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
Smoke extract – requirements and provisions

REPORT OF

Dr Barbara Lane FREng CEng

Fire Safety Engineering

12th April 2018

Specialist Field	:	Fire Safety Engineering
Assisted by	:	Dr Susan Deeny, Dr Peter 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 14 June 2017
Inspection Date(s)	:	6th October, 1st November, 7-9th November 2017

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Appendix J– Smoke extract – requirements and provisions

CONTENTS

J1 Purpose of Appendix J

J1.1.1 In this Appendix, I provide my review of the smoke extract provision at 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 documentation provided to me, at this stage.

J1.1.3 I also present an explanation of the recommended provisions for smoke extract at the time Grenfell Tower was built as set out in British Standard Code of Practice CP3 1971, and also at the time of the refurbishment works in 2012 – 2016 to ADB 2013.

J1.1.4 I have relied on technical input from my chartered mechanical engineering assistant Dr Peter Woodburn also.

J1.1.5 I have concluded that the original smoke ventilation system was not compliant with the recommended provisions of CP3 1971.

J1.1.6 I have concluded that the mechanical smoke ventilation system provided in the 2012 – 2016 refurbishment was a bespoke system which was an upgrade of the original system (also a bespoke system) and did not meet the guidance within ADB 2013.

J1.1.7 I have been unable to confirm that the smoke ventilation system was fully commissioned, or that a maintenance program was in place at the time of the fire, and I will investigate this further in the next stage of my work.

J1.1.8 I have been unable to confirm the operational status of the smoke ventilation system at the time of the fire.

J1.1.9 I have also concluded that the smoke ventilation system did not operate as intended during the fire on 14th June 2017.

J1.1.10 I have concluded that the smoke ventilation system was intended to operate on one floor only. The design was based on the principle of a fire contained to a single compartment and therefore could not have protected lobbies and the stair from smoke generated by fires on multiple floors.

J2 Purpose of smoke ventilation system in a residential building

J2.1.1 The stated purpose of providing ventilation to the common corridor 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"

J2.1.2 Diagram 52 in ADB 2013, advises

J2.1.3 *"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."*

J2.1.4 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."

J2.1.5 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."

J2.1.6 Natural ventilation smoke systems provide the means for hot smoke to ventilate from a space driven by its own buoyancy, thereby protecting escape routes.

J2.1.7 Typically, natural ventilation systems ventilate smoke from the common corridor into a shaft which is open to atmosphere at the top and acts as a chimney.

J2.1.8 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.

J2.1.9 Pressure differential systems, as described in BS EN 12101-6:2005, use fans, ducts, vents, shafts and other features to raise the pressure of the stair and common corridor above that in the fire compartment. The raised pressure generates a flow of fresh air from the stair to the fire compartment, preventing the flow of smoke into the stair.

J2.1.10 In all three systems, vents on the fire floor are opened and vents on all other floors are closed to allow the full capacity of the smoke ventilation system to be directed to the fire floor.

J2.1.11 As detailed in Section J3.2, the provisions made in ADB 2013 for smoke ventilation systems are only intended to address the effects of a fire on one floor.

J3 Recommended Provisions for the smoke ventilation system

J3.1 British Standard Code of Practice CP3 1971

J3.1.1 As I have set out in Section 17, at the time of construction of Grenfell Tower, the guidance contained in British Standard Code of Practice CP3 1971 included the means by which protection from fire and smoke to people in the building may be provided in high-rise blocks of flats.

J3.1.2 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).

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

J3.1.3 The arrangement recommended by CP3 1971 is shown in Figure J.1. In particular, the requirement for two AOVs providing fresh air ventilation is shown.

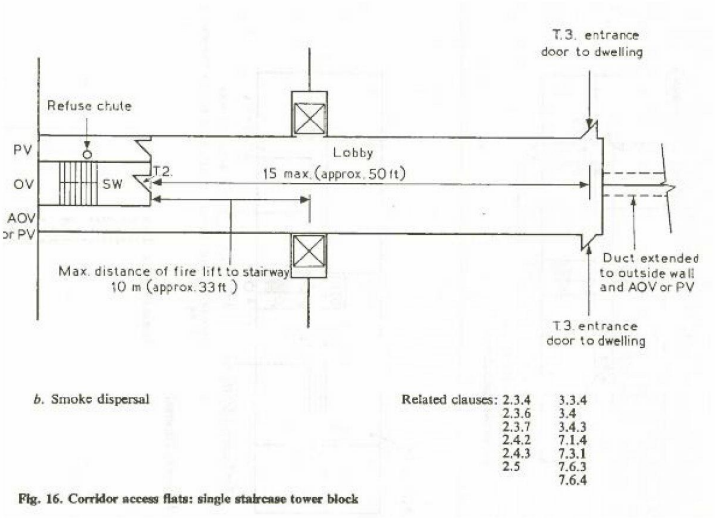


Figure J.1: Excerpt from CP3 1971 showing the recommended provisions for escape and smoke control in a single stair tower block. This is not the system which was originally installed on Grenfell Tower.

J3.2 Approved Document Part B

J3.2.1 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).

J3.2.2 The design basis fire assumed in ADB 2013 for the smoke ventilation system is therefore a fire starting in a single location, and being contained within a single compartment.

J3.2.3 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."

J3.2.4 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."

J3.2.5 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."

J3.2.6 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.

J3.2.7 Diagram 52 of ADB 2013 provides guidance on the components of a firefighting shaft. Diagram 52 is reproduced in Figure J.2. Diagram 52 Note 2 makes provisions that smoke control is provided in accordance with an additional code of practice BS5588-5:2004. Therefore, this is also a permissible code of practice for the design of mechanical smoke control to comply with ADB Section 2 and 17.

J3.2.8 However, should the building be designed using the 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.

J3.2.9 Note 2 in Diagram 52 (Figure J.2) advises that where the firefighting shaft serves only flats, the provisions for smoke control given in paragraph 2.25 may be followed instead.

J3.2.10 Therefore, with regard to smoke ventilation on the residential floors of Grenfell Tower, only the guidance of Section 2.25 of ADB 2013 for smoke control of common corridors/lobbies is relevant.

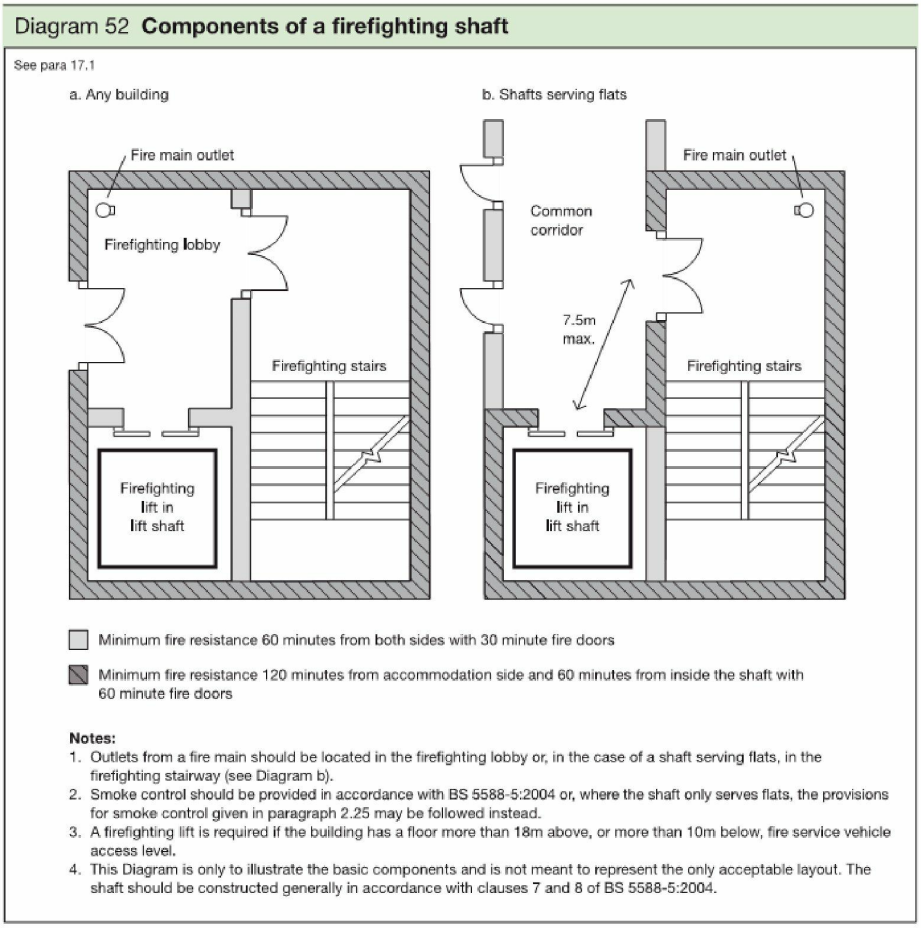


Figure J.2: Diagram 52 from ADB 2013.

J3.2.11 The ADB 2013 guidance for the zone where ventilation should be provided for residential buildings with one common stair (ADB 2013 Diagram 7) is presented in Figure J.3 (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.

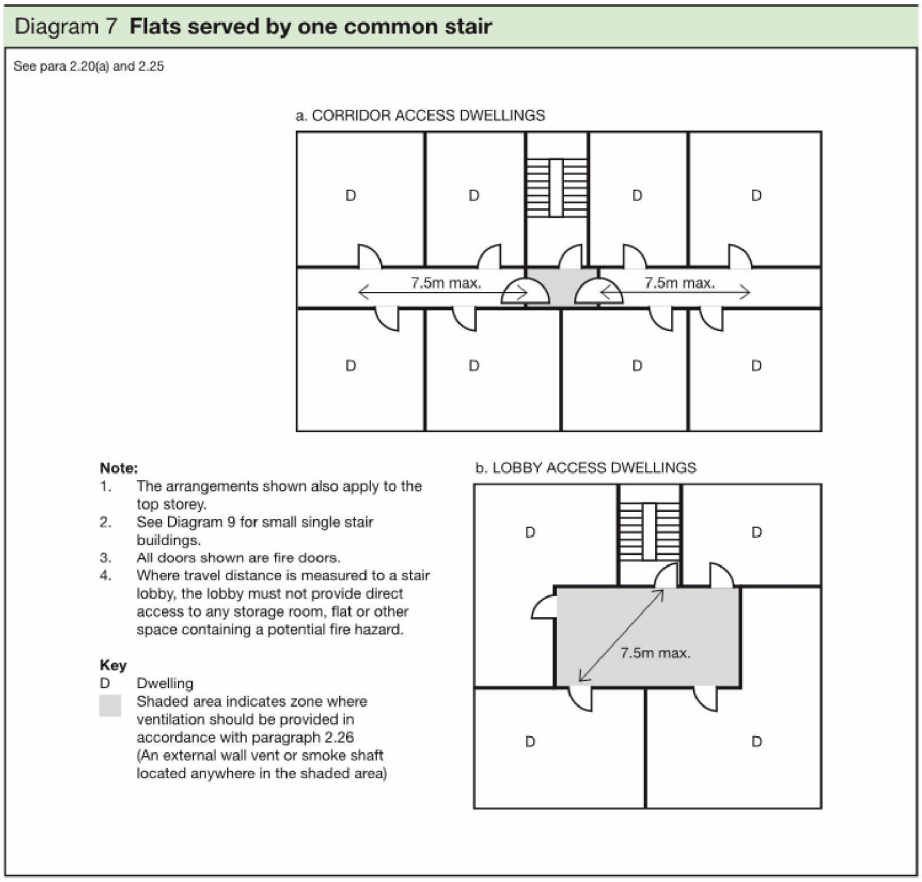


Figure J.3: Diagram 7 from ADB 2013.

J3.2.12 The north and south 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 is passes. In accordance with ADB 2013, this would be 120-minute insulation and integrity fire resistance which would be equal to the fire resistance of the floors.

J4 Description of the original and refurbishment smoke ventilation system

J4.1 Introduction

J4.1.1 Grenfell Tower was originally constructed with a lobby and stair smoke ventilation system.

J4.1.2 This smoke ventilation system was refurbished in the 2012 – 2016 works.

J4.1.3 The intent of the refurbishment was set out in the Employer's Requirements (MAX00006475) as:

"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."

J4.1.4 The performance standard of the original system was not known to RKBC, as stated in an email to Max Fordham (MAX00004353).

J4.1.5 During the design of the refurbished smoke ventilation system a number of configurations were proposed. Here I will describe only the original system and the final proposed refurbishment system which appears to have been the system installed in Grenfell Tower.

J4.1.6 In Grenfell Tower the original and refurbished smoke ventilation system were combined with an environmental ventilation system, to provide temperature control within the lobbies during day to day operation. In the event of fire, the system was designed to switch into fire mode using automatic fire detection.

J4.1.7 Some of the components of the original smoke ventilation system were retained in the refurbishment, specifically the openings for Automatic Opening Vents (AOVs) and smoke shafts within Grenfell Tower.

J4.1.8 I therefore present a description of the original system since it was the design of this system which set the layout and dimensions of the smoke shafts and AOVs. I then describe final refurbished smoke ventilation system as I understand it to have been in place on 14th June 2017.

J4.1.9 The smoke ventilation system was substantially damaged during the fire and not operational at the time of my site visit. Therefore, I have obtained information on the intended performance of the smoke ventilation system, and the methodology by which it was controlled, from design documentation only as detailed below.

J4.1.10 I have set out in Section 2 of my report the additional information I require for further investigation.

J4.2 The original system

J4.2.1 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."

J4.2.2 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.

J4.2.3 The operation of the smoke ventilation mode is visualised for the fire floor Figure J.5.

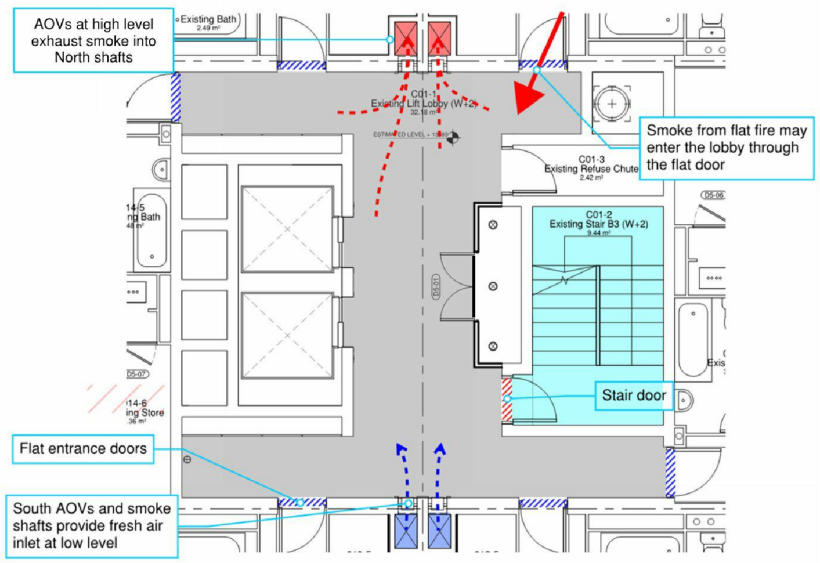


Figure J.5: Operation of the original smoke ventilation system on the fire floor, overlaid on an excerpt from SEA00010474.

J4.2.4 Components of the original system

J4.2.5 The original smoke ventilation system consisted of:

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 (aggregate area 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 (aggregate area 0.48m^2) leading to a supply fan and outlet on at Walkway + 1 level.

c) A manual fireman's override located at Ground Level.

d) Associated controls and power supplies

J4.2.6 Original system – Operation for smoke

J4.2.7 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.

J4.2.8 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.

J4.2.9 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.

J4.2.10 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

J4.2.11 **Compliance of the original system**

J4.2.12 In natural ventilation mode, the aggregate area of the smoke shafts on each side of the lobby which was 0.48m^2 was significantly lower than the equivalent free area recommended by CP3 1971 at each end of the lobby which is 1.5m^2 (Section J3.1).

J4.2.13 CP3 1971 does not include any guidance on the performance standard of mechanical smoke ventilation systems. Therefore, the flowrate generated in the mechanical ventilation mode cannot be compared with the recommended provisions from CP3 1971.

J4.2.14 The original smoke ventilation system was not compliant with the guidance in CP3 1971.

J4.3 The refurbished system

J4.3.1 **Sources of information**

J4.3.2 The smoke ventilation system was substantially damaged during the fire and hence not operational at the time of my site visit. Therefore, I was not able to measure the active performance of the smoke ventilation system during my site inspection.

J4.3.3 In addition to my site visit, I have therefore reviewed the details of the smoke ventilation system as recorded in the PSB technical submissions for the smoke ventilation system.

J4.3.4 Version 1 of this submission (dated 1/12/2014) is included within the Rydon O&M information (RYD00000577). The latest recorded version of the PSB technical submission which I have reviewed is Revision 6 dated 15/03/2016 (PSB00000214).

J4.3.5 I have therefore assumed for now, that Revision 6 (PSB00000214) represents the as-built condition.

J4.3.6 **Refurbishment works 2012 - 2016**

J4.3.7 During the refurbishment works 2012 – 2016, the existing pairs of smoke shafts serving the north and south sides of each of the lobbies on Levels 4 to 23 were retained for use in the refurbished smoke / environmental ventilation system.

J4.3.8 The pairs of shafts serving the north and south sides of the lobbies were also extended (as a single combined shaft on each of the north and south sides of the lobby) to serve Ground Level – Level 3. The existing openings between the lobbies and the shafts on Levels 4 – 23 were retained.

J4.3.9 New AOVs were fitted into the existing AOV openings in the smoke shafts. New fans, power supplies and controls were also provided for the refurbished smoke / environmental ventilation system. New ductwork was fitted between the south shafts and the Level 2 smoke and environmental fans and louvre at the façade of the building connected to outside air.

J4.3.10 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."

J4.3.11 **Refurbished environmental system**

J4.3.12 The refurbished environmental system was provided in Grenfell Tower to maintain comfortable temperatures in the lobbies on all Levels from Ground Level – Level 23.

J4.3.13 The environmental system utilised the same shafts and AOVs as the smoke ventilation system.

J4.3.14 In day to day use, warm air was exhausted from lobbies by a pair of new north AOVs located at high level on the north side of each lobby.

J4.3.15 The new north AOVs were served by the original (as extended) pair of smoke shafts leading to new fan sets (run and standby fans) used for both smoke and environmental exhaust which discharged at roof level.

J4.3.16 Fresh air was supplied to lobbies, for the environmental system, by a pair of new south AOVs located at low level on the south side of each lobby.

J4.3.17 A new environmental supply fan was located at Level 2 and served the south smoke shafts (as extended) and new south AOVs in each lobby. The environmental fan on Level 2 drew fresh air from outside via louvres and ductwork (not fire rated) on Level 2.

J4.3.18 The supply environmental fan was installed in parallel with the new smoke fan sets (run and standby fans) for the south shaft located on Level 2 – see

below. Bypass smoke dampers were installed to isolate the smoke fans from the environmental fan, in the event of a fire activation caused by detection of smoke in any one lobby.

J4.3.19 **Operation of the environmental system – environmental mode**

J4.3.20 In operation in environmental mode the AOVs on all floors were to be open.

J4.3.21 The bypass damper assembly at Level 2 was to be set to connect the environmental supply fan to the south shafts and to isolate the south shafts smoke fan set from the environmental system.

J4.3.22 Warm air was to be exhausted from the lobbies via the north AOVs and north shafts by the combined smoke / environmental fan at roof level, and the warm air discharged at roof level.

J4.3.23 The environmental supply fan located on Level 2 was to be operated to direct fresh make-up air into the lobbies via the south shafts through the south shaft AOVs. The fresh air inlet to support this action was louvres located on Level 2.

J4.3.24 Therefore, immediately prior to any fire, all AOVs could be open for the purposes of environmental control.

J4.3.25 **Operation of the environmental system – smoke mode**

J4.3.26 In the event of a fire, the environmental fan was to be shut down and electrically isolated. The environmental / smoke fan set at roof level was to be operated in smoke mode. The smoke fan set at Level 2 was to be operated in smoke mode.

J4.3.27 The environmental fan was to be isolated from the smoke extract system by the bypass smoke dampers.

J4.3.28 The AOVs on the fire floor only were to open up, if closed at the time of detecting the fire, otherwise if already open they would remain so.

J4.3.29 The AOVs on all other floors were to be closed and locked out from further automatic control signals.

J4.3.30 A control panel was provided in the Ground floor entrance foyer to permit manual operation of the smoke extract system by the fire and rescue services.

J4.3.31 **Components of the refurbished smoke ventilation system**

J4.3.32 For Levels 4 – 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.

b) 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.

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

d) The south AOVs 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 connecting the south smoke shafts to a vent 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.6).

f) The AOVs on Ground Level – Level 3 were all located at high level and served by the north and south vent shafts as above.

g) 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 ventilation system by automatically closing smoke dampers.

h) A master control panel and a Human Machine Interface (HMI) panel were both located at Ground Level. The master control panel was located in the hub room A010.

i) The HMI panel was located within the Ground floor lobby.

j) Associated controls and power supplies.

J4.3.33 The control panels were intended to allow the operator to access system configuration, maintenance and testing functions. The HMI also provided the Fireman's override facilities. A description of the override facilities is provided in Section J4.3.44.

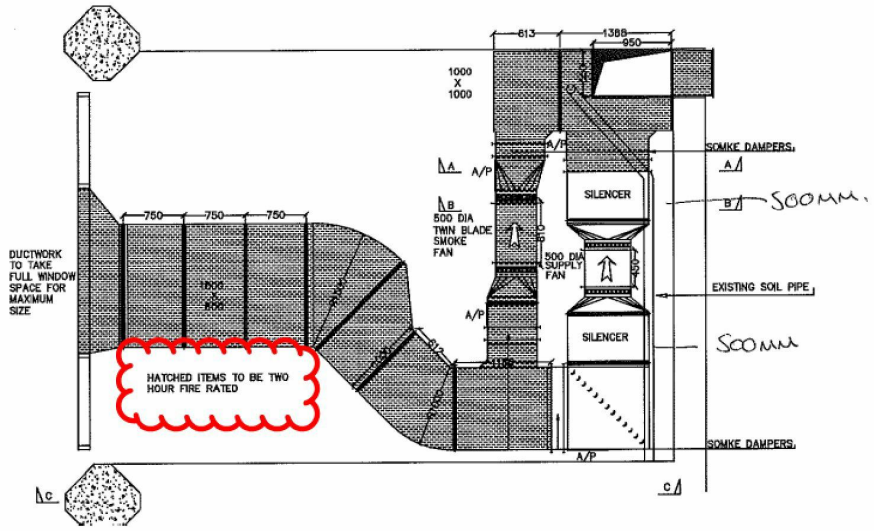


Figure J.6: Excerpt from attachment to HAR00007049 indicating extent of fire rated ductwork at Level 2 HAR000070512

J4.3.34 Operation of the smoke ventilation system

J4.3.35 According to the PSB technical submission 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 ventilation 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.

J4.3.36 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.

J4.3.37 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.

J4.3.38 The smoke exhaust fans at Level 2 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.

J4.3.39 Fresh air was to be drawn into the lobby from the stair via the permanently open vent at the head of the stair.

J4.3.40 If the stair door was open, the flow of air into the lobby from the stair would prevent smoke present within the lobby from flowing into the stair.

J4.3.41 If the stair door was closed, fresh air was to be drawn through the gaps around the edges of the stair fire door by depressurisation of the lobby. This would prevent smoke ingress through the gaps around the door.

J4.3.42 A pressure sensor in each lobby was provided to allow control of the exhaust rate to maintain the pressure difference between the lobby and the stair at a level which (a) prevents smoke ingress into the stair, but (b) still allows the stair door to be opened for evacuation or firefighting.

J4.3.43 This operation is shown schematically in Figure J.7.

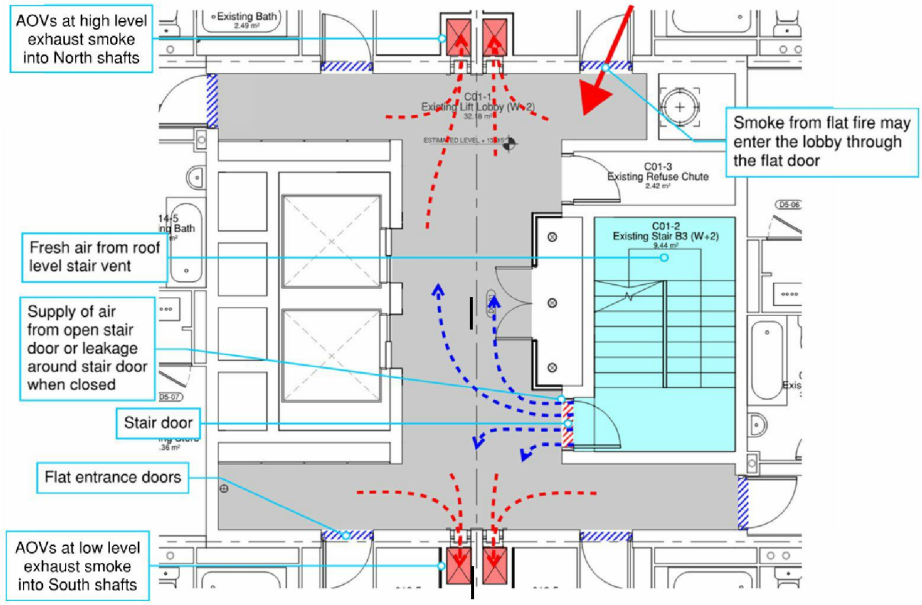
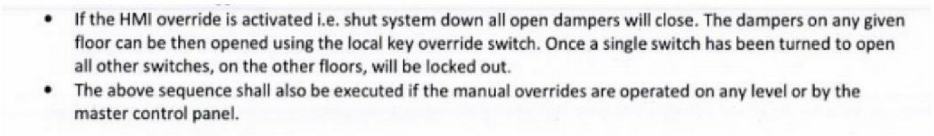


Figure J.7: Operation of the refurbished smoke ventilation system on the fire floor, overlaid on an excerpt from SEA00010474.

J4.3.44 **Override facility**

J4.3.45 PSB00000214 states that a facility was provided to enable fire fighters to change the floor on which the smoke ventilation system was operating. The description of this system is provided in the excerpt from PSB00000214 shown in Figure J.8.



- If the HMI override is activated i.e. shut system down all open dampers will close. The dampers on any given floor can be then opened using the local key override switch. Once a single switch has been turned to open all other switches, on the other floors, will be locked out.
- The above sequence shall also be executed if the manual overrides are operated on any level or by the master control panel.

Figure J.8: Excerpt from PSB00000214 detailing the override controls available to firefighters.

J4.3.46 The smoke ventilation system could therefore have been operated by fire fighters to clear smoke and support evacuation and firefighting on floors other than the fire floor. This required activating the override on the HMI first, which would switch off the system on the floor it had operated on, and then either using the key switch on the required floor, or using the controls at the HMI (if available) to operate the system on the required floor.

J4.3.47 It is unclear from PSB00000214 whether fire fighters would have to physically access each floor to operate key switches in order to change the floor on which the system is operating, or whether this could be achieved from the HMI in all cases.

J4.3.48 The override system would close and lock out the AOVs to all floors other than the floor of operation once a floor had been selected, so could only ever address the effects of fire and smoke on a single floor at any one time.

J4.3.49 I have not currently found any evidence which suggests that fire fighters successfully operated the override facility provided to the smoke ventilation system.

J5 Compliance of the refurbished system with ADB

J5.1.1 The system described in PSB00000214 is not a natural system as described by ADB 2013 Section 2.26.

J5.1.2 The system described in PSB00000214 is not a pressurisation system as described by ADB 2013 Section 2.27 and BS EN 12101-6:2005

J5.1.3 Therefore, it is a bespoke ventilation system which was provided as an upgrade to the original smoke control system.

J5.1.4 It is not clear in PSB00000214 how the adequacy of the bespoke system was to be demonstrated.

J5.1.5 The limited performance criteria set out in PSB00000214 refer to the provisions of BS EN 12101 part 6 which provides the performance standard for pressurisation systems, but the refurbished system is not a pressurisation system.

J5.1.6 Since the required performance criteria are not defined, I cannot confirm the bespoke system complies with the Building Regulations (B1 and B5) at this time.

J6 Observations from site

J6.1.1 During my site inspection, I observed a permanently open vent to the stair at roof level shown in Figure J.9. The PSB technical submission states the measured free area of the vent was 1.0m^2. I was not able during my site inspection to measure the free area of this vent.

Figure J.9: Permanently open vent at Roof Level.

J6.2 Lobby vents

J6.2.1 The positions of the AOVs within the lobby are shown in Figure J.10.

Figure J.10: Location of the AOVs in the Level 16 lobby. Left - North AOVs located at high level. Right – South AOVs located at low level.

J6.2.2 The low-level location of the south AOVs is not ideal for smoke exhaust. Smoke exhaust vents should be located as high as practicable within the lobby. The location of the south AOVs was retained from the design of the original system in which these AOVs were located at low level for their function as a fresh air inlet. PSB00000214 did not comment on the location of the south AOVs or the effect of this location on the efficiency of smoke exhaust.

J6.2.3 A selection of the existing lobby vents was measured during a site inspection between the 7th and 9th November 2017. The range of measured dimensions is indicated in Figure J.11. The vent areas therefore ranged between 0.117m^2 and 0.169m^2.

J6.2.4 The area of the smoke shafts provided on each side of the lobby was therefore substantially smaller than the 1.5m^2 recommended by CP3 1971.

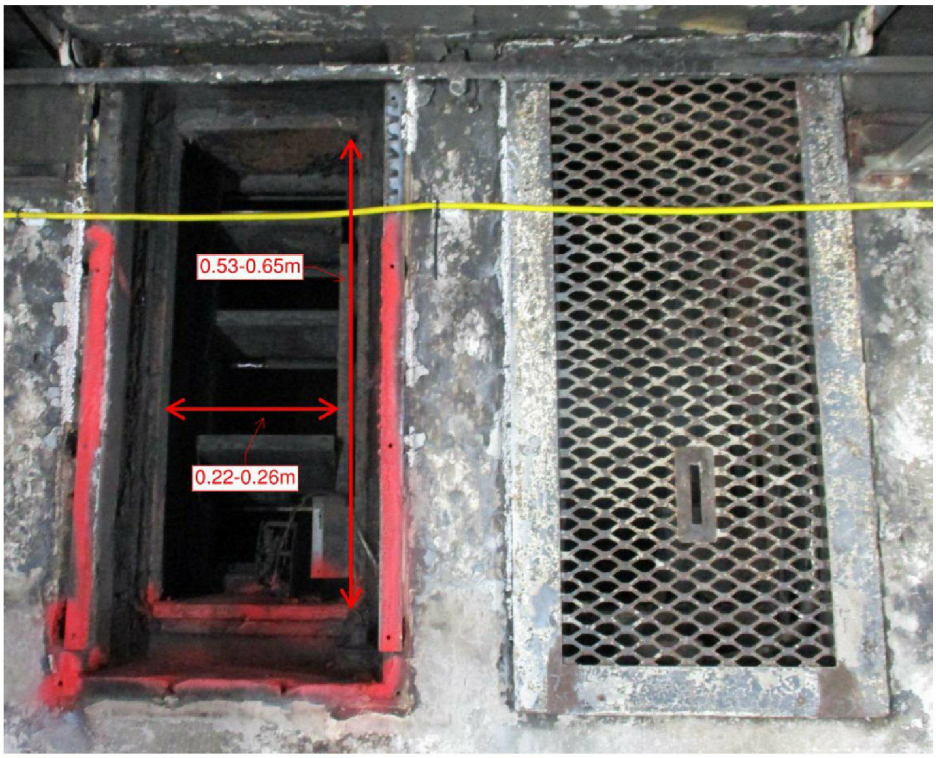


Figure J.11: Dimensions of existing vents

J6.3 Smoke shafts

J6.3.1 The original building was provided with 4 No. shafts, with 2 No. of these shafts located on each of the north and south sides of the lobby.

J6.3.2 The area of each shaft was stated by Max Fordham as being 0.24 m^2 per individual shaft (0.48 m^2 per pair of shafts).

J6.3.3 I have not been able to measure the area of the smoke shafts myself at this stage but the dimensions on site appeared to be of that magnitude.

J6.4 Provision of fans

J6.4.1 The PSB design technical submission (PSB00000214) specifies that the smoke ventilation system consists of replacement of the original two sets of fans serving the AOVs within the lobbies.

J6.4.2 New run and standby extract fans were located at Roof Level and serve the pair of shafts serving the AOVs located on the north side of the lobbies.

J6.4.3 I observed the new fans at Roof Level as shown in Figure J.12.

Figure J.12: Environmental / Smoke ventilation fans in the roof plant room

J6.4.4 A second set of new run and standby extract fans were located on Level 2 serve the other pair of shafts serving the AOVs located on the south side of the lobbies.

J6.4.5 I observed the smoke extract fans located at Level 2 as shown in Figure J.13.

Figure J.13: Smoke exhaust fans at Level 2

J6.4.6 A single new environmental control fan was connected to the smoke ventilation system at Level 2.

J6.4.7 The environmental fan at Level 2 was to be fitted with a bypass system to separate it from the extract system when the smoke extract fans are running.

J6.5 Fire rating of fans

J6.5.1 The smoke extract fans are specified in PSB00000214 as being rated for operation for 2 hours when drawing smoke at 300°C.

J6.5.2 I confirmed this performance rating of the roof fan set serving the north shaft by observation of the identification plate fixed to the fans, which I observed during a site visit between the 7th and 9th November 2017 (Figure J.14)

Figure J.14: Post fire inspection of fan information plates

J6.6 Provision of fire rated ductwork at Level 2

J6.6.1 Section 16.7 presents my observations from site relating to the provision of ductwork at high level at Level 2 within the single firefighting/escape stair between the south smoke ventilation shaft, the extract fans and the vent on the face of the building from which smoke would be exhausted.

J6.6.2 In summary, there is no evidence currently available that demonstrates that the ductwork at Level 2 was installed as fire rated, as specified by the JSW design drawings, and ADB 2013.

J6.7 Provision of smoke detectors and override switches in lobbies

J6.7.1 During the site visit I observed smoke detectors within the lobbies on levels Ground to 23 in Grenfell Tower during my site visit. An example from Level 3 is shown in Figure J.15.

Figure J.15: Smoke detector (circled) in Level 3 lobby.

J6.7.2 During the site visit I observed override switches for the smoke ventilation system in all lobbies on levels Ground to Level 23. These switches were located on the left-hand wall adjacent to the stair door, within the lobby. An example from Level 4 is shown in Figure J.16. I observed during my site visit that the override switches on Levels 5, 7 and 9 to 23 were badly damaged during the fire (Appendix C).

Figure J.16: Smoke ventilation system override switch on Level 4.

J7 Evidence of commissioning and maintenance

J7.1.1 I have only to date been provided with a summary commissioning report for the refurbished smoke ventilation system. I have not observed the supporting information to demonstrate that the full commissioning of the system has been completed to demonstrate compliance with the design specification. This includes the commissioning of the smoke detectors, fans and AOVs, and testing of the full cause and effects response of the system.

J7.1.2 I have not been provided with evidence relating to a system of maintenance for all components of the refurbished smoke ventilation system, including maintenance of the controls, power supplies, fans and AOVs.

J7.1.3 I will therefore investigate further the commissioning and maintenance of the smoke ventilation system in the next stage of my work.

J8 Evidence of defects post-commissioning

J8.1.1 I have seen evidence (email to PSB from JS Wright dated 6th June 2017 PSB00000103) that a defect in the ventilation system was identified by Rydon Maintenance stating that AOVs were not opening at Grenfell Tower. The first email recording the defect was sent by JS Wright on 6th June 2017.

J8.1.2 This evidence does not specify which AOVs may have been faulty, nor the cause of the fault. It does not state when the defect was first identified.

J8.1.3 I have not seen positive evidence that this defect was rectified.

J8.1.4 I am unable to identify therefore the operational state of the smoke ventilation system on the 14th of June.

J8.1.5 I therefore expect to investigate further the operational status of the smoke ventilation system in the next stage of my work.

J9 Operation of the Smoke ventilation on 14 June 2017

J9.1 Sources of evidence

J9.1.1 During my post fire inspection between the 7th and 9th November, I made observations of the smoke ventilation system components. I was only able to observe the smoke shafts from Level 3 – 11, in the time I had on site.

J9.1.2 Please refer to Section 14 where I present the evidence related to the post-fire condition of the smoke ventilation system from my site visit. Section 14 also presents evidence from the 14th June 2017 based on excerpts from fire fighter witness statements.

J9.2 Summary of evidence regarding operation of the smoke ventilation system

J9.2.1 If the smoke ventilation system had operated as described by PSB00000214 for operation on a single floor, I would have expected to see smoke deposition from the fire floor upwards to the Roof Level exhaust fans within the north shafts.

J9.2.2 I would also have expected to see smoke deposition within the south shafts from the fire floor downwards to the exhaust fans located at Level 2.

J9.2.3 The only floor on which I would have expected to see smoke deposition in both sets of shafts would have been the fire floor.

J9.2.4 However, in my site inspection I observed that smoke deposition was present within both the north shafts between Levels 6 and 11 and within both the south shafts between Levels 8 and 11.

J9.2.5 The fact that smoke is present in both north and south shafts on more than one level leads me to conclude that AOVs were open on more than one level during the course of the fire.

J9.2.6 This could have occurred if AOVs previously open for environmental control failed to close on first operation of the smoke extract mode, or on subsequent attempts to operate or change the operation of the smoke ventilation system.

J9.2.7 I understand from discussions with BRE on site that they found, immediately following the fire, that AOVs were open on more than one floor.

J9.2.8 The top of the north shaft and the roof level smoke exhaust fan set show light smoke deposition.

J9.2.9 The south smoke shafts below Level 5 do not show any smoke deposition.

J9.2.10 The smoke exhaust fans at Level 2 show evidence of smoke deposition during the fire. I have been unable to identify from where these deposits originated.

J9.2.11 The environmental fan at Level 2 also shows evidence of smoke deposition within the duct. This fan should have been turned off and closed from the smoke ventilation system by smoke dampers. I have been unable to identify whether this fan was operating during the fire, which it should not, and, if so, where the smoke exhausted by this fan originated.

J9.2.12 Fire fighter witness statements identify the system as being non-functional.

J9.2.13 On the basis of the above, I therefore conclude that the system did not operate as intended during the fire of 14th June 2017.

J9.3 Possible reasons for the smoke ventilation system not operating as intended

J9.3.1 Possible reasons for the smoke ventilation system not operating as intended include:

a) The smoke ventilation system was not correctly commissioned (Section J7).

b) The smoke ventilation system was not correctly operated by fire fighters (Section J4.3).

c) The smoke ventilation system had one or more defects present immediately before fire. (Section J8)

d) The smoke ventilation system developed a defect when operated during the fire.

J9.4 Consequences of smoke ventilation system not operating as intended

J9.4.1 As I have set out in Section J2, the purpose of the smoke ventilation system is to protect the means of escape and to allow fire fighters to undertake prompt and effective action.

J9.4.2 For the initial fire on Level 4, all residents from Level 4 were able to evacuate safely and fire fighters were able to extinguish the fire. Therefore, I conclude that the ventilation system not operating as intended did not have a significant impact on the outcome on the Level 4.

J9.4.3 As the fire spread to multiple floors, the system could only ever operate one floor at a time, and therefore could not have been relied upon to control smoke on more than one floor at a time.

J9.4.4 Therefore, even if the smoke ventilation system had been operating as intended, it could not have prevented smoke from fires on multiple floors impacting lobbies and the stair on multiple levels.

J9.4.5 The consequences of the smoke ventilation system not operating as intended were that firefighters were unable to utilise the smoke ventilation system to support their operations on floors other than the initial fire floor. Given the difficulties fire fighters experienced from smoke within the lobbies (described in Section 14) the option to change the floor served by the smoke ventilation system could have provided a benefit.

J9.4.6 However, it is not clear whether the fire fighters could have activated each floor in turn from the main control panel, or whether they would have to physically access each floor in turn to operate the key switch.

J9.4.7 If AOVs were open on different floors at the same time, this would provide a route for smoke spread between lobbies on different floors.

J9.5 Conclusions

J9.5.1 I have concluded that the original smoke ventilation system was not compliant with the recommended provisions of CP3 1971.

J9.5.2 I have concluded that the mechanical smoke ventilation system provided in the refurbishment was a bespoke system which was an upgrade of the original system (also a bespoke system) and did not meet the guidance in ADB 2013.

J9.5.3 I have been unable to confirm that the smoke ventilation system was fully commissioned as I have only observed a summary commissioning report. I have been unable to confirm that a maintenance program was in place at the time of the fire, and I will investigate these further in the next stage of my work.

J9.5.4 I have been unable to confirm the operational status of the smoke ventilation system at the time of the fire.

J9.5.5 There is no evidence in my site inspection or from my review of fire fighter witness statements that smoke ventilation operated automatically following the initial fire on Level 4 from the time that the call to the LFB was made at

00:55 and the time that the fire in Flat 16 was extinguished at approximately 01:20. (Photos of the AOVs and smoke shafts are in Appendix C).

J9.5.6 The AOVs are intended to be open for environmental purposes, and to shut in the event of a fire. I note that the BRE found the AOVs were open on more than one floor. There is evidence that there was smoke on lobbies above Level 4, and potentially before smoke entered the Level 4 lobby: this requires further investigation.

J9.5.7 I have found no evidence in my post fire site inspection that the smoke ventilation system operated as intended in any other lobby of Grenfell Tower (Photos of the AOVs and smoke shafts are in Appendix C).

J9.5.8 I have concluded that the smoke ventilation system was intended to operate on one floor only. The design was based on the principle of a fire contained to a single compartment and therefore could not have protected lobbies and the stair from smoke generated by fires on multiple floors.

J9.5.9 The smoke ventilation system was not intended to vent smoke from the stair, as the lobby ventilation is intended to prevent smoke entering the stair.

J9.5.10 I have concluded that the control system allowing fire fighters to change the floor of operation of smoke ventilation system was complex to operate and not typical for this type of residential building. The benefits of this facility were therefore limited. Walton (MET00005713) witnessed that a firefighter attempted to operate the smoke ventilation system without success.

J9.5.11 The benefits of the override facility to change the floor of operation were not utilised during the fire.

J9.5.12 I have found evidence in my post fire site inspection that smoke penetrated the environmental ventilation system at Level 2. The environmental system should have been automatically closed from the ventilation system by automatic smoke dampers during the fire. Therefore, this is evidence of a failure to isolate the environmental ventilation system.

J9.5.13 The evidence currently demonstrates it is more likely there was a lack of functionality of the smoke ventilation system. This may also indicate a lack of functionality in the fire alarm interface systems linking the detectors in the lobby on each floor with the ventilation system.

J9.5.14 Alternatively, it may indicate that fire fighters were unable to operate the system successfully as it required particular knowledge regarding the need to reset the panel, and open vents on another floor, should they have required to.

J9.5.15 The following information has not been provided to me, and this information is particularly relevant to finalising my opinion on the smoke ventilation systems, and other interfaces provided at Grenfell Tower:

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

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

c) Fire alarm cause and effect programme

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

J9.5.16 I will update my report if evidence is provided to me that requires me to change any of my assumptions, analysis or conclusions.