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

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

Phase 1 Report – Appendix J

Lobby smoke control – requirements and provisions

REPORT OF

Dr Barbara Lane FREng FRSE CEng

Fire Safety Engineering

24th October 2018

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

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Appendix J– Lobby smoke control – requirements and provisions

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J1 Purpose of Appendix J

J1.1.1 In this Appendix J, I provide my review of the mechanical smoke control system installed in the lobbies on every floor of Grenfell Tower.

J1.1.2 This review is based on evidence that I found during my post-fire site inspections at Grenfell Tower, and on the design and construction stage documentation which I have seen to date.

J1.1.3 I have also been provided with the software programme files for the main control panel and the Human-Machine Interface (HMI) control panel.

J1.1.4 I have sought to explain the recommended provisions for "*smoke control of common escape routes*" at the time Grenfell Tower was built, as set out in British Standard Code of Practice CP3 1971, and in the GLC Section 20 Code of Practice 1970; as well as at the time of the refurbishment works in 2012 – 2016, as set out in Approved Document B 2013.

J1.1.5 Regarding the software and controls I have relied on technical input from my chartered mechanical engineering assistant Dr Peter Woodburn and Mr Joe Wade.

J1.1.6 Mr Wade is a chartered engineer and has extensive experience (gained over 20 years) in commissioning building systems in general, and mechanical ventilation systems specifically. We have worked together handing over major projects in the last 10 years.

J1.1.7 I have concluded that the design of the original smoke control system did not use the recommended provisions of Section 20 of the GLC Code, as set out in Section J4.1. This is not to imply that this was a non-compliance with Section 20 when the building was originally constructed, but instead that the original smoke control system used a different basis of design.

J1.1.8 I have concluded that the original smoke control system was designed as a corridor smoke dispersal system as defined in Figure 16b of CP3 1971, but was not compliant with the recommended provisions of that Code, as set out in Section J4.2.

J1.1.9 I have concluded that the mechanical smoke control system designed and installed in the 2012 – 2016 refurbishment was intended to provide an "average open door velocity" between the lobby and the stair, and that this velocity was intended to comply with the airflow performance criterion of a Class B pressure differential system as defined in BSEN 12101-6:2005.

J1.1.10 As I explain in Section J5.2.16 and Table J.6, a Class B pressure differential system has substantially more performance requirements than this single open door velocity performance. I have found no evidence that any of those other performance requirements were designed for.

J1.1.11 I have concluded that the design of the lobby smoke control system was substantially non-compliant with the performance requirements of the relevant British Standard - BS EN 12101-6:2005 *Smoke and heat control systems —Part*

6: Specification for pressure differential systems — Kits - and consequently it did not meet the guidance within ADB 2013, as set out in Section J5 of this Appendix.

J1.1.12 Despite extensive documentation now being available to me, I have been unable to determine how the design was intended to meet the requirements of the Statutory Guidance and therefore comply with the functional requirements of the Building Regulations.

J1.1.13 I would like to consider in detail the project team's documentation for the system in Phase 2, in order to try and understand more clearly how compliance of the system was intended to be achieved, including whether alternative means of compliance i.e. outside the guidance in ADB, was meant to be provided.

J1.1.14 There are other issues I have identified about the compliance of the lobby smoke control system.

J1.1.15 In particular, there is substantial evidence of a number of non-compliances with the system as installed in the tower, including:

a) The existing builders work shafts do not appear to have been checked for leakage in accordance with Section 8.2.4 of the SCA guidance, or treated in accordance with the guidance in Section 11.8.2.8 of BS EN 12101-6 – and have no stated fire resistance performance in PSB's design documentation. They are marked with the required 2 hour rating in the Studio E drawings (SEA00003112).

b) Section 10.15 of ADB 2013 states that the requirement for fire and smoke dampers to a *Protected Shaft* is 60 minute rating for Integrity and Smoke leakage. Specifically, this is an ES60 rating, as classified using BS EN 13501-3, based on testing using BS EN 1366-2.

c) However, because the dampers are in a powered pressure differential system, they are required to meet the standards required for "*smoke control dampers*" and this ES60 rating must be achieved in accordance with the classification in BS EN 13501-4 and therefore based on testing to the higher standard of BS EN 1366-10.

d) The dampers installed in the north and south shafts were Gilbert Series 54 "*Smoke evacuation dampers*":

   i. The literature submitted to the Inquiry by PSB (PSB00000201) states that this product was "*fully tested to the requirements of EN1366 pt 2 for 1 hour.*" This is dated October 2011. However, no formal classification is provided in accordance with BS EN 13501-3 based on testing against BS EN 1366-2.

   ii. Additional test evidence from Gilberts was also received. WF Test Report No. 309850 (dated 06/10/2011) is a test of a damper sponsored by Gilberts to BS EN 1366-2:1999. The report specifically 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.*"

The PSB literature (PSB00000201) was therefore factually incorrect at the time of issue as the damper had not been "*fully tested to the requirements of EN1366 pt 2*".

iii. BS EN 1366-2 is the test standard for fire dampers in a natural ventilation system – i.e. testing that the damper functions when smoke is moving under buoyancy only. In a smoke control system, the fans are constantly running extracting air, therefore applying a higher pressure on the damper and a higher test standard is required.

e) The Gilberts literature dated October 2011 implied that the dampers were fully compliant with BS EN 1366-2 for fire dampers. However, the formal certification of the damper fire resistance (both E and S ratings), appears to have been rescinded by the manufacturer in April 2017. It is possible that this was because the test report dated October 2011, on which the earlier literature was based, did not in fact demonstrate a test to the full requirements of the test standard.

f) Therefore, the dampers that were installed did not have the relevant test evidence they required, to demonstrate performance to either of ADB 2013 or BS EN 12101-6. Specifically, they did not have the performance ES60 when classified against either BS EN 13501 Part 3 for fire dampers or Part 4 for smoke control dampers.

g) PSB's Technical Submission does not in fact specify any fire integrity rating or smoke leakage requirement for the AOV dampers in order to comply with the requirements of ADB 2013 or BS EN 12101-6. Further, PSB's design schematic (p1238 of RYD00000577) does not specify a fire integrity or smoke leakage performance requirement for the AOV dampers, but states that the design, supply and installation of any dampers is outside their scope of work.

J1.1.16 In addition, I have now considered the commissioning documentation which has been provided to the Inquiry. My investigation has shown that:

a) The commissioning of the system omitted a large number of the performance requirements of BS EN 12101-6:2005.

b) The commissioning of the system also omitted a substantial proportion of the provisions made within the Smoke Control Association (SCA) Guidance on Smoke Control to Common Escape routes in apartment Buildings (Flats and Maisonettes) Rev 2: October 2015.

J1.1.17 On the basis of the information I have currently been provided with, I have therefore been unable to confirm that the lobby smoke control system was fully commissioned to BS EN 12101-6:2005.

J1.1.18 Commissioning is required to demonstrate compliance with Building Regulation 7, which states:

"*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;"

J1.1.19 Without commissioning there can be no evidence that an active building system can "*adequately perform the functions for which they are designed*".

J1.1.20 Therefore, I currently consider the evidence of commissioning to be substantially non-compliant.

J1.1.21 I have found evidence of a device connected to the smoke control system that was designed to automatically call a remote monitoring control centre upon activation of the system (known as an "autodialler"). This device was activated very early in the fire on 14th June 2017.

J1.1.22 The smoke control system was also provided with a control for fire fighters. This was by means of a touch screen HMI control panel at ground level entrance lobby. From here the floor on which the system was operating could be controlled. I have found evidence that this panel was opened during the fire as I set out in Section J9.5.

J1.1.23 The smoke control system could also be operated using a (yellow) key switch control provided in each lobby. Once the HMI panel was switched from Auto to On, activation of this key switch control in a lobby, would instruct the system to operate on that floor. At this stage, I have seen no evidence which would suggest that these key switches were successfully operated during the fire.

J1.1.24 The smoke control system was intended to operate on one floor only, as per the requirements in the Statutory Guidance, ADB 2013. The system therefore could not operate on multiple lobbies simultaneously, and so could not prevent smoke entering the stair in circumstances where there was smoke on multiple floors. This is consistent with the Statutory Guidance for smoke control systems which does not require operation of any smoke control system on multiple floors.

J1.1.25 I have concluded that the shafts and ductwork for the smoke control system constituted a "*protected shaft*" as defined by ADB 2013. Therefore, in accordance with Section 8.37 of ADB 2013, they were required to meet the compartmentation requirements of the lowest rated element of compartmentation (i.e. floor or wall) that the system penetrated. The system penetrated the enclosure to the lobby at each level - where the dampers were provided. The shafts also penetrated each floor of the building. Therefore, in accordance with ADB 2013, the shafts and ductwork would need to achieve a 2 hour fire resistance rating for Integrity and Insulation, each side separately.

J1.1.26 The original design of Grenfell Tower was required to comply with Section 20 of the London Building Acts. The guidance for Section 20 that was relevant at the time of construction (please refer to Appendix H) identifies that the wall between the lobby and the flats at each level would also need to achieve a 2 hour rating. I have seen no explanation in PSB's Technical Submission as to what fire resistance performance was to be achieved by their system design.

J1.1.27 Regarding its required operational performance, BS EN 12101-6:2005 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*."

J1.1.28 To understand the performance of the system on the night, I want to make clear that this requires consideration of a series of points:

a) the performance of the system to the standard described in BS EN 12101-6:2005 was not possible as that is not what was designed or commissioned;

b) an alternative performance condition has not been clearly set out by the design team and so that performance cannot currently be assessed by me;

c) the evidence I do have shows that a substantial number of the performance requirements are omitted from the design features, and therefore I do not currently understand how the system as designed could ever achieve the performance required by BSEN 12101-6: 2005. That performance requirement is to minimise the potential for serious contamination of firefighting shafts by smoke during means of escape and fire service operations;

d) I understand that the design team considered the system as designed as being "no worse" than the existing system in Grenfell Tower. But I currently have no evidence as to how they established and proved this to be the case.

J1.1.29 There is an increasing amount of evidence from the residents about the way the system operated on the night. I will need to review this very carefully when their evidence is completed. This includes evidence of noise in the lobbies at level 23 and noise in the north and south shafts on other floors.

J1.1.30 The oral evidence of Farhad Neda (Transcript 18th October, p27) about smoke leaking into the lobby of Level 23 via the smoke shaft vents, on the north and south side, is a critical piece of evidence at this stage. This is because it could indicate a significant failure of the smoke control system to prevent contamination of compartments away from the fire compartment (in breach of Section 11.8.2.10 of BS EN 12101-6, as discussed further below).

J1.1.31 This evidence may also indicate that there was a failure to comply with the compartmentation rules for protected shafts in Section 8 of ADB 2013. The presence of non-compliant smoke control dampers, now raises concerns as it may explain this witness evidence.

J1.1.32 In Section 14 of my Expert Report I provided the evidence currently available about the operation of the smoke control system on Level 4 in the early stages of the fire. This is relevant only in the early stages of the fire, when an internal compartment fire was located on level 4 only, and therefore when the lobby smoke control system should have been operating within its required design parameters.

J1.1.33 It is to be expected that the smoke control system would have operated on the fire floor (i.e. floor 4) had it been functioning correctly. In that regard it is now clear that the autodialler had sent a signal to Tunstall by 00:55, and there is no evidence of smoke at that time on any other floor other than Floor 4. This aligns with the evidence of the residents in Flat 16 who observed smoke by their flat entrance door, and opened that door onto the lobby. A smoke detector was present in the lobby outside Flat 16 and near the north builders' work shafts.

J1.1.34 Residents on Level 4 observed smoke on the lobby. Additionally, Mohammed Ahmed, a resident of Flat 102 on the 13th floor escaped from the building at 01:21(MET000080463); as he escaped past Level 4 he reports seeing three fire men at the stair door and thick black smoke coming from the hallway into the stairs.

J1.1.35 I intend to carry on my investigations into the smoke control system and how it performed on the night during the course of my Phase 2 work. In my opinion this work is important because it may be directly relevant to the condition in the lobbies and the stairs during the fire.

J1.1.36 The condition in the lobbies and the stairs means that it is necessary to consider the consequence of failure of any active or passive system installed in Grenfell Tower.

J2 Introduction

J2.1.1 Grenfell Tower was originally constructed with a lobby smoke control system and stairway ventilation.

J2.1.2 The lobby smoke control system was refurbished in the 2012 – 2016 works.

J2.1.3 The intent of the refurbishment was set out in the Employer's Requirements (MAX00006475) as:

> **J2.1.4** *"It is not viable to adapt the existing system to comply with current standards. Given the physical constraints of the existing building, the design approach has therefore been to retain the existing system and replace all of the existing components with new, equivalent or better components."*

J2.1.5 The performance standard of the original system was not known to RKBC, as stated in an email to Max Fordham (MAX00004353).

J2.1.6 During the design process, a number of configurations were proposed. Here in Appendix J, I will describe only the original system and the final proposed refurbishment system [Rev 6 Smoke ventilation technical submission – lobby smoke control system; by PSB] which appears to have been the system installed in Grenfell Tower.

J2.1.7 The original and refurbished smoke control systems were also combined with an environmental ventilation system, to provide temperature control within the lobbies. For the refurbishment this was in order to address the increased heating of the lobbies caused by the installation of the new service risers in the lobby (p7 of RYD00000577). It was not intended as a cooling system. This was communicated to Claire Williams of the TMO in person by David Hughes on 1st June 2017 (Kennedys letter to the Inquiry dated 26th July 2018).

J2.1.8 In the event of fire, the environmental system was designed to switch into fire mode, on activation of automatic fire detection in a single lobby.

J2.1.9 Some of the components of the original smoke control system were retained in the refurbishment, specifically the openings for Automatic Opening Vents (AOVs) in each lobby, and the four builders' work shafts – 2 North and 2 South – running from level 4 to roof level.

J2.1.10 I have sought to describe the original system as it was the design of this system which determined the layout and dimensions of the smoke shafts and AOVs at the time of the primary refurbishment. I then describe the final refurbished smoke control system as I understand it to have been installed and in place, as at14th June 2017.

J2.1.11 It should be noted that the smoke control system was damaged during the fire and not operational at the time of my site visit. Therefore, I can only obtain information on the intended performance of the smoke control system, and the methodology by which it was controlled, from design documentation. I cannot take my own measurements of any of the airflow or pressure differential requirements, as would be required pursuant to BS EN 12101-6:2005.

J2.1.12 I must rely on residents and fire fighters for their observations of performance on the night. The Public Inquiry has now appointed an expert in fire chemistry and toxicity to examine soot deposition within the Tower (Professor Anna Stec), and I will also rely on any physical evidence of soot in all parts of the system.

J3 Purpose of a lobby smoke control system in a residential building

J3.1.1 The stated purpose of providing smoke control to the common lobby in ADB 2013 (Section 2.25) is as follows:

"*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"

J3.1.2 Diagram 52 in ADB 2013, advises *"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."*

J3.1.3 ADB 2013 Section 2.25 "***Smoke control of common escape routes***" states that smoke control can be achieved as follows:

"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."

J3.1.4 ADB 2013 Section 2.27 describes two types of mechanical system:

"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."

J3.1.5 Natural ventilation smoke systems provide the means for hot smoke to ventilate from a space driven by its own buoyancy, thereby protecting escape routes.

J3.1.6 Typically, natural ventilation systems ventilate smoke from the common corridor into a shaft which is open to the atmosphere at the top and acts as a chimney.

J3.1.7 Mechanical ventilation smoke systems use fans, ducts, vents, shafts and other features to draw smoke away from the stair and common corridor. Typically, mechanical exhaust systems exhaust smoke from the common corridor thereby preventing smoke spreading into the stair, and providing some protection to the common corridor.

J3.1.8 Pressure differential systems, are a form of mechanical ventilation, as described in BS EN 12101-6:2005. This is a system of fans, ducts, vents, and other features, provided for the purpose of creating a lower pressure in the fire zone than in the protected space. Pressure differential systems are designed to hold back smoke at a leaky physical barrier in a building, such as a door (either open or closed) or other similarly restricted openings.

J3.1.9 A pressure differential system can be either a *depressurisation* system, which means the air pressure in the fire zone or adjacent spaces is reduced below that in the protected space; or a *pressurization* system which means the air pressure in the spaces being protected is raised above that in the fire zone.

J3.1.10 In all types of natural or mechanical system, vents on the fire floor are opened and vents on all other floors are closed, in order to allow the full capacity of the smoke control system to be directed to a single fire floor only.

J4 Recommended Provisions for the smoke control system at Grenfell Tower at the time of original construction

J4.1 GLC Section 20 Code of Practice 1970

J4.1.1 The GLC Section 20 Code of practice 1970 requires buildings with a storey height of 24.384m or more to be provided with what is termed a *fire-fighting lobby approach staircase*.

J4.1.2 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.

J4.1.3 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 also not two separate shafts provided as required in A2.02(2) to ventilate each of the lobby and stair.

J4.1.4 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 stair case. Grenfell Tower contained a single lobby between the flats and the staircase.

J4.1.5 In Figure J.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.

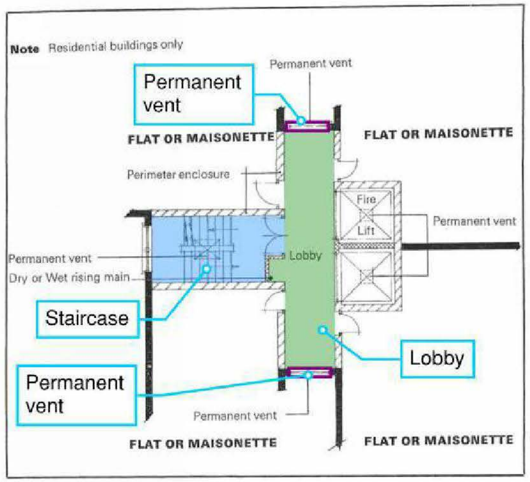
b) Separately, for the staircase, either ventilation by a shaft or by permanent openings to the open air at the top and the bottom of not less than 0.9m^2 was required. As I have explained above, no shaft was provided to ventilate the staircase of Grenfell Tower. A permanent opening of 1m^2 was provided at the head of the staircase, however I have no evidence that a permanent opening was ever provided at the bottom of the staircase.

J4.1.6 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;

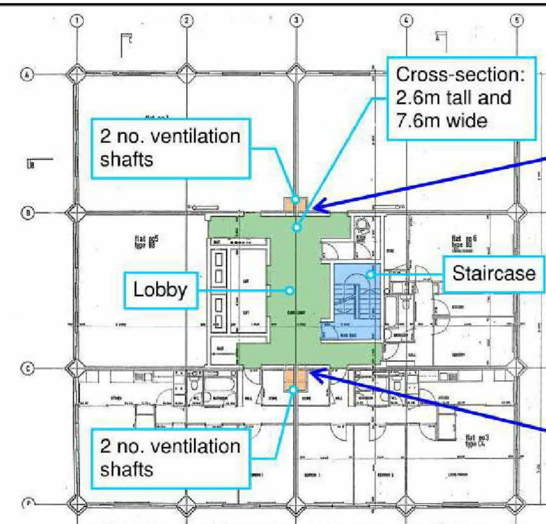
or

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.

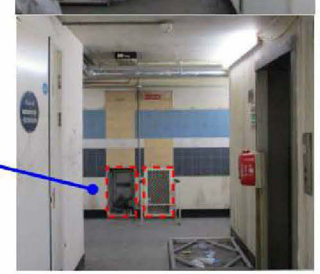
2. Required ventilation of internal staircase

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 AOV

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.

An AOV 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.

An AOV 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 J.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

J4.2 British Standard Code of Practice CP3 1971

J4.2.1 As I have explained in Appendix D, and in Section 4 of my 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 stair case in Grenfell Tower. In particular, Figure 16 of CP3 1971 "*Corridor access Flats; single staircase tower block*" was applicable, as excerpted below in Figure J.3.

J4.2.2 CP3 1971 stipulated the following provisions for smoke ventilation:

a) Permanently open vent at head of stair of 1.0m^2 (Section 3.4.6); and

b) Cross ventilation in lobby with 1.5m^2 of Automatic Opening Vent (AOV) or Permanent Vent (PV) opening to outside on each side of the lobby providing smoke dispersal from the common corridor (Section 3.3.4.3).

J4.2.3 Section 2.3.4.1(3) of CP3 1971 also 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."*

J4.2.4 However, Section 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.

J4.2.5 It is also to be noted that Section 2.5.3 of CP3 made clear that smoke control was intended to protect the stairs "*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 J.2: Section 2.5.3 of CP3 1971

J4.2.6 The arrangement recommended by CP3 1971 is shown in Figure J.3. In particular, the requirement for two remotely cited AOVs providing fresh air ventilation from the lobby is shown.

J4.2.7 The system also required doors of a particular fire resistance: Type 3 for dwellings and Type 2 to the staircase.

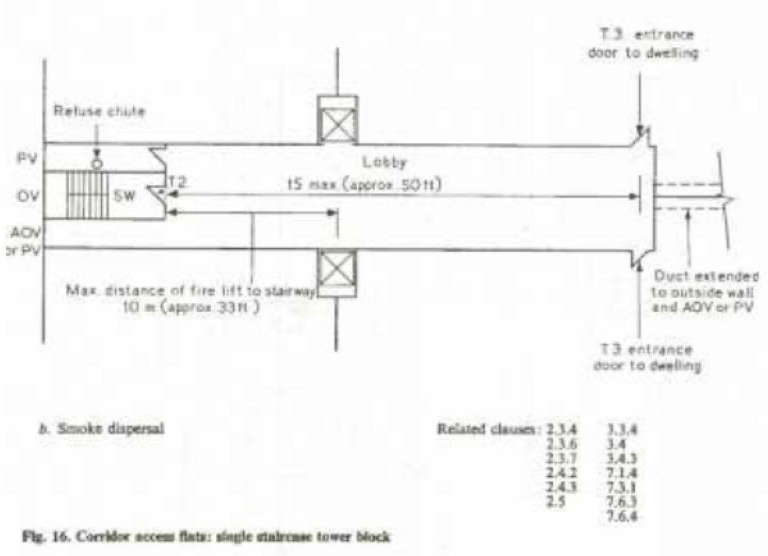


Figure J.3: Excerpt from CP3 1971 showing the recommended provisions for escape and smoke control in a single stair tower block.

J4.2.8 The original system

J4.2.9 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."

J4.2.10 Max Fordham further described the original system in MAX00002335, excerpted in Figure J.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 J.4: Excerpt from MAX00002335 describing the original smoke ventilation system and its operation during a fire.

J4.2.11 The operation of the smoke ventilation mode is visualised for the fire floor in Figure J4 below.

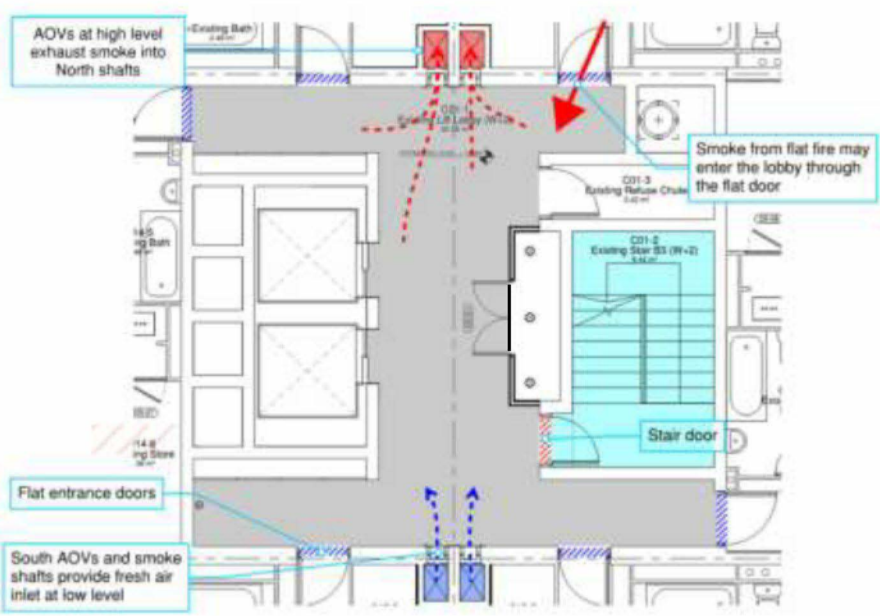


Figure J.5: Operation of the original smoke ventilation system on the fire floor, overlaid on an excerpt from SEA00010474.

J4.2.12 Components of the original system

J4.2.13 As shown in Figure J.4, Max Fordham's report described the original ventilation system as having the following elements:

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

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

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

d) Associated controls and power supplies.

J4.2.14 Original system – Operation for smoke

J4.2.15 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, available for manual operation by fire fighters.

J4.2.16 In both modes, AOVs are opened automatically on the fire floor and all other AOVs on all other floors, which are normally shut, remain closed.

J4.2.17 The default smoke mode is natural ventilation, in which smoke is exhausted via the north smoke shafts (high level AOVs) driven by the buoyancy of the smoke (the 'chimney effect'). Fresh air enters the lobby via the south smoke shafts (low level AOVs) by natural means. Therefore, the south smoke shafts provide the inlet air to replace the smoke exhausted through the north smoke shafts.

J4.2.18 A manual override facility was provided to enable fire fighters to provide additional mechanical ventilation if they required. If the mechanical ventilation mode is selected by firefighters using the manual override controls at Ground Level, then smoke is exhausted via the north smoke shafts (high level AOVs) driven by the exhaust fan. Fresh inlet air enters the lobby via the South smoke shafts (low level AOVs) driven by the supply fan. Therefore, the direction of air flow within both north and south smoke shafts remains as in the natural ventilation mode.

J4.2.19 Compliance of the original system

J4.2.20 In natural ventilation mode, the aggregate area of the smoke shafts on each side of the lobby was $0.48m^2$, which was significantly lower than the equivalent free area recommended by CP3 1971 at each end of the lobby which is $1.5m^2$ (Section J4).

J4.2.21 Therefore, the system did not comply with the requirements of CP3 1971.

J4.2.22 CP3 1971 does not specify any mechanical performance requirements for the system when being operated by the fire service but I note this mode of operation was provided.

J5 Recommended Provisions for the smoke control system at Grenfell Tower at the time of the primary refurbishment

J5.1 Approved Document Part B

J5.1.1 The basis of design for smoke control in high-rise residential buildings in accordance with the statutory guidance in ADB 2013 is as follows:

1. *"Fires do not normally start in two different places in a building at the same time"* (ADB 2013 Section B1.iii);
2. There is a low probability that it will spread beyond the flat of fire origin (ADB 2013 Section 2.3.c.);
3. *"... it is probable that some smoke will get into a common corridor or lobby from a flat in a fire, if only because the entrance door will be opened when the occupants escape."* (ADB 2013 Section 2.25); and
4. *"iv – On detection of smoke in the common corridor/lobby, the vent(s) on the fire floor, the vent at the top of the smoke shaft and to the stair should all open simultaneously. The vents from the corridors/lobbies on all other storeys should remain closed."* (ADB 2013 Section 2.26).

J5.1.2 The design basis fire assumed in ADB 2013 for the smoke control system is therefore a fire starting in a single location, and the system is required to deal with smoke from a single compartment.

J5.1.3 Section 2.25 of ADB 2013 includes the following:

"*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."

J5.1.4 Section 2.26 of ADB 2013 states:

"In buildings, other than small ones complying with Diagram 9, the corridor or lobby adjoining the stair should be provided with a vent. The vent from the corridor/lobby should be located as high as is practicable and such that the top edge is at least as high as the top of the door to the stair.

There should also be a vent, with a free area of at least 1.0m^2, from the top storey of the stairway to the outside.

In single stair buildings, the smoke vents on the fire floor and at the head of the stair should be actuated by means of smoke detectors in the common access spaces providing access to the flats."

J5.1.5 Furthermore, ADB 2013 Section 2.27 states that:

"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."

J5.1.6 Therefore, ADB 2013 Section 2.27 recommends the use of BS EN 12101-6:2005. However, Section 2.35 of ADB 2013 states that where common stairs are also required in the design to serve as firefighting stairs, account will have to be taken of the guidance in Section 17 of the ADB 2013.

J5.1.7 Diagram 52 of ADB 2013 provides guidance on the components of a firefighting shaft. Diagram 52 is reproduced in Figure J.6. Diagram 52 Note 2 requires that smoke control is provided in accordance with an additional code of practice BS5588-5:2004. Therefore, this is also a relevant code of practice for the design of mechanical smoke control, in order to comply with ADB Sections 2 and 17.

J5.1.8 However, should the building be designed using Section 17.14 of ADB 2013 that permits that in blocks of flats, the addition of a firefighting lobby between the stair and protected corridor or lobby for means of escape may be omitted (shown in arrangement (b) in Diagram 52). This is on the basis that all flats are accessed from the common corridor and none enter directly onto the stair. Therefore, there is an implicit assumption in ADB 2013 that the common corridor is sufficiently protected to function as the firefighting lobby in a high rise block of flats.

J5.1.9 Note 2 in Diagram 52 (Figure J.6) advises that where the firefighting shaft serves only flats, the provisions for smoke control given in paragraph 2.25 may be followed instead.

J5.1.10 Therefore, with regard to smoke control on the residential floors of Grenfell Tower, only the guidance in Section 2.25 of ADB 2013 for smoke control of common escape routes is relevant and BS 5588-5 does not need to be referred to.

J5.1.11 Section 2.25 then permits the use of either natural smoke ventilation systems, referred to in Section 2.26 of ADB 2013, or mechanical smoke ventilation systems (including pressure differential systems) as referred to in Section 2.27 of ADB 2013.

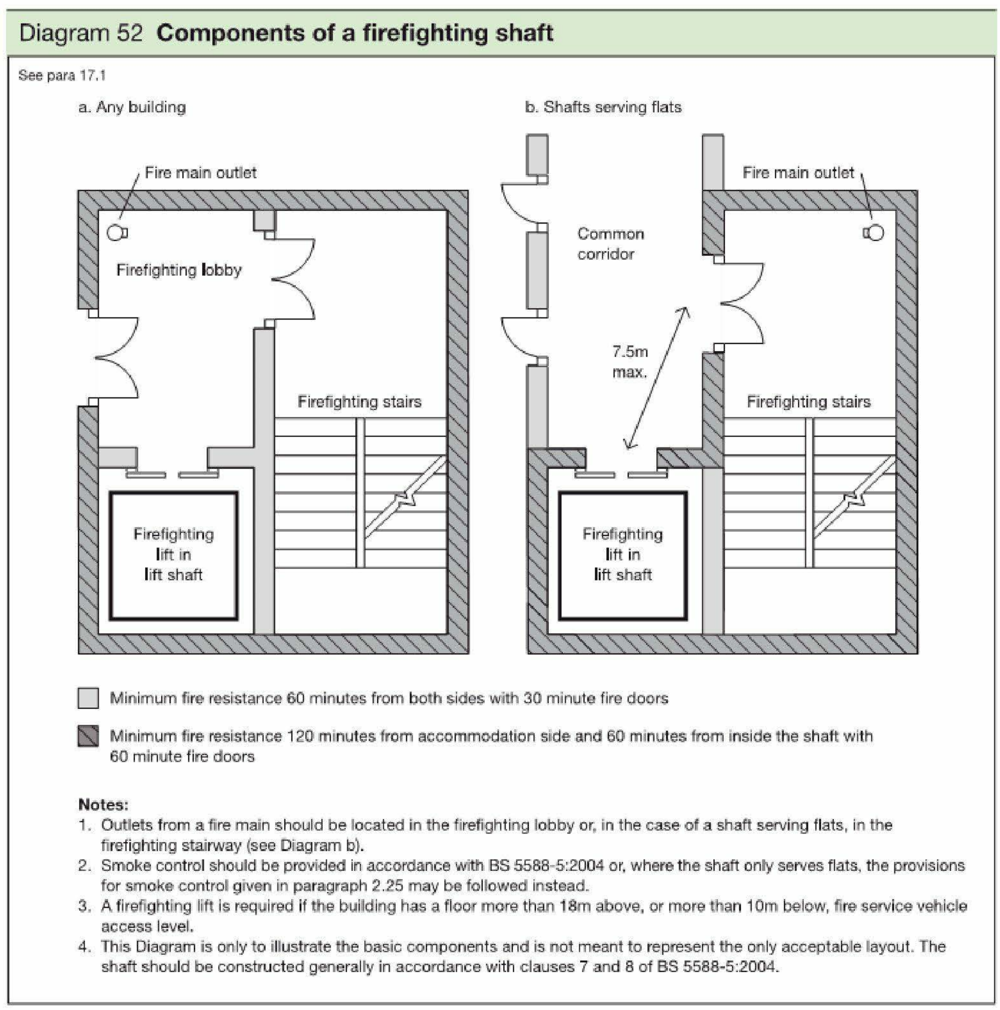


Figure J.6: Diagram 52 from ADB 2013.

J5.1.12 The ADB 2013 guidance for the zone where ventilation should be provided for residential buildings with one common stair (ADB 2013 Diagram 7) is shown in Figure J.7 (Shaded area). Diagram 7.b. is the most relevant to the design of Grenfell Tower, due to the arrangement of the common lobby to the stair.

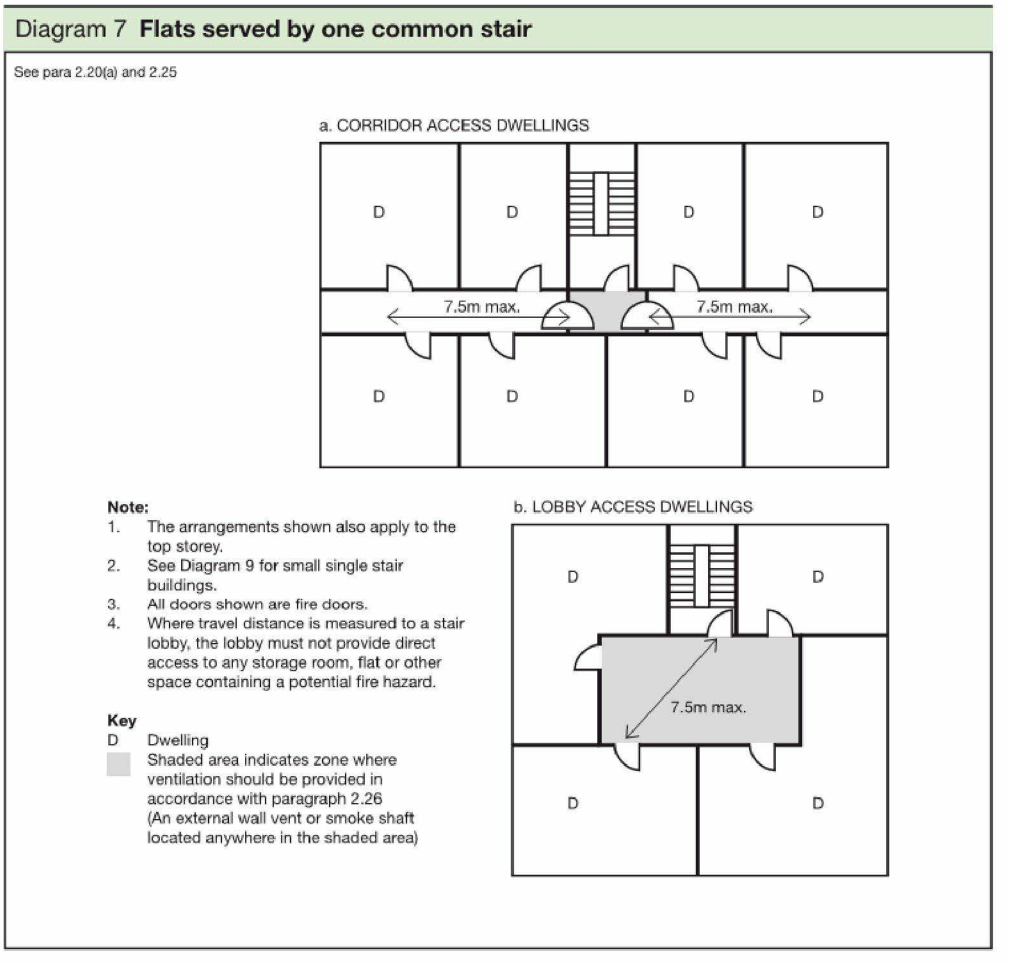


Figure J.7: Diagram 7 from ADB 2013.

J5.1.13 The north and south smoke shafts are protected shafts, defined by 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.*"

J5.1.14 Therefore, in accordance with Section 8.37 of ADB 2013, the shafts would need to be enclosed in fire resisting construction with a rating equal to that of the compartmentation through which it passes and tested from each side separately. The specific performance requirement is stated in ADB 2013, Table A1. Item 8 row c. This means loadbearing capacity (R), Integrity (E) and insulation (I); each side having to be assessed separately.

J5.1.15 This is the same principle as for any other service riser that passes between compartment floors. The shaft is required to be enclosed in a fire resisting construction to prevent the passage of fire between the compartments.

J5.1.16 **Dampers in compartmentation**

J5.1.17 In addition to the fire resistance of the shafts, Section 10.9 of ADB 2013 states:

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

J5.1.18 Therefore, where the AOV penetrations are provided between the builders' work vent shafts and the lobbies on each level, the integrity of the fire separating element must be maintained. Section 10.9 of ADB goes on to state:

"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."

J5.1.19 Because the AOV openings must be able to open and close, Methods 2 and 3 are not appropriate to maintain the integrity of the fire resisting enclosure of the lobby and therefore fire dampers are required.

J5.1.20 ADB provides definitions for two forms of damper in Appendix E:

J5.1.21 **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.

J5.1.22 **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.

J5.1.23 Section 10.13 of ADB 2013 states:

"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."

J5.1.24 The Note to Section 10.13 states:

"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.

J5.1.25 Section 10.15 of ADB 2013 then states:

"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."

J5.1.26 In accordance with the standard European nomenclature for fire resistance ratings (also used in ADB and the classification standard BS EN 13501-4):

a) The letter E stands for Integrity.

b) The letter S stands for Smoke leakage

J5.1.27 This 60 minute ES performance is determined by reference to the European standard test BS EN 1366-2:1999 *Fire resistance tests for service installations - Part 2: Fire dampers.* This is a high temperature test that uses the Standard Fire temperature-time curve for cellulosic fires. This fire curve reaches approximately 945°C after 60 minutes.

J5.1.28 In order to achieve an ES 60 rating, a damper must achieve the following performance criteria, when tested to BS EN 1366-2:1999, in accordance with Section 7.2.3.3 of BS EN 13501-3:

"*Integrity*

Integrity shall be assessed during the test as the time at which leakage through the damper after 5 min from the start of the fire test exceeds 360 $m^3/(m^2{\cdot}h)$, 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 occur. Ignition of the cotton pad shall be disregarded for dampers classified E only."

...

"*Smoke leakage (if necessary)*

For dampers for which the S class is relevant the leakage through the fire damper shall not exceed 200 $m^3/(m^2{\cdot}h)$, corrected to 20 °C at ambient temperature prior to the fire test, and shall not exceed 200 $m^3/(m^2{\cdot}h)$ corrected to 20 °C after the first 5 minutes of the fire test.

The performance criteria, taken from EN 1366-2, are given in Table 2."

Table 2 — Fire test performance criteria for fire resisting dampers

Classification	Size to be tested	Leakage limit at ambient temperature $m^3/(h.m^2)$ *10.3 of EN 1366-2:1999*	Fire test *10.4 of EN 1366-2:1999*	
			Leakage limit $m^3/h \cdot m^2$	**Temperature rise limit °C mean/max**
E	max	not required	360 [a]	not required
E-S	max	200	200 [a]	not required
	min	200	no test	not required
EI	max	not required	360 [a]	140/180
EI-S	max	200	200 [a]	140/180
	min	200	no test	no test

[a] Leakage limits only apply after 5 min from the start of the test.

Figure J.8: Excerpt of BS EN 13501-3:2005 identifying performance requirements for ES rated dampers against tests.

J5.1.29 Therefore, in Grenfell Tower, because the dampers in the AOVs are separating an escape route from the vent shafts, ADB would require the dampers to be ES classified to a minimum of 60 minutes in accordance with BS EN 13501-3 - *Fire classification of construction products and building elements — Part 3: Classification using data from fire resistance tests on products and elements used in building service installations: fire resisting ducts and fire dampers.*

J5.1.30 It should be noted that in my later Section J5.2.27, I describe the requirements of dampers in a pressurisation system, known as *smoke control dampers*. The performance requirements for smoke control dampers in terms of the classification of E and S, are the same as for the fire dampers I have just described in this section.

J5.1.31 However, the test to which smoke control dampers are exposed is carried out at a higher pressure difference, and therefore the test is more onerous with respect to prevention of leakage through the damper.

J5.2 Pressure differential systems

J5.2.1 The design of the smoke control system for Grenfell Tower, as described in PSB's Technical Submission (Rev 6, PSB00000214), does not explicitly refer to the system as either a pressurisation or a depressurisation system.

J5.2.2 The PSB Technical submission refers to the system as a *"mechanical extract system"*. Additionally, Section 3.3 of PSB's Technical Submission also states that the system was intended to maintain a pressure difference of -25Pa between the stairs and the lobby when the stair door was closed. Therefore, I consider this to be a depressurization system. Please refer to Section J6.2.11 for a detailed description of the PSB design.

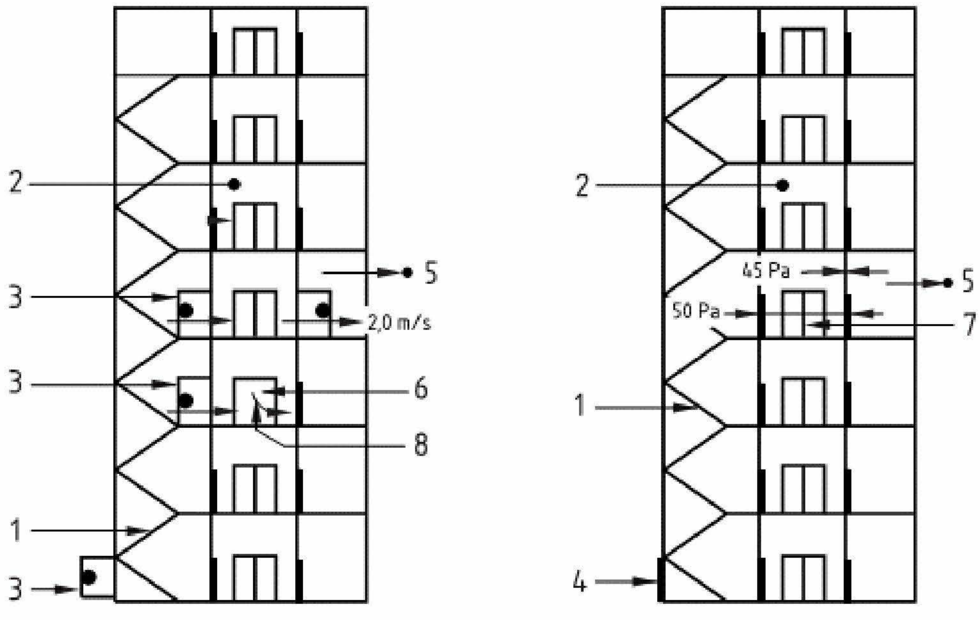
J5.2.3 In those circumstances, I have investigated the performance requirements for a pressure differential system in order to compare the performance of PSB's design.

J5.2.4 As set out above, the smoke control of escape routes required by Section 2.25 of ADB 2013 may be provided with reference to Section 2.27 of ADB 2013. Section 2.27 presents the mechanical ventilation options that are available for smoke control of escape routes. ADB 2013 Section 2.27 permits the use of pressure differentials to protect the stair from the ingress of smoke.

J5.2.5 Pressure differential systems can operate in two modes:

i) Pressurization (Figure J.9) – maintaining a positive pressure within the protected spaces; or

ii) Depressurization (Figure J.10) – removing hot gases from the fire zone, creating a lower pressure in the fire zone than the adjacent protected space.



Airflow criterion

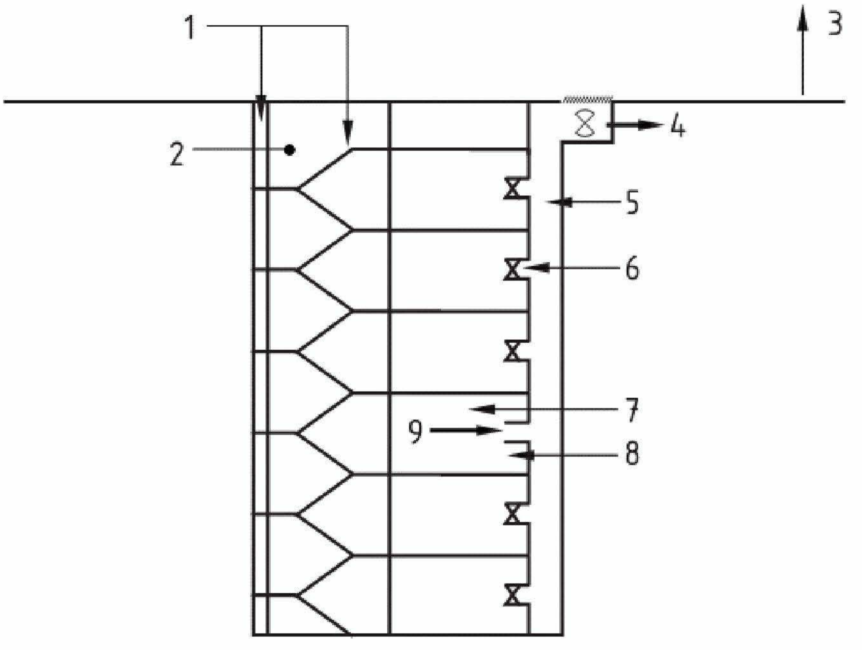
Pressure difference criterion
(all doors closed)

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 J.9: BS EN 12101-6 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 J.10: BS EN 12101-6 Depressurization system highlighting the extraction coming from the accommodation

J5.2.6 BS EN 12101-6 provides 6 different classes of system that may be used to protect stairs in different situations. I will now describe what class is relevant to Grenfell Tower.

J5.2.7 Section 16 of my report states that ADB 2013 would require the stair to be configured as a fire fighting shaft for a building of the height of Grenfell Tower

J5.2.8 The Exova Outline Fire 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.

J5.2.9 Because the stair is a firefighting shaft, this demands certain performance requirements of the lobby smoke control system, in order to meet the requirements for firefighting. It is the Class B and Class F systems in BS EN 12101-6 which provide requirements for firefighting.

J5.2.10 No reference is made to Class F by PSB (or others) in respect of the smoke control system installed in Grenfell Tower. I note that Section 6.3.2 of the Smoke Control Association (SCA) document *Guidance on Smoke Control to Common Escape Routes in Apartment Buildings (Flats and Maisonettes) Revision 2: October 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*"

J5.2.11 This note is not included in BS EN 12101-6:2005 itself, however the following text is included in BS EN 12101-6, 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.*"

J5.2.12 Table J.1 presents a comparison of the performance requirements of each of these systems.

Table J.1: Comparison of performance requirements for Class B and Class F pressurization/depressurization systems

Performance requirement	**Class B**	**Class F**
Pressure across lift and accommodation area	50Pa	50Pa
Pressure across stairway and accommodation area	50Pa	50Pa
Pressure across closed doors between each lobby and accommodation area	45Pa	45Pa

Performance requirement	Class B	Class F
Airflow criterion between the staircase and the lobby (a)	N/A	2m/s through the open door between the **staircase and the lobby** at 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	1 m/s through all open doors **between the lobby and the affected fire compartment**
Doors to be open to achieve airflow criterion (a)	NA	a) all doors between lobby and the affected fire compartment; b) the stair and the lobby on the storey below the fire storey; c) the firefighting lift shaft and the lobby on the storey below the fire storey; d) the stair and the external air at the fire service access level; e) the lobby and the accommodation on the storey below the fire storey (this only applies where the rising main outlets are located inside the accommodation in front of the lobbies).

Performance requirement	Class B	Class F
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 between the staircase and the lobby closed; b) all doors between the lobby and adjacent accommodations on the fire storey open; c) the stair and the external air at the fire service access level open; d) the air release path of the fire affected compartment open.
Alternative airflow criterion (for Class F systems only)	NA	Maintain an air exchange rate of 30 h^{-1} in the lobby on the fire storey with: a) all doors of the lobby including the door between the lobby and the staircase closed; b) the door between the stair and the external air at the fire service access level open; c) the air release path of the fire affected compartment open.
Door opening force	100N	100N

J5.2.13 PSB's Technical Submission for the Lobby Ventilation System (Rev 6, PSB00000214) references some of the performance criteria for a Class B system in BS EN 12101-6.

J5.2.14 Therefore, I have assessed the compliance of the lobby smoke control system in Grenfell Tower against the requirements of BS EN 12101-6:2005 for a Class B system.

J5.2.15 Section 4.3 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."

J5.2.16 There are five requirements set out in BS EN 12101-6: 2005 for a Class B system. These are:

a) Pressure difference criterion (Section 4.3.2.1)

b) Airflow criterion (Section 4.3.2.2)

c) Air supply (Section 4.3.2.3)

d) Fire fighting shaft (Section 4.3.2.4)

e) Door opening force (Section 4.3.2.5)

J5.2.17 Each of these requirements is described in Table J.6 and I provide my summary compliance opinion in Section J10 of this report.

J5.2.18 All five are required. 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. This is because the two different criteria address the different conditions that occur in the lobby when

(1) the doors between the fire flat and the lobby, and (2) the doors between the stair and lobby, are closed, as compared to when those doors are open.

J5.2.19 Figure J.9 (in Section J5.2.5) 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.*"

J5.2.20 BS EN 12101-6 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; or

b) depressurizing the accommodation (i.e. the flats in a residential building).

J5.2.21 The system described in the PSB Technical Submission (Rev 6, PSB00000214) does not perform either of the functions listed in Section J5.2.20, above. Please refer to Section J10 where I compare the system installed in Grenfell Tower with the requirements of the Statutory Guidance in ADB 2013.

J5.2.22 With respect to depressurization systems, Section 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.*"

J5.2.23 It should be noted that "the depressurized space" as this would apply to Grenfell Tower is the Flat.

J5.2.24 Section 9.2 of BS EN 12101-6: 2005 goes on to define ten depressurization 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 1 000 °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.*"

J5.2.25 Each of these requirements is described in Table J.6 and I provide my summary compliance opinion in Section J7 of this report.

J5.2.26 I consider the five Class B requirements and the ten depressurization requirements, to form the basis of the required compliance with ADB 2013.

J5.2.27 **Dampers in depressurization systems**

J5.2.28 In Section J5.1.16, I set out the requirements of the Statutory Guidance with respect to how compartmentation may be maintained when air handling systems penetrate compartment walls and compartment floors.

J5.2.29 In this section, I discuss the additional requirements for dampers installed as part of a depressurization system.

J5.2.30 Section 11.8 of BS EN 12101-6 addresses "*Distribution ductwork for pressure differential systems installation*". Section 11.8.2.10 goes on to state:

"*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.*"

J5.2.31 In accordance with the requirements of a Class B depressurization system, each flat of Grenfell Tower would be a separate depressurized zone. As I have stated, the PSB design was not in accordance with a Class B system, and instead it depressurized the lobbies on each floor. As all of the lobbies were connected by vent shafts, the AOVs in each lobby would require "*smoke control dampers*", rather than the specification of ES60 dampers from ADB 2013.

J5.2.32 Requirements for smoke control dampers are described in a different part of the standard for smoke control systems, BS EN 12101-8:2011 *Smoke control dampers*.

J5.2.33 Because the smoke control system in Grenfell Tower penetrates multiple compartments, the relevant section in BS EN 12101-8 is Section 4.4 *Fire resistance performance criteria: Multi compartment fire resisting smoke control dampers.*

J5.2.34 Section 4.4.1 *Integrity, insulation, leakage, HOT 400/30* states:

"*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.

When insulation characteristics are proven for multi compartment fire resisting control dampers, this shall be classified and declared, together with integrity.

A smoke leakage performance requirement is described in EN 1366-10 to allow the (S) classification, and this shall be applied, if the damper is intended for the end uses where this performance is required (largest and smallest sizes at ambient and largest size (measured continuously) after 5 (automatic operation) or 30 min (systems with manual intervention) from the start of the fire test."

J5.2.35 Section 4.1.1 of BS EN 12101-8, "*Fire resistance*" states:

"*The smoke control damper shall demonstrate the following and shall be classified in accordance with EN 13501-4*"

J5.2.36 The full title of BS EN 13501-4 is *Fire classification of construction products and building elements —Part 4: Classification using data from fire resistance tests on components of smoke control systems.*

J5.2.37 Section 7.3 of BS EN 13501-4 relates to *Classification of smoke control dampers.* Section 7.3.2 states:

"*The test method for multi and single compartment smoke control dampers shall be as given in prEN 1366-10. The method is applicable to smoke dampers installed in a duct or in fire separating elements designed to withstand the standard temperature time curve for multi compartment dampers*"

J5.2.38 'prEN' is a designation given to European standards when they are in preparation. It is used in European standards to identify other standards, or parts of standards, that must be referred to which do not exist at the time of publication. After publication of BS EN 13501-4 in 2007, work on prEN 1366-10 was completed and it was published as BS EN 1366-10:2011 *Fire resistance tests for service installations Part 10: Smoke control dampers*.

J5.2.39 Section 6.5 of BS EN 1366-10 sets out the test methodology for *Multi compartment fire resisting smoke control dampers.* This section states:

"*The test sample shall be mounted in the test equipment shown in EN 1366-2. It shall be tested for ambient leakage using the method described in EN 1366-2 and then fire tested using a pressure selected from Table 1. No fusible element is required or allowed.*

The initiation regime shall be selected from 6.2. Units shall be open at the start of the test, unless if in its application it will never be open at the commencement of a smoke situation.

The heating conditions and the furnace atmosphere shall conform to those specified in EN 1363-1 following the standard curve and tolerances.

The furnace pressure shall be controlled to EN 1366-2 throughout the test at the mid-height position of the ducts in the furnace."

J5.2.40 Therefore, while the test for a smoke control damper uses the test setup from BS EN 1366-2, it has additional requirements. I will not go into detail on the all of the specific differences between the test methods, as they are not relevant to my Phase 1 investigation. However, the following key difference between the tests should be noted:

a) Fire Damper – tested to BS EN 1366-2 – Exposed to pressure difference of 300Pa;

b) Smoke Control Damper – Tested to BS EN 1366-10 – Exposed to pressure difference of 500, 1,000 or 1,500 Pa.

J5.2.41 However, it is important to note that a damper can only be classified as a smoke control damper in accordance with BE EN 13501-4, if it has been tested to BS EN 1366-10.

J5.2.42 A damper that only has test data for BS EN 1366-2 cannot be classified as a smoke control damper. This is because it has not been tested to the more onerous pressure conditions expected when the damper is operating in a mechanical ventilation system utilizing pressure differences.

J5.2.43 As I have identified in Section J5.2.2, the smoke control system installed in Grenfell Tower was a depressurization system. Therefore, as stated in Section 11.8.2.10 of BS EN 12101-6, the dampers used in the AOVs should have been specified and installed as smoke control dampers, and therefore classified in accordance with BS EN 13501-4, through the use of the test methodology laid out in BS EN 1366-10.

J5.3 Functional requirements

J5.3.1 The functional requirement for the system as defined in Section 2.25 of ADB 2013 is that:

"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."

J5.3.2 The functional requirement for the system as defined in BS EN 12101-6:2005 is

"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."

J5.3.3 As well as the technical requirements of Class B and depressurization systems, I have also considered these stated functional requirements while carrying out my compliance assessment in Section J10.

J6 Description of the refurbishment smoke control system

J6.1 Review of information provided

J6.1.1 I have reviewed the details of the smoke control system as recorded in the PSB technical submissions for the smoke control system; and many other documents. I have provided a full list of the material I have considered in Appendix P and I refer to the key documents with their relativity references at the relevant part of the text provided herein.

J6.1.2 It should be noted that I have assumed that the PSB Technical Submission (REV 6, PSB00000214) provides the final description of the as-built condition. I would like Rydon, as main contractor, to confirm this to the Public Inquiry at Phase 2.

J6.1.3 Revision 1 of the submission prepared by PSB (dated 1/12/2014) is included within the Rydon O&M information RYD00000577.

J6.1.4 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 to comply with all the requirements of the aforementioned Code of Practice."

J6.1.5 However, the latest recorded version of the PSB technical submission which I have been provided with, is Revision 6 dated 15/03/2016 (PSB00000214).

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*" appears to have been deliberately removed, as between Rev 2 and Rev 3 of the document (please refer to e-mail dated 11/06/15 from JS Wright to PSB asking for the sentence to be deleted PSB00000569), and is therefore omitted from Rev 6.

J6.1.6 I have to assume at this stage that Revision 6 (PSB00000214) represents the as-built condition.

J6.1.7 I have relied specifically on the following key documents to investigate the provisions made for smoke control to the lobbies, in Grenfell Tower:

Table J.2: Key documents relating to smoke control system

Document	Relativity reference
PSB Smoke Ventilation Technical Submission Rev 0 issued 22/11/2014 Rev 2 issued 14/04/2015 Rev 6 issued 15/03/2016	Rev 0: PSB00000207 Rev 2: PSB00001236 / RYD00000577 Rev 6: PSB00000214
Drawing identifying other smoke control systems in addition to the PSB depressurisation system	PSB00000830
Main control panel software retrieved from the control panel by the MPS (Revision 6)	MET00018070
HMI software retrieved from the HMI panel removed from Grenfell Tower by the MPS	MET00018074
PSB "For Build" drawings of the control panel and invertor wiring	PSB00000267, PSB00000272 and PSB00000274
Sketches by Rydon showing the location of new builders work shafts and AOV dampers serving Levels Ground, 1, 2 and 3.	PSB00000603
PSB method statement on commissioning the smoke control system, dated February 2016	PSB00000941
PSB commissioning report, dated 28th April 2016	PSB00000224
E-mail from PSB to JSW attaching commissioning report and airflow measurements	PSB00001124
Evidence of door opening force check	PSB00001155

Document	Relativity reference
RJE report *Grenfell Tower: Description of electrical services*, dated May 2016	RYD00094130
Proposed wiring to connect autodialler into PSB smoke control system (It is currently unknown if this was implemented, or if some other configuration was used)	PSB00001090
E-mail from RJE to Rydon describing the actions that were required to occur on activation of the autodialler	PSB00001096
Tunstall *Visit Report* sheet, for visit on 4th May 2016	RYD00094190
Tunstall calls history log, dated 24th July 2017	THL00000002
E-mail demonstrating that Max Fordham requested door opening tests to be undertaken and RBKC requested airflow measurements, dated 10th May 2016	PSB00001161
E-mail from Rydon to JS Wright (dated 22nd March 2016), forwarded to PSB, requesting a reason as to why 25Pa had been chosen as the pressure differential criteria when "*45Pa as required by regulations*"	PSB00001066
E-mail from Rydon to Max Fordham identifying that temperature sensors had not yet been fitted. Also e-mail from Max Fordham to the TMO dated 3rd August 2018 suggesting that the operation of the smoke control system be demonstrated in fire mode if it had not already been done.	MAX00006459
E-mail from JS Wright to PSB identifying that the noise of the Level 2 environmental fan was unacceptable, dated 15th April 2016	PSB00001088
E-mail from JS Wright to PSB confirming the proposed operation of the environmental system	PSB00001111

J6.2 Basis for design of the refurbishment smoke control system

J6.2.1 Design by Max Fordham

J6.2.2 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.

J6.2.3 The performance of the original design was unknown to Max Fordham or RBKC (MAX00004353).

J6.2.4 A memorandum from Paul Hanson RBKC Building Control to John Hoban RBKC (RBK00002975, 10/11/2014) 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.

J6.2.5 RBK00002975 then discussed how a comparison between existing and proposed flowrates could be made.

J6.2.6 The *Employers Requirements for MEP Services for Grenfell Tower* (MAX00000960) 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.

J6.2.7 MAX00000960 set out the 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.

J6.2.8 This performance was based on analysis undertaken by Max Fordham (MAX00002335) to demonstrate that the new system would provide improved performance, when compared with the calculated performance of the existing system.

J6.2.9 The Max Fordham schematic for their proposed system is provided in PSB00000335 (Nov 2013) and an excerpt from PSB00000335 is shown in Figure J.11.

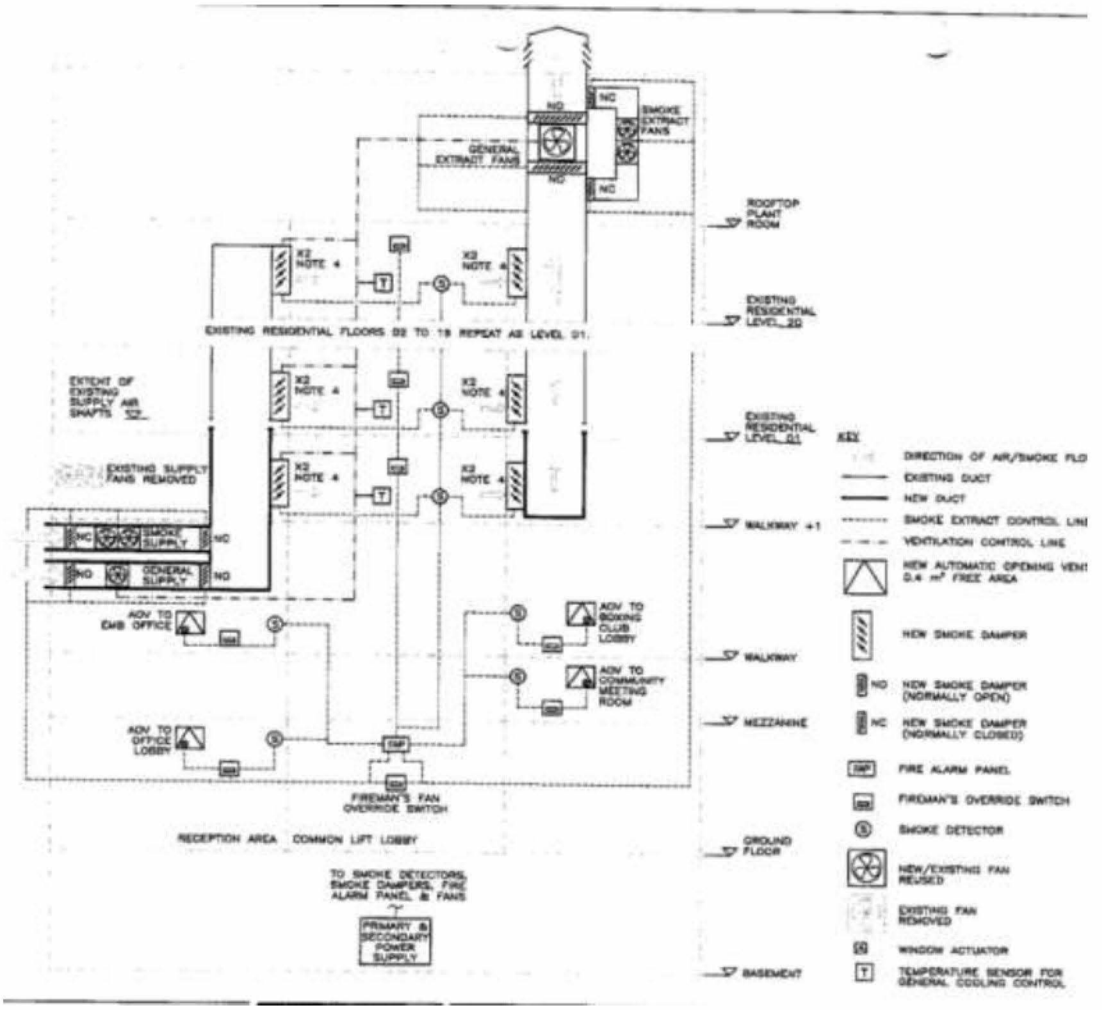


Figure J.11: Excerpt from Max Fordham schematic (PSB00000335).

J6.2.10 A diagram indicating the supply and extract methodology was included in an email from Max Fordham to RBKC (RBK00003017, dated 07/11/2013). An excerpt from this email is shown in Figure J.12.

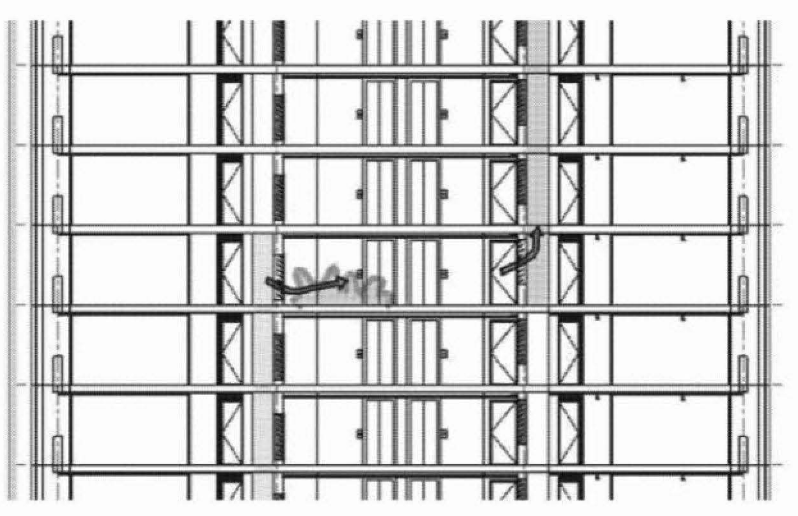


Figure J.12: Excerpt from email from Max Fordham to RBKC (RBK00003017, dated 07/11/2013) showing the concept for smoke extract proposed by Max Fordham.

J6.2.11 PSB Design development of the Smoke control system

J6.2.12 Based on my review of the documents submitted to the Inquiry so far, it appears that Rydon did not progress the smoke control system design proposed by Max Fordham. Instead, their appointed sub-contractor, PSB, returned their own design proposal in a series of Technical Submissions.

J6.2.13 The e-mail from Max Fordham to Artelia dated 19th October 2015 (MAX00005634) identifies that RBKC Building Control was requesting evidence that their proposed system would be an improvement over the existing system:

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.

J6.2.14 This e-mail also identifies the changes to the design extract rate that PSB were proposing, in order to satisfy RBKC Building Control's comments. This e-mail also documents the change from Max Fordham's proposal of a "supply and extract" type mechanical extract system, to PSB's proposal of an "extract only" system, where replacement air would not be mechanically supplied to the lobby being extracted from.

J6.2.15 In their Technical submission (Rev 6, PSB00000214), PSB term the system a 'mechanical extract system'. However, as I have described above, Section 1.1.2 of PSBs submission identifies 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. As already noted, a sentence suggesting that the system would comply fully with that code was deleted (see Section J6.1.5 above).

J6.2.16 Additionally, while PSB's Technical Submission and the correspondence from Max Fordham indicates that the system was to be a "mechanical extract" system, Section 3.3 of PSB's Technical Submission also states:

"*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"*

J6.2.17 Accordingly, while the system is described as a "mechanical extract system", the overall performance of the system, as described in the PSB Technical Submission, is a form of depressurisation system, since it is intended to maintain a single pressure differential when the stair door is closed. As I will describe immediately below, the system described in PSB's Technical Submission does not comply with any of the performance criteria in BS EN 12101-6.

J6.2.18 Pursuant to PSB's proposed system, the pressure in the lobby would be controlled to ensure that the stair door could still be opened against the pressure difference. This is described in the Technical Submission as follows:

"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"

J6.2.19 Two of the three performance criteria actually stated in the PSB Technical Submission (Rev 6, PSB00000214) were derived from BS EN 12101-6 and were:

- To achieve 2m/s across the open stair door;
- Door opening force not to exceed 100N.

J6.2.20 The third criterion in PSB's design, i.e. a requirement of 25Pa measured between the stair and the lobby, does not come from BS EN 12101-6:2005.

J6.2.21 There are multiple pressure differentials required for a Class B system, as indicated by this excerpt from BS EN 12101-6:2005:

Table 2 — Allowable minimum pressure differentials between specified areas for Class B systems

Specified area	Pressure differential to be maintained, min.
Across lift well and accommodation area	50 Pa
Across stairway and accommodation area	50 Pa
Across closed doors between each lobby and accommodation area	45 Pa
NOTE For flexibility in the acceptance test results there is ± 10 % tolerance on the measurement allowed.	

J6.2.22 In addition, the air flow condition must be achieved with various doors open, not just a single stair to lobby door only, as indicated in this excerpt from BS EN 12101-6:2005:

4.3.2.2 Airflow criterion

The air supply shall be 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 with all of the following doors open between:

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;

and the air release path on the fire floor is open.

If a door that has two leaves is assumed to be open for calculation purposes, one leaf may be assumed to be in the closed position for these calculations.

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.

J6.2.23 Given the guidance provided in BS EN 12101-6:2005, where three separate pressure differentials are required, I do not know how adequate performance of the system could be demonstrated against the Requirement of Part B1, i.e. by a system where "*The system has been designed to provide an average open door velocity, across an open lobby/stairwell door of 2.0m/s.*" only, with no other door open condition designed and with a single pressure differential of 25Pa specified between the stair and the lobby.

J6.2.24 I note that on the 1st February PSB issued to JS Wright by e-mail a *Method statement & risk assessment* document related to commissioning the Grenfell Tower smoke control system (PSB00000941). Please refer to Section J8.6 for my assessment of the commissioning tests contained in this document.

J6.2.25 Section 4.0 of this document provides a description of the smoke control system. This document presents two modes of operation, with associated performance criteria, which are wholly different to the criteria stated in PSB's own Technical Submission. I have summarised the two modes of operation from the Method Statement as follows:

a) "Means of escape" mode:

   i. Pressure between stair and lobby not to exceed 50Pa with the stair door closed;

   ii. With the stair door open, a pressure differential of 45Pa to be maintained between the stair and the lobby.

b) "Fire-fighting" mode:

i. Pressure between stair and lobby not to exceed 50Pa with the stair door closed;

ii. "In fire-fighting mode, the door from the stairwell into the lobby is fully open, the extract fan will draw smoke from the lobby at maximum rate"

J6.2.26 In response to JS Wright's request of PSB for a commissioning method statement, there is internal PSB correspondence between David Harrison and Granville Partlow (PSB00000936) that states:

From David Harrison:

"Hi Granville

This guy keeps pressing, can you draft something just to keep them informed."

Response by Granville Partlow:

"I will struggle to get it done as I am at a site today and tomorrow but will see what time I have to spare later just a thought

Tim mightily [sic] have something on file if your [sic] want to give him a call here could've [sic] sending its [sic] to me and I could adapt it"

J6.2.27 Based on this e-mail it will be necessary to investigate further at Phase 2 how the commissioning method statement came to be produced. At the present time and on the basis of this correspondence, I have assumed that the different performance criteria recorded in PSB's commissioning method statement were not intended to indicate a change in the proposal by PSB for the design and installation of the smoke control system in Grenfell Tower – this is based particularly on the commissioning data I have been provided with.

J6.3 Arrangement of spaces to be pressurized

J6.3.1 The PSB Technical Submission (Rev 6, PSB00000214) describes a system with pressure difference and airflow criteria between the stair and the lobby only. Therefore, I have examined BS EN 12101-6:2005 to determine if there is any section of that standard which might permit such a design, while still complying with the requirements for a Class B system for fire fighting.

J6.3.2 Section 6 of BS EN 12101-6 is titled "Spaces to be pressurized" and provides specific guidance on how the standard intends for different spaces to be pressurized in a variety of combinations. It includes 8 sub-sections titled:

a) Stairwells only

b) Stairwells and lobby

c) Pressurizing the stairwell and lobby, with air release from the corridor

d) Pressurizing the stairwell, lobby and corridor

e) Stairwell and lift shaft

f) Stairwells and corridors with air release from accommodation

g) Stairwells and air release from corridors/lobby; and

h) Stairwells lobbies and lift shafts

J6.3.3 Each of these sub-sections states:

"The arrangements shall comply with the appropriate class of system as defined in Clause 4"

J6.3.4 Therefore, while Section 6.1 of BS EN 12101-6 is a sub-section that describes how to apply pressurisation to "*Stairwells only*", this guidance only applies to the classes of system that are intended to pressurize the stair only (i.e. Classes A, C, D and E). (Noting that these 4 classes are stated in BS EN 12101-6 to be used for protecting means of escape only.)

J6.3.5 BS EN 12101-6 identifies that Classes B and F are intended for means of escape and for fire fighting. In order to comply with the Class B and F systems, a lobby must be provided and the smoke control system must comply with the associated requirements for the lobby.

J6.3.6 Section 9 of BS EN 12101-6 explains that depressurisation systems may be utilized to achieve the requirements of the 6 Classes of system described in Section 4 of the standard. In all cases, the accommodation is depressurised with respect to both the stair (and the lobby if present). This means smoke from the fire flat is prevented from entering the lobby and also the stair.

J6.3.7 However, 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.

J6.3.8 As the lobby was depressurised this would encourage smoke from the flat on fire into the lobby.

J6.3.9 Therefore, the smoke control system in Grenfell Tower could never have complied with the requirements of BS EN 12101, and therefore could not be considered compliant with Section 2.27 of ADB 2013.

J6.3.10 To date, I have been provided with no information as to what the intended function in the stated condition was, nor how it was considered compliant with the Statutory Guidance of ADB 2013 and, therefore, Functional Requirement B of the Building Regulations 2010.

J6.4 Use of the refurbished smoke control system for environmental ventilation

J6.4.1 According to J.S. 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.*"

J6.4.2 When used in environmental mode, system utilised all of the same components as the smoke control system, with the following 2 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 J.13 and Figure J.20).

b) Additionally, the environmental system was activated based on readings from 5 thermometers that were connected to the BMS, rather than being connected directly to the smoke control system. Please refer to Section J6.5 for a detailed description of all components of the system.

J6.4.3 The design basis of the environmental ventilation mode is described in the PSB Technical Submission (Rev 6, PSB00000214) and PSB's Electrical Schematic as follows.

J6.4.4 In day to day use, warm air was exhausted from lobbies by the new AoVs installed as part of the smoke control system. These consisted of:

a) From Level 4 to Level 23 – a pair AOVs located at high level on the north side of each lobby served by the pair of existing builders work vent shafts

b) From Ground to Level 3 – A single AOVs located at high level on the North side of each lobby served by a newly constructed extension to the existing North vent shafts.

J6.4.5 New run and standby fans (2 fans in total) were installed at the top of the existing builders work ventilation shafts at roof level. This fan set was used for both smoke and environmental exhaust and discharged at roof level.

J6.4.6 In environmental mode, fresh air was supplied to all lobbies, by the new AoVs installed as part of the smoke control system. These consisted of:

a) From Level 4 to Level 23 – a pair AOVs located at low level on the south side of each lobby served by the pair of existing builders work vent shafts.

b) From Ground to Level 3 – A single AOV located on the south side of each lobby served by a newly constructed extension to the existing South vent shafts.

J6.4.7 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.

J6.4.8 The operation of the environmental ventilation system is described in the PSB 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 5 thermometers 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.

J6.4.9 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. A new method of operation was recorded in the JS Wright e-mail dated 22nd April 2016 (PSB00001111) that would permit the environmental fan to operate at a slower speed, and therefore be quieter when operating. Please refer to Figure J.49 for details of this new operating mode.

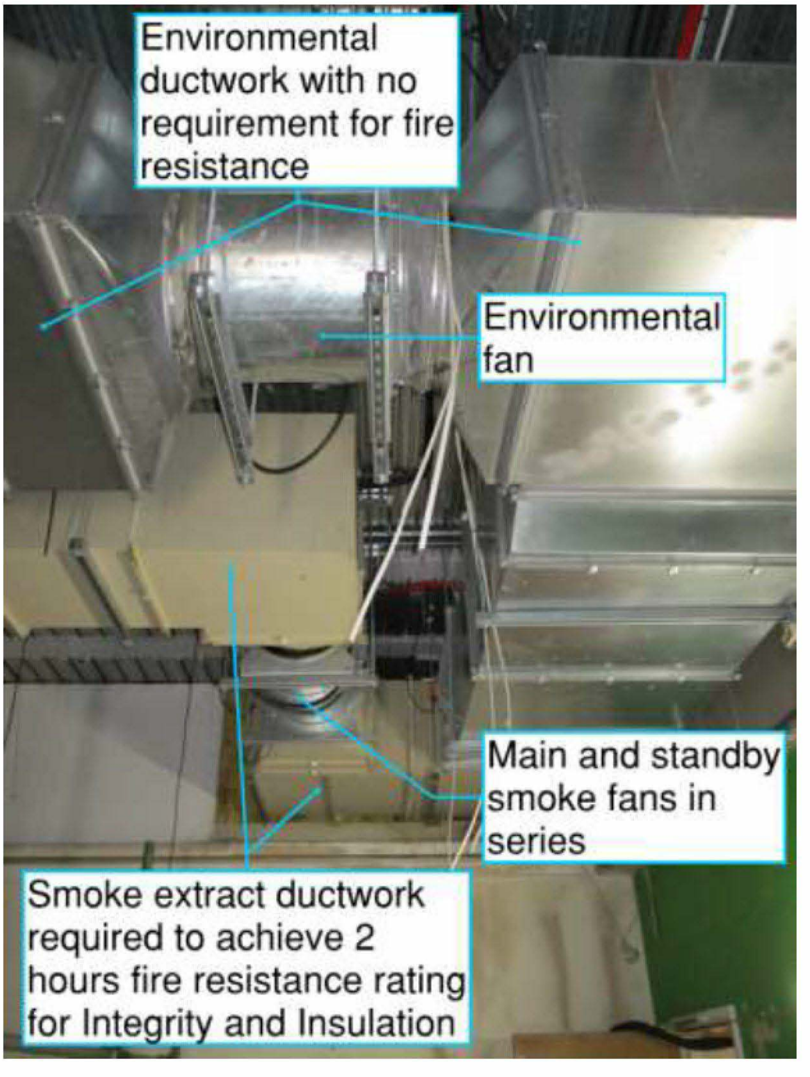


Figure J.13: Level 2 smoke fans (rear) and environmental fan (front)

J6.4.10 No additional control panels were added to operate the system in environmental mode. The main control panel for the smoke control system was programmed to perform in both operating modes.

J6.4.11 The HMI provided as part of the smoke control system also permitted a user to monitor and control the system in environmental mode.

J6.5 Primary components of the Smoke Control system

J6.5.1 Components of the refurbished smoke control system

J6.5.2 As described in PSB's Technical Submission (Rev 6, PSB00000214), from Ground level to Level 23 the system consisted of the following:

a) Smoke exhaust was provided by a pair of AOVs located at high level on the north side of each lobby (Levels 4-23).

b) The north AOVs on Levels 4 to 23 were served by the original pair of north smoke shafts (as extended, aggregate area 0.48m^2) leading to new exhaust fans and outlet on the roof.

c) Smoke exhaust was also provided by a pair of AOVs located at low level on the south side of each lobby (Levels 4-23).

d) The south AOVs on Levels 4 to 23 were served by the original pair of south smoke shafts (as extended, aggregate area 0.48m^2) leading to new exhaust fans and outlet on at Level 2.

e) New 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 JSW (HAR00007049) as requiring a 2-hour fire resistance rating (Figure J.14).

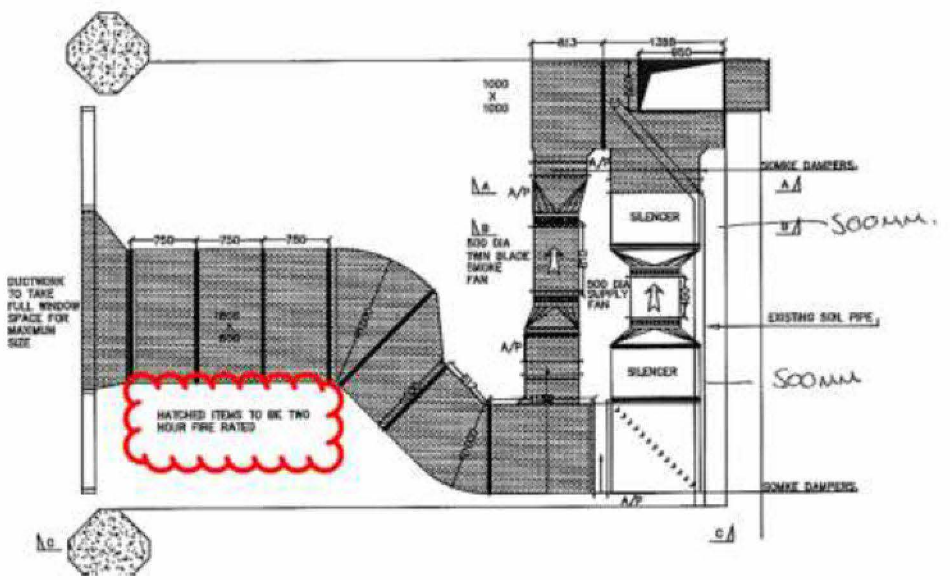


Figure J.14: Excerpt from attachment to HAR00007049 indicating extent of fire rated ductwork at Level 2

f) New builders work shafts were created - linking the bottom of the existing smoke shafts to each of the lift lobbies between Ground and Level 3.

g) A new AOV was provided on each of the levels Ground to 3, served by the new north vent shaft as above.

h) A new AOV was provided on each of the levels Ground to 3, served by the new south vent shaft as above.

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 Figure J.69)

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 key switch was provided in each ventilated lobby.

q) 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.

r) 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.

s) A secondary wired power supply was provided, connected to Grenfell Walk, to provide power to the 4 No. 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.

J6.5.3 All of these components must function correctly to produce the performance required by the five requirements of a Class B smoke control system and the ten requirements for a smoke control system using the principles of depressurisation as defined in BS EN 12101-6:2005.

J6.5.4 I have provided a simplified schematic of how the smoke control system was organised in Figure J.15.

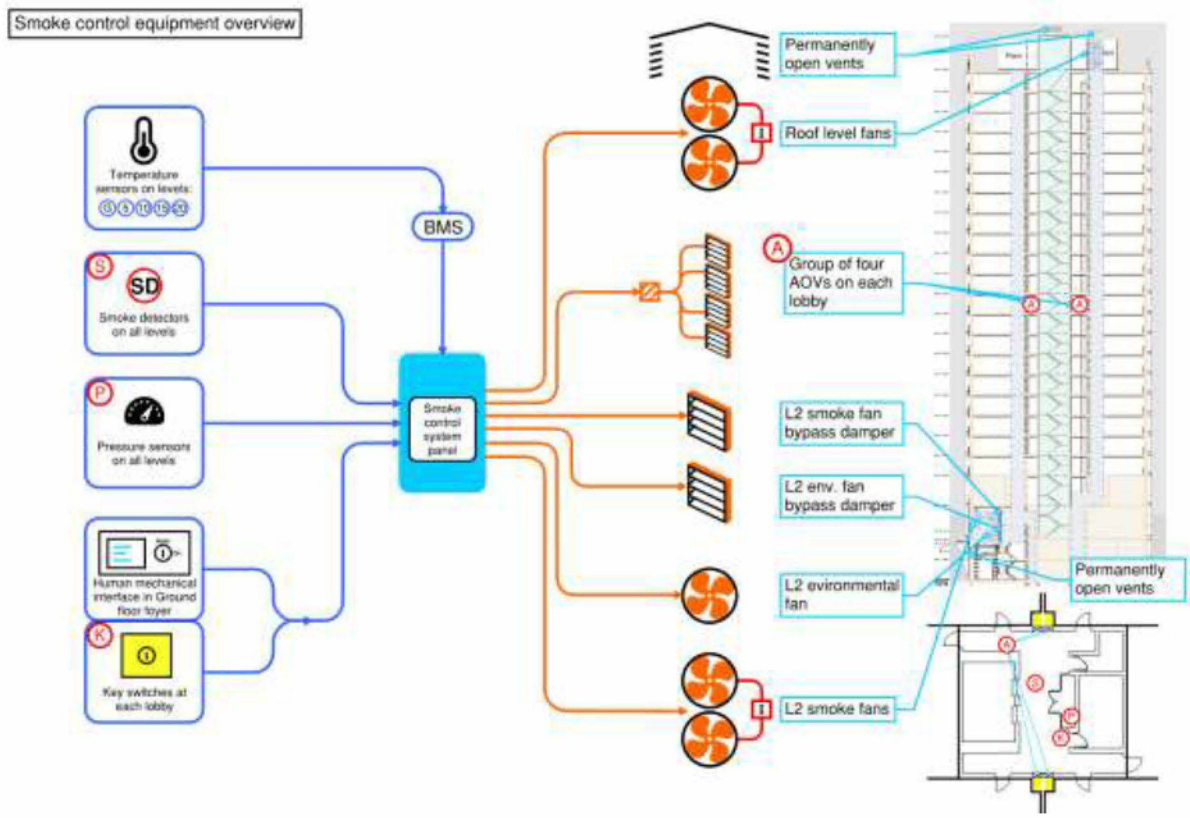


Figure J.15: Schematic layout of the smoke control system

J7 Physical evidence of the installed Refurbishment works

J7.1.1 I now explain the physical evidence I have found in respect of each of these components during my post-fire inspection of 7th-9th November 2017. First I include a description of the works undertaken during the refurbishment, before setting out the available evidence in respect of each of the components.

J7.1.2 **Description of the works**

J7.1.3 During the refurbishment works 2012 – 2016, 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.

J7.1.4 A view inside one of the builders' work shafts is shown in Figure J.25.

J7.1.5 In terms of the requirements for distribution ductwork for pressure differential systems, Section 11.8.2.8 of BS EN 12101-6 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."

J7.1.6 Based on Figure J.25 (showing one of the vent shafts at Level 5) it does not appear that the inside of the shaft is fully rendered. Figure J.16 also identifies differences between the surface finish in different areas of the shaft. The pattern of diagonal lines inside the shaft is replicated on the outside of the shaft, as presented in Figure J.17. This pattern may be seen in the grey areas of block and the yellow areas of block. The yellow areas of block also exhibit a different sandstone-like pattern in places.

J7.1.7 Mortar joints between blocks are clearly visible. These observations are replicated in Figure J.18 and Figure J.19 which show different portions of the shafts at Level 4 and Level 7 respectively.

Figure J.16: interior of smoke shaft at Level 7

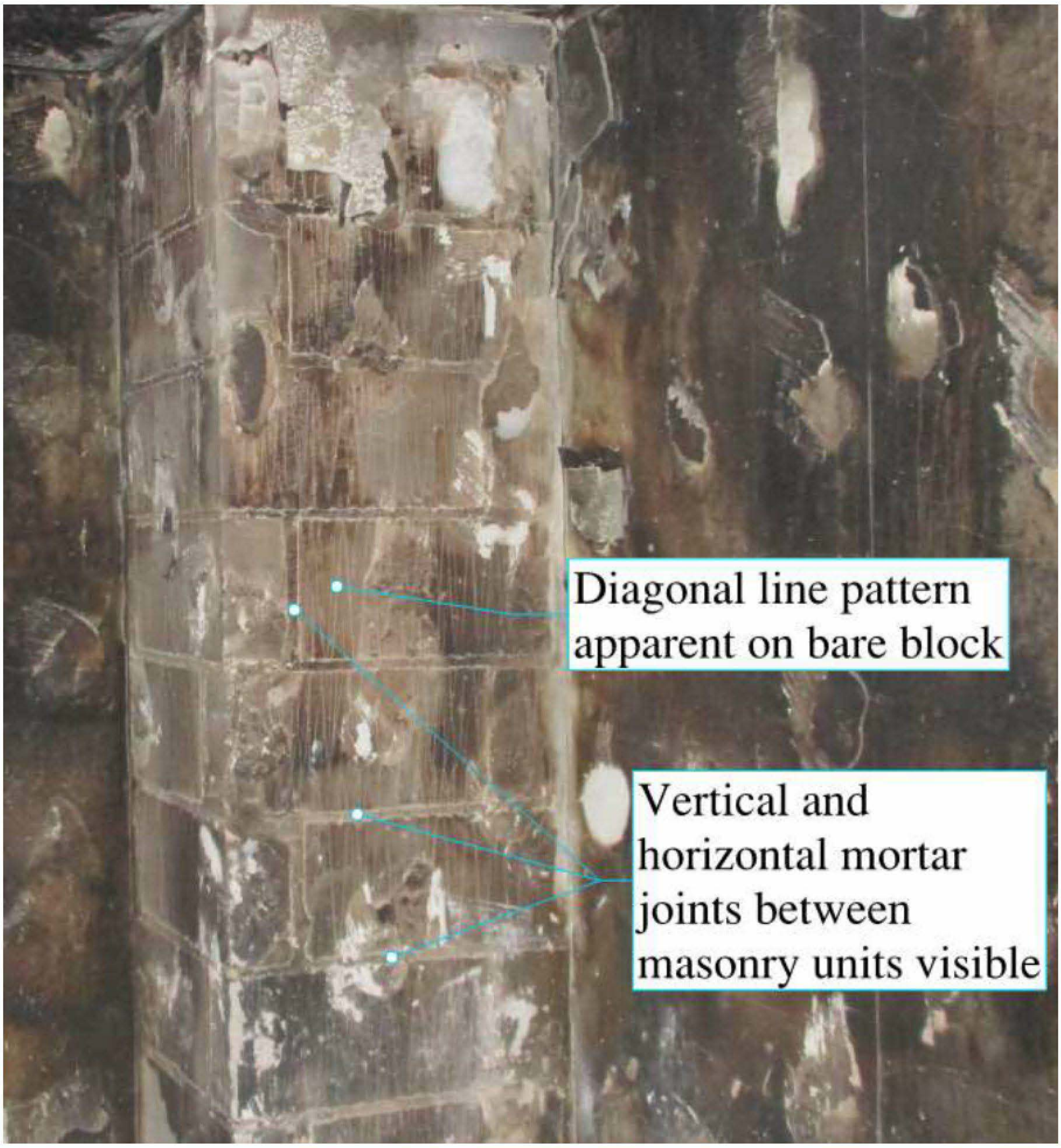


Figure J.17: Exterior of smoke shaft masonry at Level 23

Figure J.18: Inside of shaft at Level 4

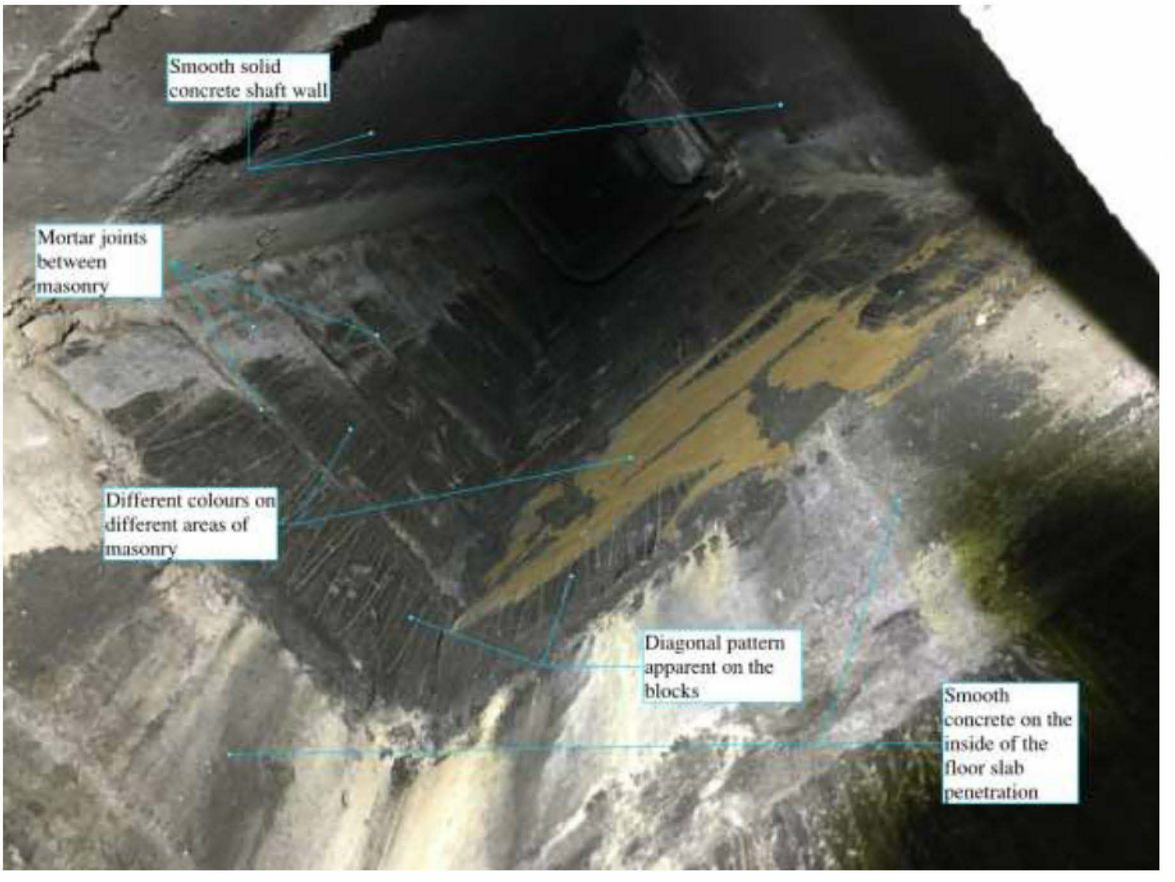


Figure J.19: Inside of shaft at Level 7

J7.1.8 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 metal sheet lining. Also, I do not know how the existing shafts were assessed in order to show that leakage was satisfactory before they were reused as part of PSB's smoke control system.

J7.1.9 The SCA guide states:

"*A builder's work shaft should have a maximum leakage rate of 3.8 m^3 per hour per m^2 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.*"

J7.1.10 I have seen no evidence that PSB undertook testing of the existing shaft to determine leakage to comply with the SCA guide.

J7.1.11 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.

J7.1.12 The existing openings between the lobbies and the shafts on Levels 4 – 23 were retained.

J7.1.13 The existing shafts already extended to the roof plantroom to serve the roof fans.

J7.1.14 New AOVs were fitted into the existing AOV openings in the 4 smoke shafts, shown in Figure J.24.

J7.1.15 One new pair of combined smoke and environmental fans was provided at roof level.

J7.1.16 A pair of smoke extract fans and one new environmental fan were provided at Level

J7.1.17 The smoke fans installed at Level 2 and at Roof level were configured as two fans installed in series as duty/standby.

J7.1.18 Power supplies and controls were also provided for the refurbished smoke / environmental ventilation system.

J7.1.19 New ductwork was fitted between the south shafts and the new Level 2 smoke and environmental fans and the louvre at the façade of the building connecting to the outside air. See Figure 14 below.

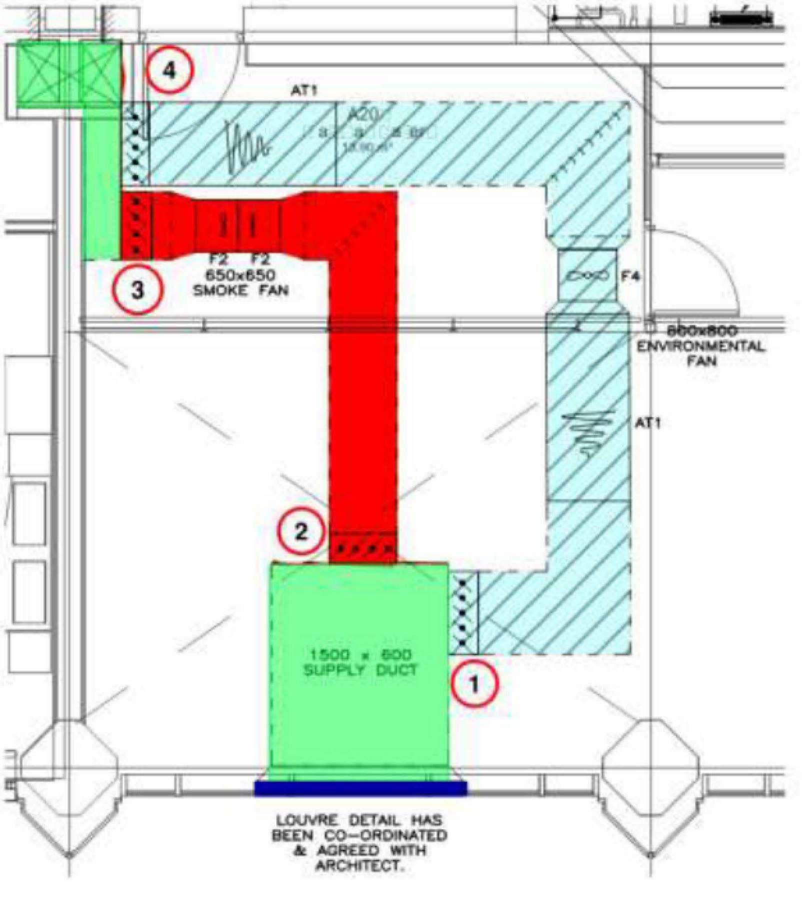


Figure J.20: Layout of ductwork at Level 2. Light blue: environmental fan, dampers and ductwork. Red: smoke fans, dampers and ductwork. Green: shared ductwork, Dark Blue: external louvres. Dampers 1 and 4 serve the environmental fan. Dampers 2 and 3 serve the smoke fans.

J7.1.20 MAX00006475 noted that shared shafts between environmental and smoke systems is 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.*"

J7.1.21 The operation of the smoke system in environmental mode is detailed in Section J7.4.4.

J7.1.22 The operation of the smoke system in smoke mode is detailed in Section J7.6.

J7.1.23 **My observations of the Components of the refurbished smoke control system**

J7.1.24 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.

J7.1.25 **a) North Shaft lobby AOVs**

J7.1.26 Smoke exhaust was provided by a pair of AOVs located at high level on the north side of each lobby.

Figure J.21: North AOVs on Level 16 (My photo. Please refer to Appendix C).

J7.1.27 The AOVs provided (Gilbert 54 series, product description in PSB00000201, replicated in Figure J.22) were stated as having been tested to EN1366 Pt 2

Fire resistance tests for service installations – Part 2: Fire dampers for 1 hour. This is the appropriate test standard for a damper to maintain compartmentation, in accordance with Section 10.15 of ADB 2013, as I explained in Section J5.1.

J7.1.28 The literature for the Gilbert Series 54 series product does not state the specific classification that has been achieved for the damper, either in accordance with BS EN 13501-3 for Fire Dampers or BS EN 13501-4 for Smoke Control Dampers. The text in Figure J.22 is the only evidence of the fire performance of the product that I have found to date in the PSB documentation.

J7.1.29 Additionally, PSB do not state in their Technical Submission (Rev 6, PSB00000214) the performance requirement for the damper in terms of fire resistance.

J7.1.30 Importantly, the Gilbert Series 54 dampers are not stated as tested to the correct test standard for smoke control dampers installed in a depressurization system in accordance with BS EN 12101-6, which is the performance standard required at Grenfell Tower.

J7.1.31 As I have described in Section J5.2.27, the correct test standard for smoke control dampers is BS EN 1366-10 Fire resistance tests for service installations Part 10: Smoke control dampers.

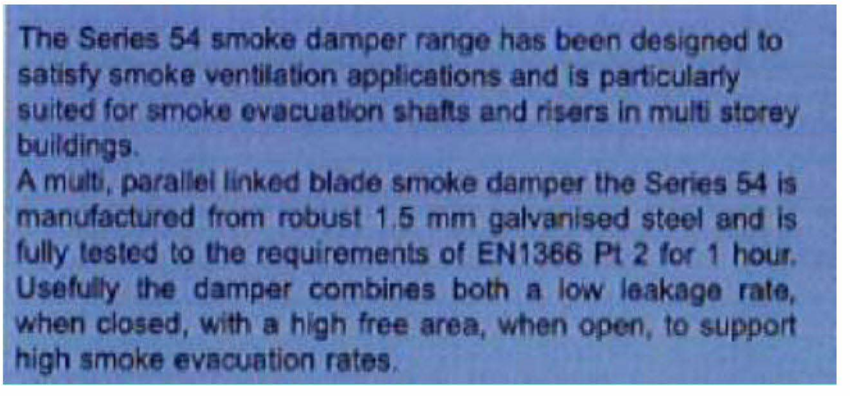
J7.1.32 The test for BS EN 1366-10 requires that the damper be subjected to a higher pressure difference (between 500Pa and 1500Pa depending on the classification required) during the test than that specified for BS EN 1366-2 (300Pa). This means that the smoke control dampers when tested in a BS EN 1366-10 test are subject to more onerous conditions for leakage of smoke.

J7.1.33 Section 10.15 of ADB identifies that dampers to a protected shaft are required to achieve a rating of ES60. The dampers are stated in the Gilbert's literature (dated October 2011, PSB00000201) as achieving a "1 hour rating" although the precise classification of the product is not given in accordance with the relevant BS EN classification standards.

J7.1.34 I have now reviewed Gilbert's test data and find this literature (PSB00000201) to be factually incorrect. WF Test Report No. 309850 (dated 06/10/2011) is a test of a damper sponsored by Gilberts to BS EN 1366-2:1999. The report specifically 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.*" Therefore, the damper had not in fact been "*fully tested to the requirements of EN1366 pt 2*" and could not claim an ES 60 rating as is required.

J7.1.35 Importantly for the use of the product in Grenfell tower was the fact that the damper was tested in the closed position only, at the request of Gilberts. The test method of BS EN 1366-2 includes a closing test as part of the fire test. As part of the test setup, the damper is installed in the test furnace in an open position. After the furnace is ignited, the time at which the damper closes is recorded. If the damper takes longer than 2 minutes to close, then the test is immediately failed.

J7.1.36 In Grenfell Tower, the AOVs functioned as environmental vents as well as part of the smoke control system. Therefore, the dampers may have been in an open or a closed position at the time that smoke was detected in the Level 4 lobby. The ability of a damper to close effectively on all floors away from the fire, when subjected to smoke and heat, therefore is a fundamental requirement of the smoke control system in Grenfell Tower.



The Series 54 smoke damper range has been designed to satisfy smoke ventilation applications and is particularly suited for smoke evacuation shafts and risers in multi storey buildings.
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. Usefully the damper combines both a low leakage rate, when closed, with a high free area, when open, to support high smoke evacuation rates.

Figure J.22: Excerpt from Series 54 product description (PSB00000201, dated October 2011)

J7.1.37 The quote from Gilberts to PSB for supplying the dampers (dated 22nd January 2015, PSB00001240) states:

"*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.*"

J7.1.38 This statement is also factually incorrect as the test report (GIL00000001) identifies that the damper failed the Smoke Leakage performance criteria immediately.

J7.1.39 I note that the current edition of Gilbert's literature for the Series 54 dampers (dated April 2017) indicates that the damper "has no formal certification" in accordance with EN1366-2, 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 J.23: Excerpt from Gilberts literature for Series 54 dampers, dated April 2017

J7.1.40 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.

J7.1.41 The only relevant test I have been provided with, which came directly from Gilberts, is dated October 2011. As I have explained above, this does not demonstrate the performance that was claimed in the previous literature.

J7.1.42 I am not aware of any other tests that Gilberts may have commissioned for their Series 54 product. I am also not aware of any changes to the Series 54 dampers that may have affected their performance after October 2011.

J7.1.43 The dampers would not be appropriate for use as a fire damper to maintain compartmentation in a protected shaft in an escape route with a sleeping risk, in accordance with ADB 2013, because it has no relevant test evidence to BS EN 1366-2, and does not therefore have the necessary classification to BS EN 13501-3.

J7.1.44 Additionally, the dampers do not comply with the requirements of a smoke control damper from BS EN 12101-8 because no relevant test evidence to BS EN 1366-10, or classification to BS EN 13501-4, has been provided.

J7.1.45 This requires further investigation by the Public Inquiry at Phase 2.

Figure J.24: North AOVs on Level 4.

J7.1.46 **b) Smoke control vent shafts**

J7.1.47 The north AOVs were served by the original pair of north smoke shafts (as extended, aggregate area 0.48m^2) leading to new exhaust fans and outlet on the roof. The south AOVs (Section J7.1.57) were served by the original pair of north smoke shafts (as extended, aggregate area 0.48m^2) leading to 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.

J7.1.48 Figure J.25 shows the inside of the South vent shaft at Level 5. The walls with yellow markings were constructed of masonry which the other two walls are formed by the concrete frame of the building. Please also refer to Figure J.16, Figure J.17, Figure J.18 and Figure J.19 for further views of the vent shafts from different levels.

J7.1.49 Figure J.26 shows the inside of the shaft at Level 22, where I observed it to have been destroyed within Flat 195. The markings around the shaft identify where the breeze block construction of the shaft was originally present. 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.

J7.1.50 I observed the damper in this location to be open, however the condition of the sides of the damper blades indicates that the damper was not open during the fire, but was instead opened by other parties after the fire.

J7.1.51 I was unable to inspect the shaft at Level 22 due to debris, however there is no indication that the shaft was blocked at this level.

Figure J.25: Picture taken within one of the South vent shafts at Level 5

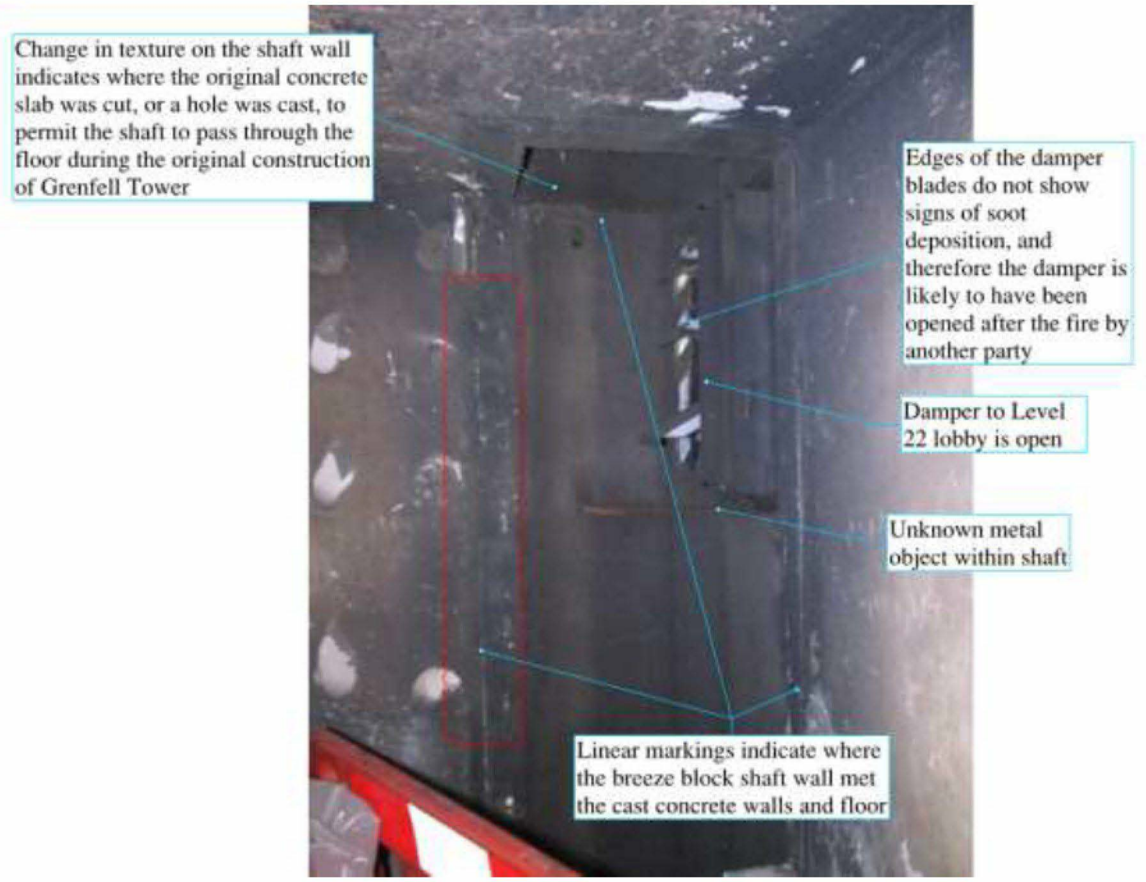


Figure J.26: Destroyed smoke shaft in flat 195 on Level 22

J7.1.52 **c) Fans at Roof Level**

J7.1.53 Figure J.27 shows the smoke control fans (duty and standby fans arranged in series) at Roof level. Figure J.28 shows the detail of the fan information plate, confirming the type of fan and the fire performance rating that it was classified as achieving. I have not investigated any relevant test evidence of the fan performance for Phase 1.

J7.1.54 Figure J.29 shows the fan as seen from above when standing on the roof and looking down the vent shaft. Figure J.30 shows the protective housing that sits above the exhaust vent at Roof level and prevents rain from getting into the shaft.

Figure J.27: Environmental / Smoke control fans in the roof plant room

Figure J.28: Post fire inspection of fan information plates stating that the temperature rating of the roof smoke fans was 300°C for 120 minutes.

Figure J.29: Roof level fan unit observed 8th November from roof outlet above

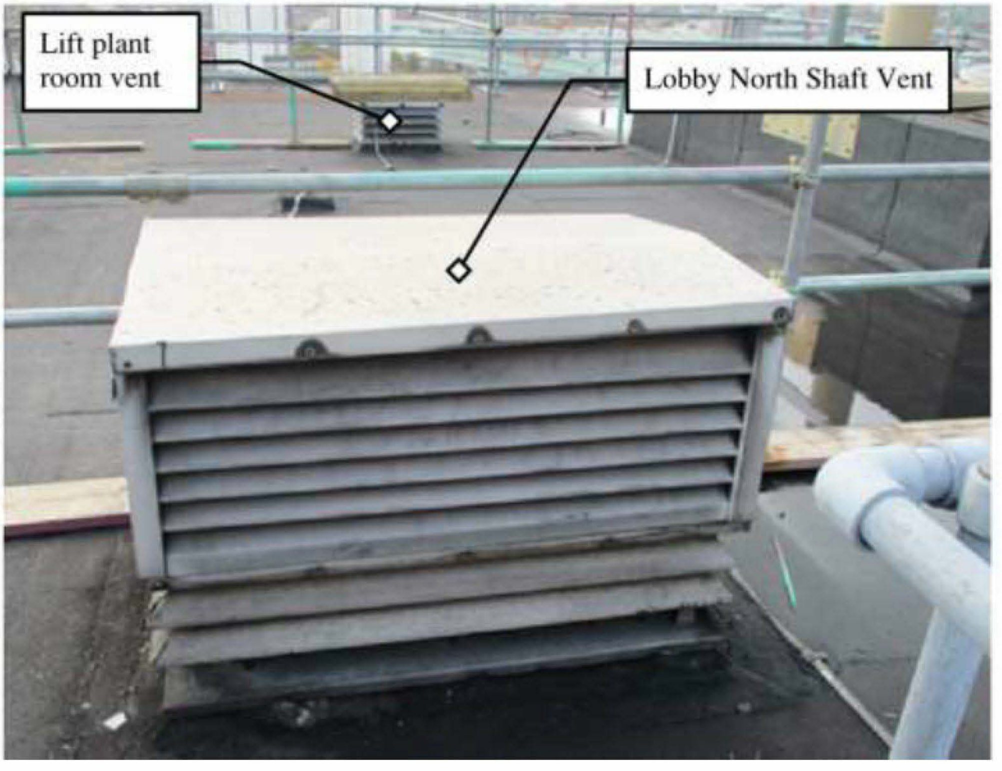


Figure J.30: North vent shaft outlet

J7.1.55 **d) Natural ventilator at the head of the Stair**

J7.1.56 Figure J.31 shows the permanently open vent at the head of the stair.

Figure J.31: Permanently open vent at head of stair

J7.1.57 **e) South shaft lobby AOVs**

J7.1.58 Smoke exhaust was also provided by a pair of AOVs located at low level on the south side of each lobby. These AOVs were fitted with the same type of dampers as I have described in Section J7.1.25.

Figure J.32: South AOVs on Level 16.

Figure J.33: South AOVs on Level 4.

J7.1.59 **f) Fans and ductwork at Level 2**

J7.1.60 New smoke control fans (duty and standby in series) were provided at Level 2, as seen in Figure J.34.

J7.1.61 An 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. The smoke and environmental sections of the layout at Level 2 are shown in Figure J.20.

J7.1.62 New ductwork was provided connecting the south smoke shafts to a vent on the outside of the building, via the smoke extract fans. This ductwork (sand-coloured ducts shown in Figure J.13 and Figure J.35) was noted by PSB (PSB00000044) and JSW (HAR00007049) as requiring a 2-hour fire resistance rating.

J7.1.63 Please refer to Section 16 for my assessment of the fire resistance rating of the ductwork.

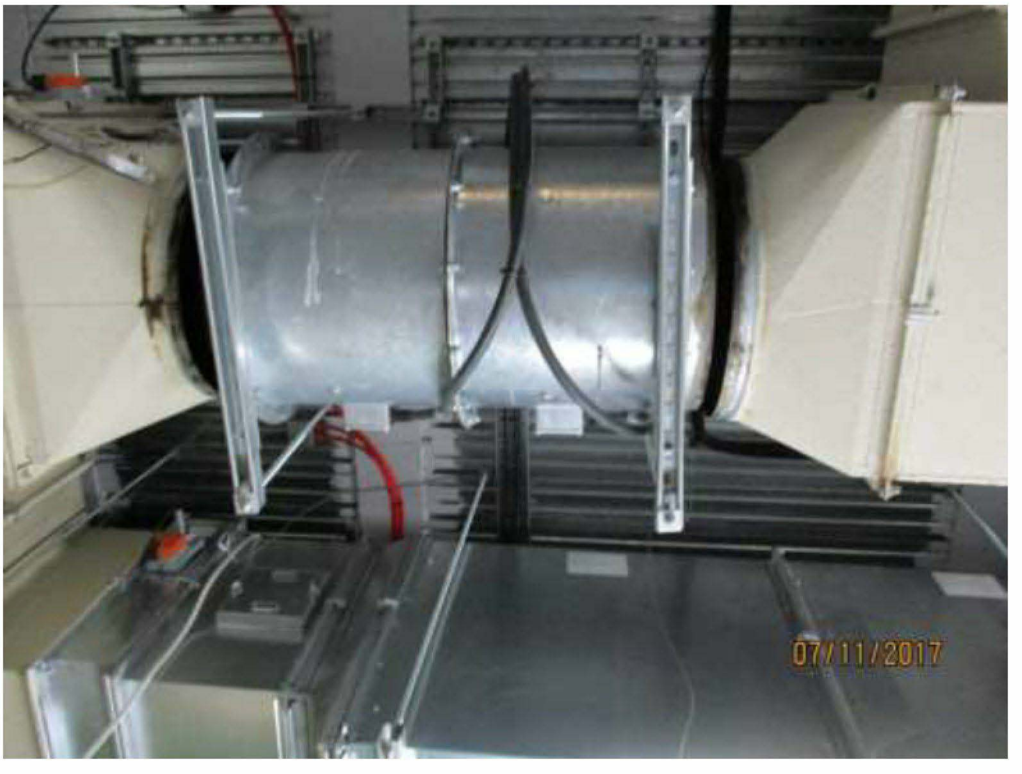


Figure J.34: Smoke exhaust fans at Level 2

Figure J.35: Fire-rated ductwork at level 2.

J7.1.64 Figure J.36 shows the louvre positioned in the façade of the building at Level 2. When the system was operating in Environmental mode, this would act as an air intake for the supply fan. When the system was operating in smoke control mode this louvre would be an exhaust vent connected to the smoke control fans at Level 2.

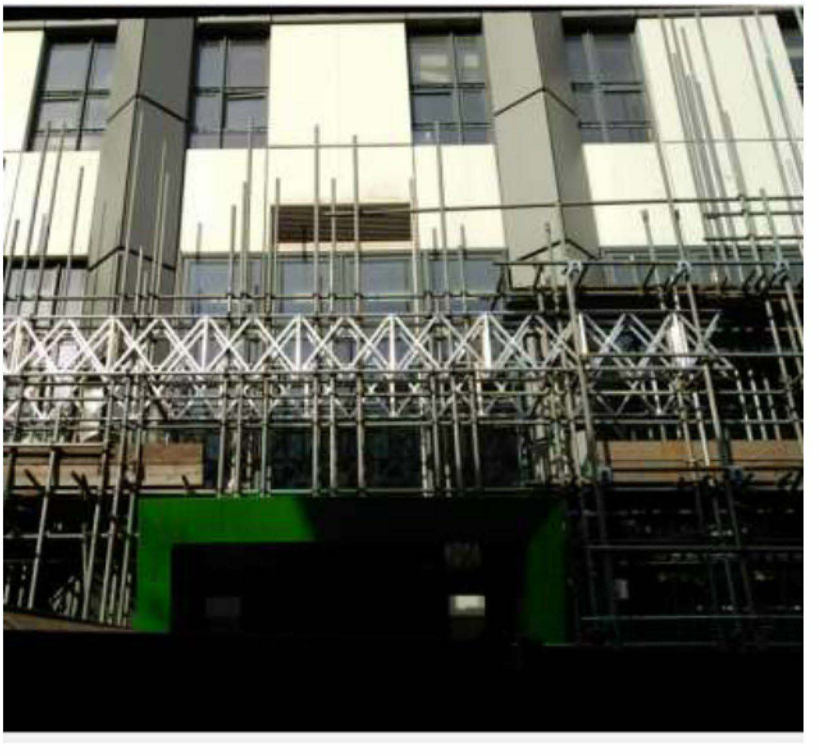


Figure J.36: Smoke system intake / exhaust louvre at Level 2. In smoke mode, smoke will be exhausted from these louvres. In environmental mode, fresh air will be drawn into the building through these louvres (BLA00004531).

J7.1.65 **g) New AOVs from Ground to Level 3**

J7.1.66 The AOVs in the lobby on Ground Level – Level 3 were all located at high level and served by the north and south vent shafts (Figure J.37).

Figure J.37: Locations of new Automatically Opening Vents (AOVs) provided to Levels Ground to 3 (PSB00000603)

J7.1.67 **h) Control equipment**

J7.1.68 A master control panel and a Human Machine Interface (HMI) panel were both located at Ground Level.

J7.1.69 The master control panel was located in the hub room A010. The control panel allows the operator to access system configuration, maintenance and testing functions (Figure J.38 and Figure J.39). Please refer to Section J7.5 and J7.6 for operation and programming of the system in environmental and smoke control modes respectively.

Figure J.38: Master outstation metal casing and labels, located in the Hub Room

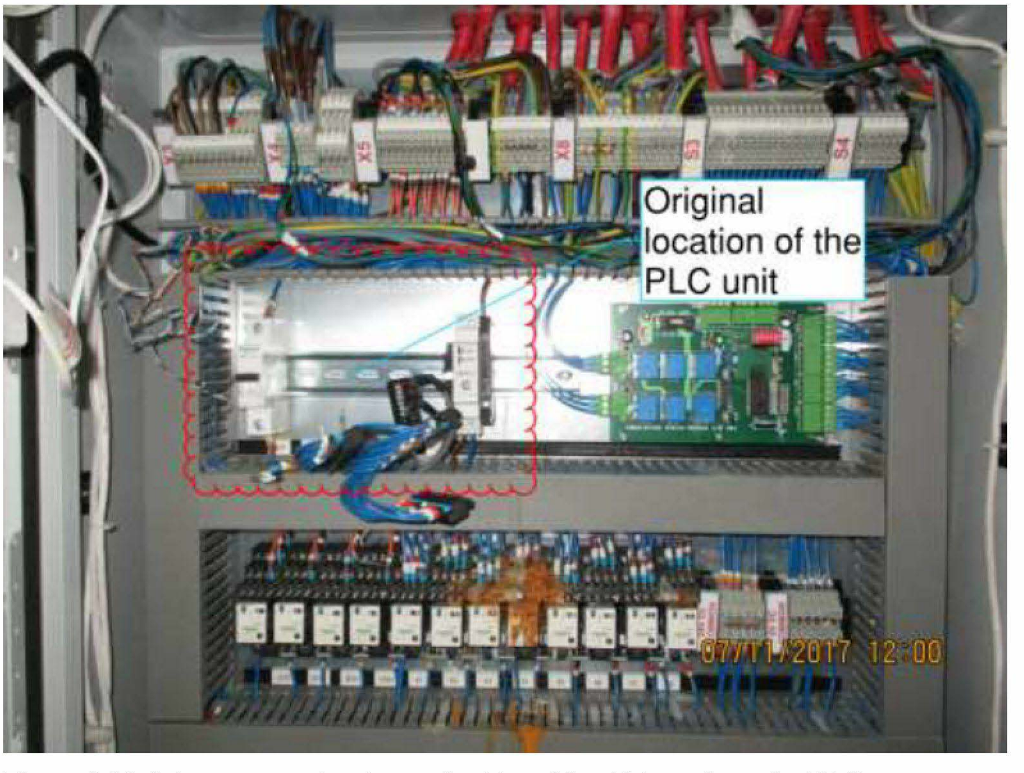


Figure J.39: Master outstation internal wiring, identifying where the PLC was positioned before being removed by the MPS

J7.1.70 The Human Machine Interface (HMI) panel was located within the Ground floor lobby (Figure J.40). The HMI panel allows fire fighters to make changes to the operation of the system including the floor of operation. Please refer to Section J7.7 for details of its programming and operation.

Figure J.40: HMI panel, located in the Entrance Lobby, photographed on 17 June 2017 showing key switched to the 'On' position. (MET00018915).

J7.1.71 A Local outstation in the riser cupboard opposite the lifts in each lobby. Outstations are control panels provided on each floor to manage the systems on that floor.

Figure J.41: Local outstation on Level 6.

J7.1.72 Fire fighter override key switch (yellow) on Lobby wall next to the stair door. In conjunction with the HMI panel the key switch can be used to change the floor of operation of the smoke system to the floor on which a key switch is operated.

Figure J.42: Fire fighter override key switch on Level 6.

J7.1.73 Pressure sensors and pressure sampling tubes to detect the pressure difference between the stair and the lobby on that level. Pressure sensors were provided on every floor (Figure J.43) and were used to control the speed of the fan between "door closed" mode and "door open" mode.

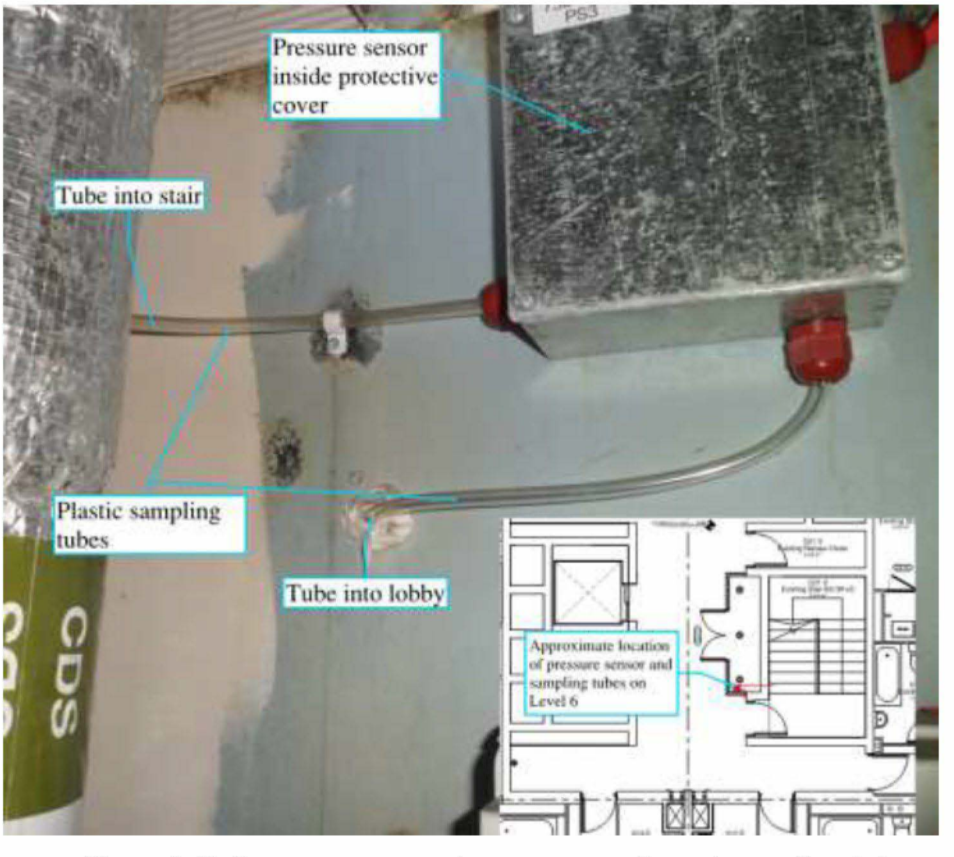


Figure J.43: Pressure sensor and pressure sampling tubes on Level 6.

J7.1.74 Fan inverter control panels and power supplies (Figure J.44 and Figure J.45). The inverter panels provide speed control and power to the fans.

Figure J.44: Environmental fan invertor panel located in the Ground Floor Hub Room

Figure J.45: Invertor panel for the smoke fans located in the Ground Floor Hub Room

J7.1.75 **i) Cables**

J7.1.76 I have made no inspection of cable routes or individual cables as part of my post-fire inspection of 7-9 November 2017.

J7.1.77 I will present the findings of my cable drawing review in Phase 2.

J7.1.78 **Summary of installation**

J7.1.79 In this section I have described the physical components of the smoke control system that was installed in Grenfell Tower.

J7.1.80 I have identified that a number of components did not comply with the relevant guidance. These non-compliances are such they can compromise either the operation of the smoke control system or the physical compartmentation of each lobby in the building.

J7.1.81 These are:

a) In respect of the existing builders work shafts, I note that BS 12101-6 provides guidance for the use of builders work ducts as part of a smoke control system (Section J7.1.5). The existing ducts do not appear to have been fully rendered inside, nor are they provided with sheet metal linings. I have seen no evidence that the ducts were checked with respect to air leakage;

b) I have seen no evidence that the existing shafts have been checked for leakage in accordance with the SCA guide section 8.2.4.

c) I have seen no evidence that PSB assessed the fire resistance rating of the shafts that were to be incorporated into their system to protect the lobbies.

d) The distribution ductwork in the main foyer at Level 2 was not provided with insulation and no evidence has been provided that this duct would have maintained the compartmentation between the stair and the smoke control system;

e) The smoke fans at Roof level were incorrectly specified to be rated for operation at 300°C, rather than 1,000°C, as required by BS EN 12101-6. I could not observe the information plate fixed to the fan at Level 2 and therefore I cannot be sure of the rating, however I have seen no evidence to suggest that this fan was installed to a higher standard than specified in the PSB Technical Submission (Rev 6); and

f) Based on the relevant test evidence, the dampers are not be appropriate for use as fire dampers to maintain compartmentation in accordance with ADB 2013.

g) The dampers also do not comply with the requirements of smoke control dampers from BS EN 12101-8 because there is no relevant test evidence to BS EN 1366-10, nor classification to BS EN 13501-4.

h) I have found no Integrity or Smoke Leakage performance requirements for dampers in the design and construction documentation available to me, at this stage of my investigation.

J7.1.82 Regarding smoke leakage from the vent shafts into the lobbies, as has been observed by residents, the formal certification of *fire dampers* and *smoke control dampers* permit a specific maximum rate of leakage. Therefore, such dampers are not intended to entirely prevent the movement of smoke between compartments. However, the use of a damper without having satisfied the appropriate higher pressure test for *Smoke Leakage* may have led to an increased passage of smoke from the builders works shafts into the lobbies on each level, compared to an untested and uncertified damper.

J7.1.83 There may be other reasons for smoke leaking out of the AOV dampers, and I am investigating this at this time.

J7.2 Autodialler

J7.2.1 An autodialler activated by the smoke control system was installed by Tunstall on 04/05/2016. The Tunstall visit record is provided in RYD00094190.

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 autodialler (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.

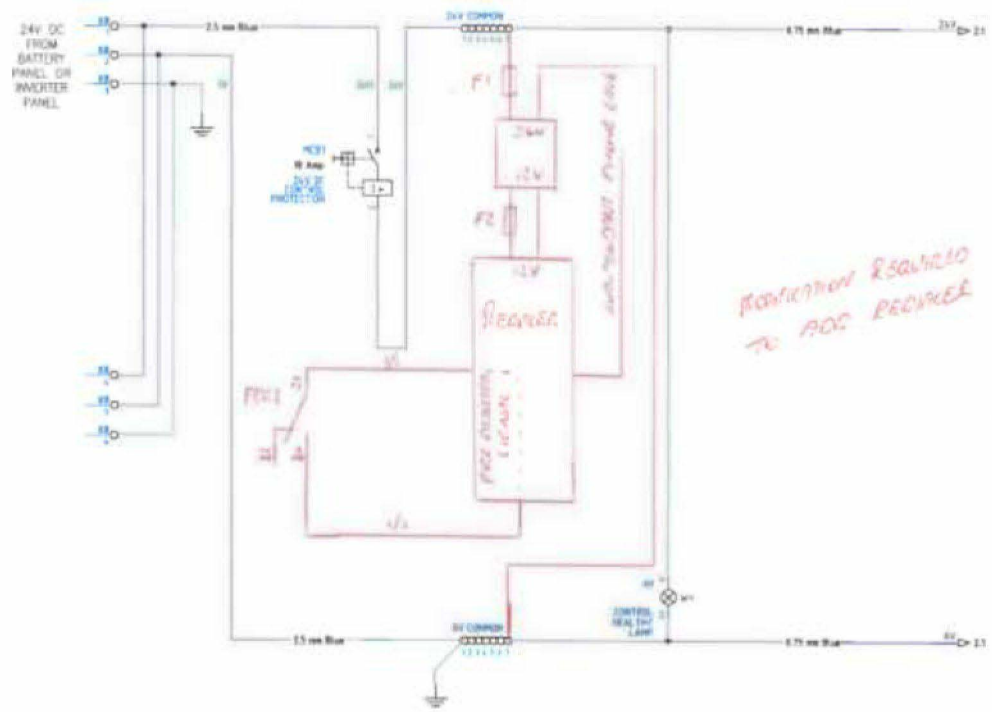


Figure J.46: Excerpt from PSB00001090 showing how the autodialler ('redialler') was to be installed in the PSB system.

J7.2.3 The Tunstall visit record states that the equipment installed in Grenfell Tower was a Lifeline Vi unit which was 'Connected to smoke extraction system'.

J7.2.4 The TMO's requested actions on activation are set out in an email from RJE to Rydon (PSB00001096) reproduced below.

> As you are aware we're installing and programming the telephone dial-out unit to the smoke extract system over the next couple of days.
>
> KCTMO have provided us with dial-out telephone numbers to Tunstall Telecom and we shall record a default message for commissioning which of course can be reprogrammed if required.
>
> For your information we are going to set a default mode on the panel as follows (as page 2 of the attached installation guide):
>
> On the trigger of the alarm, the unit will dial 08444152206, and will relay the following audio message:
>
> "This is the fire panel at Grenfell Tower, Grenfell Road, London, W11 1TQ. There is a" "Fire alarm"
>
> If this alert is not acknowledged, the unit will dial the second number - 01302333623 and relay the same message.
>
> If neither numbers are acknowledged initiall it will repeat the sequence a further 6 times.
>
> Please note, KCTMO have also provided a system ID number – 540009001. I'm currently trying to ascertain where this number fits into the process, I've talked to both Tunstall and the TMO people but I'm struggling to understand how to incorporate the number into the system. For now we can't go any further than programming the dial out unit with the 2 numbers provided and carrying out a test dial.
>
> If you can shed any light on the ID number I would be grateful.

J7.2.5 Tunstall's records of the actions to be undertaken by them in the event of an alarm are provided in THL00000001, shown in Figure J.47. The ID number in THL00000001 is the same as in PSB00001096 above, i.e. 540009001.

Requested by SJONES **Resident + Notes** **24 July 2017 21:52:25**

DISPERSED DWELLING

		Phone No.	0207 792 9345
Equip Id.	540009001	**Alt. Phone No.**	
Address	Lancaster West Estate, Grenfell Tower, Grenfell Road, London W11 1TQ	**Authority**	Kensington & Chelsea

Location Contact

Name C A S **Phone 1** 020 7605 6509 **Phone 2** 07976 628 765

RESIDENT 1

Name Fire Alarm **Date of Birth**

Keyword	**Details**
1 Info	call 999 and then see dwelling notes.

Resident Notes
<No notes found>

Resident Contact
<No contacts found>

CONTACT GROUP
<No contact group found>

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 0208 968 2738 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 0800137111 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 0208 221 6554 to reset the boiler.

4TH Call CAS to to advise and update on steps 1-3..

Figure J.47: Tunstall document (THL00000001) detailing the actions to be taken in the event of activation.

J7.2.6 THL00000001 confirms Tunstall's record of the ID number for the equipment as 540009001.

J7.2.7 THL00000001 confirms the address of the equipment as Grenfell Tower.

J7.2.8 In the event of activation, THL00000001 confirms the actions were:

a) To call the Fire Brigade 999;

b) call Estate Services 02089682738 to contact an on-call caretaker;

c) To call 0800137111 to get the boilers restarted;

d) To call CAS (TMO Out of hours service) to confirm steps 1-3.

J7.3 Activation of the Autodialler prior to 14 June 2017

J7.3.1 THL00000002 provides the call log summarising events from 04/10/2016 to 16/06/2017.

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.

J7.3.3 An excerpt from THL00000002 is shown in Figure J.48 below.

Requested by SJONES **Calls History** **24 July 2017 22:16:16**

Arrival Time	Scheme	Unit	Event	Reason
16/06/2017 00:48:28		540009001	Mains Failure	Background Call
15/06/2017 21:14:32		540009001	Outgoing call	Contact Requested
15/06/2017 21:14:27		540009001	Mains Failure	Background Call
15/06/2017 21:12:40		540009001	Alarm call failed	System Information Call
15/06/2017 16:51:33		540009001	Mains Failure	Background Call
15/06/2017 12:47:27		540009001	Mains Failure	Background Call
14/06/2017 04:13:32		540009001	Outgoing call	Check Resident
14/06/2017 01:04:20		540009001	Outgoing call	Contact Requested
14/06/2017 00:55:01		540009001	Smoke Detector	Fire Service Called
09/06/2017 10:21:43		540009001	Smoke Detector	Test Engineer/warden
02/06/2017 10:08:42		540009001	Smoke Detector	Test Engineer/warden
19/05/2017 09:53:14		540009001	Smoke Detector	Test Engineer/warden
16/05/2017 17:49:06		540009001	Outgoing call	Contact Requested
16/05/2017 17:35:05		540009001	Smoke Detector	Fire Service Called
15/05/2017 15:02:12		540009001	Smoke Detector	Reassurance Required
15/05/2017 15:00:37		540009001	Smoke Detector	Reassurance Required
15/05/2017 14:57:32		540009001	Smoke Detector	Reassurance Required
15/05/2017 14:56:01		540009001	Smoke Detector	System Information Call
15/05/2017 14:53:48		540009001	Smoke Detector	Reassurance Required
15/05/2017 14:51:09		540009001	Smoke Detector	System Information Call
15/05/2017 14:47:36		540009001	Smoke Detector	Reassurance Required
15/05/2017 14:45:44		540009001	Smoke Detector	Reassurance Required
15/05/2017 14:42:11		540009001	Smoke Detector	Reassurance Required
15/05/2017 14:37:47		540009001	Smoke Detector	System Information Call
15/05/2017 14:35:00		540009001	Smoke Detector	System Information Call
15/05/2017 14:32:32		540009001	Smoke Detector	Reassurance Required
15/05/2017 14:29:14		540009001	Smoke Detector	Reassurance Required
15/05/2017 14:27:09		540009001	Smoke Detector	Reassurance Required
15/05/2017 14:23:52		540009001	Smoke Detector	Reassurance Required
15/05/2017 14:20:02		540009001	Smoke Detector	Reassurance Required
15/05/2017 14:15:27		540009001	Smoke Detector	Reassurance Required
15/05/2017 14:06:22		540009001	Smoke Detector	Test Engineer/warden
15/05/2017 14:04:26		540009001	Outgoing call	Warden Called
15/05/2017 13:54:06		540009001	Smoke Detector	Test Engineer/warden
15/05/2017 13:47:23		540009001	Smoke Detector	Fire Service Called
05/05/2017 10:33:58		540009001	Smoke Detector	Test Engineer/warden
28/04/2017 10:09:46		540009001	Smoke Detector	System Information Call
21/04/2017 10:47:59		540009001	Smoke Detector	Test Engineer/warden
07/04/2017 10:10:39		540009001	Smoke Detector	Test Engineer/warden
31/03/2017 09:59:59		540009001	Smoke Detector	Fire Test Warden
24/03/2017 09:55:18		540009001	Smoke Detector	Fire Test Warden
10/03/2017 10:06:00		540009001	Smoke Detector	Fire Test Warden
03/03/2017 10:05:35		540009001	Smoke Detector	Fire Test Warden
24/02/2017 10:13:59		540009001	Smoke Detector	Test warden
17/02/2017 09:21:24		540009001	Smoke Detector	Fire Test Warden
10/02/2017 10:11:49		540009001	Smoke Detector	Fire Test Warden
03/02/2017 10:28:14		540009001	Smoke Detector	Fire Test Warden
03/02/2017 10:24:01		540009001	Smoke Detector	Fire Test Warden
27/01/2017 10:22:02		540009001	Smoke Detector	Fire Test Warden
20/01/2017 10:59:04		540009001	Smoke Detector	Fire Test Warden
09/12/2016 15:58:02		540009001	Outgoing call	Contact Requested
09/12/2016 15:54:37		540009001	Smoke Detector	Fire Service Called
02/11/2016 10:14:06		540009001	Smoke Detector	Fire Test Warden
09/10/2016 21:24:40		540009001	Outgoing call	Warden Called
09/10/2016 21:22:23		540009001	Outgoing call	Check Resident
09/10/2016 21:21:29		540009001	Smoke Detector	System Information Call

Figure J.48: Excerpt from THL00000002 showing the autodialler call log from 04/10/2016 to 16/06/2017

J7.3.4 The autodialler call log shows that from the 20th January 2017, a single activation of the panel occurred, generally on the Friday of each week. This is associated with 'Fire Test Warden', or 'Test Engineer / Warden'.

J7.3.5 The majority of calls prior to 14/06/2017 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 / Warden'. I intend to investigate this further in Phase 2.

J7.3.6 Residents (e.g. Flora Neda IWS00000887 and Farhad Neda IWS00000886 who lived in flat 205 on the 23rd floor) have provided evidence of hearing a noise in the floor 23 lobby and also in their flat. The Nedas recall that this was particularly on Fridays.

J7.3.7 21 signals from the panel were received on 15/05/2017. Lakehouse were undertaking maintenance of the AOVs on 15/05/17 (LAK00000011, LAK00000042). It is likely that these calls are associated with Lakehouse's activities. It is stated in LAK00000042 that this included testing of activation of the AOVs by the smoke detectors. It is noted that there should have been 24 signals if the system was tested on every floor. The representative of Lakehouse advised that he re-set the panel himself after each activation in a lobby (LAK00000042).

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.

J7.3.10 THL00000002 also shows that the autodialler received a signal from the smoke panel resulting in a call to the fire service at 00:55:01 on 14 June 2017.

J7.3.11 I do not know what time the signal was received – before or exactly at 00:55:01.

J7.3.12 THL00000003 shows that Tunstall then successfully completed the actions listed in J7.2.8.

J7.3.13 No other call from the control panel was received on the 14th June 2017.

J7.4 System controls

J7.4.1 The control of the environmental and smoke control system installed at Grenfell Tower was complex because it included elements of software control combined with physically wired control and power panels.

J7.4.2 Specialists on my team have reviewed the following program files:

1) Files relating to the main control panel (PLC) that was located in the Ground Floor Hub room, only:

   a) Main control panel software retrieved from the control panel by the MPS (Revision 6, MET00018070).

   b) A main control panel file (MET00018071) that appears to be a duplicate of MET00018070.

   c) PDF printout of control panel software held on PSB's archive server (version unknown, but appear to match MET 18070, PSB00001301).

   d) PDF printout of control panel software present on the main control panel (version unknown but appear to match MET 18070, PSB00001303).

2) Files relating to the HMI panel that was located in the Ground Floor foyer, only:

   a) HMI software retrieved from the HMI panel removed from Grenfell Tower by the MPS (MET00018074).

J7.4.3 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).

J7.4.4 In the following Sections J7.5, J7.6 and J7.7 I set out how the control system was programmed to operate.

J7.5 Operation of the refurbished system – environmental mode

J7.5.1 There is conflicting information available to me, regarding the operation of the environmental system. The health and safety file issued by J.S. Wright (RYD00000577, undated), which is the document intended to be the final information on the design of the building for use by the client in undertaking their duties under the RR(FS)O, identifies that the environmental ventilation system will operate on every level at the same time.

J7.5.2 Project correspondence has identified that this operation method was changed as I describe below.

J7.5.3 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 JSW to PSB 15/04/16).

J7.5.4 The program changes were provided to the commissioning team before final commissioning on 28/04/2016 (email M Glowacki to G Partlow, PSB00001113), although there is no record of testing of the operation of the environmental system in this mode during those commissioning tests.

J7.5.5 My team's review of the software downloaded from the panels after the fire shows the control system at Grenfell Tower was programmed to operate in this updated mode of operation for the environmental system at the time of the fire.

J7.5.6 Figure J.49 presents my current understanding of the environmental model control, from my team's review of the PSB disclosure and the control programmes for the main control panel (MET00018070) and the HMI panel (MET00018074).

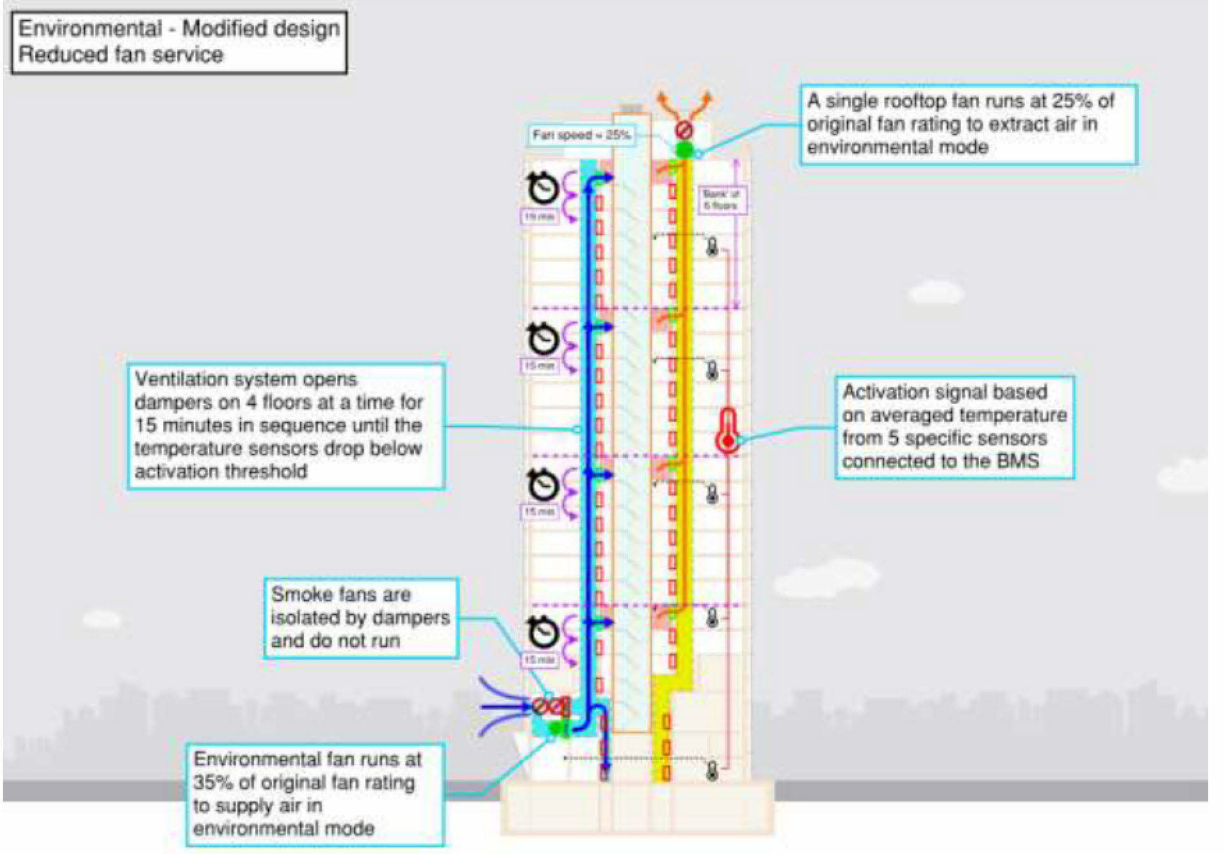


Figure J.49: illustration of the environmental mode control programme

J7.5.7 The environmental system was controlled as follows:

1. 5 thermostats (RYD00000577) were to be connected to the BMS, one each in the lobby at Ground, Level 5, Level 10, Level 15 and Level 20;
2. The readings from these thermostats were to be averaged by the BMS which then sent a single activation signal to the smoke control system to operate in environmental mode;
3. On receiving the signal, the HMI panel programming instructed the environmental fan at Level 2 to operate at approximately 35% (MET00018070) of its rated performance to supply air to the lobbies, and the main smoke fan at Roof level to operate at approximately 25% of its rated performance to extract air from the lobbies;
4. The 2 No. shut-off dampers associated with the environmental fan at Level 2 were to be signalled to open;
5. The AOVs in the building were split into 4 groups of 6;
6. On activation of the environmental system, the 4 AOVs in the top level in each of the 4 groups would open. That is: Level 5, Level 11, Level 17 and Level 23;

7. These dampers would be open for 15 minutes;
8. These dampers would then close, and the dampers on the next level down in each of the 4 groups would then open for 15 minutes;
9. This operation sequence would continue until the dampers on every floor of each group of floors had opened for 15 minutes each, and then the system would move back to the top floor of each group;
10. This pattern of operation would continue until the average temperature recorded by the thermostats dropped below the threshold level, at which point the activation signal from the BMS would stop and the environmental system would shut down;
11. The AOVs on each floor would shut, the fans would turn off and the shut-off dampers associated with the Level 2 fan would close.

J7.5.8 This system of operation was in place at the final commissioning on 28/04/2017. This is evidenced by the fact that the programming was sent to the commissioning team (PSB00001113) on 25/04/2016 and PSB00001124 includes measurements of flow velocities at AOVs for the reduced fan flowrates at roof and Level 2 fans, as required for this mode.

J7.6 Operation of the refurbished system – smoke mode

J7.6.1 According to the PSB technical submission Rev 6 PSB00000214, on detection of smoke:

a) The environmental fan was to be shut down and electrically isolated.

b) The environmental fan, and its associated unrated ductwork, was to be isolated from the smoke control system by the bypass smoke dampers.

c) The AOVs on the fire floor only were to open.

d) The AOVs on all other floors were to be closed and locked out.

e) The smoke exhaust fan sets at roof level (serving the north shaft) and at Level 2 (serving the south shaft) were to operate to exhaust smoke from the lobby on the fire floor only.

J7.6.2 The smoke exhaust fan sets at roof level (serving the north shaft) and at Level 2 (serving the south shaft) were to operate to exhaust smoke from the lobby on the fire floor only.

J7.6.3 The smoke exhaust fans at roof level were to exhaust smoke from the AOVs located at high level on the north side of the lobby into the north vent shafts to discharge at roof level.

J7.6.4 The smoke exhaust fans at Level 2 level were to exhaust smoke from the AOVs located at low level on the south side of the lobby into the south vent shafts to discharge to outside at Level 2, via fire rated ductwork.

J7.6.5 Fresh air was to be drawn into the lobby from the stair via the permanently open vent at the head of the stair.

J7.6.6 The programmed operation of the system in smoke mode is summarised in Figure J.50.

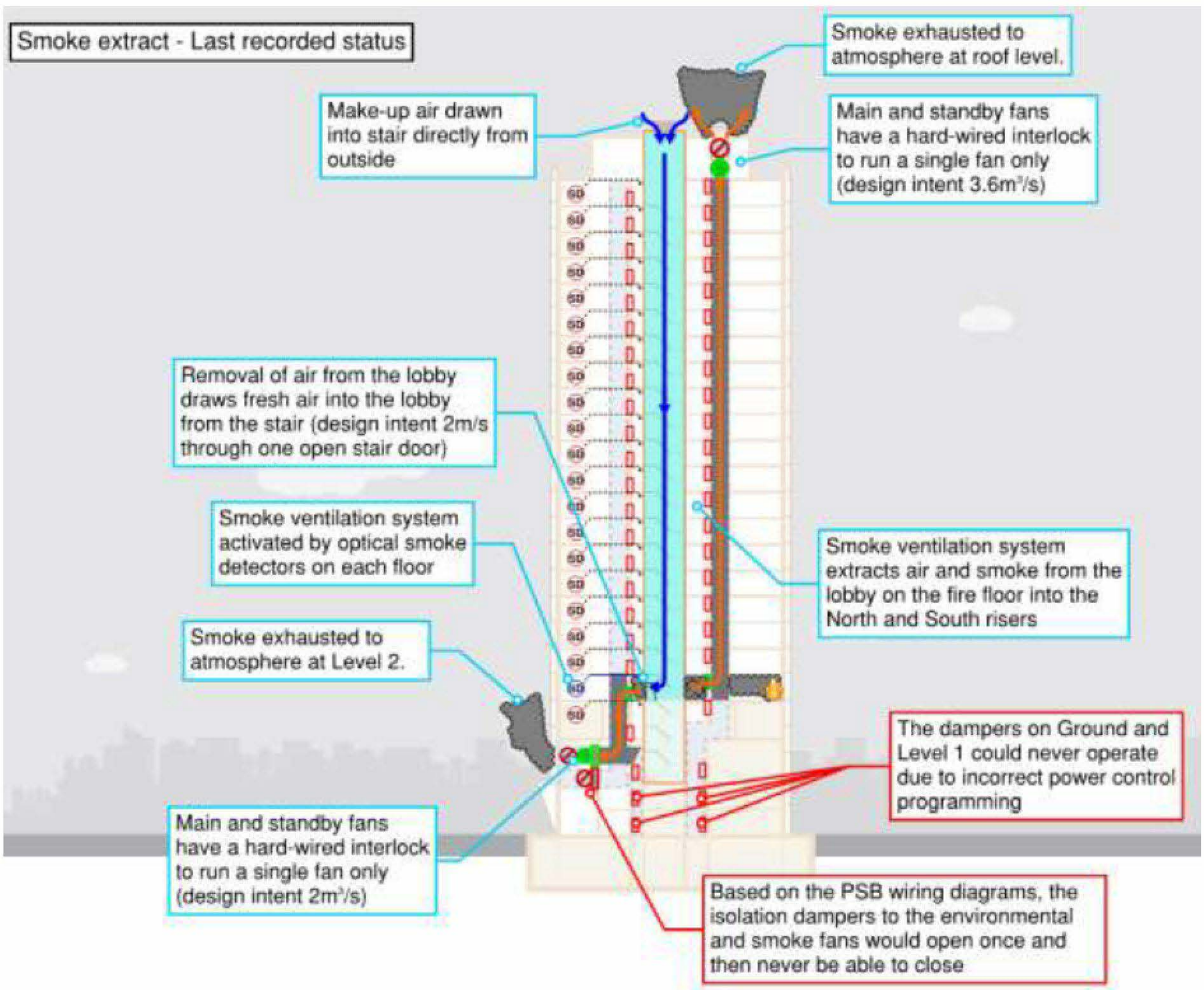


Figure J.50: Programmed operation of the smoke control system

J7.6.7 If the stair door was open, the flow of air into the lobby from the stair was intended to prevent smoke present within the lobby from flowing into the stair. This performance requirement is described in Section 1.1.2 of 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 J.51: Section 1.1.2 PSB00000214

J7.6.8 A pressure sensor in each lobby was provided to allow control of the fan exhaust rate. This performance requirement is described in Section 1.1.2 of 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 J.52: Section 1.1.2 PSB00000214

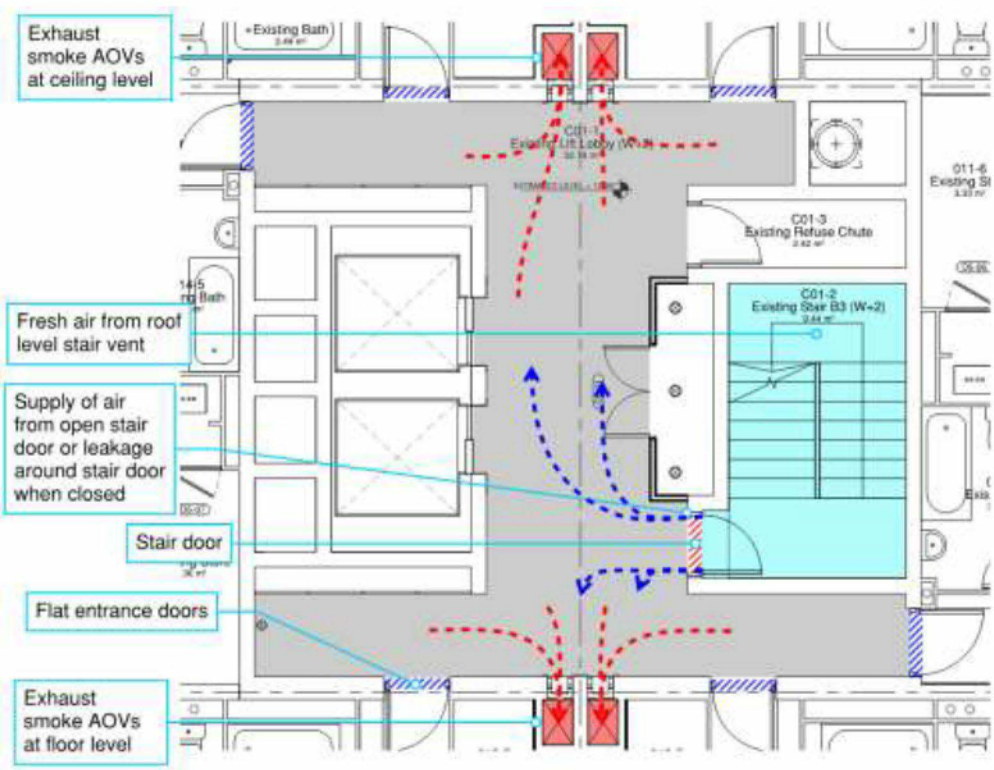
J7.6.9 When the stair door is closed, the system is intended to maintain a pressure difference of 25Pa between the lobby and the stair. This performance requirement is described in Section 3.3 of PSB00000214:

> 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 J.53: Section 3.3 PSB00000214

J7.6.10 When the stair door is open, the fans would increase in speed and the system is intended to provide an airflow of 2m/s through the open door between the stair and the lobby, as set out in the excerpt from PSB00000214 above.

J7.6.11 This operation is shown schematically in Figure J.54.



BLAS0000031_0090

Figure J.54: Design intent of the smoke extract system in Grenfell Tower (overlaid onto (SEA00010474)

J7.6.12 The operation of fans and dampers at Level 2 is set out in Figure J.55, Figure J.56 and Table J.3 below.

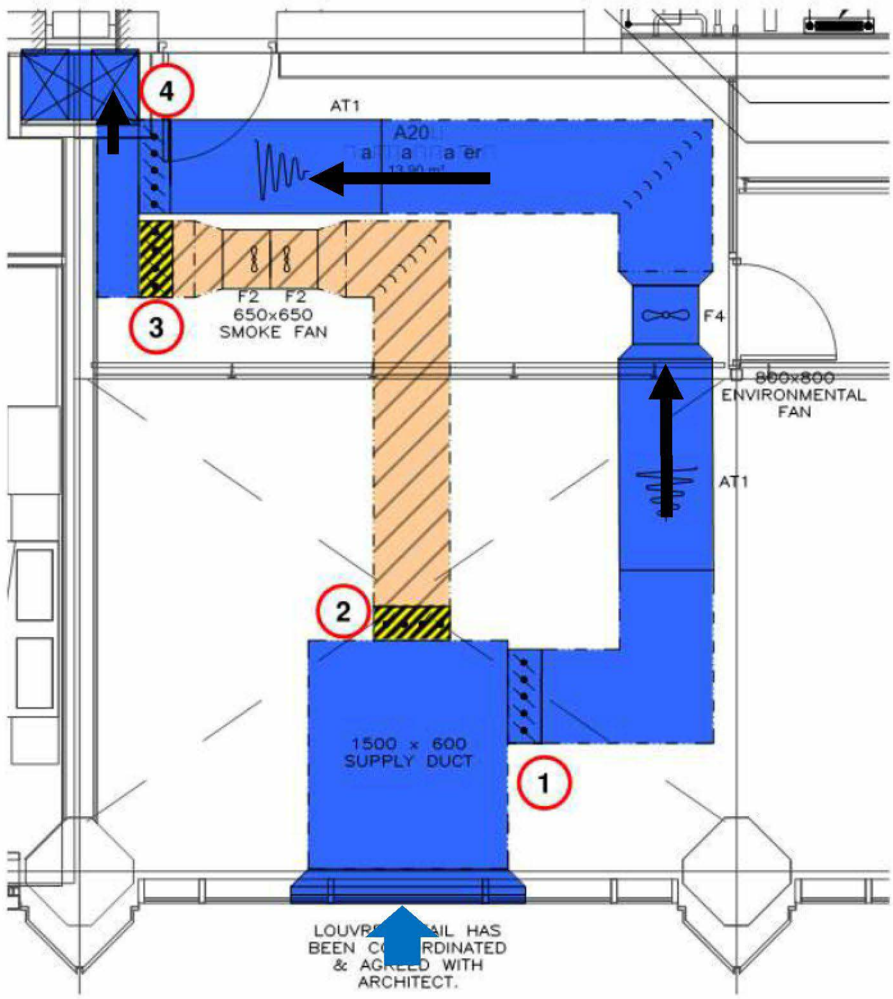


Figure J.55: Smoke system at Walkway Level – environmental operation. The route of fresh air supplied into the building is coloured blue. Original drawing was within RYD00000577.

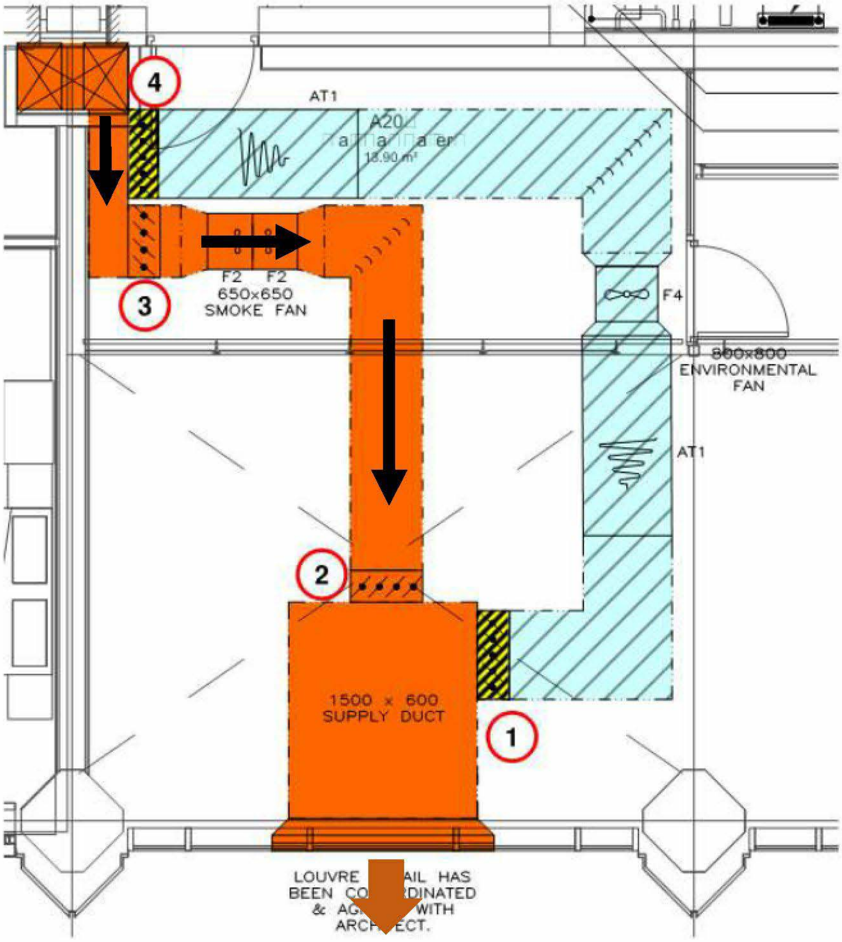


Figure J.56: Smoke system at Walkway Level – smoke control operation. The route of smoke exhaust from the shafts (top left) to the grille (bottom) is coloured orange. Original drawing was within RYD00000577.

Table J.3: Operation of fans and dampers at Level 2 for environmental and smoke operations.

	Environmental operation	Smoke operation
Smoke fan	off	on
Environmental fan	on	off
Damper 1	open	closed
Damper 2	closed	open
Damper 3	closed	open
Damper 4	open	closed

J7.6.13 Section 2.3.1 of PSB00000214 states that once they were closed, the AOVs on all other floors were to be *'electrically isolated to prevent them being opened to maintain separation and smoke contamination of the other floors'*

J7.6.14 Section 2.3.1 of PSB00000214 states that *'In the event of failure of the primary power supply the battery backup panel will provide a power secondary [sic] supply.'*

J7.6.15 Section 2.3.1 of PSB00000214 states that *'Indication on the mimic repeater panel and main control panels shall indicate the core & floor on which the alarm has been triggered.'*

J7.7 Human Mechanical Interface (HMI) panel

J7.7.1 A Human Mechanical Interface (HMI) panel was provided in the Ground floor entrance foyer. 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 J.57: Section 1.1.2 PSB00000214

J7.7.2 The HMI has a 2-state key switch permitting 2 modes of operation: "Auto" and "On". This is shown in Figure J.58.

J7.7.3 PSB00000214 did not specifically identify the switch on the panel and the two modes above, but this switch was provided as above, as can be seen in Figure J.58.

J7.7.4 Figure J.59 presents the main screen of options. I understand that this screen would be displayed on the HMI as the first page of options from which a user could select an action. Specifically, for use by the fire service, I note that this first screen includes the options to "*reset fire signal*" and "*silence alarm*".

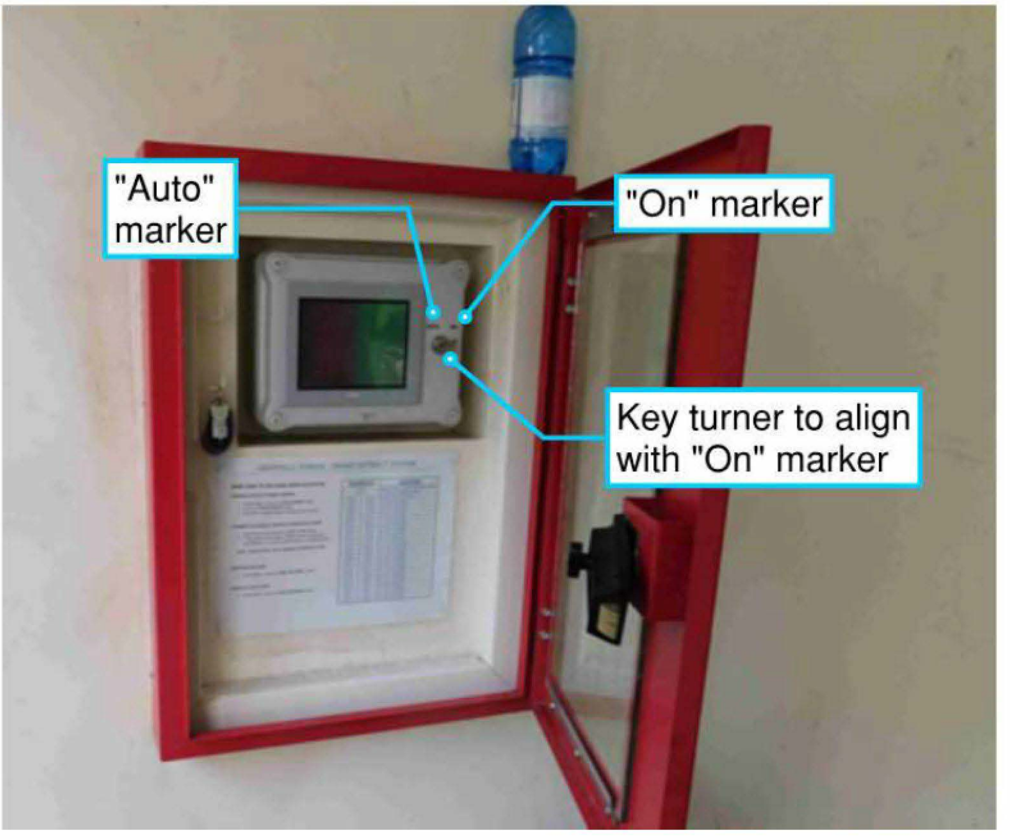


Figure J.58: Photograph of HMI panel after the fire (MET00018915)

J7.7.5 From my team's analysis of the programming of the system at the time of the fire, the interaction of these modes is programmed as follows:

1. In "Auto" mode – On detection of smoke in a lobby, the activation sequence as described in Section J7.6 above occurs.
2. If the HMI was left in 'Auto' then the system would continue its automatic (programmed) response. This would mean the override screens would not be available and the key switches on the floors, even if used, would not have any effect.
3. Switching from "Auto" to "On" does not initiate any immediate changes in the operation of the smoke control system.
4. When the HMI is set to "On" this allows Fire fighters to operate the smoke system from the HMI, to turn the system off, restart the smoke system or change the floor of operation of the smoke system (Figure J.60)
5. When the HMI is set to "On" this allows Fire fighters to operate the smoke system using the (yellow) key switch in each lobby to change the floor of operation to that floor.
6. With the HMI set to 'On', the panel displays the status of the fans and AOVs, as shown in Figure J.60 and Figure J.61, and allows fire fighters to

change the floor of operation of the smoke system from the touchscreen as shown in Figure J.62.

7. Once the system is in ‘On’: Operation of a (yellow) key switch on any floor closes the AOVs that are currently open, and then opens the AOVs on the floor the switch is being used only.
8. If a key switch on one of the floors is operated while the HMI is in ‘Auto’ no change to the smoke system is activated.
9. The key switches on the floors are interlocked such that the first lobby key switch activated must be turned off before the lobby switch on any other floor would function. (Noting that 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.)
10. If the HMI panel had been used to manually override the floor of operation, and then a key switch was operated, then the system would operate on the floor where the key switch had been operated. The system would then not act on any further manual override instructions from either another key switch or the HMI panel until the first key switch had been turned off. The key switch therefore took precedence over the operation from the HMI touch screen.
11. My team’s analysis of the programming shows that switching the HMI from “Auto” to “On” and back to “Auto” resets the AOVs such that the AOVs open on the lowest floor of smoke detection since the panel first activated. The fans continue to run.
    For example, in the event of a fire on Level 7, if smoke spreads through the building and is present on Levels 4 to 9, and the system is turned from Auto to On to Auto, then the system would open the damper on Level 4 as it is the lowest floor in the building on which smoke had been detected at the time of the change of operation.
12. My team’s analysis of the programming shows that if the “Restart System” button on the Fireman’s override screen was pressed, the system would restart at the original floor of automatic activation, even if an over-ride key switch had been activated.
13. My team’s analysis of the programming shows that while in Auto, if the ‘Reset Fire Signal’ button on the HMI menu first screen is pressed, and there is still smoke present to activate a smoke detector in one or more of the lobbies, then the system will restart on the floor from which a signal from a smoke detector is first received, regardless of the floor of original operation.

Figure J.59: HMI menu first screen

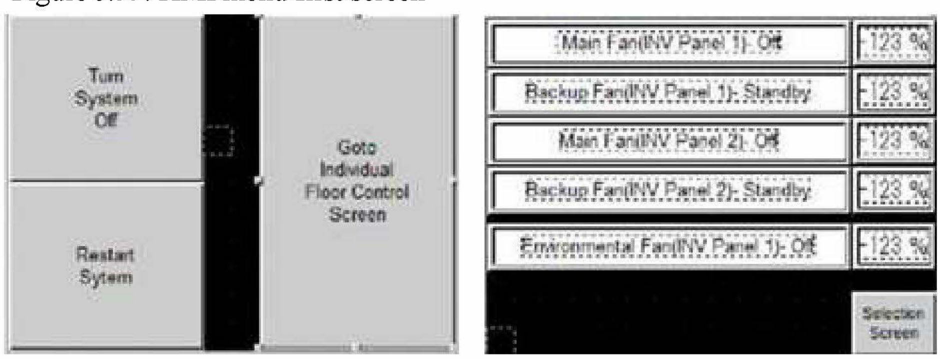


Figure J.60: Fireman's override main screen (left) and fans status screen (right) taken from MET00018074.z2g using WindOI-NV2.

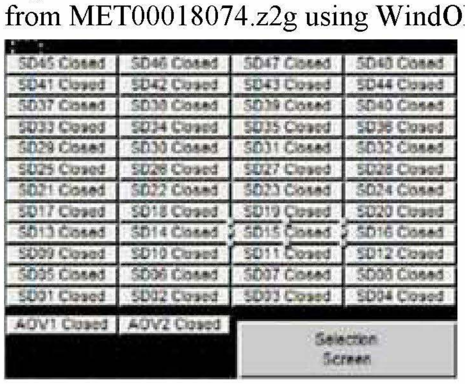


Figure J.61: Fireman's override damper status screen taken from MET00018074.z2g using WindOI-NV2.

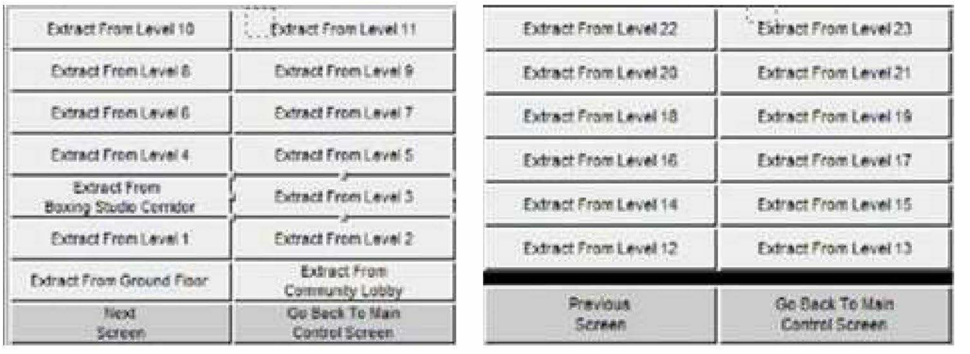


Figure J.62: Fireman's override Individual Floor Control Screens taken from MET00018074.z2g using WindOI-NV2.

J7.7.6 Figure J.59 presents the main menu page for the HMI panel. 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 J.63.

J7.7.7 The system main menu therefore could display information as to what floor the fire had been detected on, and any specific information relating to faults in different parts of the system.

J7.7.8 I assume that Messages 57 through 70 are default messages that were not deleted from the system as they refer to floors that do not exist in in Grenfell Tower.

J7.7.9 Based on my understanding of the HMI system programming, on activation of a smoke detector, the HMI panel would exhibit the message indicating the location of fire activation only. The fire message would inhibit any fault messages that the system would otherwise be reporting. This requires further investigation in Phase 2.

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 J.63: Available system status messages (from MET00018074.z2g using WindOI-NV2)

J8 Evidence of commissioning

J8.1.1 Commissioning is required to demonstrate compliance with Building Regulation 7, which states:

"*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;"

J8.1.2 Without commissioning there can be no evidence that an active building system can "*adequately perform the functions for which they are designed*".

J8.1.3 BS EN 12101-6 defines commissioning as "*act of ensuring that all components, kits and the system are installed and operating in accordance with the manufacturer's instructions and this document*".

J8.1.4 Therefore, the commissioning process should produce sufficient documented evidence that the Class B depressurization system forming the basis of design, could function as required in the event of a single flat fire.

J8.1.5 I have already concluded that the system was not-compliant by design and installation, with a Class B depressurization system.

J8.1.6 To re-iterate, I have no information available as to what protection the limited functions provided by the PSB Revision 6 system would provide to a stair in the event of a real single flat fire situation. That is against the background of the requirements to protect the fire fighting shaft as defined in BS EN 12101-6, and as required by the statutory guidance in Clause 2.25 of ADB 2013.

J8.1.7 In my review of the available commissioning information, I have therefore tried to be clear where the select number of PSB Revision 6 performance requirements were expressly commissioned, as well as assessing the commissioning against the full set of requirements.

J8.1.8 In this section, I consider the following:

a) The requirements for commissioning within BS EN 12101-6 and the SCA Guidance which was provided to PSB by RBKC on 4th May 2016.

b) The records of commissioning provided by PSB to determine whether the commissioning met the requirements of BS EN 12101-6 and the SCA Guidance.

J8.2 Available guidance for commissioning

J8.2.1 Section 2.27 of ADB 2013 states that "*Guidance on the design of smoke control systems using pressure differentials is available in BS EN 12101-6:2005.*"

J8.2.2 Section 12 of BS EN 12101-6:2005 provides specific guidance on Acceptance Testing (i.e. commissioning) of smoke control systems using pressure differentials.

J8.2.3 RBKC Building Control forwarded the Smoke Control Association document: Guidance on Smoke Control to Common Escape routes in apartment

Buildings (Flats and Maisonettes) Rev 2: October 2015 to PSB (PSB00001130) on 4th May 2016 and said:

"*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.*"

J8.2.4 Additionally, Section 9 of the SCA guide, addressing Commissioning and Acceptance Testing. Section 9.1 states:

"*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.*"

J8.2.5 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.*

J8.2.6 I have therefore reviewed the PSB commissioning report against the requirements for commissioning within the following documents.

i) BS EN 12101-6: 2005 (Section 12);

ii) Smoke Control Association document: Guidance on Smoke Control to Common Escape routes in apartment Buildings (Flats and Maisonettes) Rev 2: October 2015;

iii) BS 7346 Part 8 (Section 8).

J8.3 BS EN 12101 guidance

J8.3.1 BS EN 12101-6 states in Section 12 that the following 'acceptance tests' must be undertaken, as described in section 12 of the standard:

"12.2 ***Acceptance test requirements***

NOTE In buildings higher than eight stories, the tests specified in 12.2.1 and 12.2.2 should be carried out in groups of eight floors.

1. **Pressure differential test** – [first acceptance test]

   "The first acceptance test shall be carried out to establish pressure differential due to wind and stack effect with pressure differential fans switched off. The test(s) shall be carried out 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 relative to the first acceptance test shall comply with the minimum values indicated in Figures 2, 3, 4, 5, 6 and 7."

2. **Net pressure differential** – [second acceptance test]

"Within 15 min after having completed the requirements of 12.2.1 the second acceptance test shall be 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.

The change in measurement between the first and second pressure readings shall be compared with the performance requirements specified for the design pressure differences."

3. **Air velocity** – [third acceptance test]

"12.2.3.1 The third acceptance test shall measure the air velocity through an open door separating a pressurized and an unpressurized space, and shall comply with the requirements in Clause 4 for the appropriate class of system. The test(s) shall be carried out as follows:

12.2.3.2 Measure the air velocity using a calibrated anemometer.

12.2.3.3 The measurement of flow velocity through the relevant doors shall be taken with all other doors open or closed in accordance with the appropriate class of system described in Clause 4. The doorway shall be clear of obstructions (see Figures 2, 3, 4, 5, 6 and 7 regarding the relevant door).

12.2.3.4 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.

12.2.3.5 The calibration of all test equipment shall be such that the measurements are accurate to ± 5 %."

4. **Opening door force –**

"12.2.4 Opening door force

12.2.4.1 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. The opening force at a particular door shall be measured as follows:

12.2.4.2 Actuate the pressure differential system.

12.2.4.3 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 of opening.

12.2.4.4 Release any latching mechanism, if necessary holding it open.

12.2.4.5 Pull on the free end of the force measuring device, noting the highest value of force measured as the door opens."

5. **Activation of the system** –

"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."

J8.3.2 Section 14 of BS EN 12101-6:2005 provides guidance on how a smoke control system using pressure differentials should be documented.

J8.3.3 Section 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);

h) on completion, the results of the tests carried out on the pressure differential system (see Clause 13)."

J8.3.4 Section 14.2 *Owner/occupier requirements* states:

"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).”

J8.4 SCA Guidance

J8.4.1 Section 9 of the SCA guide addresses Commissioning and Acceptance Testing. Section 9.1 states:

“*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.*”

J8.4.2 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*. Please refer to Section J8.5 for the requirements of this code.

J8.4.3 Section 9.3.6 is the relevant section for pressure differential systems, which 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*”

J8.4.4 I have already set these out in Section J7.3 above.

J8.4.5 The SCA guide then lists the following further actions to be undertaken:

- “*Operate each motorised damper;*
- *Check that fans operate at the same time as the dampers;*
- *Measure the fan performance and check against design value;*
- *Check automatic changeover to standby fan is operational;*
- *Check automatic changeover of secondary power supply;*
- *Inspect motor drive;*
- *Operate ventilators/fans in accordance with cause & effect and inspect for correct operation;*
- *Check maximum force required to open escape doors while system operating in means of escape mode – maximum force of 100N;*
- *Check the operation of the manual control points;*
- *Operation and function of pressure sensors should be checked;*

- *Reset system upon completion, provide certificate of testing and certificate of testing."*

J8.4.6 The SCA guide for commissioning refers the reader to the requirements of BS EN 12101-6 (as I have listed in Section J8.3 above), the requirements of BS 7346 (as I set out in Section J8.5 below), and also lists supplementary testing that should be undertaken (as I have indicated above). The SCA guide is therefore not to be adopted separately to BS EN 12101-6 or BS 7346.

J8.4.7 I have reviewed the Commissioning Report against the requirements of BS EN 12101-6 and the SCA, this review is set out below.

J8.4.8 Where I have found correspondence with data regarding commissioning, not in this report, I have also considered this data too, for completeness.

J8.5 Guidance in BS 7236-8

J8.5.1 Section 8.1 of this standard addresses Commissioning and states:

"*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.

8.1.3 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.

All results obtained during the commissioning process should be clearly recorded."

J8.5.2 Section 8.2 of the standard addresses requirements of documentation and states:

"On completion of the system, the following documentation should be provided to the relevant responsible person.

a) Certificates for design, installation and commissioning of the system (see Annex B).

b) An adequate operation and maintenance manual for the system, providing information specific to the system in question, including:

1) a list of equipment provided and its configuration (e.g. schematic diagram), including use and operation of the system;

2) routine weekly and monthly testing of the system by the user or their appointed agent;

3) information about service and maintenance of the system;

4) the importance of ensuring that changes to the building, such as relocation of partitions, do not affect the standard of protection;

5) other user responsibilities.

c) As-fitted drawings indicating, but not limited to:

1) the positions of all control, indicating and power supply equipment;

2) the positions of all equipment that might require routine attention or replacement;

3) the type, sizes and actual routes of cables.

NOTE The cable routes shown in the drawings need to comprise a reasonable representation of the route followed, such as to enable a competent person to locate the cable in the event of a fault or need for modification or extension of the system. A simple schematic showing the sequence in which devices are wired is unlikely to satisfy this recommendation, other than in small, simple systems. In some complex buildings a cabling schedule cross-referencing the drawings might be necessary in order to help explain the cable routes.

d) A logbook (see Annex C) for recording the information.

e) A record of any agreed deviations from the original design specification."

J8.6 PSB commissioning method

J8.6.1 On the 1st February 2016, PSB issued to JS Wright by e-mail a *Method statement & risk assessment* document related to commissioning the Grenfell Tower smoke control system (PSB00000941).

J8.6.2 The Method Statement document identifies the following scope:

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.

J8.6.3 As I have stated in Section J6.2.25, the system description in Section 4 of this document does not match the system described in the PSB Technical Submission (Rev 6, PSB00000214). Section 4 of the method statement includes a summary description of how the system was intended to work. The pressure difference between the stair and the lobby was required to be 50Pa in PSB's commissioning Method Statement and Risk Assessment dated February 2016 (PSB00000941).

J8.6.4 This conflicts with the PSB Technical Submission (Rev 6, PSB00000214, 15/03/2016) that states that the pressure difference they planned to design would provide 25Pa. It is not clear if this difference represents a real change to the design, or if the Method Statement was in error.

J8.6.5 As I have no data from any pressure readings from site, I cannot confirm which (if either) figure was, in fact, measured as part of the commissioning process. I further note that it is the Technical Submission document (Rev 6) that is included in the JS Wright Health and Safety file (RYD00000577), and therefore it is the pressure difference of 25Pa that is in the project permanent record.

J8.6.6 The figure of 25 Pa was questioned at the time of commissioning by Max Fordham 29/03/2016, as reported in PSB0001066. I have not found evidence yet as to how this was resolved.

J8.6.7 Section 13 of the PSB method statement lists the installation tasks that must have been completed before commissioning could be undertaken.

J8.6.8 However, no standards are quoted with respect to how the commissioning was to be undertaken.

J8.6.9 The commissioning records of the smoke control system, installed as part of the 2012-2016 refurbishment, from commissioning undertaken on or shortly before the 28 April 2016 provided by PSB are provided in a commissioning report dated 28th April 2016 (PSB00000224). I understand from PSB's e-mail correspondence that the commissioning tests occurred on or around the 28th April 2016 and the smoke control system operation was then witnessed by

Max Fordham and RBKC building control on the 5th May 2016 (PSB00001129).

J8.6.10 Associated with this commissioning report, I also have a set of airspeed measurements taken in doorways and in AOV openings on each floor. The airspeed data is recorded on 2 No. loose A4 pages that are otherwise blank. Therefore, I cannot be certain that they relate to the commissioning tests undertaken on the 28th April 2016. However, because they are attached to an e-mail from PSB to JS Wright alongside the above-ground commissioning report (PSB00001152, which is the same commissioning report as PSB00000224 with the two additional sheets added) then I assume that these measurements were taken at the same time as the commissioning occurred on the rest of the system.

J8.6.11 I have not seen any records of the testing that RBKC witnessed, which took place approximately 7 days after the commissioning record that is provided in PSB00000224.

J8.6.12 I have not seen any documents from Max Fordham recording their observations during witness testing of the smoke system.

J8.6.13 On the 3rd August 2016, approximately 3 months after the system operation was witnessed by Max Fordham and RBKC Building Control, Max Fordham contacted the TMO asking the TMO to decide if a specific technical issue required pursuing (MAX00006459).

J8.6.14 The e-mail referred to an e-mail sent by Rydon identifying that temperature sensors had not been fitted as requested by Max Fordham. Based on this e-mail it is not clear what the temperature sensors were intended to do, however it appears that Max Fordham may have asked for readings to be taken to confirm the operation of the environmental ventilation system.

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 2 in the event any further evidence of commissioning of the smoke control system is provided to me.

J8.7 Commissioning tests in Grenfell Tower

J8.7.1 I will now go through in turn each of the items from the BS EN 12106-6 acceptance tests, the SCA guide and the guidance from BS 7346-8 and confirm what, if any, evidence I have that these tests were carried out for the lobby smoke control system installed in Grenfell Tower as part of the primary refurbishment.

J8.7.2 **BS EN 12101-6 – Pressure differential test (Acceptance Test 1)**

J8.7.3 Test data required:

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.:

- **i.** 50Pa across lift well and accommodation area;
- **ii.** 50Pa across stairway and accommodation area; and
- **iii.** 45Pa across closed doors between each lobby and accommodation area

J8.7.4 Because Grenfell Tower was 24 storeys tall, BS EN 12101-6 required this procedure to be carried out at least 3 times, with floors assessed in groups of 8.

J8.7.5 I have found no records of any pressure testing in the documents I have been provided with. Therefore, irrespective of the performance criteria of the system, the commissioning information is incomplete.

J8.7.6 **BS EN 12101-6 – Net pressure differential (Acceptance Test 2)**

J8.7.7 Test data required:

Within 15 min after having completed the requirements of 12.2.1 (described in Section J8.7.2) the second acceptance test shall be 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.

J8.7.8 The change in measurement between the first (described in Section J8.7.2) and second pressure readings shall be compared, with the performance requirements specified for the design pressure differences.

J8.7.9 Because Grenfell Tower was 24 storeys tall, BS EN 12101-6 required this procedure to be carried out at least 3 times, with floors assessed in groups of 8.

J8.7.10 I have found no records of any pressure testing in the documents I have been provided with. Therefore, irrespective of the performance criteria of the system, the commissioning information is incomplete.

J8.7.11 **BS EN 12101-6 – Airflow Criterion**

J8.7.12 Test data required**:**

i. Measure the air velocity through an open door separating a flat from the lobby. The open door criteria in Clause 4 of BS EN 12101-6 is that the air supply shall be 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.. All of the following doors open

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;

and the air release path on the fire floor is open.

J8.7.13 The test(s) shall be carried out as follows:

ii. Measure the air velocity using a calibrated anemometer.

iii. 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.

iv. The doorway shall be clear of obstructions

v. 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.

vi. The calibration of all test equipment shall be such that the measurements are accurate to ± 5 %.

J8.7.14 BS EN 12101-6 does not identify how many doors this test should be undertaken on.

J8.7.15 I have seen commissioning evidence for an air velocity measurement recorded across 24 doors, one door per floor (PSB00001152).

J8.7.16 The door on which the measurement in each test was made is not recorded in PSB00001152.

J8.7.17 The only door position that is recorded in PSB00001152 is that of the single open door where the measurement was taken. No other information is recorded about which of the other doors in the building were open or closed when the test was undertaken. PSB00001152 does not confirm that all doors were in the positions required by Clause 4 of BS EN 12101-6 for a Class B system.

J8.7.18 No record is made in PSB00001152 of the individual speeds of each of the smoke control fans when these measurements were made.

J8.7.19 I have seen evidence that the test equipment was calibrated, however the commissioning records do not state how the airflow measurements were made to result in the single airflow figure reported for each measurement. Therefore, irrespective of the system performance and the number and locations of doors at which readings were taken, the commissioning data is incomplete.

J8.7.20 **BS EN 12101-6 – Opening door force**

J8.7.21 Test data required:

i. *The opening force at a particular door shall be measured as follows:*
ii. *Actuate the pressure differential system.*
iii. *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 of opening.*
iv. *Release any latching mechanism, if necessary holding it open.*
v. *Pull on the free end of the force measuring device, noting the highest value of force measured as the door opens.*

J8.7.22 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.*"

J8.7.23 Therefore, for the commissioning of a Class B depressurisation system in Grenfell Tower, I would expect to see either: evidence that all 129 flat entrance doors and all 24 doors between the stair and the lobbies had been tested for door opening force requirements; 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 BS EN 12101-6:2005.

J8.7.24 Instead, I have seen evidence in an e-mail from PSB to JS Wright dated 26 May 2016 (PSB00001152) which indicates that a single door opening force check was undertaken. The commissioning information does not state where the door was located, or if it was a flat entrance or a stair door.

J8.7.25 The recorded force to open that specific door was 85N, and therefore that single door was in compliance with the BS EN 12101-6 requirement.

J8.7.26 **BS EN 12101-6 – Activation of the system**

J8.7.27 Test data required:

i. *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.*

J8.7.28 I have seen no evidence that the commissioning tests included this check.

J8.7.29 **Additional checks from the SCA Guidance**

J8.7.30 As identified in Section J8.4 above, the SCA guide would expect additional checks to have been undertaken beyond that required by BS EN 12101-6. The table below lists the additional checks and whether there is evidence of them having been undertaken by PSB as part of the commissioning process. The full list of checks undertaken are recorded in the PSB Commissioning Report PSB00000224.

J8.7.31 I note that the checks listed in Table J.4 are independent of the performance specification for the system. Therefore, the fact that PSB did not design the system to meet the requirements of Class B of BS EN 12101-6 has no bearing on whether or not the check should have been undertaken and recorded.

Table J.4: Evidence of checks required by SCA guide having been completed

SCA Guide check	Evidence of PSB having undertaken such a check (PSB00000224)
Operate each motorised damper	Yes, the PSB Commissioning Report checked each of the dampers listed in the PSB schematic when open and closed and checked for damage.
Check that fans operate at the same time as the dampers	The PSB Commissioning Report states "*Fans x 5: Correct Function – ok, Damage – ok, Pass – yes*". However, I have not seen any details of the commissioning checks that have been undertaken to determine this.
Measure the fan performance and check against design value	No evidence.

SCA Guide check	**Evidence of PSB having undertaken such a check (PSB00000224)**
Check automatic changeover to standby fan is operational	The PSB Commissioning Report indicates a test called *"Ensure correct operation of system in case of failure in one part"* However, I have not seen any details of the commissioning checks that have been undertaken to determine this.
Check automatic changeover of secondary power supply	PSB00000224 states "*Ensure correct operation of the system under simulated mains failure: Installed – Yes, Tested – Yes.*" However, I have not seen any details of the commissioning checks that have been undertaken to determine this.
Inspect motor drive	No evidence
Operate ventilators/fans in accordance with cause & effect and inspect for correct operation	The PSB Commissioning Report states "*Fans x 5: Correct Function – ok, Damage – ok, Pass – yes*" and "*System cause and effect fully programmed: installed – Yes, Tested – yes*". However, I have not seen any details of the commissioning checks that have been undertaken to determine this.
Check maximum force required to open escape doors while system operating in means of escape mode – maximum force of 100N	Only 1 door appears to have been checked
Check the operation of the manual control points	PSB00000224 states: "*FOS [fire override switch] 01 to 24: auto-Yes, Open – ok, Off – NA, Damage – ok, Pass – yes*". It also states: *"Main Panel: Correct Function – ok, Damage – ok, Pass – yes"* Therefore, only 24 of the 26 fire brigade override switches appear to have been tested. The HMI panel appears to have been tested, however I have not seen any details of the commissioning checks that have been undertaken to determine this.

SCA Guide check	Evidence of PSB having undertaken such a check (PSB00000224)
Operation and function of pressure sensors should be checked	PSB00000224 states: "*Pressure switch PS01 to PS24: Operate-ok, Damage – ok, Pass – yes*". However, I have not seen any details of the commissioning checks that have been undertaken to determine this.
Reset system upon completion,	No evidence that system was reset.
Provide certificate of testing and certificate of compliance	Certificate of testing (Commissioning report, PSB00000214) and Completion certificate (PSB00001143) provided by PSB. No evidence of a certificate of Compliance.

J8.7.32 **Checks against requirements of BS 7346**

J8.7.33 Table J.5 presents my assessment of the available commissioning evidence against the requirements of BS 7346-8.

J8.7.34 Noting that the checks listed in Table J.5 are independent of the performance specification for the system. Therefore, the fact that PSB did not design the system to meet the requirements of Class B of BS EN 12101-6 has no bearing on whether or not the check should have been undertaken and recorded.

Table J.5: checks against requirements of BS 7346-8

BS 7346 check	Evidence of PSB having undertaken such a check (PSB00000224)
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	PSB were the designer of the system and therefore had the design requirements. However, I have seen no evidence relating to the competence of the commissioning engineer
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	I have seen no evidence relating to the competence of the commissioning engineer

BS 7346 check	**Evidence of PSB having undertaken such a check (PSB00000224)**
At commissioning, the entire system should be inspected and tested to ensure that it operates satisfactorily	PSB00000224 states "*All systems are operating according to design*" However I have not seen any details of the commissioning checks that have been undertaken to determine this.
labelling or other means of visual identification, if specified, have been carried out;	My site inspection indicated that each of the components of the smoke control system that I observed was provided with a label identifying the component.
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	PSB00000224 states "*All systems are operating according to design*". PSB00000224 also states "*System Cause and Effect Fully Programmed: Installed – Yes, Tested – Yes*. However, I have not seen any details of the commissioning checks that have been undertaken to determine this.
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);	I have seen no evidence that PSB requested this information before undertaking their commissioning checks.
siting of control, indicating and power supply equipment is inspected and verified;	PSB00000224 indicates a number of checks to electrical equipment, however I have not seen any details of the commissioning checks that have been undertaken to determine that these components passed the commissioning tests.
primary power supplies are inspected as far as reasonably practicable	PSB00000224 states "*Carry out cable survey and check certification: Installed – Yes, Tested – Yes.*" However, I have not seen any details of the commissioning checks that have been undertaken to determine this.

BS 7346 check	**Evidence of PSB having undertaken such a check (PSB00000224)**
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;	I have seen no evidence of secondary power supplies and actual load currents having been checked against the designer's predictions as part of the commissioning tests.
when the primary power is removed, the secondary power supply operates within the interruption time specified in BS EN 12101-10;	PSB00000224 states "*Ensure correct operation of the system under simulated mains failure: Installed – Yes, Tested – Yes.*" However, I have not seen any details of the commissioning checks that have been undertaken to determine this.
when the duty equipment fails, standby equipment operates, e.g. duty standby fan sets and uninterruptable power supplies (UPS) equipment	PSB00000224 states "*Ensure correct operation of the system in case of failure of one part: Installed – Yes, Tested – Yes.*" However, I have not seen any details of the commissioning checks that have been undertaken to determine this.
labels, visible when secondary power supplies (e.g. batteries) are in their normal position, are fixed to batteries, indicating the date of installation	I have not inspected the labelling of batteries and therefore cannot comment on this item.
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	PSB00000224 states "*Carry out cable survey and check certification: Installed – Yes, Tested – Yes.*" However, I have not seen any details of the commissioning checks that have been undertaken to determine this.
all fault monitoring functions operate correctly by simulation of fault conditions	PSB00000224 states "*Ensure correct operation of the system in case of failure of one part: Installed – Yes, Tested – Yes.*" However, I have not seen any details of the commissioning checks that have been undertaken to determine this.

BS 7346 check	**Evidence of PSB having undertaken such a check (PSB00000224)**
all relevant documentation has been provided to the relevant responsible person;	As I have made clear in the sections above, there are significant portions of documentation missing with respect to commissioning methodologies and rest records. Therefore, PSB have not provided all the relevant documentation to the responsible person.
on completion of commissioning, a certificate signed by a competent person (see the example given in B.3) is issued.	I have seen no evidence relating to the competence of the commissioning engineer
All results obtained during the commissioning process should be clearly recorded	The results of commissioning tests have not been clearly recorded, and there are substantial amounts of information missing, such as results of pressure testing of any kind.

J8.8 Evidence of commissioning of the Autodialler

J8.8.1 I have not been provided with records of commissioning of the autodialler.

J8.8.2 I note that the autodialler is not a required system under ADB. However, I understand that the autodialler was installed on 04/05/16, which is after the date of commissioning (28/04/16), and after the date recorded on PSB's Completion Certificate (03/05/16).

J8.8.3 Section 10.3.2.2 of BS EN 12101-6 states:

"*10.3.2.2 When changes are made to the software or associated computer system, a full check of the pressure differential system shall be carried out to confirm the continual functioning of the system.*"

J8.8.4 I understand that the autodialler was wired directly to the smoke control system controls, and therefore in accordance with BS EN 12101-6, the whole system should have been recommissioned to ensure that the addition of the autodialler did not affect the operation of the system.

J8.8.5 The autodialler operated on the night as I have shown in Section J7.3.10 of this report.

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.

J8.9 Evidence of commissioning of the batteries

J8.9.1 The Above Ground Commissioning report (PSB00000214) and the PSB Commissioning Method Statement and Risk Assessment (PSB00000914) do not provide the methodology or acceptance criteria for commissioning the batteries.

J8.9.2 BS EN 12101-6 states: *'To reduce the risk of the loss of electrical supply in a fire, a secondary power supply is considered essential. A secondary supply is required from a generator or a separate substation, which is of sufficient capacity to maintain supplies to the life safety and fire protection installations, including smoke control systems, systems using pressure differentials and ancillary equipment.'*

J8.9.3 PSB00000214 includes the following with regard to back up power for the smoke system: *'In the event of failure of the primary supply the battery back-up panel will provide a secondary supply.'*

J8.9.4 Therefore, the battery back-up panels form part of a life-safety system within the building.

J8.9.5 The excerpt from PSB00000224 below shows the only information provided in that document for the commissioning of the batteries.

J8.9.6 I cannot conclude anything from this information as it is so limited.

BATTERY TEST SHEET

Number of batteries: 24

Test equipment used:

Battery number	Battery Volts	Battery Ah	Actual Volts	Actual Ah	Pass	Fail
1 to 24	12	7	12	7	yes	

Figure J.64: Excerpt of PSB00000224

J8.10 Evidence of commissioning of the HMI

J8.10.1 The Above Ground Commissioning report (PSB00000214) and the PSB Commissioning Method Statement and Risk Assessment (PSB00000914) do not provide the methodology or acceptance criteria for commissioning the HMI Panel.

J8.10.2 The following excerpt from PSB00000224 shows the full extent of the record of the commissioning of the HMI Panel.

Fire Service Override	Installed	Tested
Check functionality of the Fire Service override switch	yes	yes

Figure J.65: Excerpt of PSB00000224

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.

J8.10.4 I do not consider the briefing described by FF Walton in his oral evidence (Transcript of 20th September, p69) to constitute appropriate training.

J8.11 Evidence of commissioning of the fire brigade key switch in each lobby

J8.11.1 The Above Ground Commissioning report (PSB00000214) and the PSB Commissioning Method Statement and Risk Assessment (PSB00000914) do not provide the methodology or acceptance criteria for commissioning the fire brigade key switches.

J8.11.2 The PSB system schematic (p1238 of RYD00000577) identifies 26 key switches. The commissioning record identifies that only 24 of these switches was tested during commissioning.

J8.11.3 The excerpt from PSB00000224 shows the full extent of the record of the commissioning of the fire brigade key switch in each lobby.

Number	Auto	Open	Off	Damage	Pass	Fail
FOS 01 to 24	ok	ok	n/a	ok	yes	
	operation	reset				
Smoke	ok	ok		ok	yes	

Figure J.66: Excerpt of PSB00000224

J8.11.4 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.

J8.12 Compliance status - commissioning

J8.12.1 The commissioning records do not set out:

- the methodology used for each test;
- the acceptance criteria;
- the measurement which demonstrates that the test is passed or failed.

J8.12.2 I am therefore unable, from the documentation provided to me at this stage, to confirm that any of the commissioning tests have been fully undertaken and successfully passed.

J8.12.3 I present my assessment of compliance of the system against the 5 requirements of Section 4 and the 10 requirements of Section 9 of BS EN 12101-6 in Table J.6, based on the commissioning records available to me at this time.

J8.12.4 In summary, there is no evidence that the commissioning of the smoke control system in Grenfell Tower was commissioned to demonstrate compliance with the requirements of BS EN 12101-6.

Table J.6: Compliance assessment of PSB smoke control system design and commissioning information against the requirements of BS EN 12101-6 and ADB 2013

BS EN 12101-6 Criteria	**Stated in Rev 6 – PSB Technical Submission (PSB00000214)**	**Evidence of Commissioning from PSB Above ground commissioning report (PSB0000224)**
Performance criteria for a depressurisation system -Section 9		
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.	**Compliant** – the permanent vent at the head of the stair provides replacement air. PSB technical submission Rev 6 identifies it as a measured 1.0m^2 vent.	PSB00000224 records: *"Ensure the Fresh Air openings are in line with Design requirements:* *Installed – Yes* *Tested – Yes"* There is no evidence relating to what test PSB undertook on the fresh air vents

BS EN 12101-6 Criteria	Stated in Rev 6 – PSB Technical Submission (PSB00000214)	Evidence of Commissioning from PSB Above ground commissioning report (PSB0000224)
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. [Noting that this requirement is expanded on in Section 11.8.2.7, excerpted below] 11.8.2.7 Where air intakes are positioned at roof level there shall be two air intakes, spaced apart and facing different directions in such a manner that they could not be directly downwind of the same source of smoke. Each inlet shall be independently capable of providing the full air requirements of the system. Each inlet shall be protected by an independently operated smoke control damper system in such a way that if one damper closes due to smoke contamination, the other inlet will supply the air requirements of the system without interruption. The discharge point of a smoke ventilation duct shall be a minimum of 1 m above the air intake and 5 m horizontally from it. An override switch to reopen the closed damper and to close the open damper shall be provided for fire brigade use.	**Not compliant** The minimum distance between the permanent vent at the head of the stair and the North exhaust vent is approximately 3.8m horizontal distance (measured from Studio E rooftop plan, SEA00002593) so does not meet the requirements of 11.8.2.7 The system was not provided with two air intakes and therefore did not comply with any of the items required by Section 11.8.2.7. PSB incorporated existing vent locations, but PSB00000214 does not provide consideration of the risks of contamination as defined in Section 9.2.2 and 11.8.2.7.	I have seen no evidence that PSB reviewed risk of contamination of the protected space during commissioning

BS EN 12101-6 Criteria	Stated in Rev 6 – PSB Technical Submission (PSB00000214)	Evidence of Commissioning from PSB Above ground commissioning report (PSB0000224)
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.	**Not compliant –** Exhaust fans, associated dampers, power, wiring and controls, existing builderswork shafts, limited new ductwork are provided. However, the exhaust fans and the dampers provided to each AOV did not in fact comply with the relevant requirements of BS EN 12101-6 and therefore cannot be considered as properly provided by the system.	PSB records the following in PSB00000224: Fans x5: Correct Function – OK Damage – OK Pass – OK I have seen no evidence of the tests that PSB undertook on the fans and ductwork to determine their correct operation as part of commissioning.
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.	**Not compliant** – A passive air inlet is provided to the head of the stair. However, in the system as provided, the inlet cannot allow the relevant pressure differences of a Class B system to develop, specifically: a) 50Pa across the stair and the accommodation b) 50Pa across the lift and the accommodation; and c) 45Pa across the lobby and the accommodation And the 2m/s airflow criterion through the open lobby door into the fire compartment.	As item 9.2.1.

BS EN 12101-6 Criteria	Stated in Rev 6 – PSB Technical Submission (PSB00000214)	Evidence of Commissioning from PSB Above ground commissioning report (PSB0000224)
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.	**Safety of occupants and firefighters - Compliant** The position of the outlets is remote from occupants and firefighters; however, this is not explicitly addressed in PSB00000214 **Contribution to external fire spread - Not compliant** – the uninsulated ductwork passes through combustible insulation in the facade This risk is not considered in PSB00000214	As item 9.2.1
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.	**NOT STATED IN PSB00000214** **Not compliant**. The flat and stair doors did not provide the fire resistance required to achieve the compartmentation requirements of ADB (Appendix I), and therefore the construction bounding the depressurized zones did not have the fire resistance equal to that required for the protected space.	There is no evidence that this item is addressed by PSB's commissioning process
9.2.7 All doors to the depressurization zone shall be self-closing.	**NOT STATED IN PSB00000214** **Not compliant** – many flat doors had missing or non-functioning door closers (Appendix I) Additionally, I am not aware the design team made an attempt to understand the door closer performance or as a minimum state the requirements	PSB's commissioning method statement (PSB00000941) requires "ALL Doors to be installed complete with all door furniture, Draft proofing, etc." before their commissioning can begin. I have seen no evidence of any checks that PSB may have undertaken to confirm this.

BS EN 12101-6 Criteria	Stated in Rev 6 – PSB Technical Submission (PSB00000214)	Evidence of Commissioning from PSB Above ground commissioning report (PSB0000224)
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.	**Not compliant–** The north and south builders work smoke shafts are service risers, as defined by ADB 2013, and therefore would need to be enclosed in fire resisting construction with a rating equal to that of the compartmentation through which they pass. In accordance with ADB 2013, the fire resistance of the floors would be 120-minute insulation and integrity fire resistance, so the rating of the builders work shafts and the AOV dampers should also be 120 minutes. However, the original rating for the building was for a 1 hour standard of fire resistance. Therefore the compliance of the builders work shafts and AOV dampers would depend on the interpretation of the Building Regulations relating to the requirements for existing buildings (which I will explore further in Phase 2). The fire resistance of the existing builders work shafts was not stated in PSB00000214. The arrangement of the ductwork within the stair at Level 2 was not compliant as set out in Section 16.7. Specifically, the smoke extract ductwork was not provided with insulation and therefore would not be able to comply with the required Fire Resistance (Insulation) performance requirement.	I have seen no evidence that PSB confirmed the fire resistance performance of either the builders work shafts or the ductwork in the stair at Level 2 as part of the commissioning process.

BS EN 12101-6 Criteria	Stated in Rev 6 – PSB Technical Submission (PSB00000214)	Evidence of Commissioning from PSB Above ground commissioning report (PSB0000224)
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.	**Not compliant –** PSB00000214 states that the fans provided at Roof Level and Level 2 were rated for 300°C only while Grenfell Tower is an unsprinklered building. I have confirmed that the information plate affixed to the Roof fan states that it was rated for operation at 300°C only.	As Item 9.2.3
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."	**Not compliant** Doors closed criteria - PSB00000214 does not provide requirements for the three pressure differentials in Clause 4 for a Class B system (shown in Clause 4 criteria in rows below) open door criteria – PSB00000214 states that the velocity criterion should be achieved across the stair door, only BS EN 12101-6 requires the velocity criterion to be achieved across the door between the lobby and the accommodation. PSB00000214 does not provide a requirement for the air velocity criterion for the flat doors.	I have seen no evidence that PSB recorded any pressure differences as part of commissioning. The commissioning report does not record which doors were open during the open door tests I have seen no evidence that air velocities across the flat doors were measured

BS EN 12101-6 Criteria	Stated in Rev 6 – PSB Technical Submission (PSB00000214)	Evidence of Commissioning from PSB Above ground commissioning report (PSB0000224)
BSEN12101 Clause 4 criteria for Class B		
BSEN12101 Clause 4 Class B Criteria 1. Pressure Difference Criterion *The air supply shall be sufficient to maintain the pressure differential given in Table 2 when all doors to the lift, stair and lobby, and the final exit doors are closed and the air release path from the accommodation area is open.* *The system shall be designed so that the stairwell and lobby and, where provided, the lift shaft are kept clear of smoke. In the event of smoke entering the lobby, the pressure within the stair shall not drive smoke into the lift shaft or vice-versa. This shall be achieved by providing separate pressurization of the firefighting lift shaft, lobby and stair.* *The fan/motor units supplying air to the firefighting lift shaft shall be within its associated stairwell, but with separate supply ductwork.* *The design requirements for a Class B system are shown in Figure 3* Table 2 of Section 4.3.2.1 states: Pressure differential to be maintained between: • Lift well and accommodation area – 50Pa • Stairway and accommodation area – 50 Pa • Between each lobby and the accommodation area – 45Pa	**Not compliant –** (1) PSB00000214 does not achieve any of the pressure differentials in Table 2 The pressure differential specified in PSB00000214 was 25Pa between the stair and the lobby. This pressure and location does not correspond to any of the cases in Table 2 (2) Lobby is not kept clear of smoke in PSB00000214 (3) The issue of pressure from the stair pushing smoke into the lift shaft (and vice versa) is not considered in PSB00000214 (4) PSB00000214 does not pressurise the lift (5) PSB's design does not comply with Figure 3 of BS EN 12101-6:2005	(1) There is no evidence that PSB measured any pressures in the system during commissioning. (2) There is no evidence that PSB addressed smoke entering the lobby as part of commissioning. (3) There is no evidence that PSB recorded the relative pressures coming from the stair and the lift shafts during commissioning. (4) PSB could not commission this function as it was not provided by their design. (5) PSB only measured airflow between the stair and the lobby on each level during commissioning.

BS EN 12101-6 Criteria	Stated in Rev 6 – PSB Technical Submission (PSB00000214)	Evidence of Commissioning from PSB Above ground commissioning report (PSB0000224)
4.3.2.2 Airflow criterion *"The air supply shall be 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 with all of the following doors open between:* *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;* *and the air release path on the fire floor is open.* *...* *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."*	**Not compliant** PSB00000214 requires 2m/s across stair door but with only the stair door considered to be open. The flat door was closed. Doors open: a. Yes b. Not stated in PSB00000214 c. Not stated in PSB00000214 d. Stair and external air at fire access level – not stated in PSB00000214 PSB's design did not include an air release path from the accommodation on any floor as part of their system PSB00000214 considered stair door open, but not flat door open. In firefighting the flat door will be open.	I have seen no evidence that PSB recorded which doors were open or closed in each of their commissioning tests. Air velocity was measured across the open stair door not the flat door in compliance with BS EN 12101-6 requirements. I have seen no evidence that PSB recorded air velocity across the flat door for any open door configuration
4.3.2.3 Air supply *"Any air supply serving a firefighting staircase or lift shaft, and their associated lobbies where present, shall be separate from any other ventilation or pressure differential system."*	**Compliant -** PSB00000214 system is designed for stair and associated lobbies only No other system is provided in the building	As item 9.2.1 above

BS EN 12101-6 Criteria	Stated in Rev 6 – PSB Technical Submission (PSB00000214)	Evidence of Commissioning from PSB Above ground commissioning report (PSB0000224)
4.3.2.4 Firefighting shaft *"Firefighting shafts shall be constructed in accordance with the appropriate national provisions valid in the place of use of the system."*	**Not compliant –** Please see Section 16 for full details. With respect to the compliance of the smoke control system with the requirements of BS EN 12101-6, the key issue is the fact that the flat entrance doors did not achieve the requirements of ADB, and therefore the fire resisting enclosure of the fire fighting shaft was incomplete.	I have seen no evidence that PSB confirmed the adequacy of the fire fighting shaft construction as part of the commissioning.
4.3.2.5 Door opening force *"The system shall be designed so that the force on the door handle shall not exceed 100 N.* *NOTE 1 The corresponding maximum pressure differential across the door can be determined using the procedure in Clause 15 and Annex A, as a function of the door configuration.* *NOTE 2 The force that can be exerted to open a door will be limited by the friction between the shoes and the floor and it may be necessary to avoid having slippery floor surfaces near doors opening into pressurized spaces, particularly in buildings in which there are very young, elderly or infirm persons."*	**Non-Compliant –** The design of the system recorded in PSB00000214 states when the doors on the escape route are closed that the opening force on the door should not exceed 100N as detailed in BSEN12101-6 I have evidence that only one door was tested which is insufficient to demonstrate that the requirement in BS EN 1210-6 had been achieved.	The result of a single check of one door opening force is recorded in PSB00001152 (email from PSB to JSW, 26/05/2015). This measurement is not recorded in the main commissioning record in PSB00000224. A single door opening force check is not sufficient to demonstrate the all the required doors in the building comply with the requirement I have seen no evidence that the floor friction was assessed as part of the commissioning process.

BS EN 12101-6 Criteria	Stated in Rev 6 – PSB Technical Submission (PSB00000214)	Evidence of Commissioning from PSB Above ground commissioning report (PSB0000224)
Operation of manual control points Section 10.3 provides guidance for installation of Computerised control systems. This section refers to Section BS EN 12101-9. This part of the standard has not yet been published and therefore I cannot assess compliance by reference to this standard. However, I would expect that any commissioning process to demonstrate that all controls would work as intended by the design.	Cannot demonstrate compliance due to lack of appropriate standard.	Section 9.3.6 of The SCA guide, relating to commissioning checks for pressure differential systems states: *"Check the operation of the manual control point(s) to ensure the system operates as requested."* The commissioning report identifies that only 24 of the 26 fire brigade override switches appear to have been tested. The HMI panel appears to have been tested.

BS EN 12101-6 Criteria	Stated in Rev 6 – PSB Technical Submission (PSB00000214)	Evidence of Commissioning from PSB Above ground commissioning report (PSB0000224)
Operation of Autodialler Autodialler systems are not a requirement of ADB or BS EN 12101-6 for inclusion in a smoke control system. BS EN 12101-6 does not explicitly address the requirements of autodiallers. The standard for detection and alarm systems in residential accommodation, BS 5839-6, provides the following guidance for autodial systems in Section 20 *remote transmission of alarm signals*: Section 20.2.c) "*Before any facility for automatic transmission of fire signals to the fire and rescue service becomes operational, the organization monitoring the fire detection and fire alarm system (whether this is the fire and rescue service or an alarm receiving centre) should obtain written confirmation from the occupier (or, in the case of a house in multiple occupation, the landlord) that they have received, and read, written guidance regarding the importance of avoiding false alarms, suitable measures to avoid false alarms, and the possible need for the fire and rescue service to force entry to the dwelling in the event of a false alarm when the dwelling is unoccupied (see Clause 24 and Annex D). In the case of houses in multiple occupation, the landlord should confirm that the relevant guidance has been passed onto every occupier.*" Section 20.2.j) Any alarm receiving centre to which fire alarms signals are relayed should comply with the recommendations of BS 5979.	The Autodialler is not included in PSB's design as described in PSB00000214.	I have seen no evidence that the autodialler system was in the system when it was commissioned. I have seen no evidence to indicate that the smoke control system was recommissioned after the autodialler was added.

J8.12.5 I will provide an updated assessment of compliance in the event that further relevant evidence is provided to me.

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.

J8.12.7 There is no evidence that the full range of checks required by the relevant guidance, BS EN 12101-6 or the SCA Guidance, were completed, recorded or passed to the RBKC as the relevant Building Control Authority, as this stage.

J8.12.8 Any further evidence provided to me will be reviewed in full and I will update my report as necessary in due course.

J9 Preliminary findings from my review of the smoke control system software

J9.1.1 There are 4 specific sets of software that I have identified as relevant to the operation of the environmental and smoke control system. I present the different software packages below and indicate their purpose, and current status with respect to the review my specialist team are carrying out on each package.

J9.1.2 **Control panel software**

J9.1.3 This software was installed on the main control panel (Master Outstation) which was located in the Ground Floor Hub room in Grenfell Tower. This panel controlled the environmental and smoke control system with respect to which dampers should be opened and closed under different circumstances, and when environmental and smoke control fans should start, stop or change speed.

J9.1.4 My team has reviewed this software in detail, with the results summarised in Section J9.2.

J9.1.5 **Human Mechanical Interface (HMI) software**

J9.1.6 The HMI panel was present in the Ground floor entrance foyer and allowed people to input instructions via this panel, and so control in part, the environmental and smoke control systems.

J9.1.7 The HMI panel in Grenfell Tower provided access to system 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 5 fans attached to the system (4 smoke fans and 1 environmental fan). It is not clear at this point whether the thermometers were installed.

J9.1.8 The HMI also provided specific control of the smoke control system. The HMI permitted a user to turn the smoke control system off, to restart the smoke control system and to select a specific floor for the system to extract from, apparently bypassing the need for the key switches.

J9.1.9 The HMI also contained an alarm log. I understand that the data that this log held, with respect to the system operations on the 14th June 2017, was lost as the data was not removed from site, and was very unfortunately overwritten by entries from the days after the fire.

J9.1.10 **Building Management System (BMS) software**

J9.1.11 The BMS system was used to provide input to the environmental ventilation system. Specifically, the BMS handled the temperature data recorded from the lobbies on Ground and Levels 5, 10, 15 and 20 (RYD00000577). Based on the control system programming, a single signal was sent from the BMS to activate the environmental ventilation system.

J9.1.12 Please refer to Section J7.5 for details of the programmed operation of the environmental ventilation system.

J9.1.13 It was also intended for there to be outgoing signals from the smoke system to the BMS to allow the BMS to turn off the boilers and gas supply on activation of the smoke system (MET00018469), as well as fault indication (PSB00000247). However, MET00018469 states that this interface was not operational at the time of the fire.

J9.1.14 I have not yet been provided with the BMS software for review. Review of this software will be useful for Phase 2.

J9.1.15 **Autodialler software**

J9.1.16 The autodialler software controlled a flow of information from the Grenfell Tower smoke control system to a remote monitoring organisation.

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.

J9.2 Analysis of the main control panel and HMI panel software

J9.2.1 The primary components of the smoke system were listed in J6.5.

J9.2.2 My investigation of the software in the main control panel and HMI panel and the as-built drawings has resulted in the following preliminary findings.

J9.2.3 In this investigation my team used specific scenarios to test the programmed response of the system and confirm whether the response from the software programming obtained, matched the intended response as defined in PSB Revision 6.

J9.2.4 Fire on Level 4

J9.2.5 My team's analysis shows that the programming of the system would correctly perform the smoke control mode as described in the PSB technical design submission (PSB00000214), when a smoke detector was activated, on Level 4.

J9.2.6 Figure J.67 provides a diagram showing my understanding of the programmed operation of the smoke control system as of the 14th June 2017. Specifically, the extract fans at Level 2 and Roof 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.

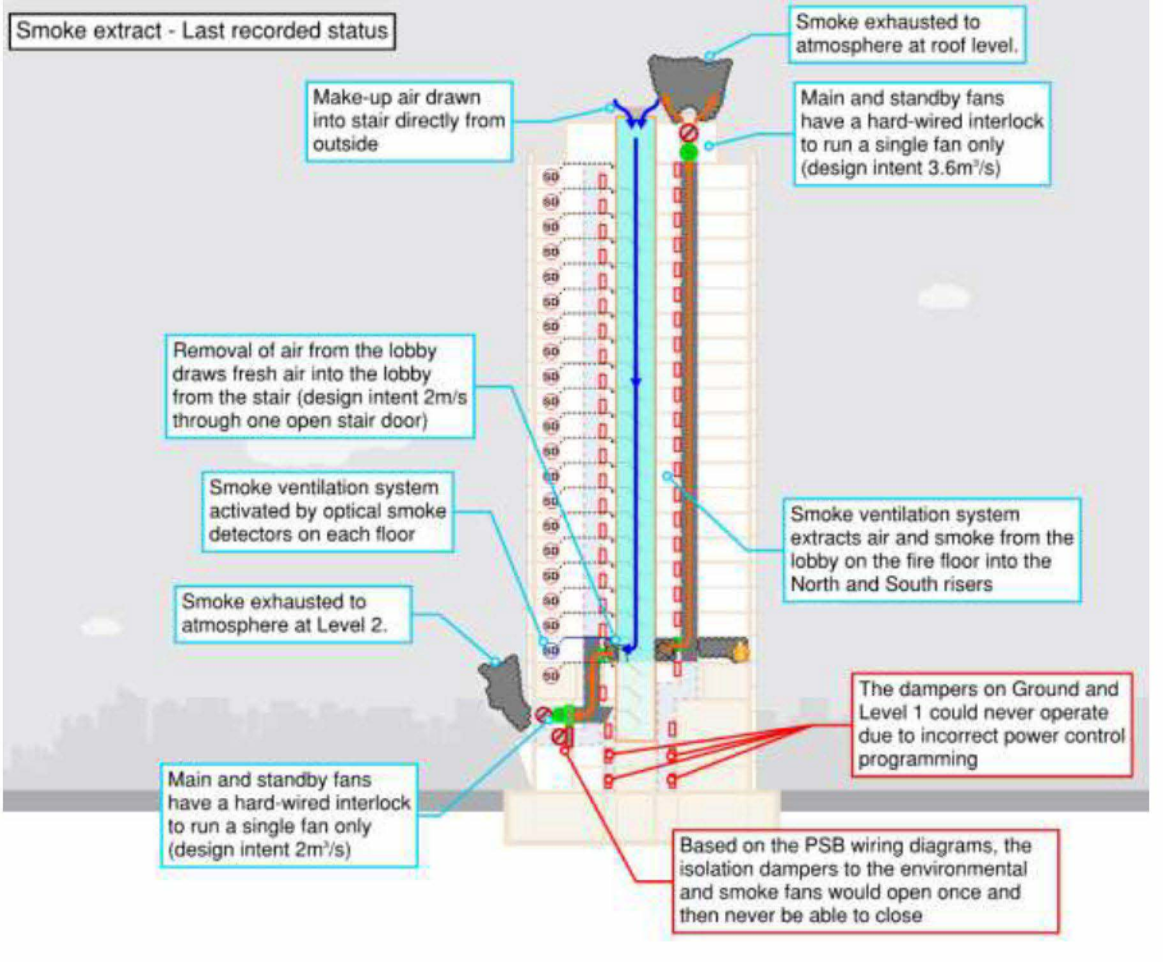


Figure J.67: Programmed operation of the smoke control system

J9.2.7 On Ground or 1st Floor

J9.2.8 There is evidence that the Ground and Level 1 lobby vent AOVs could not have operated as intended. Specifically, the control software appears to have been programmed such that power could not be supplied to these specific AOVs.

J9.2.9 The AOVs impacted are shown in Figure J.68.

Figure J.68: Location of Ground and Level 1 AOVs

J9.2.10 In the absence of power to control these dampers opening or closing, the only method to change their state is manually.

J9.2.11 This means that, in the event of the smoke detector being activated in either the Ground or 1st floor lobby, if the dampers were in the closed position, they cannot be powered open, and so the smoke control system would not be able to draw air from those lobbies.

J9.2.12 **To confirm this finding, I require the full records of maintenance testing by Lakehouse to demonstrate that these AOVs on the Ground Floor and First Floor could operate as intended.**

J9.2.13 **Fan shut-off dampers at Level 2**

J9.2.14 There is evidence that the fan shut-off dampers at Level 2 (associated with both the smoke control and environmental fans, Figure J.69) could not have operated as intended.

J9.2.15 This is because I have identified that the "For Build" drawings by PSB (PSB00000274) appear to show wiring to the cut-off dampers at Level 2 that would not permit the dampers to operate as intended by PSB's design. Specifically, the connections to the individual terminals on the dampers do not match the required connections on the damper actuator data sheet.

J9.2.16 If these dampers failed to operate as intended on the 14th June 2017 then each of these dampers may have been stuck in either an open or closed position, rather than the environmental shut-off dampers being closed and the smoke fan cut-off dampers being open as intended by PSB (based on PSB00000214).

J9.2.17 However, this may be a documentation error rather than an as-built error. I have not seen resolution of this issue in the paperwork available to me at this time.

J9.2.18 **To resolve this issue, I require detailed maintenance records from Lakehouse that demonstrate that the dampers achieved the operations required post-handover, and every time they were tested.**

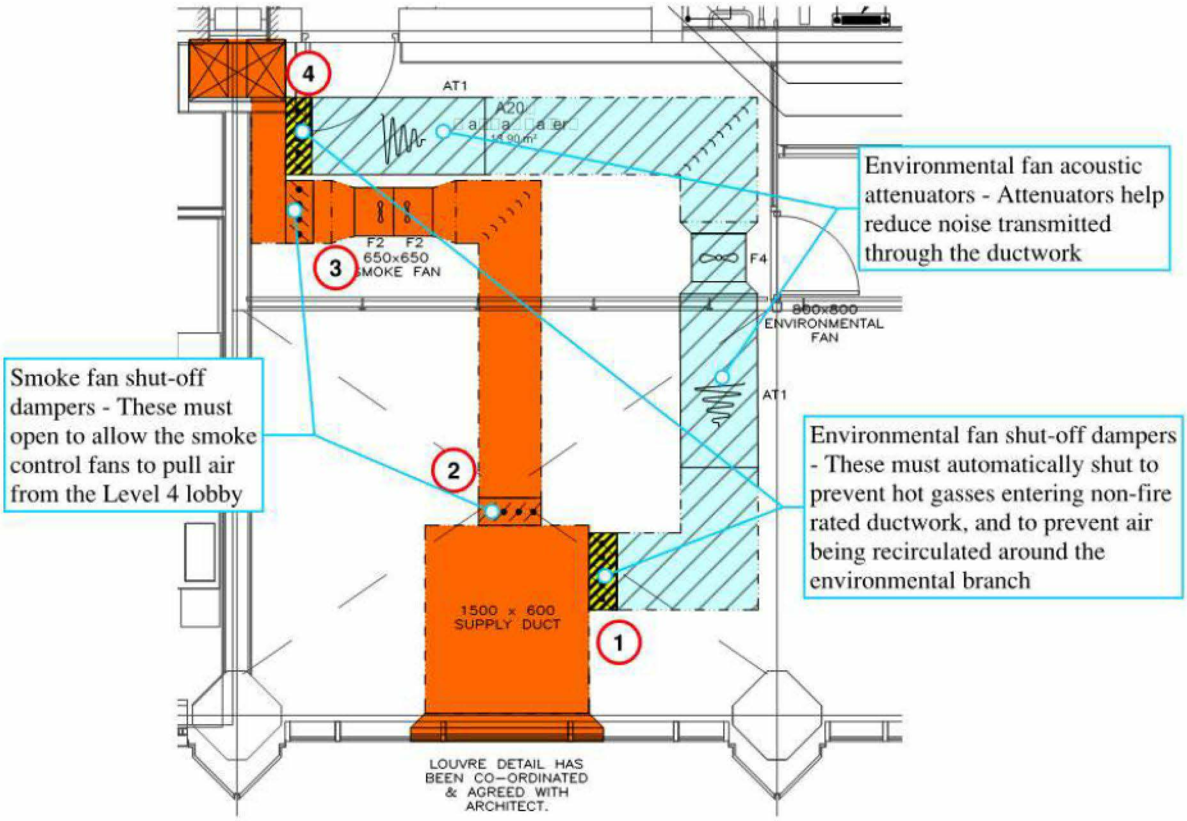


Figure J.69: Fan shut-off damper locations: the environmental branch needs to be closed off and the smoke control branch needs to open

J9.3 Status of the software review

J9.3.1 My team's analysis of the programming for the smoke control system identified that the software was programmed to activate the fans, dampers and AOVs correctly for the activation of a smoke detector on any level above Level 2.

J9.3.2 At this stage my team do not think that the smoke system could have responded correctly in the event of an activation of a smoke detector on Ground or Level 1 due to power not being supplied to the AOVs on those levels.

J9.3.3 Documentation shows that the wiring to the smoke and environmental dampers on Level 2 to separate out the smoke fans from the environmental fans would have prevented the dampers operating as required. It is not clear whether this issue was rectified on site or not.

J9.4 Instructions provided next to the HMI panel

J9.4.1 A set of instructions were provided directly below the HMI panel in Grenfell Tower, as indicated in Figure J.70 (instructions detailed in Figure J.71). I note that the title of the instructions are:

"*Basic how to use guide when activated*"

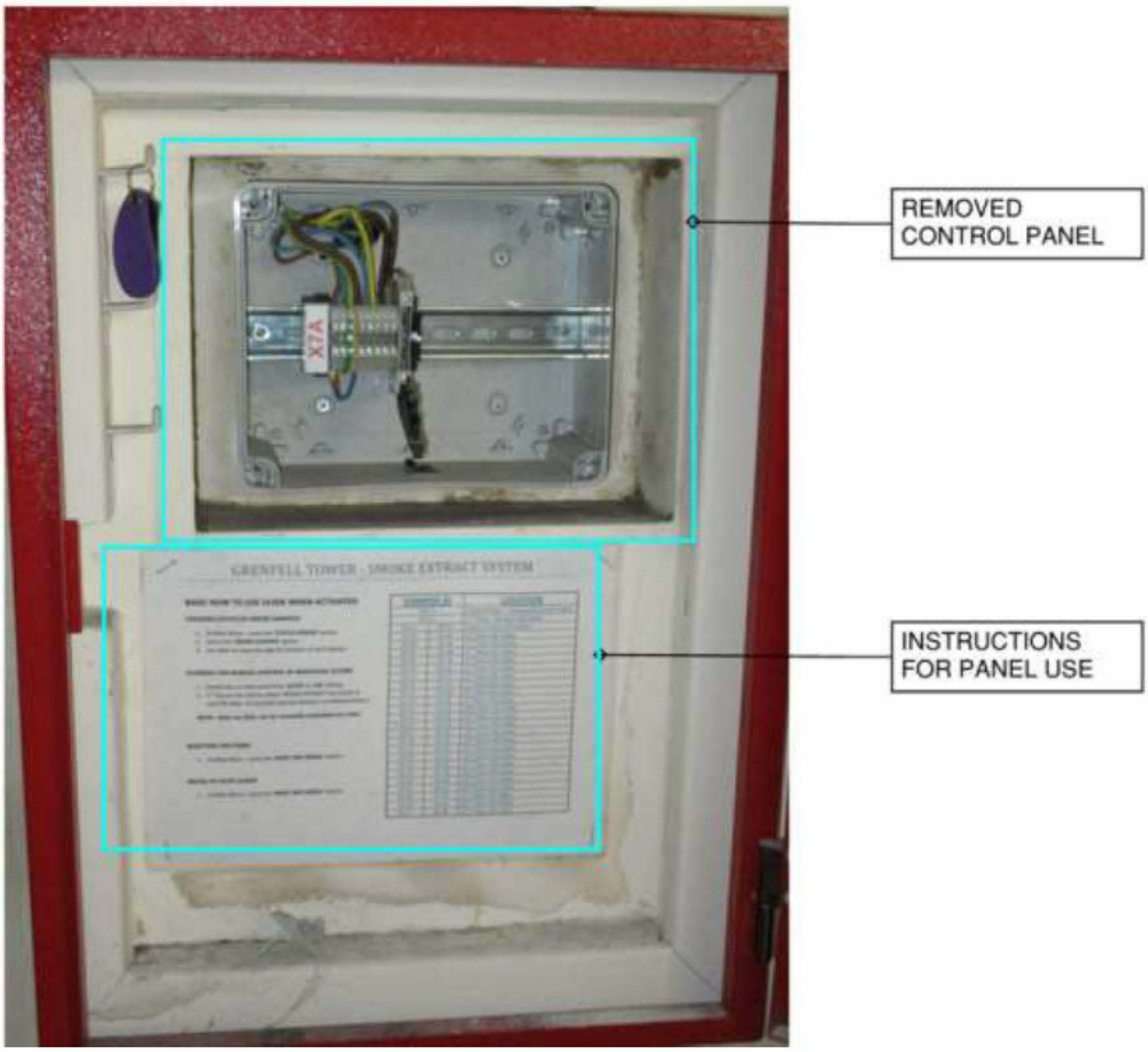


Figure J.70: Instructions located adjacent to HMI panel mounting

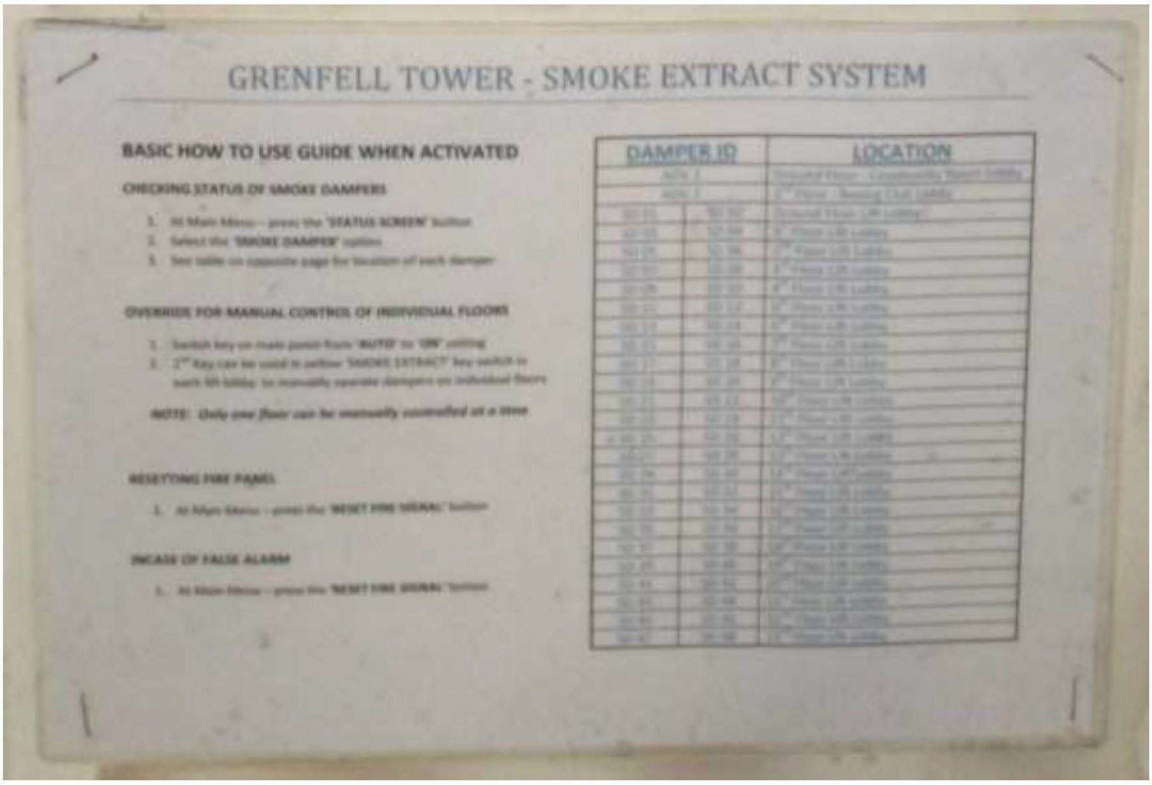


Figure J.71: Detail of laminated instructions sheet

J9.4.2 The instructions provided for the Grenfell Tower smoke extract system are broken into 4 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

J9.4.3 I will go through each of these instruction sets in the sections below and compare them to the input screens from the HMI that I have extracted from the HMI programming software (MET00018074.z2g using WindOI-NV2).

J9.4.4 **Checking status of smoke dampers**

J9.4.5 The instructions for checking smoke dampers are as shown in Figure J.72:

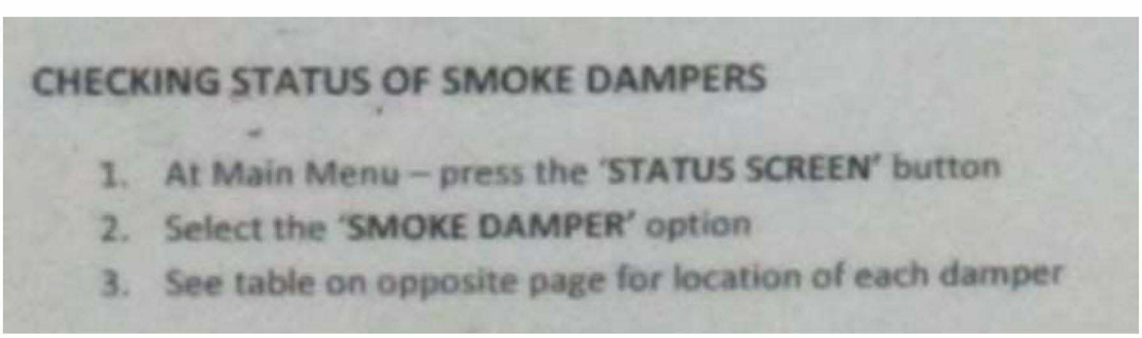


Figure J.72: Excerpt of first instruction set

J9.4.6 As can be seen in Figure J.73, the Status Screen button is on the far right. The term on the button matches the term used in the instructions.

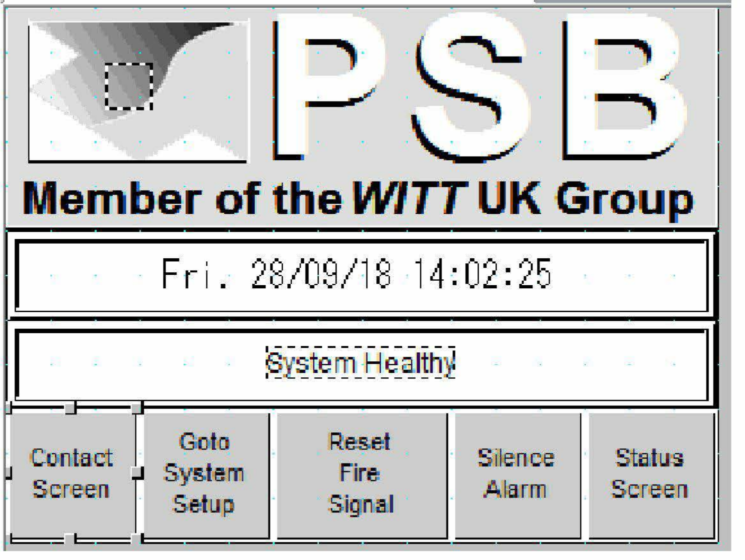


Figure J.73: Main screen of HMI panel menu

J9.4.7 On pressing the Status Screen Button, the user would be presented with the following screen:

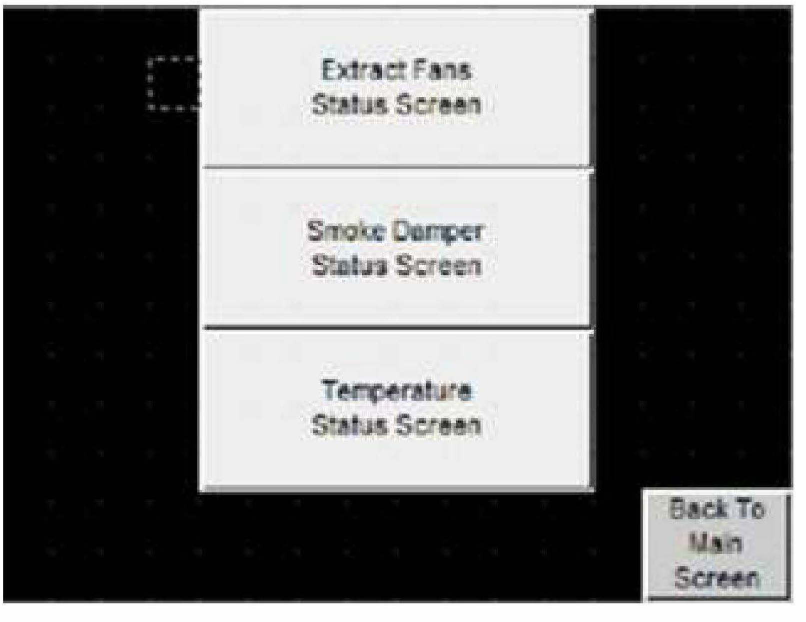


Figure J.74: HMI Status screen menu

J9.4.8 This screen allows the user to view the status of either the fans or the dampers. The instructions then tell the user to select the Smoke Damper option. Pressing this button returns the following screen:

Figure J.75: Damper status screen

J9.4.9 All of the damper IDs on the instructions sheet are replicated on the HMI screen. The HMI status screen states the current status of each damper in the location noted on the instructions sheet and whether it is open or closed.

J9.4.10 In my investigation of the dampers, I have identified that each damper mechanism had physical "end switches" that could directly identify whether a damper was closed or open and send a signal to the system control panel. However, in Grenfell tower these switches were not connected to the system. Therefore, the information on the Damper Status screen is not based on a physical reading of the damper position. Instead, the status of the damper is based on the signal sent by the control system, and an assumption that the instruction has been carried out by the damper. Therefore, the information on the damper status screen is not necessarily a true representation of the physical position of each damper.

J9.4.11 The instructions provide no guidance as to the purpose or use of the Fan Status screen or the Temperature Status screen.

J9.4.12 Therefore, whilst the instructions to access the damper status are clear, the damper status indicators may not be providing accurate information.

J9.4.13 **Override for manual control of individual floors**

J9.4.14 The second set of instructions (Figure J.76) instruct the user in how to gain manual control of the system and direct it to activate on a specific floor.

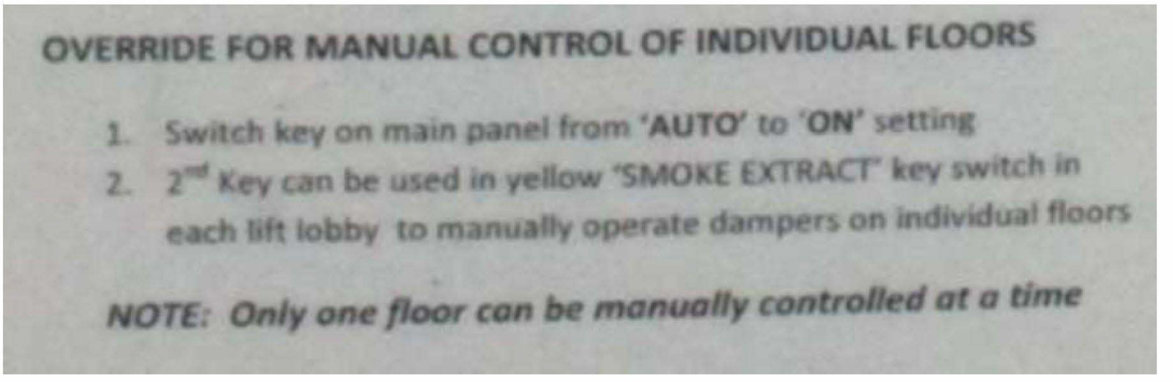


Figure J.76: Excerpt of second instruction set

J9.4.15 When the user inserts the key and turns the system from "Auto" to "On", the following screen will appear:

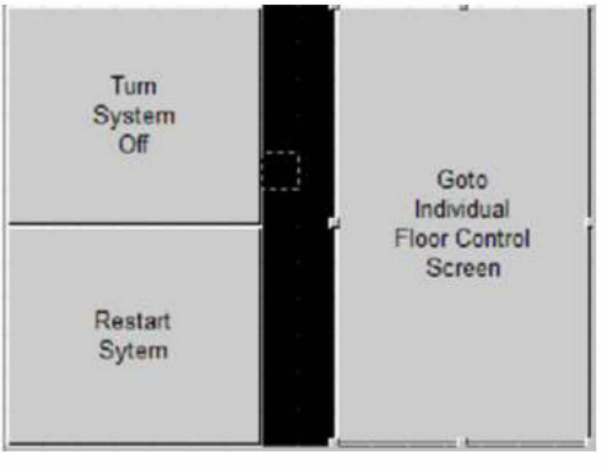


Figure J.77: Fire brigade override screen

J9.4.16 This screen provides the user with 3 options. However, the instructions do not indicate what any of these options does. Instead, the printed instructions identify that individual control of each floor requires the use of the second key provided within the HMI panel enclosure.

J9.4.17 I note that the instructions state that only one floor can be manually controlled at a time, but it does not identify that a user must turn off the key switch at the floor of operation before another key switch could be operated to change the floor of operation.

J9.4.18 The options on this screen include options to turn the system off and to restart the system. The instructions do not identify to the user what might happen if either of these options are selected. My investigation into the control software indicates that operating the "turn system off" option would close all the dampers and shut the fans off. A user would then need to press the "Restart System" for the system to restart.

J9.4.19 However, as I have identified in Section J7.7 activation of the "restart System" option would restart the system on the original floor of activation, regardless of whether a key switch had been activated. Therefore, activation of this option could lead to an unexpected operation to fire fighters, and this is not recorded on the instructions either.

J9.4.20 The override screen also provides access to an “individual floor control screen”, presented below:

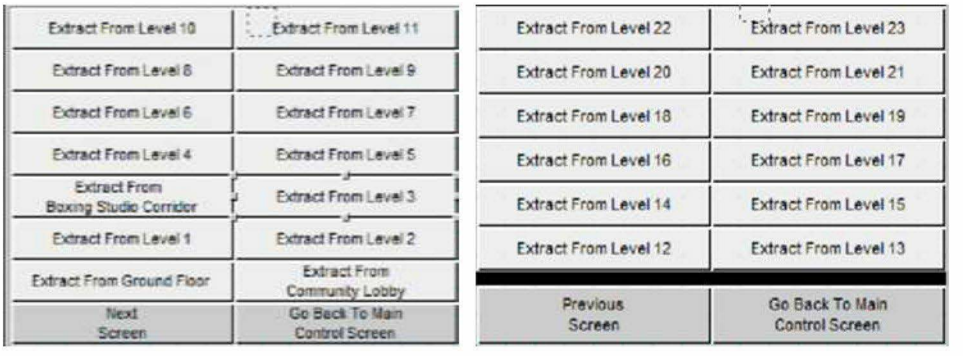


Figure J.78: HMI Individual floor control screens

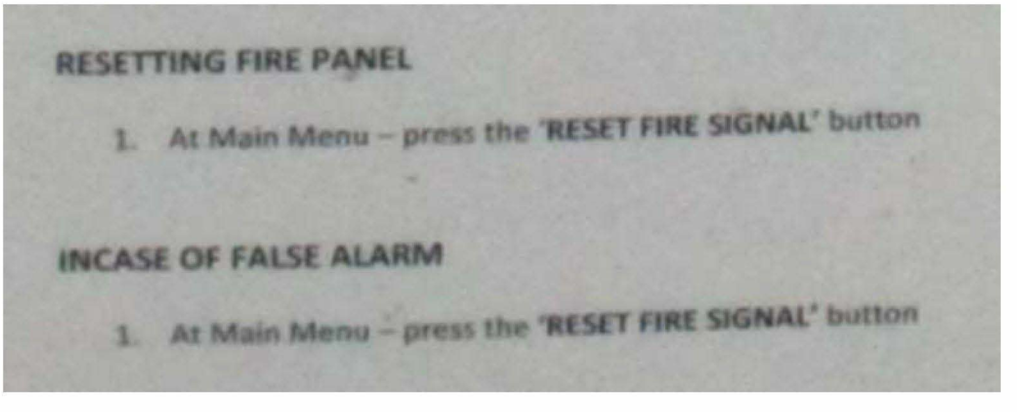
J9.4.21 This takes the form of a series of buttons, one for each floor. The instructions do not identify what would happen if one of these controls were to be used.

J9.4.22 The instructions do not identify what would happen if the key switches were to be used and then a user tried to use one of these buttons.

J9.4.23 **Resetting fire panel and In Case of False Alarm**

J9.4.24 The final 2 instruction sets relate to resetting of the smoke control system. The HMI panel button states “Reset Fire Signal”.

J9.4.25 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 J.79: Final excerpt of instructions

J9.4.26 The instructions do not identify what the user should expect to see or hear on pressing the reset button. The instructions do not identify what would happen to the smoke control system on pressing the reset button, and therefore what state the system would be in if it were to be re-activated immediately after being reset, for instance if a fire fighter reset the system while there was still smoke present on one or more floors of the building.

J9.4.27 **Functions not explained in the instructions**

J9.4.28 In Section J7.7 of my report, I identify the specific functions that the HMI panel allow a user to undertake. The following functions are not explained in the instructions provided adjacent to the HMI panel:

a) What would happen if the key switch is turned to “On” and then back to “Auto”.

b) Changing the floor of operation using the HMI touch panel interface (“individual floor control screen”).

c) How the touch screen “Individual floor control screen” interacts with the use of the physical key switched provided on every floor.

d) The purpose of any of the “System setup” functions that can be accessed from the first menu page, or how to use those functions.

J9.4.29 **Conclusions on effectiveness of smoke control system instructions**

J9.4.30 Therefore, the instructions provide a very basic indication of how to use the system. This aligns with the title of the instructions.

J9.4.31 The Instructions provide specific guidance on how to:

a) Check which dampers are closed and open;

b) Select a floor of operation manually using only 1 of 2 methods available; and

c) Reset the system.

J9.4.32 However, the instructions do not provide any guidance on what several of the buttons provided would do.

J9.4.33 The Instructions also do not expand on the consequences of using some of the controls in terms of the operation of the system, or give any indication as to what indicators could be observed within the building to confirm its operation.

J9.5 Evidence of operation by the LFB

J9.5.1 There is evidence that the HMI panel in the main entrance foyer was opened by fire fighters on the 14th June 2017.

J9.5.2 I understand that the HMI panel was first opened by Watson at approximately 01:35 (Figure J.80). However, in his oral evidence, Watson states that he did not operate the controls (Figure J.81).

Figure J.80: CCTV footage from Ground floor foyer at approx. 01:35 (INQ00000227)

Q. Was it you who opened the panel?
A. I did open the panel. I don't recall if I shut the door or not, but I didn't operate anything on the panel.

Figure J.81: Excerpt from oral evidence of Watson (Transcript of 24th July, p28)

J9.5.3 Figure J.82 shows the HMI panel in the main entrance foyer, with a fire fighter in a white helmet apparently operating the touch screen control. I understand from the oral evidence of Walton (Transcript 20th September, p164) that the fire fighter at the controls was WM Dowden. The image is taken at approximately 02:01.

Figure J.82: Foyer CCTV footage at approx 02:01 (INQ00000343)

J9.5.4 I understand from the oral evidence of Dowden (Transcript 26th June, p130) that he first observed the panel open with the keys already in place.

A. The two memories -- the first memory I have is that the panel -- you have a panel on the front, that was open and the keys were in it, and that -- I remember thinking

Figure J.83: Excerpt from oral evidence transcript of Dowden (26th June, p130)

J9.5.5 Dowden also states that he did not operate the HMI panel:

Q. Then he says:
"I know my understanding was that the system had failed and WM Dowden had tried to turn it on but it was not responding."
Is that correct?
A. I don't remember trying to actuate the panel itself.

Figure J.84: Excerpt from oral evidence of Dowden (Transcript 26th June, p136)

J9.5.6 However, Dowden did take a set of keys into the lift lobby at Ground floor and attempted to operate the override key switch in that location:

The only point that I had any sort of use of the key is when I took it out and went to, as I referred earlier, the individual lobby area to try and actuate in that lobby area, not at the main panel.

Figure J.85: Excerpt from oral evidence of Dowden (Transcript 26th June, p136)

J9.5.7 In his oral evidence, Cook (Transcript 24th July, p22) recalls that he observed the smoke control HMI panel with a flashing fault indicator. The bridgehead moved to Ground level at approximately 03:08.

"On page 12 of your statement, if you look at the -- well, it's the really long paragraph, six lines up from the bottom of the paragraph. You say: "It was at the point that we moved the Bridgehead to the ground floor that I had noticed that the smoke extraction system was not working, properly. This was situated on the ground floor and visible from the new location of the Bridgehead. I knew it was not working properly because lights were flashing, but there was no time to deal with it.""

J9.5.8 As I have presented in Figure J.58, the panel does not appear to have any specific indicator lights mounted in the HMI casing. Based on the HMI programming, it appears that on activation of the system by a smoke detector, the fire status message would override all other messages. Therefore, if the system was working as intended, I have no evidence of what on the HMI panel might flash indicating a fault. This may indicate either that Cook has mis-remembered a detail of the night, or it may indicate that the system was not operating in smoke mode as intended when Cook observed the panel.

J9.5.9 In his oral evidence (transcript of 4th July, p2), Egan observed that the switch had been turned to "on". At this time, I do not know when this observation was made by Egan.

"First of all, what is the ventilation box that you're referring to there?
A. It was just on the wall and I made an assumption that it was to do with the -- if it had an automatic smoke ventilation system for the stairwells.
Q. Okay. And you say it had a key in it turned to "on". That's your clear recollection, is it?
A. That's my recollection, yes.
Q. Do you know who turned it to "on"?
A. No, I don't, no, sorry.
Q. Is that how you left it?
A. I left it, yeah, because usually you would expect to see it in "auto", so because it was switched to "on", I just made an assumption that someone has tried to get it to work, to force it to work. "

J9.5.10 In the photographic record taken by the LFB, there is a photograph of the HMI panel taken on the 17th June 2017. I have replicated this photograph inFigure J.86.

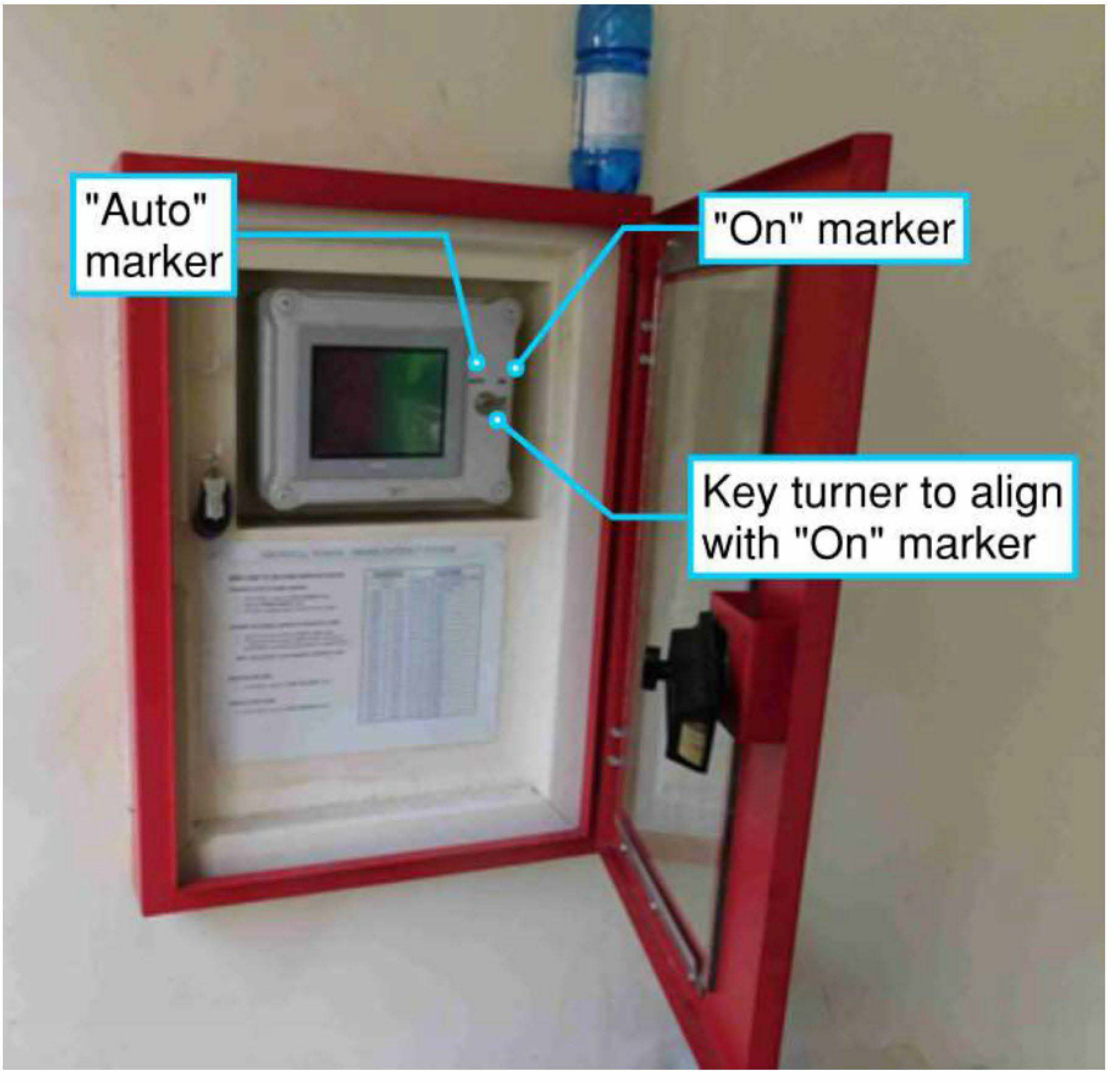


Figure J.86: Photograph of HMI panel after the fire (MET00018915)

J9.5.11 Therefore, the first evidence of a fire fighter interacting with the HMI panel was at approximately 01:35.

J9.5.12 And it is possible that at some time during the course of the fire the HMI panel was switched from “Auto” to “On” (Oral evidence of Egan, presented above).

J9.5.13 As I have described above, switching the panel to “On” permits manual control operations to be undertaken, and may lead to the system being shut down, either intentionally or accidentally by operation of the reset and/or shutdown commands.

J9.5.14 There is no specific evidence that the system was shut down intentionally, at this stage.

J9.5.15 I note that the BRE inspection identified that the AOVs on Level 11 and Level 18 were open. This could have been instructed intentionally or accidentally by fire fighters operating the touch screen on the HMI panel while it was switched to "On".

J10 Compliance of the refurbished system with ADB

J10.1.1 **Regarding the performance of the system as a lobby smoke control system:**

J10.1.2 Using the information, I have provided in Sections J3 to J9, I have assessed the compliance of the lobby smoke control system as installed at Grenfell Tower, using the ten performance requirements for a depressurisation system provided in Section 9.2 of BS EN 12101-6 and the five Class B requirements set out in Clause 4 of BS EN 12101-6.

J10.1.3 I provide my resulting compliance status in Table J.6.

J10.1.4 I conclude that the design of the smoke control system does not comply with the relevant British Standard, BS EN 12101-6 for the *Specification for pressure differential systems.*

J10.1.5 I conclude that commissioning of the system was inadequate.

J10.1.6 Furthermore, despite the extensive documentation available to me, I have been unable to determine how the design was intended to meet the requirements of the Statutory Guidance in ADB 2013.

J10.1.7 I would like to see the project team's documentation that clearly explains how compliance of the system was intended to be achieved, in order to understand this. If an alternative route to compliance was intended, this needs to be clearly explained.

J10.1.8 Regarding its required performance BS EN 12101-6:2005 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.*"

J10.1.9 To understand the performance of the system on the night, I want to make clear it requires an understanding of a series of points:

a) the performance of the system to the standard described in BS EN 12101-6:2005 was not possible as that is not what was designed or commissioned.

b) an alternative performance condition has not been clearly set out by the design team and so that performance cannot be currently assessed by me at this time.

c) however, from the evidence I do have it shows that a substantial number of the performance requirements are omitted from the design features. I therefore do not understand how the system as designed could ever achieve the performance required by BSEN 12101-6: 2005 - which is to minimise the potential for serious contamination of firefighting shafts by smoke during means of escape and fire service operations.

d) I understand the design team considered the system as designed was "no worse" than the existing system in Grenfell Tower – I currently do not understand how they clearly established and proved this to be the case.

J10.1.10 There is a substantial amount of evidence from residents about the operation of the system on the night. I will need to review this very carefully when their evidence is completed.

J10.1.11 This includes evidence of noise in the lobbies at level 23 and noise in the north and south shafts on other floors. I am still looking for any evidence of noise being heard at the Level 2 fan location.

J10.1.12 As the system is a combined system, which could operate in environmental or in smoke mode, noises must be considered in the context of both functions.

J10.1.13 The autodialler had sent a signal to Tunstall by 00:55, and there is no evidence of smoke at that time on any other floor than floor 4. This is consistent with the evidence of the residents in Flat 16 who observed smoke by their flat entrance door, and opened that door to the lobby, at approximately 00:53 (LFB00001914). A smoke detector was present in the lobby outside Flat 16 and near the north builders' work shafts.

J10.1.14 Please refer to section 14 for my assessment of the conditions in the stairs and lobbies, as impacted by the smoke control system. It appears most likely that the smoke control system activated on Level 4 at this stage. However, there is evidence of substantial smoke flow on the lobby of Level 4, and into the staircase, early in the fire, when the single fire floor condition required of the lobby smoke control applied.

J10.1.15 I will carry on my investigations of the smoke control system and how it performed on the night, and the significance of this regarding the condition in the lobbies and the stairs, when all the resident evidence is completed.

J10.1.16 However, I consider that the smoke system installed in Grenfell Tower did not meet the requirements for a pressure differential system and particularly the performance requirements outlined in BS EN 12101-6. Therefore, I consider that the system for Grenfell Tower was not in compliance with the arrangements shown in BS EN 12101-6 and hence was not compliant with the requirements of ADB.

J10.1.17 **Regarding the performance of the system as a protected shaft:**

J10.1.18 I have substantial evidence of a number of non-compliances with the system as installed in the tower:

a) The existing builders work ducts do not appear to have been checked and sealed as is required – and have no stated fire resistance performance in the design documentation. In this existing building they require a minimum of 60 minutes fire resistance each side separately.

b) Section 10.15 of ADB 2013 states that the requirement for fire and smoke dampers to a *Protected Shaft* is a 60 minutes rating for Integrity and Smoke leakage. Specifically, this is an ES60 rating as classified using BS EN 13501-3 based on testing using BS EN 1366-2.

c) Because the dampers are in a powered pressure differential system this ES60 standard must be classified using BS EN 13501-4 based on testing to the higher standard of BS EN 1366-10.

d) The dampers installed in north and south shafts were Gilbert Series 54 "*Smoke evacuation dampers*". The literature submitted to the Inquiry by PSB (PSB00000291) states that this product was "*fully tested to the requirements of EN1366 pt 2 for 2 hour.*" However, no formal classification is provided in accordance with BS EN 13501-3 within this literature.

e) BS EN 1366-2 is the test standard for dampers in a natural ventilation system, not in a powered pressure differential system. It provides a lower standard of performance of E and S compared to the test in BS EN 1366-10 due to the lower pressures applied during the test.

f) However, the formal certification of the damper fire resistance (both E and S ratings), appears to have been rescinded by the manufacturer in April 2017.

g) I assume this is because of the statement in the WarringtonFire test report (WF309850, dated 6th October 2011, GILO00000001) "*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.*". As the product did not have a valid test in accordance with the relevant standard, its performance could not be classified ,as required, using BS EN 13501-3.

h) Therefore, the dampers that were installed did not achieve the required performance of either ADB 2013 or BS EN 12101-6 for ES60 when classified against either BS EN 13501 Part 3 or Part 4.

i) At the time of their purchase in January 2015 (PSB00001240), therefore, they were not certified fire dampers, nor were they certified smoke control dampers.

j) PSB's Technical Submission does not in fact specify a fire resistance rating or a smoke leakage requirement for the AOV dampers in order to comply with the requirements of ADB 2013 or BS EN 12101-6. Further PSB's design schematic (p1238 of RYD00000577) does not specify a fire or smoke leakage performance requirement for the AOV dampers, but states that the design, supply and installation of any dampers is outside their scope of work.

J10.1.19 The British Standard tests for smoke leakage, do not intend to prevent fully smoke leakage in a fire. As stated in the Introduction to BS EN 1366-10, the intention is for smoke control dampers to:

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

J10.1.20 However, the oral evidence of Farhad Neda (Transcript 18th October, p27) about smoke leaking into the lobby of Level 23 via the smoke shaft vents, on the north and south side, is a critical piece of evidence at this stage. This is because it could indicate a significant failure of the smoke control system to prevent contamination of compartments away from the fire compartment, in breach of Section 11.8.2.10 of BS EN 12101-6, which states:

"*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.*"

J10.1.21 This evidence may also represent a failure of the compartmentation rules for protected shafts in Section 8 of ADB 2013.

J10.1.22 I will continue to investigate these matters as part of my Phase 2 work.

J11 Operation of the Smoke ventilation on 14 June 2017

J11.1.1 I have made substantial progress in my investigation into the operation of the smoke ventilation system on 14th June 2017. However, the evidence from the residents and particularly during their oral evidence, is substantial, and requires detailed consideration.

J11.1.2 I have therefore decided to wait until their oral evidence is completed before releasing this Section of my Appendix J.

J11.1.3 I have the following lines of investigation underway.

J11.1.4 **Considering whether there is any evidence of noise from operational fans in smoke mode and in environmental mode, including:**

(a) Noise - Evidence of smoke extract fan and environmental fan operation during the fire at roof level;

(b) Noise - Evidence of smoke extract fan and environmental fan operation during the fire at level 21 – 23;

(c) Noise - Evidence local to the AOVs in the lobbies – any level;

(d) Noise - Evidence at Level 2 where the extract fan and environmental fans serving the south shaft are located;

(e) Evidence of areas where no noise heard.

J11.1.5 Considering whether there is any evidence of Air movement from the combined environmental and smoke control system, including

(a) evidence of air movement between the stairs and the lobbies – level 4 before 130am;

(b) evidence of air movement between the stairs and the lobbies – any level;

(c) evidence of air movement local to a lobby – any level;

(d) evidence where no air movement observed.

J11.1.6 Analyse the data available from the post-fire condition of the smoke control system.

J11.1.7 I am aware of 4 separate inspections of components of the smoke control system after the fire:

a) On the 17th June 2017 LFB officer James Flin took photographs throughout the building, including specific elements of the smoke control system;

b) BRE inspected the positions of the dampers on each level and published a report (MET00012525);

c) I inspected the AoVs in each lobby that was accessible and the outside of the fans and ductwork in my site visit of 7-9 November 2017, as recorded in Appendix C; and

d) Professor Anna Stec of University of Central Lancashire has undertaken a separate investigation of soot deposits in the smoke control system and produced a short summary of her preliminary findings (AAS00000001).

e) I am assembling the overall evidential picture this provides for each of the 4 shafts.

J11.1.8 Evidence of smoke being detected

(a) I now have evidence that Tunstall received a call from the smoke panel in Grenfell Tower. I need to investigate what device caused that call to be made.

(b) **System activation log:** the smoke control system had the capability to log activation events as part of the HMI panel function. However, by the time the data had been downloaded from the HMI panel, the log of events on the 14th June 2017 had been overwritten by subsequent events.

J11.1.9 Evidence of operation of AOVs on specific floors

(a) I specifically note that BRE concluded in their interim report (dated 9 March 2018, MET00012525) that the dampers on Level 4 were not open at all, and that dampers on Level 11 and Level 18 were fully open.

(b) I am investigating how the dampers on Level 4 could either not open at all; or become shut during the fire.

(c) I am investigating the signals to open the dampers on Level 11 and Level 18 with regard to when and how they could have come from use of the HMI panel in the Ground floor lobby.

(d) I will also investigate if those signals may have been sent by malfunctioning control equipment.

J11.1.10 Evidence of smoke being exhausted from the roof fans

(a) I am reviewing the images taken by the 2 National Police Air Service helicopters that were present on the 14th June 2017. Stills were taken using the infrared search camera on each helicopter.

J11.1.11 Evidence of smoke being exhausted from the level 2 smoke or environmental fans

(a) I am investigating evidence of soot on the Level 2 exhaust louvre through post fire photographic evidence.

(b) I am also looking at that with reference to Prof. Stec's records of soot deposits and debris on the outside of the vent slats and on the outside of the metal mesh that prevents objects from being sucked into the building when the system was operating in environmental mode.

(c) I am collating stills from video footage taken by the NPAS helicopter and from body cameras that directly show the Level 2 vent.

J11.1.12 Evidence of soot deposition in the Level 2 ductwork

(a) I am analysing Prof. Stec photographs of the inside of the smoke control ductwork and environmental ductwork at Level 2 as part of her inspection.

(b) For all ductwork analysis I will also consider fire fighting water effects in the system where relevant.

J11.1.13 Evidence of soot deposition in the lobbies and smoke vent shafts

(a) In my post fire site inspection of 7-9 November 2017, I observed the condition of the AoVs on Level 4, Level 11 and Level 23. I was also able to observe inside the shaft at Levels 11 and 23 through dampers that were open at the time of my inspection. I note that the BRE report (MET00012525) identifies that the AoV dampers on Level 11 were found to be open immediately after the fire.

J11.1.14 I am comparing my observations with the data Prof. Stec recorded (AAS00000001) of soot deposition within the smoke vent shafts.

J11.1.15 I will then analyse the photographic evidence of soot deposits from the lobbies, and in conjunction with the soot deposits in the ducts, in order to determine if the smoke control system had operated as intended on Level 4, or operated first elsewhere (for example, at Level 11 as observed by the BRE inspection).

J11.1.16 Evidence of smoke leaking out of the AOVs:

(a) I will analyse what lobbies this occurred on and if on the north and south side;

(b) I will investigate what arrangement of fans, pressure and air flow might contribute to leakage from closed AOVs;

(c) I will investigate what leakage is possible from closed AOVs in the absence of any fan operation.

J12 Classification of Dampers in accordance with ADB and UK testing requirements

J12.1 Types of Damper

J12.1.1 In Table J.7 I have summarised the three types of damper that are defined by ADB 2013 and BS EN 12101-6; where each one is used; the fire rating required for that type of damper; the relevant test standard; and the relevant classification standard for each of the dampers. The text in square brackets is the reference where I obtained the information.

Table J.7: types of damper and test requirements

Name	*Fire Damper*	*Fire and Smoke Damper*	*Smoke control Dampers*
Use	Where air handling ducts pass through fire separating elements (excluding the protection of escape routes) [ADB 10.13]	Where air handling ducts pass through fire separating elements (including the protection of escape routes) [ADB 10.13]	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 [BS EN 12101-6 Clause 11.8.2.10]
Fire rating required	>=E60 [ADB 10.15]	>=ES60 [ADB 10.15]	>=ES60 [ADB 10.15]
Relevant fire resistance test standard	BS EN 1366-2 [ADB 10.15]	BS EN 1366-2 [ADB 10.15]	BS EN 1366-10 [BS EN 13501-4 clause 7.3.3.1]
Relevant fire resistance classification standard	BS EN 13501-3 [ADB 10.15]	BS EN 13501-3 [ADB 10.15]	BS EN 13501-4 [BS EN 12101-6 Table ZA.1]

J12.2 Differences in test requirements of BS EN 1366-2 vs BS EN 1366-10

J12.2.1 The most significant difference between testing to BS EN 1366-2 for fire or fire and smoke dampers in air handling systems vs testing to BS EN 1366-10 for smoke control dampers in smoke control systems, is the pressure applied to the damper.

J12.2.2 BS EN 1366-2 uses an applied pressure of 300 Pa.

J12.2.3 BS EN 1366-10 uses an applied pressure of either 500, 1000 or 1500 Pa depending on the maximum pressure created by the system in which the damper is intended to be used.

J12.2.4 In a fire, a standard air handling unit would shut down, therefore the only pressure in the system would be caused by the fire.

J12.2.5 In a smoke control system, the fans are constantly running extracting air, therefore applying a higher pressure on the damper.

J12.2.6 For this reason, a test to BS EN 1366-2 cannot be used to demonstrate compliance of a smoke control damper.

J12.3 Failure criteria of BS EN 1366-2 and BS EN 1366-10 testing of dampers

J12.3.1 Both BS EN 1366-2 and BS EN 1366-10 use the same failure criteria.

J12.3.2 These are replicated in Figure J.87

a) Integrity:

After the start of the fire test the leakage through the fire damper shall not exceed 360 m^3 / (h m^2) (corrected to 20 °C). The integrity around the perimeter of the fire damper shall be judged in accordance with the criteria given in EN 1363-1.

b) Insulation

The temperature criteria shall be as defined in EN 1363-1. The maximum temperature shall be taken from thermocouples T_1, T_2 ,T_s and the roving thermocouple. The average temperature shall be determined from thermocouples T_2.

c) Leakage

The leakage through the fire damper shall not exceed 200 m^3/(h m^2) (corrected to 20 °C). The requirement for leakage during the ambient leakage test need not be met after five minutes test duration.

The result of the fire test shall be stated in terms of the time elapsed to the completed minute from the commencement of the heating to the time when the fire damper failed to satisfy the criteria for integrity, insulation or leakage, or the termination of the heating, whichever is the shortest.

Figure J.87: Performance criteria for dampers in accordance with BS EN 1366 parts 2 and 10

J12.3.3 Where Integrity is termed E; insulation is termed I; and smoke leakage is termed S; under the European Classification system.

J12.3.4 As discussed above, fire dampers; fire and smoke dampers; and smoke control dampers only need to achieve integrity (E) and smoke leakage (S) values.

J12.3.5 In terms of the test procedure:

J12.3.6 Smoke leakage (S) is measured at two separate instances, once at ambient temperature before the furnace test starts and from 5 mins after start of the furnace test (i.e. three minutes after the damper has closed) to the end of the test. If either of these measurements exceed 200 $m^3/(hm^2)$ then the damper fails the S criteria.

J12.3.7 There are four measurements of integrity failure.

J12.3.8 Integrity - Leakage is the time where the leakage rate through the damper exceeds 360 $m^3/(hm^2)$, with measurements starting five minutes after the furnace tests starts (i.e. three minutes after the damper has closed). Note this is the same measurement that is taken for the S value just with a less onerous failure criteria (360 m^3/hm^2 instead of 200 m^3/hm^2).

J12.3.9 The junction between the separating wall and the damper is then checked for integrity using the remaining three methods: Integrity- sustained flaming; Integrity- gap gauge; and Integrity cotton pad.

J12.3.10 The integrity (E) is the time in minutes that the first of these 4 criteria is recorded to have failed.

J12.4 Test sample initiation requirements to BS EN 1366-2 and BS EN 1366-10

J12.4.1 BS EN 1366-2 requires that the damper is open at the start of the furnace test and then must close within two minutes, otherwise the test is deemed a failure (refer to clause 10.4.3 and 10.4.6 of the standard).

J12.4.2 BS EN 1366-10 must follow a specific initiation sequence, as prescribed by clause 6.2 of the standard.

J12.5 Review of available test evidence

J12.5.1 I have reviewed the test reports disclosed by Gilberts.

J12.5.2 Three test reports were submitted - two copies of WF Test Report No. 309850 (report dated 06/10/2011) (GIL00000001 & GIL00000008); and one copy of BMT/FEP/F14191 Revision A (report dated 24/10/2014) (GIL00000014).

J12.5.3 WF Test Report No. 309850 is a test to BS EN 1366-2:1999. This is the standard for fire and smoke dampers as part of a general ventilation system, not smoke control dampers as was required in Grenfell Tower (see Table J.7). The standard required to demonstrate compliance of the Grenfell system would be BS EN 1366-10 and subsequent classification to BS EN 13501-4, again as shown in Table J.7.

J12.5.4 Irrespective of this, the test report does not demonstrate proper compliance with the standard. The report specifically 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.*". For this reason, the test report cannot be used to classify the system to BS EN 13501-3 (noting again this is irrelevant to what should have been provided at Grenfell) and therefore cannot be used to demonstrate compliance with ADB 2013.

J12.5.5 In any event, the result of the test was 74 minutes integrity (E) however the damper failed the smoke leakage requirement (S). Therefore, even though the damper was closed at the start of the furnace test (when it should have started in the open position) it failed to achieve the leakage of $< 200\ m^3/hm^2$ as soon as measurements were taken.

J12.5.6 It therefore can only be considered a fire damper not a fire and smoke damper.

J12.5.7 Therefore, in accordance with paragraph 10.13 of ADB, it could not be used on a protected escape route (refer to Table J.7above).

J12.5.8 BMT/FEP/F14191 Revision A was a test to EN 12101-2: 2003 Annex G.

J12.5.9 BS EN 12101-2 is the standard for natural ventilation. Annex G is the test method for Resistance to heat.

J12.5.10 This test is only relevant to a natural ventilator to demonstrate that it can open and stay open when exposed to heat and therefore is not relevant to how the damper was installed in Grenfell.