switches

Upon the interlock being normalized the gas valve re-opens automatically.

A visual alarm will be raised on the control panel fascia. The alarm will be relayed to the outstation and displayed on the touch screen

11.3.36 This means that the gas supply remains open provided none of the items (i) to (vii) are activated.

11.3.37 This document is dated 15th March 2016, one day before the final commissioning date for the BMS system as recorded by DCS {DCS00000070}.

11.3.38 A report of Max Fordham's 'BMS Witnessing' dated 23rd March 2016 records that the smoke control system was observed to be interfaced with the boiler shut down {TMO00832139}:

1.6	Fire alarm – A fire alarm was simulated at the AOV panel and the boilers were shown to shutdown on this signal.

3.2	No representative from TMO / Cofely in attendance. The system will have to be demonstrated again to ensure that the TMO / Cofely have an adequate understanding of it for maintenance purposes.

Figure 11-9: Excerpt from {TMO00832139}

11.3.39 From Max Fordham's records it is not clear if it was the existing boilers and landlord gas supply were shut down. However, the subsequent fire risk assessment by Mr Stokes and correspondence from Ms Williams indicate that the existing boilers and landlord gas supply did indeed shut down but in addition to the new boilers also.

11.3.40 On 26th April 2016, Mr Stokes advised against interfacing the gas supply with the smoke control system ('the AOV system') in the 'significant findings and action plan' for his risk assessment {CST00000451}:

ITEM	PRIORITY	IDENTIFIED RISK or HAZARD	ACTIONS TO BE TAKEN	BY WHOM	DATE TO BE COMPLETED BY
17b	High	It appears that the mains gas supply to this building is interfaced with the automatic opening ventilation system and shuts off if the AOV system operates, the lifts could also be interfaced.	I would strongly recommend that the gas supply system in this building is NOT interfaced with the AOV system. Can it be confirmed if any other system are interfaced with the AOV system? If so which systems? I would also say that no systems should be interfaced with the AOV systems.		

Figure 11-10: Excerpt from Mr Stokes April 2016 significant findings and action plan {CST00000451}

11.3.41 The next day, Ms Williams (KCTMO) asked Mr Hughes (Rydon) why the gas had been shut off (Mr Hughes's reply in bold) {TMO10045024}

2 Where did the disconnection of the gas main come into the fire strategy? Was it part of Exova's recommendation, or was this in the Max Fordham specification? ***We've followed Max Fordhams specification which would have used the outline fire strategy as guidance. Matt should be able to confirm this***

11.3.42 Mr Cross Smith (Max Fordham) stated that the requirement for the interface was based on advice from Exova {TMO10045024}:

Yes, the shutdown of the boilers was based on advice at the time by Exova. Due to the issues of the old boilers not always firing up successfully on shutdown, this has been revisited by Exova. They have advised - over the 'phone, so you may want to get it in writing - that the boilers could be disconnected from the main smoke extract system and connected to the standalone system in the basement as an alternative

11.3.43 In response, Mr Hughes (Rydon) advised KCTMO and Max Fordham that any changes would need to be made as a formal request {TMO10045024}:

Matt, If a change is required at this stage we need to formalise this request.

11.3.44 I understand this to mean that it would need to be considered as a formal design change.

11.3.45 On 3rd May 2016, Ms Williams (KCTMO) instructed Max Fordham to prepare a specification for a standalone fire alarm system for the basement of Grenfell Tower (bold by me) {MAX00006238}.

Just to confirm what you are scoping for Grenfell, ***as discussed some of these items will not go to Rydon****:*

1 bulk heat meter as required to meet the Heat Networks Directive: Your contact at Wilson Energy is Andy Wilkinson director/techie on 01636 857240. I think I gave you his email last week.

2 spec for standalone alarm to the basement of Grenfell, so that the new smoke detection system does not turn off the gas boilers serving approx. 500 homes.

3 NEW –Could you perhaps put a cost on this before you spec it, so the RBKC officers can approve it? The requirement is for connecting the nursery to the existing smoke detection system with autodialler going to Tunstall/LFB.

I hope this is ok, the top one has been outstanding a while, and the second one is needed soonest.

The nursery requirement is a late requirement from the borough, so if I can have the price first, this will be something for the borough to ok before we commit.

11.3.46 On 6th May 2016, the Tunstall auto-dialler unit was commissioned (please see Section 8). Tunstall have exhibited the protocol which KCTMO provided them in the event of an alarm. I note the second call included an instruction to call out a boiler engineer:

2ND Call Estate Services on [redacted] this phone is always diverted to an on call caretaker.(if no anwer leave a message for them, explained them that the fire Panel has gone off and that they need to reset the smoke detection system). IF NO REPLY GO TO 3RD STEP AND ASK THEM TO GET HOLD OF THE ON CALL CARETAKER TO ATTEND. AS WELL AS ASKING BOILER ENGINEERS TO ATTEND.

Figure 11-11: Excerpt from {THL00000001}

11.3.47 From paragraph 152 of the witness statement of Alan Whyte (JS Wright) ({JSW00001892}) I understand that the existing boilers could not automatically restart once they had been shut down:

"the old boilers had to be manually re-set by a maintenance contractor, whereas this was not necessary to re-set the new boilers."

11.3.48 Therefore, automatic shutdown of the existing boilers on activation of the lobby smoke control system required that a maintenance contractor be called out to re-start them.

11.3.49 Max Fordham provided a *'Basement Fire Alarm Specification Rev*'* dated 12th May 2016 to KCTMO {CST00000110}. This set out a specification for a standalone automatic fire detection and alarm system for the basement plant room. It provided as follows:

In the event of the system being activated, the boilers shall be shut down via the existing interface with the BMS system. In addition to this, it shall also be connected to the Tunstall Auodialler to provide notification to the building owner that the system has been activated.

...

Provide volt-free contacts/interface units to all ancillary systems requiring an interface with the fire alarm, whether described in this document or specified elsewhere in the tender documentation. Including but not limited to the following:

- BMS to enable activation of gas safety shut off valve

- BMS to shut down boilers.

- BMS to shut down ventilation system.

- Tunstall Autodialler

11.3.50 It appears that this specification was intended to replace the interface between the refurbishment smoke control system and the existing landlord gas shut-off by means of a new automatic detection system serving the basement only, and this detection system solely interfaced with the gas shut off.

11.3.51 Therefore, an automatic gas shut-off would still be provided. However, this would only be activated by the automatic detection system in the basement where the boilers and gas supply were located.

11.3.52 No shut down would be caused by detection of smoke in any of the lobbies above ground floor at Grenfell Tower.

11.3.53 On 20th May 2016, Ms Williams forwarded this specification to KCTMO's Health Safety and Facilities Manager, Ms Wray; KCTMO's Head of Contracts, Mr Bosman; and KCTMO's fire risk assessor, Mr Stokes {CST00000109} (bold be me):

Dear all

Resume

1 spec to be reviewed

2 which contractor to price/install

I attach the Max Fordham specification for a new standalone fire alarm to Grenfell basement. ***This means we can disconnect it from the main building smoke detection system – which turns off the gas boilers serving approx. 500 homes if there is a smoke alert.***

It assumes a sounder system, with a control panel at the top of the basement stairs for re-setting.

Does anyone have any views on this, the monitoring etc? Should it be connected to Tunstall /LFB – via another phone line or whatever?

If everyone feeds back comments, then we can get this moving. ***I do not want this to go to Rydon because it would be deemed a late instruction under the contract.*** *So, the other issue is as to who should price for this work, and also allocating a budget.*

11.3.54 It would appear then that KCTMO did not intend for Rydon to carry out these works because it would be considered a late instruction in their contract. Again, Ms Williams confirms that the work is required to replace the interface between the refurbishment smoke control system, the existing landlord gas supply, and the existing boilers and new boilers created by the refurbishment.

11.3.55 I have not seen a response from Ms Wray or Mr Bosman. However, Mr Stokes responded on 23rd May 2016 advising that he did not consider the

basement boilers or any other equipment was required to be interfaced with the smoke control system {CST00000109}:

As far as the boilers being interfaced with the AOV smoke detection this was not a requirement and was not mentioned before installation, my view is that the only equipment that should be interfaced with the AOV detectors is the AOV system.

11.3.56 In the significant findings and action plan for his risk assessment on 20th June 2016 Mr Stokes again repeated his recommendation that the gas supply should not be interfaced with the smoke control system (please see 11.3.39) {CST00000101}.

11.3.57 In KCTMO's 'fire risk assessment action tracker' {TMO10017386}, this action was never recorded as closed. The action taken is recorded as *"Specification to separate main smoke system from basement with gas boilers is in production, with works due to take place this financial year."*

11.3.58 On 23rd June 2016, Mr Stokes raised this issue again in a discussion with Ms Wray regarding Adair Tower {CST00002207} (bold by me):

Please also see the attached e mails regarding the to be fitted fire alarm system in Grenfell boiler room because this will have an impact on the removal of Adair's and the one at Lancaster West.

Claire has said that a new fire alarm is to be fitted because of the fire strategy report, so if one is needed in Grenfell, one is needed in Adair and elsewhere?

I cannot say remove the Adair one, detection and call points when the TMO are fitting a new system in another building, authorised by a TMO survey and as part of a fire strategy document according to Claire.

Please advise if the Grenfell boiler room fire alarm system is being installed as per the Max Fordham spec dated the 12th May 2016?

11.3.59 From Mr Stokes's email, I understand that KCTMO's proposal to install an automatic detection system in the plant room of Grenfell Tower was inconsistent with its decision to remove detection from plant rooms in other KCTMO-managed buildings for which he undertook fire risk assessments.

11.3.60 I have seen no evidence of further discussion within KCTMO on whether to instruct Max Fordham's *'Basement Fire Alarm Specification Rev*'* to be carried out prior to hand over of the refurbishment works on 4th July 2016 {ART00006689}.

11.3.61 The Building Manual that Rydon provided to KCTMO contained the following description of the gas shut down interface {TMOM00001744}:

GAS SAFETY CIRCUIT:
In the event of any of the thermal links positioned above each boiler or the associated emergency knock-off buttons are operated, or the existing gas safety circuit operates or the natural gas detector monitors a gas leak, the existing main incoming gas valve will close and shutdown the new and existing boiler plant.

A visual alarm will be raised on the control panel fascia. The alarm will be relayed to the outstation and displayed on the touch screen

The gas valve is also interlocked with the building fire alarm system.

Figure 11-12: Excerpt from Rydon's Building Manual {TMOM00001744}

11.3.62 This is identical to the description provided in Direct Control System's *Control system description of operation Grenfell Tower* Issues 1 and 2 (attached to {JSW00002408} and {JSW00003416} respectively).

11.3.63 **Operation of the gas shut-off interface installed during the primary refurbishment**

11.3.64 In this section I set out my understanding of how this interface was installed during the primary refurbishment. I have done this in order to assess whether subsequent works to remove the interface may have affected the operation of the lobby smoke control system.

11.3.65 From my team's analysis of the DCS panel drawings for the refurbishment BMS {TMOM00001806}, PSB's Master Smoke Control Panel drawings {PSB00000267} and the WSP's BMS Report {MET00018469} I have been unable to identify the precise means by which the refurbishment smoke control system was intended to shut down the landlord gas supply.

11.3.66 In Figure 11-13: I have illustrated my team's analysis of the relevant interfaces between the refurbishment smoke control system, the refurbishment BMS system and the existing BMS system, at practical completion of the refurbishment works in July 2016.

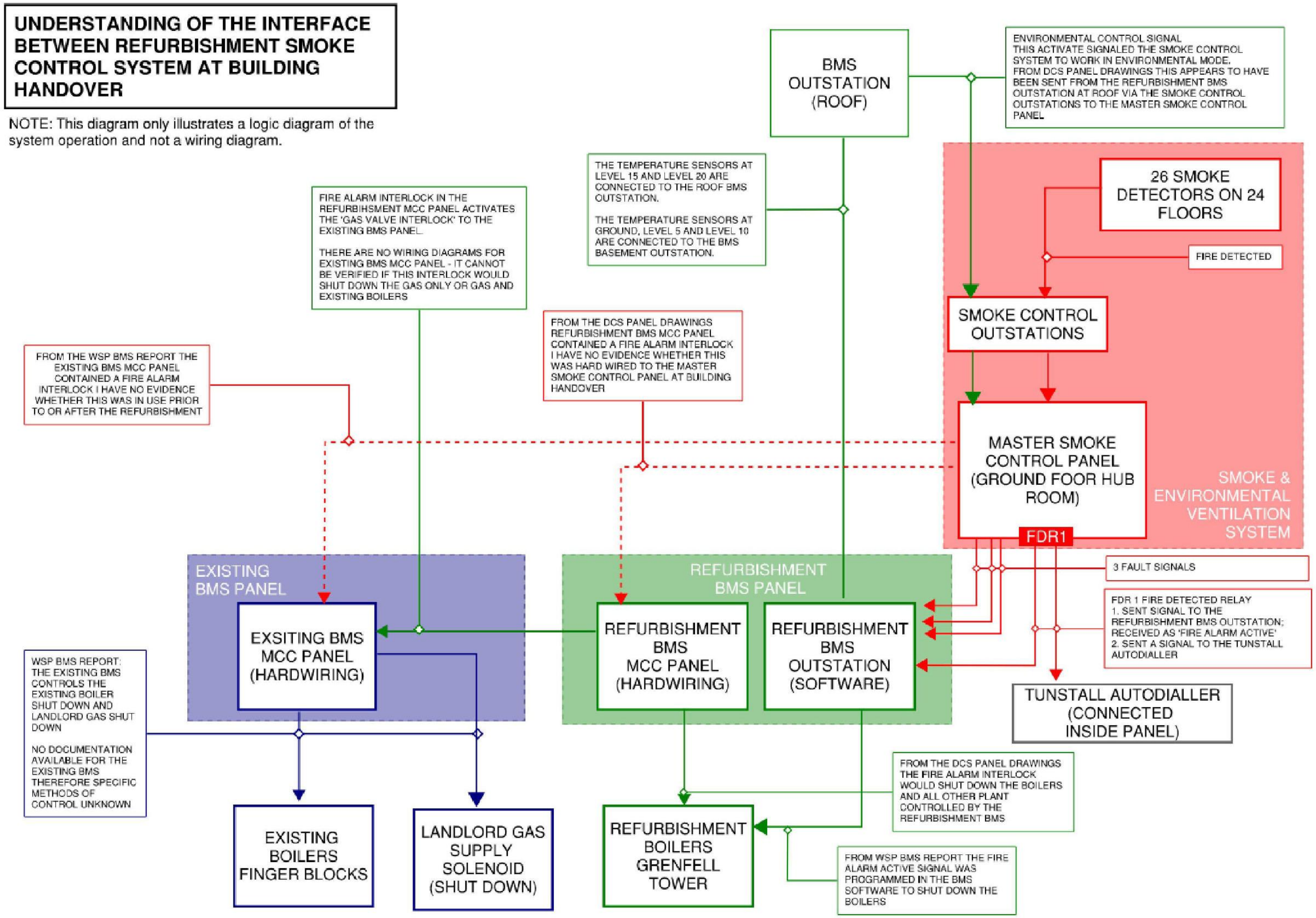


Figure 11-13: Illustration of the means by which the refurbishment lobby smoke control system may have been interfaced with the boiler and landlord gas supply shut-off during the primary refurbishment

11.3.67 In the event of a smoke detector activation in the lobbies of Grenfell Tower, a signal was sent to the Master Smoke Control Panel in the hub room at ground floor activating a fire-detected relay.

11.3.68 This sent a signal to the refurbishment BMS system in the basement. The refurbishment BMS system software was programmed to shut down the refurbishment boilers upon receipt of a fire alarm activated signal from the Master Smoke Control Panel.

11.3.69 There were no software controls in the new basement BMS panel for shutdown of the existing landlord gas supply or the existing boilers located in the basement.

11.3.70 The refurbishment BMS system also contained contacts for a fire alarm interlock which is a hardwired control to:

a) shut down all plants controlled by the refurbishment BMS system (this included the refurbishment boilers but not the existing landlord gas supply or existing boilers); and

b) activate a 'gas valve interlock' which is a hard-wired control to shut down the landlord gas supply via the existing BMS system. (This may have also caused the existing boilers to shut down but there is no documentation available for the existing BMS System to verify this.)

11.3.71 The panel drawings produced by DCS for the refurbishment BMS system are not coordinated with the drawings produced by PSB for the refurbishment smoke control system. Therefore, it cannot be determined from the drawings in the Building Manual whether the fire alarm interlock described above for the refurbishment BMS system was wired in when the building was handed over.

11.3.72 A coordinated set of drawings should have been provided by Rydon. The refurbishment smoke control system was a life safety system and therefore all interfaces with other systems should have been clearly documented. I have set out the requirement to provide fire safety information in my separate Phase 2 report *Regulation 38 Fire Safety Information* (Version 2 Updated 23 October 2020) {BLARP20000021}.

11.3.73 Based on WSP's BMS Report {MET00018469}, the existing BMS system also contained a fire alarm interlock. No documentation is available for the existing BMS so its precise controls are not known. Therefore, I cannot independently confirm whether the existing BMS system would have been able to activate shut down of the existing boilers and the existing landlord gas supply.

11.3.74 It could not, however, have shut down the refurbishment boilers as no control was apparently provided between the existing BMS and refurbishment BMS to do so. The panel drawings for the refurbishment BMS only show an

incoming gas valve status signal from the existing BMS system {DCS00000068}.

11.3.75 I am unable therefore to tell from the as-built refurbishment BMS and smoke control documentation whether either or both of the refurbishment BMS or existing BMS fire alarm interlocks were wired in at the time of building handover, but post-fire inspections found both not to be in use (please see 11.3.98).

11.3.76 Accordingly, KCTMO could not rely on the documentation in the Building Manual to determine how the fire safety and gas safety systems were interfaced within their building. This was unacceptable and would affect KCTMO's ability to safely maintain the systems and carry out any future works.

11.3.77 In the following section I set out the evidence of when and how KCTMO requested that the interface between the refurbished smoke control system and the existing landlord gas supply shut-off be removed.

11.3.78 **Request from KCTMO to remove the interface between the smoke control system and the landlord gas supply shut off**

11.3.79 Following handover Mr Stokes asked whether the works were to progress (see emails dated 8th August 2016 and 29th September {CST00002207} and 29th {CST00002158} respectively).

11.3.80 An e-mail of 30th September 2016, from Mr Bosman, Head of Contracts at KCTMO, indicates that they had not yet resolved the issue:

Thanks for looking into this; once you've spoken to Max Fordham and pulled all available information together can you agree the best contact at Exova with Janice and lead on the discussion with them to gain either agreement the boiler room does not require detection or alternatively details of why detection would be recommended so these can be reviewed by Carl and allow further challenge/discussion. As discussed we are keen to get this resolved as it is impacting on other sites please provide an update in two weeks.

11.3.81 On 24th November 2016 Ms Williams contacted Cate Cooney (Exova) {EXO00001421} regarding the requirement for a gas shutdown; on 6th December 2016 Ms Williams e-mailed Ms Cooney to record their discussion {EXO00001422} (bold by me):

I explained that Grenfell Tower is 23 storeys high, and has a basement containing communal boilers. Currently the smoke detection system covers all residential floors and the basement. Recently a resident having a 'crafty fag' in a communal lobby set off the smoke detection system which in turn cut off the gas to the basement boilers. As these boilers serve approx. 500 households, this was a problem and we had to call out heating contractors to get the boilers restarted when we checked the building was safe. Your feedback was:

1 ***As the basement is a separate compartment from the main building, with a concrete slab floor and a separate entrance, there is no regulation requiring a fire alarm system.***

2 ***However, as building manager, it would be prudent for us to install an external sounder or similar to alert people to any fire.*** *Our basement contains communal gas boilers serving approximately 500 households, - so the risk of explosion is more important than fire. If I have misconstrued anything, please let me know. Can you please just respond to confirm the above is accurate?*

11.3.82 Ms Cooney confirmed as follows:

It about covers our conversation. I wouldn't agree that explosion is more important than fire; both are highly undesirable, however, we can only advise on the fire requirements

11.3.83 On 7th December 2016, Ms Williams requested agreement from Ms Wray and Mr Bosman to proceed with the replacement of the interface between the refurbishment smoke control system and the landlord gas shut off with an interface to a new basement detection system:

I don't know if I have covered all bases, but the response from Cate should give us some reassurance. On this basis, am I ok to get Ernest Raw in our team to procure the new alarm on the basis of the attached specification from Max Fordham ? In the specification it talks about visual alarms and sounders, as well as being attached to the autodialler to Tunstall. Can you both look at this to see whether we need to discuss how we manage this, and see if we need to refine the performance specification

11.3.84 I have seen no response from Ms Wray or Mr Bosman to Ms Williams's request.

11.3.85 It would appear that between January and April 2017 KCTMO asked Rydon and JS Wright to disconnect the refurbishment smoke control system interface with the landlord gas shut-off. I have not seen any evidence, however, that they asked Rydon or JS Wright to replace the interface with a new basement detection system.

11.3.86 On 4th January 2017, Ms Williams asked Rydon to explain how the refurbishment smoke control system could be disconnected from the basement gas shut-off {JSW00006063} (bold by me):

4 Meanwhile, the only thing I did not establish, and am hoping you can get from JSW – is ***how we would disconnect the smoke detection system from the basement, when we have the new system in the basement****. Can you ask them for the logical option, in a couple of paragraphs,* ***so this can be included in the scope of the new alarm system****?*

11.3.87 I have seen no further evidence of KCTMO amending Max Fordham's *'Basement Fire Alarm Specification Rev*'* or instructing any party to install a new fire detection and alarm system in the basement of Grenfell Tower.

11.3.88 On 4th January 2017, following KCTMO's request, JS Wright asked Direct Control Systems for advice on how to go about disconnecting and also what approvals might be required {JSW00006063}:

> *Could I get your advise* [sic] *on the query below please. The KCTMO, our clients, client to disconnect the interface with the smoke ventilation system and the new install at Grenfell.* ***To my understanding the smoke vent sends a critical fault to your panel when activated, would it be as simple as disconnecting the cables??*** *Dave I do recall the interface was part of the signed of strategy,* ***would this have to go back to the author of the Fire Strategy/ Building Control for approval?*** *For your info there is an interface with the old system as we have shared knock of buttons, gas detectors, supply/extract fans and gas solenoid, so if there is an issue with these components both new and old boiler plant shuts down*

11.3.89 On 15th February 2017, Ms Williams again sought Ms Wray's agreement to proceed with disconnecting the refurbishment smoke control system from the BMS systems in the basement and replacing it with a new standalone automatic detection system in the basement {TMO00861642}:

> *I sent you an email a while ago saying that there is no statutory need for a basement fire alarm system, but Exova said it would be prudent as building manager.*
>
> *Ernest as procurement manager is progressing getting this installation tendered.*
>
> *Can you please confirm if you are happy for me to get the basement disconnected from the main building now? I think that there are 2 pressing reasons for this – firstly we are not testing the building fire alarm weekly as this will disconnect the old boilers, and secondly we are having problems with the basement fans – so anything we can do to make the basement 'standalone' would be useful.*

11.3.90 I have seen no response to Ms Williams's request for agreement by Ms Wray.

11.3.91 On 23rd March 2017, Rydon requested a quote from JS Wright for carrying out the disconnection (attached to {DCS00000082}).

11.3.92 On 24th March 2017, Direct Control Systems provided a quote for disconnecting the interface between the refurbishment smoke control system and the refurbishment BMS, requesting confirmation that the works had been approved by building control {DCS00000081}:

> *Hi Alan,* ***Our costs to attend site and disconnect the fire alarm input into the BMS from the smoke panel is £240.00****. We have availability on Tuesday next week to carry out these works but before we attend we would like a description of what you asking us to do in writing on official paperwork.* ***Please also confirm that the works your requesting us to do have been approved by building control***

11.3.93 On 27th March 2017, JS Wright e-mailed Direct Control Systems, specifying the interface which KCTMO wanted to be removed {DCS00000082}:

Please see attached from our client. Below is a screen shot from a PSB drawing the installers of the smoke vent system. ***I do believe the BMS send them a signal to activate the environment side of there system, this will need to remain in place. Under activation of the smoke extract system, a signal is sent to the BMS panel which activates the safety circuit and shuts down the gas valve, this is what the KCTMO would like removed.*** *I have advised them that it would be a go* [sic] *idea to maintain the current set-up were in the event of a fire gas to the building is shut down, you will see from the attached they still want to go ahead. Thanks for the offer to go down tomorrow, this will be a little too soon as we need acceptance of cost from Rydon before we give you the nod.*

11.3.94 An e-mail from Ms Williams to Rydon on 11th April 2017 {TMO10046998} indicates that the works had not yet been carried out:

Please confirm whether the sub-contractor still needs something from building control. I confirm I have already sent to you, and as attached:

1 Exova – our fire strategy consultants' view, that the alarm is not required under regulations but is something the landlord may want to consider as good practice

2 Max Fordham – our M&E consultants – their specification for putting in a separate fire alarm to the basement, which confirms that it does not need to be linked to the main system otherwise their professional indemnity would not let them consider a separate system

3 Carl Stokes – KCTMO's Fire Risk Assessor – has asked if we can disconnect the AOV from the basement boilers, as the attachment called 'significant findings' attached.

Is this adequate? If not, then please give me the contact details for the building regulations officier [sic] *you were dealing with – but they are notoriously slow at putting things in writing!*

11.3.95 I have found no further evidence of Rydon, JS Wright or Direct Control Systems removing the interface between the refurbishment smoke control system and the landlord gas supply shut off.

11.3.96 I have found no evidence of KCTMO instructing any other party to carry this out.

11.3.97 However, in the following sections, I set out the evidence that the refurbishment smoke control system was indeed disconnected from the landlord gas supply shut off.

11.3.98 **Evidence the interface between the smoke control system and the gas shut off had been removed**

11.3.99 During my site inspection described in Section 16 of my Phase 1 report {BLAS0000016} I observed a manual detection system only. Therefore, the automatic detection system specified by Max Fordham had not been installed in the basement of Grenfell Tower.

11.3.100 Following the fire, WSP carried out a review of the BMS System.

11.3.101 Their BMS Report {MET00018469} indicated that the *"the fire alarm shut down facility on the new MCC panel (terminals 10/11) was found to be linked out"*

11.3.102 I read *'linked out'* to mean that there was a 'dummy' piece of wire connected between two terminals to prevent a failsafe action from occurring when a connection has been deliberately removed. This is supported by a photograph from Appendix 1 of WSP's BMS report (p.16, {MET00018469}) which shows the wire linking the two numbered terminals 10 and 11.

11.3.103 The *"new MCC panel"* refers to the refurbishment BMS system in the basement.

11.3.104 It would appear, therefore, that WSP found that the refurbishment BMS system in the basement could not signal the shutdown of the landlord gas supply when it received a fire detected signal from the refurbishment smoke control system.

11.3.105 WSP's BMS Report {MET00018469} also states *"It was established that the fire alarm shut down facility on the old panel was also linked out"*.

11.3.106 Accordingly, WSP found no facility for the existing BMS to shut down the landlord gas supply either in the event of a fire detection.

11.3.107 WSP's BMS Report {MET00018469} also found, in relation to both the refurbishment BMS System and the existing BMS system, that no fire alarm appeared to have been installed.

11.3.108 I understand a 'fire alarm interface' to be a device fitted for use with the fire alarm interlock. I therefore understand that the absence of a fire alarm interface could indicate that the fire alarm interlock on either BMS was never wired.

11.3.109 If this had been the case, the refurbishment smoke control system could not have shut down the landlord gas supply or the existing boilers to the adjacent finger blocks. It was only able to shut down the refurbishment boilers' BMS software.

11.3.110 In Figure 11-14: I have illustrated the interfaces that were observed to be in place between the refurbishment smoke control system, the refurbishment BMS system and the existing BMS system following the fire on 14th June 2017 in WSP's BMS Report {MET00018469}.

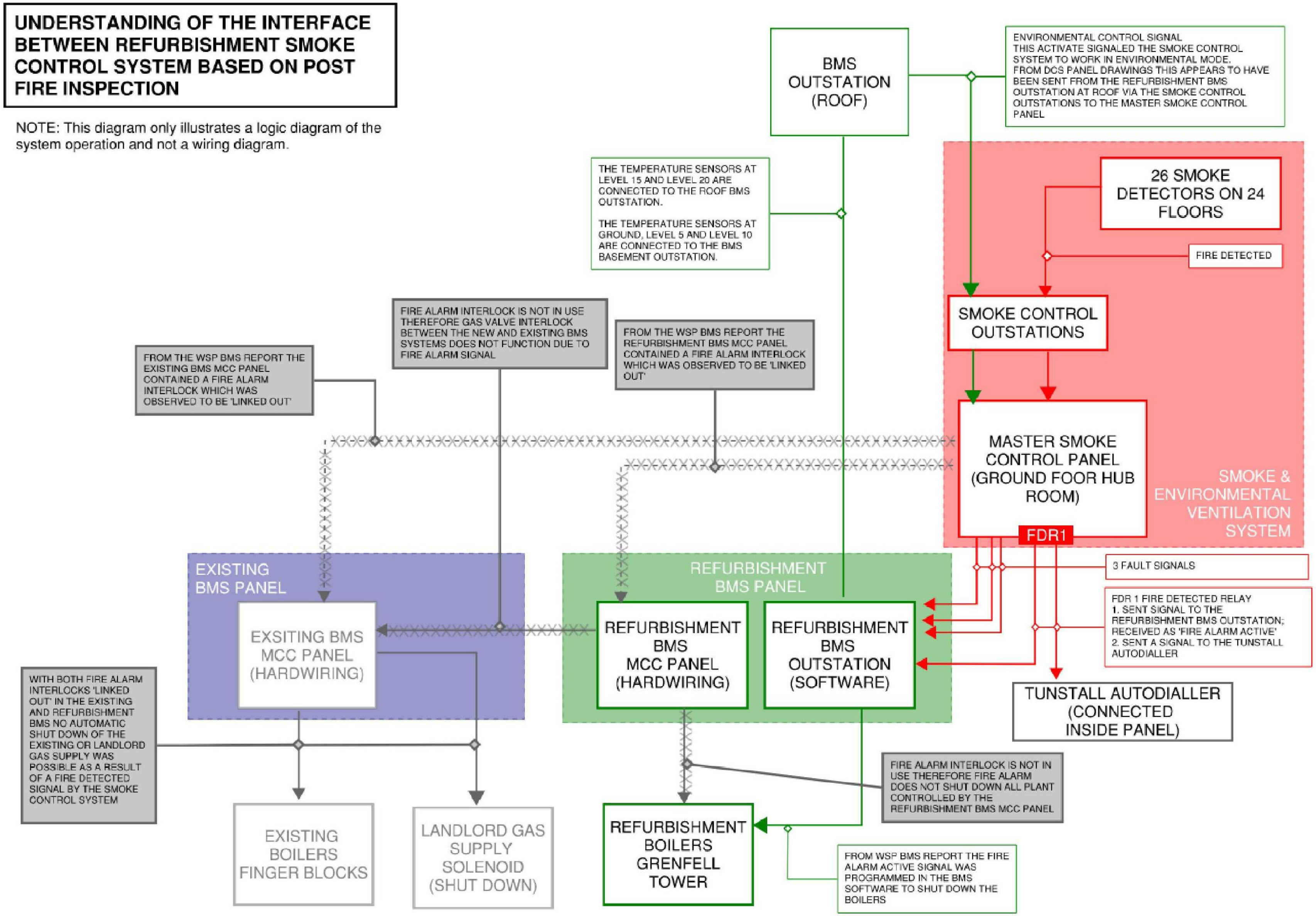


Figure 11-14: Illustration of interfaces between the refurbishment smoke control system and the landlord gas supply shut at 14th June 2017

11.3.111 Due to the lack of clarity in the documentation for the refurbishment BMS and refurbishment smoke control system, I have not been able to compare the construction at handover with that after the 14th June 2017 in order to identify what changes were made to the system.

11.3.112 Mr Whyte (JS Wright) states in his first witness statement {JSW00001892}:

I can say that I did not authorise, approve or otherwise arrange for this gas supply to be isolated from the fire safety system. As far as I am aware nobody in JSW did so either and, as far as I am aware, the gas supply to the boilers was never isolated from the fire safety system.

11.3.113 This would mean at the time of practical completion, and at the time of the fire, the activation of the smoke control system could cause shut down of the refurbishment boilers only, via software controls in the refurbishment BMS system in the basement.

11.3.114 The post-fire evidence presented by WSP is that no fire alarm interface appears to have been fitted to either BMS system{MET00018469}. Therefore, it appears there was no functioning hardwired interlock to shut down the new or the existing boilers, or the landlord gas supply valve.

11.3.115 This would seem to indicate the activation of the smoke control system could not have caused shutdown of the existing boilers and the existing landlord gas supply.

11.3.116 This evidence conflicts with evidence from the time, where it was reported by Ms Williams that the smoke control system would *"turn off the gas boilers serving approx. 500 homes."* {MAX00006185}. The evidence from the time also indicates that KCTMO included call out of their maintenance contractor, Engie, to restart the existing boilers when a smoke detector was activated (see Section 9.2.78, above).

11.3.117 This conflict of evidence could be explained by the following scenarios:

a) The fire alarm interlock to one or both of the BMS systems was removed including the fire interface unit, by an unknown party, after practical completion;

b) The fire alarm interlock to one or both of the BMS systems was wired in without a fire interface unit, which I understand would not be normal practice;

c) The evidence of Ms Williams and Alex Bosman was incorrect and it was the heating in Grenfell Tower only that was being shut down when the refurbishment smoke control system activated.

11.3.118 Ultimately I have been unable to confirm exactly what was disconnected, on the old or new BMS system, and if it could impact the lobby smoke control system.

11.3.119 Requirement to re-commission if the interface from the basement BMS to the refurbishment smoke control system was removed

11.3.120 If, after practical completion, the KCTMO instructed any party to disconnect the interface between the refurbishment smoke control system and the refurbishment BMS, a test of the refurbishment smoke control system was then required. This test was required to check the system's operation in smoke mode from the three possible states the system could be in at the time of a fire:

a) Environmental mode operating

b) Environmental mode standby (from 09:00 to 20:00)

c) Environmental mode off (from 20:00 to 09:00)

11.3.121 I believe this was required due to:

a) The complexity of the interface, which comprised three different systems: the existing BMS, the refurbishment BMS, and the environmental and smoke control system;

b) The lack of commissioning records held by any party confirming the operation of smoke mode when the system was in all three states; and

c) The lack of documentation for the existing BMS system which controlled the landlord gas supply shut off.

11.3.122 It would have been a simple exercise to undertake an operational test of the lobby ventilation system to demonstrate it could operate in smoke mode from all of the three possible states.

11.3.123 In addition to the lack of records, I cannot find any records in the evidence disclosed to me regarding how, when, and by whom the gas shut off interface was disconnected.

11.3.124 As stated in the PSB commissioning report {PSB00000224} the interaction between the ventilation system and *"other interfaced systems"* was tested.

Interfaces	Installed	Tested
Check the interaction between the ventilation system and all other interfaced systems	yes	yes
Ensure that all systems respond in the appropriate manner	yes	yes

Figure 11-15 Excerpt from PSB commissioning Report {PSB00000224}

11.3.125 There are no records of any operational tests of the smoke control system being repeated following the disconnection of the gas shut off interface.

11.3.126 I would also have expected to see recorded evidence of an assessment by a competent person that any proposed changes did not impact the smoke control

functions required, before actions were taken to remove the gas shut off interface. No such evidence has been disclosed to me to date.

11.3.127 The BMS system, as intended, was designed to send a direct signal to the lobby smoke control system via the connection from the BMS roof outstation, to the Level 23 outstation.

11.3.128 The Level 23 outstation was the outstation connected to the smoke control system (please see green arrow in Figure 11-14). This signal to the Level 23 outstation was needed in order to activate the system in environmental mode.

11.3.129 How the changes to the BMS system in the basement, affected the BMS panel on the roof, to which it was connected, remain unknown. It should have had no effect.

11.4 Requirements for maintenance of the refurbishment smoke control system

11.4.1 In Appendix J of my Phase 1 report, I stated {BLAS0000031}:

"J8.12.6 In Phase 2 I will provide my opinion on the documentation provided to the regulatory authorities, and the documentation provide to the responsible person."

11.4.2 In this Section I review the adequacy of the maintenance information provided by Rydon to KCTMO for the refurbishment lobby smoke control system.

11.4.3 I have first included the minimum performance standard for maintenance which I derived from the relevant British Standards in Chapter 7 of my Module 3 report {BLARP20000033}.

11.4.4 I then present the planned maintenance schedule from Rydon and the PSB Operation and Maintenance Manual and Technical Submission– see Section 11.4.8.

11.4.5 In Section 11.4.25 I then present my analysis of the manufacturers' literature contained within the Building Manual relevant to the smoke control system.

11.4.6 **Minimum performance standard for the maintenance of the smoke control system derived from the relevant British Standards**

11.4.7 In Section 5.9.108 of Chapter 7 {BLARP20000033} in my Module 3 report, I set out the following performance standard for maintenance based on the guidance in BS EN 12101-6:2005, BS 5839-1:2013 and BS 9999:2008:

From the guidance above, the minimum performance standard for maintenance of the smoke control system at Grenfell Tower is:

a) Daily inspection of the smoke control system panel to check if any faults are being reported by the system. This can be carried out by suitably trained KCTMO staff;

b) *Weekly - activation of the smoke control system, activating the system using a different detector head each time; ensure that the fans and powered exhaust ventilators operate correctly, smoke dampers close (or open in some systems); contact alarm receiving centre before, and immediately after, test to ensure that unwanted alarms are avoided and that fire alarm signals are correctly received; ;visual inspection of any batteries. This can be carried out by suitably trained KCTMO staff;*

c) *Monthly – in addition to the weekly checks, simulate failure of the primary power supply to ensure that the system has switched to the secondary supply; test zero airflow condition shall be simulated (i.e. simulate failure of duty fans) and a check made that the stand-by fans are running. This can be carried out by suitably trained KCTMO staff;*

d) *Quarterly - All zones should be separately tested and it should be ensured that any fans and powered exhaust ventilators operate correctly, smoke dampers close (or open in some systems). This can be carried out by suitably trained KCTMO staff;*

e) *Six monthly – Inspection and test of the fire detection system following the procedure recorded in Clause 45.3 of BS 5839-1:2013 undertaken by a competent fire alarm and detection specialist; and*

f) *Annual - Inspection and test of the fire detection system following the procedure recorded in Clause 45.4 of BS 5839-1:2013 undertaken by a competent fire alarm and detection specialist; test of entire pressure differential system in accordance with the manufacturer's recommendation and the acceptance tests for pressure differential; net pressure differential; air velocity; and door opening force described in Section 12.2 of BS EN 12101-6:2005.*

11.4.8 **Maintenance information for the smoke control system provided in Rydon's Building Manual – planned maintenance schedule**

11.4.9 Rydon planned maintenance schedule

11.4.10 On 8th August 2016 David Hughes of Rydon sent Ms Williams (KCTMO) a spreadsheet titled 'Grenfell Tower – Planned Maintenance Schedule' {TMO00869784}. The planned maintenance schedule was included in the Building Manual as Section 1.2.2 *Maintenance Schedule* {TMOM00000003}.

11.4.11 I have reproduced the maintenance for the smoke control system in Figure 11-16 below.

	A	K	L
3	Plant item	Fire Detection System	Ductwork & Dampers
4	Manufacturer		Croydon Ductwork
5–6	General Comments	It is essential for the safety of the occupants of a building that fire safety equipment is inspected frequently (BS9999)	
7–8		Monitoring call centre should be notified prior to any testing to ensure fire brigade do not attend in false alarm scenario	
9	Daily Checks		
10		Check control panel indicates normal operation	
11			
12			
13–14	Weekly Checks	The complete system should be checked weekly by deliberately simulating smoke in a lobby	
15		check extract fans work correctly	
16			
17			
18			
19			
20	Monthly Checks		
21		check secondary supply system works correctly	
22			
23–24	Quarterly Checks	all zones should be seperately tested icluding main lobbies, boxing club and community room	
25			
26	Bi-annual Checks		Check access doors for air tightness
27			Inspect fire dampers for obstructions
28	Annual Checks		Check flange bolts & tight and duct supports are not distorted
29			Check air volume and fan pressure
30			Ensure loads are not imposed not imposed on plant
31			Manual control dampers

Figure 11-16: Excerpt from Grenfell Tower – Planned Maintenance Schedule {TMOM00000003} as relate to the smoke control system

11.4.12 The planned maintenance schedule provides a complete description of one of the six periodic recommended inspections only. The daily inspections include the recommended daily checks only, as per the minimum performance standard presented in Section 11.4.7 above.

11.4.13 The planned maintenance schedule provides an incomplete description of five of the six periodic recommended inspections only. These are the weekly, monthly and quarterly checks, as per the minimum performance standard presented in Section 11.4.7 above. Specifically, the following information is missing:

a) Weekly – the schedule does not record that a different detector should be activated each time, there is no mention of visual inspection of dampers, and no reference to visual inspection of batteries;

b) Monthly – there is no record of any check of simulating duty fan failure to ensure that the stand-by fans are operational;

c) Quarterly – no record of a check to ensure that fans operate correctly and that dampers open/close as required;

d) Six monthly – no mention that fire detection should be inspected and tested following the procedure in Clause 45.3 of BS 5839-1:2013;

e) Annual – no reference to a test of the entire smoke control system in accordance with the manufacturer's recommendations and the acceptance tests, or to the inspection and test of a fire detection system in accordance with Clause 45.4 of BS 5839-1:2013.

11.4.14 <u>PSB Operation and Maintenance Manual and PSB Technical Submission</u>

11.4.15 The Building Manual contained a document by PSB titled "*Operating and maintenance instructions for the above ground smoke ventilation system at Grenfell Tower apartments, London*" {TMOM00001763}.

11.4.16 However, the PSB O&M Manual did not contain specific guidance regarding any maintenance and instead referenced separate manufacturers' literature within the Building Manual. (See Section 11.4.25 below for my analysis of the inclusion of manufacturers' maintenance requirements included in the Building Manual for the smoke control system.)

11.4.17 Revision 1 of the PSB Technical Submission {TMOM00001764} was also included in the Building Manual and contained general guidance from Annex V of BS 9999:2008 pertaining to maintenance.

11.4.18 Section 4 of the PSB Technical Submission (Revision 1, {TMOM00001764}) outlines the *Testing and Maintenance Schedule* and states in Section 4.1:

4.0 Testing and Maintenance Schedule

4.1 Maintenance Statement

It is a requirement under the Regulatory Reform Order of 2005 that a person shall be responsible for the maintenance of the smoke control system and this has to be tested and maintained in accordance with the schedules contained in BS9999 as detailed below in the extracts for the mechanical smoke control system and associated smoke detection. It is also necessary to carry out maintenance in accordance with manufacturers recommendations for each component.

Figure 11-17: Excerpt from {TMOM00001764}

11.4.19 Section 4.2 of the PSB Technical Submission {TMOM00001764} provides text excerpted from Annex V *Routine inspection and maintenance of fire safety installations* from BS 9999:2008 relevant to smoke control systems. The text appears to have been pasted directly form BS 9999:2008, therefore I have not excerpted it here.

11.4.20 As I have set out in Chapter 7 of my Module 3 report {BLARP20000033}, I derived the minimum performance standard for the smoke control system from the guidance in BS 9999:2008,BS EN 12101-6:2005, and BS 5839-1:2013 for smoke detection.

11.4.21 The maintenance requirements in the PSB Technical Submission {TMOM00001764} consider the guidance from BS 9999:2008 only.

11.4.22 The daily and quarterly inspections in the planned maintenance schedule presented in the PSB Technical Submission {TMOM00001764} meet the recommended minimum performance standard presented in Section 11.4.7 above for the daily checks only.

11.4.23 The PSB Technical Submission did not detail the following checks required for the minimum performance standard set out in Section 11.4.7 above:

a) Weekly – there is no reference to activation of the smoke control system using a different detector;

b) Monthly – there are no details regarding simulation of power failure to ensure that the system has switched to secondary power supply, nor for simulation of duty fan failure to check for changeover to the stand-by fan;

c) Six monthly – the PSB Technical Submission indicates that arrangements for inspections and tests of the fire detection by competent persons should be made, but it does not reference the standard to be followed (i.e. BS 5839-1, Clause 45.3); and

d) Annually – the PSB Technical Submission says that arrangements for inspection and testing for fire detection and smoke control systems by competent persons should be made, but it does not reference the standards to be followed (i.e. BS 5839-1 and BS EN 121016).

11.4.24 Therefore, from my analysis above, the Building Manual did not provide an adequate planned maintenance schedule for any of the equipment making up the smoke control system.

11.4.25 **Maintenance information for the smoke control system provided in Rydon's Building Manual – manufacturer's requirements**

11.4.26 In addition to the planned maintenance schedule presented above, I have extracted the recommended manufacturer's maintenance instructions for the specific components installed in Grenfell Tower.

11.4.27 Part 3, Section 1.2 of the Building Manual was titled *'Smoke Ventilation System O&M Manual'* {TMOM00000001}; this folder contained the PSB O&M manual "*Operating and maintenance instructions for the above ground smoke ventilation system at Grenfell Tower apartments, London*" {TMOM00001763}.

11.4.28 Regarding maintenance, the document states (bold by me):

The attached documents listed in Section 4.0 – Equipment Specification above are designed to give sufficient information for the servicing of manufacturer's /supplier's equipment.

Please ensure that regular maintenance is carried out on every item listed as failure to do so could cause serious damage and may invalidate warranty claims.

The system provided requires little maintenance during normal operation

11.4.29 The information for the servicing of the smoke control equipment was instead included in the Building Manual at Part 3, Section 1, Sub-section 1.1, 9 *Manufacturers Literature*, 11 *AOV* ({TMOM00001763} to {TMOM00001792}).

11.4.30 In Figure 11-18 I have shown the smoke control equipment included:

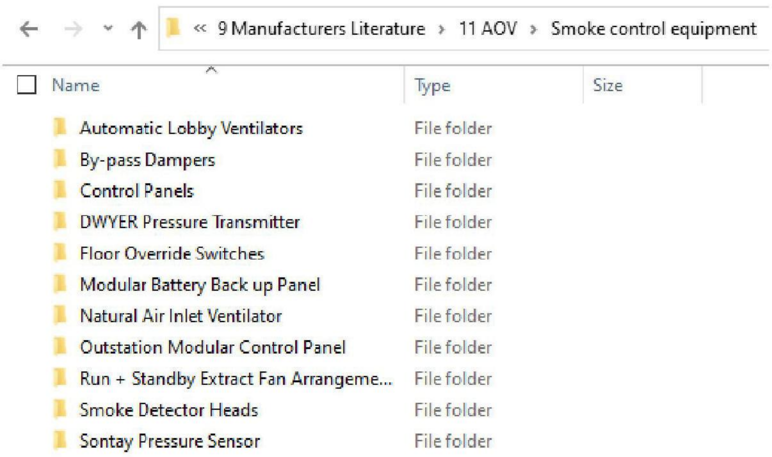


Figure 11-18: Building Manual structure for smoke control system manufacturer's literature

11.4.31 I found further relevant manufacturers' information for the smoke detection in another section of the Building Manual at Part 3 Section 2 'Electrical O&M Manual'({TMOM00001863} to {TMOM00001924}).

11.4.32 And finally, relevant manufacturers information for the auto-dialler in another section at Part 3, Section 4 'Tunstall Information' ({TMOM00001925} to {TMOM00001927}).

11.4.33 Therefore, manufacturers' literature for the equipment which formed the smoke control system was in three separate locations within the Building Manual provided to KCTMO ({TMOM00000001} to {TMOM00002199}) as follows:

a) Part 3, Section 1, Sub-section 1.1, 9 Manufacturers Literature, 11 AOV ({TMOM00001763} to {TMOM00001792});

b) Part 3, Section 2 'Electrical O&M Manual' ({TMOM00001863} to {TMOM00001924}); and

c) Part 3, Section 4 'Tunstall Information' for the Tunstall auto-dialler ({TMOM00001925} to {TMOM00001927}).

11.4.34 In Table 11-1 below I have presented the relevant information from the manufacturer's literature for the relevant components from the Mechanical Services O&M Manual.

11.4.35 In Section 11.4.42 I then present the manufacturers' literature from the Electrical O&M Manual, and in Section 11.4.51 for the Tunstall auto-dialler.

11.4.36 <u>Part 3, Section 1.1 '*Mechanical Services O&M Manual*'</u>

11.4.37 The Building Manual comprised 11 separate folders for different components of the lobby smoke control system. Of these 11 folders, three did not contain any manufacturer's literature. Further, two of the components (the Natural Air Inlet Ventilator and the Dwyer Pressure Transmitter) were not installed at Grenfell Tower.

11.4.38 For the remaining eight folders relevant to Grenfell Tower, five contained general manufacturers' literature, but only three contained information relevant to maintenance.

11.4.39 I also note that the following items, all of which were recorded on PSB's Electrical Schematic {TMOM00001888} as not being part of PSB's scope, were not included in the folder above either: shaft ductwork/plenum, power supply auto changeover, and cabling (power and control).

11.4.40 For the shaft ductwork/plenum, the relevant manufacturer's information should have been provided by Rydon. Additionally, RJ Electric were responsible for the installation of the power supply auto changeover and cabling (power and control) – see Section 11.4.42.

11.4.41 In Table 11-1 I have provided a summary of the components installed at Grenfell Tower, indicating whether the manufacturers' literature for each component was provided.

Table 11-1: Manufacturer's recommended maintenance activities from the literature provided in Part 3, Section 1 of the Rydon Building Manual {TMOM00001763} to {TMOM00001792}

Component as described by folder name in Building Manual	Manufacturer's literature in Building Manual	Product name	Evidence installed in Grenfell Tower	Manufacturer's recommended maintenance activities
Automatic lobby ventilators [Gilberts Series 54 dampers]	{TMOM00001765}, {TMOM00001766}	Series 54 Smoke Evacuation Damper	Yes	None recorded.
By-pass dampers [BSB]	{TMOM00001769}, {TMOM00001770}	SC Series Elevated Temperature Smoke Control Damper	Yes	*Maintenance:* *1. Keep the damper clean and free from any contamination.* *2. Where possible, operate the blades against airflow to ensure easy, free movement.* *3. Periodic inspection should be made the damper, to ensure efficient operation of all ancillary components.* *4. It is recommended within normal preventative maintenance procedures for the blades and inner casings to be cleaned annually, as well as inspection of Linkages, Actuators and the Thermal Device.* *5. Use of heavy oils is not recommended, due to the possible build up of dust.* *6. It is recommended to check regularly the operation Actuators to ensure correct operation.* *7. The time period can be ascertained by experience or local regulations, but should not exceed a twelve month interval. Inspection should be carried out more frequently where excessive dust or dirty conditions prevail.* {TMOM00001769}
Control panels	No documents provided in manual	PSB Right Choice Control panel PSB Right Choice Smart Control panel [Fan starter control panel]	Master smoke control panel installed in Hub Room at Ground level {MET00065879} One fan control panel at ground and one control panel at roof	-
Dwyer pressure transmitter [I understand this product was not installed at Grenfell Tower];	{TMOM00001773} {TMOM00001774} {TMOM00001775}	Series MS Magnesense Differential Pressure Transmitter	No. Sontay PA-604-90 installed	{TMOM00001773}, {TMOM00001774}: *Annual recalibration is suggested. No lubrication or other periodic servicing is required. Keep exterior and cover clean. Occasionally disconnect pressure lines to vent both sides of gauge to atmosphere and re-zero. Do not use solvent to clean transmitter. Use only plastic compatible cleaners or water.* *The Series MS is not field serviceable and should be returned if repair is needed (field repair should not be attempted and may void warranty). Be sure to include a brief description of the problem plus any relevant application notes. Contact customer service to receive a return goods authorization number before shipping.*
Floor override switches	{TMOM00001778}	KAC Class 9000 key switch	No	Not recorded.
Modular battery back up panel;	No documents provided in manual		Yes	-
Natural air inlet ventilator	-	Powrmatic OSR louvred smoke ventilator	Not installed at Grenfell Tower existing penthouse vent retained.	-
Outstation modular control panel	No documents provided in manual	PSB Right Choice Outstation Panel	Yes	-
Run + Standby extract fan arrangement	{TMOM00001787}	Elta SmokeVent SLCS	Yes	None recorded.
Smoke detector heads	{TMOM00001789} {TMOM00001790}	Apollo XP95	Apollo Series 65	None recorded.
Sontay pressure sensor [I understand a different version of the Sontay pressure switch was installed at Grenfell Tower.]	{TMOM00001792}	Sontay PA-DPS-8X Air differentail[sic] Switch	No. Sontay PA-604-90	None recorded.

11.4.42 Part 3, Section 2 'Electrical O&M Manual'

11.4.43 The Electrical O&M manual was provided in Part 3, Section 2 of the Building Manual ({TMOM00001863} to {TMOM00001924}).

11.4.44 RJE were the electrical sub-contractors appointed to JSW (Paragraph 22, {JSW00001957}).

11.4.45 RJE describe their scope of works for the smoke control system in the Building Manual as {TMOM00001865}:

1. To install the smoke detection & control elements of the building's main smoke extract system. Control equipment such as control panels, fire override switches and pressure switches have been supplied by specialists PSB. Smoke detector units have been provided as part of the electrical contract.

2. To supply and install a 'standby' life safety power supply from the adjacent Grenfell Walk building to ensure secondary power supplies should the primary Grenfell Tower supply suffer a failure.

3. Supply and install fire rated power supplies to PSB system equipment in accordance with PSB requirements.

4. Supply and install 2 no monitored smoke vent systems to serve the Boxing Club and Community Centre main entrance lobbies.

11.4.46 Within the Electrical O&M manual, a document titled 'Grenfell Tower Fire Alarm O&M' {TMOM00001887} was located in the folder 'S3. Fire Alarm & Smoke vent'.

11.4.47 The Fire Alarm O&M document included installation certificates for the Nursery fire alarm, a manufacturer's brochure for a fire alarm panel (which did not form part of the smoke control system), and manufacturer's literature for smoke detector heads.

11.4.48 The contents of the Fire Alarm O&M manual do not record the maintenance requirements for the smoke detection system associated with the lobby smoke control system.

11.4.49 Nor does the product sheet for the Apollo Series 65 detector heads which were installed in the lift lobbies {TMOM00001872} and referenced in the RJE Equipment Schedule {TMOM00001867}.

11.4.50 The Electrical O&M Manual also included manufacturer's literature for the 'Informa Speech Dialler' {TMOM00001886}. However, this item was replaced by the Tunstall auto-dialler (see Section 9.2).

11.4.51 Part 3, Section 4 'Tunstall Information'

11.4.52 Part 3, Section 4 of the Building Manual '*Tunstall Information*' contained three documents; one visit report for the installation of the auto-dialler {TMOM00001927} and two documents for the auto-dialler unit: (Installation Guide {TMOM00001925} and User Guide {TMOM00001926}).

11.4.53 Regarding maintenance of the auto-dialler unit, the Installation Guide states that {TMOM00001925}:

The unit contains no user serviceable parts. The Lifeline home unit battery should be replaced immediately upon receipt of a battery failure alarm or after 5 years.

In order to replace the battery, firstly disconnect the telephone line from the home unit and then unplug the mains power adaptor. Then remove the battery cover and replace the battery. Once replaced, reconnect the power and telephone line.

If features requiring the date and time are being used please check the date and time programmed into the unit.

For any maintenance or issues please contact your service provider.

11.4.54 Therefore, the battery for the auto-dialler was the only item which required maintenance, according to the manufacturers' literature.

11.4.55 <u>Components of the smoke control system for which manufacturers' maintenance instructions were provided in the Rydon Building Manual</u>

11.4.56 In Table 11-2 below, I have provided a summary of my analysis of the information within the Building Manual Rydon provided to KCTMO.

11.4.57 For each of the 15 components of the smoke control system I set out in Section 7.2, I have set out whether the Building Manual contained any manufacturers' information for the correct product installed and whether that information set out the maintenance requirements of the product.

Table 11-2: Summary of components detailed in the Building Manual, those installed at Grenfell Tower, and if manufacturer specific maintenance was available from the Building Manual

List of components installed in Grenfell Tower	Product installed in Grenfell tower	Manufacturers literature for installed product provided	Maintenance instructions provided in literature
Lobby dampers	Gilberts 54 Series 54 Smoke Evacuation Damper	Yes {TMOM00001765}, {TMOM00001766}	No
By-pass dampers	SC Series Elevated Temperature Smoke Control Damper	Yes {TMOM00001769}, {TMOM00001770}	Yes
Main control panel	PSB Right Choice Control panel	None	No
Inverter control panel	PSB Right Choice Smart Control panel	None	No
HMI panel	PSB Right Choice mimic HMI panel	None	No
Floor override switches	KAC K21SYS-11	No Literature provided for different product (KAC Class 9000 key switch)	No
Modular battery back up panel;	PSB Right Choice Battery Backup Panel	None	No
Permanent vent at head of stair	Existing penthouse vent	No Literature provided for a product which was not installed (Powrmatic OSR louvred smoke ventilator)	No
Outstation modular control panel	PSB Right Choice Outstation Panel	None	No
Run + Standby extract fan arrangement	Elta SmokeVent SLCS	Yes {TMOM00001787}	No
Smoke detector heads	Apollo Series 65	Yes - Apollo Series 65 {TMOM00001872} However, there was also information for Apollo XP95 but no evidence installed ({TMOM00001789}, {TMOM00001790}).	No
Pressure switch	Sontay PA-604-90 installed pressure switch	No Manufacturers literature for two products which were not installed at Grenfell Tower were included in Building Manual (Sontay PA-DPS-8X Air differentail[sic] Switch and Dwyer Series MS Magnesense Differential Pressure Transmitter)	No
Automatic opening vents (Boxing Club and Community Room lobbies)	Specific product installed not known.	No	No
Automatic changeover unit for fan power supply	Switchgear Systems Ltd Automatic Transfer switch	No	No
Auto-dialler (Lifeline VI)	Lifeline Vi	Yes – Lifeline Vi {TMOM00001925}, {TMOM00001926} However, literature for Informa Speech Dialler which was not installed also provided {TMOM00001886}	Yes

11.4.58 **Summary**

11.4.59 From my analysis, the Rydon Planned Maintenance Schedule and the PSB Planned Maintenance Schedule did not meet the required minimum performance standards, as derived from the relevant British Standards (BS EN 12101-6:2006, BS 9999: 2008, and BS 5839-1:2013).

11.4.60 There were 15 components installed at Grenfell Tower for the lobby smoke control system. Manufacturers' literature was provided for just five of the installed components.

11.4.61 Further, of the five components for which manufacturers' literature was provided, only two gave specific instructions for maintenance: the Tunstall Auto-dialler and the SC Series Dampers, which were installed in the Level 2 ductwork.

11.4.62 The building manual also included manufacturers' literature for five products which were not installed at Grenfell Tower.

11.4.63 Therefore, almost no manufacturers' maintenance requirements for any of the equipment in the smoke control system was provided.

11.4.64 From my review of the maintenance information contained in the Building Manual provided to KCTMO, I therefore find the information provided was inadequate for the purposes of developing an appropriate programme of maintenance.

11.5 Tunstall Call Log

11.5.1 In this section I present the evidence available to me of the operation of the Tunstall Lifeline Vi auto-dialler installed at Grenfell Tower by Tunstall.

11.5.2 Tunstall stated in their response to the Inquiry that Tunstall had an existing contract *"to provide social alarm monitoring services throughout the Borough"* which included *"a monitoring service in relation to two residents at Grenfell Tower"* {THL00000015}.

11.5.3 The monitoring service for the "*Lifeline unit connected to the smoke vent system*" was added to this existing contract {THL00000015}.

11.5.4 In Appendix J of my Phase 1 report, I detailed matters to be revisited as part of my Phase 2 investigations regarding the operation of the auto-dialler. I have presented these below:

Table 11-3: Matters outlined in my Phase 1 report to be revisited during Phase 2

Relevant section from Appendix J {BLAS0000031}
J7.3.2 PSB signed a completion certificate on the 3rd May 2016 that stated that the Grenfell Tower smoke control system was "fully operational, in line with the agreed specification. ". The autodialler was connected to the smoke control panel on the 4th May 2016, and therefore any activations of the system after that date should have been recorded by Tunstall. ***I have not been provided with call log events between the 4th May 2016, when the autodialler was installed, and the first entry in the log supplied in THL00000002 on the 4th October 2016.***

Relevant section from Appendix J {BLAS0000031}
J7.3.5 The majority of calls prior to 1410612017 were listed as 'Smoke Detector' events. Six calls were listed as 'Outgoing call'. ***It is not clear to me at this time what an outgoing call is, but these calls all occur in association with activations for smoke which are not listed as 'Fire Test Warden', or 'Test Engineer I Warden'. I intend to investigate this further in Phase 2.***
J7.3.8 The last activation prior to 14 June 2017 occurred on Friday 9th June 2017, and was noted in the call log as 'Test Engineer/Warden'.   *J7.3.9* ***I do not, at this stage, have information on what that test consisted of I will deal with maintenance in full in Phase 2.***

11.5.5 Tunstall have provided to the Inquiry a document titled *Q5a Call history form commissioning date* {THL00000019} – with the first entry recorded on 6th May 2016 and the last entry on 16th June 2017.

11.5.6 The first entry on 6th May 2016 corresponds with the reprogramming of the auto-dialler by Tunstall (see Section 9.2).

11.5.7 I have structured this section as follows:

a) Section 11.5.8 - Overview of entries in Tunstall log before the night of the fire;

b) Section 11.5.20 - Entries in Tunstall log understood to be the result of KCTMO ESA (Estate Services Assistant) checks;

c) Section 11.5.39 - Entries in Tunstall log understood to be the result of planned maintenance; and

d) Section 11.5.50 – Entries in Tunstall log which do not align with the evidence of KCTMO ESA checks or planned maintenance by Allied Protection.

11.5.8 **Entries in auto-dialler log before the fire (6th May 2016 to 9th June 2017)**

11.5.9 The auto-dialler log provided to the Inquiry by Tunstall records entries between 6th May 2016 and 9th June 2017 prior to the fire. There are no entries shown from 10th June 2017 to 13th June 2017.

11.5.10 I have presented the Tunstall call history {THL00000019} below:

Q5A

Call History from Commissioning Date

Requested by PGRAY — Calls History — 15 October 2018 16:01:52

Arrival Time	Scheme	Unit	Event	Reason
06/05/2016 13:24:47		540009001	Integral button	Test Call
05/07/2016 15:09:57		540009001	Smoke Detector	Fire Service Called
04/10/2016 19:38:13		540009001	Smoke Detector	Fire Service Called
04/10/2016 19:48:54		540009001	Outgoing call	Warden Called
09/10/2016 21:21:29		540009001	Smoke Detector	System Information Call
09/10/2016 21:22:23		540009001	Outgoing call	Check Resident
09/10/2016 21:24:40		540009001	Outgoing call	Warden Called
02/11/2016 10:14:06		540009001	Smoke Detector	Fire Test Warden
09/12/2016 15:54:37		540009001	Smoke Detector	Fire Service Called
09/12/2016 15:58:02		540009001	Outgoing call	Contact Requested
20/01/2017 10:59:04		540009001	Smoke Detector	Fire Test Warden
27/01/2017 10:22:02		540009001	Smoke Detector	Fire Test Warden
03/02/2017 10:24:01		540009001	Smoke Detector	Fire Test Warden
03/02/2017 10:28:14		540009001	Smoke Detector	Fire Test Warden
10/02/2017 10:11:49		540009001	Smoke Detector	Fire Test Warden
17/02/2017 09:21:24		540009001	Smoke Detector	Fire Test Warden
24/02/2017 10:13:59		540009001	Smoke Detector	Test warden
03/03/2017 10:05:35		540009001	Smoke Detector	Fire Test Warden
10/03/2017 10:06:00		540009001	Smoke Detector	Fire Test Warden
24/03/2017 09:55:18		540009001	Smoke Detector	Fire Test Warden
31/03/2017 09:59:59		540009001	Smoke Detector	Fire Test Warden
07/04/2017 10:10:39		540009001	Smoke Detector	Test Engineer/warden
21/04/2017 10:47:59		540009001	Smoke Detector	Test Engineer/warden
28/04/2017 10:09:46		540009001	Smoke Detector	System Information Call
05/05/2017 10:33:58		540009001	Smoke Detector	Test Engineer/warden
15/05/2017 13:47:23		540009001	Smoke Detector	Fire Service Called
15/05/2017 13:54:06		540009001	Smoke Detector	Test Engineer/warden
15/05/2017 14:04:26		540009001	Outgoing call	Warden Called
15/05/2017 14:06:22		540009001	Smoke Detector	Test Engineer/warden
15/05/2017 14:15:27		540009001	Smoke Detector	Reassurance Required
15/05/2017 14:20:02		540009001	Smoke Detector	Reassurance Required
15/05/2017 14:23:52		540009001	Smoke Detector	Reassurance Required
15/05/2017 14:27:09		540009001	Smoke Detector	Reassurance Required
15/05/2017 14:29:14		540009001	Smoke Detector	Reassurance Required
15/05/2017 14:32:32		540009001	Smoke Detector	Reassurance Required
15/05/2017 14:35:00		540009001	Smoke Detector	System Information Call
15/05/2017 14:37:47		540009001	Smoke Detector	System Information Call
15/05/2017 14:42:11		540009001	Smoke Detector	Reassurance Required
15/05/2017 14:45:44		540009001	Smoke Detector	Reassurance Required
15/05/2017 14:47:36		540009001	Smoke Detector	Reassurance Required
15/05/2017 14:51:09		540009001	Smoke Detector	System Information Call
15/05/2017 14:53:48		540009001	Smoke Detector	Reassurance Required
15/05/2017 14:56:01		540009001	Smoke Detector	System Information Call
15/05/2017 14:57:32		540009001	Smoke Detector	Reassurance Required
15/05/2017 15:00:37		540009001	Smoke Detector	Reassurance Required
15/05/2017 15:02:12		540009001	Smoke Detector	Reassurance Required
16/05/2017 17:35:05		540009001	Smoke Detector	Fire Service Called
16/05/2017 17:49:06		540009001	Outgoing call	Contact Requested
19/05/2017 09:53:14		540009001	Smoke Detector	Test Engineer/warden
02/06/2017 10:08:42		540009001	Smoke Detector	Test Engineer/warden
09/06/2017 10:21:43		540009001	Smoke Detector	Test Engineer/warden
14/06/2017 00:55:01		540009001	Smoke Detector	Fire Service Called
14/06/2017 01:04:20		540009001	Outgoing call	Contact Requested
14/06/2017 04:13:32		540009001	Outgoing call	Check Resident

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Requested by PGRAY — Calls History — 15 October 2018 16:01:52

15/06/2017 12:47:27	540009001	Mains Failure	Background Call
15/06/2017 16:51:33	540009001	Mains Failure	Background Call
15/06/2017 21:12:40	540009001	Alarm call failed	System Information Call
15/06/2017 21:14:27	540009001	Mains Failure	Background Call
15/06/2017 21:14:32	540009001	Outgoing call	Contact Requested
16/06/2017 00:48:28	540009001	Mains Failure	Background Call

Figure 11-19: *Q5A Call History from Commissioning Date* {THL00000019} showing auto-dialler call log from 6th May 2016 to 16th June 2017.

11.5.11 From Figure 11-19, there were a total of 60 recorded events on the Tunstall call history log {THL00000019}; 6 occurred after 14th June 2017, and therefore after the fire. I have not included those six events in my analysis.

11.5.12 The Tunstall call history {THL00000019} provides a description of the type of 'Event' and 'Reason' for that event, referring to a specific unit.

11.5.13 The calls were relevant to unit 540009001 which is *"an ID for the fire panel"* for Grenfell Tower, as Claire Williams and Janice Wray were told by Alexandra Vaughan on 25th February 2016 {ART00005660}. A separate file showing an earlier part of that email exchange indicates that Ms Vaughan was the CAS (Community Alarm Service) Manager at KCTMO {JSW00002369}.

11.5.14 In his witness statement, Mr Steadman (ESA for Grenfell Tower) stated that he would ring Tunstall every Friday before discharging a smoke canister to activate the ground floor smoke detector. He stated *"the minute I made the call they would take the system off the call to say it was being tested"* {TMO10049875}.

11.5.15 This is corroborated by Allied Protection, who sought to undertake an asset verification visit on 13th April 2017. Allied Protection's job sheet for that visit states regarding the smoke control system:

> *... AOV is link to Alarm centre and requires to be switch off line by the caretaker. Make future appointment with paul the caretaker or shamus* [sic] *the maintenance guy for this site*

11.5.16 Additionally, the *Estates Services Monthly Check at Grenfell Tower* {TMO00828849} also outlined the weekly testing of the smoke control system and the need to contact Tunstall in advance (see Section 9.2.78, above).

11.5.17 Regarding the weekly testing, Tunstall state in their response to the Inquiry {THL00000015}:

> *Tunstall was not involved in the weekly testing of any system at Grenfell Tower and is not aware of the testing procedures for the smoke vent system and/or fire alarm system. Tunstall can confirm from the call history documentation that connections have been made from the Tunstall equipment linked to the smoke vent system to the monitoring team for what appear to be regular tests. Please see document reference number: Q5A -Call History detailing calls received by the monitoring centre.*

11.5.18 In Table 11-4, I set out my understanding of what the combinations of 'Event' and 'Reason' could indicate. I have undertaken this analysis to corroborate the dates of the weekly ESA tests, evidence of planned maintenance, and any system demonstrations.

Table 11-4 My understanding of Tunstall call history log {THL00000019}.

Event	Reason	What I understand the record to mean

Event	Reason	What I understand the record to mean
Integral button	Test call	There was one instance of this event occurring on 6th May 2016. My understanding is that this call is related to the installation process (see Section 11.5.52). The Tunstall user manual for the auto-dialler {TMOM00001926}, provided as part of the Building Manual, describes how to operate the device using the button on the device. The event description on the Tunstall log 'Integral button' suggests the auto-dialler was activated using the button on the device, rather than from the connection to the smoke control system.
Smoke detector	Fire service called	Six instances of this event occurred on six separate dates including one instance on 14th June 2017. My understanding is that this event occurs as a result of an activation of the smoke detector per Tunstall's records of the actions to be undertaken by them in the event of an alarm {THL00000001}.
	System information call	Six instances of this event occurred on three separate dates. Four of the six instances occurred on 15th May 2017 when Allied Protection/ Lakehouse were undertaking planned maintenance {LAK00000011}. One was on a Friday at 10am therefore I have assumed this was a weekly test by the ESA. I have not been able to find a cause for the activation on 9th October 2016. Therefore at least five of these six instances appear to be logs of planned activation of a smoke detector.
	Fire test warden	Eleven instances of this event occurred on ten separate dates. This first occurred on Wednesday 2nd November 2016. The following ten instances occurred on a Friday. This appears to indicate planned activation of a smoke detector by caretaker and/or maintenance contractor to test the system.
	Test warden	There was one instance of this event occurring; on Friday 24th February 2017. This again appears to indicate planned activation of a smoke detector by a caretaker and/or maintenance contractor (refer to further discussion below table).
	Test engineer/warden	There were eight instances of this event which occurred on seven separate dates. Six of these events occurred on a Friday with the remaining two happening on 15th May

Event	Reason	What I understand the record to mean
		2017 when Allied Protection were undertaking planned maintenance. The six occurrences on a Friday therefore again appears to indicate planned activation of a smoke detector by a caretaker and/or maintenance contractor. (Refer to further discussion below table).
	Reassurance required	There were thirteen instances of this event all of which occurred on 15th May 2017 when Allied Protection were undertaking planned maintenance {LAK00000011}. I do not know the meaning of this message.
Outgoing call	Warden Called	There were nine outgoing call events in total: 3 No. Warden called; 2 No. Check resident; and 4 no. Contact requested. In all but one of these cases an outgoing call occurred within 20 minutes of a *Smoke detector- Fire service called* event. My understanding is therefore that this was a call made by Tunstall in accordance with step 2 of Tunstall's records of the actions to be undertaken by them in the event of an alarm {THL00000001}. The only exception to this was that on 14th June 2017 an *Outgoing call- Check resident* event occurred at 04:13 several hours after the *Smoke detector- Fire service called* event.
	Check resident	
	Contact requested	

11.5.19 In the following sections I present my comparison of these dates with my understanding from the evidence of various ESA checks, planned maintenance activity, and other information I have found.

11.5.20 **Entries in Tunstall call history log understood to be the result of ESA checks**

11.5.21 I understand Mr Steadman attended a demonstration of the system on 2nd November 2016.

11.5.22 In relation to this demonstration, Mr Hughes of Rydon states in Paragraph 112 of his witness statement {RYD00094213}:

I visited the Tower on 2nd November 2016 with Alan Whyte to conduct a further demonstration of the smoke extract system to Paul Steadman, who was KCTMO estate services caretaker. The reason for this was that Paul Steadman would be doing a weekly and monthly inspection and test of the system to ensure it was working correctly. Claire Williams was starting to implement an inspection and maintenance regime. Following this visit to the Tower, Claire Williams emailed, on 16th November 2016, a document entitled 'Estate Services Monthly Checks at Grenfell Tower' for my comments. This document included the weekly check of the smoke ventilation system. I

emailed Claire the same day attaching the document with my comments included in blue text, a copy of which is exhibited as ***DH/6*** *( ).*

11.5.23 I have found one instance of a *"Fire test Warden"* demonstration occurring on Wednesday 2nd November 2016. My understanding is that this was a demonstration of the system to the KCTMO ESAs organised by Ms Williams (KCTMO) and Mr Hughes (Rydon) {TMO00834400}.

11.5.24 Mr Steadman therefore did not receive training on how to carry out the checks he was required to make of the smoke control system until November 2016; six months after the completion certificate for the smoke control system was issued on 3rd May 2016 {TMOM00001862}.

11.5.25 In Paragraph 22 of his witness statement Mr Steadman states {TMO10049875}:

> After the refurbishment we were shown how to test the smoke detection and extraction (AOV) system and I would check this every Friday morning without fail. The process of doing this was that I would make a phone call to Tunstall and the minute I made the call they would take the system off the call to say it was being tested. I would spray the smoke from a smoke canister on the ground floor which would set the system off and I would allow it to run for a couple of minutes.

Figure 11-20: Excerpt from Mr Steadman's witness statement {TMO10049875}

11.5.26 Additionally, residents (e.g. Flora Neda {IWS00000887} and Farhad Neda {IWS00000886} who lived in Flat 205 on the 23rd floor) have provided evidence of hearing noise which they understood to be from the lobby smoke control system, both in the Level 23 lobby and also in their flat (Paragraphs 24-28 of {IWS00000887} and Paragraphs 16-19 {IWS00000886}). The Nedas' recall that this noise was heard particularly on Fridays. This evidence correlates with the test messages recorded by Tunstall.

11.5.27 From 6th May 2016 weekly activations of the smoke control system, as per the minimum performance standard (see Section 11.4.6, above), were required. No activations of a smoke detector with fire warden test are recorded on a Friday until the 20th January 2017 (except the 2nd November 2016 activation for the demonstration of the system).

11.5.28 Therefore, for the eight and a half month period from 6th May 2016 to 20th January 2017, the Tunstall records indicate that no weekly activation of a smoke detector was being carried out by the ESAs. I also note that the ESAs did not receive training on how to undertake the weekly test of the smoke control system until 2nd November 2016 (see Section 11.5.22, above).

11.5.29 In Table 11-5, I have listed every Friday from 20th January 2017 to the night of the fire and whether a test of the smoke control system was undertaken on each week.

Table 11-5: List of Fridays between 20/01/2017 and 14/06/2017 and whether a test was undertaken based on {THL00000019}

Date	Day of week	No. Calls	Arrival time	Event	Reason
20/01/2017	Friday	1	10:59:04	Smoke Detector	Fire Test Warden
27/01/2017	Friday	1	10:22:02	Smoke Detector	Fire Test Warden
03/02/2017	Friday	2	10:24:01, 10:28:14	Smoke Detector	Fire Test Warden
10/02/2017	Friday	1	10:11:49	Smoke Detector	Fire Test Warden
17/02/2017	Friday	1	09:21:24	Smoke Detector	Fire Test Warden
24/02/2017	Friday	1	10:13:59	Smoke Detector	Test warden
03/03/2017	Friday	1	10:05:35	Smoke Detector	Fire Test Warden
10/03/2017	Friday	1	10:06:00	Smoke Detector	Fire Test Warden
17/03/2017	Friday	0	No Test	No Test	No Test
24/03/2017	Friday	1	09:55:18	Smoke Detector	Fire Test Warden
31/03/2017	Friday	1	09:59:59	Smoke Detector	Fire Test Warden
07/04/2017	Friday	1	10:10:39	Smoke Detector	Test Engineer/warden
14/04/2017	Friday	0	No Test	No Test	No Test
21/04/2017	Friday	1	10:47:59	Smoke Detector	Test Engineer/warden
28/04/2017	Friday	0	No Test	No Test	No Test
05/05/2017	Friday	1	10:33:58	Smoke Detector	Test Engineer/warden
12/05/2017	Friday	0	No Test	No Test	No Test
19/05/2017	Friday	1	09:53:14	Smoke Detector	Test Engineer/warden
26/05/2017	Friday	0	No Test	No Test	No Test
02/06/2017	Friday	1	10:08:42	Smoke Detector	Test Engineer/warden
09/06/2017	Friday	1	10:21:43	Smoke Detector	Test Engineer/warden

11.5.30 From Table 11-5, it can be seen that there were 21 weeks between the first weekly activation of a smoke detector on 20th January 2017 and the night of the fire on 14th June 2017.

11.5.31 The Tunstall records indicate weekly test activation of a smoke detector on 16 of the 21 weeks between 20th January 2017 and 14th June 2017.

11.5.32 The last instance of a smoke detector test activation prior to the fire was on 9th June 2017. This is the only period of the Tunstall records which indicates that a smoke detector was deliberately activated weekly.

11.5.33 The smoke control system appears to have only been activated once per week, indicating that the detector on only one floor was tested.

11.5.34 This is consistent with Mr Steadman's witness statement where he states he would always test the ground floor detector {TMO10049875}.

11.5.35 The only exception to this was on 3rd February 2017, when two smoke detector signals are recorded within 4 minutes of each other. It is not clear whether this was the same detector activated twice or two separate detectors.

11.5.36 As I have explained in Section 9, the location of the detector could not be reported via the auto-dialler, and so I cannot confirm what device was activated.

11.5.37 The monthly H&S check records suggest Mr Steadman was present at Grenfell Tower on Friday 3rd February 2017 (Row 2768, {TMO10017294}). There is also a smoke detector activation recorded on the Tunstall log {THL00000019} with the reason 'fire test warden'.

11.5.38 Please refer to Section 11.6.22 where I set out what evidence there is of what Mr Steadman checked as part of the weekly test.

11.5.39 **Entries in Tunstall call history log understood to be the result of planned maintenance**

11.5.40 Allied Protection were KCTMO's maintenance contractor and undertook planned maintenance on the smoke control system on 17th January 2017 and 15th May 2017 (refer to Section 11.6.51 below, and Chapter 7 of my Phase 2 Module 3 report {BLARP20000033}).

11.5.41 I present my detailed analysis of the maintenance carried out for the smoke control system at Grenfell Tower by Allied Protection in Section 11.6.51 below.

11.5.42 From my review of the Tunstall call history {THL00000019}, I have found no record of an activation of the auto-dialler on 17th January 2017.

11.5.43 Allied Protection were undertaking maintenance of the dampers on 15th May 2017 ({LAK00000011}, {LAK00000042}). The 15th May 2017 inspection was carried out by Mr McAuliffe.

11.5.44 In Mr McAuliffe's witness statement to the Inquiry {LAK00000042} he states that activation of the dampers by the lobby smoke detectors was carried out. He further states that he reset the panel himself after each activation in a

lobby and therefore each activation of a smoke detector carried out would have activated the auto-dialler.

11.5.45 Twenty *"Smoke Detector"* signals were received by Tunstall on 15th May 2017 {THL00000019}. The reason for the first signal was *"Fire Service Called"*. The reason for the remaining 19 signals was either: *"Test Engineer/warden"*, *"Reassurance Required"* or *"System Information Call"*.

11.5.46 There were 26 smoke detectors in the smoke control system, therefore there should have been 26 *"Smoke Detector"* records if the system was tested for all zones.

11.5.47 I note that the Allied Protection Inspection & Servicing Certificate for the 15th May 2017 visit records that the engineer left site before all checks were completed {LAK00000011} (see Section 11.6.86).

11.5.48 It is not possible to identify from the Tunstall call history which smoke detectors were activated and which were not, as the locations of smoke detectors were not identifiable by the Tunstall auto-dialler (please see Section 9.2.44).

11.5.49 There was also one instance of an outgoing call from Tunstall on 15th May 2017 with the reason *"Warden called"*. This call was made within 20 minutes of Tunstall receiving the *"Smoke Detector- Fire Service Called"* signal. My understanding is therefore that this call was made by Tunstall in accordance with Tunstall's records of the actions to be undertaken by them in the event of an alarm {THL00000001}.

11.5.50 **Further activations recorded in the Tunstall call history log**

11.5.51 The Tunstall call history {THL00000019} lists seven further dates where the auto-dialler was activated, but these seven dates were not on known dates for the weekly ESA tests, demonstrations, or planned maintenance activities, prior to the night of the fire (refer to Table 11-6).

11.5.52 The first of these was 6th May 2016. The stated event was *Integral button* with the stated reason *Test Call*. This was two days after the auto-dialler was installed.

11.5.53 Regarding this activation, Tunstall state in their response to the Inquiry {THL00000015}:

On 4 May 2016, the Lifeline Vi+ unit was installed (by the same Tunstall engineer that carried out the survey). The visit report (for the Installation) was signed by a Richard Hamilton who accepted the installation. Please see document reference number: Q2C-Completion/ visit report. The same Tunstall engineer attended again on 6 May 2016, to re-programme the unit following a test performed by the customer on 5 May 2016.

11.5.54 This would have generated a call to the Tunstall monitoring centre and was presumably registered as a "test call" on 6th May 2016.

11.5.55 There were then six further events when a *Smoke Detector* signal was received by Tunstall. Four of these activations have associated outgoing calls from Tunstall.

11.5.56 I note that Mr Canaj, Lead Aftercare Engineer for JS Wright, states in paragraphs 28 to 32 of his witness statement {JSW00002025} that he attended Grenfell Tower due to a defect on 6th May 2017. The defect is described by JSW as "*The fire alarm is sounding and a plumber is required to attend*" {JSW00002022}.

11.5.57 Regarding the 16th May 2017 visit, he states at paragraph 32 of his witness statement{JSW00002025}:

> 32. Sometimes faults do get reported as emergencies when they aren't to try and get engineers there quicker, so I just put it down to a false call like that from someone.

Figure 11-21: Excerpt from Mr Canaj's witness statement {JSW00002025}

11.5.58 He also states at paragraph 15 of his witness statement {JSW00002025}:

*I attended Grenfell Tower due to false alarms on the AOV system on a couple of occasions during the defect period. I know from talking to Kensington and Chelsea Tenancy Management Organisation **("TMO")** and their caretakers that residents smoking in the communal lobbies triggered the smoke detectors which then caused all the plant to shut down. I recall that this was causing the TMO a nuisance as their maintenance engineers had to keep coming and resetting the existing boilers, which served the Finger Blocks.*

11.5.59 I have not seen evidence recording the outcome of Mr Canaj's other visits to Grenfell Tower due to *"false alarms on the AOV"*.

11.5.60 However from the evidence overall, I do not know what caused the smoke detector activation on these six occasions after 6th May 2016.

Table 11-6: Other activations of the auto dialler

Date	Day of week	Arrival time	Event	Reason
06/05/2016	Friday	13:24:47	Integral button	Test Call
05/07/2016	Tuesday	15:09:57	Smoke Detector	Fire Service Called
04/10/2016	Tuesday	19:38:13 19:48:54	Smoke Detector Outgoing call	Fire Service Called Warden Called
09/10/2016	Sunday	21:21:29 21:22:23 21:24:40	Smoke Detector Outgoing call Outgoing call	System Information Call Check Resident Warden Called
09/12/2016	Friday	15:54:37 15:58:02	Smoke Detector Outgoing call	Fire Service Called Contact Requested
28/04/2017	Friday	10:09:46	Smoke Detector	System Information Call
16/05/2017	Tuesday	17:35:05	Smoke Detector	Fire Service Called

Date	Day of week	Arrival time	Event	Reason
		17:49:06	Outgoing call	Contact Requested

11.6 Evidence of maintenance of the refurbishment smoke control system prior to the fire

11.6.1 In this section I set out my assessment of the records of the maintenance which KCTMO instructed be carried out for the smoke control system at Grenfell Tower.

11.6.2 As I have described in Chapter 7 of my Module 3 report {BLARP20000033}, KCTMO had no formal or documented procedures for the maintenance of the smoke control system.

11.6.3 My investigation found that, despite the lack of formal arrangements, the following limited maintenance activities were carried out for the smoke control system:

a) Weekly activation of the ground floor smoke detector by Mr Steadman, KCTMO ESA, following the steps outlined in the *Estates Services Monthly Checks at Grenfell Tower* document {MET00065673}. No records were kept of whether this procedure was being carried out. I have had to rely on the witness statement of Mr Steadman and the Tunstall call history {THL00000019} which records smoke detector activations.

b) Monthly Health and Safety Checks by KCTMO ESAs that *"known detection / extraction or ventilation systems in good working order"* (7 records) and *"Is there an AOV system?"* (4 records)

c) Inspection and servicing by Allied Protection, KCTMO's appointed maintenance contractor for which there are two records of works having been done at Grenfell Tower.

11.6.4 Draft contract documents between Allied Protection and KCTMO have been made available to me {LAK00000180}. Appendix 8 (Part B) of that document (Page 60, {LAK00000180}) details the Technical Specification for the Invitation to Tender (ITT).

11.6.5 Regarding the planned preventive maintenance relevant to the smoke control system it states in Section 4 *Fire Safety Equipment*:

4.1.6 **Hardwired Smoke Detection in Communal Areas**

For standalone smoke detection or linked smoke detection, the Service Provider shall include for an annual servicing and testing visit. All testing and checks shall be in accordance with British Standard requirements and test documentation will include reference to the identification system utilised by KCTMO in terms of individual detectors.

4.1.7 **Automatic Opening Vents (AOV's)**

The Service Provider shall include for 6 monthly servicing of AOV systems in accordance with manufacturer's instructions. The servicing shall include checking of interfaces with the fire alarm panel or AOV control system panel, together with checking and servicing of all AOV activators/mechanisms.

Figure 11-22: Excerpt from page 68 of {LAK00000180}

11.6.6 The smoke control system was provided with a hardwired smoke detection system in the communal areas. The ITT required an annual servicing and testing visit with all testing and checks in accordance with British Standard requirements.

11.6.7 The ITT states that *"6 monthly servicing of AOV systems in accordance with manufacturer's instructions"* should be provided. However, I have seen no evidence that KCTMO provided Allied Protection with any manufacturers' instructions for the smoke control system at Grenfell Tower prior to the fire.

11.6.8 For reactive repairs of 'fire safety equipment', the ITT states:

4.2 **Repairs**

The Service Provider shall provide a repair service as part of the Contract and this shall include the following types of repairs:-

- Reactive repair service relating to defective fire safety equipment.
- Completion of repairs to fire safety equipment when undertaking the Planned Maintenance visit.
- Instructed repairs such as replacement detectors, AOV repairs, etc.

Where a fire alarm has activated due to a false alarm, the Service Provider will normally be instructed to attend on an 'emergency basis' to complete the necessary repair and to silence and reset the fire alarm system.

In the event of a property being left without suitable fire safety equipment cover, the Service Provider will immediately notify the Client's Representative (by phone and e-mail) so that suitable contingency measures can be agreed.

Figure 11-23: Excerpt from Page 68 of {LAK00000180}

11.6.9 The assets to be maintained and repaired under the contract are stated as {LAK000000180}:

3.1.4. **The Assets**

KCTMO has a register of assets and this is appended as Appendix 10. Whilst the list of assets is generally accurate there may be some minor errors. As and when the Service Provider becomes aware of any errors it shall notify the Client Representative.

Figure 11-24: Excerpt from Page 13 of {LAK00000180}

11.6.10 Appendix 10 detailing the register of assets has not been made available to me.

11.6.11 I have reviewed the records available to me of the maintenance activities outlined above to understand how the system operation was tested and what inspections of the equipment of the smoke control system were carried out. I have done this to understand the operational condition of the smoke control system prior to the 14th June 2017.

11.6.12 In Table 11-7 I have set out the minimum performance standard for maintenance of the smoke control system as derived from the relevant British Standards and the minimum competence required for the person carrying out the relevant task.

11.6.13 BS 9999:2008 sets out the competency requirements for carrying out maintenance tasks. It states that certain actions can be carried out by "*suitably trained personnel*" in addition to inspections by competent person.

11.6.14 Save for the limited evidence set out in the next paragraph, I have not found any evidence that the KCTMO ESAs who were tasked with carrying out the weekly and monthly checks of the smoke control system, to ensure that the system was in good working order, were given any training on how the system operated or on the location of the equipment that was required to be inspected during these checks.

11.6.15 The only such evidence I have found is that the KCTMO ESAs attended a demonstration of the system's operation on the 2nd November 2016 {RYD00094213}, as described in Section 11.5.20 and that instructions for the weekly activation were provided in *Estates Services Monthly Checks at Grenfell Tower*, as described in Section 11.6.20.

11.6.16 I have not found any records of instruction or training regarding what inspections or tasks the ESAs were required to carry out on the smoke control system during their Monthly Health and Safety Checks (please see Section 11.6.30).

11.6.17 Therefore, I do not consider the KCTMO ESAs were suitably trained to carry out maintenance inspections of the smoke control system. I have summarised this in column 2 of Table 11-7.

11.6.18 I have then, in columns 4 and 5, summarised my analysis of the records of either KCTMO's ESAs or Allied Protection carrying out the task.

11.6.19 My analysis of the records is set out in the following sections.

Table 11-7: Minimum performance standards for maintenance of the smoke control system derived from guidance in BS EN 12101-6:2005, BS 5839-1:2013 and BS 9999:2008 {BLARP20000033} and evidence that these were carried out

Period	Maintenance action from Section 5.9.108 of Chapter 7 of my Module 3 report {BLARP20000033}	Minimum competence required	Records of maintenance action being carried out by KCTMO ESAs	Records of maintenance action being carried out by Allied Protection providing evidence of operational condition
Daily	Inspection of the smoke control system panel to check if any faults are being reported by the system.	This can be carried out by suitably trained staff;	None	None
Weekly	Activation of the smoke control system, activating the system using a different detector head each time; contact alarm receiving centre before, and immediately after, test to ensure that unwanted alarms are avoided and that fire alarm signals are correctly received; ensure that the fans and powered exhaust ventilators operate correctly, smoke dampers close (or open in some systems);	This can be carried out by suitably trained staff;	There is some evidence that 16 weekly activations may have been carried out between 20th January 2017 and 14th June 2017 only. ESAs were provided with a demonstration only on how to activate the smoke control system by a smoke detector. However, there is no evidence from these activations that the fans at the roof and Level 2 operated correctly or that the lobby dampers closed or opened as required. I also have no evidence that KCTMO ESAs were provided with suitable training to inspect the fans or dampers to check their correct operation. Please refer to Section 11.6.20.	None
	Visual inspection of any batteries –	No manufacturers information is included in the building manual for the batteries. Photos of the batteries show no indicators which could be visually inspected. No screens were included in the HMI Panel included the back battery status for the 11 batteries. Therefore I do not know how KCTMO Staff or maintenance contractors were able to inspect the batteries.	None	None
Monthly	In addition to the weekly checks, simulate failure of the primary power supply to ensure that the system has switched to the secondary supply;	This can be carried out by suitably trained KCTMO staff. ESAs completed a monthly record the system was in good working order; however I have seen no evidence that ESAs were trained or provided with instructions to carry out these tasks. Please refer to Section 11.6.30. These tasks should have been carried out by Allied Protection.		None
	Test zero airflow condition shall be simulated (i.e. simulate failure of duty fans) and a check made that the stand-by fans are running.			
Quarterly	All zones should be separately tested and it should be ensured that any fans and powered exhaust ventilators operate correctly, smoke dampers close (or open in some systems).	This can be carried out by suitably trained KCTMO staff. ESAs were not instructed by KCTMO to carry out this task, therefore it was required to be completed by Allied Protection.		Two Inspection and servicing certificates have been disclosed to me for the 13 month period between handover and the 14th June 2017. The Inspection and servicing certificates dated 17th January 2017{LAK00000009} did not carry out any operational test of the smoke control system. Please refer to Section 11.6.64 The Inspection and servicing certificates dated 15th May 2017 {LAK00000011} activated 20 smoke detectors in Grenfell Tower in a period of 1 hr and 15 minutes {THL00000019}. The engineer therefore had just under 4 minutes to check the operation of the fans and the dampers for each test before resetting the system and returning to start the next test. I do not consider it possible for the engineer to have checked the correct operation of the roof and Level 2 fans and all 91 dampers in 4 minutes. Please refer to Section

Period	Maintenance action from Section 5.9.108 of Chapter 7 of my Module 3 report {BLARP20000033}	Minimum competence required	Records of maintenance action being carried out by KCTMO ESAs	Records of maintenance action being carried out by Allied Protection providing evidence of operational condition
				11.6.86
Six monthly	Inspection and test of the fire detection system following the procedure recorded in Clause 45.3 of BS 5839-1:2013	Undertaken by a competent fire alarm and detection specialist;		None
	Inspection and test of the fire detection system following the procedure recorded in Clause 45.4 of BS 5839-1:2013	Undertaken by a competent fire alarm and detection specialist;		None
Annual	test of entire pressure differential system in accordance with the manufacturer's recommendation and the acceptance tests for pressure differential; net pressure differential; air velocity; and door opening force described in Section 12.2 of BS EN 12101-6:2005	Undertaken by a competent specialist		None

11.6.20 Weekly activation of the smoke control system by KCTMO ESAs

11.6.21 My investigation of the weekly activation of the smoke control system by Mr Steadman, KCTMO ESA, is set out in Section 18.5 of Chapter 7 of my Module 3 report {BLARP20000033}.

11.6.22 Mr Steadman describes the procedure he followed for the weekly test in paragraphs 22 and 23 of his witness statement {TMO10049875}:

> 22. After the refurbishment we were shown how to test the smoke detection and extraction (AOV) system and I would check this every Friday morning without fail. The process of doing this was that I would make a phone call to Tunstall and the minute I made the call they would take the system off the call to say it was being tested. I would spray the smoke from a smoke canister on the ground floor which would set the system off and I would allow it to run for a couple of minutes.
>
> 23. I can remember asking the question during training of whether it was necessary for me to check the smoke extractor system on every floor. However, I was told that it was not necessary as it would show on the ground floor if there were any issues with the system on any other floor. I cannot remember who gave this training now but I can recall that myself, Seamus Dunlea and Claire Williams of the TMO were present.

Figure 11-25: Paragraphs 22 and 23 from {TMO10049875}

11.6.23 In his statement to the Metropolitan Police, Mr Steadman also exhibited a document with title *Estates Services Monthly Checks at Grenfell Tower* dated 16th November 2016 {MET00065673}.

11.6.24 Despite the document being titled 'monthly', it did outline the requirement to test the smoke control system weekly and a short description of the steps involved:

> Weekly - the TMO need to check that the smoke ventilation system is working. This entails ringing Tunstall on [redacted], giving the postcode W11 1TQ and note that they manage the fire panel as a disbersed unit, and that a fire test is due. Grenfell's ID is 54000 9001. They then:
>
> - Ring 999 for the fire brigade
> - Ring TMO/Pinnacle/estates services –
>   - Boilers: Engie on [redacted]/JSWright (Rydon sub-c)
>   - Smoke vent system: estates services
> - Ring CAS (community alarm service) to update on [redacted]
>
> To do the test you can activate an alarm by using 'smoke in a can' and then press 'reset'. (The tel no of the autodialler is [redacted])

Figure 11-26: Excerpt from {MET00065673}

11.6.25 Based on the evidence available to me I have not found any records of the weekly operational test of the smoke control system at Grenfell Tower undertaken by the Estate Services Assistants.

11.6.26 From my analysis of the Tunstall call history {THL00000019} for the auto-dialler connected to the smoke control system in Section , I note that:

a) There are no records of regular smoke detector activations on a Friday before 20th January 2017, 9 months after the commissioning of the smoke control system in May 2016 .

b) There are records of regular activations on a Friday from 20th January 2017 to 14th June 2017, with smoke detector activations on 16 Fridays in that 21 week period.

11.6.27 From Mr Steadman's witness statement I therefore understand that this weekly check comprised the following only:

a) Activation of the smoke control system by activating the smoke detector head in the ground floor lobby;

b) Allowing the system to run for a couple of minutes; and

c) Inspection of the HMI panel to check for any warning messages.

11.6.28 The KCTMO weekly activation did not therefore:

a) Check the system could by activated by a different smoke detector on any floor other than Ground Floor;

b) Check the smoke extract fans at either the roof or Level 2 operated correctly; nor

c) Check that that the smoke control dampers opened on the floor of activation (which anyway was Ground Floor every time) and closed on all other floors. A visual inspection of the smoke control dampers was required to verify their position. As I have explained in Section 7, the HMI panel could not be relied on to verify damper positions as it was not wired to do so.

11.6.29 The weekly activation as carried out by the KCTMO therefore did not confirm that the smoke control system was capable of operating as intended in the event of a fire.

11.6.30 **Evidence of monthly checks of the smoke control system by KCTMO ESAs**

11.6.31 My investigation of the monthly checks of the smoke control system as part of the monthly Health and Safety Checks completed by ESAs is set out in Section 18.5 of Chapter 7 of my Module 3 report {BLARP20000033}.

11.6.32 The records of the checks relevant to the smoke control system at Grenfell Tower are excerpted in {TMO10017294}.

13	Form	Estate Services Assistant	Date of Report	Are any known detection / extraction or ventilation systems in good working order?	Is there a AOV System?
1530	Monthly ESA H&S Checks	Paul Steadman	05/08/2016	Yes	
1687	Monthly ESA H&S Checks	Paul Steadman	08/09/2016	Yes	
1999	Monthly ESA H&S Checks	Paul Steadman	07/10/2016	Yes	
2768	Monthly ESA H&S Checks	Paul Steadman	03/02/2017	Yes	Y
3000	Monthly ESA H&S Checks	Paul Steadman	10/03/2017	Yes	Y
3225	Monthly ESA H&S Checks	Paul Steadman	07/04/2017	Yes	Y
3543	Monthly ESA H&S Checks	Paul Steadman	30/05/2017	Yes	Y

Figure 11-27: Record of Monthly Health and Safety Checks {TMO10017294} completed by ESAs following completion of the smoke control system on 3rd May 2016 (spreadsheet filtered for the period 1st January 2016 to 14th June 2017)

11.6.33 Based on the above, it can be seen that on seven occasions between August 2016 and May 2017, Mr Steadman recorded "*yes*" to the check "*are any known detection / extraction or ventilation systems in good working order?*"

11.6.34 Under *"Is there a AOV System"* no entry is made for the four monthly ESA checks undertaken between 5th August 2016 and 7th October 2016. For the subsequent four checks from 3rd February 2017 to 30th May 2017 "Y" is recorded.

11.6.35 I make this point here as the completion certificate for the smoke control system was dated 3rd May 2016 {TMOM00001862}. However, it is not until after Mr Steadman attended training on 2nd November 2016 that he began to record the presence of an AOV system at Grenfell Tower.

11.6.36 I have found no associated procedural document which sets out what checks are required in order to answer the questions as either Yes or NO as KCTMO required their staff to do.

11.6.37 These records therefore provide limited evidence of the operating potential of the smoke control system in Grenfell Tower prior to the 14th June 2017.

11.6.38 A document titled *Estates Services Monthly Checks at Grenfell Tower* dated 16th November 2016 {MET00065673} has been disclosed to me. This document was prepared after the Monthly Health and Safety Checks by ESAs were in place.

11.6.39 The *Estates Services Monthly Checks at Grenfell Tower* {MET00065673} was produced 10 months after the first completed record disclosed to me of Monthly Health and Safety Checks on 1st January 2016. Therefore *Estates Services Monthly Checks at Grenfell Tower* does not appear to have been the procedures for the Monthly Health and Safety Checks carried out from January 2016.

11.6.40 I have reviewed the *Estates Services Monthly Checks at Grenfell Tower* {MET00065673} for any instructions provided to KCTMO ESAs regarding additional checks to be carried out monthly, on top of the weekly activations they were instructed to carry out.

11.6.41 The *Estates Services Monthly Checks at Grenfell Tower* {MET00065673} outlined the following monthly visual inspection:

1 ROOF

A Electrics to the communal ventilation dampers: in the main tank room

If there is a problem this should show up on the BMS panel at ground floor, but a visual check should be to look at the primary and secondary supply lights (blue and white). If these lights are not on, then a defect needs to be reported to Rydon.

Figure 11-28: Excerpt from {MET00065673}

11.6.42 I observed the equipment above during my site visit. The equipment was labelled as *'Automatic changeover unit for smoke extract system'* (see Figure 11-29) and *'Smoke Extract System Main Inverter Panel 2'* (see Figure 11-30).

Figure 11-29: Equipment labelled *'Automatic changeover unit for smoke extract system'* at roof plant room.

Figure 11-30: Equipment labelled *'Smoke Extract System Main Inverter Panel 2'* at roof plant room.

11.6.43 I have found no records of this visual inspection being undertaken.

11.6.44 The *Estates Services Monthly Checks at Grenfell Tower* {MET00065673} also stated:

> B Hub room
>
> The hub room contains the inverter, smoke ventilation system, main lobby environmental AOV and cctv. A quick visual inspection each month will ensure that everything is working and no issues are arising.

Figure 11-31: Excerpt from {MET00065673}

11.6.45 In the evidence available to me, I have not found any records of the *"quick visual inspection"* of the smoke control equipment located in the Hub Room.

11.6.46 Further, Mr Steadman makes no statement in his first or second witness statement that these visual inspection were carried out by him.

11.6.47 Therefore, I can find no evidence that KCTMO ESAs were instructed or trained to carry out any of the monthly maintenance tasks I have set out in Table 11-7.

11.6.48 I also find that the Record of Monthly Health and Safety Checks {TMO10017294}, by itself, provides no evidence of any test of the smoke control system being carried out or of any inspection of the system's equipment.

11.6.49 KCTMO, in the absence of suitably trained staff, required a competent contractor to carry out the monthly maintenance tasks in addition to the quarterly, six monthly and annual inspections.

11.6.50 I have set out my analysis of the records of maintenance for the smoke control system by KCTMO's relevant maintenance contractor maintenance in the following section.

11.6.51 **Allied Protection 'Inspection and Servicing certificates (automated opening vents)'**

11.6.52 Allied Protection were KCTMO's fire protection systems maintenance contractor who undertook maintenance of the smoke control system following completion of the refurbished smoke control system.

11.6.53 As presented above in Section 11.6.4, the draft contract documents {LAK00000180} between Allied Protection and KCTMO detailed a requirement for Allied Protection to undertake annual servicing and testing of the hardwired smoke detection in common areas in accordance with the relevant British Standard, and 6 monthly servicing of the smoke control system per the manufacturers' instructions.

11.6.54 I have seen a job sheet from Allied Protection which suggests a 'Quarterly FIRE service of 25% of Fire Detection Equipment' was to be carried out {LAK00000144}.

11.6.55 I have found two records of 'inspection and servicing' visits carried out by Allied Protection for the smoke control system in the 13 month period between handover in July 2016 and 14th June 2017. The first was on 17th January 2017 {LAK00000009}, and the second on 15th May 2017 {LAK00000011}.

11.6.56 I also note that Allied Protection sought to undertake an *Asset verification visit* on 13th April 2017. However, no caretaker was on site and this was not completed {LAK00000510}, with the following comment recorded by Allied Protection on their job sheet:

> *...also can't test AOV until next week Tuesday as the AOV is link the main boiler room and switches them off when AOV are activated. requires the caretaker paul to be on site to switch them extractors on switch controls boiler room as building recently had a refurb. Also AOV is link to Alarm centre and requires to be switch off line by the caretaker. Make future appointments with paul the caretaker or shamus the maintenance guy for this site* [sic].

11.6.57 In this section I carry out a more detailed analysis of the evidence provided by the two Allied Protection Inspection & Servicing Certificates recording the 'tests / checks done' undertaken.

11.6.58 Each Inspection & Servicing Certificate records the duration of the maintenance visit and contains a list of 11 checks/tests which are completed as 'Yes', 'No' or 'N/A'.

11.6.59 No method statement setting out the actions to be undertaken as part of inspection and servicing by Allied Protection has been made available to me., I can therefore rely only on the 'tests/checks done' listed in the Inspection & Servicing Certificate (Automated Opening Vents) {LAK00000009}.

11.6.60 In Table 11-8 I have set out each of the 11 checks/tests and the quantity of equipment relevant to the inspection/test in Grenfell Tower, in order to assess the extent of inspection possible in the time recorded for each maintenance visit.

11.6.61 In columns 1 to 3 of Table 11-8 below, I have presented the 'tests/checks done' as recorded on the Allied Protection Inspection & Servicing Certificate, along with the outcome of those, for the 17th January 2017 {LAK00000009} and 15th May 2017 {LAK00000011} visits.

11.6.62 I have set out in column 4 the equipment which I have derived as relevant to the 'tests/checks' in column 1 in order to satisfy the minimum performance standard set in Table 11-7. I have also provided a description of the equipment to be checked in column 5 and its location.

11.6.63 In column 6 I provide a summary of the equipment to be checked. I have done this to allow an understanding of the extent of the tests and checks.

Table 11-8: Equipment to be tested/checked as part of the planned maintenance visits by Allied Protection

Allied Protection Certificate 'Tests/Checks Done'	17th January 2017 Certificate {LAK00000009} Record of check	15th May 2017 Certificate {LAK00000011} Record of check	Component(s) of smoke control system relevant to the Allied Protection test/check derived by me	Description of item to be checked in Grenfell Tower derived by me	Quantum of equipment be checked/serviced as derived by me
Actuators working correctly?	*Yes*	*Yes*	Actuator controlling the position of the lobby dampers, AOVs and fan bypass dampers	A total of 91 dampers and 2 AOVs were installed with actuators: Dampers in the lobbies (North and South) - 88: - G to L3: 2 per floor - L4 to 23: 4 per floor Community Room lobby AOV: 1 Boxing Club lobby AOV: 1 Fan by-pass dampers at level 2: 4[14]	The position of the dampers and AOVs controlled by the actuators was required to be inspected visually for each test as the feedback function from the actuators to the Master Control Panel was not wired in. Therefore, the positions of the dampers and AOVs as indicated by the HMI Panel could not be relied upon. The data on the touchscreen reflected the intended position, not the condition of the dampers at the time of inspection. Therefore, for a test of each zone, a visual inspection was required of 93 actuators across 24 floors to confirm they were in the correct open and then closed position.
Clean, lubricate and tighten all actuators, dampers and louvres?	*Yes*	*No*	All dampers, AOVs and fan bypass dampers and their actuators	Per Row 1	93 actuators, dampers, and AOV's to be cleaned, lubricated and tightened. I note the lobby dampers were located behind fixed metal grilles. Level 2 fan by pass dampers were located at high level in a double height space and therefore, would have required an access platform.
Left vents in closed position?	*Yes*	*Yes*	Lobby dampers, AOVs and fan bypass dampers	Per Row 1	The position of the dampers and AOVs controlled by the actuators was required to be inspected visually for each test as the feedback function from the actuators to the Master Smoke Control Panel was not wired in. Therefore, the positions of the dampers and AOVs as indicated by the HMI Panel could not be relied upon. At the completion of the maintenance, a visual inspection was therefore required to check all 93 AOVs and dampers across 24 floors were in the closed position.
Control and indicating equipment operating correctly?	*Yes*	*Yes*	I understand the following components comprise the control and indicating equipment for the smoke control system: Main control panel HMI Panel	 1 no. at Ground level (Hub Room) 1 no. at Ground level	Visual inspection of the control equipment (81 devices). I understand the HMI panel provided indication of the system operation. Therefore, for the test of the system at each floor, a visual inspection of the HMI Panel at Ground Level to check it was indicating the correct floor of operation and the correct position of all dampers was required for every test in each lobby.

[14] Although there are four by-pass dampers installed within the Level 2 ductwork, one of the dampers was not wired to the smoke control system and was permanently open {MET00065879}.

Allied Protection Certificate **'Tests/Checks Done'**	**17th January 2017 Certificate** **{LAK00000009}** **Record of check**	**15th May 2017 Certificate** **{LAK00000011}** **Record of check**	**Component(s) of smoke control system relevant to the Allied Protection test/check derived by me**	**Description of item to be checked in Grenfell Tower derived by me**	**Quantum of equipment be checked/serviced as derived by me**
			Outstation panels Inverters Pressure switch Firefighter override switches	1 per lobby (L2 to L23; 22 total) located in riser cupboard except the L3 outstation which was located behind the MDF wall panel (not within a riser cupboard) There is also an additional two outstations: one within the panel at Ground floor Hub Room that contains the inverters for the fans at L2 and one within the panel at roof level that contains the inverters for fans at roof. 3 no. of inverters at Ground level Hub room controlling the environmental fan, main smoke fan and the back-up smoke fan at Level 2 2 no. of inverters at the roof level plant room controlling the main smoke fan and the backup smoke fan at roof. 1 per lobby (G to L23; 24 total) located in riser cupboard except L3 which was located behind MDF wall panel and ground level pressure switch located in Hub Room. 1 per lobby (G to L23) plus 1 for Community Room, and 1 for Boxing Club (26 total)	
Power supply test OK?	*Yes*	*Yes*	Primary power supply Secondary power supply	Test automatic switchover from primary to secondary power for extract fans. 1 at ground level and 1 in the plant room at roof level.	The engineer would be required to activate the system, and then turn off the primary supply, and ensure that the fans continue to run on the secondary power supply. They would then reinstate the primary power supply, the fans may or may not automatically transfer back to the primary source. This would be a single test for each automatic transfer switch it doesn't need to be carried out for each floor. A duty fan failure should also have been carried out to bring on the stand by fans. This could have been completed separate to the power supply test. I note that this may not occur under the power supply test. The Allied Protection Service and Inspection certificate included no test or check of the fans.

Allied Protection Certificate 'Tests/Checks Done'	17th January 2017 Certificate {LAK00000009} Record of check	15th May 2017 Certificate {LAK00000011} Record of check	Component(s) of smoke control system relevant to the Allied Protection test/check derived by me	Description of item to be checked in Grenfell Tower derived by me	Quantum of equipment be checked/serviced as derived by me
Back up batteries test ok?	*Yes*	*Yes*	Back-up batteries for inverter panels at ground and roof Back-up batteries for the outstations and the devices connected to the outstations	1 at Ground level, plus 1 per every second lobby between Level 3 and 21 {TMOM00001859} and one at roof level (12 total). BRE's site investigation reported "*9 Battery Back-up Panels (located on approximately every other floor)*" {MET00065879} above ground instead of 10. I note that from post-fire pictures from the Metropolitan Police, I have found 11 battery back-up panels installed on ground level and levels 5, 7, 9, 11, 13, 15, 17, 19, 21 and roof plant room. I have not seen evidence of the battery at Level 3 being installed.	Operational test of the back-up batteries (12 total) The test procedure should be provided by the battery manufacturer. No manufacturers literature for the batteries was included in the building manual (Table 11-1). A physical check of the voltage of each battery could be carried out to check it was operational.
Wiring ok?	*Yes*	*Yes*	Control & power cabling	Between all components	As a minimum I would expect the contractor to check that all the cable terminations in the panels are secure, i.e. no loose cables. I would also expect them to check the earthing arrangement and check all the components for temperature to ensure they are not getting excessively hot. This would normally be a visual inspection of the condition of the cables. All equipment should be labelled, wiring diagrams should be kept in the panels. Isolators and switches should be checked for operation, protection settings and ratings of devices should be checked. Panels should be inspected to be clean/dust free All plantroom safety circuits should be checked and tested.
Rain / wind sensors tested?	*N/A*	*N/A*	None present at Grenfell Tower.	-	-
Interfacing confirmed as working?	*N/A*	*Yes*	Interfacing with BMS	Interface with refurbishment BMS System in the basement to: - Receive a signal to the BMS run in environmental mode; - Send a fire detected signal to the BMS to shut down the basement boilers (existing and new) and the landlord gas supply	Operational test to ensure operation of smoke control system sends signal to BMS to shut down boilers and close gas shut-off solenoid. I am aware that the interface with the gas shut-off to the landlord gas supply in the basement was removed. However, I do not know on what date it was removed. Operational test of operation of the system in environmental mode upon signal from the BMS All plantroom safety circuits should be checked and tested.
			Auto-dialler	Interface with auto-dialler	Operational test with activation confirmed by remote call centre.

Allied Protection Certificate 'Tests/Checks Done'	**17th January 2017 Certificate {LAK00000009} Record of check**	**15th May 2017 Certificate {LAK00000011} Record of check**	**Component(s) of smoke control system relevant to the Allied Protection test/check derived by me**	**Description of item to be checked in Grenfell Tower derived by me**	**Quantum of equipment be checked/serviced as derived by me**
Smoke detectors tested?	*N/A*	*Yes*	Smoke detector	Locations: Ground to L23: 1 per lobby Ground: 1 in Community room lobby Level 2: Boxing gym lobby	Operational test of the 26 smoke detectors between Ground and Level 23. The six monthly and annual servicing requirements for smoke detection systems are set out in Clause 45.3 and 45.4 of BS 5839-1:2013.
Cause and effects tested?	*Yes*	*Yes*	Smoke control system and interface with BMS	Written narrative of cause and effect in PSB's O&M for the smoke control system {TMOM00001858}. However, no detailed cause and effect matrix for the components was provided for smoke extract mode.	Carry out separate operational tests of the smoke control system using each of the installed initiation devices in the 24 residential lobbies and 2 non-residential lobbies: - 26 smoke detectors - 26 yellow firefighter override switches - Initiation of all 26 zones from HMI panel Operational test of initiation of smoke extract mode when system is in both environmental mode on and environmental mode off separately. `Cause and effect proving activation of the pressure switch and the signal sent to the inverters to control the speed of the relevant fans. Cause and effect of BMS panel interface functions including: - Activation of environmental mode from the input BMS signal - Sends a fire alarm active signal out which is received by the BMS system.

11.6.64 In that context, I provide my analysis of the actions undertaken by Allied Protection in their 17th January 2017, and 15th May 2017 site visits.

11.6.65 **Allied Protection Inspection & Servicing Certificate (automated opening vents) 17th January 2017**

11.6.66 The 17th January 2017 'Inspection and servicing certificate (automated opening vents)' records the works undertaken by Karl Russell of Allied Protection which are stated to have lasted 3 hours (arrival: 09.00 and departure: 12.00) {LAK00000009}.

11.6.67 I have not been provided with a witness statement from Mr Russell. As such, I have no detailed information about his recollection of his activities on that day.

11.6.68 I have excerpted the 17th January 2017 'Inspection and servicing certificate (automated opening vents)' in Figure 11-32.

AlliedProtection
Part of the Lakehouse Group

INSPECTION & SERVICING CERTIFICATE (Automated Opening Vents)

Tel: [redacted]
Fax: [redacted]
service@alliedprotection.co.uk

Client Name: Lakehouse - K&T - Kensington & Chelsea TMO
Property Address: Grenfell Tower 11-206, Lancaster West Estate, , , W11 1TQ
Job Number: K&C195982-1
Date: 17.01.17

Description of works carried out:
Service of the aovs

Tests / Checks done	**YES / NO / N/A**
Actuators working Correctly?	Yes
Clean, Lubricate and tighten all actuators, dampers and louvres?	Yes
Left Vents in Closed Position?	Yes
Control and Indicating Equipment operating correctly?	Yes
Power Supply test OK?	Yes
Back up Batteries test OK?	Yes
Wiring OK?	Yes
Rain / Wind Sensors tested?	N/A
Interfacing confirmed as working?	N/A
Smoke detectors tested?	N/A
Cause and Effects Tested?	Yes

Cause & Effects arrangements & Checks completed:
Service of the aovs

Comments / Remedial Works required:
Service of the aovs

Customer Signature:
Client/Representative's Name: A
Engineer Signature:
Arrival Time: 09.00
Engineer Name: Karl Russell
Departure Time: 12.00

Head Office : Unit 2, Regent Business Centre, Jubilee Rd, Burgess Hill, W Sussex, RH15 9TL

Figure 11-32: Allied Protection Inspection and Servicing certificate (automated Opening Vents) {LAK00000009} 17th January 2017

11.6.69 Eight of the 11 listed checks are recorded as being carried out.

11.6.70 The 3 checks recorded 'N/A' were "Rain/wind sensors tested?", 'Interfacing confirmed as working?' and "Smoke detectors tested?".

11.6.71 In respect of these three checks, no rain/wind sensors were installed at Grenfell Tower therefore no check was required for this. The smoke control system was interfaced with an auto-dialler and the new BMS system. Therefore interfaces were present that could have been tested. A total of 26 smoke detectors were installed as part of the smoke control system. These detectors were the means of activating the smoke control system automatically in the event of a fire. It is not clear why a test of the smoke detectors was considered not applicable.

11.6.72 The auto-dialler records from Tunstall {THL00000019} do not list any smoke detector activations for 17th January 2017, confirming that no activation of the system was carried by Mr Russell.

11.6.73 Secondly, in respect of the checks that the certificate records were completed, the cause and effects are recorded as being checked/tested. However, a complete check of the cause and effect is not possible without activation of the system using the activating devices the smoke detectors.

11.6.74 Under the field *'Cause & Effects arrangements & checks completed'* Mr Russell recorded *"Service of the aovs"*. I understand the 'aovs' to refer the dampers installed as part of the smoke control system. From Table 11-8, there were a total of 93 dampers and automatic opening vents installed in Grenfell Tower over 24 floors.

11.6.75 Mr Russell records that all actuators are working correctly. As I have explained in Section 7.12 an actuator is a device controlling the position of a damper. It is not clear to me how Mr Russell activated the actuators to confirm their correct operation. There are no entries on the Tunstall log from 17th January 2017 recording the system being activated (see section 11.5.39). Mr Russell could only therefore have operated the dampers in the lobbies of Grenfell Tower manually from the HMI panel at ground level in 'ON' mode.

11.6.76 If Mr Russell did operate the dampers from the HMI panel in ON mode, he was not able to rely on the damper position status reported by the HMI panel. This is because the feedback function from the actuators controlling the dampers to the master control panel, which would have signalled the true state/position of the dampers, was not wired in (see Section 7.12).

11.6.77 Thus, if Mr Russell relied on activating the actuators using the HMI panel, and then observing the status recorded on said panel, he would not have known if the dampers had in fact opened or closed as necessary.

11.6.78 Mr Russell records *'YES'* to *'Clean, lubricate and tighten all actuators, dampers and louvres?'* In a three hour visit Mr Russell had 7.5 minutes to visit every floor of Grenfell Tower to clean, lubricate and tighten the actuators, dampers, and louvres for 91 dampers and 2 AOVs in the smoke control system. This allows just under two minutes for each actuator and damper.

11.6.79 The actuators and dampers for the Lobby were located behind metal grilles – these needed to be removed to access the damper and actuator. The actuator was positioned in a metal casing in front of the damper (see Figure 11-33).

11.6.80 I note that the actuators do not contain any serviceable parts. Where an actuator failed, the component would be required to be replaced. No relevant manufacturer's literature from Belimo was included in the Building Manual.

11.6.81 However, JS Wright have disclosed to the Inquiry the Technical Data Sheet for the Belimo actuators {JSW00003199} which states:

The device may only be opened at the actuator manufacturer's site. It does not contain any parts that can be replaced or repaired by the user.

11.6.82 The actuator was held in position with a metal bracket, and the actuator was attached to the damper shaft using a metal clamp. I have outlined the location of the actuator with a blue dashed line in Figure 11-33.

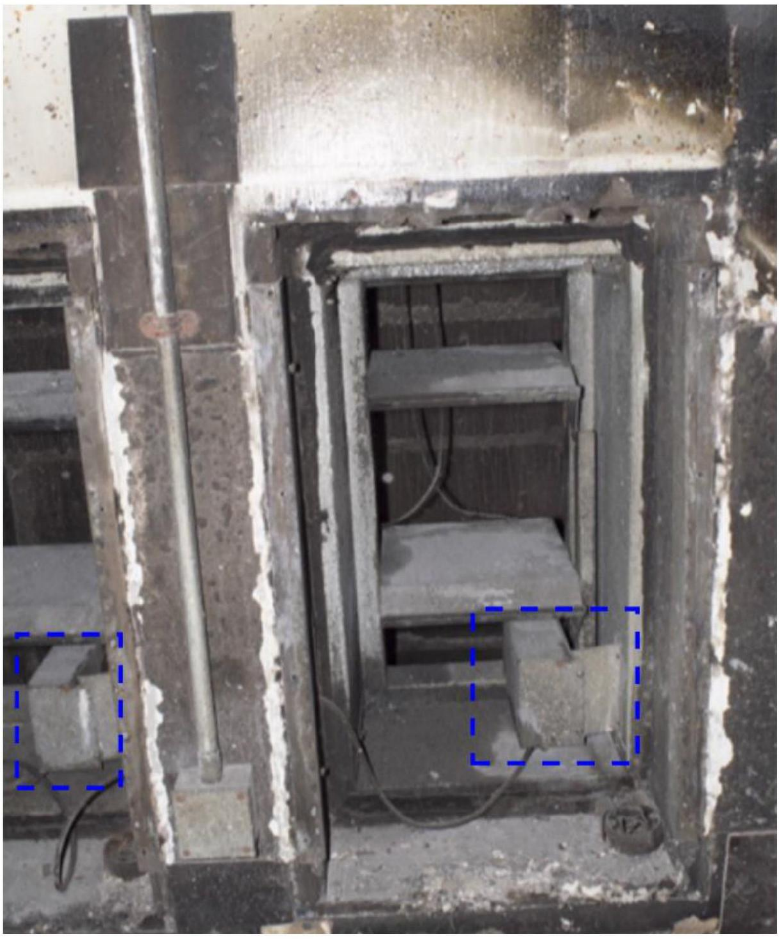

Figure 11-33: Image showing grille removed, actuator located in bottom right in front of damper (indicated with blue dashed line)

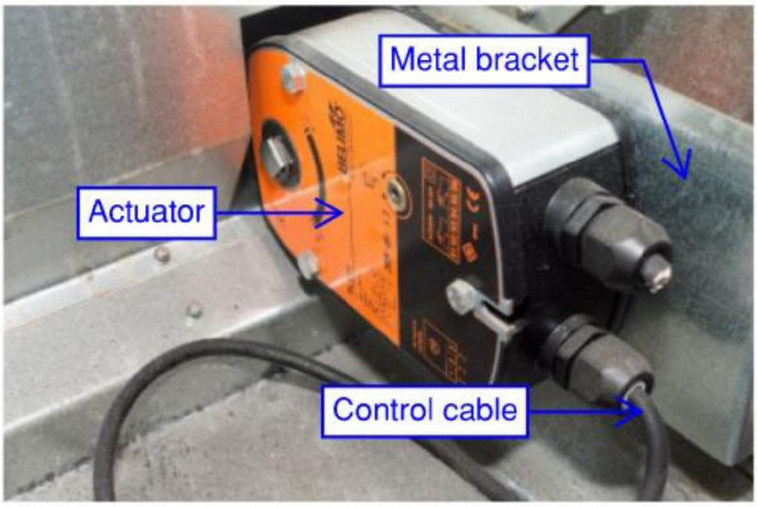

Figure 115 – Undamaged Belimo actuator (C1_2612606__DSC_0078.jpg)

Figure 11-34: Figure 115 from {MET00039807} showing actuator with metal casing removed. Mark-up added by me to show actuator, metal bracket, and control cable.

11.6.83 Mr Russell also recorded 'yes' to the following tests:

Control and indicating equipment operating correctly?

Power supply test OK?

Back up batteries test ok?

Wiring ok?

Cause and effects tested?

11.6.84 The records therefore suggest that in the three hours Mr Russell spent in Grenfell Tower, in addition to checks carried out for the dampers he carried out the following operational tests (see Table 11-8):

a) For the control and indicating equipment over 24 floors as I have listed in Section 7.2.3;

b) Tested the auto switchover from primary to secondary power supply located at roof and ground level;

c) Tested 11 backup batteries; and

d) Inspected wiring between components.

11.6.85 I do not consider it possible for the stated checks and servicing for the dampers to have been carried out in the three hour period it is stated the engineer was present in Grenfell Tower.

11.6.86 Allied Protection Inspection & Servicing Certificate (Automated opening vents) 15th May 2017

11.6.87 Barry McAuliffe of Allied Protection attended Grenfell Tower on 15th May 2017 and his visit is recorded as lasting 2 hours (arrival: 12:15 and departure: 14:15) {LAK00000011}.

11.6.88 I have excerpted the 15th May 2017 'Inspection and servicing certificate (automated opening vents)' in Figure 11-35:.

AlliedProtection
Part of the Lakehouse Group

INSPECTION & SERVICING CERTIFICATE (Automated Opening Vents)

Tel: [redacted]
service@alliedprotection.co.uk

Client Name: Kensington and Chelsea TMO
Property Address: Grenfell Tower 1-206, Grenfell Road, Grenfell Tower 1-206 Grenfell Ro
Job Number: KCT258358-1
Date: 15/05/17

Description of works carried out:
AOV tested, all ok.

Tests / Checks done	**YES / NO / N/A**
Actuators working Correctly?	Yes
Clean, Lubricate and tighten all actuators, dampers and louvres?	No
Left Vents in Closed Position?	Yes
Control and Indicating Equipment operating correctly?	Yes
Power Supply test OK?	Yes
Back up Batteries test OK?	Yes
Wiring OK?	Yes
Rain / Wind Sensors tested?	N/A
Interfacing confirmed as working?	Yes
Smoke detectors tested?	Yes
Cause and Effects Tested?	Yes

Cause & Effects arrangements & Checks completed:
Mag lock doors, where fitted, opened on aov activation.

Comments / Remedial Works required:
Fire alarm system is a detector linked aov with each floor having local vents/dampers with a smoke vent at top of staircase to roof. All lift lobby detectors tested and operated vents. Grd gr community area was not tested as called out to investigate multiple aov failures in other local blocks.

Customer Signature: Client/Representative's Name: no client available
Engineer Signature: Arrival Time: 12:15
Engineer Name: Barry McAuliffe Departure Time: 14:15

BAFE
Head Office : Unit 2, Regent Business Centre, Jubilee Rd, Burgess Hill, W Sussex, RH15 9TL

Figure 11-35: Allied Protection Inspection and Servicing certificate (automated Opening Vents) {LAK00000011} 15th May 2017 .

11.6.89 The field *'description of the works carried out'* is completed as *'AOV tested. All ok.'*

11.6.90 The inspection and servicing on the 15th May 2015 {LAK00000011}, lasted just two hours and yet this certificate states that 9 of the 11 listed checks were carried out. It recorded every one of these checks as 'Yes', other than "*Rain / wind sensors tested?*", which were not present in Grenfell Tower, and were correctly recorded 'N/A'.

11.6.91 Mr McAuliffe records that he did not *"clean, lubricate and tighten all actuators, dampers and louvres"*.

11.6.92 More checks were therefore undertaken in this site visit than the site visit on the 17th Jan 2017, and apparently in a shorter duration of time.

11.6.93 Mr McAuliffe has provided a witness statement to the Inquiry dated 16th June 2020 {LAK00000522}.

11.6.94 With regard to the provision of instructions and documentation relating to the operation of the smoke control system at Grenfell Tower, prior to his 15th May 2017 visit, Mr McAuliffe states at paragraph 19 {LAK00000522}:

I can confirm that I was not provided with any written instructions or other documentation relating to the operation of the AOV system.

11.6.95 To physically undertake the operational test of the smoke control system for every zone, as required quarterly (see Table 11-7), the maintenance engineer was required, as a minimum, to do the following to ensure the system and all its components were operating correctly for each operational test of the system:

a) Activate the system using a smoke detector;
b) Inspect the position of the dampers in the lobbies on all floors;
c) Inspect the position of the by-pass dampers at Level 2;
d) Inspect the operation of the smoke extract fan at roof level;
e) Inspect the operation of the smoke extract fan at Level 2;
f) Inspect the HMI panel, to check that it correctly indicates the system operation, floor activation and status of all dampers;
g) Reset the HMI panel at the Ground Floor once all inspections of dampers and fans have been completed.

11.6.96 Therefore, the engineer was required to activate the system 24 times (i.e. once for each lobby), and for each activation of the system, carry out the relevant checks on the other 23 floors.

11.6.97 The engineer was also required to carry out checks on the Boxing Gym corridor AOV at Level 2 and Community Room lobby AOV at ground level.

11.6.98 Mr McAuliffe describes at Paragraphs 23, 25, and 26 of his witness statement the parts of the smoke control system he tested and how that testing was carried out; stating {LAK00000522}:

23… When I started the job I focused on testing the automatic system in relation to every smoke detector head in the lift lobbies on each floor, (starting from the top floor and using the stair).

25… I carried out the testing one floor at a time. I set off each smoke detector head using my own artificial smoke (until the red light turned on) and checked that the smoke extract system in the lift lobbies started. I then proceeded to the AOV control panel in the reception lobby and reset the system. I repeated this for each floor, using the emergency stairs for access…

26… I was not able to test the smoke detectors on the ground floor lift lobby due to being called away to complete a reactive repair.

11.6.99 Mr McAuliffe does not state that he inspected any dampers, fans or the HMI panel to check the correct operation.

11.6.100 First Mr. McAuliffe [LAK00000522] doesn't say that he opened the grilles to inspect the dampers. In response to question 24 (how did you carry out this testing?) he said:

I carried out the testing one floor at a time. I set off each smoke detector head using my own artificial smoke (until the red light turned on) and checked that the smoke extract system in the lift lobbies started. I then proceeded to the AOV control panel in the reception lobby and reset the system. I repeated this for each floor, using the emergency stairs for access.

11.6.101 At par 40 and 42 he responds to which vents are noted on the Inspection Certificate to have been left in 'closed position' and why were the vents left closed:

40. This relates to the smoke extraction system in each lift lobby that automatically starts once the smoke detector heads are activated. The smoke extraction system stops once the AOV system is reset at the control panel in the ground floor reception lobby. I noted that the extraction system was closed down on reset.

42. The vents opened when the smoke extraction system was activated by the testing. The smoke extraction system turned off and the vents closed down upon reset of the AOV system.

11.6.102 Secondly, Mr. McAuliffe provided a statement (written down by his manager based on an interview but signed by McAuliffe on 26.6.17) [LAK00000486]. Regarding the steps he had taken during the May inspection, he says "*I then proceeded to activate the smoke detector in the lift lobby of each floor, listed [sic] for the vents to open, you can both see and hear this activity*".

11.6.103 The Tunstall auto-dialler records {THL00000019} for the 15th May 2017 visit show the auto-dialler being activated 20 times between 13:47:23 and 15:02:12 (a period of 1 hour and 15 minutes). But I note that those times do not match the recorded visit time on the certificate (Arrival 12:15 and departure 14:15).

11.6.104 As I have explained in Section 11.5 the auto-dialler records do not identify the location of the smoke detectors activated; therefore it is not possible to identify which smoke detectors Mr McAuliffe activated and on how many floors. However as only 20 activations are recorded at least 6 smoke detectors were not tested.

11.6.105 Mr McAuliffe records only that the ground lobby detector was not tested in the certificate.

11.6.106 For the 1 hr 15 minute period the smoke detectors were recorded as activating this meant Mr McAuliffe had just under 4 minutes to carry out the 20 tests he purports to have carried out. For the reasons set out in Table 11-7, I do not consider this to have been viable.

11.6.107 Taking Level 18 as an example, Mr McAuliffe needed to go to Level 18, trigger the smoke detector, go back down to the Lobby to read the HMI Panel; it is not clear how he inspected the 4 dampers before or after he injected the smoke in the detector at Level 18 from his evidence.

11.6.108 Once down in the lobby he hit reset on the HMI panel, and then needed to travel back up to Level 18 to visually confirm the dampers had shut. He could not rely on the HMI Panel to do that as it did not record the physical state of the dampers, only the signal being sent to them.

11.6.109 Mr McAuliffe recorded 'yes' to 'power supply test ok' {LAK00000011}, and states in his witness statement {LAK00000522}:

> 30 I recall that I did not directly test the power supply as the AOV control panel in the ground floor reception lobby contained a light indicating power was being applied to the panel. As this light was illuminated I could establish that the AOV control panel had power supply (we would usually only directly test panels where there is no such light on the panel or the light was not illuminated).

11.6.110 Therefore, Mr McAuliffe only considered if there was power to the system (i.e. there was no consideration of primary and secondary power supply switchover at ground and roof level for the fans).

11.6.111 Mr McAuliffe recorded that back battery tests were completed; Mr McAuliffe makes no statement regarding testing the 12 back-up batteries (one at ground level, one at roof level, and 1 per level on Levels 3, 5, 7, 9, 11, 13, 15, 17, 19, 21). I note I have seen evidence only of 11 backup batteries physically installed in Grenfell Tower.

11.6.112 Mr McAuliffe answered 'yes' to 'wiring ok', however he records in his witness statement that he "*did not test the wiring as there was no requirement to do so.*" {LAK00000522}.

11.6.113 Mr McAuliffe answered 'yes' to "*Control and indicating equipment operating correctly*", however, in his witness statement states {LAK00000522}:

> 33 **Question 5(f) of the Request ("BM01": ________________):** *In addition to testing automatic operation, did you test the manual function of the smoke control system?*
>
> 34 I did not test the manual function. Due to time constraints I focused on testing the automatic operation.

Figure 11-36: Excerpt from {LAK00000522}

11.6.114 Therefore, Mr McAuliffe did not test all the control equipment.

11.6.115 Further, in his witness statement Mr McAuliffe states {LAK00000522}:

> 35 **Question 5(g) of the Request ("BM01": ________________):** *Did you test, or assess in any way, the* environmental *function of the AOV system? What was the condition of the environmental aspects of the system?*
>
> 36 I did not test the environmental function and I do not know the condition of the environmental aspects of the system at the time of the visit.

Figure 11-37: Excerpt from {LAK00000522}

11.6.116 Therefore, while Mr McAuliffe answered yes to "*interfacing confirmed as working*?", interfacing of the smoke control system with the BMS was not checked as part of his visit.

11.6.117 Thus, based on the Inspection and Servicing Certificate (automated opening vents) {LAK00000011} and Mr McAuliffe's witness statement {LAK00000522}, the 15th May 2017 visit was limited to activating 20 smoke detectors in Grenfell Tower.

11.6.118 This record of maintenance therefore does not provide evidence of the operational condition of the smoke control system prior to the 14th June 2017.

11.6.119 My summary of what maintenance was carried out by Allied Protection for the smoke control system against the minimum performance requirements is set out in Table 11-7.

11.7 Concluding remarks

11.7.1 Reported defects in the environmental and smoke control system

11.7.2 I have identified two reported defects relevant to the smoke control system; Rydon's report that the system was not operating in environmental mode on the 1st of June 2017 and Carl Stokes' report of a loose fire protected cable in the roof plant room in April 2016

11.7.3 The evidence provided by Rydon (of the system not working) was not conclusive. It would appear that the Temperature Status Screen, photographed by Rydon, was a redundant part of the system. And so, in itself, does not indicate a fault with the system.

11.7.4 There is no reference to a defect with the smoke extract mode, the only defect recorded is in relation to the environmental mode. However, neither JS Wright, PSB or Direct Control Systems appear to have attended site to confirm if the system was, in fact, not operational prior to 14th June 2017.

11.7.5 It is therefore not known whether this report was in fact an actual defect.

11.7.6 However, KCTMO did not instruct any test of the smoke control system to check it was operable. As they were a combined system and there was a potential physical defect with the environmental system, the impact on the smoke control system could not be known without a system test.

11.7.7 Physical failures of the equipment required to operate both in environmental and smoke mode could affect operation in either mode. The issues in the environmental mode could involve physical defects such as dampers not being able to open or fans unable to operate. These could also cause the system not to operate as intended in smoke mode. Therefore, without knowing the extent of the issues involved in these faults, it cannot be concluded without doubt, that these did not have an impact in smoke mode.

11.7.8 Mr Stokes reported a loose fire protected cable in the roof plant room in April 2016. The exact purpose of this cable and whether its 'loose' condition could impact the smoke control system had also not been resolved by KCTMO by the time of the fire.

11.7.9 Based on my analysis of post-fire photographs and the PSB design documentation, it seems likely this cable was installed for an automatic shut off damper beneath the fan at roof level. This automatic damper was never installed. An existing damper was retained and fixed in the open position. In this case the loose cable would appear to not have impacted on the operation of the smoke control system.

11.7.10 However, I have seen no evidence that Rydon or KCTMO had resolved this potential defect by the time of the fire.

11.7.11 **Removal of the interface between smoke control system and landlord gas supply and basement boilers**

11.7.12 Following practical completion KCTMO were proposing to disconnect an interface between the smoke control system and the boilers and gas supply in the basement of Grenfell Tower.

11.7.13 My analysis of the design documentation shows that a complex interface between the refurbishment smoke control system, the refurbishment BMS system in the basement and an existing BMS system in the basement was relied on to shut down the boilers and the landlord gas supply.

11.7.14 My analysis also shows that the exact method of interfacing these three separate systems carried out during the refurbishment is not documented.

11.7.15 However, there is some evidence that the smoke control system was shutting down both the refurbishment boilers which served Grenfell Tower and the existing boilers which served the adjacent finger blocks.

11.7.16 KCTMO wished to disconnect this shut down, as the existing boilers were required to be manually restarted every time there was an activation of a smoke detector in Grenfell Tower.

11.7.17 KCTMO were aware of this issue prior to practical completion of the refurbishment but Ms Williams chose not to instruct a change, citing contractual conditions regarding late instructions.

11.7.18 KCTMO requested after practical completion Rydon to carry out the disconnection. However, I have been unable to identify from the evidence whether Rydon or any of their sub-contractors carried out this work.

11.7.19 An alternative solution, to install a new automatic detection system in the basement which would be interfaced to shut down the boilers and landlord gas supply instead of the smoke control system, was never instructed.

11.7.20 The post-fire inspection of the refurbishment BMS by WSP shows that hardwired controls to shut down the refurbishment BMS and the existing BMS (and therefore all boilers and the landlord gas supply) were not in place at the time of the fire. It is not clear which of these controls had been in place at the time of practical completion of the refurbishment

11.7.21 The post-fire inspection found that the wiring from the refurbishment BMS to the Master Smoke Control Panel to send a signal to run in environmental mode was still in place.

11.7.22 The post-fire inspection also found that the wiring from the Master Smoke Control Panel to the refurbishment BMS to send a fire alarm active signal and three types of fault signal was still in place.

11.7.23 My team's analysis of these interfaces and the programme logic in the Master Smoke Control Panel indicate that the smoke control system should have been able to operate as intended by the PSB design with these interfaces in place.

11.7.24 However, I consider the interface between the refurbishment smoke control system, the refurbishment BMS system and the existing BMS system (both in the basement) to be complex. Therefore any changes to the wiring or programming of these three systems required testing of the smoke control system to ensure its operation was not impacted by those changes

11.7.25 This was particularly required as no coordinated documentation for the interfaces was provided by Rydon in their building manual to KCTMO.

11.7.26 I have no evidence that KCTMO instructed any operational test of the smoke control system to check the controls were not impacted by those changes.

11.7.27 **Adequacy of maintenance information provided by Rydon to KCTMO for the smoke control system**

11.7.28 Two planned maintenance schedules were provided in the Building Manual for the smoke control system. I have found both to provide an incomplete description of the periodic checks set out in the relevant British Standards. In particular, no planned maintenance schedule for the detection system which activates the smoke control system is included.

11.7.29 Manufacturers' literature was included in the building manual with the stated purpose being to provide manufacturers' instructions for servicing and maintenance.

11.7.30 Of the 15 components in the smoke control system, manufacturers' information relevant to the product installed was provided for just 5 components.

11.7.31 For 2 of those components, the smoke detectors and the auto-dialler, I additionally found manufacturers' information for products that were not installed at practical completion.

11.7.32 For 3 components, the pressure switch, the vent at the head of the stair, and the floor override switches, I found manufacturers' information for products which were not installed.

11.7.33 No manufacturers' information was therefore provided for 10 of the components of the smoke control system.

11.7.34 Therefore I consider the maintenance information for the smoke control system contained in the Building Manual provided to KCTMO by Rydon following the primary refurbishment to be inadequate.

11.7.35 **Maintenance of the smoke control system**

11.7.36 Further to my investigation of the compliance of the smoke control system with the Building Regulations, my investigation in this section has considered what evidence there is that the smoke control system was *"maintained in an efficient state, in efficient working order and in good repair"* as per KCTMO's duty under article 17 of the RR(FS)O.

11.7.37 My summary of the evidence of the operational condition of the smoke control system is in Table 11-7.

11.7.38 I have found no evidence from the ESAs' weekly activation of the smoke control system or the monthly records that the system was in 'good working order' or that the correct operation of the smoke control system was checked in any way.

11.7.39 From analysis of the two Allied Protection Inspection and Servicing Certificates (automated opening vents), it appears that no automatic activation of the system was carried out using any detectors during the first visit on 17th January 2017.

11.7.40 I also do not consider it possible for all the 91 dampers to be serviced and for their correct operation checked in the 3 hour visit which allowed just 7.5 minutes to visit each floor and just under 2 minutes per damper.

11.7.41 From my analysis of the second visit on 15th May 2017 it appears that 20 detectors were activated; therefore 6 detectors were not tested. In the 1 hr 15 min period detectors were activated, the engineer had just under 4 minutes to carry out each of the 20 tests.

11.7.42 I do not consider it possible for the engineer to have checked the correct operation of the fans at the roof level and Level 2 and the position of all 91 dampers for each test, as was required.

11.7.43 I do not therefore consider any of the records of maintenance to provide evidence of the operating potential of the smoke control system prior to the fire on the 14th June 2017.

11.7.44 Based on my own experiences of signing off the tests and records for fire safety systems, on the basis of the above, I would not be able to confirm to a client that the system had the potential to operate as intended in the event of a fire.

11.7.45 I am therefore required to consider the possibility in my investigation of the operation of the smoke control system on 14th June 2017 that the smoke control system was not fully functioning as per PSB's intended operation.

12 Analysis of the lobby smoke control system performance the night of the fire

13 Analysis of the smoke control system installation as a protected shaft the night of the fire

14 Expert 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, 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 will 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. I understand that proceedings for contempt of court may be brought against anyone who makes, or causes to be made, a false statement in a document verified by a statement of truth without an honest belief in its truth.

Signature Barbara Lane. Date 21 May 2021

Name in full Dr Barbara Ann Lane